U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Fuel Cell Technologies Market Report 2014

(This page intentionally left blank)

Authors

This report was compiled and written by Sandra Curtin and Jennifer Gangi of the Fuel Cell and Hydrogen Energy Association, in Washington, D.C.

Acknowledgement

The authors relied upon the hard work and valuable contributions of many men and women in government and in the fuel cell industry. The authors especially wish to thank Sunita Satyapal and the staff of the U.S. Department of Energy's Fuel Cell Technologies Office for their support and guidance. Also thanks to Philipp Beiter, Tian Tian, and Jeff Logan of the National Renewable Energy Laboratory, and David Hart and Franz Lehner of E4Tech.

Notice

Cover Image

Cal State L.A. Hydrogen Research and Fueling Facility in Los Angeles, California. The station was formally opened on May 7, 2014 and is the largest University located hydrogen fueling facility in the nation. Image courtesy of California Fuel Cell Partnership.

List of Acronyms

AFCB	American Fuel Cell Bus
APU	Auxiliary power unit
ARFVTP	California's Alternative and Renewable Fuel and Vehicle Technology Program
ARPA-E	Advanced Research Projects Agency – Energy (DOE)
CEC	California Energy Commission
CHP	Combined heat and power
CTE	Center for Transportation and the Environment
DMFC	Direct methanol fuel cell
CO2	Carbon dioxide
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
EERE	Office of Energy Efficiency and Renewable Energy (DOE)
FCEV	Fuel cell electric vehicle
FCTO	Fuel Cell Technologies Office (DOE)
FTA	U.S. Federal Transit Administration
HNEI	Hawaii Natural Energy Institute
IP	Intellectual property
IPO	Initial public offering
kg	Kilogram
km	Kilometer
km/h	Kilometers per hour
kW	Kilowatt
kWh	Kilowatt-hour
MARAD	U.S. Maritime Administration
MCFC	Molten carbonate fuel cell
m-CHP	Micro-combined heat and power
MEA	Membrane electrode assembly
METI	Japan's Ministry of Economy, Trade and Industry
MHE	Material handling equipment
mph	miles per hour

MoU	Memorandum of Understanding
MPa	Megapascal
MW	Megawatt
NFCBP	National Fuel Cell Bus Program
NREL	National Renewable Energy Laboratory
OEM	Original equipment manufacturer
OTC	Over-the-counter
PAFC	Phosphoric acid fuel cell
PE	Private equity
PEM	Proton exchange membrane
PIPE	Private in public equities
R&D	Research and development
RD&D	Research, development and demonstration
REBELS	ARPA-E's Reliable Electricity Based on ELectrochemical Systems
SBIR/STTR	Small Business Innovation Research/Small Business Technology Transfer
SOFC	Solid oxide fuel cell
UAV	Unmanned Aerial Vehicle
VC	Venture capital
W	Watt

Table of Contents

List of Figures

List of Tables

Currency Exchange Rates

The U.S. Internal Revenue Service 2014 yearly average exchange rates were used to convert foreign currencies to U.S. dollars using the following rates. If unspecified, amounts are reported in U.S. dollars.

Table 1. 2014 Average Exchange Rates for Converting Foreign Currencies into U.S. Dollars

2014 Average Exchange Rates			
Country	**Currency**	**Abbreviation/Symbol**	**Rate**
Australia	Dollar	AU$	1.154
Canada	Dollar	CA$	1.149
Euro Zone	Euro	€	0.784
Japan	Yen	¥	110.101
Sweden	Krona	kr	7.138
United Kingdom	Pound	£	0.632

Source: U.S. Internal Revenue Service

Introduction

Fuel cells are devices that electrochemically combine hydrogen and oxygen to produce electricity, water, and heat. Unlike batteries, fuel cells continuously generate electricity as long as a source of fuel is supplied. Fuel cells do not burn fuel, making the process quiet, pollution-free, and two to three times more efficient than combustion. A fuel cell system can be a truly zero-emission source of electricity when hydrogen is produced from nonpolluting sources.

There are three main markets for fuel cell technology: stationary power, transportation, and portable power. Stationary power includes any application in which the fuel cells are operated at a fixed location for primary power, backup power, or combined heat and power (CHP). Transportation applications include motive power for passenger cars, buses and other fuel cell electric vehicles (FCEVs), specialty vehicles, material handling equipment (MHE), and auxiliary power units (APUs) for off-road vehicles. Portable power applications include fuel cells that are not permanently installed or fuel cells in a portable device.

There are many types of fuel cells currently in operation in a wide range of applications, including molten carbonate fuel cells (MCFC), solid oxide fuel cells (SOFC), phosphoric acid fuel cells (PAFC), direct methanol fuel cells (DMFC) and low and high temperature proton exchange membrane (PEM) fuel cells.

In 2014, the fuel cell industry grew by almost $1 billion, reaching $2.2 billion in sales, up from $1.3 billion in 2013. Major increases were seen in North America and Asia Pacific revenues, spurred by fuel cells for material handling (U.S.) and large-scale stationary sales by U.S. companies and residential fuel cells in Japan.

A number of ongoing market trends continued in 2014, contributing to an increase in shipments and revenue:

- State incentives drove large stationary deployments, primarily in California and Connecticut, but other states in the Northeast have begun to fund fuel cells as part of microgrids and other resiliency efforts.
- Major corporations deployed fuel cells at retail, corporate, and warehouse facilities, many in multiple locations. Municipalities are following suit, installing fuel cells at facilities that provide critical city and county services, such as administrative centers, jails, and wastewater treatment plants.
- Japan and South Korea continued their strong support of fuel cell technology. Customer sales of the Enefarm residential fuel cell system surpassed 115,000 units in Japan in 2014, while Korean utilities continued to construct larger and larger multi-megawatt (MW) fuel cell power parks to generate grid power.
- Energy storage and Power-to-Gas (P2G) projects grew in Europe, while Japan began exploring large-scale production of renewable hydrogen from various sources.

Notable in 2014

The fuel cell Industry grew to $2.2 billion in 2014, up from $1.3 billion in 2013.

More than 50,000 fuel cells were shipped in 2014, totaling 180 MW.

Almost 10% of Fortune 500 companies now use fuel cells for stationary or motive power generation. Of the top 100 companies on the Fortune list, 25% use fuel cells. These fuel cells are often deployed in multiple locations, powering forklifts, data centers, cell phone towers, and corporate or retail facilities.

More than 2,500 fuel cells for material handling vehicles were ordered or installed in 2014, bringing the number of fuel cell-powered forklifts in North America to more than 7,500 units, located at more than 60 warehouses and distribution facilities in 20 states and Canada.

Commercial introduction of FCEVs started in late 2014, when Hyundai started leasing vehicles in southern California and in a number of countries around the world. Toyota announced it will begin FCEV sales in the U.S. in 2015 and Honda claimed its FCEV sales will start in 2016.

More than 90 new, planned, or upgraded hydrogen fueling stations were announced worldwide.

California's Energy Commission awarded $46.6 million for 28 new public hydrogen stations and one mobile hydrogen refueler. The state will provide at least $20 million annually until an initial network of 100 hydrogen stations exists in California.

FCEVs generated major headlines and excitement as automakers delivered FCEVs to customers in select locations around the world and unveiled new FCEV models and market introduction strategies. The United Kingdom (U.K.), Germany, Japan, and California reaffirmed both commitments and funding to accelerate development of the hydrogen fueling infrastructure, as did Toyota, which announced plans to help to fund hydrogen fueling station development in the United States (U.S.), in California and the Northeast.

The fuel cell industry also saw the formation of strategic alliances, business reorganizations and expansions, successful capital raising efforts, and more fuel cell companies going public. There were company acquisitions from within and outside of the fuel cell industry, including the acquisition of a fuel cell manufacturer by Hyster-Yale, a major global MHE company, with plans to integrate fuel cells and hydrogen fueling across large parts of the company's MHE products.

Business and Financial Data

This section provides information regarding a range of activity regarding fuel cell and hydrogen company financials. It includes business activities – mergers and acquisitions, company expansions, joint ventures, industry investment, memoranda of understanding (MOUs) and collaborations. It provides an overview and analysis of venture capital, private equity, and other investment activity, including equity and stock offerings to raise capital, and an overview of intellectual property and patent activity in 2014. This section also includes fuel cell company revenues, cost of revenue, and other key data for selected publicly traded fuel cell companies that have fuel cells as their primary business. The focus is on public companies because many private companies do not release financial information.

Business Activities

There were many business acquisitions in 2014 that allowed purchasers to expand their end-user markets and fuel cell product offerings.

In April 2014, Latham, New York, fuel cell manufacturer Plug Power acquired the assets of ReliOn, Inc., a fuel cell company based in Spokane, Washington.[1] Following the acquisition, Plug Power restructured to offer ReliOn, a Plug Power company, as a product brand, and announced plans to integrate ReliOn's fuel cell stack technology and products into several models of its GenDrive fuel cell systems for the backup and grid-support power requirements of the telecommunications, transportation, utility and government sectors. ReliOn will continue its operations in Spokane as a Plug Power company.[2]

In April, fuel cell manufacturer ClearEdge Power announced it intended to file for bankruptcy.[3] In June 2014, South Korean company Doosan Co. Ltd. entered into an asset purchase agreement to acquire the assets of ClearEdge Power, Inc. for $32.4 million.[4] Doosan also acquired FuelCellPower Co. Ltd., another South Korean company which focuses on smaller fuel cells for residential applications. Following its acquisition of ClearEdge Power and Fuel Cell Power, Doosan Corporation formed the Doosan Fuel Cell Group, and from that, Doosan Fuel Cell America, Inc. Doosan resumed operations at ClearEdge's South Windsor, Connecticut, facility, focusing primarily on manufacturing 400-kilowatt (kW) stationary fuel cell systems.

Prior to the ClearEdge bankruptcy and subsequent Doosan acquisition, Connecticut-based United Technologies Corporation (UTC), once the parent company of UTC Power (ClearEdge Power's predecessor), entered into arrangements with other fuel cell companies:

- In January 2014, UTC entered into a global licensing agreement with US Hybrid Corporation, located in Torrance, California, to commercialize UTC's PEM fuel cell technologies, focusing on the medium and heavy duty commercial vehicle sectors.[5] US Hybrid formed US FuelCell Corporation, a new division, located at the former UTC Power plant in Windsor, Connecticut, and the company has taken over all contracts previously awarded to UTC Corporation, including ones from the Federal Transit Administration (FTA) through its National Fuel Cell Bus Program (NFCBP).

- In May 2014, UTC completed the sale of intellectual property (IP) assets related to its PEM transportation- and stationary-related fuel cell technology, including approximately 800 patents and patent applications, to Ballard Power Systems, a Canada-based fuel cell manufacturer. In exchange for the IP, UTC received 5.1 million Ballard common shares, $2 million in cash, a grant-back license to use the patent portfolio in UTC's existing businesses and a royalty on Ballard's future IP licensing income generated from the combined IP portfolio. The companies also formed a strategic alliance, led by a joint Advisory Council, to focus on licensing and other commercial market opportunities arising from the combination of the UTC portfolio with Ballard's existing IP.[6]

In February, U.K.-based Western Standard Energy Corp. acquired Dominovas Energy, LLC (California), renamed the company Dominovas Energy Corporation and moved its headquarters to Atlanta, Georgia. The company manufactures the RUBICON® SOFC system.[7]

Ballard Power Systems signed a definitive agreement for the sub-license of IP and engineering services with M-Field Energy Corporation (Taiwan) for fuel cell material handling systems to be deployed in Europe.[8] The agreement has a value of approximately $1 million. Ballard's subsidiary, Dantherm Power entered into an agreement with H2 Logic A/S (Denmark) for a complete transfer of H2 Logic's H2Drive® material handling fuel cell activities, mainly its collaboration with M-Field. H2 Logic will instead focus and expand efforts on its H2Station® hydrogen refueling stations.[9]

In May, the Michelin Group (France) undertook a significant minority stake in Symbio FCell, a French fuel cell manufacturer developing fuel cell range extenders currently being tested by major commercial fleet operators, including La Poste (the French post office).[10]

In June, Heliocentris Energy Solutions AG (Germany) acquired FutureE Fuel Cell Solutions GmbH, a German company focused on the telecommunications industry.[11]

In October, WATT Fuel Cell Corp., a New York developer of SOFC components and systems, purchased Pennsylvania-based tubular SOFC developer Pittsburgh Electric Engines, Inc. (PEEI), making PEEI a wholly owned subsidiary of WATT. The company opened a new 15,000 square foot manufacturing plant in Pennsylvania and seeks to transition to larger systems for residential power and small-scale distributed generation.[12]

In December, Hyster-Yale Materials Handling, Inc.'s operating company, NACCO Materials Handling Group, Inc. (Ohio) acquired Massachusetts-based Nuvera Fuel Cells, Inc.[13] NACCO intends to integrate Nuvera's fuel cells into its MHE vehicles, including its Hyster® and Yale® product line, as well as offer customers hydrogen generation and refueling equipment.

Hydrogen Future Corp. (Texas), previously known as A5 Laboratories Inc., completed the acquisition of Hydra Fuel Cell Corporation (Oregon) from American Security Resources Corporation. Hydra has developed fuel cell technology for residential and small commercial grid replacement for electric generation.[14]

Several companies expanded their operations, opening new facilities or setting up establishing offices outside their home country:

- General Electric (GE) opened a fuel cell testing and research facility in Malta, New York, to focus on developing its SOFC technology. GE expects to begin commercial production of systems with capacities ranging from 1 to 10 MW in 2017.[15]

- Fuel cell manufacturer PowerCell (Sweden) expanded its international business operations into Korea and Asia for its new generation S2 fuel cell stack.[16]

- U.K. fuel cell company Ceres Power opened an office in the Kansai area of Japan to service commercial activity and support further strategic opportunities in Asia.[17]

- FuelCell Energy announced a two-stage expansion project that will increase the size of its manufacturing facility in Torrington, Connecticut.[18]

- In addition, a few companies faced significant challenges.
- Vision Industries Corp., a California developer of zero emission electric/hydrogen hybrid powered vehicles and turnkey hydrogen fueling systems, filed for Chapter 11 bankruptcy protection. During the reorganization process, Vision will continue to operate and work on ongoing government-supported programs and research and development (R&D) projects.[19]
- Lilliputian Systems, a Massachusetts Institute of Technology-spinout company that developed a butane-powered fuel cell charger called Nectar, sold its physical and intellectual property assets and closed. In the past, the company raised about $150 million in investment from a half-dozen venture capital firms, but was unsuccessful in raising additional investment.[20]
- Danish company Haldor Topsoe A/S announced its plan to close Topsoe Fuel Cell A/S, a subsidiary company focused on components and technology for high temperature SOFCs. Haldor Topsoe will focus on the development of selected applications in solid oxide electrolysis cell development.[21]

There were also several announcements of joint ventures, MOUs and collaborations during the year:

- Plug Power signed a non-binding MOU with Hyundai Hysco Co. Ltd. to create a joint venture partnership to develop and sell hydrogen fuel cells in countries throughout Asia.[22]
- Air Products joined with Nippon Steel & Sumkin Pipeline & Engineering Co. Ltd. to work together on Japan's developing hydrogen fueling infrastructure market and work towards finalizing a long-term marketing and supply relationship agreement.[23]
- Hydrogenics Corporation and Universiti Teknologi Malaysia entered into an MOU to focus on the development of highly efficient PEM fuel cell integrated systems using hydrogen.[24]
- Hydrogenics created a joint venture, Kolon Hydrogenics, with Kolon Water & Energy of South Korea to work on renewable power generation projects in Asia. This contract includes both a fuel cell system and a 20-year maintenance and service agreement.[25]
- Oorja Fuel Cells and Los Alamos National Laboratory (LANL) entered into a licensing agreement allowing Oorja Fuel Cells to deploy two key energy technologies developed by LANL aimed at improving power density and reducing the cost of DMFC based power systems.[26]

Revenues, Assets, and R&D Expenses

Fuel cell companies derive revenue from the sale of fuel cells and related equipment (such as hydrogen generators), support and maintenance contracts, and contract research and development.

Tables 2 through 4 provide financial data for select public companies. These companies were chosen because fuel cells are their primary product, and because they are traded on major stock exchanges and thus must report detailed data.

Table 2 shows gross revenue and cost of revenue for select fuel cell companies over the past three years. Gross revenue is money generated by all of a company's operations during a specific period, before deductions for expenses. Cost of revenue is the total cost of manufacturing and delivering a product or service. It represents the direct costs associated with the goods and services the company provides and includes costs outside of production, such as distribution and marketing. Indirect costs, such as salaries, are not included.

Table 2. Gross Revenue and Cost of Revenue for Select Public Fuel Cell Companies

Gross Revenue and Cost of Revenue for Select Public Fuel Cell Companies (Thousands US$ except where noted)						
Companies	2014		2013		2012	
	Gross Revenue	Cost of Revenue	Gross Revenue	Cost of Revenue	Gross Revenue	Cost of Revenue
Ballard Power Systems (Canada)	68,721	58,475	61,251	44,492	43,690	36,321
FuelCell Energy[1] (U.S.)	180,293	166,567	187,658	180,536	120,603	120,158
Hydrogenics Corp. (Canada)	45,548	34,334	42,413	30,352	31,697	26,448
Plug Power (U.S.)	64,230	69,092	26,601	37,849	26,108	40,463
Ceramic Fuel Cells, Ltd.[2, 3] (Australia)	6,102	24,540	4,266	21,544	6,717	27,228
Ceres Power[2, 4] (U.K.)	1,224	10,128	523	13,255	226	18,480
SFC Energy AG[5] (Germany)	53,631	37,970	32,413	22,4886	31,260	18,497

[1] Year ends October 31 [2] Year ends June 30 [3] AU$ Thousands [4] £ Thousands [5] € Thousands [6] Updated (audited) number from SFC Energy's 2014 Annual Report. Source: Annual reports and investor presentations

The following discussion provides additional details regarding revenue drivers for select companies in 2014.

Ballard Power Systems' gross revenue was $68.7 million for 2014, an increase of $7.5 million compared to 2013 revenue of $61.3 million. The increase was ascribed to significantly higher engineering services and material handling revenues, which more than offset the decline in telecom backup power and development stage revenues.[27] The company did not record any engineering services, bus or telecom backup power revenue in the fourth quarter of 2014 from the Azure Bus and Azure Telecom Backup Power Agreements as a result of contract breaches by Azure Hydrogen (China).[28] Prior to the contract breaches by Azure, Ballard recognized a total of $8.7 million on the two agreements in 2014 and a total of $5 million in 2013.[29] Ballard's cost of revenue was $58.5 million.

FuelCell Energy reported that gross revenue for fiscal year (FY) 2014 decreased by $7.4 million, to $180.3 million, down from $187.7 million in FY2013. This was due to a change in product mix with less revenue from multi-megawatt installations and associated engineering, procurement and construction services.[30] Cost of revenue for FY2014 was $166.6 million.

Hydrogenics' gross revenue increased by $3.1 million to $45.5 million in 2014 compared to $42.4 million in 2013. Growth in 2014 revenue was attributed to increases in Onsite Generation revenue, offset by decreases in Power Systems revenue as a result of orders from the first and second quarters of 2013, with no comparable orders during the same periods in 2014.[31] The company's cost of revenue was $34.3 million. Hydrogenics also reported that the company posted its first profitable quarter during the fourth quarter of 2014, earning $0.6 million in net income on revenue of $15.7 million.[32, 33]

Plug Power's gross revenue was $64.2 million, an increase of 141% over total revenue of $26.6 million in 2013. This growth was predominantly driven by sales of the company's new GenKey solution, comprised of GenDrive or ReliOn hydrogen fuel cells for material handling equipment, GenFuel hydrogen infrastructure, and GenCare customer service contracts.[34] Total cost of revenue was $69.1 million in 2014, compared to total cost of revenue of $37.8 million in 2013, which Plug Power attributes to an improvement from a net margin rate of (42%) for 2013 versus a full year rate of (8%) for 2014, as well as higher product and installation site sales, substantial volume leverage, supply chain cost downs, and continued product design improvements.[35]

Ceramic Fuel Cells Ltd.'s gross revenue increased by AU$1.8 million ($1.6 million), to AU$6.1 million ($5.3 million), up from AU$4.3 million ($3.7 million) in FY2013. The increase in revenue was attributed to 210 fuel cell units sold during the year compared to 147 units in 2013.[36] The cost of revenue was AU$24.5 million ($21.2 million) in FY2014.

Ceres Power's gross revenue grew by £0.7 million ($1.1 million), reaching £1.2 million ($1.9 million) in FY2014, up from £0.5 million ($0.8 million) in 2013. The company reported that its 2014 revenue was derived from one customer in the U.K. (£0.7 million, or $1.1 million), one customer in Asia (£0.3 million, or $0.5 million) and several customers outside of Europe.[37] The company's cost of revenue was £10.1 million ($16 million) in FY2014.

SFC Energy reported that gross revenue increased by €21.2 million ($27.1 million) to €53.6 million ($68.4 million) in FY2014, up from €32.4 million ($41.3 million) in FY 2013. Cost of revenue was €38.0 million ($48.5 million) in FY2014.

R&D expenditures are shown in Table 3.

Table 3. R&D Expenditures for Select Public Fuel Cell Companies

R&D Expenditures for Select Public Fuel Cell Companies (Thousands US$, unless footnoted)			
Companies	**2014**	**2013**	**2012**
Ballard Power Systems (Canada)	14,294	17,117	19,273
FuelCell Energy[1] (U.S.)	18,240	15,717	14,354
Hydrogenics Corp. (Canada)	3,284	2,566	4,452
Plug Power (U.S.)	6,469	3,121	5,434
Ceramic Fuel Cells, Ltd.[2, 3] (Australia)	7,610	7,870	11,539
Ceres Power[2, 4] (U.K.)	7,138	7,190	13,205
SFC Energy AG[5] (Germany)	4,530	5,4336	4,257

[1] Year ends October 31 [2] Year ends June 30 [3] AU$ Thousands [4] £ Thousands [5] € Thousands [6] Updated (audited) number from SFC Energy's 2014 Annual Report. Source: Annual reports and investor presentations

Ballard Power Systems reported that R&D expenditures were $14.3 million in 2014, $2.8 million lower than 2013 expenditures of $17.1 million, largely driven by a 43% increase in engineering services revenues that resulted in engineering staff resources being redirected to revenue generating engineering service projects.[38]

Ceramic Fuel Cells also reported lower R&D expenditures, at AU$7.6 million ($6.59 million) in FY2014, which is AU$0.3 million ($0.26 million) lower than FY2013 expenditures of AU$7.9 million ($6.85 million), attributed to the March 2014 company restructuring that led to a reduction in work force and a lowering of operational and production costs.[39, 40]

Ceres Power showed a small decline in R&D expenditures, down by £0.05 million ($0.08 million) to £7.14 million ($11.3 million) in FY2014, from £7.19 million ($11.38 million) in FY2013.

FuelCell Energy's R&D expenditures increased by $2.5 million, to $18.2 million during FY2014, compared to $15.7 million FY2013. This increase was attributed to: continued product development initiatives to consolidate select componentry and processes for the balance of plant functions as part of ongoing cost reduction programs; product enhancements to further enhance the customer value proposition such as high-efficiency solutions for targeted applications; and a program to support European market development.[41]

Hydrogenics' R&D expenditures were $3.3 million for FY2014, compared to $2.6 million in FY2013, with the $0.7 million increase due to the development of the company's Celerity™ fuel power system for medium and heavy duty vehicles and power-to-gas projects.[42]

Plug Power's R&D expenditures for 2014 were $6.4 million, an increase of $3.3 million over 2013 expenditures of $3.1 million. The increase mainly stemmed from investments commensurate with the company's growth, as well as incremental costs assumed with the acquisition of ReliOn, which will allow Plug Power to expand its fuel cell stack development capabilities.[43]

SFC Energy reported R&D expenditures of €4.5 million ($5.7 million) for 2014, down by €0.9 million ($1.1 million) from 2013 expenditures of €5.4 million ($6.9 million).

Table 4 shows each company's total assets and liabilities. Plug Power's assets increased significantly in 2014, growing from $35 million in 2013 to more than $205 million in 2014, an increase of $170.5 million. Much of the growth resulted from an increase in cash and cash equivalents, which rose from $5 million in at the end of 2013, to more than $146 million at the end of 2014.

Table 4. Total Assets and Liabilities for Select Public Fuel Cell Companies

Total Assets and Liabilities for Select Public Fuel Cell Companies (Thousands US$ except where noted)						
Companies	2014		2013		2012	
	Assets	Liabilities	Assets	Liabilities	Assets	Liabilities
Ballard Power Systems (Canada)	127,905	48,715	120,214	49,960	127,547	69,545
FuelCell Energy[1] (U.S.)	280,636	108,420	237,636	190,971	191,485	117,119
Hydrogenics Corp. (Canada)	47,555	32,079	40,070	33,909	41,877	37,570
Plug Power (U.S.)	205,881	46,445	35,355	50,856	39,460	24,430
Ceramic Fuel Cells, Ltd.[2, 3] (Australia)	26,330	18,415	33,326	17,580	32,810	11,913
Ceres Power[2, 4] (U.K.)	10,084	3,726	16,935	4,561	13,168	4,487
SFC Energy AG[5] (Germany)	47,256	19,667	47,649	18,586	47,617	11,224

[1] Year ends October 31 [2] Year ends June 30 [3] AU$ Thousands [4] £ Thousands [5] € Thousands [6] Updated (audited) number from SFC Energy's 2014 Annual Report. Source: Annual reports and investor presentations

Investment

Disclosed cumulative global investment in fuel cell companies - venture capital (VC), private equity (PE), over-the-counter (OTC), and private investment in public equities (PIPE) - totaled $736.2 million for the period of 2012 to 2014, declining from $1.038.8 billion between 2011 and 2013 and $853.6 million between 2010 and 2012, as reported in the 2013 and 2012 editions of this report. Figure 1 provides a breakdown by quarter and by investment type.

Examining the numbers on a year-by-year basis, global investment declined from $307.1 million in 2012 and $274.5 million in 2013, to $154.6 million in 2014.

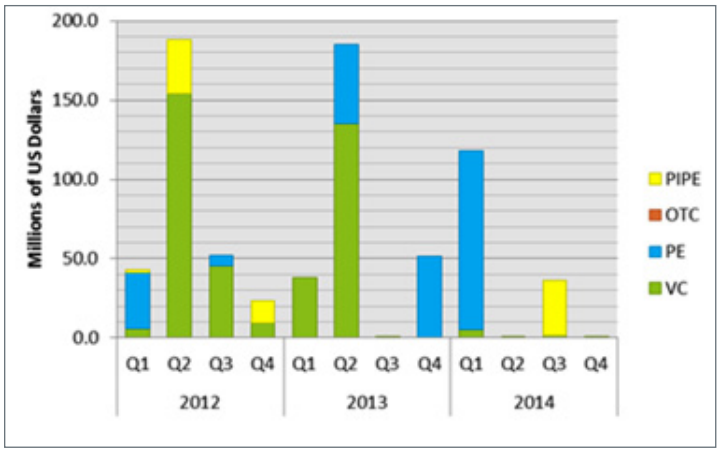

Chart created by Fuel Cell and Hydrogen Energy Association using data from Bloomberg New Energy Finance and New Zealand Superannuation Fund. Data provided by Bloomberg New Energy Finance includes only disclosed and completed deals.

Figure 1. Worldwide Venture Capital, Private Equity, Over-the-Counter, and Private Investment in Public Equities Investments in Fuel Cell Companies (2012-2014)

Figure 2 shows disclosed total U.S. investment in fuel cell companies between 2012 and 2014. U.S. investment totaled $40.0 million in 2014, down from $172.7 million in 2013 and $245.8 million in 2012. The U.S. contribution to global fuel cell investment was 62% between 2012 and 2014, reflecting a decrease from the 80% reported for the period 2011 to 2013.

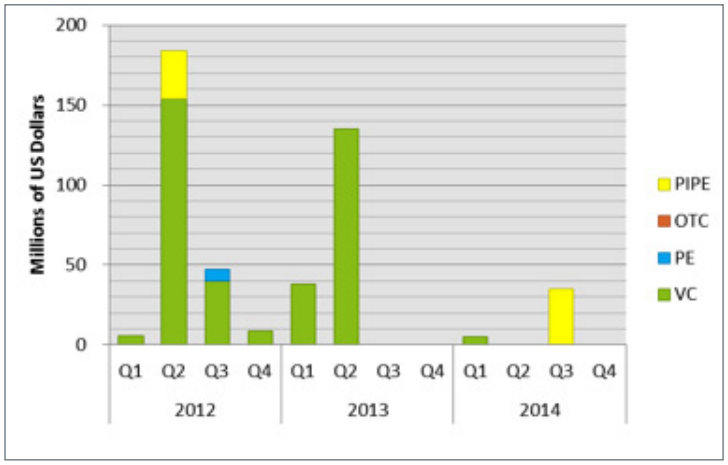

Chart created by Fuel Cell and Hydrogen Energy Association using data from Bloomberg New Energy Finance. Data provided by Bloomberg New Energy Finance includes only disclosed and completed deals.

Figure 2. U.S. Venture Capital, Private Equity, Over-the-Counter, and Private Investment in Public Equities Investments in Fuel Cell Companies (2012-2014)

Table 5 shows disclosed VC and PE investments in fuel cell-related companies during 2014, totaling $119.9 million. These investments were made by the following firms:

- The largest investment was made by Singapore's GIC Pte Ltd (the Government of Singapore Investment Corporation), which invested $63 million in Intelligent Energy Holdings (U.K.), a manufacturer of PEM fuel cell systems.
- The New Zealand Superannuation Fund made a second investment of $50 million in SOFC manufacturer, Bloom Energy (U.S.), having invested $50 million in Bloom during 2013.
- An undisclosed U.S. investor provided $5 million to CEP Reorganization, Inc., formerly ClearEdge Power (U.S.), several months prior ClearEdge's bankruptcy announcement in May. The PAFC manufacturer was purchased in July by South Korea's Doosan Corp., creating Doosan Fuel Cell America.
- Intelligent Energy Holdings PLC, SSE PLC, and Scottish Enterprise (U.K.) made a $1.3 million investment in IE CHP UK & Eire Ltd. IE CHP UK & Eire operates as a subsidiary of Scottish & Southern Energy PLC and is a joint venture company with Intelligent Energy, specializing in combined heat and power fuel cells.
- 350 Investment Partners (U.K.) invested a total of $0.3 million in PEM fuel cell manufacturer, Acal Energy, making three separate investments of $0.1 million (March, June, and December).

Table 5. Disclosed Top Venture Capital and Private Equity Investors in Fuel Cells, By Company and By Country (2014)

Top Fuel Cell Investors (2014)	
Company	**Amount (million US$)**
GIC Pte Ltd. (Singapore)	63.0
Superannuation Fund (New Zealand)	50.0
Undisclosed investor (U.S.)	5.0
Intelligent Energy Holdings PLC, SSE PLC, and Scottish Enterprise (U.K.)	1.3
350 Investment Partners LLC (U.K.)	0.3
TOTAL	**$119.6**

Source: Bloomberg New Energy Finance and New Zealand's Superannuation Fund

Further investments were made in 2014, but the values were not revealed:

- DAG Ventures LLC (U.S.) made an investment in Oorja Fuel Cells (U.S.).
- Idinvest Partners SA (France) and Total Energy Ventures International (France) invested in Sunfire GmbH (Germany).
- IPSA SA, CEA Investissement SA, and Michelin Group Inc. (France) invested in Symbio FCell SAS (France).

In addition, Phystech Ventures and North Energy Ventures (Russia) completed an investment in PEM fuel cell company AT Energy (Russia). The investment, reported to be about $1.9-$2.0 million, is expected to help develop the company's fuel cells for unmanned aerial vehicles and standby power supply systems for telecommunications projects.[44, 45] The investment made by Phystech Ventures and North Energy Ventures in AT Energy was not included in Figure 1 or Tables 5 and 6 as the exact dollar value of the investment is not clear.

Table 6 lists the top 10 reported global investors in fuel cells between 2000 and 2014, as well as countries with the highest level of investment during that period. The top five firms investing in fuel cell companies in the period are Credit Suisse (Switzerland); Kleiner, Perkins, Caufield & Byers (U.S.); Superannuation Fund (New Zealand), New Enterprise Associates (U.S.), and Mobius Venture Capital, Inc. (U.S.). In aggregate, the U.S. made the greatest cumulative investment during the period, at $794.9 million, followed by the U.K. at $244.7 million and Switzerland at $156.5 million. Overall, the Top 10 investor countries have provided 94% of reported global investment in fuel cell companies during the period 2000 through 2014.

Table 6. Top Ten Venture Capital and Private Equity Investors in Fuel Cells, By Company and By Country, Cumulative 1/1/2000-12/31/2014)

Top Ten Fuel Cell Investors		Top Ten Countries with Highest Levels of Private Investment in Fuel Cells	
Company	**Amount (million US$)**	**Country**	**Total All VC and PE Investment (million US$)**
Credit Suisse (Switzerland)	136.2	U.S.	794.9
Kleiner Perkins Caufield & Byers (U.S.)	105.7	U.K.	244.7
Superannuation Fund (New Zealand)	100.0	Switzerland	156.5
New Enterprise Associates (U.S.)	71.0	Singapore	113.0
Mobius Venture Capital, Inc. (U.S.)	68.2	New Zealand	100.0
GIC Pte. Ltd. (Singapore)	63.0	Canada	73.8
GSV Capital Corp. (U.S.)	54.2	Germany	42.5
DAG Ventures LLC (U.S.)	54.2	Sweden	23.6
Rolls-Royce Holdings PLC (U.K.)	50.0	Russian Federation	21.0
Enertek Services Pte. Ltd. (Singapore)	50.0	Denmark	20.0
Subtotal (top 10 only)	**$752.5**	**Subtotal (top 10)**	**$1,590.0**
TOTAL (All Companies and Countries)			**$1,697.0**

Source: Bloomberg New Energy Finance and New Zealand's Superannuation Fund

Raising Capital/Equity Offerings

Aside from private equity from venture capital firms or industry investment, a number of fuel cell companies raised money to support their R&D, capital expenditures, and/or commercialization efforts by pricing stock shares and making them available to the public. These efforts raised more than $340 million in 2014 by the companies involved.

In January, FuelCell Energy completed an underwritten public offering of 25.3 million shares of its common stock at $1.25 per share, including 3.3 million shares sold pursuant to the full exercise of an over-allotment option previously granted to the underwriters. The total net proceeds after expenses were approximately $29.4 million, which FuelCell Energy intends to use for project development, project finance, working capital support, and general corporate purposes.[46]

FuelCell Energy strengthened its existing relationship with NRG Energy in July, with the utility investing $35 million in FuelCell Energy common stock (14,644,352 shares at $2.39 a share) and establishing a new $40 million revolving construction and term loan facility for project development. That deal brought NRG Energy's ownership to approximately 17 million shares of the FuelCell Energy's common stock, or 6%, including 2.4 million shares owned prior to this transaction.[47] FuelCell Energy intends to use the money for project development, project finance, working capital support and general corporate purposes. The terms of the equity transaction include a warrant giving NRG the right to purchase an additional 2 million shares of common stock at a price $3.35 per share. The warrant has a term of three years.

Plug Power completed an underwritten registered offering of 10 million shares of its common stock and accompanying warrants to purchase 4 million shares of its common stock in January. The shares and the warrants were sold together in a fixed combination, with each combination consisting of one share of common stock and 0.40 of a warrant to purchase one share of common stock, at a price to the public of $3.00 per fixed combination for gross proceeds of $30.0 million. The securities were placed with a single investor.[48, 49]

Plug Power completed an underwritten public offering of 22.6 million shares of its common stock in April, at $5.50 per share. Net proceeds, after underwriting discounts and commissions and other estimated fees and expenses payable by Plug Power, were approximately $116.3 million, which Plug Power said it would to use for working capital and other general corporate purposes that may include capital expenditures and potential acquisitions.[50]

Ceramic Fuel Cells Ltd. conditionally raised approximately £3.36 million ($5.3 million) in March through the placement of 672 million New Ordinary Shares at a price of 0.5 pence (0.8 cents) per share.[51]

In May, Hydrogenics Corporation successfully completed its underwritten public offering of 1.5 million common shares (including 0.5 million secondary shares by CommScope, Inc. of North Carolina, a selling shareholder) at a price of $15.00 per share. The net proceeds before expenses were $14,212,500, which Hydrogenics said it would use for general corporate purposes. The company did not receive any proceeds from the sale of common shares by CommScope.[52]

SFC Energy placed a capital increase in November to accelerate growth with existing institutional shareholders and new investors, raising gross proceeds of €3.26 million ($4.16 million). SFC states that it plans to use the funds to accelerate growth in the oil and gas segment, with a focus on the U.S. market, and to launch the new EFOY GO! product.[53]

In October, AFC Energy raised funds through a placement and open offer to shareholders amounting to £6.1 million ($9.7 million) before expenses.[54]

In addition, several private companies have gone public:

- In July, Intelligent Energy's initial public offering (IPO) in London valued the company at £639.3 million ($1 billion). The offering of 16.2 million shares was priced at £3.40 ($5.38) a share, raising £55 million ($87 million) in proceeds. The IPO represented about 8.8% of Intelligent Energy's outstanding shares.[55]
- In May, myFC Holding began trading on First North at NASDAQ OMX Stockholm in May.[56]
- PowerCell Sweden AB also began trading on First North at NASDAQ Stockholm in December, attracting SEK108 million ($15.1 million) in new capital from more than 2,300 new shareholders.[57]

Intellectual Property

The Clean Energy Patent Growth Index report[58] from the Cleantech Group-Heslin Rothenberg Farley & Mesiti P.C. tracks the intellectual property of the clean energy sector and provides detailed coverage on the different sectors involved, including fuel cells.

In 2014, solar once again topped fuel cells with 1,238 patents, compared to 880 fuel cell patents.

Figure 3 shows that Toyota was the leader in fuel cell patents (101), with General Motors, Samsung, Honda and Hyundai rounding out the top five. The report indicates that approximately 300 different entities were granted fuel cell patents in 2014.

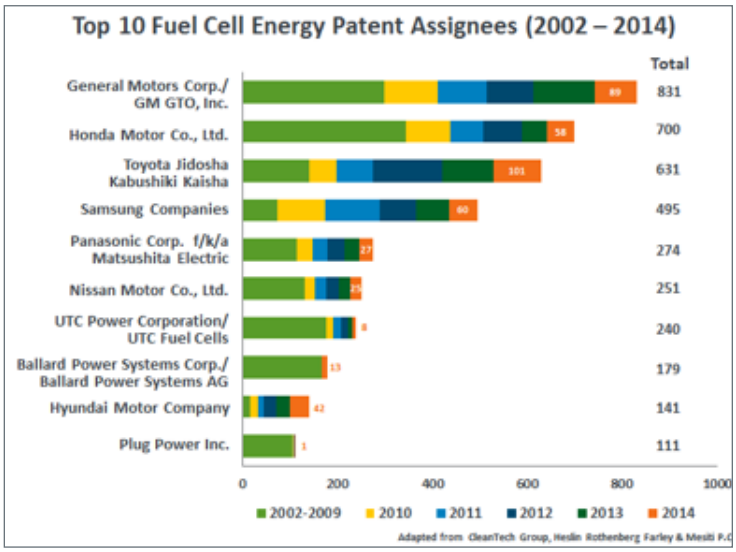

Figure 3. Top 10 Fuel Cell Energy Patent Assignees (2002-2014)

Figure 4 shows that Japan regained the top country spot, moving the U.S. to second place, with Korea coming in third. Within the U.S., Michigan was once again the leading state (99 patents), with California (44) coming in second and Connecticut (18) taking third.

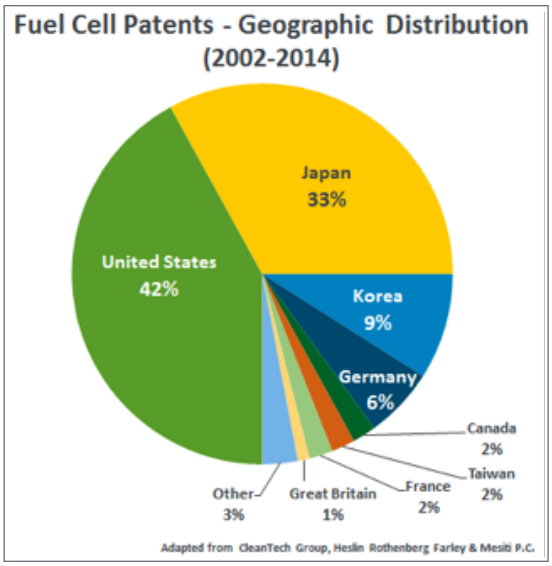

Figure 4. Fuel Cell Patents Geographic Distribution (2002-2014)

Revenue

Fuel cell companies derive revenue from the sale of fuel cells and related equipment (such as hydrogen generation and distribution infrastructure), support and maintenance contracts, and from contract research and development.

In 2014, worldwide fuel cell system revenue grew by almost $1 billion, reaching approximately $2.2 billion, up from $1.3 billion in 2013 (Figure 5). Major increases were seen in North America and Asia Pacific revenues, spurred by fuel cells for material handling (U.S.) and large-scale stationary sales by U.S. companies and residential fuel cells in Japan.

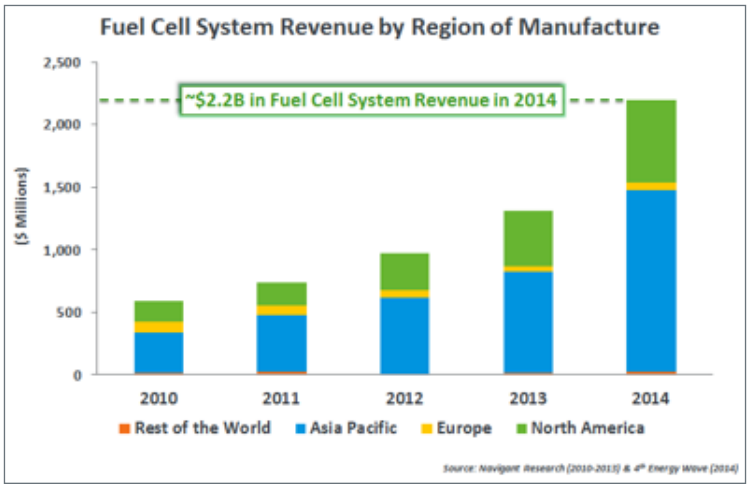

Figure 5. Fuel Cell System Revenue by Region of Manufacture

Shipments

Globally, fuel cell shipments increased by around 37% over 2013 (Figure 6) and the number of MWs shipped grew by about 7% (Figure 7). More than 50,000 fuel cells, totaling over 180 MW, were shipped worldwide in 2014.

North American (Figure 8) companies shipped more than 140 MW worldwide, more than triple the shipments of Asia and Europe combined. Units ranged from kW to multi-MW in size and included large-scale stationary systems, telecommunications backup systems and fuel cells for material handling, shipped to U.S. customers and exported to Korea, Japan, Europe and range of other countries.

Japan (Figure 8) continues to deploy its Ene-Farm residential fuel cell system and from 2009-2014, the cumulative number sold reached more than 115,000. In 2014, companies selling Ene-Farm systems installed more than 43,000, representing 30 MW of fuel cells.

Portable fuel cell shipments grew substantially with increased sales to the oil and gas and security/surveillance (remote power), recreation (auxiliary power units for RV, camping, boats), and military (portable soldier power) market sectors.

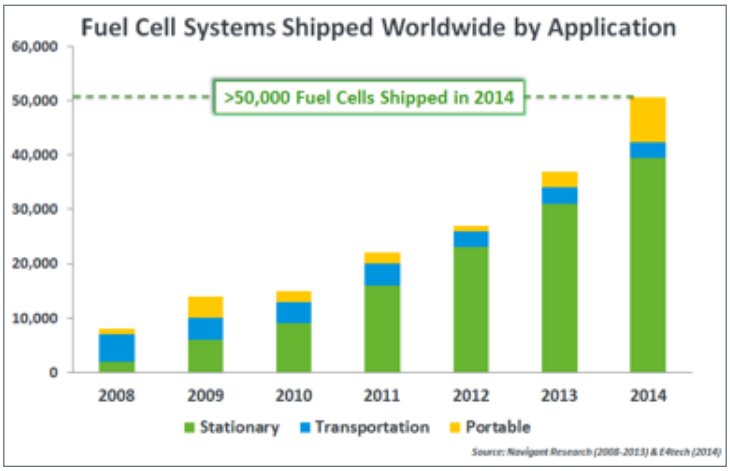

Figure 6. Fuel Cell Systems Shipped Worldwide by Application

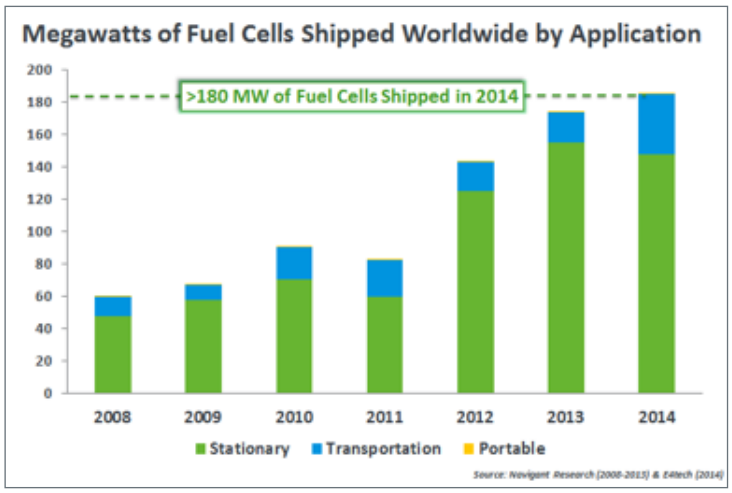

Figure 7. Megawatts of Fuel Cells Shipped Worldwide by Application

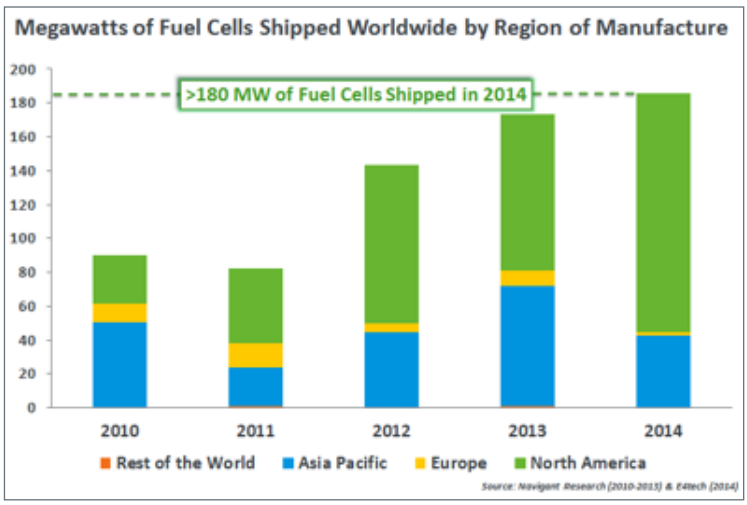

Figure 8. Megawatts of fuel Cells Shipped Worldwide by Region of Manufacture

Government Policies, Activities, and Funding

The federal government continues to fund a range of fuel cell and hydrogen research, development and demonstration (RD&D) activities. At the state level, numerous policies, both new and revamped, supported the development and deployment of fuel cells and hydrogen fueling stations and state agencies made funding awards to fuel cell companies and researchers.

Federal

The U.S. Department of Energy (DOE), through its Office of Energy Efficiency and Renewable Energy (EERE) Fuel Cell Technologies Office (FCTO), funds many research, development and deployment projects, via requests for proposals or through programs such as the Small Business Innovation Research and Small Business Technology Transfer (SBIR/STTR). These funding awards are summarized in Table 7.

Table 7. U.S. Department of Energy (DOE) 2014 Funding Awards

DOE 2014 Funding Awards		
Company/Location	**Project**	**Award**
Amsen Technologies, LLC Tucson, Arizona	SBIR/STTR Phase I Release 1 – To develop high-performance proton exchange membranes for electrolysis cells.	$150,000
Ardica San Francisco, California	To transition and scale-up a low-cost production process for the production of aluminum hydride, a potential high-capacity hydrogen storage material.	$1.2 million
Center for Transportation and the Environment (CTE) Atlanta, Georgia	To develop a fuel cell hybrid electric walk-in delivery van with a 150-mile range per fueling. The project will also retrofit 15 UPS delivery vans with fuel cell hybrid power trains for testing at UPS distribution facilities across California.	$3 million
Composite Technology Development, Inc. Lafayette, Colorado	SBIR Phase II Release 3 – To optimize the cost and performance of composite cylinders for hydrogen storage using a graded construction.	$999,927
FuelCell Energy Danbury, Connecticut	To increase U.S. competitiveness in the fuel cell market by enhancing the performance, increasing the lifespan, and decreasing the cost of stationary fuel cells being used for distributed generation and combined heat and power applications.	$3 million
	To develop a novel hybrid system for low-cost, low greenhouse gas hydrogen production.	$900,000
	Continuation of an award from DOE's Advanced Manufacturing Office to install a DFC-H2® fuel cell at its manufacturing facility in Torrington, Connecticut, to generate hydrogen, electricity and heat.	$2.8 million
	For advanced material development to enhance power density and performance of the next generation of the company's Direct FuelCell® products.	$3.2 million
	To enhance the performance and durability of the company's solid oxide fuel cell technology to attain market expectations.	$7.5 million

Giner, Inc. Newton, Massachusetts	SBIR Phase I Release 1 – To develop a water electrolysis process that can provide high-pressure hydrogen straight to storage tanks or vehicles.	$1,149,984
	First-of-its-kind award under a new EERE SBIR technology-to-market topic. Giner will use catalyst materials patented by Los Alamos National Laboratory with its dimensionally-stabilized membrane technology to develop advanced, high-performance and durable polymer electrolyte membrane electrode assemblies for fuel cell and electrolysis applications.	$149,949
GVD Cambridge, Massachusetts	SBIR Phase I Release 1 – To develop improved plastic and elastomer seal coatings to enable reliable performance of hydrogen systems.	$149,830
HRL Laboratories Malibu, California	To develop high capacity reversible hydrogen storage materials that have properties needed for practical hydrogen storage applications.	$1 million
Lawrence Livermore National Laboratory Livermore, California	To develop a reversible, high-capacity storage material that can bond to and release hydrogen in a vehicle, reducing the amount of hydrogen that needs to be pumped in the tank.	$1.2 million
Materia Pasadena, California	To demonstrate a novel resin system that reduces the use of expensive carbon fiber composites for high pressure storage tanks.	$2 million
Michigan State University College of Engineering Lansing, Michigan	To develop the technology needed to improve SOFCs and design new brazing alloys.	$694,000
National Renewable Energy Laboratory Golden, Colorado	To develop high-efficiency tandem absorbers based on novel semiconductor materials that can produce hydrogen from water using solar energy.	$3 million
Nuvera Fuel Cells Billerica, Massachusetts	To design and demonstrate an integrated, intelligent high pressure hydrogen dispenser for fuel cell electric vehicle fueling.	$1.5 million
Oak Ridge National Laboratory Oak Ridge, Tennessee	To demonstrate a low cost, steel concrete composite vessel for high pressure hydrogen storage.	$2 million
Ohio Fuel Cell Coalition Elyria, Ohio	To develop a robust supply chain for fuel cell and hydrogen systems that will accelerate mass production, reduce cost, and improve performance and durability.	$450,000
Pacific Northwest National Laboratory Richmond, Washington	To develop a reactor for hydrogen production from bio-derived liquids.	$2.2 million
PPG Industries Greensboro, North Carolina	To demonstrate a novel high strength glass fiber that is stronger than the carbon fibers used today at half of the cost.	$1.2 million
Sandia National Laboratories Livermore, California	To systematically screen low cost alternative materials for use in hydrogen storage systems.	$1.2 million
	To develop an innovative high-efficiency solar thermochemical reactor for solar hydrogen production.	$2.2 million

Southwest Research Institute San Antonio, Texas	To demonstrate a hydrogen compression system.	$1.8 million
Tetramer Technologies, LLC Pendleton, South Carolina	SBIR Phase I Release 1 – To leverage membrane technology developed through a previous EERE membrane humidifier project to design improved PEM electrolyzer ion exchange membranes.	$150,000
Treadstone Technologies Princeton, New Jersey	SBIR Phase II Release 3 - To develop novel structured metal bipolar plates for low cost manufacturing	$991,774
University of Colorado, Boulder Boulder, Colorado	To develop a novel solar-thermal reactor to split water with concentrated sunlight.	$2 million
University of Hawaii Honolulu, Hawaii	To develop photoelectrodes for direct water splitting.	$3 million
US Hybrid Torrance, California	SBIR Phase I Release 2 - To develop a proof-of-concept design approach for a fuel cell-battery electric hybrid truck for waste transportation.	$149,562
Virginia Clean Cities at James Madison University Harrisonburg, Virginia	To develop a nationwide Fuel Cell and Hydrogen Opportunity Center consisting of an innovative internet-based resource to grow the domestic fuel cell and hydrogen industry.	$450,000
Vision Industries Corporation Long Beach, California	SBIR Phase I Release 2 - To develop a proof-of-concept design approach for a fuel cell electric truck for waste transportation. If this project is selected to proceed to Phase 2, the design will be prototyped as a Class 8 Hydrogen Fuel Cell Electric Refuse Truck that will be demonstrated with the Santa Monica Public Works Division.	$148,746
Westside Industrial Retention & Expansion Network's GLWN Cleveland, Ohio	To complete detailed global manufacturing analysis of fuel cell systems (automotive and stationary), high pressure hydrogen storage systems, and key high value hydrogen and fuel cell subsystems and components.	$695,000
Wiretough Cylinders LLC Bristol, Virginia	To demonstrate a low cost, high pressure hydrogen storage vessel using a steel wire overwrap.	$2 million
	TOTAL	**$42.8 million**

DOE's Advanced Research Projects Agency-Energy (ARPA-E) awarded $33 million in funding in June through its Reliable Electricity Based on ELectrochemical Systems (REBELS) program for 13 new projects aimed at developing transformational fuel cell technologies for low-cost distributed power generation (Table 8).

Table 8. DOE's Advanced Research Projects Agency-Energy's (ARPA-E) Reliable Electricity Based on ELectrochemical Systems (REBELS) 2014 Funding Awards

DOE's (ARPA-E Reliable Electricity Based on ELectrochemical Systems (REBELS) 2014 Funding Awards		
Company/Location	**Project**	**Award**
Argonne National Laboratory Argonne, Illinois	To develop a hybrid fuel cell technology that will both generate electricity and produce liquid fuel.	$2 million
Colorado School of Mines Golden, Colorado	To develop a mixed proton and oxygen ion conducting electrolyte that allows a fuel cell to operate at temperatures less than 500°C.	$1 million
FuelCell Energy Danbury, Connecticut	To develop an intermediate-temperature fuel cell that will directly convert methane to methanol and other liquid fuels using advanced metal catalysts.	$3.5 million
Georgia Tech Research Corporation Atlanta, Georgia	To develop a fuel cell that operates at temperatures less than 500°C by integrating nanostructured materials into all cell components.	$1 million
Materials & Systems Research, Inc. Salt Lake City, Utah	To develop an intermediate-temperature fuel cell capable of electrochemically converting natural gas into electricity or liquid fuel in a single step.	$2.8 million
Oak Ridge National Laboratory Oak Ridge, Tennessee	To redesign a fuel cell electrode that operates at 250°C using highly porous carbon nanostructures that dramatically increase the amount of surface area, lowering the amount of expensive platinum catalysts used in the cell.	$2.75 million
Palo Alto Research Center Palo Alto, California	To develop an intermediate-temperature fuel cell capable of utilizing a wide variety of carbon-based input fuels.	$1.5 million
Redox Power Systems Fulton, Maryland	To develop a fuel cell with a mid-temperature operating target of 400°C while maintaining high power density and enabling faster cycling.	$5 million
SAFCell Pasadena, California	To develop solid acid fuel cells that will operate at 250°C and use new catalysts based on carbon nanotubes and metal organic frameworks.	$3.7 million
SiEnergy Systems Cambridge, Massachusetts	To develop a hybrid electrochemical system that uses a multi-functional electrode to allow the cell to perform as both a fuel cell and a battery.	$2.65 million
United Technologies Research Center East Hartford, Connecticut	To develop an intermediate-temperature fuel cell for residential applications that will combine a building's heating and power systems into one unit.	$3.2 million
University of California Los Angeles Los Angeles, California	To develop a low-cost, intermediate-temperature fuel cell that will use new metal-oxide electrode materials.	$1 million
University of South Carolina Columbia, South Carolina	To develop an intermediate-temperature, ceramic-based fuel cell that will incorporate a newly discovered ceramic electrolyte and nanostructured electrodes that enable it to operate at temperatures lower than 500˚C.	$3.2 million
	TOTAL	**$33.3 million**

To support H2USA, a public-private partnership formed in 2013 to accelerate the rollout of a U.S. hydrogen infrastructure for FCEVs, FCTO established the Hydrogen Fueling Infrastructure Research and Station Technology (H2FIRST) project, a collaborative effort between Sandia National Laboratories and the National Renewable Energy Laboratory (NREL). H2FIRST aims to provide world-class technical facilities to demonstrate hydrogen refueling technologies and infrastructure and to reduce the cost and time of new fueling station construction and improve station availability and reliability. Two research facilities, Sandia's Center for Infrastructure Research and Innovation and the NREL Energy Systems Integration Facility in Colorado, serve as hubs for H2FIRST to help achieve its goals.[59]

In October, FCTO and the Hydrogen Education Foundation launched the $1 Million H2 Refuel H-Prize. This two-year competition challenges America's engineers and entrepreneurs to develop affordable systems for small-scale hydrogen using electricity or natural gas for refueling hydrogen vehicles.[60]

As part of a DOE-supported project, Massachusetts-based fuel cell manufacturer Acumentrics tested two of its 250-watt (W) SOFCs to power several remote broadcast cameras and two 1-kW SOFCs to power lights in pit row at the 2014 Daytona 500, the first race in the NASCAR Sprint Cup series. Sandia National Laboratories analyzed the results of the project in the report, "*Fuel cell mobile lighting: A fuel cell market transformation project*,"[61] and found that NASCAR could save more than $2,000 per race weekend by replacing gasoline-powered generators with fuel cells – a savings of $77,000 over the course of the season.[62]

Sandia National Laboratories also signed an umbrella Cooperative Research & Development Agreement (CRADA) with Linde LLC that includes two new research and development projects to accelerate the expansion of hydrogen fueling stations to continue to support the market growth of FCEVs.[63]

The Maritime Administration (MARAD), an agency of the Department of Transportation (DOT), partnered with DOE and Sandia National Laboratories to explore the potential cost savings and emissions reductions through the use of hydrogen fuel cells to provide electrical power to ships at berths.[64] MARAD is providing $700,000 to support the construction of a 100-kW portable fuel cell power system at the Port of Honolulu to help power vessel onboard systems pierside for ships, tugs, and barges operating between the Hawaiian Islands.

MARAD is also testing fuel cells onboard the Training Ship Kennedy, a National Defense Reserve Fleet vessel, for a one-year project evaluating fuel cell performance and pathways that use low sulfur marine diesel fuel to efficiently power a fuel cell to produce auxiliary power for shipboard electrical systems.[65]

The Department of Commerce's National Institute of Standards awarded $100,000 to the Rochester Institute of Technology's Golisano Institute for Sustainability in Rochester, New York, to fund the final phase of its research and design of a prototype residential fuel cell power system.[66]

The U.S. Trade Development Agency (USTDA) signed an agreement with Oorja Fuel Cells to share the costs of a project to pilot fuel cell technology for cell tower operations in South Africa, and also signed a corresponding grant agreement with Plessey, a South African telecommunications systems integrator. These projects are funded under the U.S.-Africa Clean Energy Finance Initiative, a U.S. government effort to catalyze private sector investment for clean energy projects in sub-Saharan Africa by supporting early-stage project development.[67]

State Policies and Funding

At the state level, numerous policies, both new and revamped, support the development and deployment of fuel cells and hydrogen fueling stations. California, which has dedicated $20 million annually for at least 100 public hydrogen fueling stations by 2017, announced significant funding awards during 2014. Several state agencies also made funding awards to fuel cell companies and researchers (Table 9).

Table 9. State Funding for Fuel Cells and Hydrogen 2014

State Funding for Fuel Cells and Hydrogen 2014		
Funder	**Award**	**Details**
California		
California Energy Commission (CEC) Alternative and Renewable Fuel and Vehicle Technology Program (ARFVTP)	$46.6 million and $1.2 million	Providing $46.6 million for 28 new hydrogen fueling stations and a mobile refueler. Will also provide another $1.2 million for the operation and maintenance of hydrogen refueling stations in the state. See the Hydrogen Fueling section of this report for more details.
Connecticut		
Connecticut's Department of Economic and Community Development	$20 million low-interest loan, up to $10 million in tax credits	Loan to FuelCell Energy for an expansion of its Torrington manufacturing facility. Includes $20 million in low interest, long-term loans and up to $10 million in tax credits, predicated on certain terms and conditions, including the forgiveness of 50% of the loan principal if certain job retention and job creation targets are reached.
Connecticut's Department of Energy and Environmental Protection Microgrid Program	$2.2 million	Awarded to the University of Bridgeport to install a 1.4-MW FuelCell Energy fuel cell system as part of a microgrid to power campus buildings.
New York		
New York State Energy Research and Development Authority (NYSERDA) and New York Battery and Energy Storage Technology (NY-BEST) Consortium	$250,000	Awarded to Cornell University to develop and demonstrate a regenerative fuel cell energy storage system, using a Cornell-designed membrane, to produce hydrogen.
New York State's Economic Development Awards	$600,000	• $500,000 to American Fuel Cell (Rochester) to further develop membrane electrode assemblies (MEAs). • $100,000 to MICROrganic Technologies, Inc. (Albany) to commercialize its microbial fuel cell technology and to advance the development of original equipment manufacturer (OEM) production equipment to convert from chemical to electrical energy the organic waste processed at wastewater treatment facilities.
Ohio		
Edison Advanced Manufacturing Program	$297,056	To help develop and promote local advanced manufacturing projects in fuel cell technology. The Ohio Fuel Cell Coalition will provide $335,154 in matching funds.

International Policies and Investment

With the anticipated increase in fuel cell vehicle deployments by major automakers, international efforts focused largely on support for FCEVs and the development of hydrogen fueling infrastructure. Japan also reinforced its goal to create a hydrogen society, with vehicles, homes and businesses powered by fuel cells. Table 10 gives an overview of international funding efforts announced during 2014.

Table 10. Overview of International Policies and Funding for Fuel Cells and Hydrogen 2014

Overview of International Funding for Fuel Cells and Hydrogen 2014		
Country	**Funding**	**Details**
Germany	$1.6 billion	The National Organization Hydrogen Fuel Cell Technology (NOW), Clean Energy Partnership, H2Mobility and Performing Energy reaffirmed their commitment to the development of a German hydrogen fueling infrastructure by signing a declaration to invest €2 billion ($2.6 billion) over the next 10 years.
U.K.	$7 million	Unveiled a plan to provide up to £11 million ($17.4 million) to facilitate the roll-out of hydrogen-fueled vehicles and associated hydrogen refueling station infrastructure.

See the Vehicles, Hydrogen Infrastructure and Stationary sections for additional details on U.S. and international policies.

Applications and Market Assessment

Today, fuel cells deliver power to a variety of industries, including transportation, stationary/backup and portable power applications. Users are finding that fuel cells provide a wide range of benefits including: low-to-zero emissions, high efficiency, reliability/resiliency, fuel flexibility, energy security, durability, scalability, and quiet operation.

Appendix 1 provides a listing of companies in this report with commercially available fuel cell products.

Transportation

Fuel cells have been demonstrated and deployed in just about every form of motive transportation there is, from light-duty passenger cars to buses; a portfolio of material handling vehicles; boats, planes, scooters and a range of other specialty vehicles; and also onboard internal combustion engine or other alternative-fueled or battery-electric vehicles as range extenders or auxiliary power units. In 2014, fuel cells were given the spotlight with regards to light-duty vehicles, but also saw great progress with fuel cell bus and fuel cell-powered forklift orders and deployments.

Light Duty Vehicles

In 2014, major automakers garnered major press coverage from FCEV debuts and commercialization announcements and several countries reinforced their support with policies and funding commitments.

A 10,000-km, 52-day road show, sponsored by SAIC Motor Corp., drove through 64 cities in 15 provinces in China. During the tour, Air Liquide supplied a total of 3,000 m^3 of hydrogen, fueling the three hydrogen-powered cars 128 times with a mobile refueler. The longest daily distance driven per car in a day was 365 miles. The mobile station fueled the cars at elevations of up to 6,500 feet and test drives were successfully conducted at an elevation of 13,000 meters in Tibet.

In April, five automakers – BMW, Daimler, Honda, Hyundai, and Toyota – joined together to launch the HyFive project, agreeing to deploy 110 fuel cell electric vehicles in several European cities. The £31 million ($49 million) program will also develop hydrogen refueling stations in London, Denmark, and Austria, working with fuel providers Air Products, Linde, ITM Power, and other stakeholders.[69]

Japan's government announced it will offer a rebate of at least ¥2 million ($18,165) to customers purchasing FCEVs and will make FCEVs the official car of its ministries and other government offices.[70]

China's government mandated that electric cars, including FCEVs, comprise at least 30% of government vehicle purchases by 2016. This percentage will be raised after 2016, when local provinces are required to meet the target. Electric cars were also exempted from a purchase tax.[71]

To prepare for the increase in FCEVs entering the marketplace, 51 countries and regions, including Japan, the European Union, and Russia, agreed to relax inspection regulations on FCEVs, based on common safety standards to be implemented among them. Common safety standards for FCEVs were set mainly on fuel tanks into which hydrogen is injected at high pressure. If automobile makers manufacture vehicles based on the unified standards and the products pass each manufacturing country's screening, safety inspections which have been conventionally conducted for each export destination could be skipped.[72]

The United Nations Economic Commission for Europe World Forum for Harmonization of Vehicle Regulations (WP.29) adopted a United Nations Global Technical Regulation (UN GTR) governing the safety of hydrogen and both internal combustion engines fueled by liquefied hydrogen and fuel cell electric vehicles fueled by compressed gaseous hydrogen. This new UN GTR represents the first international legislation in this field and specifies provisions to ensure that such vehicles attain the same safety level as conventional gasoline vehicles.[73]

Hyundai

After making news in 2014 with its announcements about the Tucson Fuel Cell FCEV, Hyundai previewed its latest fuel cell concept car, the Intrado, in advance of the Geneva Auto Show in March.[74]

In June, Hyundai started to accept leasing applications for its 2015 Tucson Fuel Cell FCEV (known as the Hyundai ix35 Fuel Cell FCEV outside of the U.S.) at three select Southern California Hyundai dealers.[75] Hyundai also announced that it was negotiating with several insurance companies to simplify the Tucson Fuel Cell leasing process and had negotiated an insurance strategy with State Farm Insurance.[76]

The vehicle is currently available to customers in a number of countries around the world (U.S., the U.K., Germany, France, Belgium, Italy, Austria, Netherland, Denmark, Sweden, Norway, Finland, and South Korea) and in November, Hyundai announced it would begin leasing in Vancouver, Canada in early 2015.[77] In addition, Hyundai Australia imported an ix35 FCEV, the country's first, and unveiled proposals to build a national Hydrogen Highway between Sydney, Canberra, and Melbourne.[78]

Toyota

Toyota introduced its new Mirai – which means "future" in Japanese – FCEV at the Paris Motor show[79] and sales began in Japan on December 15, 2014.[80] The vehicle can travel up to 300 miles on a single tank of hydrogen.[81]

The company also announced plans to invest around ¥20 billion ($182 million) to triple domestic production capacity of the Mirai in response to demand, adding two lines at its factory by the end of 2015.[82] The car is hand-built at the former Lexus LFA Works Plant One in Motomachi, Japan.[83]

Honda

At the Los Angeles Auto Show, Honda unveiled its FCV CONCEPT, a successor to the FCX Clarity, which it plans to begin selling in Japan by the end of March 2016, and in the U.S. and Europe after that.[84]

The FCV CONCEPT features a next generation fuel cell stack that is 33% smaller than Honda's previous fuel cell stack, with an output of more than 100 kW and an output density as high as 3.1 kW per liter. Honda claims overall performance is improved by approximately 60% and the vehicle is equipped with 70 MPa high-pressure hydrogen

storage tank to give it a range of more than 430 miles. The FCV CONCEPT is world's first fuel cell sedan with the entire powertrain, including the fuel cell stack, located under the hood of the vehicle.

The Honda FCV CONCEPT also features an external power feeding function, which when combined with an external power feeding device, allows it to function as a small-sized mobile power plant to provide electricity in times of disaster or power outages.

Volkswagen

At the Los Angeles Auto Show, Volkswagen premiered the Golf SportWagen HyMotion, a research vehicle with a fourth-generation 100-kW fuel cell powertrain.[85] The front-wheel-drive HyMotion accelerates from 0 to 62 mph (100 km/h) in 10.0 seconds. The hydrogen is stored under the vehicle in four high-tech carbon fiber tanks, and the vehicle has a driving range of 310 mi (500 km).

Several research vehicles have been built based on the U.S. version of the Passat, using the same drive components as the Golf SportWagen HyMotion. This fleet of Passat HyMotion vehicles is currently being tested in California.

At the show, Volkswagen Group brand Audi showcased the same fuel cell system in an A7 Sportback h-tron quattro vehicle.[86]

Daimler

In October, the Mercedes-Benz FCEV fleet passed the 300,000 km (186,000 mi) mark in their long-term test under everyday driving conditions. For this achievement, Daimler AG was honored with the "f-cell Award 2014."

Daimler debuted its G-Code sport utility vehicle concept at the opening of its new Mercedes-Benz Research & Development Center in Beijing, China in November. The vehicle is powered by both a compact, turbocharged hydrogen-fueled combustion engine which solely drives the front wheels, and an electric motor which drives the rear axle and transmits its power selectively to the two wheels via a dual multi-disc clutch.[87]

General Motors (GM)

DOE's NREL and GM have partnered on a multi-year, multi-million dollar joint effort to accelerate the reduction of automotive fuel cell stack costs through fuel cell material and manufacturing R&D.[88] NREL and GM will focus on critical next-generation FCEV challenges, which include reducing platinum loading, achieving high power densities, understanding the implication of contaminants on fuel cell performance and durability, and accelerating manufacturing processes to achieve the benefits of increased economies of scale. The work will be done under a CRADA between NREL and GM and takes advantage of NREL's state-of-the-art Energy Systems Integration Facility.

Table 11. Examples of Commercially Available Fuel Cells for Transportation 2014

Examples of Commercially Available Fuel Cells for Transportation 2014				
Manufacturer/ Location	**Product Name**	**Type**	**Output**	**Vehicle Type**
Ballard Power Systems Canada	FCvelocity-HD6	PEM	75 kW & 150 kW	Cars, buses
Hydrogenics Canada	Celerity/CelerityPlus	PEM	60 kW	Buses, trucks
	HyPM™ HD 30	PEM	33 kW	Vehicles with existing electric drive platform
	HyPM™ HD 90	PEM	99 kW	Vehicles with existing electric drive platform
	HyPM™ HD 180	PEM	198 kW	Vehicles with existing electric drive platform

SymbioFC France	ALP®	PEM	80 kW-100 kW (full system)	Utility vehicles, trucks
US FuelCell* U.S.	Model 80 auxiliary power unit (APU)	PEM	80 kW	Cars, buses
	Model 150 APU	PEM	150 kW	Buses, trucks
	UTC PureMotion®	PEM	120 kW, Legacy	Buses

For the purpose of this chart, transportation includes light duty vehicles, trucks and buses. Many automakers are developing and manufacturing proprietary fuel cells for their fuel cell electric vehicles.
*In January 2014, US Hybrid (US FuelCell's parent company) entered a global licensing agreement with United Technologies Corporation (UTC) for UTC's PEM fuel cell technologies for the vehicle market.

Additionally, fuel cell company Intelligent Energy signed a two-year, multi-million dollar development agreement with a Japanese automotive OEM to focus on the development of Intelligent Energy's fuel cell engine technology for compact cars and two-wheeled vehicles, as well as for range extenders.[89]

Buses

Five major European bus manufacturers, Daimler Buses (EvoBus), MAN, Solaris, Van Hool and VDL Bus & Coach, signed a joint Letter of Understanding in November underlining their commitment for the commercialization and market introduction of fuel cell electric buses in urban public transport.[90]

Ballard Power Systems, with partners BC Transit, New Flyer, and PW Transit, was awarded the Canadian Urban Transit Association (CUTA) 2014 Corporate Leadership Innovation Award for its Whistler Fuel Cell Bus Project. The project terminated in 2014, and at the completion of the five-year evaluation, the 20 fuel cell buses had logged close to 4 million km (2.5 million mi) of revenue service.[91] The buses have been since slated for sale and conversion to utilize diesel or another fuel.[92]

In November, Ballard and Van Hool N.V. opened a dedicated joint European Service and Parts Centre for fuel cell buses (ESPACE), co-located with Van Hool's Lier, Belgium manufacturing facility, to support Van Hool fuel cell buses in Europe that are powered by Ballard fuel cell modules.[93] By the end of 2014, 27 Ballard/Van Hool fuel cell buses were expected to be in operation in five European cities.

Ballard was also involved with many sales, orders and deployments of its fuel cell system for transit buses in 2014, partnering with bus manufacturers and transit agencies around the world.

Table 12. Ballard Power Systems' Bus Orders and Deliveries in 2014

Ballard Power Systems' Bus Orders and Deliveries, 2014			
Organization	**Deployment Site**	**# of Fuel Cells**	**Details**
Aberdeen City Council	Aberdeen, Scotland	4	Four of 10 fuel cell buses on order from Van Hool were delivered as part of the Aberdeen Hydrogen Bus Project.
Center for Transportation and the Environment (CTE)	Birmingham, Alabama	1	Delivered a fuel cell bus with a 75-kW Ballard fuel cell to the Birmingham-Jefferson County Transit Metro Area Express (MAX) for daily use in a two-year demonstration project. Funded by the FTA National Fuel Cell Bus Program (NFCBP). Air Liquide constructed the hydrogen fueling station.

New Flyer Industries	Not specified	1	Received a purchase order from New Flyer Industries for a FCvelocity®-HD7 fuel cell power module to be used in a next-generation New Flyer Industries fuel cell bus in a project administered by CALSTART. The bus will be sent to Altoona, Pennsylvania for testing and qualification prior to deployment in revenue service under the NFCBP.
SunLine Transit Agency	Thousand Palms, California	2	SunLine deployed two new fuel cell buses powered by Ballard's FCvelocity®-HD6 fuel cell module. The buses evolve the previously deployed American Fuel Cell Bus (AFCB) configuration, first introduced with SunLine in 2011.
University of California, Irvine	Irvine, California	1	Ballard, with partners BAE Systems and ElDorado National, signed an agreement with CALSTART to deploy a fuel cell hybrid bus at the University of California, Irvine, in 2015. Ballard will supply the Company's 6th generation FCvelocity®-HD6 power module. This is the 6th fuel cell hybrid bus produced based on the AFCB configuration.
Solaris Bus and Coach and Hamburger Hochbahn AG	Hamburg, Germany	2	Signed an equipment supply agreement with Solaris for two FCvelocity®-HD7 fuel cell power modules to be used in buses planned for deployment by Hamburger Hochbahn AG. The fuel cells were delivered in late 2014 and will be used as range extenders, in combination with batteries, in Solaris electric bus platforms.
Van Hool and Regional Verkehr Koln (RVK)	Cologne, Germany	2	Ballard and partner Van Hool NV delivered two new buses powered by Ballard's FCvelocity®-HD6 fuel cell modules to transit authority RVK, joining two fuel cell buses that have been in regular transit service since 2011.
Škoda Electric and Rigas Satiksme	Riga, Latvia	Up to 27	Signed a non-binding MOU with Latvian transit bus operator Rigas Satiksme and Czech Republic bus and tram manufacturer Škoda Electric regarding the Hy-Trolley fuel cell trolley bus development and deployment program for Riga, Latvia. Škoda and Ballard will perform a feasibility study and product evaluation, followed by potential replacement of up to 27 diesel generators on existing trolley buses with Ballard's FCvelocity®-HD7 fuel cell power module in the 2016 timeframe.
	TOTAL	**Up to 40**	

The first of two Urbino 18.75 electric buses had its world premiere in Hamburg, Germany, in December 2014. Designed for operator Hochbahn, the Solaris buses are equipped with 120 kilowatt-hour (kWh) batteries as the main energy provider to the drive system. The batteries will be charged by Ballard 101-kW fuel cells during operation. The fuel cells are used only when 100% of output is required, which significantly increases their durability.

The bus will be fueled with hydrogen at night in the depot. Battery charging cycles will be pre-programmed so the bus is able to drive 300 km (186 mi) per day.[94]

The Stark Area Regional Transit Authority (SARTA) in Ohio has partnered with California organization CALSTART to deploy two fuel cell buses through its No Emissions Bus Program. The buses are tentatively scheduled for production in February 2015 for the first bus and July 2015 for the second, with delivery in August 2015 and December 2015. The Ohio Department of Transportation granted SARTA $500,000 to construct a hydrogen station to fuel the bus.[95]

US Hybrid was awarded a contract by the Hawaii Center for Advanced Transportation Technologies (HCATT) to design, integrate, and deliver its H2Ride™ Fuel Cell Plug-In Shuttle Bus for operation by the County of Hawaii Mass Transit Agency's HELE-ON Big Island bus service. The project is funded by the State of Hawaii and Office of Naval Research via the Hawaii Natural Energy Institute (HNEI). The 25-passenger shuttle bus will be integrated at US Hybrid's Honolulu facility and utilizes a 30-kW fuel cell, 20 kilograms (kg) of hydrogen storage and delivery system, and a lithium ion battery.[96]

Material Handling

Fuel cells for material handling received a big boost in 2014 from several repeat customers, including Walmart, Ace Hardware, and Central Grocers.

Plug Power launched the GenKey package in January, an all-inclusive hydrogen solution for material handling sites that includes fuel cells, fueling, and maintenance, thus offering customers one-stop shopping.[97] GenKey is comprised of three separate elements: GenDrive fuel cell units, GenFuel hydrogen fuel and infrastructure, and GenCare maintenance service. Plug Power was also named to the 2014 Food Logistics FL100+ list, a list of innovative technology and software providers that influence the global food and beverage supply chains.[98]

In October, Ballard Power Systems signed a long term supply agreement with Plug Power to provide fuel cell stacks for use in Plug's GenDrive® systems for material handling vehicles. The new supply agreement replaces an existing agreement and runs to the end of 2017, with the provision for two 1-year extensions.[99] This new supply agreement includes Ballard's FCgenTM-1020ACS air-cooled stacks used in GenDrive® systems to power Class 3 pallet jacks; and FCvelocityTM-9SSL liquid-cooled stacks used in systems to power Class 2 reach trucks and Class 1 counterbalanced lift trucks.

Table 13. Notable Plug Power 2014 GenDrive® Sales

Notable Plug Power 2014 GenDrive® Sales			
Customer	**Deployment Site**	**# of Fuel Cells**	**Details**
Ace Hardware	West Jefferson, Ohio	71	The fleet of fuel cell-powered Class 2 and Class 3 lift and reach trucks at its newly constructed 450,000-square-foot Retail Support Center in Wilmer, Texas, has performed so well that Ace Hardware ordered 35 fuel cell-powered reach trucks and 36 fuel cell pallet jacks for its new Ohio facility. A Nuvera PowerTap™ generator was installed at the Ohio facility, dispensing up to 50 kg/day of high-purity hydrogen.
Central Grocers	Joliet, Illinois	182	The new units will replace the original fuel cell forklifts Central Grocers has had in place since 2009 – the entire fleet at this site – which have operated for more than two million hours. Central Grocers also signed a 5-year GenCare service contract.

Golden State Foods	McCook, Illinois	39	GenDrive fuel cells will power 39 material handling vehicles – 11 Class 2 stand-up reach lift trucks and 28 class-3 rider pallet trucks – at a new food distribution center west of Chicago serving more than 460 McDonald's in the Midwest region. Will also provide GenCare onsite maintenance and service. Nuvera supplied a PowerTap™ hydrogen station to the site.
Newark Farmers Market	Newark, New Jersey	110	This is the second purchase, more than doubling the size of the facility's fuel cell-powered lift truck fleet at the Newark location. The new order is comprised of 25 class-2 standup reach truck units and 85 class-3 pallet jack units.
Volkswagen	Chattanooga, Tennessee	45	No details are available.
Walmart	7 sites, including Sterling, Illinois; Pottsville, Pennsylvania; and Johnstown, New York	2,069	The GenKey purchase order also includes GenFuel infrastructure construction and hydrogen fuel supply and six-year GenCare service contracts for each site.
	Cologne, Germany	2	Ballard and partner Van Hool NV delivered two new buses powered by Ballard's FCvelocity®-HD6 fuel cell modules to transit authority RVK, joining two fuel cell buses that have been in regular transit service since 2011.
Škoda Electric and Rigas Satiksme	Riga, Latvia	Up to 27	Signed a non-binding MOU with Latvian transit bus operator Rigas Satiksme and Czech Republic bus and tram manufacturer Škoda Electric regarding the Hy-Trolley fuel cell trolley bus development and deployment program for Riga, Latvia. Škoda and Ballard will perform a feasibility study and product evaluation, followed by potential replacement of up to 27 diesel generators on existing trolley buses with Ballard's FCvelocity®-HD7 fuel cell power module in the 2016 timeframe.
	TOTAL	**2,516**	

Fuel cell-powered material handling equipment is being tested for use in airport operations.

In late 2014, as part of a DOE $2.5 million project, Plug Power delivered its GSE (ground support equipment) fuel cells, to power a 15-truck fleet of FedEx airport tuggers at the FedEx hub of the Memphis Airport. Plug Power also installed its first GenFuel hydrogen infrastructure, including a standard hydrogen storage tank, compression system, fuel pipelines, and Plug Power's first outdoor GenFuel hydrogen dispensers.

In Japan, New Kansai International Airport Co. launched a demonstration project at Kansai Airport in May to test two fuel cell-powered forklifts at the airport's shared drug storage, cargo shed, and other areas. A full-scale

hydrogen station will be built to fuel the forklifts and other fuel cell vehicles that will operate in and around the terminal area.[100]

Table 14. Examples of Commercially Available Fuel Cells for Material Handling 2014

Examples of Commercially Available Fuel Cells for Material Handling 2014			
Manufacturer/Location	**Product**	**Type**	**Output**
Ballard Power Systems Canada	FCgen-1020ACS	PEM	1.5-3.6 kW
	FCvelocity-9SSL	PEM	4-19 kW
H2Logic Denmark	H2Drive	PEM	~10 kW
Hydrogenics Canada	HyPX Power Packs	PEM/ hybrid	N/a
Intelligent Energy U.K.	Gen4	PEM	3.9 kW
Nuvera Fuel Cells U.S.	Orion	PEM	10-30 kW
Oorja Protonics U.S.	OorjaPac Model III	DMFC	1.5 kW
Plug Power U.S.	GenDrive Series 1000	PEM	8–10 kW
	GenDrive Series 2000	PEM	8–10 kW
	GenDrive Series 3000	PEM	1.8–3.2 kW
Proton Motor GmbH Germany	HyRange® 8	PEM	8.2 kW
	HyRange® 25	PEM	25 kW
	PM400	PEM	Up to 30 kW
SymbioFC France	ALP®	PEM	5 kW-20 kW (range extender)

For purpose of this chart, material handling includes fuel cells for forklifts, lift trucks, two-wheeled vehicles, as well as range extenders for battery-electric utility and commercial vehicles.

Other Transport

Fuel cells are being integrated into a wide range of other transportation vehicles, including utility and delivery vehicles which don't require as large a fuel cell or hydrogen storage system as passenger cars or buses; as range extenders for battery electric vehicles; two-wheeled scooters; and to provide long-running power to unmanned vehicles and even trains.

The California Energy Commission (CEC) approved a $1.1 million grant to CTE to develop and deploy fuel cell hybrid electric walk-in delivery vans.[101] This funding award builds upon the $3 million that CTE was awarded from DOE in January (see Table 7).

Microcab, a spin-off of Coventry University in the U.K., produced a new commercial version of its H2EV that features a 3-kW fuel cell system, has a range of 180 miles per tank, and a top speed of 55 mph.[102] The H2EV features a hybrid powertrain architecture that combines the power capability of a lithium-ion battery with the energy capability of a hydrogen fuel cell.[103]

A fleet of 50 hybrid electric/hydrogen-powered Renault Kangoo ZEs utility vehicles, equipped with Symbio FCell's fuel cell range extender, were deployed in the Hyway program in the Rhône-Alpes region of France. Two hydrogen filling stations will be built in Grenoble and Lyon in early 2015. The HyWay project received financial backing of the Rhône-Alpes regional government, the French national energy management, and several other government agencies.[104]

Proton Power Systems PLC was selected to integrate its new HyRange® 25 system as a range extender into a 3-ton battery passenger transport vehicle manufactured by a major automotive OEM. The project is funded by the Austrian government.[105] Proton was also contracted to perform a feasibility study for a fuel cell maritime application from an Asia Pacific-based customer, in a deal worth €297,000 ($379,000).[106]

National Cheng Kung University in southern Taiwan unveiled its first hydrogen-fueled electric scooter called "Pegasus One," which completed a maiden voyage of 80 km (50 mi). The scooter combines a lithium battery with a 3-kW Ballard Power Systems' fuel cell to enhance range and battery charging.[107]

Israeli company Bluebird demonstrated the WanderB, the first-ever civilian operational unmanned aerial vehicle (UAV) to be powered by a fuel cell. The Horizon Energy Systems' fuel cell was integrated into the UAV by Bluebird with support from the Singapore Israel Industrial R&D Foundation.[108]

South Africa's HySA Systems Competence Centre at the University of the Western Cape joined with the National Aerospace Centre and Airbus to examine fuel cell APUs to generate onboard electrical power and heat while an aircraft is on the ground.[109]

Alstom has signed Letters of Intent with the German regions of Lower Saxony, North Rhine-Westphalia, Baden-Württemberg, and the Public Transportation Authorities of Hesse, for the use of a new generation of emission-free train equipped with fuel cell drive. The German Federal Ministry of Transportation intends to support the development of the train. Two prototypes will be tested in 2018.[110]

Hydrogen

Hydrogen station development progressed in 2014, with significant policy efforts and funding commitments that will enable the number of hydrogen fueling stations to grow across the U.S., Europe, and Asia. These efforts support the expected growth in commercial FCEV deployments by Hyundai, Honda, Toyota, and other automakers.

Hydrogen energy storage is also increasingly regarded as a way to utilize surplus energy produced by wind or solar technologies. This renewably-generated hydrogen can be injected in natural gas pipelines for widespread distribution, or used for fuel cell power generation or for hydrogen vehicle fueling.

Hydrogen Infrastructure Development

An annual assessment by H2stations.org, a website of Ludwig-Bölkow-Systemtechnik (LBST) and TÜV SÜD, reports that 17 new hydrogen stations were opened worldwide in 2014 – two In North America, three in Asia, 12 in Europe.[111]

The H2USA partnership, which was first announced in 2013 to accelerate the rollout of a U.S. hydrogen infrastructure for FCEVs, has grown to more than 30 businesses and organizations, including the U.S. Department of Energy, automakers, fuel cell suppliers, materials and component manufacturers, energy companies, national laboratories, associations, and NGOs. In 2014, H2USA welcomed several new participants, including:[112]

- California, represented by the state's Energy Commission and the Air Resources Board;
- Northeast States for Coordinated Air Use Management (NESCAUM);

- Pacific Northwest National Laboratory; and
- Intelligent Energy.

The CEC awarded $46.6 million from the ARFVTP for 28 new public hydrogen stations and one mobile hydrogen refueler (Table 15). This funding adds 13 new stations in Northern California and 15 in Southern California. Six of the stations will generate 100% renewable hydrogen.[113]

Table 15. California Energy Commission's Alternative and Renewable Fuel and Vehicle Technology Program Proceedings (ARFVTP) Funding Awards for New Public Hydrogen Refueling Stations

California Energy Commission – ARFVTP Funding Awards for New Public Hydrogen Refueling Stations		
Company	**Award**	**Details**
FirstElement Fuel, Inc.	$2,902,000	To construct two 100% renewable refueling stations in Los Angeles.
	$24,667,000	For 17 stations located in Campbell, Coalinga, Costa Mesa, Hayward, Laguna Niguel, Lake Forest, La Canada Flintridge, Long Beach, Mill Valley, San Diego, San Jose, Santa Barbara, Saratoga, South Pasadena, South San Francisco, Redwood City, and Truckee.
HyGen Industries, LLC	$5,306,814	To construct three 100% renewable hydrogen refueling stations located in Orange, Pacific Palisades, and Rohnert Park.
Linde LLC	$4,250,000	To install two hydrogen refueling stations in San Ramon and Oakland.
ITM Power Inc.	$2,125,000	To install a hydrogen refueling station in Riverside.
Air Liquide Industrial US	$2,125,000	To install a hydrogen refueling station in Palo Alto.
HTEC Hydrogen Technology & Energy Corporation	$2,125,000	To install a hydrogen refueling station in Woodside.
Ontario CNG Station Inc.	$2,125,000	To install a 100% renewable hydrogen refueling station in Ontario.
Gas Technology Institute	$999,677	To design, fabricate, test, and deploy a fully operational, commercial mobile hydrogen refueler with the capability to fill either 350 bar or 700 bar vehicle tanks through onboard metered dispensing hoses.
TOTAL	**$46,625,491**	

FirstElement Fuel, which was awarded more than $27 million in ARFVTP funding for 19 hydrogen fueling stations, will receive an additional $7.3 million loan from Toyota to aid in the development of these stations.

Honda will provide $13.8 million to FirstElement Fuel to build additional hydrogen fueling stations in California. Combined with state grants, Honda's funding could enable FirstElement to add at least 12 more stations, expanding FirstElement's California network to 31 or more hydrogen fueling stations.[114]

Toyota and Air Liquide announced a partnership to develop and supply a phased network of 12 state-of-the-art hydrogen stations in New York, New Jersey, Massachusetts, Connecticut, and Rhode Island, targeting the greater New York and Boston areas first to provide the backbone of a northeast corridor hydrogen highway.[115]

In Japan, the Ministry of Economy, Trade and Industry (METI) Hydrogen/Fuel Cell Strategy Council released a "Hydrogen/Fuel Cell Strategy Roadmap" that outlines three phases to introduce and expand hydrogen and fuel cell technologies in Japan.

- Phase 1: Increase the number of residential fuel cell units in Japan to 1.4 million in 2020 and 5.3 million in 2030; increase the number of hydrogen stations for FCEVs to 100 in 2015; and to commercialize FCEVs in 2015, fuel cell buses in 2016, and commercial/industrial fuel cell systems using SOFCs in 2017.
- Phase 2: 2025-2030. Introduction of hydrogen-based power generation on a full scale and the establishment of large-scale hydrogen supply systems.
- Phase 3: 2040 and beyond. Full-scale production, transportation and storage of hydrogen without emitting carbon dioxide using carbon capture and storage.[116]

Japan's Environment Ministry announced a model project to use surplus energy from renewable sources to produce hydrogen.[117]

Japan's JX Nippon Oil & Energy plans to build a nationwide hydrogen fueling infrastructure to provide fuel for FCEVs and other hydrogen-powered technologies. The company will develop 10 Japan-based hydrogen production sites by 2020, including seven located at the company's refineries. JX is also working to open 40 hydrogen fueling stations, most located in the Tokyo area, by the end of FY2015.[118]

The Gwangju Metropolitan City in Korea declared that it will aggressively foster the hydrogen fuel and fuel cell automobile industry as its core and strategic industry. The plan includes developing technologies, installing hydrogen fueling stations, and providing commercially-available FCEVs. As part of the action plan, Gwangju established a fueling station at Jingok Industrial Complex for test operation.[119]

The European Union (EU) adopted new rules to ensure the build-up of alternative refueling points, but dropped proposed targets for the number of hydrogen stations and electric charging points that member countries must install by 2020. Member states must set and make public their targets and present their national policy frameworks by the end of 2016. In member states that opt for hydrogen fueling infrastructure, the directive aims at ensuring a sufficient number of publicly accessible refueling points, with common standards, to be built by the end of 2025.[120]

The EU's Trans-European Transport Network (TEN-T) Program will develop national implementation plans for Belgium, Finland, Poland and a regional implementation plan for Riga, Latvia, as well as deploy and test three hydrogen refueling stations with innovative elements in Finland and Sweden.[121]

Germany's National Organization Hydrogen Fuel Cell Technology (NOW), Clean Energy Partnership, H2Mobility, and Performing Energy reaffirmed their commitment to the development of a German hydrogen fueling infrastructure by signing a declaration to invest €2 billion ($2.6 billion) over the next 10 years.[122]

Daimler and the Linde Group are partnering with oil and gas companies TOTAL, OMV, Avia and Hoyer to increase the number of hydrogen fueling stations in Germany. Daimler and The Linde Group will invest around €10 million ($12.8 million) in 10 fueling stations each. In September, the first of the Daimler and Linde-initiated public hydrogen fueling stations opened at a TOTAL multi-energy fueling station in Berlin-Charlottenburg.[123]

Linde also opened the world's first small-series production facility for hydrogen fueling stations in Vienna, Austria.[125]

The U.K. government unveiled a plan to provide up to £11 million ($17.4 million) to facilitate the roll-out of FCEVs and a hydrogen refueling station infrastructure. The government will provide £7.5 million ($11.9 million) in funding:

- £2 million ($3.2 million) to upgrade six to eight hydrogen stations that are already operational or are in development, taking them from demonstration projects to publicly accessible sites;
- £3.5 million ($5.5 million) to be matched by industry for four to seven new hydrogen stations. This will include mobile stations, stand-alone sites, and stations integrated into conventional gas station forecourts; and
- £2 million ($3.2 million) for public sector fleets to encourage deployment of around 40 hydrogen FCEVs in focused geographical clusters.

Industry will contribute £3.5 million ($5.5 million) to the U.K. effort.

Table 16. New, Planned and Upgraded Hydrogen Fueling Stations 2014

New, Planned and Upgraded Hydrogen Fueling Stations 2014			
Supplier	**Station Site**	**# of Stations**	**Details**
Air Liquide	Connecticut, Massachusetts, New Jersey, New York, and Rhode Island	12	To support 2016 FCEV introduction to the northeastern U.S., Toyota and Air Liquide are collaborating to develop and supply a phased network of 12 state-of-the-art hydrogen stations. States and locations have been strategically selected in the greater New York and Boston areas to provide the backbone of a hydrogen highway for the northeast corridor.
	Copenhagen, Aalborg and Vejle, Denmark	4	Four stations are planned as part of the Copenhagen Hydrogen Network. Two will be located in Copenhagen.
	Saint-Lô, France	1	Won a competitive bid launched by the Conseil Général de la Manche to supply and install a hydrogen filling station.
	Torrance, California	1	A SmartFuel® branded station is located at Honda's R&D headquarters and was completed in just seven months.
Air Products and Chemicals, Inc.	New South Wales, Australia	1	Working with Coregas to install a fueling station at Hyundai's Australian headquarters.
	Heathrow, England	1	The existing station, which began operation in 2012, was upgraded for 350 and 700 bar refueling. The Heathrow station is part of the Fuel Cells and Hydrogen Joint Undertaking's Hydrogen Transport in European Cities (HyTEC) initiative and a part of the London hydrogen refueling network within the HyFIVE project.
	Hendon, England	1	British supermarket chain Sainsbury's announced the U.K.'s first supermarket forecourt hydrogen dispenser, located at its Hendon store. The 700-bar SmartFuel® station is part of the London Hydrogen Network Expansion project, backed by the U.K. government and co-funded by Innovate UK.

	California	--	FirstElement Fuel has contracted with Air Products to supply hydrogen fueling and fuel technology for 19 stations. See FirstElement Fuel's entry, below, for further details.
	Hamburg, Germany	1	Station will be based on the company's H2Station® CAR-100 product and will include onsite electrolysis production.
FirstElement Fuel	Ontario, California	1	Awarded a contract to install a 700 bar hydrogen fueling station at an existing "76" fuel and electric charging location.
	Various locations, California	19	Awarded a $27 million grant from CEC to develop the first phase of the California Hydrogen Network (19 stations). Toyota also announced a $7.3 million loan to FirstElement Fuel to support the operation and maintenance of the stations. Air Products will supply the hydrogen fueling technology and hydrogen fuel for the 19 sites.
H2Logic, Proton OnSite, Hydrogenics	Los Angeles, California	1	Located at the College of Engineering, Computer Science, and Technology at California State University. Hydrogenics' HySTAT-30 electrolyzers provide 65 kg of hydrogen per day.
Hydrogenics	Swindon, England	1	Will provide a HySTAT™ 30 electrolyzer to be installed as part of a fueling station at Honda Motors' Swindon, England plant. Solar energy will power the electrolysis. BOC will operate the station.
	Aberdeen, Scotland	1	Working with BOC and providing three HySTAT™ 60 electrolyzers for a large fueling station to be constructed for Aberdeen City Council's Kittybrewster depot. The station is part of the Aberdeen Hydrogen Bus Project and will fuel 10 fuel cell buses.
	Aberdeen, Scotland	1	Will supply a turnkey 350/700 bar hydrogen fueling station that will produce up to 130 kg of hydrogen/day onsite using a HySTAT™ electrolyzer. The station is part of the Aberdeen City Hydrogen Energy Storage project and also includes a HyPM®10-kW fuel cell.
	Isle of Wight, England	4	Granted planning permission for four 80 kg/day hydrogen refueling stations at four locations and one 15kg/day marine hydrogen refueling station.
	Tokyo and Aichi Prefecture, Japan	2	Teaming with Seven-Eleven Japan Co. to open convenience stores with hydrogen stations on the premises. The two companies plan to open two outlets in Tokyo and Aichi Prefecture in 2015. Seven-Eleven will demonstrate using hydrogen from the stations to generate electricity for the stores.

ITM Power	West Sacramento, California	1	Hydrogen fueling is located alongside other fueling pumps at the Ramos Oil Company fueling station.
Iwatani Corp.	Berlin, Germany	1	With partner, Daimler, developed hydrogen fueling at a TOTAL multi-energy public fueling station.
Linde LLC	Rotterdam, the Netherlands	1	First hydrogen fueling station in Rotterdam.
	Amagasaki, and other locations in Japan	28	Finalized a deal with Iwatani Corporation for the delivery of 28 hydrogen fueling stations with ionic compressors. The first of these units is operating in a station in Amagasaki near Osaka, Japan.
	Berlin, Germany	1	TOTAL operates two hydrogen fueling pumps at the Berlin-Brandenburg Airport, one for cars and one for buses. Hydrogen is produced onsite via a McPhy 500-kW alkaline electrolyzer, producing more than 200 kg/day.
McPhy	Gothenburg, Sweden	1	Will be open to the public in 2015 and located next to the premises of fuel cell manufacturer PowerCell.
Oy Woikoski	Port of Finland	1	The Port of Helsinki deployed Finland's first commercial hydrogen station for private vehicles and buses.
Unspecified	Fort Armstrong, Honolulu, Hawaii	1	DOE and the General Services Administration are conducting a feasibility study for a $5 million hydrogen fueling station that would serve as a production concept that could be replicated at other sites in Hawaii. The publicly accessible station, which would include a rooftop solar energy system and a small hydrogen production and distribution station, would support fueling for 85 to 100 vehicles per day. The station could be operational in the fourth quarter of 2017.
	TOTAL	**88+**	

Table 17 provides examples of commercially available hydrogen fueling stations. Hydrogen fueling stations may use delivered hydrogen or may generate hydrogen onsite. The stations also include liquid or gaseous hydrogen storage, a hydrogen compressor, and hydrogen dispensing equipment.

Table 17. Examples of Commercially Available Hydrogen Fueling Stations 2014

Examples of Commercially Available Hydrogen Fueling Stations 2014				
Company	**Product**	**Application**	**Dispensing pressure**	**Dispensing output/ day**
Air Liquide France	F Series	Forklift	350 bar	20-200 kg/day
	B200	Bus	350 bar	200 kg/day
	C Series	Car	700 bar	50-200 kg/day
Air Products and Chemicals, Inc. U.S.	SmartFuel H70/ H35	Automotive	350 and 700 bar	N/a
	SmartFuel S150	Material handling vehicles	350 bar	Up to 100 kg/day
	SmartFuel S7000	Material handling vehicles	350 bar	More than 100 kg day
H2 Logic Denmark	H2 Station CAR-100	Automotive	70 MPa fast-fill	50-100kg/day
	H2 Station MH-100	Material handling vehicles	35 MPa	25-100 kg/day
Hydrogenics Canada	HyStat™ Hydrogen Station	Material handling vehicles, cars	350 and 700 bar	22-130 kg/day and larger
ITM Power U.K.	HFuel Hydrogen Station	Automotive	350 and 700 bar	5-92 vehicle fuelings/day
Nuvera Fuel Cells U.S.	PowerTap Hydrogen Station	Automotive	700 bar	50 kg/day
	PowerTap Hydrogen Station	Industrial vehicles	350 bar	50 kg/day
Linde Germany	Large, small and portable hydrogen fueling stations	Car, bus, material handling vehicles	350 and 700 bar	N/a
Plug Power U.S.	GenFuel	Material handling vehicles	350 bar	N/a
Powertech Canada	Modular hydrogen fueling station	Automotive	700 bar	Up to 500 kg/day, or more

Hydrogen Supply

Hydrogen supply activities expanded in 2014 to meet the growing demand of fuel cell and FCEV applications.

Airgas, Inc. announced plans to build a liquid hydrogen plant in Calvert City, Kentucky. The new facility is targeted to be on-stream in the summer of 2016 with the capacity to produce 10 tons per day of liquid hydrogen for use in a range of applications including fuel cells.[126]

Plug Power signed a long-term hydrogen distribution agreement with Praxair, Inc. to offer Praxair hydrogen to its customers throughout the U.S. who are using the company's GenKey package, which includes both hydrogen fueling and infrastructure.[127]

Praxair is building a steam methane reformer to increase the supply of hydrogen for customers served from its liquid hydrogen plant in Niagara Falls, New York. When completed in 2015, Praxair's Niagara Falls liquid hydrogen production capacity will be increased by 50%.[128]

In addition to delivered hydrogen, hydrogen gas can also be generated onsite using a reformer or electrolyzer. Table 18 shows commercial hydrogen generation systems and their manufacturers.

Table 18. Examples of Commercially Available Hydrogen Generation Systems 2014

Examples of Commercially Available Hydrogen Generation Systems 2014			
Manufacturer	**Product**	**Type**	**Hydrogen Production**
Acta S.p.A. Italy	EL 250	Alkaline solid polymeric electrolytic process	50 liters (l)/hr
	EL 500	Alkaline solid polymeric electrolytic process	500 l/hr
	EL 1000	Alkaline solid polymeric electrolytic process	1000 l/hr
Air Products and Chemicals, Inc. U.S.	PRISM®	Reformer	Onsite: 200-500 kg/day Mobile: 50-150 kg/day
	Hydrogen electrolyzer	PEM or potassium hydroxide electrolysis	Various quantities/day
Element 1 U.S.	H-Series	Reformer	9.7-19.5 kg/day
	S-Series	Reformer	1.9-4.5 kg/day
	NG-Series	Reformer	Depends upon customer requirements
Hydrogenics Canada	HySTAT	Alkaline Electrolysis	8.6 kg-130 kg/day
	HyLYZER	PEM Electrolysis	1-2 Nm3/hr
HyGear Netherlands	HyGEN 5	Reformer	5 Nm3/hr
	HyGEN 50	Reformer	52 Nm3/hr
	HyGEN 100	Reformer	104 Nm3/hr

ITM Power U.K.	HPac 20	PEM electrolysis	2.5 kg/day
	HPac 40	PEM electrolysis	5 kg/day
	HFuel Hydrogen Station	PEM electrolysis	25-462 kg/day
	HGas	PEM electrolysis	25-462 kg/day
McPhy France	Baby McPhy	Alkaline electrolysis	400 Nlt/hr
	McLyzer	Alkaline electrolysis	1-20 Nm3/hr
	Large H2 production units	Alkaline electrolysis	100-400 Nm3/hr
Nuvera Fuel Cells U.S.	PowerTap	Reformer	50 kg/day
Osaka Gas Japan	HYSERVE-30	Reformer	30 Nm3/hr
	HYSERVE-100	Reformer	100 Nm3/hr
	HYSERVE-300	Reformer	300 Nm3/hr
Proton OnSite U.S.	G Series	PEM electrolysis	200-600 cc/min
	G4800	PEM electrolysis	4800 cc/min
	S Series	PEM electrolysis	0.57-2.27 kg/day
	H Series	PEM electrolysis	4.31-12.94 kg/day
	C Series	PEM electrolysis	21.6-65 kg/day
	M Series	PEM electrolysis	Up to 1000 kg/day

Power-to-Gas/Hydrogen Energy Storage

Power-to-gas (P2G) applications continued to grow, with new projects announced in Canada, Europe, Australia, and Japan (Table 19). P2G uses surplus electrical energy, typically generated from wind or solar technologies, to produce hydrogen by electrolysis. This hydrogen gas either "stores" the excess energy for later use or is injected into existing natural gas supply pipelines, to generate power using a fuel cell or to supply vehicle fuel at hydrogen refueling stations.

To assist the growing P2G market, DNV GL in Norway initiated the global HYREADY industry project to develop guidelines for the preparation of transmission and distribution system operator networks for the injection of hydrogen produced from renewable sources. Stakeholders from the natural gas industry, including transmission and distribution system operators, have signed up. The HYREADY initiative will encourage the industry to "Be ready for Hydrogen" by developing practical processes and procedures for the introduction of hydrogen to the grid.[129]

Table 19. Power-to-Gas/Hydrogen Energy Storage Projects Announced in 2014

Power-to-Gas/Hydrogen Energy Storage Projects Announced in 2014		
Manufacturer	**Deployment Site**	**Details**
Acta SpA	Seville, Spain	Clean technology company, Abengoa, installed an Acta electrolyzer hydrogen generator at its Palmas Altas campus in a demonstration project. Electricity produced by solar panels is converted into hydrogen by the electrolyzer and stored onsite in metal hydride canisters. When required, the hydrogen is converted back to electricity through a Ballard fuel cell.
AREVA	La Croix Valmer, France	Signed a strategic partnership agreement with Schneider Electric to develop fuel cell energy management and storage solutions. AREVA will provide the Greenergy Box™ (an electrolyzer and fuel cell) which will be connected to 35-kW peak power photovoltaic panels. The companies also signed an R&D agreement to develop a new energy storage solution, the flow battery, to produce and store electricity by combining hydrobromic acid and hydrogen.
Hydrogenics	Denmark	Will install a 1-MW water electrolysis plant at one of the Denmark's largest wastewater treatment plants under the Power-to-Gas Biological Catalysis (BioCat) project. Hydrogen, generated via electrolysis using surplus grid electricity, will be combined with CO2 from raw biogas and fed into a separate bioreactor where microorganisms will perform a catalytic reaction to produce pipeline-grade renewable methane. Product gas will be injected into a nearby gas distribution system.
	Toronto, Ontario, Canada	Will supply PEM electrolyzers to a power-to-gas project that will deliver 2 MW of storage capacity. Hydrogenics is partnering with Enbridge to develop, build, and operate the energy storage facility.
	Canada	Will supply a microgrid energy storage application in Canada, storing surplus wind energy as hydrogen using a Hydrogenics electrolyzer. Hydrogen will be stored onsite and converted back to energy when needed using a Hydrogenics fuel cell system. When complete, the project will replace a diesel generation system. Hydrogenics was awarded CA$3.8 million ($3.3 million) for the project.
ITM Power	Cardiff, Wales	Received a grant of £897,000 ($1.4 million) from Innovate UK's Local Energy Systems Scheme for the Hydrogen Enabled Local Energy Systems (HELES) project, conducted in partnership with Cardiff City Council. The project will use a rapid response electrolyzer to generate solar PV hydrogen and inject the hydrogen directly into a landfill gas engine.
	Germany	ITM Power won a competitive tender for the sale of a rapid response PEM Power-to-Gas electrolyzer system from RWE Deutschland AG. ITM will supply the plant with a two year warranty and is supplying a three-year after sales support contract.

McPhy Energy	Queensland, Australia	Signed an agreement to sell an integrated production-storage solution to Petawatt® Energy-Electrygen Pty Ltd., enabling Petawatt® Energy to complete work to build its first sun, water, and wind land-based hydrogen energy production system designed for both isolated and grid-connected sites across Australia and Oceania. The first test system will be set up at Petawatt® Energy's client demonstration site in Queensland State, Australia, which will be fitted with a small-capacity (4 kg) solid hydrogen storage solution, making it possible to store 130 kW of energy.
Not specified	Japan	Japan's Environment Ministry launched a 3 billion yen ($27 million) power-to-fuel project to covert excess renewables into hydrogen, via electrolysis, for use later in use in transport. The ministry will launch projects in several locations in FY2015. Full-scale operation of these facilities is anticipated in three years.

Hydrogen storage RD&D continued in 2014, undertaken by both public and private entities.

A Sandia National Laboratories study, sponsored by FCTO, reported that large-scale storage of low-pressure, gaseous hydrogen in salt caverns and other underground sites for transportation fuel and grid-scale energy applications offers both cost and volume advantages over above-ground storage. The researchers concluded that geologic storage of hydrogen gas could make it possible to produce and distribute large quantities of hydrogen fuel for the growing fuel cell electric vehicle market.[130]

Hitachi Zosen Corporation and Daiki Ataka Engineering Co., Ltd. were selected to undertake research and development of a low-cost hydrogen production system as part of the 2013 Technology Development for the Storage and Transport of Renewable Energy program, organized by Japan's METI. The program aims to reduce the costs of power conversion and electrolysis, as well as to develop an energy carrier technology for the long-distance transport and long-term storage of hydrogen at a price competitive with fossil fuels.[131]

ITM Power secured a commercial contract from AMEC and National Grid to assess the cost and energy benefit of deploying P2G technology at specific sites on the gas network to reduce energy losses and increase system efficiency. AMEC will undertake a third party assessment of the cost benefit analysis.[132]

In a new manufacturing partnership, AREVA, SMART ENERGIES through its subsidiary CETH2, and the ADEME (French Environment and Energy Management Agency) joined to launch the AREVA H2-Gen joint venture to manufacture PEM electrolyzers for industrial applications and renewable energy storage markets, to supply service stations with hydrogen for fuel cell vehicles, or to supply natural gas networks via P2G platforms.[133]

The Thüga Group's P2G project, located at the Mainova AG site in Frankfurt am Main, Germany, successfully passed its first annual reassessment, meeting every aspect of its specification including efficiency, remote control functionality and response time. The project includes a 300-kW rapid response PEM electrolyzer supplied by ITM Power.[134]

Hydrogen Regulations/Codes and Standards

After 13 years of testing and development with the international automotive and hydrogen industry, including BMW, Daimler, Hyundai, and Toyota, the Society of Automotive Engineers (SAE) published J2601, "Fueling Protocols for Light Duty Gaseous Hydrogen Surface Vehicles." The standard will serve as the baseline for commercial fueling at 35 MPa (300 bar) and 70 MPa (700 bar) and establishes safety limits and performance requirements for gaseous hydrogen fuel dispensers. SAE also published J2799, "Hydrogen Surface Vehicle to Station Hardware and Software," which specifies the communications hardware and software requirements for fueling Hydrogen Surface Vehicles and is intended to be used in conjunction with J2601 and J2600, "Compressed Hydrogen Surface Vehicle Fueling Connection Devices."[135]

Japan's METI passed several revisions to hydrogen fueling station regulations, making it easier to install and operate the stations:[136]

- Hydrogen refueling stations can use composite storage tanks for the first time in Japan, allowing the use of materials like carbon fiber-reinforced plastics.
- The temperature operating range of steel-based tanks has been expanded, making them less costly and easier to install and maintain.
- Operators can transport and store liquefied hydrogen, which takes up less space than compressed hydrogen, making it easier to transport and allowing stations to store greater quantities of the fuel. Hydrogen can be compressed during the pre-filling and filling process.
- The concept of hydrogen freezing, or pre-cooling, was introduced to help cool FCEV tanks prior to refueling. Pre-cooling a vehicle's tanks enables a faster refueling time while curbing an increase in temperature of the compressed gas due to adiabatic compression of the hydrogen as it passes from filling station tank into the vehicle.

METI will also allow hydrogen tanks to be filled to a maximum pressure of 875 atmospheres (886 bar), up from about 700 atmospheres (709 bar), which will extend fuel cell vehicle range by about 20% without refueling.[137]

Toyota Motor Corporation received approval from METI to self-inspect and manufacture high-pressure hydrogen tanks for FCEVs and is the first company to become a registered manufacturer of 70 MPa (700 bar) hydrogen tanks under Japan's High Pressure Gas Safety Act.[138]

In the U.S., researchers at the Department of Commerce's National Institute of Standards and Technology (NIST) developed a prototype field test standard to test the accuracy of hydrogen fuel dispensers.[139]

The U.S. Environmental Protection Agency (EPA) finalized their Renewable Fuel Standard Pathways II Rule, which classifies biogas as a transportation fuel feedstock rather than a fuel itself. Hydrogen generated from biogas projects used to power FCEVs would be eligible for cellulosic renewable fuel credits.[140]

Hydrogen Technology Advancements

Given the expected increase in the number of fuel cell vehicles in coming years, many 2014 technology developments centered on hydrogen for transportation. This was particularly true in Japan, where many RD&D efforts focused on large-scale hydrogen production and the efficient transport of hydrogen for vehicle fueling and other uses.

Kawasaki Heavy Industries Ltd. (KHI) established a plant that turns hydrogen into liquid fuel with one-800th the volume of hydrogen gas, with the capability of producing about five tons of liquid hydrogen a day. In two years, KHI will begin sales of the plant to operators of steel factories that generate hydrogen as a byproduct. The company also intends to establish a mass production system and long-distance transport of liquid hydrogen before the 2020 Tokyo Olympic Games.[141]

KHI will also conduct an experiment with Australia in which hydrogen will be extracted from low-grade Australian brown coal using a catalyst. The hydrogen will be transported to Japan by sea. The company plans to establish a small-scale system to supply hydrogen by 2020 and introduce six large ocean carriers in 2030.[142]

Industrial plant engineering firm, Chiyoda Corp., has developed technology to convert hydrogen into toluene, which can be transported commercially using ordinary tankers, and transform it back to hydrogen. Chiyoda hopes to put the technology into practical use in 2020. Chiyoda has also developed a floating facility with Mitsubishi Heavy Industries Ltd. to produce hydrogen from petroleum gas contained in undersea oil fields.[143]

Industrial gas provider, Taiyo Nippon Sanso, is partnering with Toyota Tsusho and Sumitomo Mitsui Finance and Leasing to in a new company that will operate mobile hydrogen fueling stations using Taiyo Nippon Sanso's equipment.[144]

Fujitsu launched a new hydrogen station data management service, the first in Japan, which enables people to access real-time information on the location and hours of operation of both fixed and mobile hydrogen fueling stations via their car-navigation systems, smartphones, or other devices. The service became available to automakers in December 2014.

For its Mirai FCEV, Toyota is providing a special application, Hydrogen Station List, for the navigation system included in its T-Connect Data Communication Module package, as well as a "Pocket Mirai" smartphone application.[145]

Outside of Japan, Royal DSM of Singapore reported that a combination of two of its thermoplastics technologies has resulted in high-performance pressure vessels that are well suited for use as lightweight fuel tanks for automobiles running on compressed natural gas or hydrogen. With a solution for both the inner liner and the outer tape reinforcement, DSM is able to reduce the weight of the tank by up to 70%.[146]

Quantum Fuel Systems Technologies Worldwide, in partnership with Linde North America, has developed a specialized hydrogen dispenser system for 35 and 70 MPa service that, for the first time, measures the mass of hydrogen from a dispensing unit with connection to retail interface and user-friendly payment features. The technology has received conditional approval for commercial service in California by the state's Department of Measurements and Standards. The system is in operation at a new hydrogen fueling station located in West Sacramento, California.[147]

Stationary Power

The stationary fuel cell market includes several sizes and sectors including large-scale systems for prime power, backup power or combined heat and power, small systems for micro combined heat and power (m-CHP) for residential or commercial operations, and prime and backup systems for remote or essential applications such as data centers and telecommunications towers. Systems can range from several kilowatts to multiple megawatts in size.

Table 20. Examples of Commercially Available Stationary Fuel Cells 2014

Examples of Commercially Available Stationary Fuel Cells 2014 - Prime Power and m-CHP			
Manufacturer	**Product**	**Type**	**Output**
Ballard Power Systems Canada	ClearGen	PEM	Multi-500 kW power banks
Bloom Energy U.S.	ES-5400	SOFC	100 kW
	ES-5700	SOFC	200 kW
	UPM-570	SOFC	160 kW
Ceramic Fuel Cells Ltd. Australia	BlueGen	SOFC	2 kW
	Gennex	SOFC	1.5 kW
Doosan Fuel Cell America U.S.	PureCell System Model 400	PAFC	400 kW
Elcore GmbH Germany	Elcore 2400	SOFC	300 W
ENEOS CellTech Japan	Ene-Farm	PEM	250-700 W

FuelCell Energy U.S.	DFC 300	MCFC	300 kW
	DFC 1500	MCFC	1,400 kW
	DFC 3000	MCFC	2,800 kW
	DFC-ERG	MCFC	Multi-MW
Fuji Electric Japan	FP-100i	PAFC	100 kW
Panasonic Japan	Ene-Farm	PEM	200-750 W
Toshiba Japan	Ene-Farm	PEM	250-700 W

Prime Power

More than 81 MW of large stationary fuel cells were deployed or ordered in 2014.

FuelCell Energy (FCE) saw multi-MW sales in the U.S. and Korea, and continued its growth in the German market with FuelCell Energy Solutions GmbH (FCES). The company now has Direct FuelCell® (DFC®) units operating in nine countries in North America, Asia, and Europe.

In Korea, FuelCell Energy continued to strengthen its strategic relationship with POSCO Energy. In addition to the 37+ MW sold or installed to POSCO in 2014 as outlined in the Table 21, the two companies reinforced and enhanced their integrated global supply chain agreement. POSCO is also constructing a manufacturing facility in Pohang, set to be operational in mid-2015, that will double FuelCell Energy's global manufacturing capacity.[148] In February, the Gyeonggi Green Energy fuel cell park, located in Hwasung City, became the largest fuel cell park in the world (59 MW), comprised of 21 DFC3000® power plants to provide continuous baseload electricity to the South Korean electric grid as well as heat for a district heating system.[149]

FuelCell Energy also secured a multi-million dollar contract with a global energy company in October to evaluate the potential integration of DFC® power plants with combustion-based natural gas fueled processes.[150]

In Germany, FCES received nearly €5 million ($6.4 million) in awards from the Federal Ministry for Economic Affairs and Energy to support a three-year research and development project between FCES and partner Fraunhofer Institute for Ceramic Technologies and Systems (IKTS) to increase power density and operating life of the DFC®system.[151]

In December, FuelCell Energy reached three billion kWh of power generation from its fleet of DFC® power plants in nine countries in North America, Asia and Europe since its first commercial installation in 2003.

Table 21. Summary of FuelCell Energy Projects 2014

Summary of FuelCell Energy Projects 2014		
Customer/Location	**Capacity**	**Details**
Federal Ministry of Education and Research Berlin, Germany	N/A	FuelCell Energy Solutions installed a fuel cell power plant to supply about 40% of the electricity needs of the office complex and 20% of its thermal requirements.
FuelCell Energy Torrington, Connecticut	300 kW	A tri-generation DFC-H2 plant will be installed at FuelCell Energy's facility to showcase production of electricity, heat, and hydrogen for industrial applications. Supported by DOE's Advanced Manufacturing Office.

Microsoft Cheyenne, Wyoming	300 kW	In November, Microsoft opened a fuel cell-powered mini-data center to replicate a data center environment. The fuel cell generates electricity using biogas from the adjacent Dry Creek Water Reclamation Facility and provides about 200 kW of energy to power the Data Plant's 200 computer servers. Excess electricity from the fuel cell is delivered back to the wastewater treatment plant to reduce its electrical bills.
POSCO Energy Korea	3.7 MW	Two 1.4-MW and three 300-kW fuel cell modules.
	5.6 MW	Four fuel cell modules.
	8.4 MW	Six fuel cell modules. These modules are in addition to the monthly fuel cell kit shipments under an existing multi-year 122-MW order. In total for fiscal year 2014 [11/1/2013 to 10/31/2014], POSCO Energy has purchased 17.7-MW of fuel cell modules and 42 MW of fuel cell kits.
	19.6 MW	Godeok Rolling Stock Management Office fuel cell park in Seoul City.
United Illuminating (UI) Bridgeport and New Haven, Connecticut	5.6 MW (2.8 MW at each site)	UI Is installing 2.8 MWs of fuel cell power plants at two of its sites – Bridgeport and New Haven. The Bridgeport fuel cell will be located at a former landfill site that will also include 2.2 MW of solar power to create a renewable energy park. The New Haven fuel cell will be located in the port area of the city near an electrical substation owned by UI and will provide continuous power to the substation.
UIL Holdings Corp. Glastonbury, Connecticut	2.8 MW	UIL Holdings (parent company of UI) is purchasing a 3.4-MW fuel cell plant that will be installed at a Connecticut Natural Gas Corp. pressure reduction facility in Glastonbury. The plant includes a 2.8-MW fuel cell and a 600-kW turbo expander that will generate renewable power by harnessing energy not used during the process of reducing natural gas pressure. UIL will sell the electricity to Connecticut Light & Power under a 20-year contract. Production will begin in late 2015.
University of Bridgeport Bridgeport, Connecticut	1.4 MW	The fuel cell will be installed as part of a microgrid to power campus buildings, including a dining hall, recreation center, student center, police station, and two residence halls, and will supply approximately 80% of the campus power needs. The university buildings will serve as an emergency shelter during power outages.
University of California, Irvine Medical Center Irvine, California	1.4 MW	The fuel cell will generate about 30% of the facility power needs and the excess heat produced will be used in a direct exhaust absorption chiller to produce 200 tons of cooling for an office building and associated institutional requirements.
TOTAL	**49+ MW**	

Chart based on publicly available data.

Bloom Energy announced many installations of its SOFC systems during 2014, most in California, but also several in other states: Connecticut, Maryland, New Jersey, and New York. The company also revealed two installations in Japan.

Table 22. Summary of Bloom Energy Projects 2014

Summary of Bloom Energy Projects 2014		
Location	**Capacity**	**Details**
Macerich/Danbury Fair Mall, Danbury, Connecticut	750 kW	Will help to power to the 1.3 million-square-foot building.
Chino Valley Medical Center, Chino, California	600 kW	Reduces the facility's carbon footprint by 22%.
DreamWorks Animation SKG Glendale, California	750 kW	Will provide 6 million kWh of electricity for the 6 acre campus and 460,000 square feet of office space.
Exelon Corporation California, Connecticut, New Jersey and New York	21 MW	Exelon is providing equity financing for 21 MW of fuel cell projects for two customers (one being AT&T for nine sites) at 75 commercial facilities in California, Connecticut, New Jersey, and New York.
Hines/LPL Financial San Diego, California	500 kW	The LPL Financial LLC headquarters, Tower II at La Jolla Commons, is believed to be the largest net-zero energy commercial office building in the U.S. The surplus power generated is delivered back to the grid.
JP Morgan Chase Newark, Delaware	500 kW	Powers about 10% of JPMorgan Chase's 155-acre Christiana Center Campus.
Keio University Fujisawa-shi, Japan	200 kW	Installed at the Delta building and powers the Delta and Tau buildings. As the biggest risk for this research center is a power outage, Keio was eager to implement energy redundancy by installing Bloom fuel cells for the stable running of mission critical activities.
Medtronic Santa Rosa, California	400 kW	Will provide 96% of the electrical requirement for the Fountaingrove B building, while generating an estimated $2.3 million in energy savings over 15 years.
Morgan Stanley Purchase, New York	250 kW	Located at the firm's headquarters, the fuel cell system will constant base load power to the facility, as well as grid-independent electricity to power portions of the building's critical load during grid outages.
National Security Agency (NSA) campus Fort Meade, Maryland	1.6 MW	No further details available.
Pacific Cheese Hayward, California	300 kW	No further details available.

Santa Clara County, California	2.6 MW	Four fuel cell installations located at the county's Government Center (400 kW), Main Jail North (1 MW), Berger Service Center (400 kW), Elmwood Correctional Facility (800 kW). Washington Gas Energy Systems will finance, build, own, and operate the fuel cell system and sell all energy generated to the County under a 20-year power purchase agreement (PPA).
Disney Pixar Animation Studios Emeryville, California	1 MW	No further details are available.
Panasonic Avionics Lake Forest, California	750 kW	Installed in the parking lot of Panasonic Avionic's global headquarters, the fuel cell provides 85% of the facility's energy load.
SoftBank headquarters Tokyo, Japan	200 kW	Installed at SoftBank's headquarters at the Tokyo Shiodome Building in Tokyo, the fuel cell provides 14% of the building's overall electricity needs. The electricity generated is also used for electric vehicle charging stations installed in the underground parking garage of the building, and can also be directed to streetlights and public power outlets in the case of an emergency.
Sutter Santa Rosa Hospital, Santa Rosa, California	375 kW	Sutter Medical Center opened its newest $284 million dollar hospital, Sutter Santa Rosa Hospital in October. The fuel cells generate about 70% of the hospital's electricity needs. The total output of electricity will be about 3 million kWh annually. The hospital plans to buy natural gas from Pacific Gas & Electric (PG&E) and sell back any excess electricity.
Yahoo! Sunnyvale, California	1 MW	Fuel cell provides one-third of the electricity for the campus.
TOTAL	**32+ MW**	

Chart based on publicly available data. It includes installations from 2013 made public in 2014 and not included in the 2013 report.

In other SOFC news, a new European Union project, Solid Oxide Cell Testing, Safety and Quality Assurance (SOCTESQA), will develop new uniform and industry wide test procedures for high temperature solid oxide fuel cells by gathering the experience and the methodology gained by European research institutes, plus input from the industry on requirements from different applications. The consortium will make a complete set of application-specific test procedures addressing function, performance, durability, and degradation.[152]

Dominovas Energy Corporation (U.S.) signed an MOU with Delphi Automotive Systems LLC to jointly develop new technology that will facilitate the manufacture, assembly, sale, and deployment of electrical power generation equipment using SOFC technology.[153]

U.K.-based AFC Energy, a manufacturer of alkaline fuel cell systems, had several new partnerships arise in 2014, including:

- A non-binding MOU with Allied New Technologies Inc. to conduct a feasibility study for a fuel cell system to generate clean energy from surplus hydrogen produced at Allied's chlor-alkaline plant in Florida. The MOU marks AFC Energy's first move into the U.S. market.[154]
- A new cooperation agreement with Waste2Tricity International Ltd. and Alter NRG Corporation to focus on incorporating fuel cell systems in proposed energy-from-waste projects in Thailand.[155]

- A Heads of Agreement with South Korean company Daniel Inc. for an initial 1-MW fuel cell system that will be installed at Daniel's facility and use a mixture of liquefied natural gas and biomass gas. The agreement includes a follow-on option for an additional 3-MW project that could increase the value of the contract to approximately $15 million.[156]

- An MOU with Chang Shin Chemical Co., for the supply of multiple fuel cell systems with a total potential generating capacity of up to 5 MW.[157]

Other projects announced in 2014 include the following:

- GEI Global Energy Corp. received a purchase order from Lynntech, Inc. for a biogas fuel cell power generation system that will provide hydrogen fuel to a high temperature PEM fuel cell stack. The GEI fuel cell system will extract hydrogen from a bio-methane fuel produced via a proprietary biogas generation technology.[158]

- NovoFuel, Inc., a wholly-owned subsidiary of AlumiFuel Power Corporation, completed the design of a Renewable Energy System to power lights, heat, air conditioning, dehumidifiers, driers, and other ancillary equipment for indoor facilities, and massive irrigation for legal outdoor marijuana growing locations. These integrated RES components include mini-wind turbine systems, solar panels, batteries, and hydrogen fuel cells – all integrated by a real-time microgrid energy management and control system.[159] In late 2014, NovoFuel finalized a series of strategic partnerships related to the development and installation of a Michigan-based renewable energy project within the cannabis industry.[160]

- As part of the EU project, Biogas2 PEM-FC, PowerCell, working with partners from Spain, Greece, Sweden, and the U.K., developed a three-part subsystem at an olive mill in Andalucía that includes the reprocessing of waste from olive oil production, biogas production from waste, reforming of biogas, and a fuel cell power generation system that will utilize the reformate gas, converting it to electricity and heat that can be used by the olive mill. The project is now in its final stage and a complete pilot plant has been built and tested on the cooperative of San Isidro de Loja, Granada.[161]

- VTT Technical Research Centre of Finland developed a pilot-scale fuel cell power plant that produces electricity from hydrogen generated as a by-product of a sodium chlorate process at the Kemira Chemicals' site in Finland and is the first of its kind in the Nordic Countries.[162]

With the increase of large-scale stationary fuel cell sales and deployments, several energy companies have taken on the role of financier, providing funding for installations.

- Energy provider Exelon Corporation is providing equity financing for 21 MW of Bloom Energy fuel cell projects at 75 commercial facilities in California, Connecticut, New Jersey, and New York.[163] The customers include AT&T, which will use the fuel cells to power operations at nine sites. Exelon will finance Bloom Energy projects through Bloom Electrons™, a service that allows customers to buy power as a service, rather than purchasing the equipment directly.

- NRG Energy extended a $40 million revolving construction and term financing facility for the purpose of accelerating project development by FuelCell Energy and its subsidiaries.[164]

In addition, XL Group's Complex Accounts unit, Munich Re's Green Tech Solutions team, and consultants New Energy Risk, have teamed to deliver a performance insurance policy for a portfolio of fuel cell servers installed across the U.S. The insurance covers critical support for project financing by insuring the fuel cells' performance over 15 years, should the manufacturer be unable to meet its warranty obligations. The $99 million bond issued to help finance the portfolio of servers was granted investment grade rating, which resulted in notable financing efficiencies.[165]

Micro Combined Heat and Power

Micro combined heat and power fuel cell systems generate power and heat for residential or other smaller-scale applications. PEMs and SOFCs are the two main types of fuel cells used in m-CHP applications. Hundreds of

m-CHP fuel cells have been deployed in Europe in field trials, and more than 100,000 fuel cells have been sold to power Japanese homes. A number of new projects and sales were announced in 2014.

Panasonic reports that Japan's stationary fuel cell market continues to develop, with more than 40,000 Ene-farm units sold during 2014 (compared to 26,000 units sold in 2013). By September 2014, the Ene-farm program had cumulatively sold about 100,000 units since sales began in 2009. Panasonic also offered a condominium Ene-Farm model for Japanese market in 2014. In April, Panasonic started sales of a fuel cell model for Europe in Germany, in a partnership between German heating and renewable energy systems company Viessmann.[166]

GDF SUEZ installed two residential CHP fuel cells in the towns of Hagenau and MunschHausen in eastern France in April, the first project of its kind to be completed anywhere in the country. The Group plans to install around 30 systems in French homes and offices by summer 2015. Manufactured by BAXI, the first two fuel cells were installed in recently-built houses, with installation and maintenance support from DeDietrich. Three more installations were planned in new-build homes. The fuel cells were installed as part of the European ene.field project, which will eventually install 1,000 fuel cells in homes in 12 European countries.[167]

Ceramic Fuel Cells Ltd. (CFCL) announced the commencement of the first fully funded BlueGEN program, where the end user doesn't pay for the fuel cell installation, just the cost of gas and maintenance. The program, comprising a 100-kW fleet of BlueGENs (a minimum of 65 units) is targeted primarily at public sector organizations and will be run by one of CFCL's U.K. distributors, iPower.[168]

CFCL also received an order for 100 BlueGEN units from Avilos GmbH on a take-or-pay basis to sell to private and small commercial customers.[169]

In addition, CFCL reported that it has achieved a reduction of up to 70% of the average degradation rate experienced in its BlueGEN product. These improvements were validated via in-house and field testing as well as at a EWE, a current BlueGEN customer, site.[170]

With funding of £230,000 ($364,000) from U.K.'s innovation agency, the Technology Strategy Board, fuel cell manufacturer Ceres Power and engineers from Lancaster University are collaborating on the development of low-cost, intermediate-temperature SOFC technology for m-CHP.[171]

Ceres Power and DEK, a U.K.-based global provider of screen printing equipment and processes, were awarded £0.7 million ($1.1 million) by the Technology Strategy Board's Fuel Cell Manufacturing and the Supply Chain collaboration initiative. The award co-funds a £1.1 million ($1.7 million) collaboration project that will combine DEK's photovoltaic manufacturing processes with Ceres' existing manufacturing capability to scale up production in response to growing market opportunities.[172]

Ceres Power signed a next-stage Joint Development Agreement with a Japanese power systems company following extensive testing both in the U.K. and Japan. The non-exclusive agreement enables the companies to combine their respective engineering and R&D expertise to produce a jointly developed Steel Cell SOFC stack using Ceres' Steel Cell technology. The stacks will be supplied from Ceres manufacturing facility in the U.K. followed by system level testing in Japan.[173]

Backup and Remote Power

Fuel cells provide reliable backup power for telecommunications networks which, in many cases, are located in remote areas without a developed power infrastructure. The backup and remote power fuel cell markets continued to grow in countries such as India and Africa and 2014 saw new partnerships between fuel cell manufacturers and companies in the Middle East and China.

Table 23. Summary of Ballard/Dantherm Projects 2014

Summary of Ballard/Dantherm Projects 2014		
Location	**# of Units**	**Details**
AECi Philippines	20	Methanol-fuelled ElectraGen™-ME backup power systems were installed on rooftop locations in Manila for Globe Telecom.
Eskom, Anglo American Platinum South Africa	1	A 12-month field trial of a 5-kW ElectraGen™-ME fuel cell in an off-grid residential application in the rural community of Naledi Trust. The fuel cell will be integrated with a battery bank and inverter to operate within a micro-grid to power 34 rural homes, with monthly delivery of liquid methanol fuel to an external storage tank.
Cascadiant Pakistan	N/a	Conducted a successful Mobile Energy Efficiency Optimization field trial with Warid Telecom and the Global System for Mobile Communications Association trialing ElectraGen™-ME systems at a number of Warid Telecom network sites. Fuel theft was reduced and reliability improved with the fuel cell system, both of which positively impacted operating cost of the network site.
Precision Power & Air Caribbean	13	Methanol-fuelled ElectraGen™-ME backup power systems were deployed at critical sites in the Digicel Group Limited's network in Jamaica, bringing the total number for Digicel to 25.
TOTAL	**34**	

Chart based on publicly available data.

Ballard sold approximately 400 kW of its FCgen™-1300 fuel cell stacks to M-Field Energy Ltd. of Taiwan to integrate into multiple 100-kW fuel cell systems to provide baseload power in combination with wind turbines or photovoltaic power as part of a complete hybrid renewable energy solution. These systems will be deployed throughout Asia.[174]

Italian company Acta S.p.A entered into a cooperation agreement with ReliOn for the product launch and North America marketing/promotion of a new Acta Power backup power system incorporating ReliOn's fuel cell system.[175] Acta also formed a product development partnership with Dantherm Power A/S to develop a self-recharging fuel cell backup power system for remote areas in colder climates. The system will integrate Acta's EL 1000 electrolyzer with Dantherm's fuel cell backup power system and then deploy on an island location near the Arctic Circle, where it will be powered by a wind turbine.

Acta sold an additional three fuel cell systems to SEFCA Pty Ltd, its Australian distributor, for use by one of Australia's largest mobile phone operators. The three Acta systems will each incorporate a ReliOn fuel cell module with a power output of 2.5 kW.[176] Acta also received an order for two of its systems for a renewable power storage application in Chiang Mai, Thailand. The systems, which have a combined power output of 4 kW, will be installed at a low-carbon residential and tourist development project to provide a secure and grid-independent source of power with renewable energy storage.[177]

In September, an Acta system successfully supplied electricity to a mobile telecommunication base station in Cairo, during a city-wide electricity outage that caused major disruption for almost 12 hours, including taking more than 2,000 mobile phone towers offline.[178]

In March, German company Heliocentris Energy Solutions AG announced it will replace diesel generators at 25 digital radio base stations owned by BOS Digitalfunk in the German state of Brandenburg with its fuel cells in a €1 million ($1.3 million) deal.[179] The company also received a follow-up order for 30 units from the Emirates

Integrated Telecommunications Company, "du", in the Middle East, which has already deployed 100 Heliocentris units on its network.[180]

In June, Heliocentris acquired FutureE Fuel Cell Solutions GmbH, a company focused on the telecommunications industry.[181] In August, FutureE entered into a master distribution agreement with a Beijing IT banking solutions provider to market its Jupiter fuel cell systems to Chinese banking customers. The contract aims for delivery of at least 300 in 2015 with a potential sales value of €12 million ($15 million).[182]

U.K. fuel cell manufacturer Intelligent Energy entered into several collaboration agreements with companies in India in 2014, including:

- Microqual Techno Limited – an exclusive 15-year agreement to provide Intelligent Energy's fuel cell power solutions to Microqual-installed mobile telecom base station equipment on existing electricity transmission towers.[183]
- Ascend Telecom Infrastructure Private Limited – multi-year agreement to provide advanced power solutions, including fuel cell power systems, to reduce both operating costs and the carbon footprint relative to the current traditional diesel generators used to power India's telecom tower network.[184]
- Hydro Industries – collaboration with Intelligent Energy's subsidiary Essential Energy, to support the commercialization of Hydro's water purification technology across India. The partnership could result in Hydro's technology being powered by Intelligent Energy's fuel cells and deployed at thousands of sites over the next five years.[185]

In April, Communication Infrastructure Corp. (CIC) installed two Plug Power ReliOn E-200 fuel cell systems to provide primary power to a remote microwave relay site with two microwave radios.[186] The equipment's power requirements can be met for 17-19 days by the fuel cell system without being refueled and that window could be pushed to 21 days if a storm prevented access during the normal refueling window.

In December, Plug Power executed a $20 million, multi-year contract for its ReliOn integrated fuel cell solution and GenFuel hydrogen services with a major North American telecommunications provider for use in the customer's wireless network. In January 2015, the telecommunications company was revealed to be SouthernLINC Wireless.[187] Through this contract, Plug Power anticipates supporting as many as 500 new sites.[188]

First Element Energy partnered with Fuel Cell Solutions to install a PEM hydrogen fuel cell at La Universidad APEC (UNAPEC) in the Dominican Republic. The fuel cell is installed on the Engineering campus at UNAPEC.[189]

First Element Energy was also involved in a feasibility study and pilot project, partially funded by the USTDA, for Jiangsu Communications Services Company, Ltd. to evaluate fuel cell applications for busload and off-grid power within the telecommunications infrastructure in China.[190] The pilot portion consisted of installation of First Element Energy's fuel cell units at two sites. The first unit, which is fueled by compressed hydrogen gas, was successfully tested and approved by a major Chinese carrier. The second system uses a mixture of liquid methanol and water as fuel. The company also has a hydrogen fuel cell project in China providing 15 kW AC voltage for a railroad, as well as methanol-powered fuel cell telecom projects in Indonesia and the Philippines (2.5 and 5-kW systems), and India (2.5 kW systems).

Fuel cells were also deployed in a variety of other backup and remote applications.

BOC provided two of its Hymera portable hydrogen-fueled fuel cells to power a week-long live radio broadcast of visiting and local artists, called Remote Performances, from a remote tree-house studio in Glen Nevis, Scotland.[191]

In 2014, SFC Energy AG introduced new products and features:

- The EFOY ProCabinet fuel cell power solution designed for demanding industrial applications in arctic conditions.[192]

- The EFOY Pro fuel cell power systems for oil and gas applications added a new intelligent, secure, remote support, control, notification and data acquisition/logging feature, jointly developed by SFC Group member Simark Controls and Semaphore.[193]
- In June, TÜV SÜD Product Service GmbH certified SFC's environmental management system according to International Organization for Standardization (ISO) 14001:2004.[194]

The first EFOY ProCabinet systems were developed to power off-grid oil and gas devices in the extreme cold and are already in operation across Canada. To support these units and future sales, SFC Energy has opened a new service center and warehouse in Calgary, Canada, at the head office of SFC Energy Group member Simark Controls, which helped develop the fuel cell system.

SFC's EFOY Pro fuel cells also provided temporary power to the obstruction lights of wind turbines during the construction phase of wind energy plants. SFC is working with Windkraft Service GmbH, Lutherstadt Eisleben, which leases the systems to the wind energy plant companies for powering obstruction lights during the plant construction phase.[195]

In other SFC news, the company received a €400,000 ($510,200) order from Singapore-based Innoverde that uses EFOY Pro fuel cell generators and solar modules for its integrated hybrid power solution to power closed circuit television for various applications, including construction sites.[196]

Toshiba and the Kawasaki municipal authorities in Japan announced plans to combine a fuel cell, a 25-kW solar array, and a lithium ion battery into an independent energy demonstration system to provide electricity during emergencies. The system will be tested from April 2015 through the end of fiscal year 2020 and will be located at an emergency evacuation area near the Kawasaki port and able to supply power and hot water to roughly 300 people.[197]

Table 24. Examples of Commercially Available Backup and Remote Power Fuel Cells 2014

Examples of Commercially Available Backup and Remote Power Fuel Cells 2014			
Manufacturer	**Product Name**	**Type**	**Output**
Acta S.p.A. Italy	Acta Power	PEM	2 kW & 4 kW
Ajusa Spain	NOIL 5000 AC UPS	PEM	5 kW
Acumentrics U.S.	RP250P-LITE	SOFC	250 W
	RP250/RP500	SOFC	250 W/500 W
	RP1000/RP1500	SOFC	1 kW/1.5 kW
Altergy Systems U.S.	Freedom Power™	PEM	500 W, 1 kW, 5 kW & 7.5 kW
Axane France	CommPAC 500™	PEM	500 W-10 kW
Ballard Power Systems Canada/Dantherm Power Denmark	FCgen-1020ACS	PEM	1.5-3.6 kW
	FCgen-1300	PEM	2-11 kW
	ElectraGen-ME	PEM	2.5 & 5 kW
	ElectraGen-H2	PEM	1.7, 2.5 & 5 kW

PowerCell Sweden	S1	PEM	3 kW
Electro Power Systems S.p.A. Italy/VP Energy, LLC U.S.	Electro™, ElectroSelf™	PEM	1.5 kW-10 kW
First Element Energy U.S.	Air-cooled/Water-cooled	PEM	2 kW-25 kW
Heliocentris Fuel Cells AG Germany	Nexa 1200	PEM	1.2 kW
Horizon Fuel Cell Technologies Singapore	H-Series	PEM	10W-5 kW
	Ecobox-MR	PEM	1-10 kW
	GreenHub Powerbox	PEM	500 W-2 kW
Hydrogenics Canada	HyPM XR Power Modules	PEM	4.5 kW-12.6 kW
	HyPM Rack	PEM	2-200 kW
Intelligent Energy U.K./ Essential Energy India	Air-cooled	PEM	5 kW
Oorja Fuel Cells U.S.	Model T	DMFC	1.5 kW
ReliOn, a Plug Power Company U.S.	E-200	PEM	175-525 W
	E-1000x	PEM	1-4 kW
	E-1100	PEM	1.1-4.4 kW
	E-1100v	PEM	1.1 kW
	E-2200x	PEM	2.2-17.5 kW
	E-2500	PEM	2.5-20 kW
	T-2000	PEM	100 W-6 kW+
SFC Energy Germany	EFOY Pro 800	DMFC	45 W
	EFOY Pro 2400	DMFC	110 W
	EFOY ProCube	DMFC hybrid	Depends on configuration
	EFOY ProEnergyBox	DMFC hybrid	Depends on configuration
	EFOY ProCabinet	DMFC	90 W
UltraCell U.S.	XX25	RMFC	50 W
	Blade 50	RMFC	50 W
	Blade 0-165	RMFC	75, 100, and 150 W

Micro Fuel Cells

Following up on its launch of its Upp™ fuel cell personal energy device in 2013, Intelligent Energy announced new distribution and sales partners in 2014, including:

- U.S. retailer Brookstone;[199]
- Apple stores across the U.K.;[200]
- Telecommunications services supplier Sure stores across the Channel Islands and the Isle of Man;[201] and
- U.K. parcel exchange hub, Doddle, for cartridge exchange.[202]

In November, the Upp™ was named a 2015 Consumer Electronics Show (CES) Innovation Awards Honoree by the Consumer Electronics Association.[203]

Neah Power Systems Inc. began shipping its BuzzBar Suite of products in August, and also completed both Federal Communications Commission (U.S.) and CE (EU) certifications.[204]

AK GlobalTech unveiled a new alcohol sensor breathalyzer product, the AlcoMate Revo, which includes a fuel cell sensor.[205]

Military

NexTech Materials, Ltd. received a Phase II SBIR contract from the U.S. Army Tank Automotive Research, Development and Engineering Center (TARDEC) to design, develop and demonstrate a SOFC stack to be integrated into a 10-kW scale APU for military ground vehicles. In Phase I, NexTech incorporated its sulfur-tolerant anode technology into its stack design to enable use with military logistic fuels. In Phase II, NexTech will build and test these stacks to validate its design against key military specifications. Additional engineering efforts will focus on reducing stack weight and volume, improving stack efficiency, and increasing sulfur tolerance. The project will culminate with the delivery of a 10-kW stack to the Army for testing and evaluation.[206]

The Office of Naval Research (ONR) selected UTC Aerospace Systems to proceed with the next phases of the Long Endurance Undersea Vehicle Propulsion energy program. UTC Aerospace Systems will continue the design and development of a PEM-based fuel cell energy system for a 21-inch diameter unmanned undersea vehicle.[207] In the previous phase, the system operated successfully for over 30 hours using an integrated cryogenic reactant system and fuel cell power plant to provide 42 kWh of total energy over a power range of 100 to 3800 W.

UltraCell unveiled its BLADE Fuel Cell Power System for professional and military customers. The company also announced that after development and field testing in extreme conditions, its XX55 fuel cell system exceeded Air Force requirements for meantime between failures and cycling.[208]

Neah Power Systems, Inc. is partnering with Silent Falcon UAS Technologies to integrate the Formira™, formic acid fuel cell reformer into the Silent Falcon UAV.[209]

The U.S. Navy is working with the Japanese Defense Ministry to develop a 30-ft. fuel cell-powered unmanned underwater vehicle (UUV) that would be capable of conducting undersea surveillance activities for 30 days.[210] The Ministry plans to spend about ¥2.6 billion ($23.6 million) for the project during a four-year period through fiscal 2018.

Materials/Components/Testing

ElectroChem introduced its new compact liquid-cooled PEM fuel cell stacks (500-1,500 W) with MEAs to understand the effect of reactant gas supply on power generation, and the effect of heat and water in the performance.[211]

Toray Industries' carbon fiber material will be used for a range of parts in Toyota Motor Corporation's Mirai FCEV. In particular, Carbon Fiber Reinforced Thermoplastics will be used in a stack frame part, equivalent to the vehicle

floor. Toray also supplied carbon paper for the electrode substrate of fuel cell stack and a high strength carbon fiber for the high pressure hydrogen tank.[212]

University News

Researchers at universities around the world, both staff and student, made news in 2014 with technical advancements in materials, stacks, systems, and fueling for the fuel cell and hydrogen industry.

- Binghamton University (New York): The University broke ground on a $70 million, 114,000-square-foot Smart Energy Research and Development Facility at the campus' Innovative Technologies Complex. The facility, scheduled for completion in 2017, will house the physics and chemistry departments and plans include installing a fuel cell to produce electricity at a reduced cost to heat and cool the building. Fuel cells will also be part of the research conducted at the facility.[213]
- Georgia Institute of Technology: Researchers developed a new type of low-temperature fuel cell that directly converts biomass to electricity with assistance from a catalyst activated by solar or thermal energy. The hybrid fuel cell can use a wide variety of biomass sources, including starch, cellulose, lignin, switchgrass, powdered wood, algae, and waste from poultry processing.[214]
- Michigan State University: Researchers developed a new fuel cell concept that allows biodiesel plants to eliminate the creation of hazardous wastes while removing their dependence on fossil fuel from their production process.[215]
- Northwestern University (Illinois): Engineers invented inks that a 3-D printer can use to create the individual components of a solid oxide fuel cell, the cathode, anode, electrolyte, and interconnects.[216]
- Rice University (Texas): Researchers combined graphene quantum dots from coal with microscopic sheets of grapheme to create a hybrid material that outperforms and is less costly than platinum/carbon hybrid catalysts used in some types of fuel cells.[217]
- Rice University (Texas): Scientists have turned molybdenum disulfide's two-dimensional form into a nanoporous film that can catalyze the production of hydrogen or be used for energy storage.[218]
- University of New Mexico: In December, UNM received a "Top 10 Innovation" award at the inaugural conference of the Innovation for Cool Earth Forum held in Tokyo, Japan, for an novel method for making non-platinum-based fuel cells jointly developed with Daihatsu Motor Co., Ltd.[219]
- University of Utah: A professor developed a fuel cell which can convert jet fuel to electricity at room temperature without igniting the fuel, using enzymes as catalysts in the reaction.[220]
- Washington State University: A team from WSU won the Hydrogen Education Foundation's 2014 Hydrogen Student Design Contest. The contest, supported by DOE, challenged teams to design a transportable, containerized, cost-effective hydrogen fueling station solution for areas of initial low demand.[221]
- Banaras Hindu University (India): Researchers at the Hydrogen Energy Center have discovered that carbonized coconut flesh can serve as a hydrogen storage medium.[222]
- Universiti Teknologi Mara (UiTM) Malaysia: A team from UiTM Malaysia won both the Urban Concept and Prototype categories at the 2014 Shell Eco Marathon Asia which took place in the Philippines using fuel cells from Horizon Fuel Cell Technologies.[223] The second place participant, Universiti Kebangsaan Malaysia (UKM), also used Horizon hybrid technology in the contest that drew more than 100 teams from top universities and Engineering institutes all over Asia.
- École polytechnique fédérale de Lausanne (EPFL) (Switzerland): EPFL researchers combined solar cells made with a mineral called perovskite and low cost electrodes to achieve a 12.3% conversion efficiency from solar energy to hydrogen, a record using earth-abundant materials as opposed to rare metals.[224]

- University of Manchester (U.K.): Researchers suggests that the use of graphene or monolayer boron nitride can allow the existing membranes to become thinner and more efficient, with less fuel crossover and poisoning, boosting the competitiveness of fuel cells. The Manchester group also demonstrated that their one-atom-thick membranes can be used to extract hydrogen from a humid atmosphere.[225]

Reports and Studies

DOE's FCTO released the latest edition of the report, *Pathways to Commercial Success: Technologies and Products Supported by the Fuel Cell Technologies Office*, which shows that FCTO's R&D efforts over the last decade have resulted in more than 500 patents, 45 commercial technologies that have entered the market, and 65 technologies that are projected to be commercialized within three to five years (as of November 2014). These include fuel cell systems and components as well as hydrogen production, delivery, and storage technologies.

Safety, Codes and Standards for Hydrogen Installations: Hydrogen Fueling System Footprint Metric Development, published in April 2014 by Sandia National Laboratories, examined 70 commercial gasoline stations in the state of California and sought to determine which, if any, could integrate hydrogen fuel at their sites based on the National Fire Protection Association (NFPA) hydrogen technologies code published in 2011. The study found that 14 of the 70 gas stations involved in the study could readily accept hydrogen fuel and that 17 more possibly could accept hydrogen with property expansions.

NREL published *Zero Emission Bay Area (ZEBA) Fuel Cell Bus Demonstration Results: Third Report*, *BC Transit Fuel Cell Bus Project Evaluation Results: Second Report*, *BC Transit Fuel Cell Bus Project: Evaluation Results Report*, *Fuel Cell Buses in U.S. Transit Fleets: Current Status 2014*, and *Fuel Cell Bus Evaluations*.

The California Air Resources Board (ARB) published the *Annual Evaluation of Fuel Cell Electric Vehicle Deployment and Hydrogen Fuel Station Network Development, Pursuant to AB 8, Statutes of 2013*.

The California Fuel Cell Partnership (CaFCP) published the *Hydrogen Progress, Priorities and Opportunities* report that reviewed its progress toward roadmap goals and defines important next steps to create a 100-station hydrogen network in California.

The CaFCP also published *Air Climate Energy Water Security: a guide to understanding the well-to-wheels impact of fuel cell electric vehicles,* which summarizes the most common vehicle/fuel pathways in California.

The NextSTEPS (Sustainable Transportation Energy Pathways) Program at the University of California, Davis Institute of Transportation Studies (ITS-Davis) published a white paper, *The Hydrogen Transition*, which details the convergence of new factors propelling an international market rollout of hydrogen fuel cell vehicles.

The Business Case for Fuel Cells 2014: Powering the Bottom Line for Businesses and Communities, written and compiled by Breakthrough Technologies Institute (BTI) with support from DOE, was published in November. The report provides an overview of fuel cell installations at businesses and municipal buildings or facilities run by non-profit organizations or institutions. These include wastewater treatment plants, government buildings, universities, military bases, hospitals, and other sites.

State of the States: Fuel Cells in America 2014, the fifth edition of this report series, also written by BTI and partially funded by DOE, provides details on the fuel cell and hydrogen progress and activities of the 50 states and District of Columbia and includes in-depth profiles of policies, initiatives, and installations that have contributed to the fuel cell industry in specific states, the country, and the world.

The *New York State Renewable Portfolio Standard Annual Performance Report Through December 31, 2013* was released in March 2014 and reports that, under the Customer-Sited Tier, small fuel cells were installed at 19 sites between 2007 and December 31, 2013, comprising 187-kW of installed capacity, and large fuel cells were installed at two sites comprising 600-kW of installed capacity. Additional fuel cells are planned under the Main Tier component of the program, with five fuel cell facilities, totaling 3.2 MW of power, expected to be in operation by December 31, 2014. The report notes that, since Superstorm Sandy, there has been a resurgence of applications

for large-scale fuel cells, with eight applications for $1 million each on track for implementation. There has also renewed interest in emergency backup power fuel cells – the 19 backup power fuel cells installed during the program's early years played a role in keeping communications open during Superstorm Sandy for both residents and emergency responders.

Appendix 1: Compilation of Companies in this Report with Commercially Available Fuel Cell Products

Companies with Commercially Available Fuel Cells 2014						
Company	**Company Type**	**Headquarters**	**Annual Manufacturing Capability**	**# of Employees**	**Fuel Cell Type**	**Applications**
Acta S.p.A.	Public - AIM: ACTA.L	Italy	2.4 MW	60	PEM	Backup/ remote
Ajusa	Private	Spain	N/a	N/a	PEM	Backup/ remote
Acumentrics	Private	U.S.	N/a	N/a	SOFC	Backup/ remote
Altergy Systems	Private	U.S.	N/a	N/a	PEM	Backup/ remote
Axane	Subsidiary of Air Liquide	France	N/a	N/a	PEM	Backup/ remote
Ballard Power Systems	Public - NASDAQ: BLDP, TSX:BLD	Canada	>150 MW	400	PEM	Transport, MHE, stationary, backup/ remote
Bloom Energy	Private	U.S.	N/a	N/a	SOFC	Stationary
Ceramic Fuel Cells Ltd.	Public - AIM:CFU, ASX:CFU 2015 – Company is in liquidation	Australia	N/a	N/a	SOFC	Stationary (m-CHP)
Doosan Fuel Cell America	Subsidiary of Doosan Corp.	U.S.	Plans to manufacture 90 units in 2015	241	PAFC	Stationary
Elcore GmbH	Private	Germany	500 units	100	SOFC	Stationary (m-CHP)
ENEOS CellTech	A joint company of JX Holdings Inc. and Sanyo Electric Company	Japan	N/a	N/a	PEM	Stationary (m-CHP)
First Element Energy	Private	U.S.	1000-1500 systems	N/a	PEM	Backup/ remote
FuelCell Energy	Public - NASDAQ: FCEL	U.S.	U.S.: 100 MW Germany: 20 MW South Korea: Will have initial capacity of 100 MW	622	MCFC	Stationary

Fuji Electric	Public - 6504:Tokyo	Japan	2+ MW (under expansion)	N/a	PAFC	Stationary
Heliocentris Fuel Cells AG	Public	Germany	N/a	185	PEM	Backup/ remote
Horizon Fuel Cell Technologies	Private	Singapore	1 MW	130	PEM	Backup/ remote, educational, specialty vehicles
Hydrogenics	Public - NASDAQ: HYGS	Canada	300 power units/year in Missisauga, Canada facility	170	PEM	Transport, MHE, backup/ remote
Intelligent Energy	Public	U.K.	Manufacturing is contracted out or assigned to joint venture partners	380	PEM	MHE, backup/ remote
Nuvera	Private	U.S.	N/a	119	PEM	MHE
Oorja Fuel Cells	Private	U.S.	N/a	N/a	DMFC	MHE, backup/ remote
Panasonic	Public - NYSE:PCRFY	Japan	approximately 25,000 units/ year	N/a	PEM	Stationary (m-CHP)
Plug Power/ ReliOn	Public - NYSE:PLUG	U.S.	10,000 units	326	PEM	MHE, backup/ remote
PowerCell	Public	Sweden	10 MW (2,000 units)	25+	PEM	Backup/ remote
Proton Motor Fuel Cell GmbH	Subsidiary of Proton Power Systems	Germany	N/a	60	PEM	MHE
SFC Energy	Public - F3CG. DE	Germany	N/a	250	DMFC	Backup/ remote
Symbio FCell	Private	France	N/a	N/a	PEM	Transport, MHE
Toshiba	Public - NYSE:TOSBF	Japan	N/a	N/a	PEM	Stationary (m-CHP)
UltraCell	Private	U.S.	100 kW	N/a	RMFC	Backup/ remote
US FuelCell Corporation	Division of US Hybrid	U.S.	N/a	N/a	PEM	Transport

Companies list is derived from the commercial products charts in this report.

Acronyms:

m-CHP - micro combined heat and power; MCFC - molten carbonate fuel cell; MHE – material handling equipment; N/a – information is not available; PAFC - phosphoric acid fuel cell; PEM - proton exchange membrane fuel cell; RMFC - reformed methanol fuel cell; SOFC - solid oxide fuel cell

Endnotes

1. http://www.plugpower.com/news/pressreleases/14-04-02/PLUG_POWER_ACQUIRES_RELION_INC_BRINGING_INNOVATIVE_FUEL_CELL_STACK_TECHNOLOGY_IN-HOUSE.aspx
2. http://www.plugpower.com/news/pressreleases/14-11-11/PLUG_POWER_STRUCTURES_RELION_AS_STATIONARY_POWER_PRODUCT_BRAND.aspx
3. http://www.hartfordbusiness.com/article/20140429/NEWS01/140429939
4. http://www.doosanfuelcell.com/en/resources/releases_view.do?page=1&pressSeq=6&parSrchTxt=&contentsCode=7041
5. http://www.ushybrid.com/index.php/news/98-us-hybrid-executes-global-fuel-cell-technology-licensing-agreement-with-united-technologies
6. http://www.utc.com/News/News-Center/Pages/United-Technologies-Closes-Strategic-Intellectual-Property-Transaction-with-Balla.aspx
7. http://www.dominovasenergy.com/wp-content/uploads/2014/05/DEC-Press-Release-24-Feb-2014.pdf
8. http://ballard.com/about-ballard/newsroom/news-releases/news06291401.aspx
9. http://www.h2logic.com/com/shownews.asp?lang=en&id=448
10. http://www.greencarcongress.com/2014/05/20140506-symbio.html
11. http://www.heliocentris.com/en/our-company/press/press-releases/new-details/article/heliocentris-uebernimmt-futuree.html
12. http://powersource.post-gazette.com/powersource/companies-powersource/2014/10/25/Watt-Fuel-Cell-Inc-welcome-sight-for-research-industry-begin-operations-in-Mt-Pleasant/stories/201410250012
13. http://www.nuvera.com/pressroom/press-releases/187-hypress-release
14. http://filings.irdirect.net/data/1381054/000135448815000264/hfco_10k.pdf
15. http://www.bloomberg.com/news/2014-07-22/general-electric-opens-fuel-cell-pilot-plant-in-new-york.html
16. http://www.powercell.se/2014/11/
17. http://www.cerespower.com/news-media/press-releases/2014-02-12-ceres-announces-commercial-progress-and-expansion-in-japan
18. http://fcel.client.shareholder.com/releasedetail.cfm?ReleaseID=879097
19. http://www.stockhouse.com/news/press-releases/2014/09/25/vision-industries-files-for-voluntary-chapter-11-bankruptcy-protection#j5i1aA5EFa5vRgk4.99
20. http://www.betaboston.com/news/2014/07/31/lilliputian-systems-mit-spin-out-that-raised-150-million-runs-out-of-fuel/
21. http://www.topsoefuelcell.com/news_and_info/press_releases/120814.aspx
22. http://www.plugpower.com/news/pressreleases/14-04-21/PLUG_POWER_AND_HYUNDAI_HYSCO_SIGN_MEMORANDUM_OF_UNDERSTANDING_TO_FORM_FUEL_CELL_JOINT_VENTURE_IN_ASIA.aspx
23. http://www.airproducts.com/company/news-center/2014/02/0227-air-products-and-nippon-steel-sign-agreement-for-hydrogen-fueling-station-work-in-japan.aspx
24. http://www.hydrogenics.com/about-the-company/news-updates/2014/06/18/hydrogenics-and-universiti-teknologi-malaysia-signed-a-memorandum-of-understanding-in-korea

25. http://www.hydrogenics.com/about-the-company/news-updates/2014/06/23/hydrogenics-signs-agreement-to-create-kolon-hydrogenics-joint-venture-for-power-generation-in-south-korea

26. http://oorjafuelcells.com/wp-content/uploads/2014/05/LICENSE-PRESS-RELEASE_OorjaFinal_1.pdf

27. http://www.sec.gov/Archives/edgar/data/1453015/000091228215000077/ex99_2.htm

28. http://www.sec.gov/Archives/edgar/data/1453015/000091228215000077/ex99_2.htm

29. http://www.sec.gov/Archives/edgar/data/1453015/000091228215000077/ex99_2.htm

30. http://files.shareholder.com/downloads/FCEL/3511873063x7757298x805460/04E94953-CA46-4377-8498-4F670A41E241/FuelCell_14AR_FINAL.pdf

31. http://www.sedar.com/GetFile.do?lang=EN&docClass=2&issuerNo=00029022&fileName=/csfsprod/data150/filings/02316107/00000001/t%3A%5CHydrogenics%5CSEDAR%5C0047945_Mar3_2015%5Cfile%5Chydrogenics0304ar.pdf

32. http://www.hydrogenics.com/docs/default-source/earnings-releases-pdf/hydrogenics-reports-fourth-quarter-and-full-year-2014.pdf?sfvrsn=0

33. http://www.hydrogenics.com/docs/default-source/default-document-library/hygs-q4-2014-earnings-call-presentation-(final).pdf?sfvrsn=0

34. http://www.plugpower.com/News/PressReleases/15-03-17/PLUG_POWER_ANNOUNCES_2014_FOURTH_QUARTER_AND_YEAR-END_RESULTS.aspx

35. http://www.plugpower.com/News/PressReleases/15-03-17/PLUG_POWER_ANNOUNCES_2014_FOURTH_QUARTER_AND_YEAR-END_RESULTS.aspx

36. http://www.cfcl.com.au/Assets/Files/20140926%20-%20CFCL%20Annual%20Report%202014%20FINAL.pdf

37. http://www.cerespower.com/admin/resources/cerespowerar14.pdf

38. http://www.sec.gov/Archives/edgar/data/1453015/000091228215000077/ex99_2.htm

39. http://www.cfcl.com.au/Assets/Files/20140926%20-%20CFCL%20Annual%20Report%202014%20FINAL.pdf

40. http://www.cfcl.com.au/Assets/Files/20140430%20-%20Quarterly%20Cashflow%20Report.pdf

41. http://files.shareholder.com/downloads/FCEL/3511873063x7757298x805460/04E94953-CA46-4377-8498-4F670A41E241/FuelCell_14AR_FINAL.pdf

42. http://www.hydrogenics.com/docs/default-source/earnings-releases-pdf/hydrogenics-reports-fourth-quarter-and-full-year-2014.pdf?sfvrsn=0

43. http://www.plugpower.com/News/PressReleases/15-03-17/PLUG_POWER_ANNOUNCES_2014_FOURTH_QUARTER_AND_YEAR-END_RESULTS.aspx

44. https://www.facebook.com/phystechventures

45. http://rusbase.com/news/author/robinmunby/investment-phystech-ventures/

46. http://fcel.client.shareholder.com/releasedetail.cfm?ReleaseID=820858

47. http://fcel.client.shareholder.com/releasedetail.cfm?ReleaseID=863343

48. http://www.b2i.us/profiles/investor/ResLibraryView.asp?ResLibraryID=67306&GoTopage=7&Category=44&BzID=604

49. http://www.b2i.us/profiles/investor/ResLibraryView.asp?ResLibraryID=67306&GoTopage=7&Category=44&BzID=604 and http://www.thestreet.com/story/12241641/1/plug-power-inc-announces-closing-of-30-million-registered-offering.html

50. http://www.plugpower.com/News/PressReleases/14-04-25/PLUG_POWER_INC_ANNOUNCES_PRICING_OF_124_300_000_REGISTERED_OFFERING.aspx

51. http://www.cfcl.com.au/Assets/Files/20140324%20ASX%20and%20AIM%20Fundraising%20Announcement.pdf

52. http://www.hydrogenics.com/about-the-company/news-updates/2014/05/16/Hydrogenics-Announces-Closing-of-Underwritten-Public-Offering

53. http://www.sfc.com/en/investors/ir-home#header

54. http://www.afcenergy.com/_userfiles/pages/files/AFC%20Annual%20Report%202014%20Web-ready.pdf

55. http://dealbook.nytimes.com/2014/07/04/intelligent-energy-valued-at-1-09-billion-in-london-i-p-o/?_php=true&_type=blogs&_r=0

56. http://www.nasdaqomxnordic.com/news/listings/firstnorth/2014/myfc

57. http://www.nasdaqomxnordic.com/news/listings/firstnorth/2014/powercell and www.bequoted.com/beQPress/download.asp?Id=14077

58. http://www.cepgi.com/2015/04/2014-year-end.html#more

59. http://energy.gov/eere/articles/leveraging-national-laboratories-support-h2usa

60. http://www.altenergymag.com/news/2014/10/29/us-doe-launches-1-million-h2-refuel-h-prize-competition-for-small-scale-hydrogen-refueling-system/35214

61. https://share.sandia.gov/news/resources/news_releases/mobile_lights/#.VEFqtyLF_Ns

62. http://energy.gov/articles/nascar-green-gets-first-place-daytona-500

63. https://share.sandia.gov/news/resources/news_releases/linde_crada/#.VJRuasAA

64. http://www.dot.gov/fastlane/maritime-administration-helping-green-port-honolulu

65. http://www.marad.dot.gov/news_room_landing_page/news_releases_summary/news_release/dot100-14.htm

66. http://www.rit.edu/news/story.php?id=50887

67. http://www.ustda.gov/news/pressreleases/2014/SubSaharanAfrica/Ethiopia/USAfricaEnergyMinisterial_060414.asp

68. http://www.governor.ct.gov/malloy/cwp/view.asp?Q=555864&A=4010

69. http://www.london.gov.uk/media/mayor-press-releases/2014/04/global-leaders-sign-up-to-31m-plan-to-demonstrate-viability-of

70. http://www.reuters.com/article/2014/07/23/us-japan-autos-fuelcells-idUSKBN0FS19420140723 and http://www.japantimes.co.jp/news/2014/07/25/business/japanese-government-to-make-fuel-cell-cars-the-official-vehicle-for-all-ministries/#.U9Y_8WBOXIU

71. http://www.bloomberg.com/news/2014-07-13/china-targets-30-new-government-vehicles-use-alternative-energy.html and http://www.gov.cn/xinwen/2014-07/13/content_2716563.htm

72. http://the-japan-news.com/news/article/0001874527

73. http://www.unece.org/fileadmin/DAM/trans/doc/2013/wp29/ECE-TRANS-WP29-2013-041e.pdf

74. http://worldwide.hyundai.com/WW/Corporate/News/News/DF_WW_GLOBALNEWSVIEW_131210.html?testValue=DF_WW_RD_GLOBALNEWS&title=DF_WW_GLOBALNEWSVIEW_131210&selx2=intrado

75. https://www.hyundaiusa.com/about-hyundai/news/Corporate_HYUNDAI_PROUDLY_HANDS_KEYS_TO_FIRST_TUCSON_FUEL_CELL_CUSTOMER_AT_TUSTIN_HYUNDAI-20140613.aspx

76. http://www.edmunds.com/car-news/hyundai-negotiates-insurance-deals-for-2015-hyundai-tucson-fuel-cell-vehicle.html
77. http://news.yahoo.com/hyundai-first-offer-hydrogen-fuel-181000055.html
78. http://www.canberratimes.com.au/act-news/hydrogen-fuel-pumps-could-be-headed-for-canberra-20141210-124816.html
79. http://www.autonet.ca/en/2014/10/03/toyota-brings-economy-to-paris
80. http://www.japantimes.co.jp/news/2014/12/15/business/toyotas-hydrogen-powered-mirai-goes-sale-japan/#.VI9EkNLF_Ns
81. http://newsroom.toyota.co.jp/en/detail/4198334/
82. http://www.foxbusiness.com/2014/12/05/report-toyota-to-boost-fuel-cell-sedan-output/
83. http://newsroom.toyota.co.jp/en/detail/6402089/
84. http://world.honda.com/news/2014/4141117All-New-Fuel-Cell-Vehicle-FCV-CONCEPT/index.html
85. http://media.vw.com/release/889/
86. http://www.audi.com/com/brand/en/vorsprung_durch_technik/content/2014/11/audi-a7-sportback-h-tron-quattro.html
87. http://www.greencarcongress.com/2014/11/20141104-gcode.html
88. http://www.nrel.gov/news/press/2014/14370.html
89. http://www.intelligent-energy.com/about-us/media-room/news/company-news/2014/07/29/intelligent-energy-signs-agreement-with-japanese-volume-automotive-oem-to-develop-its-class-leading-fuel-cell-engine-technology-towards-commercial-launch
90. http://www.fch-ju.eu/sites/default/files/Joint%20press%20-%20release%20-%20zero-%20emission%20buses.pdf
91. http://www.ballard.com/about-ballard/newsroom/news-releases/news06171401.aspx
92. http://www.cbc.ca/news/canada/british-columbia/bc-transit-s-90m-hydrogen-bus-fleet-to-be-sold-off-converted-to-diesel-1.2861060
93. http://www.ballard.com/about-ballard/newsroom/news-releases/news10211401.aspx
94. http://www.solarisbus.com/busmania/news/
95. http://www.sartaonline.com/ohio-to-test-fuel-cells-for-public-transit
96. http://www.ushybrid.com/index.php/news/140-us-hybrid-awarded-contract-to-deliver-hydrogen-powered-shuttle-bus-to-hawaii-county-mass-transit-agency
97. http://www.plugpower.com/news/pressreleases/14-01-16/PLUG_POWER_LAUNCHES_NEW_TURNKEY_SOLUTION_TO_SMOOTH_CUSTOMER_TRANSITION_TO_HYDROGEN_FUEL_CELLS.aspx
98. http://www.plugpower.com/news/pressreleases/14-12-16/PLUG_POWER_HYDROGEN_AND_FUEL_CELL_SOLUTION_EARNS_A_SPOT_ON_FOOD_LOGISTICS_2014_FL100_LIST.aspx
99. http://www.ballard.com/about-ballard/newsroom/news-releases/news10081401.aspx
100. http://fuelcellsworks.com/news/2014/05/22/hydrogen-to-power-kansai-airport/
101. http://www.energy.ca.gov/releases/2014_releases/2014-04-22_investing_in_electricity_r_and_d_and_alt_fuels_nr.html
102. http://www.thegreencarwebsite.co.uk/blog/index.php/2014/11/04/microcab-to-showcase-new-hydrogen-fuelled-van/
103. http://www.microcab.co.uk/h2ev.html

104. http://www.businesswire.com/news/home/20141014005088/en/Symbio-FCell-Announces-World-Real-Life-Hydrogen#.VEFs_iLF_Ns

105. http://www.protonpowersystems.com/fileadmin/documents_pps/20140902_RNS_PPS_Development_Project_Austria_Sep_2014.pdf

106. http://www.lse.co.uk/AllNews.asp?code=9877y8dh&headline=Proton_Power_Systems_Secures_Asian_Contract_For_Maritime_Fuel_Cell_Study

107. http://www.businesswire.com/news/home/20141203006607/en/NCKU-Unveils-Hydrogen-Fueled-Electric-Scooter#.VIh1MtLF_Ns

108. http://www.unmannedsystemstechnology.com/2014/02/singapore-israel-cooperation-leads-to-worlds-first-civilian-fuel-cell-uav/

109. http://www.uwc.ac.za/News/Pages/HySA,-NAC-and-Airbus-project-takes-flight.aspx#.VG9KVPnF-Ck

110. http://www.alstom.com/press-centre/2014/9/innotrans2014-alstom-to-develop-a-new-emission-free-train-for-passengers-in-germany/

111. http://www.tuv-sud.com/news-media/news-archive/17-new-hydrogen-refuelling-stations-worldwide-in-2014

112. http://www.pnnl.gov/news/release.aspx?id=1045, http://www.nescaum.org/documents/nescaum-joins-h2usa-press-release-20140429.pdf, http://www.energy.ca.gov/releases/2014_releases/2014-04-29_Energy_Commission_and_ARB_H2USA_news_release.pdf, and http://www.intelligent-energy.com/about-us/media-room/news/company-news/2014/06/19/intelligent-energy-joins-h2usa

113. http://www.energy.ca.gov/releases/2014_releases/2014-05-01_hydrogen_refueling_stations_funding_awards_nr.html

114. http://green.autoblog.com/2014/11/19/honda-spending-13-8-million-on-hydrogen-infrastructure-with-fir/

115. http://pressroom.toyota.com/releases/toyota+names+fuel+cell+vehicle+mirai.htm

116. http://techon.nikkeibp.co.jp/english/NEWS_EN/20140703/362860/

117. http://the-japan-news.com/news/article/0001620485

118. http://asia.nikkei.com/Business/Companies/JX-Energy-to-build-expansive-hydrogen-infrastructure-in-Japan

119. http://koreabizwire.com/gwangju-dreams-of-mecca-of-eco-friendly-hydrogen-vehicles/21331

120. http://www.autoexpress.co.uk/car-news/consumer-news/88920/eu-drops-targets-for-number-of-ev-and-hydrogen-stations#ixzz3GQYFsTYV and http://europa.eu/rapid/press-release_IP-14-1053_en.htm

121. http://www.nationaljournal.com/library/214662

122. http://www.now-gmbh.de/en/presse-aktuelles/2014/visit-state-secretary-reiche.html

123. http://www.daimler.com/dccom/0-5-658451-1-1747646-1-0-0-0-0-0-9293-0-0-0-0-0-0-0-0.html

124. http://www.the-linde-group.com/en/news_and_media/press_releases/news_20140714.html

125. http://www.h2euro.org/2014/uk-government-unveils-major-investment-in-h2-infrastructure

126. http://www.inddist.com/news/2014/12/airgas-build-liquid-hydrogen-plant-kentucky

127. http://globenewswire.com/news-release/2014/11/04/679457/10106081/en/Plug-Power-Signs-Long-Term-Agreement-to-Use-Praxair-Hydrogen-for-State-of-the-Art-Fuel-Cell-Solution.html#sthash.8i9LO4Lu.dpuf

128. http://globenewswire.com/news-release/2014/11/04/679457/10106081/en/Plug-Power-Signs-Long-Term-Agreement-to-Use-Praxair-Hydrogen-for-State-of-the-Art-Fuel-Cell-Solution.html#sthash.8i9LO4Lu.dpuf

129. http://www.dnvgl.com/news-events/news/dnv-gl-jip-urges-natural-gas-industry-to-be-ready-for-hydrogen.aspx

130. https://share.sandia.gov/news/resources/news_releases/underground_hydrogen/#.VIhdzdLF_Ns

131. http://www.hitachizosen.co.jp/english/news/2014/01/001148.html

132. http://www.itm-power.com/news-item/gas-network-optimisation-contract-with-amec-and-national-grid/

133. http://www.areva.com/EN/news-10217/hydrogen-production-creation-of-a-global-leader-in-pem-electrolysis.html

134. http://www.csp-world.com/news/20141125/001502/th-ga-groups-p2g-project-marks-first-year-succesfully-injecting-hydrogen-gas

135. http://standards.sae.org/j2601_201407/, http://www.prweb.com/releases/2014/07/prweb12042788.htm, http://standards.sae.org/j2601_201407/, and http://standards.sae.org/j2799_201404/

136. https://transportevolved.com/2014/12/03/japanese-government-revises-rules-hydrogen-refueling-stations-make-easier-install/

137. http://www.cnet.com/news/japan-putting-full-weight-of-government-behind-fuel-cell-vehicles/

138. http://newsroom.toyota.co.jp/en/detail/3906446

139. http://www.nist.gov/pml/div685/hydrogen-meter-072114.cfm

140. http://www.epa.gov/otaq/fuels/renewablefuels/documents/rfs-path-II-fr-07-02-14.pdf

141. http://ajw.asahi.com/article/business/AJ201411200039

142. http://the-japan-news.com/news/article/0001808388

143. http://the-japan-news.com/news/article/0001808388, http://www.greencarcongress.com/2013/06/mch-20130603.html and http://www.chiyoda-corp.com/technology/en/spera-hydrogen/spera02.html

144. http://asia.nikkei.com/Tech-Science/Tech/Taiyo-Nippon-Sanso-to-cut-costs-of-hydrogen-fueling-stations

145. http://www.fujitsu.com/global/about/resources/news/press-releases/2014/1215-01.html

146. http://www.compositesworld.com/news/dsm-thermoplastics-featured-in-cng-and-hydrogen-tanks

147. http://www.prnewswire.com/news-releases/quantum-delivers-hydrogen-dispensing-system-to-linde-for-a-retail-fueling-station-in-west-sacramento-ca-300009314.html

148. http://fcel.client.shareholder.com/releasedetail.cfm?ReleaseID=847482

149. http://fcel.client.shareholder.com/releasedetail.cfm?ReleaseID=826618

150. http://fcel.client.shareholder.com/releasedetail.cfm?ReleaseID=874910

151. http://fcel.client.shareholder.com/releasedetail.cfm?ReleaseID=861060

152. http://www.ecs.dtu.dk/english/News/2014/09/Research-in-hydrogen-and-fuel-cell-energy-systems-to-be-accelerated-through-standardization

153. http://finance.yahoo.com/news/dominovas-energy-delphi-sign-mou-123000948.html

154. http://www.afcenergy.com/news/2014/2/2/1268/mou_signed_with_allied_new_technologies

155. http://www.afcenergy.com/news/2014/2/24/1273/new_drive_to_accelerate_launch_of_energyfromwaste_projects_in_thailand

156. http://www.afcenergy.com/news/2014/7/7/1284/landmark_agreement___signed_for_stationary_fuel_cell_systems_in_south_korea

157. Ibid.

158. http://globenewswire.com/news-release/2014/06/10/643007/10085181/en/GEI-Global-Energy-Corp-Announces-Biogas-Power-Generation-Order.html

159. http://www.alumifuelpowertech.com/?page_id=1073/

160. http://www.cannabisfn.com/novofuel-gears-power-cannabis-operation-michigan/

161. http://www.biogas2pemfc.eu/

162. http://www.theengineer.co.uk/energy/news/finland-pilots-waste-hydrogen-power-plant/1018756.article#ixzz3KlxekJmT

163. http://www.exeloncorp.com/newsroom/pr_20140729_EXC_Bloom.aspx

164. http://fcel.client.shareholder.com/releasedetail.cfm?ReleaseID=863343

165. http://xlgroup.com/press/xl-munich-and-new-energy-risk-product-for-fuel-cell-portfolio

166. Email contact with Panasonic.

167. http://www.gasworld.com/regions/west-europe/range-extender-win-for-hyway/2004419.article

168. http://www.cfcl.com.au/Assets/Files/20141117%20-%20ASX%20Announcement%20iPower%20draft.pdf

169. http://www.cfcl.com.au/Assets/Files/20140303%20-%20ASX%20Announcement%20-%20Avilos%20order.pdf

170. http://www.cfcl.com.au/Assets/Files/20140630%20-%20Technology%20Update%5b1%5d.pdf

171. http://www.renewableenergyfocus.com/view/40255/ceres-power-working-with-energy-lancaster-to-study-next-generation-solid-oxide-fuel-cell-materials/

172. http://www.cerespower.com/admin/resources/0.7millionfundingaward.pdf

173. http://www.cerespower.com/admin/resources/japan-da-29-oct14-agreed-v3.pdf

174. ttp://www.ballard.com/about-ballard/newsroom/news-releases/news01091401.aspx

175. http://www.relion-inc.com/news.asp#52

176. http://www.actaspa.com/first-repeat-order-from-australian-telco-customer/

177. http://www.actaspa.com/product-sales-and-trading-update/

178. http://www.actaspa.com/acta-power-successfully-delivers-back-up-power-during-blackout/#sthash.NT9S0Ar3.dpuf

179. http://www.heliocentris.com/en/our-company/press/press-releases/new-details/article/bos-digitalfunk-brandenburg-chooses-heliocentris.html

180. http://www.heliocentris.com/en/our-company/press/press-releases/new-details/article/heliocentris-deploys-first-free-cooling-system-in-dus-mobile-network-in-the-middle-east-and.html

181. http://www.heliocentris.com/en/our-company/press/press-releases/new-details/article/heliocentris-uebernimmt-futuree.html

182. http://www.heliocentris.com/en/our-company/press/press-releases/new-details/article/heliocentris-signs-major-distribution-agreement-in-china.html

183. http://www.intelligent-energy.com/about-us/media-room/news/company-news/2014/03/27/intelligent-energy-signs-a-long-term-exclusive-contract-with-microqual-to-power-mobile-telecom-equipment-to-be-mounted-on-existing-transmission-towers

184. http://www.intelligent-energy.com/about-us/media-room/news/company-news/2014/01/14/intelligent-energy-delivers-cost-effective-clean-power-for-ascend-telecom-towers

185. http://www.intelligent-energy.com/about-us/media-room/news/company-news/2014/03/20/hydro-industries-to-provide-water-purification-technology-to-supply-clean-water-across-india

186. http://www.nxtbook.com/nxtbooks/webcom/remote_2015spring/#/10

187. http://www.plugpower.com/news/pressreleases/15-01-05/PLUG_POWER_IDENTIFIES_SOUTHERNLINC_WIRELESS_AS_MULTI-YEAR_RELION_FUEL_CELL_CUSTOMER.aspx

188. http://www.plugpower.com/news/pressreleases/14-12-04/PLUG_POWER_SIGNS_MULTI-YEAR_RELION_FUEL_CELL_CONTRACT_WITH_COMMUNICATIONS_COMPANY_VALUED_AT_20M.aspx

189. http://firstelementenergy.com/dominican-republic-university-installs-fuel-cell/

190. http://library.ustda.gov/tradeleads/april2014/tradelead04072014web.html

191. http://www.boconline.co.uk/en/news-and-media/press_releases/news2014-08-08.html

192. http://www.sfc.com/en/SFC-Energy-launches-new-extreme-temperature-EFOY-ProCabinet-fuel-cell-solution-and-opens-EFOY-service-center-in-Canada

193. http://www.sfc.com/en/New-integrated-remote-control-power-solution-with-EFOY-Pro-fuel-cells-for-oil-%26-gas-applications

194. http://www.sfc.com/en/SFC-Energy%E2%80%99s-environmental-management-system-certified-to-ISO-14001%3A2004

195. http://www.sfc.com/en/EFOY-Pro-fuel-cells-by-SFC-Energy-power-obstruction-lights-of-wind-turbines

196. http://www.sfc.com/en/SFC-Energy-receives-major-Singapore-order-for-EFOY-Pro-fuel-cell-power-solution

197. http://www.rechargenews.com/solar/1383378/Toshiba-to-test-PV-hydrogen-based-emergency-energy-system

198. http://thehill.com/blogs/transportation-report/aviation/197115-court-overturns-ban-on-micro-fuel-cells-on-planes

199. http://www.intelligent-energy.com/about-us/media-room/news/company-news/2014/01/06/intelligent-energy-announces-brookstone-as-us-launch-partner-for-upptm-a-new-category-of-portable-energy-device

200. http://www.intelligent-energy.com/about-us/media-room/news/company-news/2014/11/19/upptm-now-available-at-apple-stores-across-the-uk

201. http://www.intelligent-energy.com/about-us/media-room/news/company-news/2014/07/09/sure-launches-upptm-fuel-cell-technology-from-intelligent-energy

202. http://www.intelligent-energy.com/about-us/media-room/news/company-news/2014/12/11/doddle-joins-upp-cartridge-exchange-point-network

203. http://www.businesswire.com/news/home/20141112005349/en/Upp%E2%84%A2-Fuel-Cell-Power-Solution-Named-2015#.VGS8cjTF_Ns

204. http://neahpower.com/2014/09/neah-shipping-buzzbar-suite-of-products-successfully-completes-ce-certification/

205. http://www.policeone.com/police-products/traffic-enforcement/breathalyzers-dui-enforcement/articles/8056322-New-breathalyzer-with-fuel-cell-precision-decreases-time-risk/

206. http://www.nextechmaterials.com/energy/index.php?option=com_content&view=article&id=47%3A04-nov-2014-nextech-awarded-army-contract-for-sofc-stack-technology&catid=7%3Apress-release&Itemid=18

207. http://news.utcaerospacesystems.com/2014-05-14-Office-of-Naval-Research-selects-UTC-Aerospace-Systems-to-continue-development-of-a-UUV-energy-dense-PES-propulsion-system

208. http://www.ultracell-llc.com/assets/UltraCell_BT_press_release_final_9th_April_2014.pdf

209. http://neahpower.com/2014/10/neah-power-partners-with-silent-falcon-to-integrate-fuel-cells-into-unmanned-aerial-vehicles-uav/

210. http://www.stripes.com/blogs/stripes-central/stripes-central-1.8040/calling-it-a-submarine-doesn-t-float-japan-s-boat-1.297715

211. http://fuelcell.com/httpfuelcell-comp860/

212. http://www.reinforcedplastics.com/view/40814/toray-frp-used-in-toyota-s-new-fuel-cell-vehicle/

213. http://www.binghamton.edu/inside/index.php/inside/story/9053/university-breaks-ground-on-smart-energy-facility/

214. http://www.news.gatech.edu/2014/02/15/solar-induced-hybrid-fuel-cell-produces-electricity-directly-biomass

215. http://msutoday.msu.edu/news/2014/new-fossil-fuel-free-process-makes-biodiesel-sustainable/

216. http://spectrum.ieee.org/energywise/green-tech/fuel-cells/engineers-invent-inks-for-making-3d-printed-fuel-cells

217. http://electroiq.com/blog/2014/10/platinum-meets-its-match-in-quantum-dots-from-coal/

218. http://news.rice.edu/2014/11/03/rice-chemists-gain-edge-in-next-gen-energy-2/

219. http://news.unm.edu/news/unm-jointly-developed-fuel-cells-win-innovation-award

220. http://phys.org/news/2014-11-jet-fueled-electricity-room-temperature-fuel.html#jCp

221. http://www.hydrogencontest.org/2014.asp

222. http://www.technologyreview.com/view/531416/why-coconuts-could-be-the-hydrogen-storage-material-of-the-future/

223. http://media.wix.com/ugd/047f54_a79b28efd8124d9eb08731a3ebccae9c.pdf

224. http://www.scientificcomputing.com/news/2014/09/cheap-hydrogen-fuel-sun-%E2%80%93-without-rare-metals-0

225. http://www.manchester.ac.uk/discover/news/article/?id=13372

U.S. DEPARTMENT OF
ENERGY

Energy Efficiency &
Renewable Energy

For more information, visit: energy.gov/eere

DOE/Publication Number • October 2015