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

Fuel Cell Technologies Market Report 2015

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Authors

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Acknowledgement

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Notice

Cover Image

Hyundai, Toyota and Honda fuel cell vehicles – photo courtesy of Jennifer Gangi

List of Acronyms

ARFVTP	Alternative and Renewable Fuel and Vehicle Technology Program (California)
ARPA-E	Advanced Research Projects Agency – Energy (DOE)
BEV	Battery electric vehicle
CaFCP	California Fuel Cell Partnership
CEC	California Energy Commission
CHP	Combined heat and power
DMFC	Direct methanol fuel cell
DOE	U.S. Department of Energy
EERE	Office of Energy Efficiency and Renewable Energy (DOE)
FCEV	Fuel cell electric vehicle
FCH-JU	Fuel Cells and Hydrogen Joint Undertaking (Europe)
FCTO	Fuel Cell Technologies Office (DOE)
FTA	U.S. Federal Transit Administration
MARAD	U.S. Maritime Administration
MCFC	Molten carbonate fuel cell
m-CHP	Micro-combined heat and power
MEA	Membrane electrode assembly
MoU	Memorandum of Understanding
NETL	National Energy Technology Laboratory
NIST	National Institute of Standards and Technology (Department of Commerce)
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
PGM	Platinum group metals
PIPE	Private investment in public equities
PNNL	Pacific Northwest National Laboratory
PPA	Power purchase agreement

R&D	Research and development
RD&D	Research, development and demonstration
RMFC	Reformed methanol fuel cell
SBIR	Small Business Innovation Research
SOFC	Solid oxide fuel cell
STTR	Small Business Technology Transfer
UAV	Unmanned Aerial Vehicle
VC	Venture capital

Measures

cc	cubic centimeter
ft^2	square feet
kg	kilogram
km	kilometer
kph	kilometers per hour
kW	kilowatt
kWh	kilowatt-hour
l	liter
mi	miles
mph	miles per hour
MW	megawatt
MWh	megawatt-hour
nm^3	normal cubic meter
W	watts
Wh	watt-hour

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Currency Exchange Rates

This report uses U.S. Internal Revenue Service 2015 yearly average exchange rates to convert foreign currencies to U.S. dollars using the following rates. If unspecified, amounts are U.S. dollars.

Table i: 2015 Average Exchange Rates for Converting Foreign Currencies into U.S. Dollars

2015 Average Exchange Rates			
Country	**Currency**	**Symbol**	**Rate**
Euro Zone	Euro	€	0.937
Japan	Yen	¥	125.911
Norway	Kroner	kr	8.392
South Korea	Won	₩	1179.128
Sweden	Krona	kr	8.775
United Kingdom	Pound	£	0.681

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 up to two to three times more efficient than combustion technologies. A fuel cell system can be a truly zero-emission source of electricity when hydrogen is produced from nonpolluting sources.

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 polymer electrolyte membrane (PEM) fuel cells.

The three main markets for fuel cell technology are 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 for off-road vehicles. Portable power applications include fuel cells that are not permanently installed or fuel cells in a portable device.

Of particular note in 2015—on October 8, the inaugural National Hydrogen and Fuel Cell Day officially recognized and celebrated the benefits provided by fuel cell and hydrogen energy technologies. The selected date references to the atomic weight of hydrogen, 1.008. As part of the day's events, the U.S. Senate passed Senate Resolution 217[1] declaring October 8 to be National Hydrogen and Fuel Cell Day and the U.S. House of Representatives introduced House Resolution 468[2] expressing support. Fuel cell and hydrogen energy companies and its industry allies, friends, and champions celebrated National Hydrogen and Fuel Cell Day with a range of activities and announcements in the United States (U.S.) and abroad.

This report is based on publically available information and prior year data may be updated as more accurate information becomes available. Companies were selected because they're publically traded or have readily available published data.

Industry Trends and Data

Shipments

Globally, more than 60,000 fuel cells, totaling over 300 MW, were shipped worldwide in 2015. The number of megawatts (MW) shipped grew substantially—by more than 65% (Figure 1)—over 2014. The increase in total megawatts shipped in 2015 could be attributed to several factors, including growth in both the stationary and transportation sectors.

Industry Milestones in 2015

In 2015, Toyota started selling its fuel cell Mirai and Hyundai continued commercial sales of its fuel cell Tucson (U.S) and ix35 (outside the U.S.). Honda unveiled its FCEV Concept at several 2015 auto shows and anticipates market entry in 2016.

Industrial gas company Linde reached a major milestone—more than 1 million hydrogen fuelings at BMW's plant in Spartanburg, South Carolina. BMW operates more than 350 fuel cell-powered forklifts to service the plant's production and logistics functions, making it the largest single-site fuel cell forklift fleet in the world.

FuelCell Energy announced a significant industry milestone by generating 4 billion kilowatt-hours (kWh) of virtually pollutant-free electricity from its global fleet of Direct FuelCell® (DFC®) power plants since the first commercial installation in 2003.

In just one year after Doosan bought the assets of ClearEdge Power and formed Doosan Fuel Cell America, the Connecticut plant reached full production, with global contracts and nearly 300 employees.

In December, Plug Power reported that it had more than 10,000 fuel cells in operation in material handling equipment, accumulating more than 107 million hours of runtime.

The U.S. Secretary of Commerce presented hydrogen energy company Proton OnSite with the President's "E" Award for Exports, the highest recognition any U.S. entity can receive for making a significant contribution to the expansion of U.S. exports.

In the stationary sector, commercial, next-generation fuel cell systems provide increased power output, and customers are often deploying larger systems. Several utilities in the U.S. and in Korea are installing multi-megawatt, large-scale fuel cell power parks. U.S. fuel cell manufacturers are exporting these fuel cell systems to Korea, accounting for much of the 20% growth in fuel cell shipments (Figure 2). Also contributing to the increase were continued sales of Ene-Farm residential fuel cell systems in Japan.

Fuel cell light duty vehicles were only just beginning to enter the market in 2015 in California, parts of Europe and Japan, but those sales, combined with fuel cell bus deployments and a continued growth in MHE in the U.S., accounts for the growth in the shipments of fuel cells for transportation applications.

North American (Figure 3) companies shipped more than 150 MW worldwide, around 30% more than the shipments from Asia and Europe combined. Aside from large-scale stationary systems, shipments from U.S. manufacturers included units for telecommunications backup systems and material handling, shipped to U.S. customers and exported to Korea, Japan, Europe and range of other countries.

In 2015, Asian shipments more than doubled, from under 50 MW in 2014, to more than 100 MW in 2015. This number reflects the shipments of fuel cell electric vehicles from Toyota and Hyundai, combined with stationary fuel cells from Japan (Ene-Farm) and Korea (POSCO Energy).

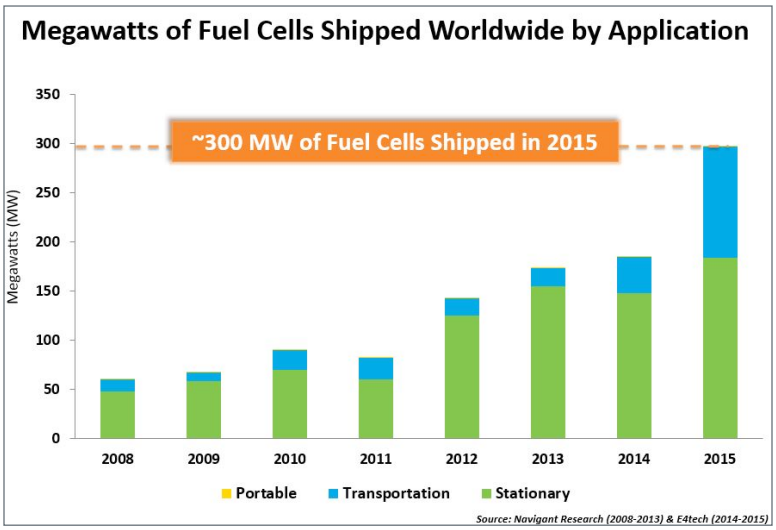

Figure 1. Megawatts of Fuel Cells Shipped in 2015, by Application

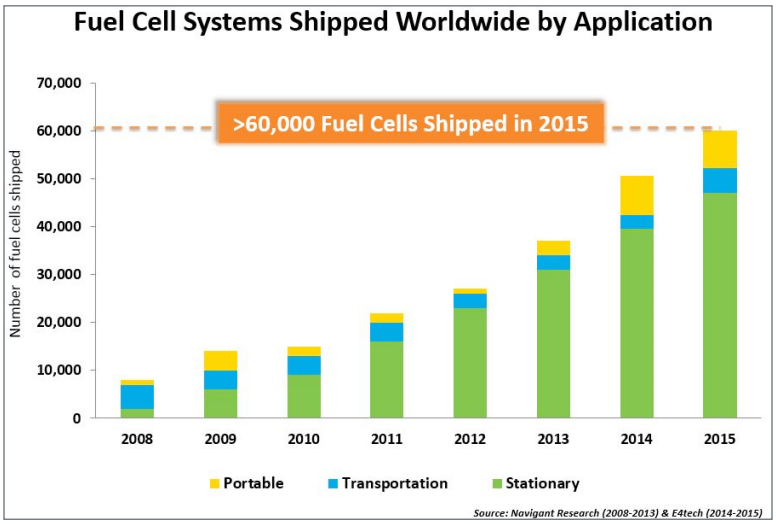

Figure 2. Fuel Cell Systems Shipped Globally, by Application

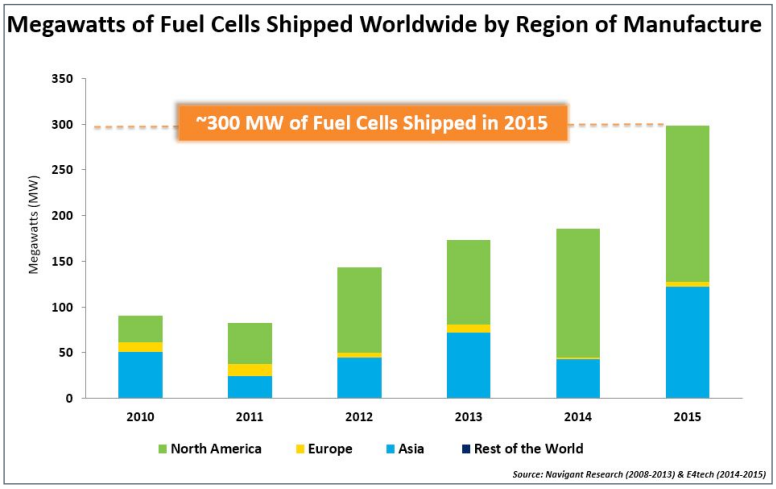

Figure 3. MW of Fuel Cells Shipped Globally, by Region of Manufacture

Business and Financial Activities

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, and industry investment, and provides an overview and analysis of venture capital (VC), private equity, and other investment activity, including equity and stock offerings to raise capital.

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.

Mergers and Acquisitions

In 2015, fuel cell and hydrogen companies expanded their business activities through mergers with other businesses or through acquisitions. These activities are summarized in Table 1.

Additionally, other companies expanded their business operations during 2015:

- Fuel cell developer PowerCell Sweden established a new branch in Germany.[3]
- Italian company hydrogen energy storage company Electro Power Systems opened an office in San Francisco, California.[4]
- Fuel cell manufacturer FuelCell Energy began an expansion that will increase the size of its Connecticut manufacturing facility and its manufacturing capacity.[5]

Table 1. Business Mergers and Acquisitions in 2015

Business Mergers and Acquisitions in 2015			
Company	**Acquired**	**Transaction Value**	**Notes**
Ballard Power Systems Canada	**Protonex Technology Corporation** U.S.	$30 million	Assumed certain of Protonex's debt obligations and transaction costs of approximately $4 million and paid the remaining consideration through the issuance of approximately 11.4 million Ballard shares.
Intelligent Energy U.K.	**Société Bic S.A.** France	$15 million	Acquired portable fuel cell and disposable fuel cartridge assets of Société Bic.
NEL ASA Norway	**H2 Logic** Denmark	NOK300 million ($35.7 million)	Entered into a binding agreement to acquire H2 Logic, a manufacturer of hydrogen fueling stations.
	Rotoboost H2 AS Norway	N/A	Acquired RotoBoost H2 AS, a subsidiary of RotoBoost AS, which holds all assets related to the RotoLyzer®, a compact electrolyzer.
Plug Power U.S.	**HyPulsion** France	$11.47 million	Agreement with Axane, a subsidiary of Air Liquide, to acquire the remaining 80% of HyPulsion, its European joint venture. Plug Power and Air Liquide founded HyPulsion in 2012.
SolidPower GmbH Germany	**Ceramic Fuel Cells Limited GmbH** Australia	N/A	Took over the assets and all employees of Ceramic Fuel Cells Ltd., which filed for insolvency in March 2015.
Toray Japan	**SolviCore** Germany	N/A	Umicore and Solvay sold their respective 50% stakes in joint venture SolviCore, which focuses on membrane electrode assemblies (MEAs) used in fuel cells and PEM electrolysis.
UQM Technologies U.S.	**Roush Performance Products** U.S.	N/A	Acquired fuel cell compressor module business from Roush.

Revenues, Assets, and Research and Development 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 (R&D).

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 operating expenses directly related to the goods sold and services provided, such as selling and marketing activities associated with a sale.

R&D expenditures are shown in Table 3.

Table 4 shows each company's total assets and liabilities.

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	2015		2014		2013	
	Gross Revenue	Cost of Revenue	Gross Revenue	Cost of Revenue	Gross Revenue	Cost of Revenue
Ballard Power Systems (Canada)	56,463	46,489	68,721	58,475	61,251	44,492
FuelCell Energy[1] (U.S.)	163,077	150,301	180,293	166,567	187,658	180,536
Hydrogenics Corp. (Canada)	35,864	29,893	45,548	34,334	42,413	30,352
Plug Power (U.S.)	103,288	113,178	64,230	69,092	26,601	37,849
Ceres Power[2, 3] (U.K.)	324	12,476	1,224	10,128	523	13,255
SFC Energy AG[4] (Germany)	47,310	34,083	53,631	37,970	32,413	22,488

[1] Year ends October 31 [2] Year ends June 30 [3] £ Thousands [4] € Thousands
Source: Annual reports and investor presentations

Total revenues reported for the fuel cell industry as a whole has varied widely—from less than $1 billion to over $3 billion for 2015. A number of factors are involved in the broad range, such as inclusion—to varying degrees—of not only revenue from fuel cell product sales but project funds, government grants, and sales of small educational fuel cell units. Because some companies do not report revenue separately for their fuel cell business units, data is based on readily available information or estimates of product sales revenue. With such an emerging industry, developing consistency in assumptions (such as use of currency exchange rates and items included in the total revenue calculation) is an ongoing process. This annual market report will continue to report approximately $2 billion in revenue for the industry for 2015, roughly consistent with the 2014 value. As more information becomes available and consistency is developed in the compilation of data, prior year data may be adjusted as necessary.

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	**2015**	**2014**	**2013**
Ballard Power Systems (Canada)	16,206	14,294	17,117
FuelCell Energy[1] (U.S.)	17,442	18,240	15,717
Hydrogenics Corp. (Canada)	4,070	3,284	2,566
Plug Power (U.S.)	14,948	6,469	3,121
Ceres Power[2, 3] (U.K.)	9,146	7,138	7,190
SFC Energy AG[4] (Germany)	5,806	4,530	5,433

[1] Period ending October 31 [2] Period ending June 30 [3] £ Thousands [4] € Thousands
Source: Annual reports and investor presentations

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

Total Assets and Liabilities for Select Public Fuel Cell Companies (Thousands US$, unless footnoted)						
Companies	**2015**		**2014**		**2013**	
	Assets	**Liabilities**	**Assets**	**Liabilities**	**Assets**	**Liabilities**
Ballard Power Systems (Canada)	161,331	49,717	127,949	48,715	120,214	49,960
FuelCell Energy[1] (U.S.)	277,231	122,620	280,636	122,330	237,636	190,971
Hydrogenics Corp. (Canada)	59,368	39,120	47,555	32,079	40,070	33,909
Plug Power (U.S.)	209,456	83,567	204,181	44,715	35,356	50,857
Ceres Power[2, 3] (U.K.)	20,685	4,084	10,084	3,726	16,935	4,561
SFC Energy AG[4] (Germany)	35,889	19,131	47,256	19,667	47,649	18,586

[1] Period ending October 31 [2] Period ending June 30 [3] £ Thousands [4] € Thousands
Source: Annual reports and investor presentations

The following discussion provides additional details regarding revenue drivers for select companies in 2015:

- Plug Power's 2015 revenue increased by $39.1 million compared to 2014, driven by increased sales of GenDrive units, more hydrogen infrastructure installations, and increased GenCare service revenues. Total cost of revenue for 2015 increased by $44.1 million compared to 2014.
- Ballard Power Systems' overall revenue in 2015 was down $12.2 million from 2014 due to the termination of Chinese licensing contracts and a lower Canadian dollar exchange rate impacting contracts. Ballard's cost of revenue was down $12 million compared to 2014.

- FuelCell Energy's revenue for 2015 (for the fiscal year ending October 31) decreased by $17.2 million from 2014. The decline in revenue during the period is due to decreased sales of fuel cell kits to Korean partner POSCO and power plant revenue, partly offset by an increase in engineering and construction services. Total cost of revenue for the year decreased by $16.3 million compared to the same period in 2014.
- Hydrogenics' 2015 revenue decreased by $9.6 million from 2014. The company reports that this primarily reflects the impact of the weakening Euro year-over-year against the U.S. dollar, combined with reduced order volume in both Hydrogenics' Power Systems and OnSite Generation groups. Total cost of revenue for 2015 was $4.4 million lower compared to 2014.
- Ceres Power's 2015 revenue declined by £0.9 million ($1.3 million) compared to 2014. The 2014 revenue was higher than other years due to a release of deferred revenue from the ending of a legacy agreement with Bord Gáis Éireann. The 2015 cost of revenue increased by £2.3 million ($3.4 million) compared to 2014.
- SFC's revenue decreased by €6.3 million ($6.7 million) attributed to a weakness in the oil and gas market and the postponement of a large defense project. The cost of revenue decreased by €3.9 million ($4.1 million) compared to 2014.

Investment

Disclosed cumulative global investment in fuel cell companies—VC, private equity (PE), over-the-counter (OTC) and private investment in public equities (PIPE)—totaled $592.7 million for the period 2013 to 2015, declining from $736.2 million for the period 2012 to 2014 and $1.038 billion between 2011 and 2013, as reported in the 2014 and 2013 editions of this report.

Figure 1 provides a breakdown by quarter and by investment type. Global investment increased to $163.6 million in 2015, up slightly from $154.6 million in 2014, but down from $274.5 million in investment in 2013.

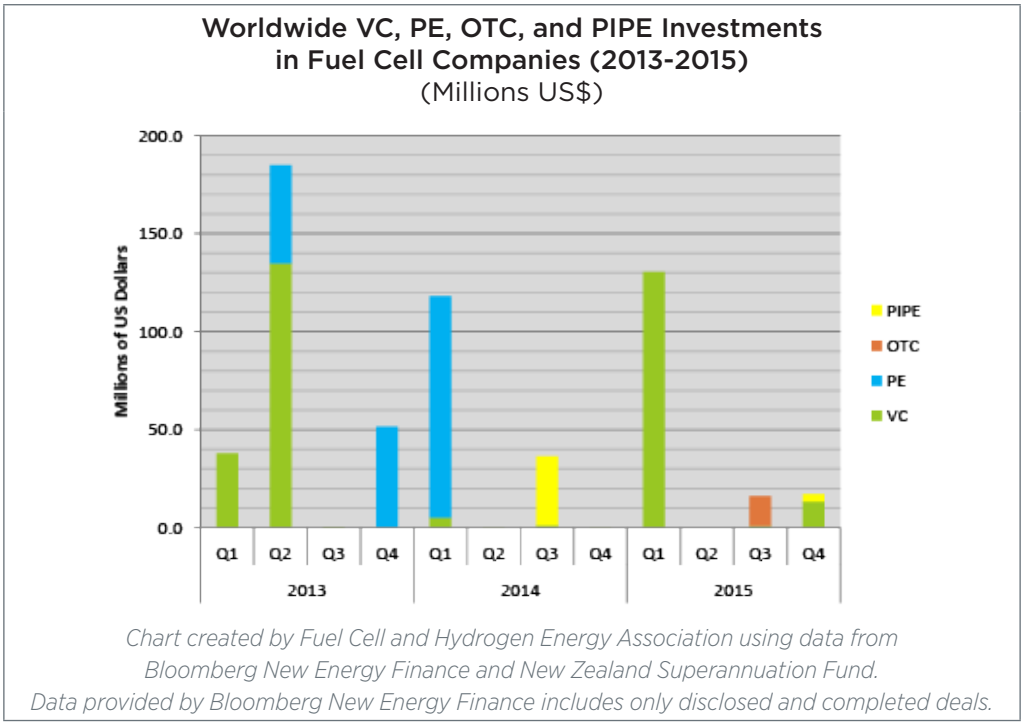

Figure 4. Worldwide Venture Capital, Private Equity, Over-the-Counter, and Private Investment in Public Equities Investments in Fuel Cell Companies (2013-2015)

Figure 2 shows publically disclosed total investment in U.S. fuel cell companies between 2013 and 2015. Investment in U.S. companies totaled $131.1 million in 2015, up from $40.0 million in 2014. The U.S. contribution to global fuel cell investment was 58% between 2013 and 2015, reflecting a slight decrease from the 62% reported for the period 2012 to 2014.

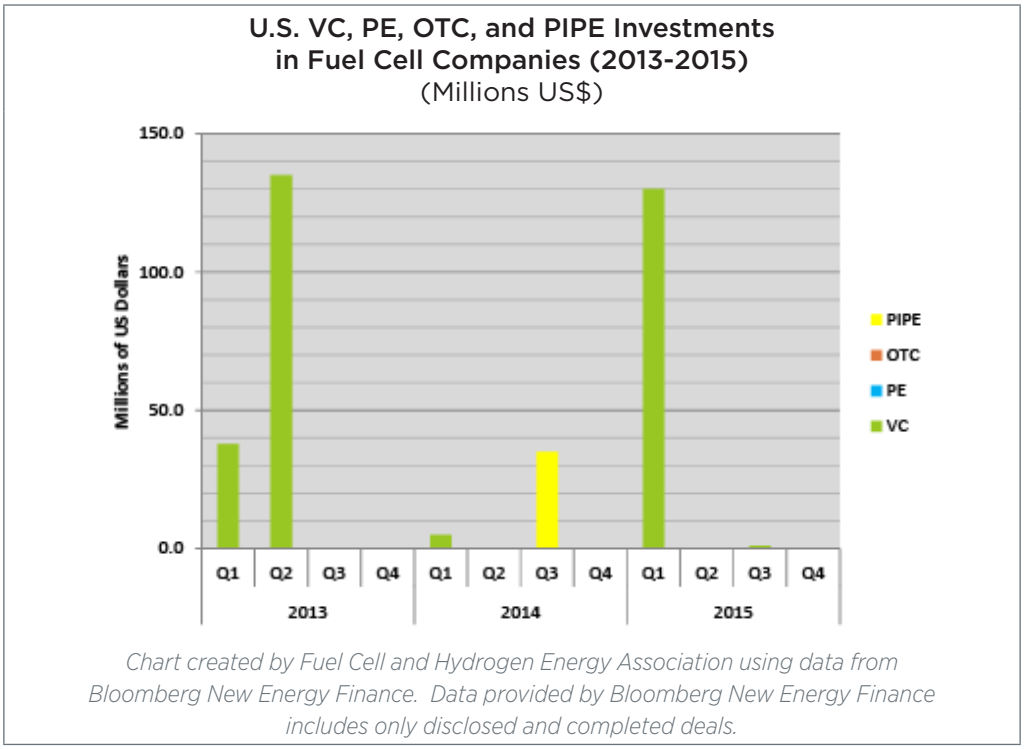

Figure 5. U.S. Venture Capital, Private Equity, Over-the-Counter, and Private Investment in Public Equities Investments in Fuel Cell Companies (2013-2015)

Table 5 shows disclosed VC and PE investments in fuel cell-related companies during 2015, totaling $132.3 million. These investments were made by the following firms:

- Credit Suisse (Switzerland) invested $130 million in U.S. SOFC manufacturer Bloom Energy. Credit Suisse also invested in Bloom in 2013.
- Emerald Technology Ventures (Switzerland) was the lead investor in Elcomax GmbH, a German fuel cell company. Total investment was $13.3 million.
- 350 Investment Partners (U.K.) made several investments in U.K. fuel cell company ACAL Energy, Ltd. These investments include $0.4 million in February and $0.03 million in August.

Table 5. Disclosed Top Venture Capital and Private Equity Investors in Fuel Cells, By Company (2015)

Disclosed Top Venture Capital and Private Equity Investors in Fuel Cells, By Company and By Country (2015)	
Company	**Amount** (million US$)
Credit Suisse AG (Switzerland)	130.0
Emerald Technology Ventures AG (Switzerland)	13.3
350 Investment Partners LLP (U.K.)	0.4
TOTAL	$143.7

Source: Bloomberg New Energy Finance
Disclosed and completed deals only. Figures are in nominal dollars.
All disclosed transaction values are added to the lead investor.

Several additional investments were made in 2015, although the investment amounts were undisclosed:[6]

- 350 Investment Partners made a third investment in Acal Energy, a fuel cell manufacturer, in September.
- In November, Inven Capital (Germany) was the lead investor in Sunfire GmbH, a German high-temperature fuel cell developer.

Additionally, Ardica Technologies, a U.S. micro fuel cell company, raised $1.1 million in September 2015, however the investor(s) were not revealed.

Table 6 lists the top 10 reported global investors in fuel cells between 2000 and 2015, 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. Switzerland moved up to the number two position, with total investment of $299.8 million, followed by the U.K. at $245.1 million. Overall, the Top 10 investor countries have provided 94% of reported global investment in fuel cell companies during the period 2000 through 2015.

Table 6. Top Ten Venture Capital and Private Equity Investors in Fuel Cells, By Company and By Country, Cumulative 1/1/2000-12/31/2015)

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)	266.2	**U.S.**	794.9
Kleiner Perkins Caufield & Byers (U.S.)	105.7	**Switzerland**	299.8
Superannuation Fund (New Zealand)	100.0	**U.K.**	245.1
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)	$882.5	**Subtotal (top 10)**	$1,733.7
		TOTAL (All Companies and Countries)	**$1,840.7**

Source: Bloomberg New Energy Finance and the New Zealand Superannuation Fund
Disclosed and completed deals only. Figures are in nominal dollars. All disclosed transaction values are added to the lead investor.

Raising Capital/Equity Offerings

Aside from private equity from venture capital firms or industry investment, a number of fuel cell and hydrogen 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 $58 million in 2015 by the companies involved (Table 7).

Table 7. Capital and Equity Investment Activity

2015 Capital and Equity Investment Activity			
Company	**Net Proceeds**	**# of Shares**	**Notes**
Ballard Power Systems Canada	$13.6 million	9,343,750	Underwritten public offering.
	$5 million	3,322,479	Strategic equity investment by Nisshinbo Holdings (Japan) made through a private placement subscription.
Electro Power Systems Italy	€14.2 million ($15.2 million)	1,941,177	Initial public offering on Euronext Paris, raising
Hydrogenics Canada	$17.8 million	2,448,385	Underwritten public offering.
ITM Power U.K.	£4.856 million ($7.131 million)	J.C.B 12,853,127	J.C.B. Research and Valebond Consultants Ltd. together acquired strategic shareholding by way of subscription for new ordinary shares.
		Valebond Consultants 3,333,333	
NEL ASA Norway	NOK 67.5million ($8.2 million)	30,000,000	In August, NEL ASA raised funds via a secondary share placement on the Oslo Stock Exchange.
	NOK 69.3 million ($8.9 million)	51,301,852	In June, NEL ASA raised funds via a secondary share placement on the Oslo Stock Exchange.
	NOK 30 million ($3.8million)	148,148,148	In June, NEL ASA raised funds through a rights issue.
	NOK 13 million ($1.7million)	10,000,000	In February, NEL ASA raised funds via a secondary share placement on the Oslo Stock Exchange.

In addition, Toyota created a new security, "Model AA" shares, named after its first passenger car, offering 7.1 million shares in July to raise ¥499.2 billion ($4 billion) for R&D of next generation technologies, including FCEVs. Toyota anticipates that the company will sell up to 150 million Model AA shares, or up to 5% of its outstanding shares.[7]

Government Activities

The federal government provides funding for a range of fuel cell and hydrogen research, development and demonstration (RD&D) activities at U.S. universities and conducted by private industry.

At the state level, numerous policies, both new and updated, supported the development and deployment of fuel cells and hydrogen fueling stations and state agencies made funding awards to fuel cell companies and researchers. Among the most active states are California, Connecticut, and New York.

Federal

2015 was a landmark year for DOE. Title VIII of the Energy Policy Act of 2005 (EPAct), which established a research and development program on technologies relating to the production, purification, distribution, storage, and use of hydrogen energy, fuel cells, and related infrastructure, outlined a goal to demonstrate and commercialize the use of hydrogen for transportation—including a commitment by automakers to offer FCEVs in the consumer market no later than 2015 (Figure 6). DOE has met this goal, with commercial FCEVs from two automakers (Hyundai, Toyota) now available and another set enter the market in 2017 (Honda).

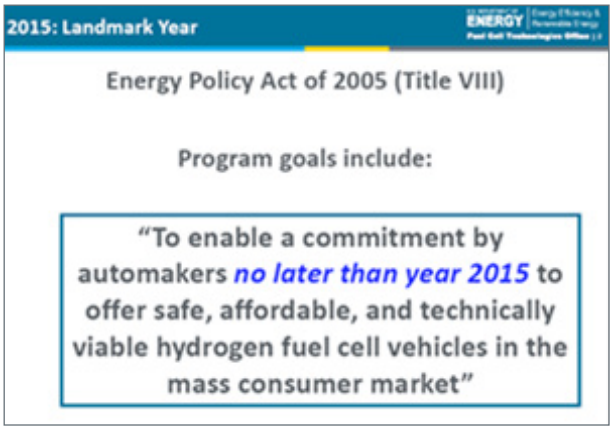

Figure 6. EPACT set specific FCEV program goals for DOE.

In March, President Obama issued an Executive Order, Planning for Federal Sustainability in the Next Decade, laying out sustainability goals for federal agencies. These goals include increasing the proportion of renewably-generated building electric energy and thermal energy at federal facilities, using fuel cells and other alternative technologies where feasible, and supporting the adoption and use of alternative fuel vehicles in federal fleets, including the use of zero emission vehicles, such as FCEVs.[8]

In December, President Obama signed the Transportation bill which includes Section 1413, National electric vehicle charging and hydrogen, propane, and natural gas fueling corridors.[9] The language instructs the Secretary of Transportation to designate alternative fueling corridors for electric, natural gas, and hydrogen vehicles, as well as to identify the near- and long-term need for, and location of, these fueling spots at strategic locations along major national highways.

In January, the U.S. Congress retroactively extended a tax credit of up to $8,000 for the purchase of FCEVs. This credit had expired at the end of 2014.[10]

In Fiscal Year 2015, Congress appropriated approximately $97 million for the U.S. Department of Energy (DOE) Office of Energy Efficiency and Renewable Energy (EERE) Fuel Cell Technologies Office (FCTO) and $30 million for SOFC-related activities within the Office of Fossil Energy. With the Advanced Research Projects Agency – Energy (ARPA-E) and Office of Science funding, the total U.S. DOE funding for hydrogen and fuel cells was approximately $150 million.

DOE's FCTO funds many RD&D projects, via requests for proposals or through programs such as the Small Business Innovation Research and Small Business Technology Transfer (SBIR/STTR), Advanced Hydrogen Storage Systems Awards and Research, Development, and Demonstrations Funding Awards. In addition, FCTO market transformation efforts seek to accelerate the commercialization and promote the early adoption of hydrogen and fuel cell technologies. Through funded project activities such as these, DOE has supported significant advancements in technology development and cost reduction, and has encouraged early markets for fuel cell technologies.

DOE's 2015 federal funding awards are summarized in Tables 8 through 13.

Table 8. 2015 DOE Hydrogen and Fuel Cell Technologies Research, Development, and Demonstrations Solicitation

2015 DOE Hydrogen and Fuel Cell Technologies Research, Development, and Demonstrations Solicitation		
Recipient	**Amount**	**Details**
3M Company St. Paul, Minnesota	$3 million	Highly active, durable, and ultra-low PGM NSTF thin film ORR catalysts and supports
Automated Dynamics Schenectady, New York	$1.5 million	Continuous fiber composite electrofusion couplers
City of Ithaca Ithaca, New York	$0.3 million	Ithaca, NY—An exemplary Climate Community of Excellence for the northeastern U.S.
Electricore, Inc. Valencia, California	$1.3 million	Innovative advanced hydrogen mobile fueler
General Motors LLC Pontiac, Michigan	$3 million	Highly-accessible catalysts for durable high-power performance
Illinois Institute of Technology Chicago, Illinois	$3 million	Corrosion-resistant non-carbon electrocatalyst supports for PEFCs
Ivys, Inc. Waltham, Massachusetts	$2 million	Advancing hydrogen dispenser technology by using innovative intelligent networks
National Renewable Energy Laboratory (NREL) Golden, Colorado	$3 million	Extended surface electrocatalyst development
Oregon State University Corvallis, Oregon	$1.5 million	Novel hybrid microbial electrochemical system for efficient hydrogen generation from biomass
US Hybrid Corporation Torrance, California	$3 million	Northeast demonstration and deployment of FC-e-NV200
TOTAL FUNDING	**$21.6 million**	

Table 9. 2015 DOE Advanced Hydrogen Storage Systems Awards

2015 DOE Advanced Hydrogen Storage Systems Awards		
Recipient	**Amount**	**Details**
Ames Laboratory Ames, Iowa	Up to $1.2 million	Will investigate the development of novel high-capacity silicon-based borohydride/graphene composite hydrogen storage materials produced through mechanochemical processes.
California Institute of Technology Pasadena, California	Up to $1 million	Will develop novel new high-capacity hydrogen sorbents based on high surface area graphene.
Texas A&M University College Station, Texas	Up to $1.2 million	Will develop new low-cost hydrogen sorbents that have high hydrogen sorption capacities that exceed the "Chahine rule" or the expected hydrogen adsorption per unit of surface area.
University of Michigan Ann Arbor, Michigan	Up to $1.2 million	Will develop "best-in-class" hydrogen sorbent materials, with a focus on achieving simultaneously high volumetric and high gravimetric densities.
TOTAL FUNDING	**Up to $4.6 million**	

Table 10. DOE 2015 Fuel Cell Technologies Innovations in Fuel Cell and Hydrogen Fuel Technologies Awards

DOE 2015 Fuel Cell Technologies Innovations in Fuel Cell and Hydrogen Fuel Technologies Awards	
Recipient	**Details**
Advent Technologies, Inc. East Hartford, Connecticut	Will advance liquid-fueled and higher temperature fuel cell technology at the catalyst, gas diffusion electrode, and MEA levels for stationary and auxiliary power unit applications.
Center for Transportation and the Environment Atlanta, Georgia	Will develop 700 bar conformable hydrogen storage systems based on novel pressure vessel designs developed by the founder of High Energy Coil Reservoirs.
Gas Technology Institute Des Plaines, Illinois	Will assess the technical and economic feasibility of thermal compression for cost-effective pressurization of hydrogen to 700 bar for hydrogen fueling stations, as well as demonstrate the concept in a small-scale test system.
Giner, Inc. Newton, Massachusetts	Will develop reversible fuel cells for energy storage applications based on alkaline exchange membrane technology.
Northeastern University Boston, Massachusetts	Will develop non-platinum group metal (PGM), anion poisoning-resistant, oxygen reduction reaction electrocatalysts to replace high platinum loadings in phosphoric acid-based fuel cells for combined heat and power stationary applications.
Proton OnSite Wallingford, Connecticut	Will advance alkaline exchange membrane-based electrolysis technology by developing durable and efficient PGM-free electrolysis cells.
University of California Irvine, California	Will develop a novel photocatalyst particle-based slurry reactor with the potential for low-cost renewable hydrogen production via solar water splitting.

University of Delaware Newark, Delaware	Will develop a new class of anion exchange membranes with high oxidative-stability for use in cerium redox-flow batteries and with potential for use in fuel cell applications.
University of New Mexico Albuquerque, New Mexico	Will address a major challenge for anion exchange membrane fuel cells, which is the absence of a reliable anode catalyst for the hydrogen oxidation reaction.
Versa Power Systems Littleton, Colorado	Will develop hydrogen production technologies using high temperature solid oxide electrolysis capable of operating at high current densities (i.e., high hydrogen production rates) and high efficiencies.
Virginia Tech Blacksburg, Virginia	Will develop biological hydrogen production technology based on an in vitro synthetic biosystem composed of numerous thermoenzymes and biomimetic coenzymes.
TOTAL FUNDING	**The 11 projects will receive up to $10 million**

Table 11. DOE 2015 SBIR/STTR Funding Awards

DOE 2015 SBIR/STTR Funding Awards		
Recipient	**Amount**	**Details**
Phase 1 Release 1 - Fuel Cell and Hydrogen Awards		
pH Matter, LLC Columbus, Ohio	$0.15 million	Will develop a non-precious metal catalyst based on phosphorus-doped carbon-nitrogen materials.
Pneumaticoat Technologies, LLC Stoughton, Massachusetts	$0.15 million	Will significantly improve the efficiency of SOFCs by adopting a low-cost, lean-manufacturing approach to coating conventional raw materials.
Proton OnSite Wallingford, Connecticut	$0.15 million	Will develop a non-precious metal catalyst based on doped cobalt oxides.
Sonata, LLC Bethel, Connecticut	$0.15 million	Investigating how to dramatically increase SOFC reliability by using advanced, cost effective technology.
Southwest Sciences, Inc. Santa Fe, New Mexico	$0.15 million	Will develop a diode laser sensor for detection of typical impurities found in hydrogen fuel at refueling stations.
Structured Materials Industries, Inc. Piscataway, New Jersey	$0.15 million	Developing fluidized bed production of surface functionalized powders for SOFC cathodes.
Sustainable Innovations, LLC East Hartford, Connecticut	$0.15 million	Teaming with the University of Connecticut to develop an innovative multi-channel hydrogen fuel quality monitor to detect multiple hydrogen impurities at refueling stations.
Phase 1 Release 2 - Fuel Cell and Hydrogen Awards		
US Hybrid Corp. Torrance, California	$0.15 million	Will develop and demonstrate PEM fuel cell-battery electric hybrid trucks for medium-duty or heavy-duty bucket trucks with drivetrain-integrated electric power take-off systems.
Mainstream Engineering Corporation Rockledge, Florida	$0.15 million	Will develop a real-time, in-line optical detector for the measurement of fuel cell membrane thickness and defects in membranes.

Phase 2 Release 1 - Fuel Cell and Hydrogen Awards		
Giner, Inc. Newton, Massachusetts	$1 million	Will address the high capital and operating costs of electrolysis by working to commercialize advanced water electrolysis catalysts that are more active and require a significantly less amount of precious metal than those used in conventional PEM electrolyzers.
GVD Corp. Cambridge, Massachusetts	$1 million	Will develop improved plastic and elastomer seals coatings to enable reliable performance of hydrogen systems supporting FCEVs.
Sonata, LLC Bethel, Connecticut	$1 million	Will develop a cost-effective highly robust SOFC interconnect coating process.
Tetramer Technologies, LLC Pendleton, South Carolina	$1 million	Will improve PEM electrolyzer ion exchange membranes to develop a lower cost, higher performance method of commercially generating on-site hydrogen, by electrolyzing water.
Phase 2 Release 2 - Fuel Cell and Hydrogen Awards		
Giner, Inc. Newton, Massachusetts	$1 million	Will develop advanced membrane and electrode components to significantly enhance the durability and performance of fuel cells and electrolyzers.
NexTech Materials, Ltd. Lewis Center, Ohio	$0.84 million	Will develop a low-cost, scalable coating to improve high temperature corrosion resistance of stainless steel, enabling them to replace expensive nickel-based superalloys in fuel cell systems.
Tetramer Technologies LLC Pendleton, South Carolina	$1 million	Will develop new high performance water vapor membranes to improve fuel cell balance-of-plant efficiency and lower cost.
TOTAL FUNDING	**$8.2 million**	

In addition, DOE's Loan Programs Office (LPO) issued guidance for potential applicants on the kinds of Distributed Energy Projects it can support, in the form of supplements to its existing Renewable Energy and Efficient Energy (REEE) Projects and Advanced Fossil Energy Projects solicitations.[11] The LPO also increased the loan guarantees available under these solicitations by up to an additional $1 billion.[12] Fuel cells powered by landfill methane are eligible under the REEE Project solicitation and natural gas-powered fuel cells are eligible under the Advanced Fossil Energy Project solicitation.

Market Transformation Projects

The FCTO and the U.S. Department of Transportation's Maritime Administration (MARAD) co-funded a pilot Maritime Hydrogen Fuel Cell Project that began in Hawaii in August 2015. The project consists of a six-month deployment of a containerized 100-kW Hydrogenics fuel cell at a Young Brothers' facility in the Honolulu Harbor. Once completed, Young Brothers will deploy the unit to power refrigerated containers onboard barges traveling between the Honolulu and Kahului harbors. Sandia National Laboratories is analyzing the operational, safety, and cost performance data from the project to develop a business case for using hydrogen fuel cells at other commercial ports.[13]

The South Carolina Research Authority (SCRA) successfully completed the Landfill Gas-to-Hydrogen project, conducted at BMW's Spartanburg, South Carolina, manufacturing facility.[14] The DOE-supported project explored the economic and technical feasibility of converting landfill gas into hydrogen of sufficient purity to power FCEVs, including material handling equipment.

Other DOE/National Laboratory Activities

In 2015, DOE's ARPA-E issued its third open funding opportunity announcement, OPEN 2015, for up to $125 million. OPEN 2015 supports energy research and development projects from America's top innovators for disruptive new technologies in transportation and stationary applications. Three of the awards support hydrogen projects (Table 12).

Table 12. DOE's Advanced Research Projects Agency-Energy (ARPA-E) OPEN 2015 Program Awards

DOE's ARPA-E OPEN 2015 Program Awards		
Recipient	**Amount**	**Details**
Dioxide Materials, Inc. Boca Raton, Florida	$2 million	Will develop an alkaline water electrolyzer for an improved power-to-gas system, which is used to store energy in the hydrogen chemical bond.
Pajarito Powder, LLC Albuquerque, New Mexico	$2.79 million	Will develop a reversible hydrogen electrode that would enable cost-effective hydrogen production and reversible fuel cells.
Proton Energy Systems Wallingford, Connecticut	$2.5 million	Will develop a hydrogen-iron flow battery that can generate hydrogen for fueling fuel cell vehicles and also store energy on the electric grid.
TOTAL FUNDING	**$7.29 million**	

DOE's National Energy Technology Laboratory (NETL) also awarded funding to 16 research projects in its SOFC Program (Table 13).[15] The grants were awarded with two primary objectives: to design, construct, and field-test a SOFC prototype system, and to support innovations that improve the reliability, robustness, and endurance of SOFC cell and stack technology.

Table 13. 2015 NETL Solid Oxide Fuel Cell Program Awards

2015 NETL SOFC Program Awards		
Recipient	**Amount**	**Details**
Acumentrics Westwood, Massachusetts	$0.2 million	Acumentrics and a collaborator are partnering on a project to support an SOFC industry goal to rate fuel cells at constant operational performance for more than 40,000 hours.
Boston University Boston, Massachusetts	$0.2 million	Will design SOFC anodes that are functional at intermediate temperatures and maintain high power densities at high fuel utilizations.
FuelCell Energy, Inc. Danbury, Connecticut	$2.5 million	FuelCell Energy and its subsidiary will collaborate to develop a low-cost method for manufacturing the anode support layer for SOFCs.
FuelCell Energy, Inc. Danbury, Connecticut	$6 million	FuelCell Energy and its subsidiary will design, fabricate, and test a state-of-the-art, 400 kW, thermally self-sustaining atmospheric-pressure SOFC prototype system.

GE Global Research Niskayuna, New York	$2.5 million	GE Global Research and its partners will develop a thermal-spray, redox stable, ceramic anode that will enable robust, large scale, metal-supported SOFCs.
Georgia Institute of Technology Atlanta, Georgia	$0.2 million	The Georgia Institute of Technology and an industry partner will collaborate to develop innovative, robust and durable cathode materials and structures with high tolerance to common contaminants encountered under realistic operating conditions.
Kettering University Flint, Michigan	$0.16 million	Will improve SOFC cathodes by fabricating and evaluating novel composite materials to enhance the performance, reliability, robustness, and endurance of commercial SOFC systems.
LG Fuel Cell Systems North Canton, Ohio	$2.5 million	Will qualify a material and process solution for selected metallic components of an advanced integrated stack block.
Massachusetts Institute of Technology Cambridge, Massachusetts	$0.2 million	Will develop SOFC electrodes that are tolerant to two of the most prevalent cathode electrode impurities: chromium and silicon.
Montana State University Bozeman, Montana	$0.2 million	Will develop, characterize, and refine electrode preparation methods for SOFCs to mechanically strengthen the anode support structure and facilitate the binding of metal catalysts to ion-conducting ceramic scaffolds.
Redox Power Systems College Park, Maryland	$2.5 million	Will head a partnership to improve the performance and reduce the stack costs of Redox's high power density, natural gas fueled, SOFCs.
Tennessee Technological University Cookeville, Tennessee	$0.2 million	Will develop and demonstrate a cobalt-free nickel iron oxide spinel, a type of hard mineral,—for SOFC cathode-side contact application.
University of California, San Diego La Jolla, California	$2.5 million	Will conduct a three-year project to evaluate and demonstrate an innovative, versatile, and cost-competitive SOFC stack concept suitable for a broad range of power generation applications.
University of Maryland College Park, Maryland	$0.2 million	Will investigate cathode composition and structure under applied voltage/current using real ambient gas contaminants to determine their effects on SOFC cathode oxygen reduction reactions.
University of South Carolina Columbia, South Carolina	$0.2 million	Will develop accelerated test protocols to establish common approaches for determining and projecting the durability of SOFC cathodes under simulated operation conditions.
West Virginia University Morgantown, West Virginia	$0.2 million	Will use an atomic layer deposition coating and thermal treatment process on commercial SOFCs to tailor the nanostructure on anode surfaces.
TOTAL FUNDING	**$20.4 million**	

Sandia National Laboratories signed a cooperative research and development agreement with San Francisco's Red and White Fleet.[16] The SF-BREEZE (San Francisco Bay Renewable Energy Electric vessel with Zero Emissions) project aims to design, build and operate a high-speed fuel cell passenger ferry and hydrogen refueling station. MARAD is funding a feasibility study to examine the technical, regulatory, and economic aspects of the project. The high-speed passenger ferry would use about 1,000 kg of hydrogen per day. To support the ferry and other potential users, the refueling station would have a capacity of 1,500 kg daily, about twice the size of the largest hydrogen refueling station in the world. It would also be the first hydrogen refueling station to simultaneously serve land and marine uses.

Two new DOE EERE research efforts were awarded $8 million:[17]

- The Fuel Cell-Consortium for Performance and Durability (FC-PAD) aims to improve PEM fuel cell performance and increasing durability. The consortium is led by Los Alamos National Laboratory and Lawrence Berkeley National Laboratory (LBNL) and also includes Argonne National Laboratory, Oak Ridge National Laboratory, and NREL.
- The Hydrogen Materials-Advanced Research Consortium (HyMARC) consortium is comprised of Sandia, Lawrence Livermore National Laboratory, and LBNL and is working on safe and cost-effective hydrogen storage.

In February, FCTO launched a free, online national hydrogen safety training resource for emergency responders developed by the Pacific Northwest National Laboratory (PNNL) and the California Fuel Cell Partnership (CaFCP).[18] This is incorporated in DOE's H2Tools.org website, which is a "one stop shop," that brings together and enhances the utility of a variety of tools and web-based content on the safety aspects of hydrogen and fuel cell technologies. The website is intended to help inform those tasked with designing, approving, or using systems and facilities, as well as those responding to incidents. This website has also been translated to Japanese.

Other Federal Agencies

In 2015, the Department of Transportation Federal Transit Administration (FTA) and the Defense Department's Defense Logistics Agency (DLA) funded several transportation-focused activities.

The FTA announced projects selected for funding under the Low and No Emission Vehicle Deployment (LoNo) Program. The LoNo Program provides funding for transit agencies for capital acquisitions and leases of zero emission and low-emission transit buses, including acquisition, construction, and leasing of required supporting facilities such as recharging, refueling, and maintenance facilities. Funded projects include five fuel cell buses for SunLine Transit (California) and five fuel cell buses for the Stark Area Regional Transit Authority (Ohio) (Table 14).[19] In September, FTA announced another round of the LoNo program, with $22.5 million of funding available.[20]

Table 14. 2015 FTA Low and No Emission (LoNo) Program Funding Awards

2015 FTA LoNo Funding Awards for Fuel Cell Buses			
Location	**Project Sponsor**	**Project Description**	**Amount**
Thousand Palms, California	Sunline Transit Agency, in partnership with Southern California Association of Governments	To build and deploy five hybrid electric fuel cell buses with partners BAE Systems, Ballard Power Systems and ElDorado National. This project will allow the agency to offer expanded transit service in the Coachella Valley area of Southern California.	$9.8 million
Canton, Ohio	Stark Area Regional Transit Authority (SARTA)	To purchase and deploy five fuel cell buses from Ballard Power Systems, BAE Systems, and ElDorado National.	$8.9 million
		TOTAL FUNDING	$18.7 million

In addition, DLA awarded a $100,000 SBIR grant to Sierra Energy to further explore the production of hydrogen fuel from waste.[21]

States

Many U.S. state efforts during the year focused on encouraging the growth of FCEVs on state roadways, particularly in California, where two commercial FCEVs are available to customers (Hyundai Tucson Fuel Cell and Toyota Mirai), as well as the development of hydrogen fueling infrastructure. These efforts, in California, Hawaii, Connecticut, Massachusetts and New York, include grant funding for station development and rebates for the purchase of FCEVs.

California, Connecticut, and New York continue to provide support and funding to encourage new distributed generation and microgrids to improve power resiliency to critical sites in the face of powerful storms and other emergencies. Several of these states enacted new policies enabling shared/community ownership of distributed generation projects.

In addition, Hawaii's legislature created a new position, Hydrogen Implementation Coordinator, to promote the expansion of hydrogen-based energy in the state.[22]

The 2015 State Policy Activity Wrap Up: Fuel Cells & Hydrogen report (Jan. 2016) provides a detailed profile of U.S. state policies enacted or introduced in 2015. The State of the States: Fuel Cells in America 2015 report examines state activities to support fuel cell and hydrogen development and deployment.

Applications and Market Assessment

Fuel cells now serve a variety of industries, including transportation, stationary/backup and portable power applications. Users find that fuel cells provide a wide range of benefits including: low-to-zero emissions, high efficiency, reliable and resilient power, fuel flexibility, energy security, durability, scalability, and quiet operation.

Transportation

In addition to light duty (passenger) vehicles, the transportation section covers fuel cell buses, material handling and specialty vehicles.

Light Duty Vehicles

Hyundai and Toyota continued their FCEV roll out in 2015 (Table 15). Although initial FCEV production is limited, it is expected to increase and expand in the next few years as hydrogen fueling infrastructure grows. These efforts are supported by governments worldwide, through financial support for FCEVs and hydrogen stations, vehicle rebates, and other measures to encourage the deployment of zero-emission FCEVs (Table 16).

Table 15. Commercially Available FCEVs—2015 Activities and 2016 Plans

Commercially Available FCEVs – 2015 Activities and 2016 Plans				
Automaker	**Model**	**Image**	**2015 News**	**Specs**
Hyundai	**Tucson Fuel Cell (North America)** **ix35 Fuel Cell (South Korea, Europe)**		The first Tucson Fuel Cell vehicles were delivered to customers in Vancouver, Canada. 70 vehicles delivered in the U.S.through May 2015.	50 miles/gallon gas equivalent (gge) 265 mile range 100 kW stack

Toyota	**Mirai**		Mirai sales were started in California, The U.K., Belgium, Denmark and Germany. 200 vehicles delivered in the U.S. in 2015.	67 miles/gge 312 mile range 114 kW fuel cell stack
Honda	**Clarity Fuel Cell**		Honda unveiled its new FCEV, the Clarity Fuel Cell, at the Tokyo Motor Show.	300) mile range (preliminary range estimate determined by Honda) 100 kW stack

Table 16. Examples of International 2015 Zero Emission, FCEV and Hydrogen Fueling Infrastructure Policies and Activities

Examples of International 2015 Zero-emission, FCEV and Hydrogen Fueling Infrastructure Policies and Activities	
Government	**Action**
Denmark	Extended a FCEV tax exemption until the end of 2018. Denmark applies up to a 180% registration tax and 25% value added tax on the base vehicle price, so a €17.000 ($18,000) gasoline vehicle would reach a total consumer price of more than €50.000 ($53,000). The tax exemption makes FCEVs competitive with gasoline vehicles.
Japan	Will introduce self-service hydrogen filling stations and ease other regulations related to fuel cells.
Tokyo Metropolitan Government (Japan)	Will spend ¥45.2 billion ($359 million) to build 35 hydrogen stations for the 2020 Olympic and Paralympic Games and is in negotiations with Toyota and Honda to put 6,000 FCEVs on its roads. Tokyo also aims develop the Athletes' Village as a "hydrogen town." Tokyo FCEV buyers will be entitled to a subsidy of ¥1 million ($7,942), in addition to ¥2 million ($15,884) provided by the central government. More than 80% of the costs of building hydrogen stations will be subsidized by the Tokyo government, capping the costs for operators at ¥100 million ($794,000).
Kyoto City Government (Japan)	Announced plans to buy three Toyota Mirai FCEVs that will be made available for hourly rental with an online reservation.
South Korea	The Ministry of Trade, Industry and Energy's 2016-2020 plan seeks to have more than 1 million eco-friendly cars on the road by 2020, including FCEVs, and calls for building the necessary infrastructure, including 80 new hydrogen stations. Will offer a ₩27.5 million ($23,322) subsidy to each buyer of an FCEV, which sell for around ₩85 million ($72,000).
Ulsan Metropolitan City Government (South Korea)	Plans to spend ₩45.5 billion ($38.6 million) to increase the number of FCEVs and hydrogen fueling stations.

U.K.	The Office for Low Emission Vehicles launched the Hydrogen Refueling Station Infrastructure Grant Scheme and approved £6.6 million ($9.7 million) in funding over two years for 12 hydrogen infrastructure projects in the U.K. The Department for Transport extended its plug-in car grant, which includes a £4,500 ($6,600) rebate for FCEVs, until March 2018.
Alliance	**Action**
Japan, European Union	Agreed to cooperate in standardizing future regulations in 12 emerging industry fields, including FCEVs, to foster investments and trade.
Germany; the Netherlands; Norway; U.K.; British Columbia and Quebec in Canada; California, Connecticut, Maryland, Massachusetts, New York, Oregon, Rhode Island, and Vermont in the U.S.	Pledged at the COP21 talks in Paris in December to ensure all new vehicles are zero-emissions models by 2050.
Hydrogen Mobility Europe project (H2ME)	Co-funded with €32 million ($34 million) from the Fuel Cells and Hydrogen Joint Undertaking (FCH-JU). The project will deploy 200 FCEVs, 125 fuel cell range-extended electric commercial vans and 29 new stations in 10 countries – Austria, Belgium, Denmark, France, Germany, Iceland, Netherlands, Norway, Sweden and the U.K. – by 2019.

Major Automobile Manufacturers

Toyota

After starting sales of its new FCEV, the Mirai, in Japan in December 2014, the number of orders for the vehicle outpaced Toyota's production. In the first month, Toyota received about 1,500 Mirai orders, with 60% coming from Japanese government offices and corporate fleets.

The first production Toyota Mirai vehicles were introduced in Europe in August, in Bristol, U.K. and Zeebrugge, Belgium.[23] Annual volume is estimated to be between 50-100 cars a year for 2015 and 2016, with a price of €66,000 ($70,400) + value added tax in Germany. In December, two Toyota Mirais were deployed with passenger car service greentomatocars in London, becoming the first hydrogen-fueled private hire cars.

Toyota officially launched the Mirai FCEV in the U.S. in October 2015, initially in California, selling the vehicle, or making it available through monthly lease agreements. Leading up to the launch in the U.S., Toyota ramped up its public outreach campaign, including a series of short videos such as "Turning Point" and "Fueled by Everything" promoting and explaining fuel cells and hydrogen generation.

In November, to meet demand, Toyota announced that it will increase production of the Mirai from the 2015 level of 700 units to approximately 2,000 units in 2016 and approximately 3,000 units in 2017.[24]

At the 2015 Consumer Electronics Show (CES) in January, Toyota announced it would offer 5,800 royalty-free hydrogen and fuel cell patents, including approximately 1,970 patents related to fuel cell stacks, 290 associated with high-pressure hydrogen tanks, 3,350 related to fuel cell system software control and 70 patents related to hydrogen production and supply.[25]

In October, at the Tokyo Auto Show, Toyota unveiled two fuel cell concept cars, the FCV Plus Concept[26] and the LF-FC Flagship Concept, under its Lexus division.[27]

Hyundai

In January, Hyundai joined the Hydrogen Technology in European Cities (HyTEC) consortium and expanded into Oslo, Norway, with plans to deliver eight Hyundai ix35 Fuel Cell vehicles. By the end of 2015, the model was available to buy or lease in 13 European countries, with Spain and Switzerland joining the distribution network. Hyundai delivered five of the ix35 Fuel Cell vehicles to the Paris, France-based electric taxi start-up STEP (Société du Taxi Electrique Parisien) to begin the establishment of a fuel cell electric taxi fleet called "hype" (Hydrogen Powered Electric), serving the Greater Paris area.

Hyundai delivered the first Tucson FCEV to a Canadian customer In February under a 3-year lease.[28] Hyundai Auto Canada Corp. commissioned a two-pronged research study from Ipsos Reid that revealed that 74% of Canadians see a major benefit of FCEVs as not being reliant on highly volatile fuel prices. More significantly, an even higher proportion (82%) thinks that producing no greenhouse gas emissions is a major benefit of FCEVs.

June 2015 marked a year of leasing for the Tucson Fuel Cell in Southern California. In December, the Tucson Fuel Cell set the land speed record for a production hydrogen-powered sport utility vehicle at the Soggy Dry Lake Bed of the California desert, with a top speed of 94.6 miles per hour.[29] Hyundai also began the first tests of a fully-autonomous Tucson Fuel Cell vehicle on public roads in the U.S. having been granted a license by the state of Nevada.[30] Hyundai also continues to work with DOE as part of its Technology Validation program, providing data on vehicle and infrastructure performance.

In Korea, Hyundai and Kia formed a joint fund worth ₩177 billion ($150 million) along with the central government, Gwangju city government and some individual investors to be spent operating a creative economy innovation center in Gwangju.[31] A portion of the funds, ₩15 billion ($13 million), will be used to research hydrogen fuel cell batteries and support related start-up companies. Hyundai and Kia also decided to open 1,000 patents they own to the public to encourage more start-ups entering the hydrogen fuel cell business and related industries.[32]

Honda

Honda debuted its next-generation fuel cell car, the FCV Concept, at the Detroit Auto Show in January.[33]

In October, Honda unveiled its all-new FCEV, the Clarity Fuel Cell, at the Tokyo Motor Show.[34] The 5-seater vehicle has a 33% smaller fuel cell stack compared to the previous version with an output of more than 100 kW and output density of 3.1kW/l, a 60% improvement. The vehicle provides a cruising range of more than 700 km (435 miles). The Clarity Fuel Cell can also utilize Honda's new external power feeding device, the Power Exporter 9000, which enables a maximum AC power output of 9 kW. This allows the Clarity Fuel Cell to provide approximately seven days of electricity for an average household or community in times of a disaster or other events. Honda will begin small-volume lease sales in Japan of the Clarity Fuel Cell in March 2016 with an initial price of ¥7.66 million (about $60,800).[35]

Daimler/Mercedes-Benz

In January, Mercedes-Benz introduced its F015 Luxury in Motion fuel cell-hybrid self-driving concept car at the Consumer Electronics Show.[36] The vehicle features four rotating lounge chairs that allow a face-to-face configuration and an estimated range of about 683 miles.

At the Tokyo Auto Show, Daimler showcased the Vision Tokyo concept which, like the F015 Luxury in Motion, is an autonomous battery fuel cell-hybrid vehicle.[37] The electric hybrid system has a total range of 980 km (609 miles), 190 km (118 miles) from the battery and 790 km (491 miles) on the electricity produced by the fuel cell.

Mercedes-Benz announced that it will launch its first commercially available hydrogen fuel cell model, the GLC F-Cell, at the Frankfurt motor show in 2017, with plans for it to be available to customers in 2018.[38] Daimler also announced that it is modernizing the Mercedes-Benz plant in Stuttgart-Untertürkheim, to become a center of competence for highly efficient engines, including the production of fuel cell systems.[39]

BMW

In June, BMW revealed its i8 fuel cell prototype test vehicle.[40] BMW is concurrently demonstrating a hydrogen fuel cell-powered 5-series GT prototype, which has a range of more than 300 miles.

At the Tokyo Auto Show, BMW AG said that its first commercial FCEV would likely be a larger-sized sedan which would go on the market after 2020, when its hydrogen development partnership ends with Toyota.[41]

General Motors (GM)

In October, GM confirmed its plans to jointly develop commercially viable fuel cell technologies with Honda in the 2020 timeframe.[42]

GM and the U.S. Army Tank Automotive Research, Development & Engineering Center (TARDEC) have been working together to test and evaluate various fuel cell materials and systems.[43]

Volkswagen

In February, Volkswagen (Volkswagen AG and Audi AG) and Ballard Power Systems entered into a Technology Solutions transaction worth approximately $80 million for the transfer of certain automotive-related fuel cell intellectual property and a two-year extension of an engineering services contract.[44] The engineering services agreement involves the design and manufacture of next-generation fuel cell stacks for use in the demonstration car program, MEA, plate and stack component design, and testing and integration.

Additional Automotive Activity

RiverSimple (UK)

Riversimple Engineering has opened a new R&D headquarters in Llandrindod Wells, Wales, where the company is building a two-seater fuel cell production prototype vehicle.[45] The vehicle will be capable of travelling at up to 60 miles per hour, will reach an energy efficiency equivalent to 240 miles per gallon, a range of 300 miles, and will be capable of accelerating from 0-50 miles per hour in eight seconds. The company received a £2 million ($2.9 million) grant from the Welsh Government.[46] If the vehicle achieves certification and goes into production, Riversimple plans to build 5,000 cars each year, which will be leased and reused. Customers will pay a single monthly fee covering the cost of the vehicle, as well as its maintenance, insurance and fuel.

Intelligent Energy (UK)

In March, PEM fuel cell manufacturer Intelligent Energy introduced its new 100-kW automotive fuel cell architecture for next-generation FCEVs.[47] The fuel cell and core technology will be available to vehicle manufacturers through technology licensing programs and joint development agreements.

In September, Intelligent Energy extended its joint development program with one of its existing Asian automotive original equipment manufacturer (OEM) customers.[48] The new contract is worth £6.5 million ($9.5 million) and is expected to last for approximately 2.5 years.

The company was also named the lead in two new programs in 2015:

- In March, Intelligent Energy was chosen to lead a U.K. industry consortium to develop a new class of zero-emission, light commercial vehicles for fleets by integrating fuel cell technology into battery electric vehicles (BEVs).[49] The three-year project will receive a £6.3 million ($9.2 million) grant from the Advanced Propulsion Centre as part of the £12.7 million ($18.6 million) project.
- In October, Intelligent Energy announced it will be leading a pan-European industry working group to develop a 90-kW fuel cell for mass manufacture for automotive applications by 2020. The three-year program, called VolumetriQ, is supported by €5 million ($5.3 million) in funding from Europe's FCH-JU.[50]

Hydrogenics (Canada)

In November, Hydrogenics signed separate supply agreements with several Chinese electric vehicle integrators to bring its fuel cell and fueling station technology to China.[51] The deals signed cover more than 2,000 vehicles over the course of the next three-to-five years.

Buses

Fuel cell bus deployments continued to grow in 2015, with more than 370 fuel cell systems delivered or on order (Table 17). Ballard Power Systems signed several large supply agreements with Chinese companies, and also delivered, or received orders for, fuel cell buses in for deployment in cities in the U.S. and Europe. In addition, Toyota developed and deployed its next-generation fuel cell bus in Japan and three new fuel cell buses were placed in service in Brazil.

DOE's National Renewable Energy Laboratory's Hydrogen and Fuel Cell Bus Evaluations webpage provides more details on status and performance of fuel cell buses.

Table 17. 2015 Announced Fuel Cell Bus Deployments and Orders

2015 Announced Fuel Cell Bus Deployments and Orders			
Fuel Cell Manufacturer	**Location**	**#**	**Details**
Ballard Power Systems Canada	Irvine, California	1	The University of California, Irvine deployed the fifth American Fuel Cell Bus using Ballard's FCvelocity®-HD6 fuel cell module.
	Thousand Palms, California and Canton, Ohio	10	Will supply 10 FCvelocity®-HD6 fuel cell modules to power buses awarded funding under FTA's Low and No Emission Vehicle Deployment Program—5 buses each to SunLine Transit Agency (California) and Stark Area Regional Transit Authority (Ohio).
	Flint, Michigan	1	Flint's Mass Transportation Authority deployed its 2nd fuel cell bus.
	Cities of Rugao and Yunfu, China	33	Signed definitive license and supply agreements with Synergy and Nantong Zehe New Energy Technology Co., Ltd. valued at $10 million, for FCvelocity®-HD7 90-kW net power modules for 33 fuel cell buses.
	Cities of Foshan and Yunfu, China	300	Signed a long-term license and supply agreement with Guangdong Synergy Hydrogen Power Technology Co., Ltd. to provide fuel cells for approximately 300 buses.
	Europe	21	Will deliver the next-generation fuel cell power module, FCvelocity®-HD7, for 21 fuel cell buses under the 3Emotion Program.
	Europe	1	Follow-on order for a FCvelocity®-HD7 power module from Solaris Bus & Coach to be used in a zero-emission bus deployment in Europe.
Marco Polo Brazil	Sao Paulo, Brazil	3	Three new fuel cell buses, built in Brazil, were deployed under the Brazilian Hydrogen Bus Project.
Toyota Japan	Toyota City, Japan	1	Toyota and Hino Motors, Ltd. developed a new Toyota Fuel Cell System-equipped bus that services the Toyota Oiden bus route.
	TOTAL	**371**	

In addition to the deployments and orders, Ballard Power Systems signed a strategic collaboration agreement with Xiamen King Long United Automotive Industry Co., Ltd. (King Long), to design and deploy fuel cell-powered buses, initially in China and eventually in King Long's global network.[52]

Ballard also announced an agreement with Transport for London (TfL) to extend the operation of eight fuel cell buses for five more years. The buses are powered by Ballard's FCvelocity® fuel cell module and have operated for more than 107,000 hours and traveled more than 428,000 miles.[53]

Other 2015 milestones:

- In August, a fuel cell installed in an Alameda-Contra Costa Transit District (AC Transit) bus completed more than 20,000 hours of continuous operation with no stack failures—exceeding all performance and durability expectations, including DOE/DOT targets.[54] AC Transit has operated emission-free fuel cell buses in the San Francisco Bay Area since 2001 and its fleet (12 buses) has cumulatively traveled more than 1,250,000 miles.[55]
- Five fuel cell buses operated by PostBus Switzerland AG reached more than 600,000 miles of travel. The buses were first deployed in 2011 as part of the CHIC (Clean Hydrogen in European Cities) project and are slated to be operated through 2016.[56]

Interest in fuel cells for range extenders also grew, with Polish bus-maker Solaris adding a battery-fuel cell model to its line of Urbino buses. The electric bus uses batteries as the main energy provider to the drive system with the fuel cell acting as a range extender, charging the batteries during operation. The bus is fueled with hydrogen once daily, traveling up to 186 miles per fueling.[57]

Material Handling

In 2015, more new businesses chose fuel cells to power material handling fleets. Many orders were on a larger scale, requesting 100 or more fuel cells units per site. Fuel cell manufacturers making sales in the material handling industry during 2015 included Hydrogenics, Plug Power, and Toyota, with a cumulative total of more than 1,000 fuel cell units deployed or ordered during the year (Table 18).

Forklift deployments began to expand beyond North America, with French and Belgian companies making purchases or conducting trial demonstrations. The Kansai International Airport in Japan announced plans to convert its entire material handling fleet to fuel cells.

Walmart—the top user of fuel cell-powered forklifts, with more than 3,000 fuel cell forklifts operating at almost a dozen North American sites—placed another fuel cell order to expand the existing fuel cell fleet at its Ontario, Canada, warehouse.

Table 18. 2015 Announced Fuel Cell Material Handling Equipment Deployments and Orders

2015 Announced Fuel Cell Material Handling Equipment Deployments and Orders			
Fuel Cell Manufacturer	**Location**	**#**	**Details**
Hydrogenics Canada	**Not specified** U.S.	N/A	Received $2 million in orders from a U.S.-based developer to integrate its forklifts into forklifts for a big box retailer.
Plug Power New York	**Colruyt Group** Halle, Belgium	200	This European supermarket chain will deploy 200 GenDrive fuel cells at its Halle facility. The units will be rolled-out in two phases: 75 in Phase 1 and 125 in Phase 2.
	FreezPak Logistics Carteret, New Jersey	25	25 GenDrive fuel cells will be deployed at a new cold storage distribution center freezer warehouse.
	Dietz & Watson Philadelphia, Pennsylvania	N/A	Will deploy GenDrive fuel cells in its entire fleet of class-2 and class-3 lift trucks in its new warehouse building.
	Home Depot Troy Township, Ohio	177	Will power a mix of class-2 and class-3 lift and reach trucks.
	Federal Express Memphis, Tennessee	15	The FedEx hub at Memphis International Airport deployed 15 hydrogen fuel cell-powered ground support equipment (cargo tugs), becoming the world's first zero-emissions ground support fleet. DOE's FCTO provided a $2.5 million grant with matching cost-share from private sector partners.
	Nike U.S.	N/A	Master sales agreement signed after completing a successful demonstration at one of its distribution centers.
	Prelodis Saint Cry en Val, France	N/A	Shipped and commissioned GenDrive units a new 20,000 sq. ft. retail food warehouse that operates three shifts.
	Uline Pleasant Prairie, Wisconsin	130+	Uline purchased more than 130 GenDrive units for material handling vehicles that will operate at two facilities.
	Walmart Canada Balzac, Ontario, Canada	124	Ordered 124 GenDrive fuel cells for its distribution center. This expansion adds on to the current fleet, which has been operating since 2010 and brings the GenDrive total above 230 units at the site.
Toyota Industries Corp. Japan	**Kansai International Airport** Izumisano, Japan	400	Will replace the airport's entire fleet with fuel cell-powered forklifts.
	FM Logistics Neuville aux Bois, France	10	Operating a mixed fleet of battery-electric forklifts and 10 fuel cell-powered forklifts. After completion of the pilot project, the site's 84 forklifts could be powered by fuel cells.
	TOTAL	**More than 1,082**	

Other Transport

The versatility of fuel cells—especially the scalability, with the ability to deliver power ranging from watts, to kilowatts, or more—makes them a candidate for a wide range of large and small zero-emission motive applications.

There is growing Interest in Europe in using fuel cells as range extenders for light commercial vehicles (LCVs), with two beginning in commercial production, as well as to provide power for e-bikes (electric bicycles). In 2015, the French Post office, La Poste, began small-scale trials of both in daily mail delivery service.

Several major development and supply agreements were announced during the year for the use of customized fuel cells to power trains and trams in Europe and China, to be used on submarines in naval fleets, and by aerospace OEMs moving into serial production of unmanned aerial vehicles (UAVs).

Fuel cell prototypes were also announced, or started in demonstration projects, in several other maritime and aviation applications.

Table 19 summarizes these announcements and projects.

Table 19. 2015 Specialty Vehicle Announcements and Deployments

2015 Specialty Vehicle Announcements and Deployments		
Vehicle Type	**Companies**	**Details**
Light Commercial Vehicles (LCVs)	**Arcola Energy** **ITM Power** U.K. **Symbio FCell** France	The companies signed an agreement to provide an integrated package of zero emission LCVs, on-site fuel and after-sales support for U.K. commercial fleet operators. • The Renault Kangoo ZE-H2 electric van—which offers a range of over 200 miles, more than double the range of the electric-only van with fuel cell range extender from Symbio FCell—began series production. • A similar vehicle, adapted to the Renault Trucks Maxity 4.5 T electric light duty truck is being tested at La Poste (France) and will be commercially available in 2016.
	Intelligent Energy U.K.	Leading a U.K. industry consortium in a 3-year project to integrate fuel cell technology into BEVs, to improve range and reduce refueling time.
Ground Support Equipment	**Plug Power** New York	FedEx and Plug Power deployed the world's first fuel cell-powered airport ground support equipment truck at its Memphis airport facility. Supported by DOE's FCTO, 15 ground support equipment trucks will be demonstrated for a period of two years at the FedEx airport hub location. In addition, FedEx Express is developing a hydrogen fuel cell delivery truck with a range of up to 150 miles per fueling and will test 20 of these trucks at FedEx facilities in Tennessee and California. Plug Power and Smith Electric Vehicles will join FedEx in this project.

Bicycles	**Canyon** Germany	The Eco Speed concept bike uses a fuel cell to drive an electric motor, supplying 500 W of additional power and allowing the bicyclist to ride a high speeds for a longer period of time.
	Cycle Europe **Pragma Industries** **Ventec** France	The French postal service La Poste has started testing 12 Alter fuel cell-powered e-bikes, which were was developed as a joint project of Cycle Europe, Pragma Industries, and Ventec. The companies plan sales of the Alter Bike under the Gitane brand name is in 2016.
	Linde Group Germany	The H2 bike uses a fuel cell to support assisted pedaling with a range of more than 60 miles with a single cylinder of hydrogen that can be refilled in less than 6 minutes. Linde will produce the bike in a limited prototype series.
	Pragma Industries France	Launched the Alpha fuel cell electric bike that can be refilled with hydrogen in 5 minutes and has a range 62 miles. Production will begin with 100 bikes in 2016, and up to 1,000 in 2017.
Trams/Trains	**Hydrogenics** Canada	Hydrogenics signed a 10-year agreement to supply Alstom Transport with at least 200 fuel cell systems for regional commuter trains in Europe.
	Ballard Power Systems Canada	Signed joint agreements to develop and commercialize a fuel cell engine for low floor trams manufactured by CRRC Qingdao Sifang Company, Ltd., with 10 customized FCvelocity® modules to be delivered in 2016. An initial deployment of 8 fuel cell-powered trams is planned by CRRC Sifang and the City of Foshan starting in 2017.
	Ballard Power Systems Canada	Signed an agreement with Tangshan Railway Vehicle Company, Ltd. for development of a new fuel cell module for tram or rail applications, with a goal of powering the initial prototype by 2016.
	Emaar Properties United Arab Emirates **TIG/m** California	Debuted the first of a planned fleet of fuel cell-powered trams for testing along the initial section of a line serving downtown Dubai.
Ships/Boats	**Sunfire** **ThyssenKrupp Marine Systems** Germany	Sunfire supplied ThyssenKrupp Marine System with a 50-kW SOFC that runs on low-sulfur diesel that will deliver between 25—50% of on-board power as part of the Ship-Integrated Fuel Cell project (SchiBZ).
	YC Synergy Taiwan	Deployed a 55-ft. passenger ferry integrated with a YCS fuel cell electric powertrain into daily service in Sun Moon Lake, Taiwan.
Submarines	**Proton OnSite** Connecticut	Received follow-on orders from the Navy for PEM electrolyzer stacks from UTC Aerospace Systems. The orders for 17 cell stacks, to be delivered over the course of several years, will provide oxygen generation for new submarines in the American, British and French Navy fleets.

UAVs	**Horizon Energy Systems** Singapore	Announced development of new 700 Wh/kg solid fuel AEROPAK-S on-demand hydrogen generation technology that can improve the flight endurance of small fuel cell electric drones. Custom versions of the system have been in development with several leading aerospace OEMs, some of which are moving to serial production.
	Horizon Unmanned Systems Singapore	Unveiled HYCOPTER, a fuel cell-powered, multi-rotor UAV that uses its frame structure to store energy in the form of hydrogen instead of air, eliminating energy storage weight. HYCOPTER's fuel cell was designed by sister company Horizon Energy Systems.
	Intelligent Energy U.K.	Announced development of a prototype fuel cell-powered range extender for drones that provide longer flight time and fast refueling.
Aircraft	**Hydrogenics** Canada	Announced its participation in the German H2FLY consortium to develop the world's first zero-emission 4-seater passenger plane. The HY4 aircraft has a PEM fuel cell, an 80-kW electric motor, top speed of about 200 kph (124 mph), and cruising speed of 145 kph (90 mph). The HY4 will make its first test flights in 2016.

Stationary Power

Stationary power covers any application in which the fuel cells are operated at a fixed location for primary power, backup power, or CHP. The stationary sector includes both large-scale (200 kW and higher) and small-scale (up to 200 kW) and a wide range of markets including retail, data centers, residential, telecommunications and many more. This section is organized by large scale, small scale, and backup and remote power.

Large-Scale Stationary Power

The three major U.S. fuel cell manufacturers, Bloom Energy, Doosan Fuel Cell America and FuelCell Energy, sold or installed more than 70 megawatts (MW) of fuel cell systems in 2015 (publicly disclosed). In other parts of the world, there were several other big deployments and projects, several utilizing byproduct hydrogen as a result of chemical processing.

Bloom Energy

In August, Bloom Energy and Constellation, a subsidiary of Exelon Corporation, announced an agreement to develop 40 MW of fuel cell projects for commercial and public sector customers in California, Connecticut, New Jersey and New York.[58] Under the agreement, Constellation will provide equity financing and will own a majority equity interest in Bloom Energy Servers at more than 170 customer sites, including AT&T, Walmart, and the City of Hartford, Connecticut, among others.

Bloom Energy also partnered with Vapor IO to decrease cost and increase the efficiencies of distributed green data centers globally.[59]

Bloom Energy's 2015 publicly announced orders and installations are summarized in Table 20.

Table 20. Bloom Energy 2015 Publicly Disclosed Orders and Installations

Bloom Energy 2015 Publicly Disclosed Orders and Installations		
Customer	**Power**	**Details**
CenturyLink Irvine, California	500 kW	Commissioned in April, the fuel cells are expected to produce nearly 4.4 million kWh of annual electricity and will help power cloud, managed hosting and colocation services housed within the data center.
Comcast Berlin, Connecticut	400 kW	Will provide up to 80% of the facility's total energy load. The facility serves as regional headquarters for five New England states and is the master facility for receiving and processing television signals for distribution on the Comcast network.
Equinix San Jose, California	1 MW	Will provide an estimated 8.3 million kWh of electricity annually, powering a portion of the SV5 data center.
Hyatt Regency Greenwich Old Greenwich, Connecticut	500 kW	Will provide up to 75% of the hotel's energy load, reducing carbon emissions by 40% compared to electricity purchased from the grid.
IKEA Emeryville, California	300 kW	The retail store's fuel cell system is powered by biogas and is combined with a solar energy system to generate a majority of the store's energy onsite.
Johnson & Johnson-Advanced Sterilization Products (ASP) Irvine, California	500 kW	The 500-kW fuel cells installed with uninterruptible power modules provide 25% of the daily energy consumption.
Staples Center Los Angeles, California	500 kW	Provides about 25% of the power required by the sports and entertainment venue each year.
Stop & Shop Mt. Vernon, New York	250 kW	Will generate more than 2 million kWh each year.
Osaka Prefectural Central Wholesale Market Ibaraki City, Japan	1.2 MW	Provides 50% of the buildings' overall electricity needs.
TOTAL	**5.15 MW**	

Doosan Fuel Cell America

In November 2015, Doosan Fuel Cell America announced that with recent deals with Korean utilities, its Korea fleet will grow to 129 fuel cell power plants totaling 50 MW.[60]

Doosan's 2015 publicly announced orders and installations are summarized in Table 21.

Table 21. Doosan Fuel Cell America Publicly Disclosed 2015 Orders and Installations

Doosan Fuel Cell America Publicly Disclosed 2015 Orders and Installations		
Customer	**Power**	**Details**
Amgraph Packaging Baltic, Connecticut	880 kW	Two PureCell® Model 400 power plants will CHP.
California State University, San Marcos San Marcos, California	880 kW	Two fuel cells were installed to help the university adhere to strict sustainability standards and reduce greenhouse gas emissions.
CTTransit Hamden, Connecticut	440 kW	Fuel cell supplies electricity, heat, and hot water to its maintenance and storage facility.
Norco College Norco, California	440 kW	Provides 60% of the campus's average daily requirement for electricity.
Korean South East Power Co. Ltd. (KOSEP) Ansan, South Korea	2.6 MW	Six PureCell® Model 400 fuel cell power plants are located at the KOSEP facility in Ansan, providing energy and heat to the local electric grid and KOSEP customers.
KOSEP Bundang, South Korea	5.6 MW	Will deliver 13 PureCell® Model 400 fuel cells worth ₩28 billion (~$25 million) for KOSEP's combined cycle power plant in Bundang, with multiple 400-kW fuel cells installed on each floor of a two-story structure.
Samsung C&T Corp. and Korea Hydro & Nuclear Power Busan South Korea	30.8 MW	70 fuel cells totaling 30.8 MW for the Busan Green Energy Project.
Korea Western Power and Serveone, an LG affiliated company Incheon, South Korea	5 MW	Eleven PureCell® Model 400 power plants were installed at Korea Western Power's facility to generate electricity for nearly 3,000 homes.
TOTAL	**46.64 MW**	

FuelCell Energy

In September, FuelCell Energy announced that its global fleet of Direct FuelCell® (DFC®) power plants reached significant milestone by generating four billion kWh of electricity since the first commercial installation in 2003.[61]

In 2015, FuelCell Energy received $8.5 million in funding from DOE for two SOFC projects. See Table 13 for more details on amounts and project focus.

FuelCell Energy announced a $30 million project financing facility with PNC Energy Capital, LLC, to provide long term financing for projects that FuelCell Energy is developing under power purchase agreements (PPA).[62] PNC Energy Capital will provide financing through a sale/leaseback structure to select project subsidiaries formed and owned by FuelCell Energy.

FuelCell Energy affiliate FuelCell Energy Solutions, GmbH (FCES) is joining with E.ON Connecting Energies GmbH to offer decentralized CHP solutions with megawatt and multi-megawatt DFC® power plants to its existing and prospective customer base, via a PPA financing or leasing structure.[63]

FuelCell Energy's 2015 publicly announced orders and installations are summarized in Table 22.

Table 22. FuelCell Energy and FuelCell Energy Solutions, GmbH 2015 Publicly Disclosed Orders and Installations

FuelCell Energy and FCES, GmbH 2015 Publicly Disclosed Orders and Installations			
Customer	**Location**	**Power**	**Details**
Alameda County	Dublin, California	1.4 MW	Will install a 1.4-MW fuel cell CHP plant at Santa Rita Jail to replace a smaller FuelCell Energy power plant installed in 2006. The fuel cell plant will meet approximately 60% of the jail's total baseload power demand and 70% of the energy use, while the excess heat will be used for hot water for a range of facility uses.
Riverside Wastewater Quality Control Plant	Riverside, California	1.4 MW	The fuel cell power plant will convert biogas from the wastewater treatment process to power the facility and two electric vehicle charging stations, as well as provide thermal energy for the water treatment process.
Pepperidge Farm	Bloomfield, Connecticut	1.4 MW	Will install a DFC® power plant at its bakery to supplement the existing DFC® fuel cell that was installed at the bakery in 2008.
United Illuminating	Woodbridge, Connecticut	2.2 MW	The United Illuminating Company finalized an agreement with the town of Woodbridge to build a state-of-the-art microgrid connecting the Woodbridge Town hall, Library, Fire House, Police Station, Public Works Facility, Senior Center (which also serves as an emergency center), and Amity Regional High School.
University of Bridgeport	Bridgeport, Connecticut	1.4 MW	Closed a previously announced agreement to sell the fuel cell power plant at the University of Bridgeport to NRG Energy, Inc.
E.ON	Mannheim, Germany	1.4 MW	A FCES fuel cell system is located at FRAITEC's headquarters and production facility.
POSCO Energy	South Korea	33.6 MW	Under a long-term existing contract, FuelCell Energy shipped 2.8 MW (two 1.4 MW kits) a month to POSCO in 2015, totaling 24 units and 33.6 MW.
		5.6 MW	5.6 MW of fuel cell modules were delivered to POSCO Energy.
		8.4 MW	Sale of six fuel cell modules totaling 8.4 MW to POSCO Energy.
TOTAL		**56.8 MW**	

A proposed project from FuelCell Energy and CT Energy & Technology, the Beacon Falls Energy Park, in Beacon Falls, Connecticut, would be a 63.3 MW power park, the world's largest. That project is working its way through the approval process.

Other Companies

In 2015, U.K. fuel cell manufacturer AFC Energy installed 24 fuel cell cartridges at the KORE system build at the Stade facility in Germany.[64] The company also reported that it successfully operated the first 101-cell stack cartridge for its alkaline fuel cell system at an Air Products gas facility in Germany.[65] AFC Energy also signed several agreements in 2015:

- A Memorandum of Understanding (MoU) with Dubai Carbon Centre of Excellence to provide a framework for the assessment and potential deployment of an estimated 300 MW of fuel cell generation capacity in Dubai.[66]

- A Heads of Agreement with DNR Industries Ltd. to jointly fund and develop a business plan for the large-scale deployment of AFC's fuel cells across the Middle East.[67]
- A Project Development Agreement with Samyoung Corporation and Changshin Chemical Co. for the deployment of an initial 50 MW of fuel cell generation capacity in Daesan, South Korea.[68]

Ballard Power Systems signed an agreement to provide a 1-MW ClearGen™ fuel cell distributed generation system for Hydrogène de France that will be deployed at an AkzoNobel sodium chlorate chemical plant in Bordeaux Métropole, France, utilizing hydrogen by-product from the plant's production processes.[69]

Hydrogenics began commercial operations of a 1-MW fuel cell power system owned and operated by the Kolon Hydrogenics joint venture at a Hanwha-Total oil refinery site in Daesan, South Korea.[70] The fuel cell uses surplus hydrogen generated as part of other refinery processes at the site.

Nedstack signed a final contract to deliver a 2-MW PEM fuel cell power plant to Ynnovate Sanzheng Fine Chemicals Co Ltd in Yingkou, Liaoning Province, China.[71] The chemical facility produces hydrogen as a by-product in the chlor-alkali process.

Small-Scale Stationary Power

Small scale fuel cells in this section include residential units and micro-CHP (m-CHP) sales and installations, primarily in Asia and Europe.

In Japan, the Ene-Farm residential fuel cell systems, manufactured by several different companies under same brand name, have been available since 2009, with a total of more than 140,000 systems sold.[72] In 2015, 25,848 Ene-Farm units were sold.

Panasonic showcased a prototype of a hydrogen fuel cell under development[73] and in April, launched its new Ene-Farm fuel cell system in Japan that has a durability of 70,000 hours. The fuel cell sells for ¥1.6 million ($12,700) before tax and installation by Tokyo Gas.

Toshiba opened the Toshiba Group Hydrogen Energy Research & Development Center Tokyo to concentrate on group-wide initiatives and solutions integrating hydrogen-related energy technologies. The Center will install a solid oxide electrolysis cell (SOEC) and use it in combination with solar photovoltaic generation systems, fuel cells and other apparatus to carry out demonstration experiments. The center will also be an exhibition space for hydrogen-related technologies.[74]

Toshiba Corporation began offering its H2One™, a hydrogen-based autonomous energy supply system that combines a battery, an electrolyzer, a hydrogen storage tank and a fuel cell. Since its launch:

- An H2One unit began operation at the Kawasaki Marien public facility and Higashi-Ogishima-Naka Park in Kawasaki.[75]
- Toshiba received an order from Huis Ten Bosch, Co., Ltd., the operator of the Henn na Hotel, a Holland-themed resort in Nagasaki, Kyushu, for an H2One to supply power for its Phase 2 building.[76]
- Toshiba received an order from the City of Yokohama's Port & Harbor Bureau for an H2One to be installed at the Yokohama Cargo Center on Daikoku Futo, an artificial island and pier within the port.[77]

Japanese company FCO Power Inc. announced advancements of its next-generation SOFC stack, the Printed Fuel Cell™ for residential fuel cell systems.[78]

In Europe, Viessmann joined the ene.field residential fuel cell CHP project, which aims to deploy up to 1,000 fuel cells in 11 European countries. As of October 2015, more than 350 units have been installed in eight countries—Italy, Germany, Denmark, France, Australia, Luxembourg, and Switzerland.[79]

Horizon 2020 is providing €4.2 million ($4.5 million) to a five-year DEMOSOFC project to demonstrate solid oxide CHP fuel cell systems utilizing biogas produced from waste water treatment.[80] Project members Convion

and VTT will install three fuel cell modules at the Collegno waste water treatment plant of the Italian Società Metropolitana Acque Torino S.p.A. in Turin. The project has an overall budget of €5.9 million ($6.3 million).

In January, PowerCell Sweden was awarded kr5 million ($570,000) by the Swedish Energy Agency to develop a modular fuel cell system for stationary applications.[81] The company also:

- Signed an agreement in May with H-O Enterprise AB to supply a fuel cell system an energy efficient house in Gothenburg, Sweden, that will also include photovoltaic cells, energy storage, an electrolyzer, and hydrogen tanks.[82]
- Signed a collaboration agreement in November with TeliaSonera to trial the PowerPac diesel fuel cell solution at a base station in Sweden for 12 months using simulated power failures.[83]
- Received a repeating order of its S1 fuel cell stacks from a customer in Taiwan for a 1-kW m-CHP system, designed to use natural gas for the residential market.[84]
- Received orders for its 25-kW S2 next generation fuel cell stack platform from a German and from a French company.[85]

U.S. companies Golden Age Resources and Global Energy Corporation, Inc. entered strategic alliance to focus on developing fuel cell projects in Mexico, Central and South America, and the Caribbean.[86] The companies announced plans for the construction of a 5-kW cogeneration pilot project in Mexico, using biogas, which will lead to a 100-kW cogeneration pilot project in the Yucatan to provide energy from organic waste.[87]

Table 23. Examples of Commercially Available Stationary Fuel Cells 2015—Prime Power and micro-combined heat and power (m-CHP)

Examples of Commercially Available Stationary Fuel Cells 2015 - 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-5700	SOFC	200 kW
	ES-5710	SOFC	250 kW
	UPM-570	SOFC	160 kW
	UPM-571	SOFC	200 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
Hydrogenics (Canada)	MW power plant	PEM	1 MW

Nedstack (the Netherlands)	HP	PEM	2-10 kW (scalable)
	XXL	PEM	2-9.5 kW (scalable)
Panasonic (Japan)	Ene-Farm	PEM	200-750 W
Toshiba (Japan)	Ene-Farm	PEM	250-700 W
	H2One™	PEM	N/A

Backup and Remote Power

Fuel cells are increasingly installed to provide reliable backup power to expand communications networks in rural, rugged and remote areas that may not have an established electrical grid or infrastructure. Markets include telecommunications, rail, energy exploration and more. In 2015, the backup and remote power fuel cell markets continued expanding into India with several companies making substantial sales and deliveries to telecommunications companies there, as well as in other parts of the world. Table 24 gives examples of commercially available backup and remote power fuel cells.

In December, Ballard Power delivered its three-thousandth ElectraGen fuel cell backup power system.[88] The delivery was part of a 100 unit order of ElectraGen™-ME systems by Reliance Jio Infocomm Ltd., an Indian telecommunications company.[89]

Ballard also sold 50 of its ElectraGen™-H2 systems to Aditya Birla the Idea Cellular network in India.[90]

Intelligent Energy announced it will purchase contracts from GTL Limited to supply energy-management services across more than 27,400 telecom towers in India.[91] Essential Energy India, Intelligent Energy's partner intends to transition around 70% of GTL's telecom towers from diesel power to hydrogen fuel cells throughout the contracts' tenure. This transaction is estimated to be worth approximately £1.2 billion ($1.8 billion) over 10 years.

In the U.S., Plug Power entered into a multi-year contract with SouthernLINC Wireless, a wholly-owned subsidiary of Southern Company, for its ReliOn integrated fuel cell solution and GenFuel hydrogen services. SouthernLINC Wireless anticipates deploying fuel cells at as many as 500 new LTE sites.[92]

New products were introduced in other backup and remote power market sectors.

The Green Trade Project Office in Taiwan developed the Eco-Power Station (EPS), an off-the-grid system that incorporates solar, battery and a fuel cell from M-Field.[93] The EPS is a 40 foot by 8 foot shipping container that will serve as an electric-bicycle rental station in Liberty State Park, New Jersey, in March 2016.

Trenergi, a Massachusetts-based fuel cell developer, demonstrated its 1-kW high temperature PEM fuel cell prototype to a group of investors.[94] Trenergi also has developed a 3-kW fuel cell prototype, which has been sold to a major defense contractor for testing.

In May, Acumentrics SOFC Corporation reached a milestone, delivering more than 250 of its RP™ solid oxide propane and natural gas fuel cell generators to more than three dozen customers in the U.S., Canada, and Mexico.[95] In October, Acumentrics updated that number to more than 300.[96] The company also added Sirius Integrator as the North American reseller of its RP™ line.[97]

Several other companies also announced new collaborations and partners:

- Altergy Systems added Shields Environmental as a new distributor partner to support overall company growth.[98]
- Horizon Fuel Cell Technologies appointed Innoverde Pte Ltd, as its distributor and system integrator in South East Asia.[99]

- Cascadiant Pte. Ltd. expanded its partnership with Indonesia's agency for the Assessment and Application of Technology and has launched a second research facility in the new Baron Jogyakarta Technopark.[100] Cascadiant deployed a methanol fuel cell and will integrate a wind turbine.
- Proton Power Systems signed a reseller deal with German state-backed rail company Deutsche Bahn (DB) to sell and install Proton's containerized fuel cell systems as uninterruptible power supply applications to parts of the DB group and external third party customers.[101]
- German fuel cell manufacturer SFC Energy is partnering with Fisheries Supply Company, Seattle, Washington, to serve as a new marine distributor for EFOY COMFORT fuel cells in the United States.[102]
- SFC Energy also signed a new partner agreement with Toyota Tsusho Corporation to become an official representative of SFC in Japan. A first order of EFOY Pro fuel cells has already been shipped for sale by Toyota Tsusho in Japan.[103]

SFC Energy also reported other activities in 2015:

- ZephIR Lidar, Ledbury, U.K., is now offering SFC Energy's EFOY Pro 2400 fuel cell within its "ZephIR Power" remote sensing system for the wind industry. With the addition of the EFOY Pro, the system is now capable of up to 12 months of autonomous operation.[104]
- After two years of field tests, SFC integrated its EFOY Pro fuel cell into the autonomous energy system САЭ-110 developed by LLC Gazprom Georesurs to supply power to off-grid gas applications operated by Gazprom in Russia.[105]
- SFC received a follow up order for equipping another 306 Volkswagen T5 transporters with EFOY Pro fuel cells. The Federal Office for Goods Transport uses the vehicles for toll inspection purposes all across Germany.[106]
- SFC's company PBF Group B.V. received a €3.16 million order ($3.37 million) from an international security systems company for the delivery of premium power supply solutions for public address and professional audio systems used at airports, railway stations, and event locations in Asia and Europe.[107]
- SFC received an order with a total value of more than €700,000 ($747,000) from an international defense force for the delivery of its JENNY portable fuel cells for use by soldiers in multi-day missions.[108]
- SFC received an order worth approximately €1.3 million ($1.4 million) from German Bundeswehr for fuel cells to power devices on military vehicles and for soldiers in the field.[109]
- SFC was awarded an initial production order valued at €1.2 million ($1.3 million) by an international defense force for the shipment of a next generation fuel cell system for defense applications.[110]

Table 24. Examples of Commercially Available Backup and Remote Power Fuel Cells 2015

Examples of Commercially Available Backup and Remote Power Fuel Cells 2015			
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	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	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
	MFC Mini	DMFC	50 W
Hydrogenics Canada	HyPM XR Power Modules	PEM	4.5 kW-12.6 kW
	HyPM Rack	PEM	2-200 kW
Intelligent Energy U.K.	Air-cooled	PEM	5 kW
Nedstack the Netherlands	HP	PEM	2-10 kW (scalable)
	XXL	PEM	2-9.5 kW (scalable)
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

Spotlight: Fuel Cells in Africa

With two out of three people in Sub-Saharan Africa lacking access to electricity,[111] and unreliability issues where grids do exist,[112] there is growing interest in distributed (onsite) power generation, including the use of fuel cells. 2015 found several fuel cell manufacturers entered into collaborations with African entities, both government and private sector, and announced plans for fuel cell installations and deployments.

In 2015, Atlanta-based fuel cell provider Dominovas Energy entered into business arrangements with several additional African entities to generate power using the company's proprietary RUBICON™ SOFC system. These arrangements are highlighted in Table 25.

Table 25. 2015 Dominovas Energy Agreements to Supply Fuel Cell Power Generation

2015 Dominovas Energy Agreements to Supply Fuel Cell Power Generation		
Party	**Country**	**Details**
Somico Mine	Democratic Republic of the Congo (DRC)	Multi-year PPA to provide 3 MW of fuel cells to the Somico Mine in the DRC's Sankuru/Lusambo region. This deal is valued at more than $107 million.
City of David	DRC	A 3-MW, multi-year PPA to provide electricity using its RUBICON™ SOFC system to the City of David, which will include 3,000 homes, a hospital, health clinics, schools, malls, parks, food markets, sports centers, police stations, and waste treatment facilities across 8,000 hectares. This deal is valued at more than $100 million.
South Kivu Province	DRC	Guaranteed 200-MW, multi-year PPA to provide electricity to the South Kivu Province, in the DRC, via its RUBICON™ SOFC system.
Ministry of Petroleum	Angola	Authorized by the Angolan Ministry of Petroleum to provide electricity to companies in the oil and gas industry, using its RUBICON™ SOFC fuel cell technology.

Dominovas was also named a private sector partner to President Barack Obama's Power Africa Initiative, a multi-stakeholder partnership comprised of private sector participants, the U.S. government and governments of several African countries.[113]

Another fuel cell manufacturer, PowerCell Sweden, signed a Letter of Intent with energy services company Mitochondria Energy Co. Ltd. to collaborate on the development diesel-fueled fuel cell power solutions for the African market.

South Africa

South Africa, as the world's main producer of platinum—which is used as a catalyst in PEM fuel cells for FCEVs and other fuel cell applications – sees the supply of PGMs to fuel cell markets as a potential leading industry. The country aims to supply 25 percent of global PGM-based catalyst demand by 2020.[114] South Africa's Department of Science and Technology's (DST) National Hydrogen and Fuel Cell Technologies Flagship Project, also known as Hydrogen South Africa or HySA, is also pioneering the production and usage of renewable hydrogen in South Africa for fuel cell and energy storage applications. Several fuel cell projects were announced in 2015 and are highlighted in Table 26.

Table 26. 2015 Fuel Cell Deployments in South Africa

2015 Fuel Cell Deployments in South Africa	
Partners	**Details**
DST Anglo American Platinum, Air Products	Deployed three 5-kW hydrogen fuel cell systems to provide backup power for three schools in the Cofimvaba area of the Eastern Cape, providing power for lights, staff computers and tablet devices as part of the Technology for Rural Education Development initiative. Hydrogen gas cylinders were refilled once a month.
DST, City of Johannesburg, Air Products South Africa, Clean Energy Investments	Deployed a fuel cell at the Windsor East Clinic in Randburg, to provide backup power during periods of load-shedding. The fuel cell ensured an uninterrupted power supply for both the vaccine refrigerators and the air conditioner unit in the clinic's pharmacy.

South African mining company Impala Platinum (Implats) announced it will install a PAFC system from Japan's Fuji Electric in early 2016. The system will supply an initial 1.8 MW of power in two tranches, as well as by-product heat that will be integrated into the operation. The fuel cells will utilize excess hydrogen piped in to the facility for the metal reduction process. In the second phase of the project, a fuel cell system will be installed producing up to 22 MW of power, operating on natural gas and hydrogen. This system will enable Implats' refinery to operate independent of South Africa's national electricity grid.[115]

Additionally, U.S. manufacturer Neah Power Systems signed a MoU with a large South Africa-based entity to license its technology, which includes Neah's PowerChip® fuel cell technology, the Formira HOD® (Hydrogen on Demand) technology, and BuzzBar technology (a hand-held lithium-ion charger that can be recharged using a wall outlet, solar panel, or fuel cells).

Micro Fuel Cells/Portable Applications

As mentioned in the Spotlight: Fuel Cells and Africa section, Neah Power Systems, Inc. signed a licensing agreement with a South African company for its micro fuel cell technology. In addition, there were other advancements and product launches in the micro fuel cell and fuel cell battery charger market sector.

Intelligent Energy entered an agreement with a smartphone OEM to create a tailored development and integration program for a specific application.[116] The company also demonstrated a working iPhone 6 prototype containing both a rechargeable battery and its own patented fuel cell technology. For the commercial launch, Intelligent Energy is developing a disposable cartridge that contains enough hydrogen-releasing powder for a week of normal use without recharging.[117]

Apple was granted a patent from the U.S. Patent and Trademark Office for an external fuel cell system with a removable fuel module designed to power mobile devices.[118]

In February, myFC won the "Technology Provider of the Year" Award at the Swedish Telecom Awards.[119] Also that month, the company unveiled its new fuel cell charger, JAQ, at the Mobile World Congress. The JAQ uses a slimline card, consisting of water and salt to charge mobile phones and tablets.[120] Since the launch, myFC has:

- Signed a North American distribution agreement with Mobileistic. The JAQ will launch in North America at the Consumer Electronics Show (CES) in Las Vegas, in January 2016.[121]
- Joined with ABB to utilize ABB's new YuMi robot technology to make production tests and the assembly of the PowerCards for the myFC JAQ charger. With this collaboration, myFC will build their first factory in Sweden.[122]
- Won the German Design Award in the Excellent Product Design segment Energy category for the JAQ.[123]

German fuel cell manufacturer eZelleron, Inc. raised $1.6 million via a Kickstarter campaign to help bring its butane-powered "kraftwerk" fuel cell-powered cell phone charger to market.[124] The charger's single USB port puts out 2 watts of continuous power, with a peak of 10 W. eZelleron has subsidiaries located in Florida and Delaware.

Two portable power fuel cell manufacturers made strides in the military market:

- UltraCell LLC announced the first serial production order from an international military customer for portable power systems based on its XX55™ reformed methanol fuel cell.[125]
- Ardica Technologies signed a new Technology Solutions contract with Ballard Power Systems for the next phase in the development of a wearable PEM fuel cell power system for military use.[126] The contract focuses on cost reduction and the development of additional manufacturing capabilities.

Hydrogen

This section reviews hydrogen station, hydrogen generation and supply, and hydrogen energy storage and power-to-gas announcements during 2015.

Hydrogen Fueling Stations

The number of hydrogen station openings has grown worldwide, with 54 new hydrogen stations opened in 2015.[127] The majority, 48, are publicly accessible, with the others used either for fleet customers or for bus fueling. Japan led the way with 28 new stations, Europe had 19, and 7 stations were opened in the U.S.—6 in California and 1 in Colorado at NREL. Plans were also announced in 2015 for 104 more hydrogen stations: 35 in the U.S., 5 in Japan, and 64 in Europe, with 34 of those to be located in Germany. See Table 27 for examples of hydrogen stations opened or announced during 2015 and Table 28 for California hydrogen station funding awards. Table 29 provides examples of commercial hydrogen refueling stations that are available today.

Table 27. Examples of Announced Hydrogen Stations Plans, Upgrades and Openings 2015

Examples of Announced Hydrogen Station Plans, Upgrades and Openings 2015		
Supplier	**Location**	**Details**
Abengoa	Seville, Spain	Station located at Abengoa's Torrecuéllar Industrial and Logistics Center. Produces hydrogen onsite by electrolysis using solar photovoltaics.
Air Liquide	Zaventem, Belgium	Public fueling station will be located on Toyota land adjacent to the R&D Technical and Training Centers of Toyota Motor Europe. Will open mid-2016.
	Grenoble, France	Will open in 2016.
	Paris, France	For COP21 (attended by representatives of more than 170 countries) Air Liquide installed the first hydrogen charging station in Paris, in partnership with the start-up STEP (Société du Taxi Electrique Parisien) and with the support of Paris City Hall. This station enables the deployment of "hype", a fleet of electric taxis powered by hydrogen.
	Sassenage, France	Located at an Air Liquide facility that will serve users such as La Poste, France's postal service, and three Kangoo ZE-H2 vehicles.
	Saint-Lô, France	First local authority with a hydrogen station. Serves the community's 10 FCEVs. Will also fuel buses and 30 vehicles from partnering communities.
	Multiple sites, Japan	The first public-use filling stations for FCEVs are located in the central Nagoya area and in Toyota City.
	Saga City, Japan	Will open a new public hydrogen fueling station.
Air Products	Diamond Bar, California	South Coast Air Quality Management District public hydrogen station, replaces one installed in 2004. Low- and high-pressure fueling; 100 kg/day capacity; capable of fueling 20-25 cars/day.
	Multiple sites, California	Los Angeles, Santa Monica, and Irvine stations were opened using SmartFuel 700 bar fueling technology and an advanced retail hydrogen fuel dispenser.
	Golden, Colorado	700-bar fueling using a SmartFuel fueling system is located at NREL.
	Sydney, Australia	Located at Hyundai Motor Company's offices. Will initially be used to fuel a Hyundai ix35 FCEV, the first FCEV to be imported into Australia.
	Delhi, India	India's first solar-powered renewable fueling station. Part of a mass public transport bus fueling and vehicle demonstration program.
	London, U.K.	First public hydrogen filling station at a supermarket, located at Sainsbury's Hendon store in North London.
	Multiple sites, U.K.	Department for Transport (DfT) funding award for upgrades to existing Hatton Cross and Hendon stations and upgrade to a mobile station.

Fuel Cell Systems, Ltd.	Southern England	DfT awarded funds for a new mobile hydrogen station in the southern U.K., covering integration, supply and operation of a hydrogen refueler.
H2Logic	Multiple sites, Denmark	Energy and industrial gases suppliers OK A.m.b.a., and Strandmøllen A/S will establish up to five Danish hydrogen fuelling stations in collaboration with H2 Logic, operated by a joint-venture company, Danish Hydrogen Fuel A/S.
	Hamburg, Germany	Shell Deutschland Oil GmbH opened a new station using H2 Logic's H2Station® technology.
	Unspecified, Germany	Will supply a H2Station® to H2 MOBILITY Deutschland with an option for multiple repeat orders. Will be installed in a north German city in 2016.
Honda UK	Swindon, U.K.	Awarded funding from DfT for an upgrade to an existing station.
Hydrogenics	Aberdeen, Scotland	Supplied hydrogen fueling station and three electrolyzers producing up to 400 kg of hydrogen/day for 10 fuel cell buses.
HYOP	Oslo, Norway	HYOP hydrogen station opened at Oslo airport to fuel FCEV used for airport patrols.
ITM Power	Riverside, California	Station opened less than 11 weeks from local permit issuance. Hydrogen produced by electrolysis.
	Multiple sites, U.K.	Awarded funding by TfL for two new hydrogen refueling stations in Brentford and Croydon, and for four upgrades to Sheffield and London stations.
	Unspecified sites, U.K.	Signed a partnership agreement with Shell for the delivery of three hydrogen refueling stations for Shell retail forecourts.
	Rotherham, U.K.	Launched its first public hydrogen station near the M1 motorway. Facility was upgraded, features a wind turbine powering an electrolyzer, hydrogen storage/ dispensing and fuel cell supplying backup power to nearby buildings.
	Rainham, U.K.	Public hydrogen station in East London, opening 2016, located at The Centre for Engineering and Manufacturing.
Iwatani	Shunan City, Japan	Commercial hydrogen station to be located at a wholesale market. Both 35 and 70MPa dispensers to refuel forklifts at the market and autos. Hydrogen pipelines from the station will supply a planned fuel cell at the market.

The Linde Group	San Juan Capistrano, California	California's second retail hydrogen station. Located at San Juan Capistrano Gas and Auto Services.
	West Sacramento, California	California's 10th hydrogen station and the first in Northern California that is part of an existing fuel station, owned by Ramos Oil. Open 24/7, the station can fuel up to 70 FCEVs daily.
	Innsbruck, Austria	Opened by Linde and OMV, is Austria's second public hydrogen station, bridging the existing hydrogen hubs in Munich, Germany and Bolzano, Italy.
	Fellbach, Germany	Opened by Daimler, Linde and TOTAL, the hydrogen station is the fifth in Baden-Wuerttemberg. Offers 700 bar fueling.
	Geiselwind, Germany	Germany's first highway hydrogen pump at a TOTAL station between Würzburg and Nuremberg that links Frankfurt/Main, Stuttgart, Munich.
	Munich, Germany	TOTAL Multi-Energy fueling station in Detmoldstrasse, Munich commissioned by TOTAL and BMW. Offers 300 and 700 bar fueling at separate pumps.
	Stockholm, Sweden	Stockholm's first, and the country's largest, hydrogen station. Located near the Stockholm airport. Has a capacity of 180 fuelings daily at 700 bars.
McPhy Energy	Lyon, France	Awarded its first project in France to equip a station to be built in Lyon for GNVert, the sustainable mobility subsidiary of Engie Group.
	Paris, France	Paris has selected the Idex-McPhy Energy team to install and manage a hydrogen refueling station to be located in Ivry-sur-Seine.
	Sarreguemines, France	Planned start-up in the second half of 2016.
	Valence, France	Awarded the call for tender by the Valence Romans Sud Rhône-Alpes intercommunity authority for its first hydrogen refueling station.
NEL ASA	Multiple sites, Norway	In a joint-venture with Uno-X Gruppen AS, will build at least 20 hydrogen stations, allowing FCEVs to operate between all the major Norwegian cities.
Nippon Mobile Hydrogen Station Services	Tokyo, Japan	Opened its first mobile station in March in Tokyo's Chiyoda Ward. The station is available on weekdays from 9AM—1PM and can carry enough fuel for about five vehicles.
Oy Woikoski	Gothenburg, Sweden	Gothenburg's first permanent hydrogen refueling station, located next to the facility of fuel cell manufacturer PowerCell Sweden.
PGE	Multiple sites, Poland	Will build hydrogen stations along Poland's main routes, including two in Warsaw and Poznań, Tri-city, Białystok, Kraków, Katowice, Wrocław and Łódź.
Shell	Multiple sites, Germany	Will install a nationwide network of hydrogen pumps at retail sites from 2016 under agreement with H2 Mobility Germany and the transport minister.
University of South Wales	Port Talbot, Wales	Received funding from DfT for an upgrade to an existing hydrogen station.

In the U.S., the California Energy Commission's (CEC) Alternative and Renewable Fuel and Vehicle Technology Program (ARFVTP) awarded $10.74 million in funding for 38 hydrogen stations.[128] See Table 28 for site and funding details.

Table 28. California Energy Commission's 2015 ARFVTP Hydrogen Station Funding Awards

CEC 2015 ARFVTP Hydrogen Station Funding Awards		
Supplier	**Total Award**	**Station Location**
June 2015—$2.7 million		
Air Products & Chemicals, Inc.	$1.5 million	Woodland Hills, Santa Monica, Los Angeles (2), Irvine
Air Liquide Industrial US LP	$300,000	Anaheim
H2 Frontier, Inc.	$300,000	Chino
Linde LLC	$300,000	San Juan Capistrano
FirstElement Fuel Inc.	$300,000	San Francisco
August 2015—$3.9 million		
HTEC Hydrogen Technology & Energy Corporation	$300,000	Woodside
ITM Power Inc.	$300,000	Riverside
Ontario CNG Station Inc.	$300,000	Ontario
HyGen Industries, LLC	$600,000	Rohnert Park, Orange
FirstElement Fuel Inc.	$2.4 million	San Jose, Hayward, Los Angeles (2), Long Beach, Coalinga, Truckee, Santa Barbara
September 2015—$1.5 million		
FirstElement Fuel Inc.	$900,000	Costa Mesa, Saratoga, La Canada-Flintridge
Air Products & Chemicals, Inc.	$300,000	Irvine
H2 Frontier, Inc.	$300,000	Gardena
December 2015—$2.64 million		
Air Products & Chemicals, Inc.	$480,000	Lawndale, Redondo Beach
Air Liquide International US LP	$240,000	Palo Alto
HyGen Industries, LLC	$240,000	Pacific Palisades
Linde LLC	$480,000	Foster City, Mountain View
FirstElement Fuel Inc.	$1.2 million	Campbell, Mill Valley, South Pasadena, San Diego, Lake Forest

In support of the efforts by the California Air Resources Board (ARB) to incorporate automobile OEM input into its June 2015 AB-8 report, the CaFCP OEM Advisory Group members—American Honda, General Motors, Hyundai, Mercedes-Benz, Nissan, Toyota and Volkswagen—developed a consensus list of recommended station priority locations for the next 19 hydrogen stations in California, focused on the Northern California, Southern California and Central Valley regions.[129]

The California Governor's Office of Business Development published the first edition of a guidebook that provides a detailed discussion of the permitting process and suggested best practices for California local and regional governments and station developers seeking to open (or in the process of opening) a hydrogen fueling station in California.[130]

To reduce the time to commission new hydrogen fueling stations, Sandia National Laboratories and NREL contracted with Powertech Labs to develop and build the Hydrogen Station Equipment Performance (HyStEP) Device, with funding provided by the DOE FCTO under the Hydrogen Fueling Infrastructure Research and Station Technology (H2FIRST) project. HyStEP is used to measure the performance of hydrogen dispensers, acting as a surrogate for vehicles and eliminating the need for each auto manufacturer to perform its own validation tests to measure hydrogen dispenser performance with respect to fueling protocol standards.[131]

Several hydrogen stations reported that they met rigorous fueling standards:

- The California State University Los Angeles (CSULA) Hydrogen Research and Fueling Facility became the first station in the U.S., and possibly the world, to be certified to sell hydrogen by the kilogram to the public.[132] The CSULA station is a DOE-funded technology validation project providing data on station equipment and FCEV fueling.
- The Applied Research Center (South Carolina), in partnership with the Department of Commerce's National Institute of Standards and Technology (NIST), tested hydrogen fueling standards at the Sage Mill Fueling Station (Aiken County, South Carolina) to ensure customers will have standardized fueling experiences and are able to accurately fill a tank with hydrogen.[133]
- A fast-fill, high-pressure hydrogen fueling station at Marine Corps Base Hawaii that supports a fleet of General Motors' Equinox FCEVs used by Marine Corps and Navy personnel was certified for unattended operation, allowing drivers to self-fill their vehicles.[134]

In Japan, Toyota, Nissan, and Honda agreed to work together to accelerate development of Japan's hydrogen station infrastructure. The companies will support as much as one-third of operating expenses for stations run by infrastructure companies, capped at ¥11 million (about $87,000) per station. The program will run until about 2020 and will cost an estimated ¥5 billion to ¥6 billion ($40 million to $48 million). Japan's national and local governments have also said they will subsidize the cost of operating hydrogen stations[135].

Denmark's H2 Logic A/S executed a technology transfer agreement with Mitsubishi Kakoki Kaisha, Ltd. that includes the adaption of its H2Station® CAR-100 product for the Japanese market.[136] Air Products and Suzuki Shokan Co., Ltd. also signed an agreement to work together on the design, construction and operation of hydrogen fueling stations for use in fueling the material handling vehicle market in Japan.[137]

Korea's Ministry of Environment announced plans to increase the number of hydrogen stations to 200 by 2025, up from 10 hydrogen stations in operation in 2015.[138]

Air Liquide, Daimler, Linde, OMV, Shell and Total formed H2 MOBILITY Deutschland GmbH & Co. KG to focus on a staged expansion of hydrogen filling stations across Germany, to bring the total to around 400 by 2023. The group plans investments of around €400 million ($427 million).[139]

Air Products and Bohlen & Doyen (Germany) signed an alliance agreement to support further development of Europe's hydrogen fueling market.[140] Air Products will provide 700 bar SmartFuel® hydrogen fueling station technology and the fueling protocol license, while Bohlen & Doyen will provide the associated engineering, construction, and maintenance services to fuel retailers.

U.K. hydrogen solutions company ITM Power signed an agreement with Ove Arup & Partners Ltd. for siting and business development of both hydrogen refueling stations and hydrogen energy systems.[141]

For the fifth consecutive year, The Linde Group (Germany) provided hydrogen for the 54 teams competing in the fuel cell category at the Shell Eco-marathon.[142]

Table 29. Examples of Commercially Available Hydrogen Fueling Station Products 2015

Examples of Commercially Available Hydrogen Fueling Station Products 2015				
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
FirstElement Fuel	True Zero	Cars	N/A	N/A
H2 Logic Denmark	H2 Station CAR-100	Automotive	70 MPa fast-fill	Up to 200 kg/day
	H2 Station MH-100	Material handling vehicles, cars, buses	35 MPa	Up to 200 kg/day
Hydrogenics Canada	HyStat™ Hydrogen Station	Material handling vehicles, cars	350 and 700 bar	20 – 130 kg/day and larger
ITM Power U.K.	HFuel Hydrogen Station	Automotive	350 and 700 bar	25 – 500+ kg/day
Nuvera Fuel Cells U.S.	PowerTap Hydrogen Station	Cars, buses, industrial vehicles	350 and 700 bar	50 – 250 kg/day
Linde Germany	Large, small and portable hydrogen fueling stations	Cars, buses, material handling vehicles	350 and 700 bar	N/A
McPhy France	McFilling®	Cars	350 and 700 bar	5 – 100 kg
Plug Power U.S.	GenFuel	Material handling vehicles	350 bar	N/A
Powertech Canada	Modular hydrogen fueling station	Automotive	700 bar	N/A

Hydrogen Generation and Supply

Table 30 provides examples of commercially available hydrogen generation systems. These systems produce hydrogen using either electrolysis (running an electrical current through water to produce hydrogen) or by reforming hydrocarbon or bio-based fuels (a process in which methane from the source fuel is heated, with steam, to produce hydrogen).

In the U.S., the Nebraska Public Power District (NPPD), Nebraska's largest electric utility, plans to replace an existing coal-fired boiler at its Sheldon Station plant with one that uses hydrogen fuel using hydrogen produced by Monolith Materials as a co-product from its production of carbon black using natural gas as a feedstock.[143] The Sheldon Station boiler using hydrogen as a fuel will continue to be capable of generating 125 MW of electricity for NPPD's customers.

The Commerce Department's National Institute of Standards and Technology (NIST) calculated the costs of installing pipelines to transport hydrogen fuel and suggested modifying industry codes to allow the use of a higher-strength grade of steel alloy without requiring thicker pipe walls, to reduce costs.[144] The stronger steel is more expensive, but dropping the requirement for thicker walls would reduce materials use and related welding and labor costs, resulting in a net cost reduction.

Japan is taking steps to realize its vision of a hydrogen society, with several major projects planned or under way in 2015 by government and industry. The steps include:

- A demonstration project by Japan's Environment of Ministry that will use excess electricity generated from offshore wind to create hydrogen. The project will take place at a wind power facility in waters off Kabashima Island in Nagasaki prefecture, with the goal of supplying electricity to islands surrounding the power plant.[145]
- A renewable energy project to test and refine a model of hydrogen-supply infrastructure, launched by Fukushima and the National Institute of Advanced Industrial Science and Technology's Fukushima Renewable Energy Institute.[146]
- A project producing hydrogen by reforming biogas from sludge fermentation at the Chubu Wastewater Treatment Center in Fukuoka City as part of the Breakthrough by Dynamic Approach in Sewage High Technology Project (B-DASH). A hydrogen station will be built in Fukuoka City to distribute the hydrogen produced at the facility.[147]
- A project by Kawasaki Heavy Industries, Ltd. and Obayashi Corp. to produce liquid hydrogen by utilizing geothermal power on the volcanic island of Iojima in Mishima, Kagoshima Prefecture.[148]
- A four-year trial that will use renewable energy from the Yokohama City Wind Power Plant to convert water into hydrogen for use in a mobile fueling station in the Keihin coastal area to service fuel cell forklift trucks, while also studying the feasibility of a hydrogen supply chain. The project is under development by the Kanagawa Prefectural Government, Yokohama City, Kawasaki City, Toyota, Toshiba, and Iwatani.[149]

In addition, Iwatani is taking steps to raise production capacity for hydrogen gas 80% by fiscal 2018 to meet future demand from FCEVs. The Japanese company will invest as much as ¥12 billion ($95 million) to expand its two existing factories in Chiba and Yamaguchi prefectures and to build a plant with two hydrogen gas production facilities in Kanagawa Prefecture. The investments will give Iwatani the capacity to produce 504,000 liters of liquefied hydrogen daily.[150]

Australian hydrogen company Hydrexia entered an agreement with HyGear, supplier of industrial gases and on-site generation systems, to supply hydrogen in Europe.[151] The hydrogen will be produced by HyGear's Hy.GEN steam methane reforming (SMR) facilities located across Europe.

French hydrogen company McPhy Energy entered into a technology partnership agreement with the De Nora group where De Nora will supply McPhy Energy with activated electrodes for its range of new-generation alkaline water electrolyzers.[152]

Table 30. Examples of Commercially Available Hydrogen Generation Systems 2015

Examples of Commercially Available Hydrogen Generation Systems 2015			
Manufacturer	**Product**	**Type**	**Hydrogen Production**
Acta S.p.A. Italy	EL Series	Alkaline solid polymeric electrolytic process	0.54 – 2.2 kg/day
Air Products and Chemicals, Inc. U.S.	PRISM®	Reformer	11,600 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 – 1,080 kg/day
	HyLYZER	PEM Electrolysis	2.4 – 4.8 kg/day
HyGear Netherlands	HyGEN Series	Reformer	10.8 – 225 kg/day
ITM Power U.K.	HPac Series	PEM electrolysis	2.5 – 5 kg/day
	HGas	PEM electrolysis	25 – 462 kg/day
Linde Germany	HYDROPRIME	Reformer	713 – 2,160 kg/day
McPhy France	Baby McPhy	Alkaline electrolysis	0.86 kg/day
	McLyzer	Alkaline electrolysis	2.2 – 43 kg/day
	Large H2 production units	Alkaline electrolysis	216 – 865 kg/day
Nuvera Fuel Cells U.S.	PowerTap	Reformer	Up to 500 kg/day
Osaka Gas Japan	HYSERVE series	Reformer	64.8 – 648 kg/day
Proton OnSite U.S.	G Series	PEM electrolysis	0.03 – 0.08 kg/day
	G4800	PEM electrolysis	0.6 kg/day
	S Series	PEM electrolysis	1.2 – 2.4 kg/day
	H Series	PEM electrolysis	4.3 – 13 kg/day
	C Series	PEM electrolysis	21.6 – 64.8 kg/day
	M Series	PEM electrolysis	Up to 1,000 kg/day

Siemens Germany	SILYZER Series	PEM electrolysis	48 – 5,400 kg/day
Verde LLC U.S.	Portable Hydrogen Generators	Alkaline electrolysis	0.39 – 64.8 kg/day
	Hydrogen Generating Plant	Alkaline electrolysis	4.3 – 1,080 kg/day
	Hydrogen Generating Plant	Reformer	108 – 43,200 kg/day

Hydrogen Energy Storage and Power-to-Gas

There is interest, particularly in Europe, in the use of hydrogen energy storage to store excess renewable energy produced in off-grid areas and to mitigate the intermittencies inherent in sources such as wind and solar power. Hydrogen gas is produced by electrolysis using renewable power and is stored for later use, or can be injected into natural gas pipelines. This process is also known as Power-to-Gas (P2G). A number of hydrogen energy storage projects were announced in 2015 and are summarized in Table 31.

Table 31. Examples of Energy Storage Projects in 2015

Examples of Energy Storage Projects in 2015		
Company	**Site**	**Details**
Hydrogenics	Fife, Scotland	Will deploy an alkaline electrolyzer, PEM electrolyzers, and a fuel cell module as part of a wind-powered energy storage system as part of the Levenmouth Community Energy Project.
	Hamburg, Germany	A 1.5-MW PEM electrolyzer energy storage system was inaugurated at E.ON´s site, producing hydrogen using surplus renewable energy produced primarily from wind. Hydrogen will be fed into Hamburg's natural gas grid. The unit stores up to 36 MWh per day of renewable energy.
ITM Power	Ibbenbüren, Germany	Delivered a rapid response Power-to-Gas PEM electrolyzer to RWE Deutschland AG. RWE will inject hydrogen into the gas network as part of their Power-to-Gas installation and evaluate its system response and explore its use in grid balancing.
	Eday, Scotland	Will supply an integrated hydrogen system featuring a 0.5-MW PEM electrolyzer with integrated compression and up to 500 kg of storage. The electrolyzer will absorb excess power generated by tidal turbines testing at EMEC Energy Centre.
McPhy Energy	Hebei province, China	Will supply a power-to-gas system for the recovery of surplus energy generated by a 200-MW wind farm site currently under construction.
	Apulia region, Italy	Will provide a solid state hydrogen storage system for a 39 MWh energy storage facility that will match energy supply with demand through integrated storage solutions combined with renewable energy.
	Fos-sur-Mer, France	Will supply GRTgaz with hydrogen production equipment with a total power of 1 MW as part of the Jupiter 1000 power-to-gas project to be commissioned in 2018.
Proton OnSite	Irvine, California	Participating in America's first power-to-gas project, announced by Southern California Gas Co. Will test two Proton electrolyzers that will generate hydrogen from a photovoltaic source. The hydrogen will be injected into a simulated natural gas pipeline system at the University of California, Irvine.

Siemens	Mainz, Germany	Launched a hydrogen production plant in July. Siemens' PEM electrolyzer can process up to 6 MW of electricity, converting wind power into hydrogen for use as a general fuel or in natural gas pipelines. Project is a collaboration of the Mainz energy utility, Linde, and the Rhein-Main University of Applied Sciences.
Toshiba Corp.	Kawasaki, Japan	Installed a small-scale test system comprised of fuel cells, electrolysis equipment and hydrogen storage tanks capable of storing 350 kWh of electricity.
	Fife, Scotland	Toshiba will deploy its hydrogen energy management system (H2 EMS) as part of the Levenmouth Community Energy Project.

French hydrogen company McPhy also entered into several agreements:

- An MoU with Compagnie Nationale du Rhône, a French renewable energy producer, for the joint development of hydrogen energy projects, focusing on zero emission mobility and power-to-gas markets.
- A strategic commercial agreement for McPhy to become ThyssenKrupp Uhde Chlorine Engineers' exclusive supplier for its high-capacity and high-pressure water electrolysis-based hydrogen generation equipment for the renewable energy storage market.

A study from FCH-JU, Commercialization of Energy Storage in Europe, examines three types of storage technologies: power-to-power, conversion of power to heat, and conversion of power to hydrogen for use outside of the power sector as gas or use as fuel for mobility and industry. One finding is that the conversion of electricity to hydrogen for use outside the power sector has the potential to productively utilize nearly all excess renewable electricity that would be curtailed.

Components

Plug Power entered into a supply agreement with 3M for MEAs to be used in its PEM fuel cell stacks.[153]

W. L. Gore & Associates is providing its GORE-SELECT® Membrane for the stacks used in Toyota's Mirai FCEV.[154]

Worthington Industries, Inc. signed a multi-year contract with Teijin Engineering of Osaka, Japan, to supply Type 3, composite hydrogen cylinders to a major Japanese automotive OEM, to be used on a new FCEV.[155]

Doosan Fuel Cell America and ABB extended their partnership agreement through 2016. ABB is supplying specialized electrical modules that serve as the control system for Doosan fuel cell power plants.[156]

Ballard Power Systems received a purchase order from Nisshinbo Holdings Inc. for the next phase of Technology Solutions project work related to the development of catalyst technology.[157]

Ballard Power Systems began collaborating with Zenyatta Ventures Ltd. on high purity graphite required in bipolar plate and gas diffusion layer for fuel cells.[158] In October, the companies initiated a project utilizing high purity Albany graphite in an MEA.[159]

Since its acquisition of Roush Performance Products' fuel cell compressor module business in February, Colorado-based UQM Technologies has received several purchase orders from Ballard Power Systems.[160]

Bosch Engineering offered a new product for fuel cells in off-highway applications, the Fuel Cell Control Unit (FCCU), which manages the interactions of all system components and serves as a key component of the fuel cell system.[161] Bosch plans to test operation of the FCCU in fuel cell baggage tractors at Stuttgart Airport.

Reports

U.S. Department of Energy

The 2015 Hydrogen and Fuel Cells Annual Progress Report documents accomplishments achieved by DOE-funded projects over the past year, including the H2 Refuel H-Prize, the launch of the world's first fuel cell-powered ground support equipment fleet, and support of H2USA.

Pathways to Commercial Success: Technologies and Products Supported by the Fuel Cell Technologies Office provides a look at commercial and lab-tested hydrogen and fuel cell technologies that were supported by DOE R&D efforts.

2016-2020 Strategic Plan and Implementing Framework is a blueprint for launching the nation's leadership in a global clean energy economy. The plan includes strategic goals within EERE's core technologies, including hydrogen and fuel cell technologies.

Business Deployments

The Business Case for Fuel Cells 2015: Powering Corporate Sustainability provides an overview of recent private sector fuel cell installations at U.S. businesses, as well as highlighting international deployments through September 2015.

State-Level Analysis

State of the States: Fuel Cells in America 2015 provides a comprehensive look at state activities supporting hydrogen and fuel cell technology, and profiles leading states in the industry.

2015 State Policy Activity Wrapup—Fuel Cells & Hydrogen profiles state-level legislation, policies, and incentives that impacted the fuel cell and hydrogen industry during 2015.

Roadmaps

The Northeast Electrochemical Energy Storage Cluster (NEESC), administered by Connecticut Center for Advanced Technology Inc. (CCAT), released the 2015 Hydrogen and Fuel Cell Development Plans for each of the eight states in the Northeast U.S.—Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, and Vermont.

An International Energy Agency (IEA) report, Technology Roadmap: Hydrogen and Fuel Cells, details the steps governments, industry and researchers need to take to foster and track deployment of the technology if hydrogen is to become a significant energy carrier by 2050.

FCEVs

NREL released Fuel Cell Buses in U.S. Transit Fleets: Current Status 2014, which summarizes the progress of fuel cell electric bus development in the United States and discusses the achievements and challenges of introducing fuel cell propulsion in transit. The summary results are from four demonstrations at three transit agencies: Zero Emission Bay Area (ZEBA) Demonstration Group led by Alameda-Contra Costa Transit District (AC Transit) in California, BC Transit Fuel Cell Bus Project (final year of in-service operation) in Whistler, British Columbia, Canada, Advanced Technology Fuel Cell Electric Bus (FCEB) and American Fuel Cell Bus Project at SunLine Transit Agency in California. The results for these buses account for more than 938,444 miles traveled and 85,061 hours of fuel cell power system operation.

Sandia National Laboratories released the workshop report, Transitioning the Transportation Sector: Exploring the Intersection of Hydrogen Fuel Cell and Natural Gas Vehicles. Organized by Sandia, the American Gas Association, and Toyota, the workshop included participants from the auto industry, freight delivery fleets, gas

suppliers, gas storage developers, utilities, academia, industry associations, national laboratories, and federal and state governments. Participants identified several areas where companies can better capitalize on synergies between hydrogen and natural gas, finding that there is substantial potential for co-locating natural gas and hydrogen stations rather than building them separately. As natural gas and hydrogen fuels are unlikely to compete for the same market segments (natural gas for fleets and hydrogen for consumers), station operators could cater to both types of users. Because hydrogen production can use natural gas as a feedstock, selling both fuels could also take advantage of common supply chains.

Hydrogen Fueling

DOE released two new tools and two reports developed through H2USA to support hydrogen fueling infrastructure deployment. The tools, the Hydrogen Refueling Stations Analysis Model (HRSAM) and the Hydrogen Financial Analysis Tool (H2FAST), were developed by Argonne National Laboratory and NREL respectively to address the key technical and financial barriers to hydrogen fueling infrastructure deployment. HRSAM will help to assess the impact of station design on the economics and incorporates a station's capital and operating cost based on key design variables such as station capacity and mode of hydrogen delivery. To complement HRSAM, H2FAST provides in-depth financial analysis including cash flow and return on investments for hydrogen fueling stations based on key financial inputs such as station capital cost, operating cost, and financing mechanisms.

The Hydrogen Fueling Infrastructure Research and Station Technology (H2FIRST) project published two reports. The Reference Station Design report details engineering designs and economic analyses of five hydrogen refueling station designs that can meet near-term market needs. The Hydrogen Contaminant Detection report describes the current commercial state of the art in contamination detection and identifies the technical requirements for implementing a hydrogen detection device at a station.

Kalibrate released the results of its California hydrogen refueling infrastructure analysis to NREL. More than 30,000 locations were identified within the state of California and then ranked from best to worst based on their viability for introducing a hydrogen refueling station.[162]

Stationary Fuel Cells

A study conducted by researchers at DOE's PNNL, The Case for Natural Gas Fueled Solid Oxide Fuel Cell Power Systems for Distributed Generation, concludes that natural gas SOFCs could play a significant role in meeting future energy demand. The researchers based their cost modeling study on a small-scale SOFC system designed, built, and tested at PNNL and a larger, conceptual system of 270 kW. The study showed that for the same power output, a natural gas SOFC would cost almost one-third less to build than a centralized natural gas combined cycle plant.[163]

Advancing Europe's Energy Systems: Stationary Fuel Cells in Distributed Generation, a study sponsored by FCH-JU, outlines a pathway for commercializing stationary fuel cells in Europe.

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