

Canadian Hydrogen and Fuel Cell Sector Profile

November 2018

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CANADIAN HYDROGEN AND FUEL CELL SECTOR PROFILE 2018

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:

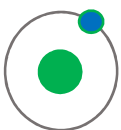
- Capture trends, growth and achievements for the Canadian sector.
- Offer insights into the current state of the sector.
- Provide valuable information for policy makers, investors and other stakeholders.

The 2018 profile was commissioned by the CHFCA in partnership with Innovation, Science and Economic Development Canada (ISED), 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 2017. 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 2018.

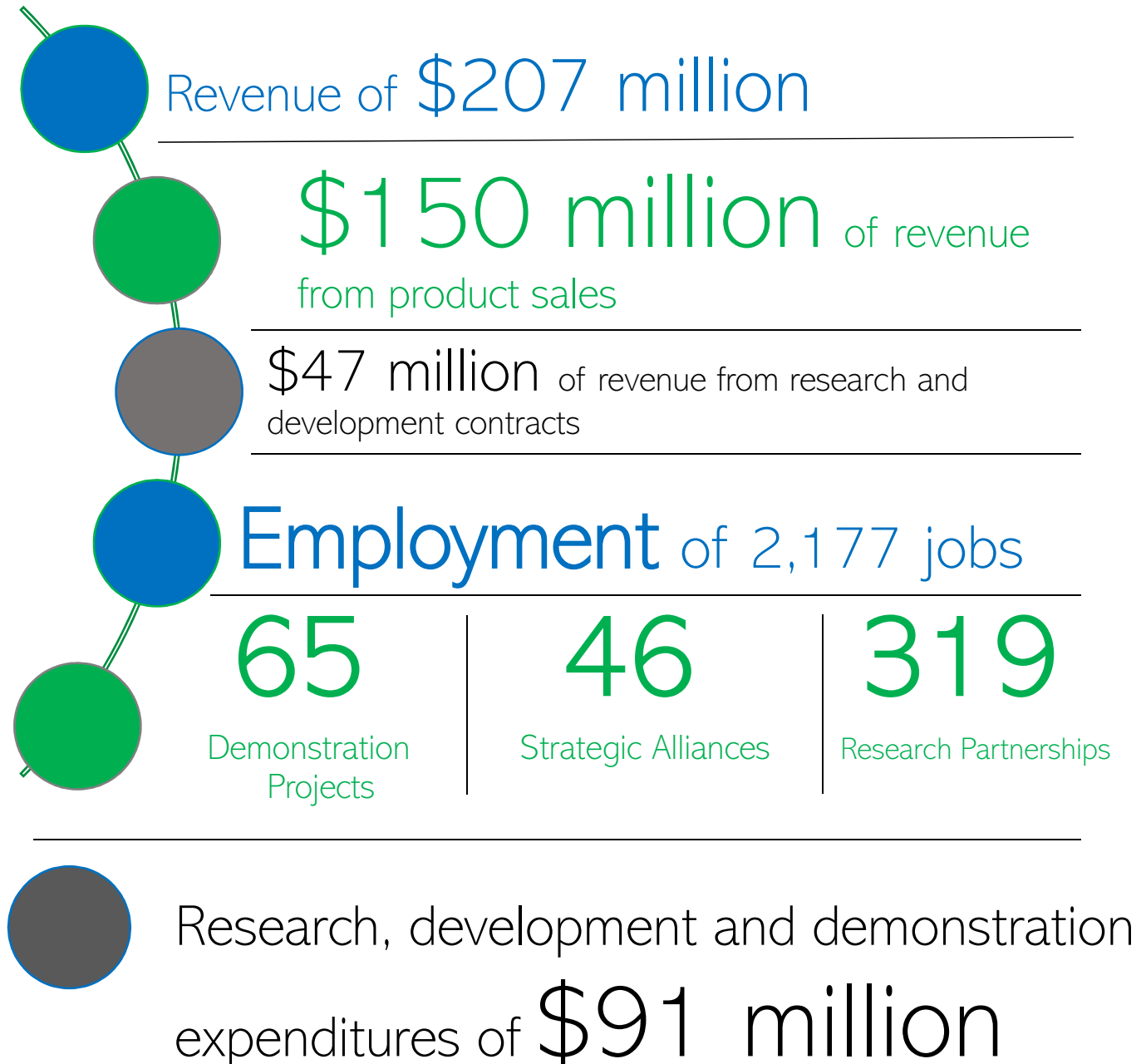
INTRODUCTION

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.

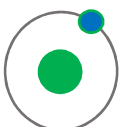


THE INDUSTRY AT A GLANCE IN 2017

In 2017, survey respondents from the Canadian hydrogen and fuel cell sector reported the following*:



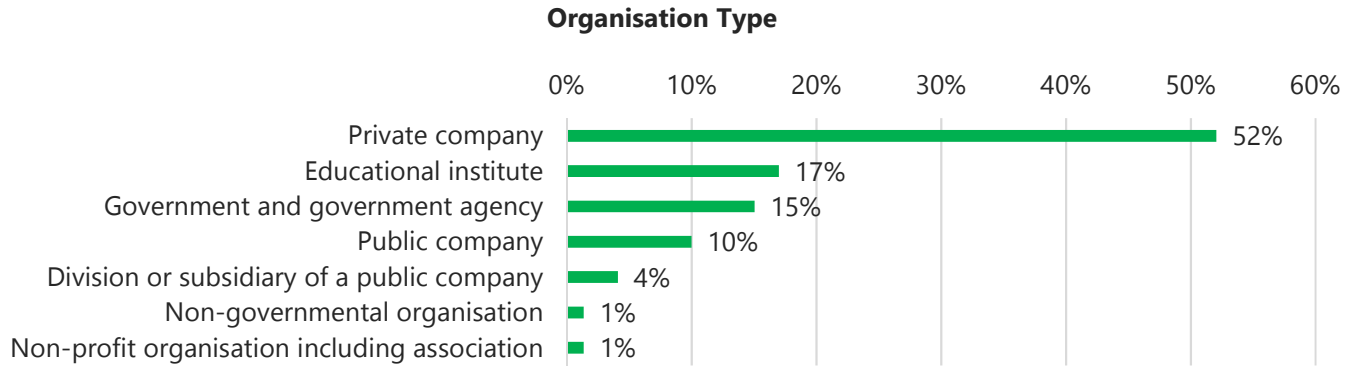
*Please note that all information was collected from voluntary survey participation. Year-over-year data may not be fully comparable due to differing survey respondents and participation rates.



ORGANISATION PROFILE

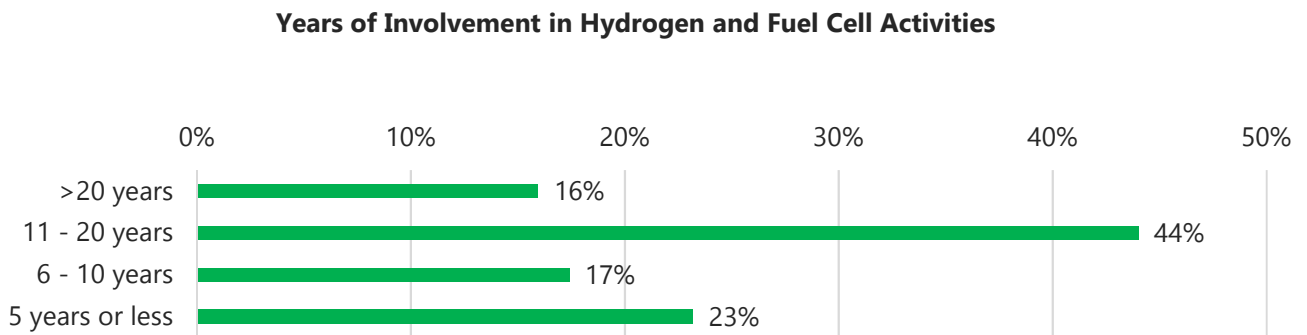
Organisation Type

Corporate organisations, including private companies and public companies and their subsidiaries, represented 66% of total survey respondents. Educational institutes and governments accounted for 17% and 15%, respectively, and non-governmental and non-profit organisations, including associations, represented the remaining 2% of respondents.



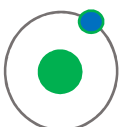
Years of Involvement in Hydrogen and Fuel Cell Activities

The majority of survey respondents (60%) reported being involved 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 (92%) reporting that their headquarters for hydrogen and fuel cell activities were located in Canada. Other survey respondents had headquarters in Germany, the United States, South Korea, and the United Kingdom.

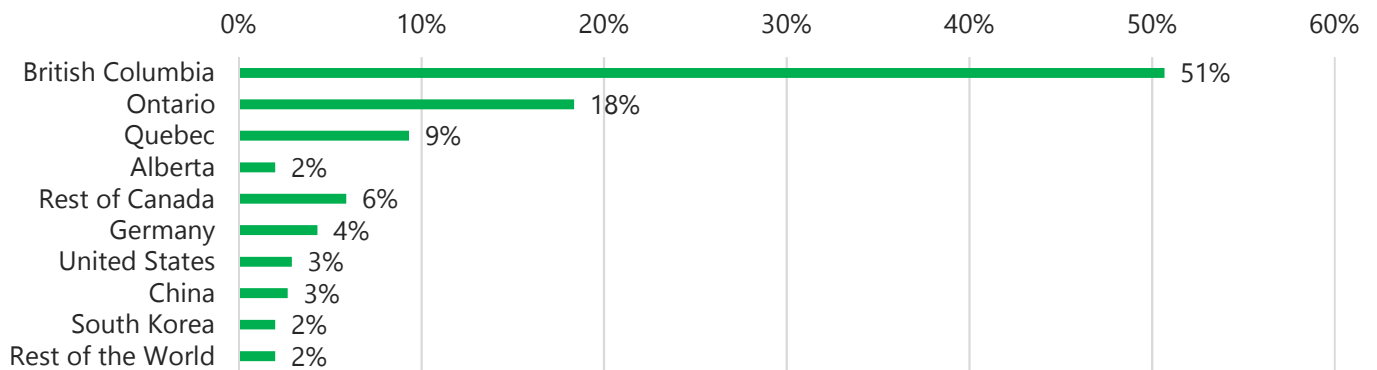


Hydrogen and Fuel Cell Facilities by Region

Survey respondents reported that 86% of facilities were located in Canada, 4% in Germany, 3% in the United States, 3% in China, and 2% in South Korea. The remaining 2% were in the United Kingdom, Japan, India, Belgium and Sweden.

In 2017, hydrogen and fuel cell activities took place in most provinces within Canada. The majority of facilities and activities were in British Columbia (51%) and Ontario (18%), followed by Quebec (9%) and Alberta (2%). The rest of Canada (6%) included facilities in Manitoba, Newfoundland and Labrador, P.E.I. and New Brunswick.

Hydrogen and Fuel Cell Facilities by Region

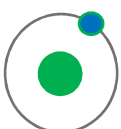
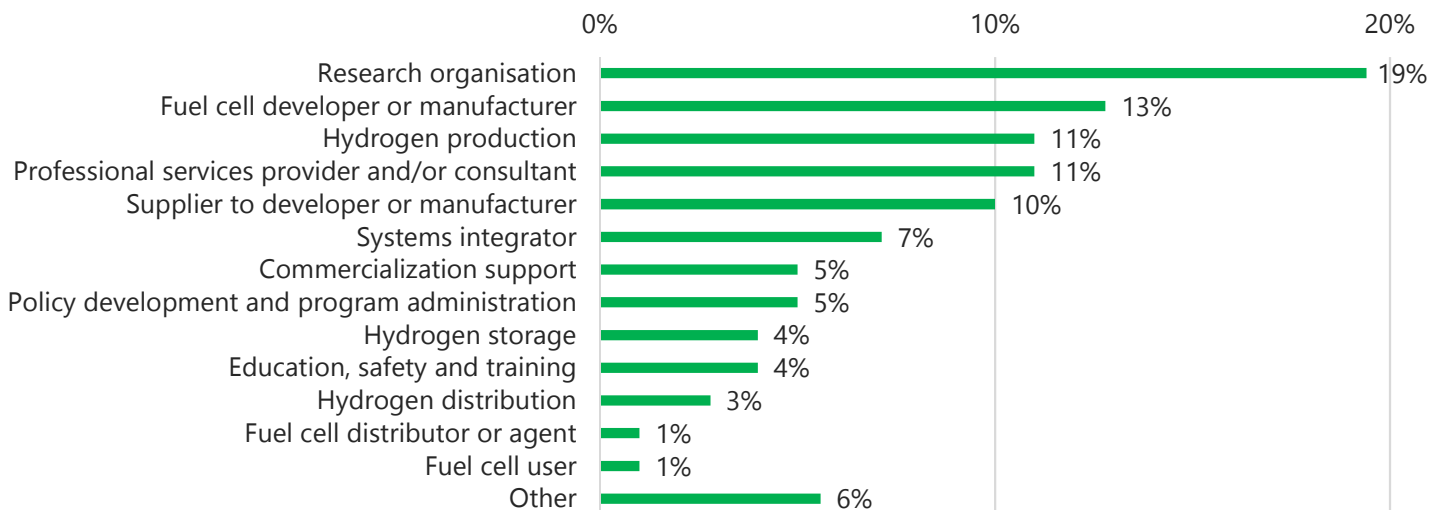


Areas of Expertise

Survey respondents' main area of expertise in 2017 was research (19%). Other areas of expertise included fuel cell development or manufacturing (13%), hydrogen production (11%), professional services and/or consulting (11%), and supplying to developers or manufacturers (10%).

Systems integration, commercialization support, policy development and program administration, hydrogen storage, education, safety and training, hydrogen distribution, fuel cell distributor or agent, and fuel cell user each represented 7% or less of the survey respondents' expertise.

Areas of Expertise

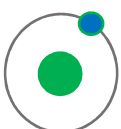


Ballard Power Systems (Ballard), headquartered in Vancouver, British Columbia, develops and manufactures proton exchange membrane (PEM) fuel cell products for commercialization. Ballard is considered a leader in the global market for customized fuel cell engineering solutions and services. Ballard's fuel cell power modules provide zero-emission mobility solutions to buses, trucks, trains and ships. According to Ballard, their products have powered hundreds of fuel cell buses and trucks, and thousands of forklifts. Ballard's technology is used in the production of vehicles by Volkswagen, Audi, Siemens and New Flyer.

Ballard powered fuel cell bus in service with Transport London.
(Source: Ballard)

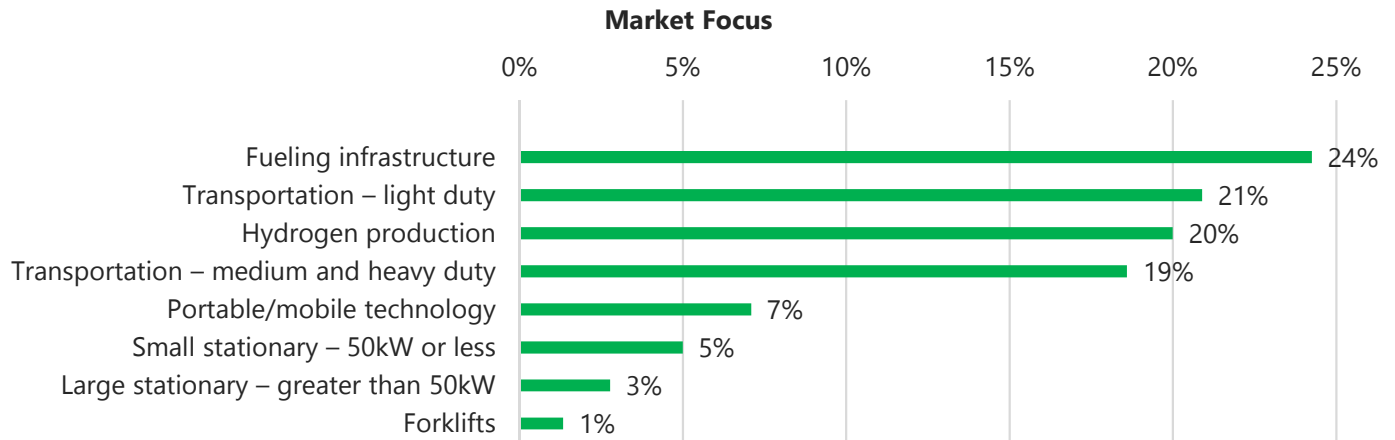


In 2017, a fuel cell electric bus powered by Ballard's FCveloCity®-HD6 fuel cells achieved a new durability record with more than 25,000 hours of revenue service. This is equivalent to operating a bus on a 14-hour daily schedule, five days per week for 6.9 years with no significant maintenance to the fuel cell stack, a core engine component. The bus is part of Transport London's fleet of eight fuel cell electric buses, all powered by Ballard's FCveloCity®-HD6 fuel cells. The buses, originally funded under the Clean Hydrogen in European Cities (CHIC) fuel cell bus program, have been carrying paying passengers on London's Tower Gateway route since 2010. (<http://www.ballard.com>)



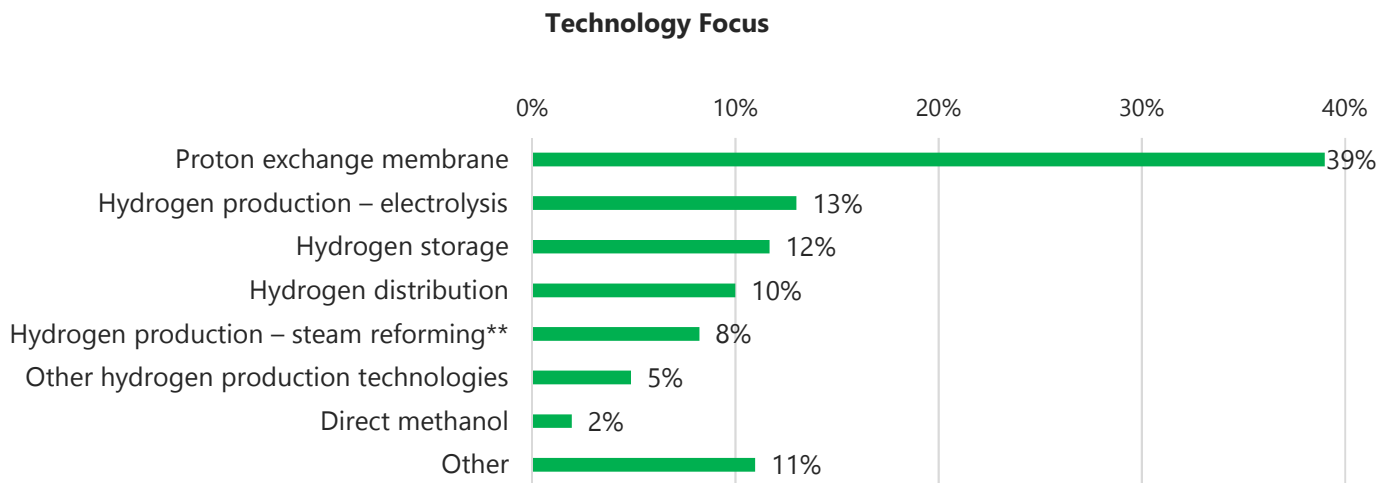
Market Focus

In 2017, the combined applications of light, medium and heavy-duty transportation represented 40% of survey respondents' market focus. Fueling infrastructure represented 24% of survey respondents' market focus, and hydrogen production represented 20%. Portable/mobile technology, small and large stationary applications, and forklifts represented the remaining 16%.*



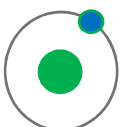
Technology Focus

Proton Exchange Membrane (PEM) fuel cells comprised the largest share of survey respondents' technology-focused activities in 2017 (39%). Together, hydrogen production, storage and distribution accounted for 48% of survey respondents' technology focus. Direct methanol represented 2%, and other categories represented 11% of survey respondents' technology focus.*



*Please note that these are unweighted percentages based on the percentage breakdown provided by responding organisations.

**Steam reforming and related technologies





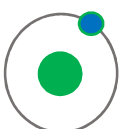
Kraus Global Inc., located in Winnipeg, Manitoba, develops and engineers alternative fueling systems focused on compressed natural gas (CNG) and hydrogen dispensing systems, and liquefied petroleum gas (LPG) dispensing kits, electronic metering and automotive temperature compensations. Kraus Global has developed Optima™, a new retail alternative fuel dispenser cabinet for use with hydrogen and natural gas refueling. Optima™ is currently being used by a number of CNG fuel providers, including Alternative Vehicle Services Group (AVSG), Clean Energy, Independent Fueling Systems, Love's Trillium, Nopetro, Pacific Gas & Electric, Timco, US GAIN, and others. (<http://krausglobal.com/>)

Retail alternative fuel dispenser cabinet. (Source: Kraus Global)

Hydrogen Technology & Energy Corporation (HTEC), located in North Vancouver, British Columbia, is a leading developer and provider of hydrogen supply solutions, including the design and installation of retail hydrogen refueling stations. HTEC has been involved with the deployment of two retail hydrogen fueling stations, one in Vancouver, British Columbia and one in Silicon Valley, California. HTEC, in partnership with Shell, is now working to develop six retail hydrogen stations in British Columbia. (<https://www.htec.ca/>)



HTEC event at a Shell retail hydrogen fueling station in June 2018. The station, located at 8686 Granville Street, Vancouver, has enabled the deployment of the first 1,000 zero-emission hydrogen fuel cell electric vehicles in British Columbia. (Source: HTEC)



REVENUE

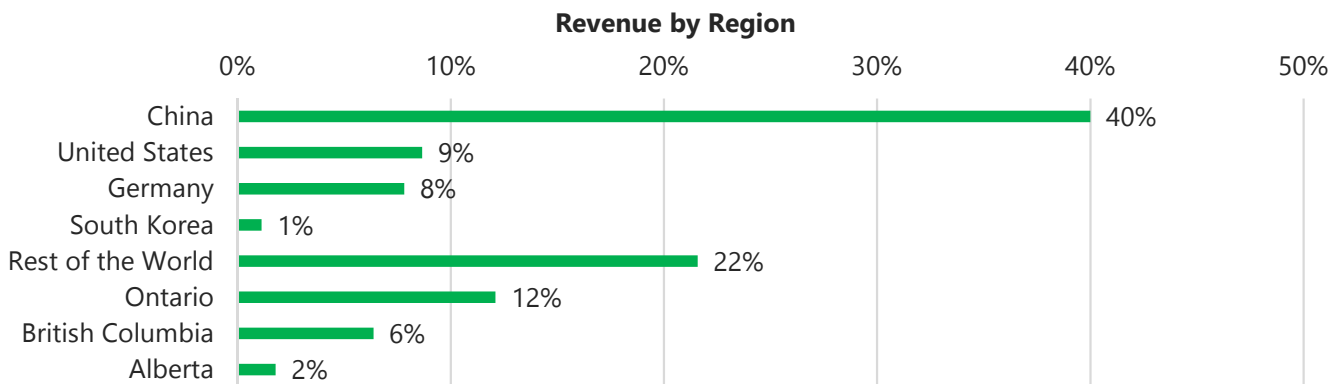
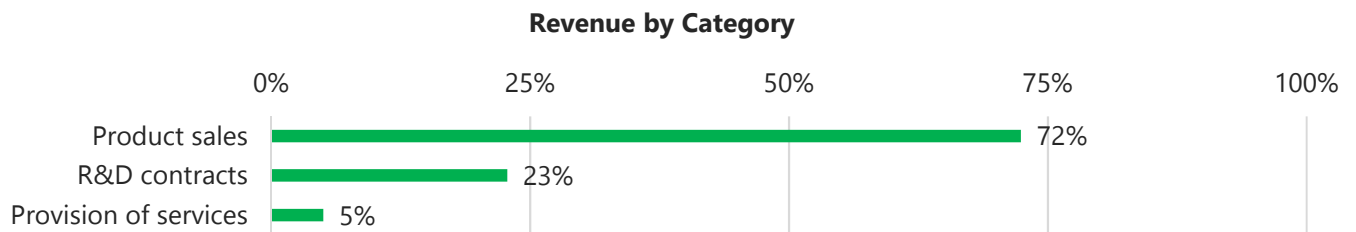
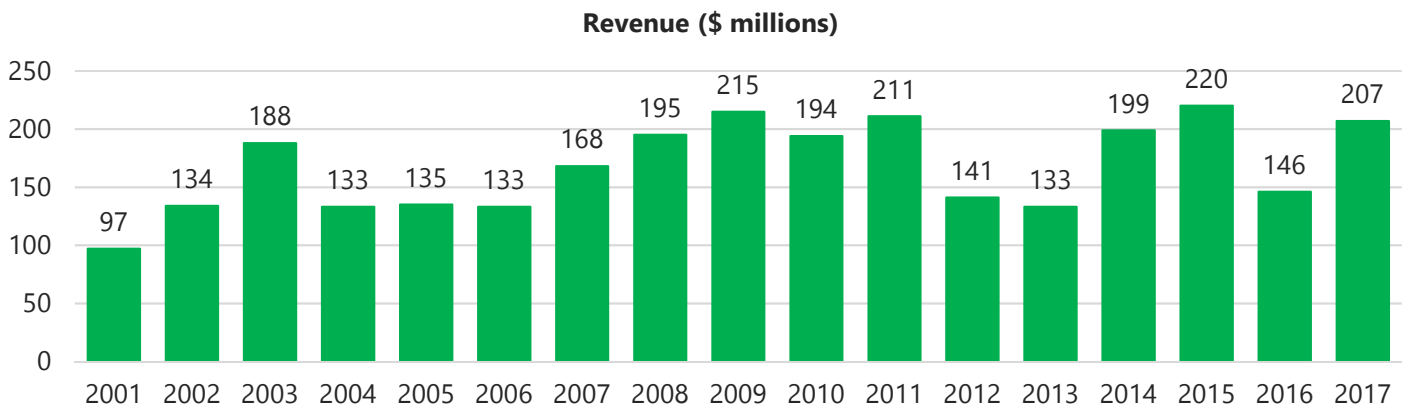
In 2017, 41% of survey respondents generated revenue from hydrogen and fuel cell activities, totalling approximately \$207 million.

For survey respondents that provided their revenue in both 2015 and 2017, total revenue increased approximately 37% between 2015 and 2017.*

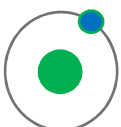
Of the survey respondents that provided their revenue in 2017, 20% reported more than \$5 million in revenue (of which 10% reported revenue of more than \$25 million), and 14% reported revenue between \$1 million and \$5 million, while 66% reported less than \$1 million in revenue.

In 2017, survey respondents generated the most revenue from product sales and R&D contracts, which generated 72% (\$149 million) and 23% (\$47 million) in revenue, respectively.

The region in which survey respondents generated the most hydrogen and fuel cell-related revenue in 2017 was China (40%). Other countries accounted for 40%, which included revenues in the United States, Germany, South Korea, Denmark, and Belgium. Overall, 20% of survey respondents' revenues were generated in Canada.



*Please note that the results are driven by a few large organisations in the industry. In 2017, these organisations accounted for over 70% of the total revenues reported by survey respondents.

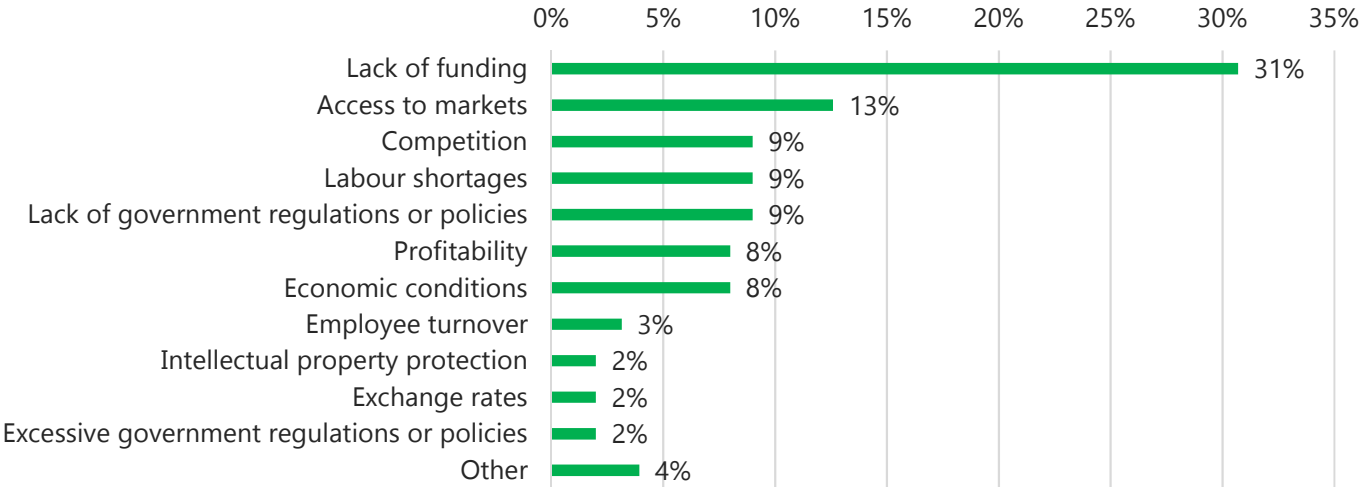


COMPETITIVE PERFORMANCE AND CHALLENGES

Survey respondents were asked to identify challenges faced by their organisations in 2017. The main challenges identified by survey respondents included lack of funding (31%) and access to markets (13%), followed by competition (9%), labour shortages (9%) and lack of government regulations or policies (9%).

Respondents also reported profitability (8%), economic conditions (8%), employee turnover (3%), intellectual property protection (2%), exchange rates (2%), and excessive government regulations or policies (2%) as challenges faced in 2017.

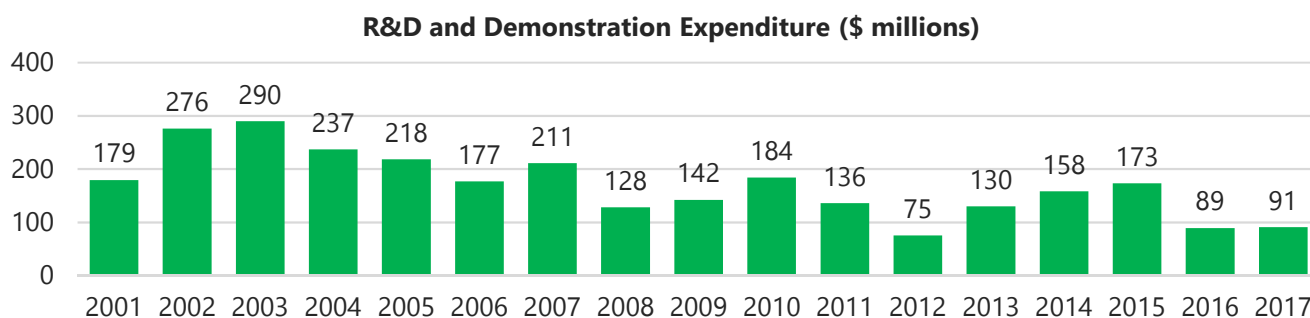
Challenges Faced in 2017



RESEARCH AND DEVELOPMENT (R&D) AND DEMONSTRATION

In 2017, 66% of survey respondents participated in research and development (R&D) and demonstration activities, reporting total expenditures of approximately \$91 million. Total R&D expenditures were \$86.1 million and demonstration expenditures were \$5.1 million.

For survey respondents that provided their R&D and demonstration expenditures in both 2015 and 2017, total R&D and demonstration expenditures decreased approximately 5% between 2015 and 2017.*



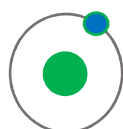
2017 Total R&D and Demonstration Expenditure (\$ millions)			
Type of Organisation	R&D	Demonstration	Total
Corporate	68.1	4.8	72.9
Government, Academic and Non-Profit	18.0	0.3	18.3
Total	86.1	5.1	91.2

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. Operations, together with parent, affiliated or subsidiary organisations, funded 68% of total reported R&D expenditures and 77% of reported demonstration expenditures. Canadian governments funded \$22.8 million or 27% of R&D expenditures and \$1.1 million or 22% of demonstration expenditures.

2017 Source of Funding for R&D and Demonstration Expenditure	R&D		Demonstration		Total
	\$ millions	%	\$ millions	%	\$ millions
Parent, affiliated or subsidiary organisation	51.4	60	2.2	44	53.6
Canadian government (all levels)	22.8	27	1.1	22	23.9
Operations	6.9	8	1.7	33	8.6
Research, non-profit, non-governmental institute	3.0	3	-	-	3.0
Contract work conducted for another institute	0.1	0	0.1	1	0.2
University or academic institute	0.2	0	-	-	0.2
Other	1.7	2	-	-	1.7
Total	86.1	100%	5.1	100%	91.2

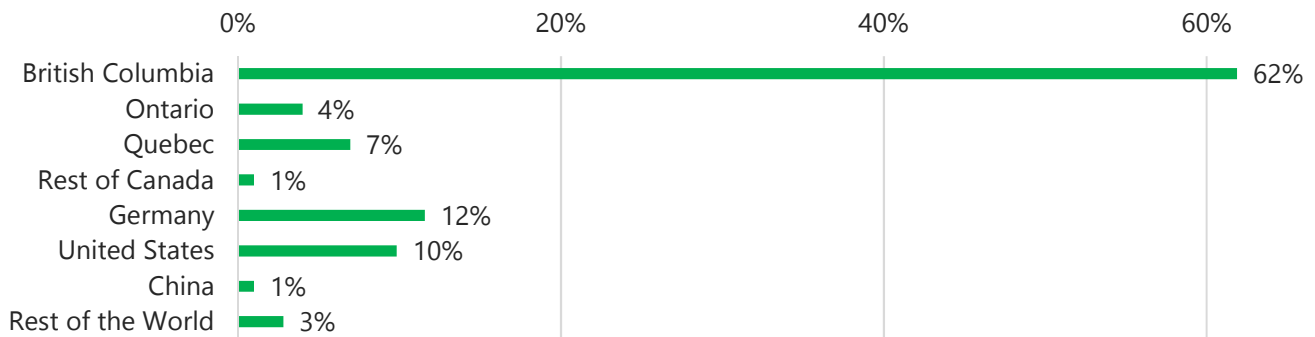
*Please note that the results are driven by a few large organisations in the industry.



R&D Expenditures by Region

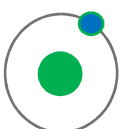
Sixty-two percent of survey respondents' R&D expenditures took place in British Columbia, followed by Germany (12%). Ten percent of respondents' R&D expenditures occurred in the United States, 7% in Quebec, 4% in Ontario and 1% in China.

R&D Expenditures by Region



Transport Canada's Innovation Centre is conducting a feasibility analysis of advanced technology and systems for marine vessels. The objective of this project is to obtain a detailed understanding of high efficiency and low-emission technologies such as solid oxide and molten carbonate fuel cells for marine application. A review of current Canadian marine vessels was conducted as well as a feasibility study regarding the existing power units with fuel cells for marine applications. An analysis of the current technology readiness will be conducted with regard to power range, cost range, and market availability of the power units of high temperature fuel cells in marine application. A full cost assessment will also be obtained. The findings will be published upon completion of the project.

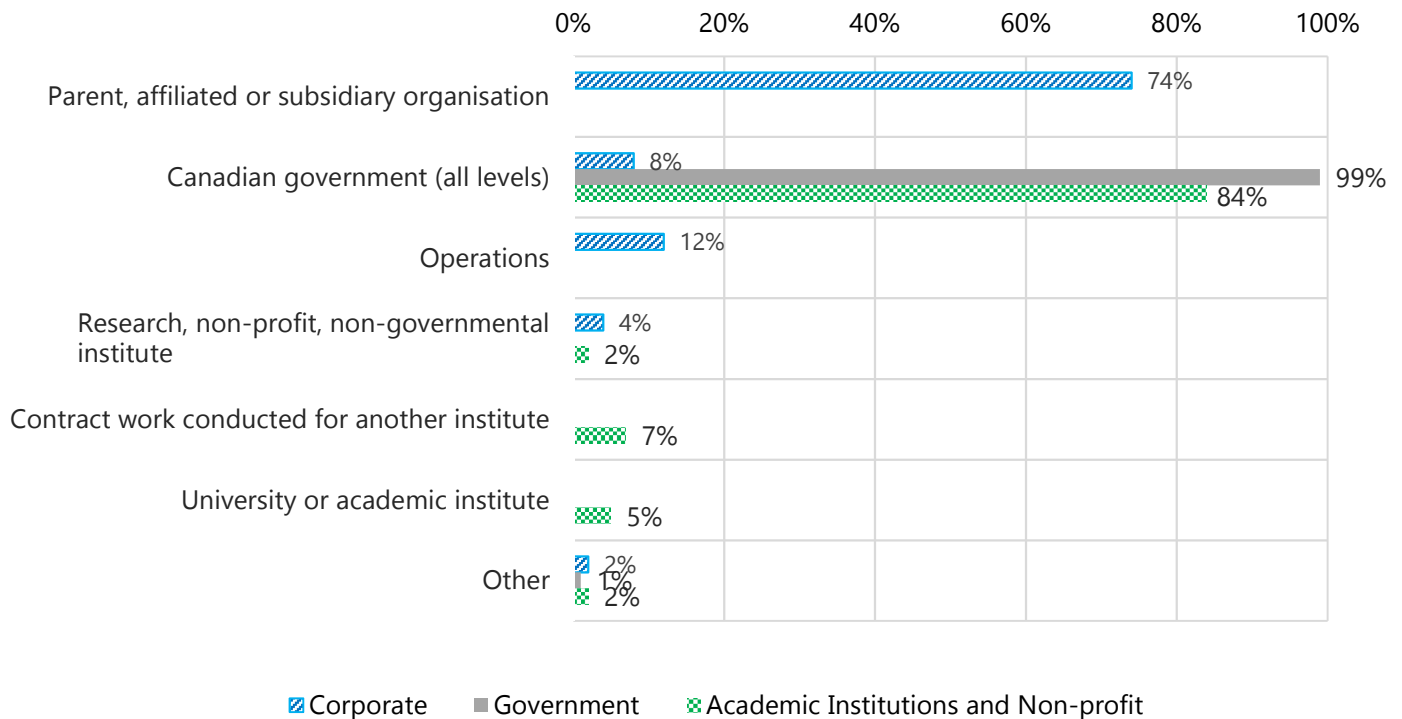
Mirai Fuel Cell Testing, Argonne National Laboratory
(Source : Transport Canada)



Sources of Funding for R&D and Demonstration Expenditure

In 2017, corporate survey respondents received the majority of their funding for R&D and demonstration expenditure from parent, affiliated or subsidiary organisations (74%) and operations (12%). Government survey respondents and academic institution and non-profit respondents received most of their funding for R&D and demonstration expenditure from Canadian government sources (99% and 84% respectively).

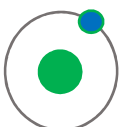
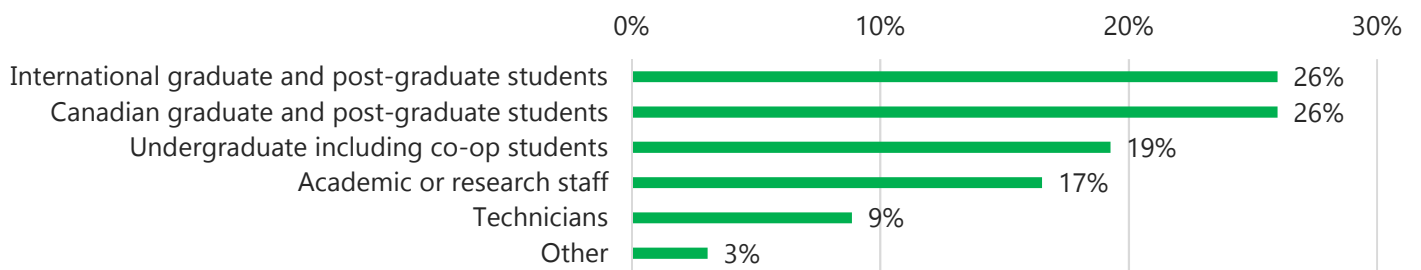
Sources of Funding for R&D and Demonstration Expenditures by Type of Organisation



People Involved in Research

Academic survey respondents reported that a total of 327 people were involved in hydrogen and fuel cell-related research activity in 2017. Of the total reported number of people involved in research, 26% were international graduate and post-graduate students, 26% were Canadian graduate and post-graduate students, 19% were undergraduate (including co-op) students, 17% were academic or research staff, and 9% were technicians.

People Involved in Research



Hydrogen In Motion Inc. (H2M), located in Vancouver, British Columbia, develops innovative mobile hydrogen storage tanks for hydrogen fuel cell vehicles and equipment. H2M has engineered a proprietary nanomaterial that selectively attracts hydrogen under ambient temperature and low pressure, providing twice the hydrogen in the same volume at half the cost. As the H2M nanomaterial is conformable, H2M hydrogen storage containers can be shaped to meet the requirements of the application, for example, extending flight duration for drones, or providing utility-scale renewable energy storage. (<http://www.hydrogeninmotion.com/>)



Demonstration tank.

(Source: Hydrogen In Motion)



PowerTech Labs, located in Surrey, British Columbia, is a wholly owned subsidiary of BC Hydro. It is a testing and research laboratory that provides support to electrical utilities, original equipment manufacturers, and the automotive industries. PowerTech's Advanced Transportation business unit supports the reduction of carbon emissions from transportation systems through work involved in hydrogen infrastructure, gas systems testing, and electric vehicle infrastructure. (<https://www.powertechlabs.com/>)

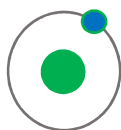
PowerTech's refueling station testing and certification equipment can assess a hydrogen station's performance to ensure it meets the requirements needed. (Source: PowerTech)



Hyteon Inc., located in Laval, Quebec, manufactures alternative methods of electricity production based on fuel cells for residential applications. Its products have been tested by utilities in Europe, Canada and Japan. Hyteon's combined heat and power (CHP) fuel cell-based units provide fuel-to-electricity efficiencies, commercially-required durability and reliability. Using a derivative of the CHP product, Hyteon is currently developing a fuel cell generator designed to be included in off-grid hybrid power systems.

Combined heat and power fuel cell-based unit. (Source: Hyteon)

Zen Clean Energy Solutions Inc. (Zen Energy), located in Vancouver, British Columbia, is a boutique consulting firm that works with organisations to commercially advance and deploy clean energy solutions and technologies. Zen Energy was selected by SunLine Transit to administer a \$12.5 million award for fuel cell electric buses and a heavy-duty fueling station in Coachella Valley, California, featuring renewable hydrogen generated through electrolysis. (<http://zenenergysolutions.com/>)



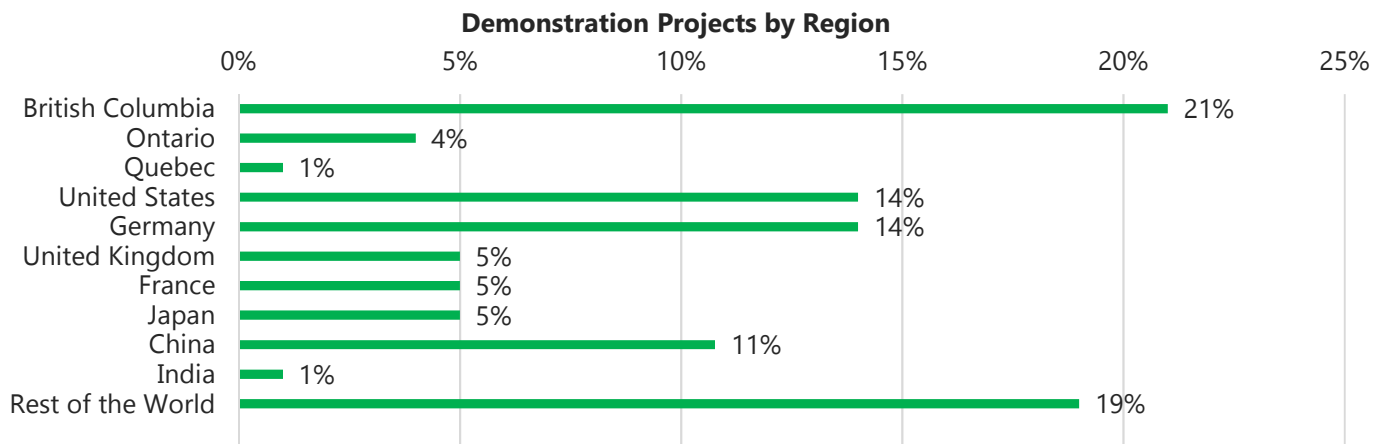
DEMONSTRATION PROJECTS AND PATENTS

Demonstration Projects

In 2017, survey respondents reported their participation in 65 demonstration projects around the world.

Demonstration Projects by Region

Canadian provinces hosted 26% of survey respondents' total demonstration projects in 2017, the majority of which took place in British Columbia (21%). Other Canadian provinces accounted for 5% of demonstrations, which were hosted in Ontario (4%) and Quebec (1%). The remainder took place in the United States (14%), Germany (14%), China (11%), and other countries (35%).

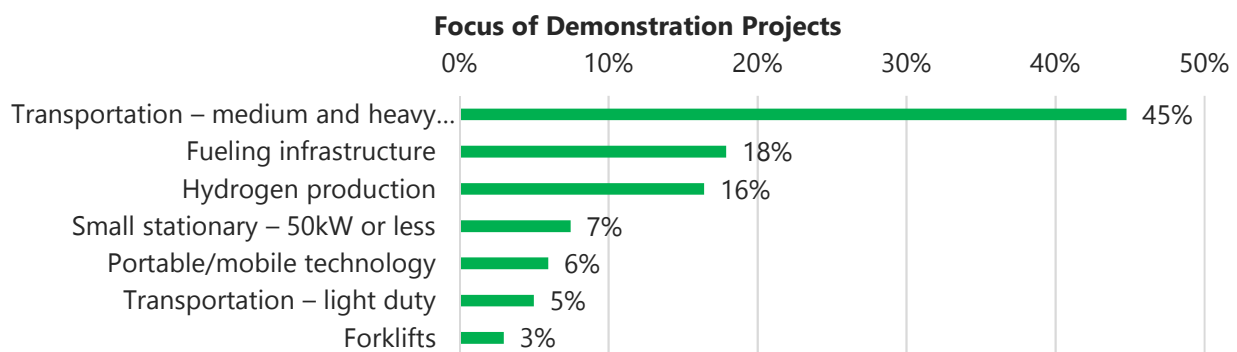


Sources of Funding for Demonstration Projects

In 2017, parent, affiliated or subsidiary organisations funded 44% of the \$5.1 million in demonstration expenditure reported by survey respondents, while operations funded 33%, the Canadian government funded 22%, and contract work funded 1%.

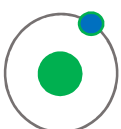
Focus of Demonstration Projects

Survey respondents' main area of focus for demonstration projects was transportation – medium and heavy duty (45%), followed by fueling infrastructure (18%) and hydrogen production (16%).



Patents and Licenses

In 2017, survey respondents had access to 434 approved patents and licenses and had 95 patents pending.





The Canadian FCEV Coalition (FCEV Coalition), is a coalition composed of six automakers: BMW Canada, Honda Canada, Hyundai Canada, Kia Canada, Mercedes Benz Canada and Toyota Canada. The FCEV Coalition is dedicated to raising awareness of the advanced engineering, safety, environmental benefits and transformative potential of FCEVs. In addition, the coalition aims to foster new FCEV consumer and fleet markets in Canada through the support and creation of new and publicly accessible FCEV fuelling infrastructure in Canada.

Fuel cell vehicles at the University of British Columbia campus. (Source: FCEV Coalition Ride and Drive - Hydrogen in Vancouver)



Hydrogenics, located in Mississauga, Ontario, is involved in designing, manufacturing, building and installing industrial and commercial hydrogen fuel cells. Hydrogenics is part of a consortium of European companies, including Air Liquide, for a €15 million Power-to-Gas demonstration project in Denmark. The HyBalance project is expected to validate electrolysis technology and hydrogen delivery processes involved in a real industrial environment, using Hydrogenics' 1 MW PEM electrolyser. (<https://www.hydrogenics.com/>)

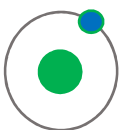


HyBalance demonstration project in Hasbro, Denmark (Source: Hydrogenics)

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 of partner economies. (<https://www.iphe.today/>)



International Partnership for Hydrogen and Fuel Cells in the Economy



EMPLOYMENT

Survey respondents reported a total of 2,177 employees involved in hydrogen and fuel cell activities in 2017. Corporate organisations employed the majority of these employees (77%).

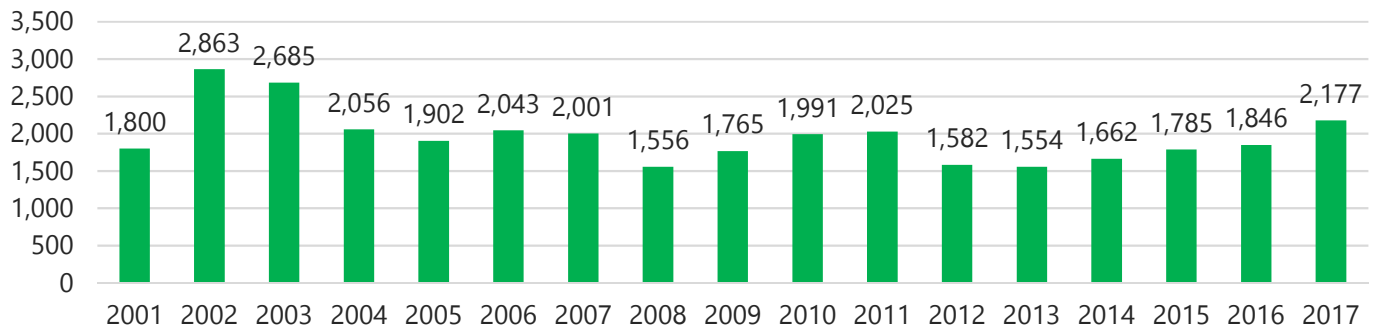
For survey respondents that provided their employment in both 2015 and 2017, total employment increased approximately 38% between 2015 and 2017.*

In 2017, the largest proportion of survey respondents' employees (approximately 76%) 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 (6%), Germany (5%), China (2%) and Japan (1%). The remaining 10% were in other countries, including the United Kingdom, France, India and South Korea.

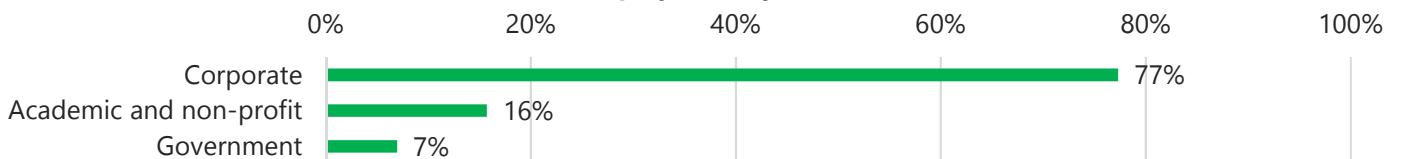
Most survey respondents (70%) had 10 or fewer employees. Eleven percent had between 11 and 25 employees, 4% had between 26 and 50 employees, and 14% had more than 50 employees.

Based on the data provided by survey respondents for the number of employees and total salaries, the average annual salary paid to employees was \$74,024 in 2017. Extrapolating the average salary to the 1,630 employees reported in Canada, survey respondents contributed approximately \$121 million in salaries to the national economy.

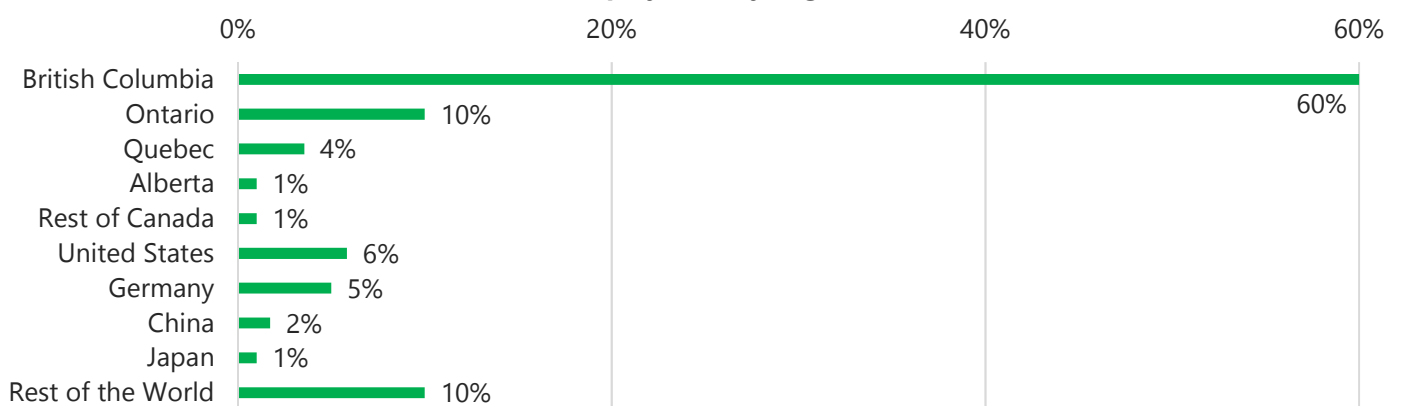
Employment



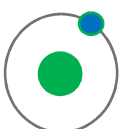
Employment by Sector



Employment by Region



*Please note that the results are driven by a few large organisations in the industry.



RESEARCH PARTNERSHIPS AND STRATEGIC ALLIANCES

Research Partnerships

Research partnerships promote closer collaboration between the university research community, government and industry. Survey respondents reported 319 research partnerships in 2017. Please note, 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 research partnerships reported by survey respondents in the hydrogen and fuel cell sector within Canada and abroad.

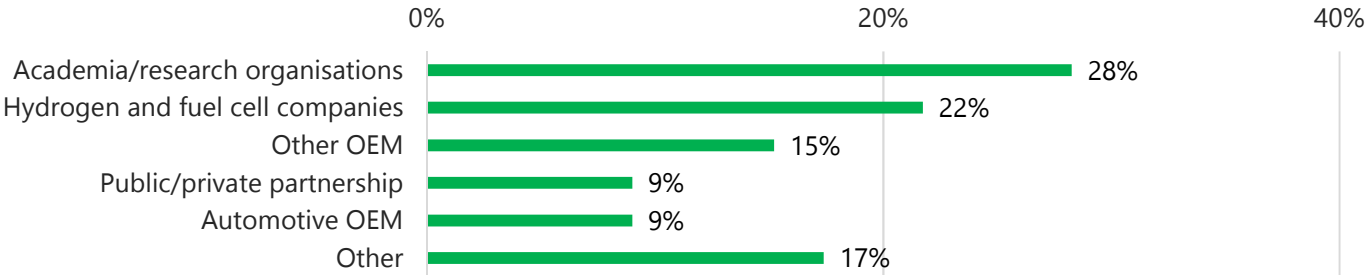
In 2017, partnerships with Canadian academia/non-profit/associations represented 28% of all reported research partnerships. Partnerships with industry in Canada represented 25%, and partnerships with the Canadian government represented 20%. Partnerships outside the country, including partnerships with industry outside of Canada, foreign governments, and foreign academia/non-profit/associations represented a combined 27% of reported research partnerships in 2017.

Research Partnerships	Number	%
Partnership(s) with Canadian academia/non-profit/associations	88	28%
Partnership(s) with industry in Canada	81	25%
Partnership(s) with Canadian government	63	20%
Partnership(s) with industry outside of Canada	57	18%
Partnership(s) with foreign governments	16	5%
Partnership(s) with foreign academia/non-profit/associations	14	4%
Total	319	100%

Strategic Partnerships and Alliances

In 2017, survey respondents reported 46 strategic partnerships and alliances. Academia/research organisations represented 28% of these partnerships and alliances, while hydrogen and fuel cell companies represented 22%. Public/private partnerships, automotive original equipment manufacturers (OEM), other OEM and other partnerships and alliances represented the remaining 50%.

Strategic Partnerships and Alliances





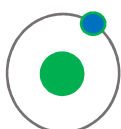
Loop Energy fuel cell range extender. (Source: Loop Energy)

Loop Energy, based in Burnaby, British Columbia, develops, manufactures and supplies hydrogen fuel cell solutions for commercial users. Loop Energy's fuel cell range extender provides extended range for electric powertrains. Available in 30kW or 50kW net power ranges, the range extender is a compact, powerful and economic power module for medium-to-heavy duty trucks and buses. (<https://loopenergy.com/>)



Loop range-extended yard truck – Loop Energy's fuel cell range extender acts as an on-board power generator to charge batteries for a China National Heavy-Duty Truck Company terminal tractor (or yard truck). This hybrid solution reduces the size and weight of a pure battery-electric truck to provide extended range, super high-torque for heavy loads, quick fill-ups and emission-free freight movement.

(Source: Loop Energy)



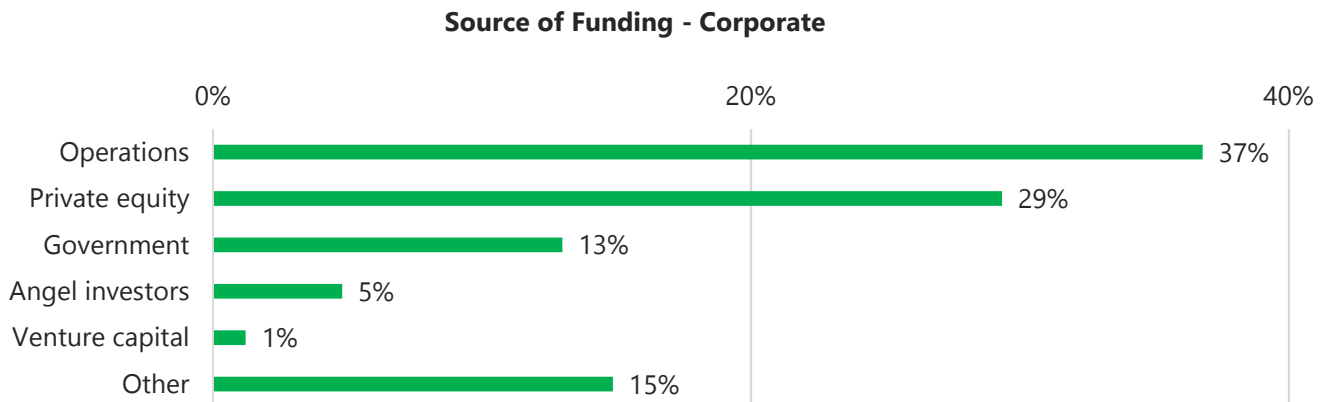
FUNDING REQUIREMENTS

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 2017 were from operations (37%), private equity (29%) and government (13%).

Corporate survey respondents estimated their financial requirements for the next five years to be approximately \$321 million.



Thirty-eight percent of corporate survey respondents reported new investment in the sector in 2017. The majority of new investments originated within Canada (47%), followed by China (21%). In Canada, British Columbia, Ontario and Alberta accounted for 35%, 4% and 7% of new investments, respectively, while other provinces represented 1%. The remaining new investment in the sector was from the United States (11%), Germany (5%) and other international sources (16%).

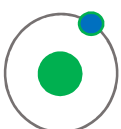
Corporate survey respondents' main targets for new investment in 2017 were transportation – medium and heavy duty (38%), fueling infrastructure (19%), transportation – light duty (14%), hydrogen production (14%), small stationary (10%) and portable/mobile technology (5%).

Government

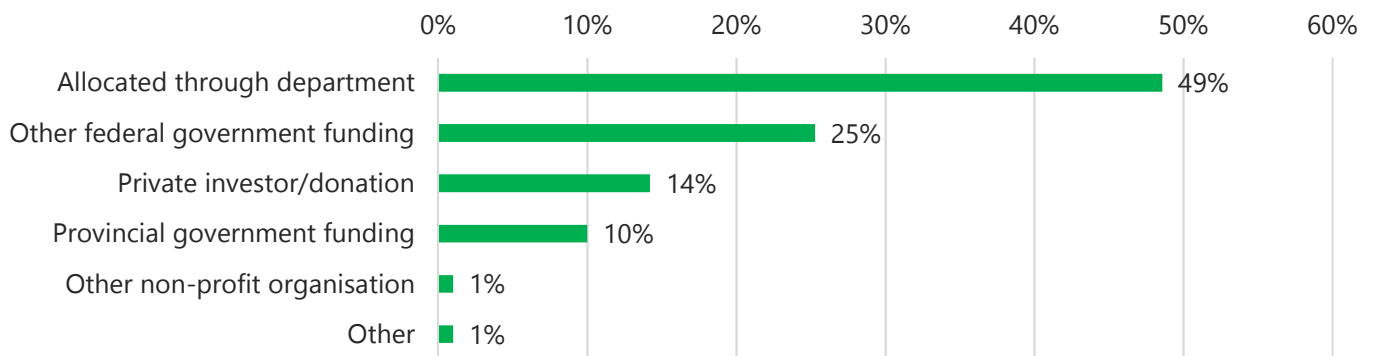
Government survey respondents reported a total budget for hydrogen and fuel cell-related activities in 2017, for which they were directly responsible, of approximately \$6.5 million (including employee salaries and benefits). Programs contributed approximately 63% of the funding, while A-base and other operations represented the remaining 37%.

Academic and Non-Profit

The total budget for hydrogen and fuel cell-related activities reported by academic and non-profit survey respondents in 2017, for which they were directly responsible, was \$16.7 million (including employee salaries and benefits). Departmental budgets represented 49% of total funding, other federal government funding represented 25%, private investments/donations represented 14%, provincial government funding represented 10%, and other sources, including non-profit organisations, represented 2% of total funding.



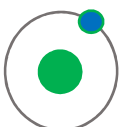
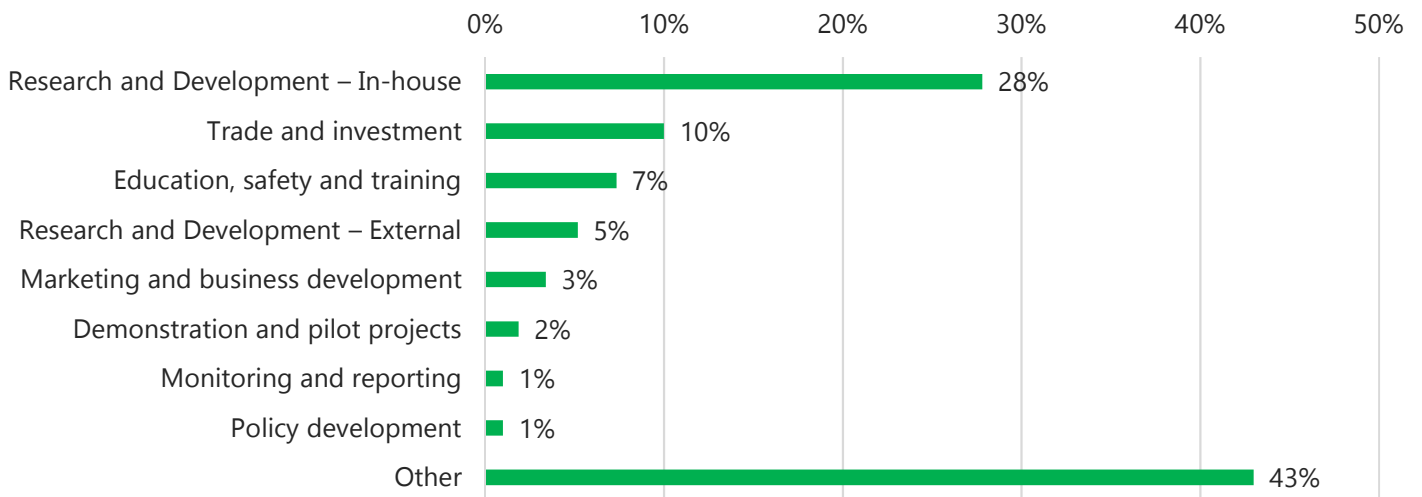
Source of Funding - Academic and Non-profit



Government, Academic and Non-Profit

In 2017, government, academic, and non-profit survey respondents collectively allocated over 30% of their funding to R&D (28% in-house and 5% external). Ten percent of funding was allocated to trade and investment, and 7% to education, safety and training. In total, seven percent of funding was allocated to marketing and business development, demonstration and pilot projects, monitoring and reporting, and policy development, while 43% of funding went towards other initiatives.

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





SILYZER 200 electrolyser system. (Source: Siemens)

Siemens' Canadian headquarters are located in Oakville, Ontario. Siemens is a supplier of gas and steam turbines for power generation and power transmission solutions, and a developer in infrastructure solutions and automotive, drive and software solutions for industry. Siemens has developed the SILYZER 200, an electrolysis system that uses wind and solar energy to produce hydrogen and produces no carbon dioxide emissions. The system can be used for re-cooling systems, water treatment systems, and power grid connections.

Siemens, as part of the H2FUTURE consortium, recently announced the construction of the world's largest pilot plant for the production of "green" hydrogen in Linz, Austria. The plant will use a Siemens PEM electrolyser module, and will test the application of "green" hydrogen in the steel production process. The plant has a capacity of six mega watts and is scheduled to be operational in 2019.

(<https://www.siemens.com/press/en/pressrelease/?press=/en/pressrelease/2018/corporate/pr2018040253coen.htm>)



Final assembly of the Siemens electrolyser for Project Mainz, a joint energy storage project of Stadtwerke Mainz, Siemens, Linde, and RheinMain University. The system, equipped with an electrolyser from Siemens, will convert surplus electricity from wind farms to hydrogen. (Source: Siemens)

Simulent Consulting Inc. (Simulent), located in Toronto, Ontario, is an engineering consulting company affiliated with the University of Toronto which has been involved in heat and mass transfer initiatives for the past 20 years. Simulent has been working with the University of Toronto on heat exchanger technology applications for the fuel cell market. (<http://simulent.com/>)

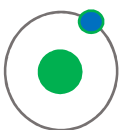


(a)



(b)

10 mm thick, 10 PPI nickel foam with end caps attached in the shape of (a) a flat plate (b) a section of a cylinder. (Source: Simulent Consulting)



OUTLOOK

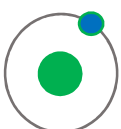
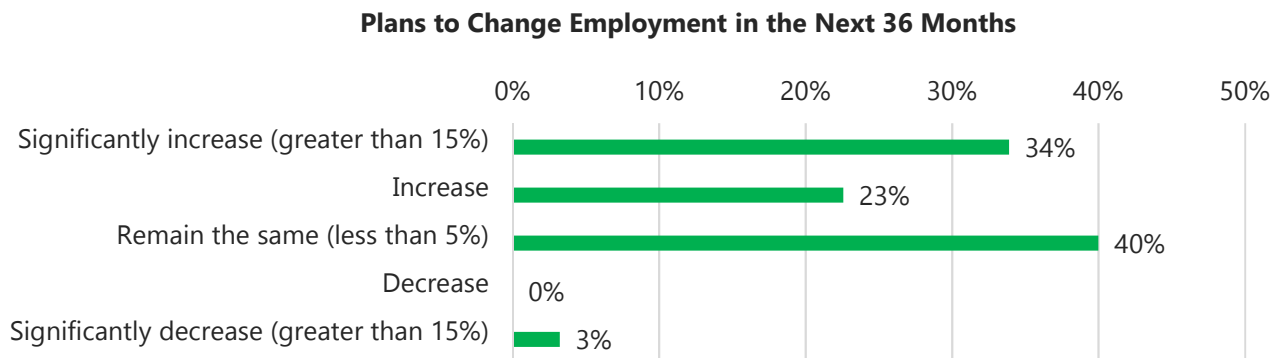
Survey respondents were asked to identify their top three priorities to enhance their competitive performance, looking ahead. Their top priorities were technology development (23%) and collaboration and strategic alliances (22%). This was followed by cost reduction (11%), improving processes (10%), and growing market share (9%).

Plans for expansion, better targeting of customers, staff retention, better market or customer data, and outsourcing were also named as priorities.



Employment Outlook

Within the next 36 months, 57% of survey respondents planned to increase or significantly increase employment, 40% planned to keep employment the same, and 3% planned to reduce employment.



Hydra Energy (Hydra), headquartered in Vancouver, British Columbia, provides vehicle retrofits and refueling infrastructure to fleet operators at no up-front cost, in exchange for an exclusive hydrogen fuel supply agreement. Any heavy-duty diesel truck can be retrofitted with Hydra technology to operate as a dual fuel, hydrogen and diesel vehicle without performance loss while cutting greenhouse gas (GHG) and air emissions in half. According to Hydra, this enables fleet operators to reduce fuel costs with no technology risk. As of April 2018, Hydra has begun delivering commercial vehicles and is scaling up to meet the market demand. (<http://hydra-energy.ca/>)

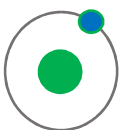


Hydra truck. (Source: Hydra)



IRDI System, based in Richmond, British Columbia, is a manufacturer of infrared communication equipment and other products used by the hydrogen and fuel cell industry. IRDI's products sold to Europe, Japan, and the US. In 2017, with help from the Canadian Trade Commissioner Service, IRDI's products supplied equipment to build hydrogen stations in South Korea. (<http://irdisystem.com/>)

Hydrogen dispenser in South Korea using IRDI System parts supplied through its German partner, WEH. (Source: IRDI System)

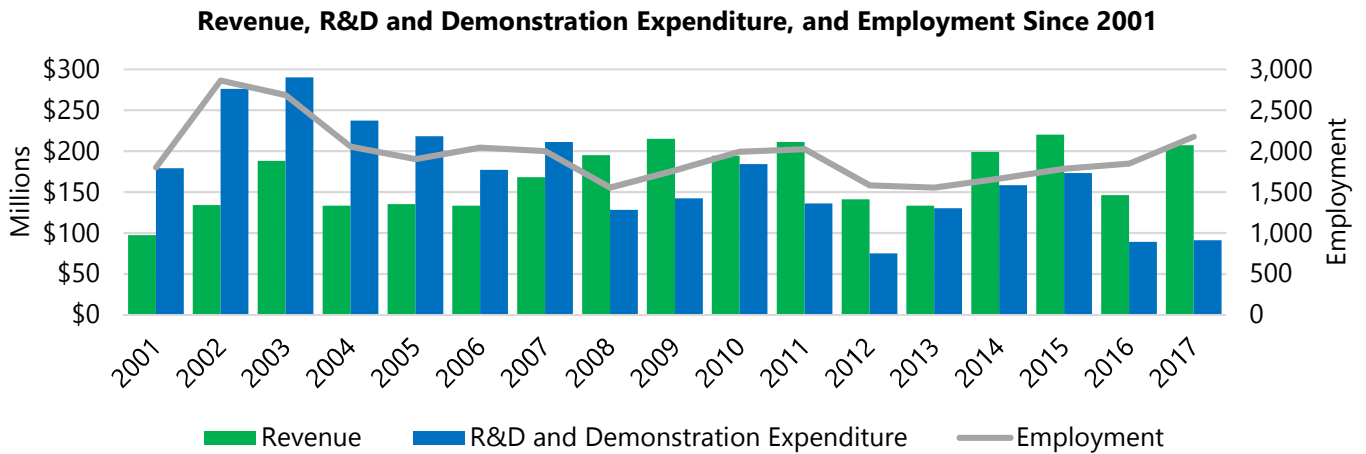


CONCLUSION

The Canadian hydrogen and fuel cell sector is recognised for its role in the development of clean technology applications. In 2017, approximately 60% of survey respondents reported involvement in hydrogen and fuel cell activities for more than 10 years, which suggests the sector has a stable base of organisations. Research and fuel cell development manufacturing were the largest areas of focus and expertise for most survey participants. The top priorities in 2018 for survey respondents were technology development and collaboration and strategic alliances.

In 2017, survey respondents from the Canadian hydrogen and fuel cell sector reported:

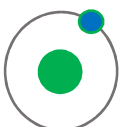
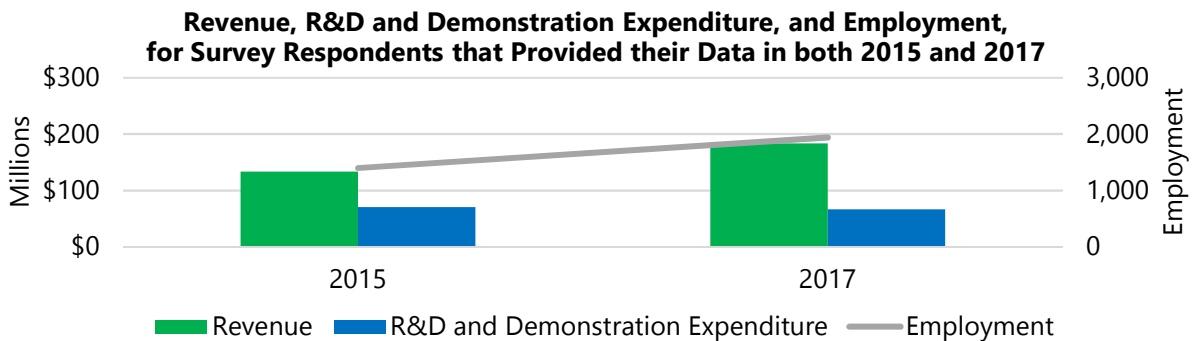
- Revenue of \$207 million.
- \$150 million of revenue from product sales.
- \$47 million of revenue from research and development contracts.
- Research, development and demonstration expenditures of \$91 million.
- Employment of 2,177 jobs.
- 65 demonstration projects.
- 46 strategic alliances.
- 319 research partnerships.



For survey respondents that provided data for both 2015 and 2017:

- Total revenue increased approximately 37% between 2015 and 2017.
- Total R&D and demonstration expenditures decreased approximately 5% between 2015 and 2017.
- Total employment increased approximately 38% between 2015 and 2017.

(Please note that the results are driven by a few large organisations in the industry.)



Canadian Hydrogen and Fuel Cell Association (CHFCA)

The Canadian Hydrogen and Fuel Cell Association (CHFCA) is the national association accelerating Canada's world-recognised hydrogen and fuel cell sector. As the collective voice of the hydrogen and fuel cell industry, the CHFCA raises awareness of the many economic, environmental and social benefits of hydrogen and fuel cells. Its mission is to champion the Canadian hydrogen and fuel cell sector, strengthen its leadership and accelerate the commercialization of members' products and services in Canada and abroad. 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 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 4,000 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.



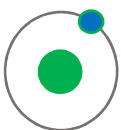
www.chfca.ca



www.ic.gc.ca



www.mnp.ca



METHODOLOGY

Information on the state of the Canadian hydrogen and fuel cell industry has been collected for 17 years. 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 organisations (educational, non-profit and non-governmental organisations (NGOs)).

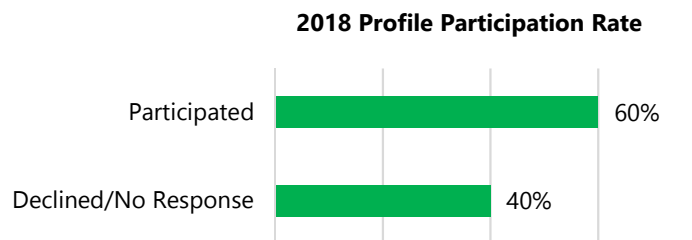
All monetary results are presented in Canadian dollars.

A total of 124 organisations associated with hydrogen and fuel cells in Canada were invited to participate in the development of this Sector Profile.

In total, 74 responses were received, representing an overall response rate of 60%. 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 low due to concerns about inferring financial information from survey data.

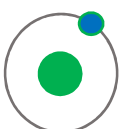


A list of survey respondents is included at the end of the report. Note that some respondents did not consent to having their organisation's name published in the sector profile.

Figures presented for 2017 and 2016 were collected by an online questionnaire in early 2018. Figures for previous years are presented as they were reported in previous Sector Profiles and, therefore, may not be fully comparable due to differing respondents and/or participation rates.

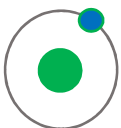
Please note that this report presents only direct impacts of the industry. Indirect and induced impacts (or multiplier impacts) associated with the industry were not part of the study.

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



2018 PARTICIPANTS

Advanced Flow Systems
Associated Plastics & Supply Corp.
Aurora Scientific Corp.
Ballard Power Systems
BC Ministry of Energy, Mines, and Petroleum Resources
Blue-O Technology Inc.
Canadian Nuclear Laboratories
Cellula Robotics Ltd.
Centre for Nuclear Energy Research - University of New Brunswick
Change Energy Services Inc.
Canadian Hydrogen and Fuel Cell Association
Clean Energy Research Centre, UBC
CSA Group
Ecole Polytechnique de Montreal
G&S Budd Consulting Ltd.
Global Affairs Canada - Trade Commissioner Service
Greenlight Innovation Corp.
HTEC Hydrogen Technology & Energy Corp.
Hydra Energy Corp.
Hydrogen In Motion Inc. (H2M)
Hydrogen Research Institute
Hydrogenics Corp.
Hyteon Inc.
Innovation, Science and Economic Development Canada
Institut National de la Recherche Scientifique (INRS)
Ionomr Innovations Inc.
IRDI System
Kraus Global Ltd.
Loop Energy Inc.
Luxfer Canada Ltd.
National Research Council - Industrial Research Assistance Program (IRAP)
National Research Council Canada
GREEN Groupe de recherche en energie et environnement
Next Hydrogen Corporation
NORAM Engineering & Constructors Ltd.
Nu:ionic Technologies
OverDrive Fuel Cell Engineering Inc.
Pacific Welfare Resource Investment
Palcan Energy Corp.
Pathway Industries Inc.
Powertech Labs
Quadrogen Power Systems, Inc.
Sacre-Davey Engineering
Sustainable Development Technology Canada
Siemens
Simulent Consulting Inc.
Sustainable Energy Engineering Queen's University
Tandem Technologies
Terrella Energy Systems Ltd.
The CCS Global Group Inc.
Toyota Canada
Transport Canada
Truckenbrodt Clean Energy Consulting
University of Windsor
University of Alberta
University of Waterloo
University of Ontario Institute of Technology
Xebec Adsorption Inc.
XRG Energytech Solutions Inc.
Zen Clean Energy Solutions Inc.



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