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

2013 Fuel Cell Technologies Market Report

Fuel Cell Technologies Office

November 2014

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Authors

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Acknowledgement

The authors relied upon the hard work and valuable contributions of many men and women in government and in the fuel cell industry. The authors especially wish to thank Sunita Satyapal and the staff of the U.S. Department of Energy's Fuel Cell Technologies Office for their support and guidance. Also thanks to Rachel Gelman, Jeff Logan, and Ted James of the National Renewable Energy Laboratory and the staff at Navigant Research.

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Cover Image

14.9-MW FuelCell Energy fuel cell system generating power at Dominion's Bridgeport Fuel Cell Power Park.

Image source: FuelCell Energy 2013 Annual Report, ***http://files.shareholder.com/downloads/FCEL/3376881510x0x724661/D703F85E-D67A-441D-81E2-76401A391857/Fuel_Cell__13AR_compiled.pdf***

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List of Acronyms

APU	Auxiliary Power Unit
ARPA-E	Advanced Research Projects Agency – Energy (DOE)
CEC	California Energy Commission
CHP	Combined Heat and Power
CTE	Center for Transportation and the Environment
DMFC	Direct Methanol Fuel Cell
DoD	U.S. Department of Defense
DOE	U.S. Department of Energy
EERE	Office of Energy Efficiency and Renewable Energy (DOE)
FCEV	Fuel Cell Electric Vehicle
FCH JU	Fuel Cell and Hydrogen Joint Undertaking (European Commission)
FTA	U.S. Federal Transit Administration
FY	Fiscal Year
HT-PEM	High Temperature PEM Fuel Cell
kg	Kilograms
kW	Kilowatt
LPG	Liquefied Petroleum Gas
MCFC	Molten Carbonate Fuel Cell
m-CHP	Micro-Combined Heat and Power
MoU	Memorandum of Understanding
MW	Megawatt
NIP	National Innovation Program (Germany)
OTC	Over-the-Counter
PAFC	Phosphoric Acid Fuel Cell
PE	Private Equity
PEM	Proton Exchange Membrane
PIPE	Private Investment in Public Equities
R&D	Research and Development
RD&D	Research, Development and Demonstration
RV	Recreational Vehicle
SBIR/STTR	Small Business Innovation Research/Small Business Technology Transfer
SOFC	Solid Oxide Fuel Cell
UAV	Unmanned Aerial Vehicle
UPS	Uninterruptible Power Supply
VC	Venture Capital
W	Watt
ZEV	Zero-Emission Vehicle

Currency Exchange Rates

The ***U.S. Internal Revenue Service (IRS) 2013 yearly average exchange rates*** were used to convert foreign currencies to U.S. dollars using the following rates. If unspecified, amounts are reported in U.S. dollars.

2013 Average Exchange Rates for Converting Foreign Currencies into U.S. Dollars

Country	Currency	Abbreviation/ Symbol	Rate
Australia	Dollar	AUD	1.078
Canada	Dollar	CAN	1.071
Euro Zone	Euro	€	0.783
Japan	Yen	¥	101.517
United Kingdom	Pound	£	0.665

Introduction

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

There are three main markets for fuel cell technology: stationary power, transportation, and portable power. Stationary power includes any application in which the fuel cells are operated at a fixed location for primary power, backup power or combined heat and power (CHP). Transportation applications include motive power for passenger cars, buses and other fuel cell electric vehicles (FCEVs), specialty vehicles, material handling equipment (e.g. forklifts), and auxiliary power units (APUs) for off-road vehicles. Portable power applications use fuel cells that are not permanently installed or fuel cells in a portable device. There are many types of fuel cells currently in operation in a wide range of applications, including the molten carbonate fuel cell (MCFC), solid oxide fuel cell (SOFC), phosphoric acid fuel cell (PAFC), direct methanol fuel cell (DMFC) and low and high temperature proton exchange membrane (PEM) fuel cell.

There were several notable industry trends in 2013:

Repeat customers

After purchasing and then experiencing fuel cell benefits firsthand, many companies have become repeat customers, purchasing additional, and in several cases, larger systems for their facilities. In 2013, these included two of the earliest adopters of fuel cells. Verizon, which first invested in fuel cell power in the early 2000s, is investing $100 million in a fuel cell and solar energy project that includes more than 9 megawatts (MW) of fuel cells to power critical data centers, central offices, call switching stations and office buildings across several states. The First National Bank of Omaha upgraded to a next generation fuel cell to safeguard its credit card processing operations at its data center in Nebraska. The bank has used a fuel cell system to power that data center since 1999.

On the material handling side, several companies increased their fleets of fuel cell-powered vehicles, including BMW and Mercedes-Benz.

Budget Commitments

A number of budget commitments were announced during 2013. The European Commission renewed the Fuel Cells and Hydrogen Joint Undertaking (FCH JU) for the period 2014-2024 with a budget of €1.4 billion (US$1.8 billion), a 27% increase over the first phase of the program. Japan's 2013 RD&D budget for fuel cells and hydrogen was almost double the 2012 budget, at ¥36.83 billion (US$363 million).

Notable in 2013

- In 2013, worldwide fuel cell industry sales surpassed $1 billion for the first time—reaching $1.3 billion.
- About 35,000 fuel cell systems were shipped in 2013, an increase of 26% over 2012, and 400% more than 2008.
- 150 MW of stationary fuel cells shipped worldwide in 2013, an increase of 24% over 2012 and 244% over 2008.
- In the U.S., a 14.9 MW fuel cell power park opened in Bridgeport, Connecticut.
- Installation of the world's largest fuel cell power plant, 59 MW, began in Korea.
- Hyundai announced plans to begin leasing its first series production fuel cell electric vehicle at select dealerships in Southern California starting in 2014. Hyundai has already delivered production vehicles to Denmark and Sweden.
- H2USA, a public-private partnership focused on advancing the hydrogen infrastructure in the U.S., was launched and by the end of 2013, had 25 members.
- The U.K. launched a similar initiative with UKH2Mobility.
- Eight U.S. states signed a Memorandum of Understanding to coordinate on zero-emission vehicle implementation.
- The European Commission proposed €1.4 billion (US$1.8 billion) to fund its fuel cell program, FCH JU, until 2024–a 27% increase over the last phase.
- Deployments and orders of fuel cells for telecommunications backup expanded into the Middle East, China, Philippines, and other international markets.
- With an addition of 175+ fuel cell-powered material handling vehicles to its existing fleet in Spartanburg, South Carolina, BMW now claims the largest number at a single location in North America and arguably in the world.

In support of FCEV commercialization and refueling infrastructure, California has committed funding for the development of 100 hydrogen fueling stations to help the state meet its goal of 1.5 million zero-emission vehicles (ZEVs) by 2025. Japan's government proposed ¥7.2 billion (US$71 million) to build hydrogen fueling stations starting in Fiscal Year (FY) 2014. The U.K. announced over £500 million (US$752 million) of new capital investment between 2015 and 2020 in support of ultra-low emission vehicles (ULEVs), including FCEVs.

In the wake of severe weather events, stationary fuel cell programs are becoming more active on the East Coast. New Jersey launched the second round of the Large Scale Combined Heat and Power/Fuel Cell Program to enhance energy efficiency through on-site power generation, providing up to $3 million per project. Connecticut's Microgrid Pilot Program also committed more than $5 million for two fuel cell projects to help increase power resilience during extreme weather.

Expansion of fuel cell power generation beyond the "Big 3" states

California, Connecticut and New York have long been leaders in stationary fuel cell power generation, particularly for larger systems that range from multi-kilowatts to multi-megawatts. This trend continues in 2013, but we also began to see fuel cell deployments outside of these states. New Jersey's Clean Energy Program provides funding through its Large- and Small-Scale CHP-Fuel Cell funding program, which has helped to fund a fuel cell located at Owens-Corning's Basking Ridge site (the company's second fuel cell installation; the first is in California). Telecom giant Verizon, which has deployed fuel cells in California and New York, has also expanded its fuel cell deployment into New Jersey. Data center applications provided another area of investment, with fuel cells operating or planned in Wyoming (Microsoft pilot project), Utah (eBay), and Delaware (JP Morgan Chase). Also in Delaware, energy utility Delmarva Power deployed 27 MW of fuel cells in 2013 to generate power for the electric grid. The Delaware utility now provides 30 MW of fuel cell power generation – the largest fuel cell deployment in the United States.

Delivering power to the electric grid

Other energy utilities are turning to fuel cells to help generate clean energy and improve grid stability. Dominion started up a 14.9 MW fuel cell power plant in Bridgeport, Connecticut, in December 2013, selling electricity to Connecticut Light & Power. NRG Energy is adding a 5.6 MW fuel cell system to its Montville, Connecticut biomass power plant, and is partnering with fuel cell manufacturer FuelCell Energy to co-market fuel cell power plants to its customer base. NRG has the option to purchase and own fuel cell power plants for its own portfolio and sell the power to the electric grid. In 2013, installation began on the largest fuel cell power plant in the world; South Korea's POSCO Energy will operate the 59 MW Gyeonggi Green Energy fuel cell park that will deliver power to the electric grid and steam to a district heating system.

More fuel cell vehicle partnerships and funding

Daimler, Honda and Hyundai will introduce fuel cell electric vehicles (FCEVs) in consumer markets starting in 2015-2017 focusing on areas where a hydrogen infrastructure exists. A few Hyundai FCEVs are already in showrooms in Europe and the automaker announced plans to begin leasing FCEVs in California in 2014. Worldwide, private and public partnerships are preparing for FCEV commercialization through joint initiatives and projects to facilitate FCEV sales and hydrogen infrastructure, including efforts launched in 2013 in the U.K. (UKH2Mobility) and plans for France (Hydrogen Mobility France). In the U.S., the governors of eight states (California, Connecticut, Massachusetts, Maryland, New York, Oregon, Rhode Island, and Vermont) agreed to coordinate actions to implement ZEV programs that support battery and FCEVs. H2USA, a public-private partnership focused on advancing the hydrogen infrastructure in the U. S., was launched. Germany, Japan, and California also announced further funding commitments for expansion of hydrogen refueling infrastructure. Many automakers announced collaborations on fuel cell system development.

Energy Storage

Power-to-Gas projects are on the rise, particularly in Europe, allowing surplus wind or solar energy to be converted to hydrogen (via an electrolytic process) or synthetic natural gas (SNG, or methane, via an additional step). This fuel can be stored for later use – to power a fuel cell or hydrogen vehicle – or can be injected into an existing natural gas pipeline. A number of Power-to-Gas projects are under way, primarily in the U.K and Germany, and several consortia were formed in 2013 to develop and fund new projects.

Financial Data

This section provides publicly available information regarding mergers and acquisitions in the industry, 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. Finally, venture capital, private equity, and other investment activity within the industry are discussed in this section.

Mergers & Expansions

In 2013, there were significant changes in the fuel cell industry, including both consolidations and expansions.

PEM fuel cell manufacturer ClearEdge Power completed its acquisition of UTC Power, adding UTC's 400-kW PAFC fuel cell system to its portfolio.[1]

HT-PEM materials company Advent Technologies S.A. of Athens, Greece, relocated its headquarters to East Hartford, Connecticut, with $1 million of state assistance.[2]

Key personnel from Wärtsilä Finland Oy's fuel cell development started up a new company, Convion Oy, to focus on SOFC fuel cell technology development. Wärtsilä holds a minority interest (around 20%) in the new company.[3]

Neah Power Systems completed a fuel cell technology asset acquisition of Clean Tech Investors LLC, which the company claims will bolster its current product lineup and open up opportunities in the renewable energy sector.[4]

Nevada's Suja Minerals Corporation acquired Global Energy Innovations, Inc. (GEI), a high-temperature proton exchange membrane (HT-PEM) fuel cell business that spun out of Kettering University in 2007. The new company is called GEI Global Energy Corporation.[5]

Ballard Material Products, which produces gas diffusion layer materials, was purchased by the investor group AvCarb LLC to form AvCarb Material Solutions.[6]

SFC Energy signed a contract to acquire Simark Controls Ltd., a Canadian value added (VAR) distributing company.[7]

AlumiFuel Power Corporation signed a Term Sheet with Italian company Genport to create a new U.S. corporate entity, NovoFuel, Inc. and construct a new lab facility in Philadelphia, Pennsylvania, to develop a 5-kilowatt (kW) fuel cell backup power system for the telecommunications market.[8]

Italian company Electro Power Systems S.p.A. (EPS) entered into an exclusive manufacturing, operations and distribution agreement of its "ElectroSelf" fuel cell system for the United States, Canada and Mexico with VP Energy LLC of Michigan.[9]

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

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

Tables 1 through 3 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 1: Gross Revenue and Cost of Revenue for Select Public Fuel Cell Companies

(Thousands US$ except where noted)	2013		2012		2011	
North American Companies	Gross Revenue	Cost of Revenue	Gross Revenue	Cost of Revenue	Gross Revenue	Cost of Revenue
Ballard Power Systems	61,251	44,492	43,690	36,321	55,773	48,494
FuelCell Energy [1]	187,658	180,536	120,603	120,158	122,570	135,180
Hydrogenics Corp.	42,413	30,352	31,697[6]	26,448[6]	23,918[6]	18,351[6]
Plug Power	26,601	37,849	26,108	40,463	27,626	36,902
Other Companies						
Ceramic Fuel Cells Ltd [2,3]	4,266	21,544	6,717	27,228	3,681	29,142
Ceres Power [2,4]	523	13,265	226	18,480	692	17,702
SFC Energy AG [5]	32,413	21,773	31,260	18,497	15,425	10,056

[1] Year ends October 31 [2] Year ends June 30 [3] $AUD Thousands [4] £ Thousands [5] € Thousands [6] Revised 2012 and 2011 gross revenues and cost of revenues from Hydrogenics' 2013 Consolidated Financial Statements and Results of Operations

Source: Annual reports and investor presentations.

The following discussion offers additional details regarding revenue drivers in 2013.

- FuelCell Energy's revenue grew by $67.1 million, reaching $187.7 million during FY2013 (year ended October 31). Product sales, service agreements, and license revenues increased by $60.1 million to $173.2 million, primarily due to revenue recognition for the Bridgeport, Connecticut, fuel cell park project of approximately $55.1 million, license and royalty income of $4.1 million and service revenue related to a new Master Service Agreement with POSCO Energy (South Korea). Cost of revenue increased by $60.3 million, to $180.5 million.[10]
- Ballard Power Systems' 2013 revenue increased by $17.6 million over 2012, to $61.2 million. Key growth drivers were a 74% increase in ElectraGen product sales for telecom backup power, with revenue growth to $20.5 million, and by a 24% increase in engineering services revenue, to $21.1 million. Material handling product sales also grew by 5%, to $6.5 million. Cost of revenue increased by $8.1 million, to $44.4 million.[11,12]
- Hydrogenics' 2013 revenue increased by $10.7 million, to $42.4 million, attributed to increased revenue in the Power Systems business unit, including a propulsion systems contract and a major order of fuel cell modules for backup power. Power Systems business unit revenue grew by $13.9 million, to $18.3 million, while the Onsite Generation business revenue declined by $3.2 million, to $24.1 million. Cost of revenue increased by $3.9 million, to $30.3 million.[13,14]
- Plug Power's revenue grew by $0.49 million to $26.6 million, comprised of $25.1 million in product and service revenue (up 3% from 2012) and $1.5 million in R&D contract revenue (down 12%). In 2013 three customers comprised a third of Plug Power's total consolidated revenue, with Mercedes-Benz, Procter & Gamble, and Lowe's representing 11.6%, 11.2%, and 10.4% of revenue, respectively. Cost of revenue decreased by $2.6 million, to $37.8 million.[15]

- Ceramic Fuel Cells Ltd. revenue decreased during 2013 to AUD4.3 million (US$4.0 million) due primarily to a delay in a North Rhine-Westphalia (Germany) funding program that led purchasers to hold off on buying in the 3rd quarter of the financial year. Cost of revenue declined by AUD5.7 million (US$5.3 million) to AUD21.5 million (US$19.9 million).[16]

- In 2013, Ceres Power implemented its new business strategy based on core technology only, with product development implemented by OEM partners. Revenue increased by £0.3 million (US$0.45 million), to £0.5 million (US$0.75 million). Cost of revenue decreased by £5.2 million (US$7.8 million), to £13.2 million (US$19.8 million).[17]

- SFC Energy reports that 2013 revenue increased by €1.2 million (US$1.5 million) to €32.4 million (US$41.4 million). Revenue for the Industry segment increased to €25 million (US$32 million), attributed to SFC Energy's acquisition of Simark Controls. Consumer segment revenue fell slightly, from €4.838 million (US$6.179 million) to €4.799 million (US$6.129 million), which SFC Energy attributes to a downward trend in the leisure market. In the Defense & Security segment, 2013 revenue declined from €8.9 million (US$11.4 million) to €2.6 million (US$3.3 million) due to government and contract delays. Cost of revenue increased by €3.3 million (US$4.2 million) to €21.7 million (US$27.7 million).[18]

For many companies, R&D expenditures were lower in 2013 (Table 2), continuing a downward trend. Ceramic Fuel Cells Ltd. offers some detail, reporting that R&D expenses were 32% lower than in 2012 due to the corporate and board restructuring that took place in FY 2013, as well as from a 34% reduction in expenditure on core R&D development activities as the company moved into product development, manufacturing and sales.[18] Expeditures, however, increased for SFC Energy and FuelCell Energy. FuelCell Energy reports that R&D expenses increased slightly due to initiatives to reduce the cost of large scale multi-megawatt installations through consolidation of certain aspects of balance of plant functions.[20]

Table 2: R&D Expenditures for Select Public Fuel Cell Companies (Thousands US$, unless footnoted)

North American Companies	2013	2012	2011
Ballard Power Systems	17,117	19,273	24,896
FuelCell Energy [1]	15,717	14,354	16,768
Hydrogenics Corp.	2,566	4,452[6]	2,934
Plug Power	3,121	5,434	5,656
Other Companies			
Ceramic Fuel Cells Ltd [2, 3]	7,800	11,539	15,127
Ceres Power [2, 4]	7,200	13,205	12,869
SFC Energy AG [5]	6,148	4,257	2,537

[1] Year ends October 31 [2] Year ends June 30 [3] $AUD Thousands [4] £ Thousands [5] € Thousands [6] Revised 2012 and 2011 gross revenues and cost of revenues from Hydrogenics' 2013 Consolidated Financial Statements and Results of Operations

Source: Annual reports and investor presentations.

Table 3: R&D Total Assets and Liabilities for Select Public Fuel Cell Companies (Thousands US$, unless footnoted)

(Thousands US$ except where noted)	2013		2012		2011	
North American Companies	**Assets**	**Liabilities**	**Assets**	**Liabilities**	**Assets**	**Liabilities**
Ballard Power Systems	120,214	49,960	127,547	69,545[1]	165,290	72,945[1]
FuelCell Energy[2]	237,636	190,971	191,485	117,119	183,630	137,224
Hydrogenics Corp.	40,070	33,909	41,877[7]	37,570[7]	31,061	20,288
Plug Power	35,355	50,856	39,460	24,430	55,656	26,620
Other Companies						
Ceramic Fuel Cells Ltd[3,4]	33,326	17,580	32,810	11,913	42,785	9,250
Ceres Power[3,5]	16,935	4,561	13,168	4,487	33,873	6,465
SFC Energy AG[6]	47,649	18,586	47,617	11,224	48,782	11,994

[1] Audited financial statements (2011/2012) [2] Period ending October 31 [3] Period ending June 30 [4] $AUS Thousands [5] £ Thousands [6] € Thousands [7] Revised 2012 assets and liabilities from Hydrogenics' 2013 Consolidated Financial Statements and Results of Operations

Source: Annual reports and investor presentations.

Venture Capital and Private Equity

Cumulative global investment in fuel cell companies (venture capital, private equity, over-the-counter and private investment) totaled more than $1.038 billion between 2011 and 2013, growing from $853.6 million between 2010 and 2012 and $671.4 million between 2009 and 2011, as reported in the 2012 and 2011 editions of this report. Figure 1 provides a breakdown by quarter and by investment type.

Figure 2 shows total U.S. investment in fuel cell companies between 2011 and 2013. U.S. investment totaled $172.7 million in 2013, down from $245.8 million in 2012 and $408.7 million in 2011. Global investment also has declined from $457.2 million in 2011, to $307.1 million in 2012 and $224.5 million in 2013. Despite this decline, during 2011 through 2013, the U.S. contribution to global investment remained steady at 80%, compared to to the 81% reported for the period 2010 through 2012.[21]

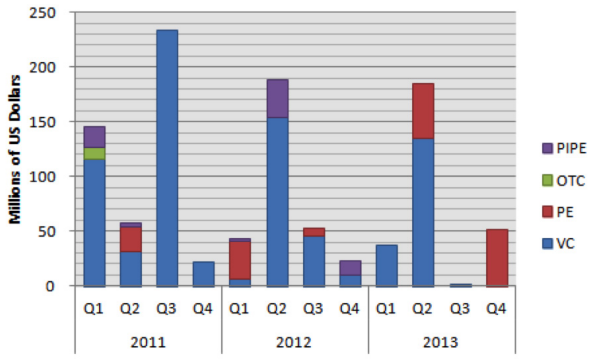

Figure 1: Worldwide Venture Capital (VC), Private Equity (PE), Over-the-Counter (OTC), and Private Investment in Public Equities (PIPE) Investments in Fuel Cell Companies (2011-2013)[1,2]

Chart created by Breakthrough Technologies Institute using data from Bloomberg New Energy Finance and New Zealand Superannuation Fund

[1] Cinven Group's $1.988 billion purchase of CeramTec is omitted from this chart.

[2] Data provided by Bloomberg New Energy Finance includes only disclosed and completed deals.

Table 4 shows disclosed venture capital (VC) and private equity (PE) investments in fuel cell-related companies during 2013.

Credit Suisse invested $130 million in U.S. SOFC manufacturer, Bloom Energy. According to Reuters, $100 million reportedly came from European investor-owned power and gas company E.ON and $30 million came from Credit Suisse.[22]

New Zealand's Superannuation Fund, which invests globally to help pre-fund New Zealanders' retirement entitlements, made a $50 million private equity investment in Bloom Energy through the Innovation Alliance.[23] Alliance members include the Alberta (Canada) Investment Management Corporation (AIMCo), which lists Bloom Energy among its top five private equity investments,[24] and the Abu Dhabi Investment Authority (ADIA).[25]

350 Investment Partners LLP (formerly CT Investment Partners) invested $0.2 million in U.K.-based ACAL Energy, a developer of PEM fuel cells for stationary and automotive applications. In past years, 350 Investment Partners has made investments in ACAL Energy, CMR Fuel Cell and Ceres Power.[26]

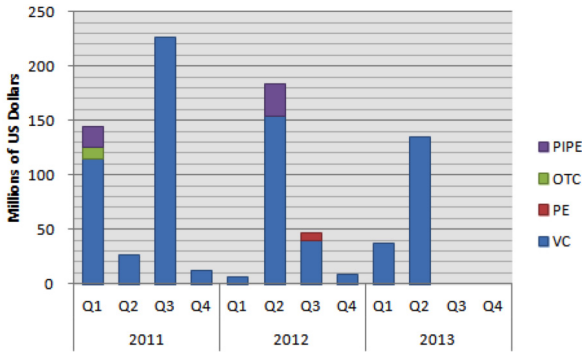

Figure 2: U.S. Venture Capital (VC), Private Equity (PE), Over-the-Counter (OTC), and Private Investment in Public Equities (PIPE) Investments in Fuel Cell Companies (2011-2013)[1,2]

Chart created by Breakthrough Technologies Institute using data from Bloomberg New Energy Finance

[1] Cinven Group's $1.988 billion purchase of CeramTec is omitted from this chart.

[2] All data provided by Bloomberg New Energy Finance and includes only disclosed and completed deals.

Table 4: Disclosed Top Venture Capital and Private Equity Investors in Fuel Cells, By Company and By Country (2013)[27]

Top Fuel Cell Investors	
Company	**Amount (million US$)**
Credit Suisse AG (Switzerland)	130.0
Superannuation Fund (New Zealand)	50.0
350 Investment Partners LLP (U.K.)	0.2
TOTAL	**$180.2**

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

Note: In 2013, there was an additional fuel cell investment of more than $117 million, made by unidentified VC and PE investors.

Table 5 lists the top 10 global investors in fuel cells between 2000 and 2013, 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 is Switzerland's Credit Suisse, followed by four U.S. companies: Kleiner, Perkins, Caufield & Byers; New Enterprise Associates Inc.; Mobius Venture Capital Inc.; and GSV Capital Corp. In aggregate, the U.S. made the greatest cumulative investment during the period, at $789.9 million, followed by the U.K. at $243.1 million and Switzerland

at $156.5 million. Overall, the Top 10 investor countries have provided 93% of reported global investment in fuel cell companies during the period 2000 through 2013.

Table 5: Top Ten Venture Capital and Private Equity Investors in Fuel Cells, By Company and By Country (Cumulative 1/1/2000-12/31/2013)

Top Ten Fuel Cell Investors		Top Ten Countries with Highest Levels of Private Investment in Fuel Cells	
Company	**Amount (million USD)**	**Country**	**Total All VC and PE Investment (million USD)**
Credit Suisse (Switzerland)	136.2	U.S.	789.9
Kleiner Perkins Caufield & Byers (U.S.)	105.7	U.K.	243.1
New Enterprise Associates (U.S.)	71.0	Switzerland	156.5
Mobius Venture Capital, Inc. (U.S.)	68.2	Canada	73.8
GSV Capital Corp. (U.S.)	54.2	Singapore	50.0
DAG Ventures LLC (U.S.)	54.2	New Zealand	50.0
Rolls-Royce Holdings PLC (U.K.)	50.0	Germany	42.5
Enertek Services Pte Ltd (Singapore)	50.0	Sweden	23.6
Superannuation Fund (New Zealand)	50.0	Russian Federation	21.0
Meditor Capital Management (U.K.)	36.7	Denmark	20.0
Subtotal (top 10 only)	**$676.2**	**Subtotal (top 10)**	**$1,470.4**
TOTAL (All Companies and Countries)			**$1,577.4**

Source: Bloomberg New Energy Finance and the New Zealand Superannuation Fund

Raising Capital/Equity Offerings

Aside from private equity from venture capital firms or industry investment, a number of fuel cell companies raised money to support their R&D, capital expenditures, and/or commercialization efforts by pricing stock shares and making them available to the public. These efforts raised more than $87 million during 2013.

In February 2013, Plug Power priced an underwritten public offering of its common stock and after the sale, raised approximately $2.4 million.[28] In September, Plug Power did the same for more than 18 million shares and raised $9.1 million.[29]

In that same vein, Acta S.p.A. raised £2.1 million (US$3.2 million) gross though the issue and allotment of 30 million ordinary shares with net proceeds used to finance the working capital requirements of the Company's current commercial expansion.[30]

Heliocentris was also successful raising money this way, placing more than 1.7 million new shares in March 2013 equaling gross proceeds of €10.65 million (US$13.6 million).[31]

Also in March, Protonex Technology Corporation received a $2 million credit facility from WindSail CapitalGroup, LLC, which will be used for working capital and sales channel expansion.[32]

In May, Ceramic Fuel Cells Limited raised £4.3 million (US$6.5 million) through the issue of Secured Convertible Loan Notes to a number of institutional investors and £0.7 million (US$1.05 million) through the placing of more than 32 million new ordinary shares of nil par value.[33]

In October, Intelligent Energy raised £31.9 million (US$48 million) in capital to finance the next stages of its development.[34]

In November, Ceres Power secured £1 million (US$1.5 million) in grant funding from the U.K. Department of Energy & Climate Change Energy Entrepreneurs Fund to develop its 'Steel Cell' technology platform.[35] The company also raised money in March through a stock placement.[36]

Industry Investment

There was significant investment in several fuel cell companies from the fuel cell/hydrogen/component industry itself, as well as from other stakeholder companies–totaling $22.5 million during 2013.

- Anglo American Platinum invested $4 million in Ballard Power Systems, through its PGM Development Fund.[37]
- Azure Hydrogen Energy Science and Technology Corporation, Ballard's partner in China, acquired a 10% ownership position in Dantherm Power, Ballard's telecom backup power subsidiary, for $2 million. Following the transaction, Ballard's ownership position in Dantherm Power is 52% and Dantherm A/S holds the remaining 38%.[38]
- Plug Power Inc. received a $6.5 million strategic investment from its partner and hydrogen provider Air Liquide, which included a preferred stock purchase, increased ownership of the companies' HyPulsion joint venture and an engineering services contract.[39]
- Stationary fuel cell manufacturer Bloom Energy partnered with Japanese technology investment firm SoftBank, each investing $10 million to set up a joint venture focused on the Japanese market.[40]

Intellectual Property

The Clean Energy Patent Growth Index report from the Cleantech Group-Heslin Rothenberg Farley & Mesiti P.C. tracks the intellectual property of the clean energy sector and provides detailed coverage on the different sectors involved, including fuel cells.[41]

In 2013, solar patents overtook fuel cells for the first time since 2002. There were 886 patents awarded to the fuel cell industry in 2013 (solar had 965), down from 1024 in 2012.

Automakers dominated. General Motors (GM) received the most fuel cell patents for the third year in a row, with 128. Toyota had the second highest with 110. Honda had 52, putting it in fourth place behind Samsung, but overall the company is number two as far as cumulative patents since 2002. By that measure, GM is also number one. Approximately 300 different entities were granted fuel cell patents in 2013. The Top Ten are highlighted in Figure 3.

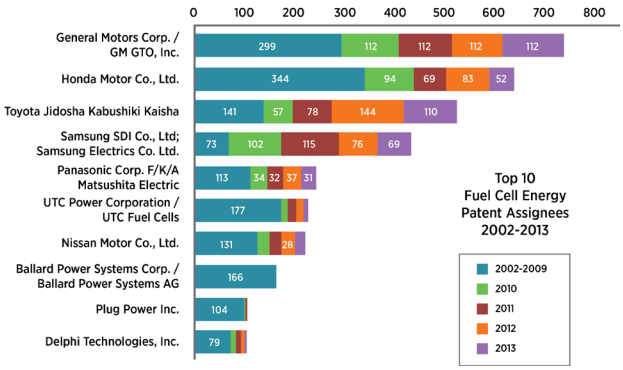

Figure 3: Top Ten U.S. Fuel Cell Patent Assignees (2002-2013)
Source: Heslin Rothenberg Farley & Mesiti P.C.

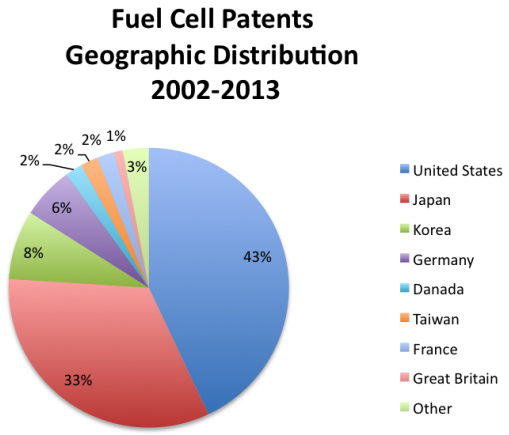

Figure 4: Fuel Cell Patents Geographic Distribution (2002-2013)
Source: Heslin Rothenberg Farley & Mesiti P.C.

The U.S. won back the title for most fuel cell patents in 2013 with 317 and since 2002, has boasted an impressive 43% of the world's fuel cell patents.

At the state level, Michigan led the country with 139 patents, up 14 from last year. The rest of the top five, California, Connecticut, Massachusetts and Ohio, have a cumulative total that is less than Michigan on its own.

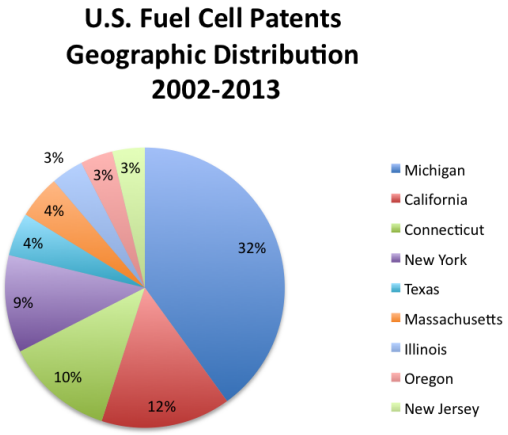

Figure 5: U.S. Fuel Cell Patents Geographic Distribution (2002-2013)
Source: Heslin Rothenberg Farley & Mesiti P.C.

Revenue

In 2013, fuel cell industry sales broke the billion dollar mark, with revenues of approximately $1.3 billion (Figure 6). Fuel cell system revenues grew by 35% over 2012, with significant growth seen both in North America, with a revenue increase of about 50% over 2012, and Asia, with about 33% growth over 2012. Europe showed a slight decline in fuel cell system revenues.

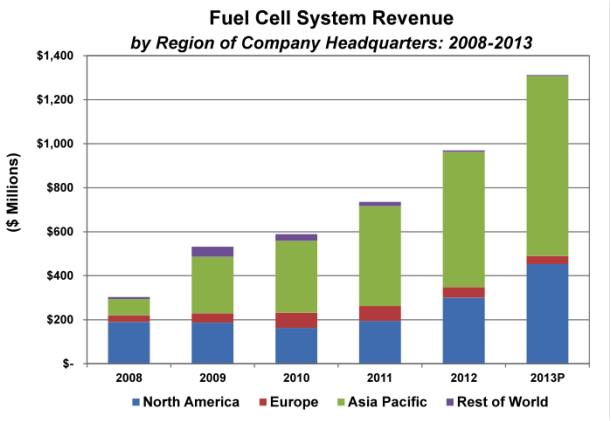

Figure 6: Fuel Cell System Revenue by Region of Company Headquarters (2008-2013)
Source: Navigant Research. 2013P = Projected for 2013

Shipments

Globally, fuel cell system shipments increased by 26% over 2012 (Figure 7) and the number of megawatts shipped grew by 19% (Figure 8). The stationary fuel cell market continues to develop, with more than 26,000 Ene-Farm residential fuel cell units deployed in Japan during 2013.

There have been a growing number of megawatt-scale shipments by three U.S. fuel cell manufacturers, Bloom Energy, ClearEdge Power and FuelCell Energy. About 150 MW of stationary fuel cells were shipped worldwide in 2013, an increase of about 24% over 2012 and 244% more than in 2008.

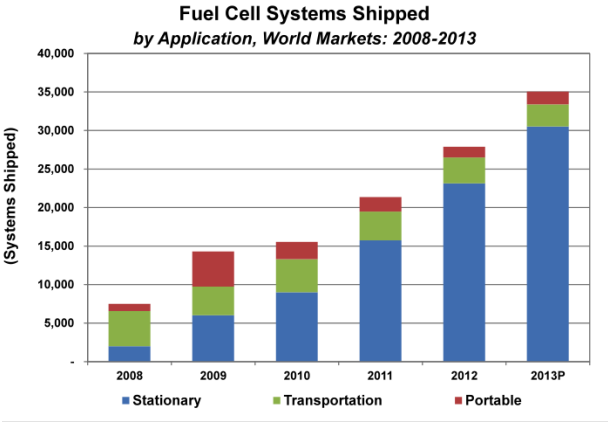

Figure 7: Fuel Cell System Shipments by Application, World Markets (2008-2013)
Source: Navigant Research. 2013P = Projected for 2013

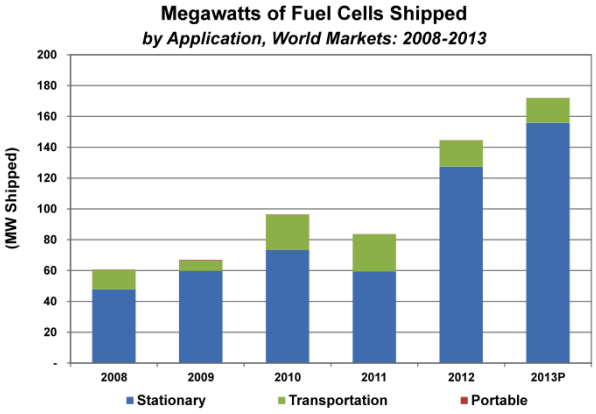

Figure 8: Megawatts of Fuel Cells Shipped by Application, World Markets (2008-2013)
Source: Navigant Research. 2013P = Projected for 2013
Note: Portable shipments are less than 1 MW for each year.

There was a 17% year-to-year decrease in the number of U.S. fuel cell shipments during 2013 (Figure 9), but at the same time megawatts shipped from the U.S. grew by 2% (Figure 10)–meaning that fewer, but larger, fuel cells were shipped by U.S. fuel cell manufacturers. A marked increase was seen in the number of fuel cell systems shipped from Japan, in large part attributed to the Japanese Ene-Farm residential fuel cell program. South Korea also showed significant growth in the number of megawatts shipped during 2013, reflecting the large-scale fuel cell units manufactured in that country through the partnership of POSCO Energy and FuelCell Energy.

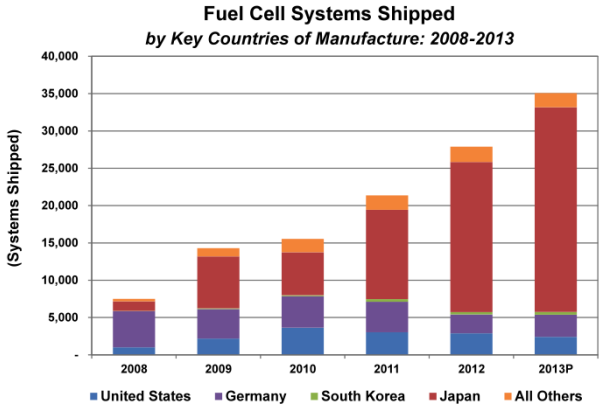

Figure 9: Fuel Cells Shipped By Key Countries of Manufacture (2008-2013)
Source: Navigant Research. 2013P = Projected for 2013

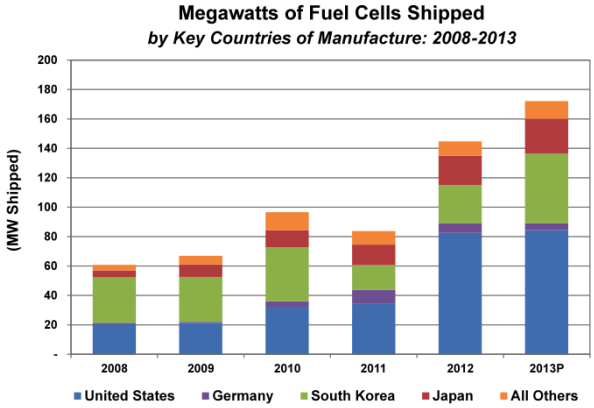

Figure 10: Megawatts of Fuel Cells Shipped By Key Countries of Manufacture (2008-2013)
Source: Navigant Research. 2013P = Projected for 2013

Overall, total North American fuel cell systems shipped declined by 7% (Figure 11), attributed to a roughly 26% decrease in shipments of fuel cells for transport, which includes both passenger vehicles and material handling equipment. Hyundai began deliveries of its ix35 fuel cell electric vehicle to European customers in 2013 (U.S. shipments will start in 2014), but shipments of fuel cell electric vehicles in the U.S. and globally remained low as major auto manufacturers (Honda, Toyota) prepare for the commercial release of their fuel cell electric vehicles into global markets, starting with California, Germany and Japan, beginning in 2015-2017.

The end of the federal American Recovery and Reinvestment Act (ARRA) funding likely led to the decline of fuel cell forklift shipments during 2013, a decline expected to be reversed in 2014. Fuel cell forklift shipments, which grew in the U.S. after receiving a boost from ARRA, encouraged a number of companies to deploy partial or total fuel cell fleets during the period 2009-2012. Their experience with fuel cells led a number of companies to purchase additional units for the same site, or to deploy fuel cells at new warehouse locations. Additional orders, including a large order from Walmart, and growing international interest in fuel cell-powered forklifts will likely boost shipments in 2014.

The number of fuel cell systems shipped from North America grew for both stationary and portable fuel cell applications.[42] Corporations such as eBay, Apple, and Microsoft have recognized the benefits of reducing reliance on the power grid, using onsite stationary fuel cells to deliver high quality, reliable power to data centers. U.S. energy utilities are also turning to fuel cell power plants to generate megawatt-scale power for the electric grid. Portable fuel cell markets are expanding, particularly for remote power applications.

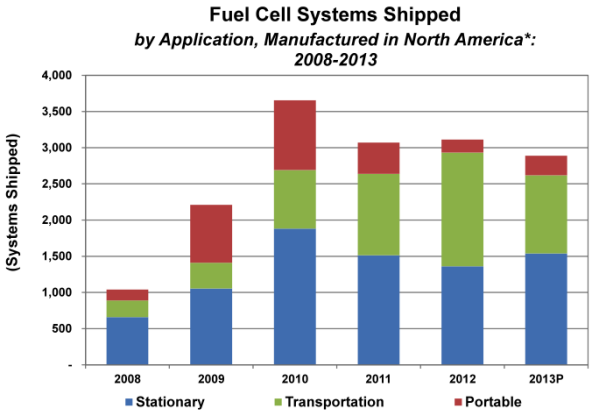

Figure 11: Fuel Cells Shipped – Manufactured in North America, by Application (2008-2013)
Source: Navigant Research. 2013P = Projected for 2013
Note: Shipments are from the U.S. and Canada.

Asian fuel cell shipments grew by 3%, driven by the stationary fuel cell markets in Japan and South Korea (Figure 12). The Japanese government wants to deploy 1.4 million residential Ene-Farm fuel cell units by 2020 and 5.3 million by 2030, and is currently providing financial support to buyers. This has helped to spur sales of 200 watt-700 watt units from several manufacturers—with more than 26,000 units sold during fiscal year 2013. In addition, South Korean energy provider POSCO Energy is licensed to manufacture FuelCell Energy's Direct

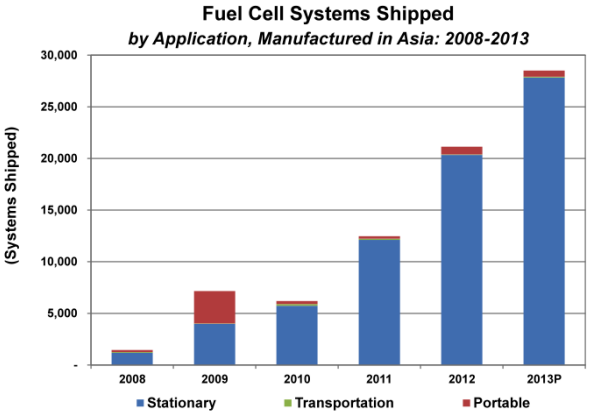

Figure 12: Fuel Cells Shipped – Manufactured in Asia, by Application (2008-2013)
Source: Navigant Research. 2013P = Projected for 2013

FuelCell® products in South Korea for sale in Asia, with many megawatts of fuel cells planned in 2014 to generate electricity for the South Korean power grid, and byproduct heat that will be sourced to district heating systems.

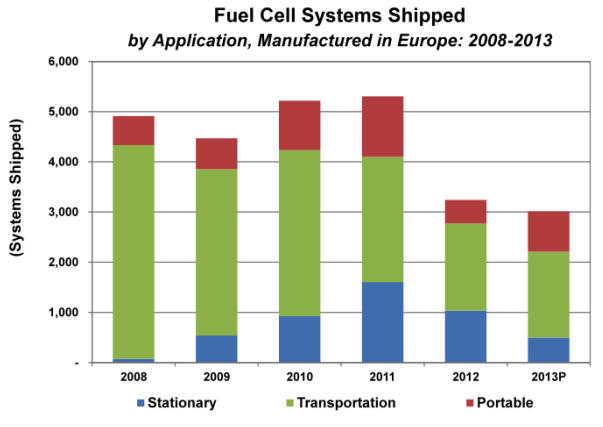

Figure 13: Fuel Cells Shipped – Manufactured in Europe, by Application (2008-2013)
Source: Navigant Research. 2013P = Projected for 2013

Total shipments of European fuel cell systems declined by 7% (Figure 13) attributed to a year-to-year decrease of about 50% in the number of stationary fuel cell shipments. Shipments of portable fuel cell systems increased by more than 8%, attributed to an increase in the use of fuel cells in remote monitoring systems, in applications such as light detection and ranging (LIDAR) for the wind industry, supervisory control and data acquisition (SCADA) for the oil and gas industry, and a range of remote monitoring for environmental applications (e.g. weather stations, remote wildlife monitoring stations).

Government Policy, Standards, and Regulation

The year 2013 saw a change of leadership at the U.S. Department of Energy (DOE).[43] Early in the year, Ernest Moniz was confirmed as Secretary of Energy. Moniz, a physicist, directed the Energy Initiative at the Massachusetts Institute of Technology (MIT).

In April, the Obama Administration proposed a new Energy Security Trust (EST), a 10-year, $2 billion program designed to invest in breakthrough

research into a range of cost-effective technologies, including FCEVs. Although the EST was not approved by Congress in 2013, it placed hydrogen and fuel cells on par with other major clean energy technologies as shown in Figure 14.

In May 2013, DOE and others led the launch of H_2USA,[44] a public-private partnership consisting of automakers, government agencies, gas suppliers, and the hydrogen and fuel cell industries to coordinate research and identify cost-effective solutions to deploy the hydrogen infrastructure in the United States. Through H_2USA, industry and government partners will focus on identifying actions to encourage early adopters of fuel cell electric vehicles, conduct coordinated technical and market analysis, and evaluate alternative fueling infrastructure that can enable cost reductions and economies of scale. After the initial launch, other organizations followed suit and joined in August 2013.[45] A full list of H_2USA members can be found in Appendix I.

In September, DOE opened the Energy Systems Integration Facility (ESIF), a 182,500-square-foot facility at the National Renewable Energy Laboratory (NREL) in Golden, Colorado, to help public and private sector researchers promising clean energy technologies and test how they interact with each other and the electric power grid at utility-scale. ESIF includes a state-of-the-art Fuel Cell Development and Test Laboratory.[46]

DOE, through its Energy Efficiency and Renewable Energy (EERE) Fuel Cell Technologies Office, also funded numerous projects at fuel cell companies, universities and other organizations to help further fuel cell and hydrogen research, development and deployment. This includes funding through Funding Opportunity Announcements and the Small Business Innovation Research/Small Business Technology Transfer (SBIR/STTR) program. The Advanced Research Projects Agency (ARPA-E) at DOE also funded several projects in 2013. See Table 6 for a complete list.

Table 6: U.S. Department of Energy (DOE) 2013 Funding Awards

Company	Project	Award
3M	To develop innovative fuel cell membranes with improved durability and performance using processes which are easily scalable to commercial size.	$3,000,000
Air Products and Chemicals, Inc.	Will partner with Structural Composites Industries to develop a cost-effective tube trailer for hydrogen delivery and storage that can withstand high pressures. Air Products and Chemicals will also test this new technology under real-world operating conditions at hydrogen fueling stations in southern California.	$900,000
Applied Nanotech, Inc.	SBIR/STTR - Hydrogen Leak Detector for Hydrogen Dispenser	$149,967
Bio2Electric, LLC	ARPA-E - Methane Converter to Electricity and Fuel	$601,860
Center for Transportation and the Environment	To develop a fuel cell hybrid electric walk-in delivery van with a 150-mile range per fueling. The project will also retrofit 15 UPS delivery vans with fuel cell hybrid power trains and test these vehicles at distribution facilities across California. The University of Texas's Center for Electromechanics, Electric Vehicles International, Hydrogenics USA and Valence Technology will also participate in this project.	$3,000,000
Ceramatec, Inc.	ARPA-E - Mid-Temperature Fuel Cells for Transportation Applications	$2,113,985

Colorado School of Mines	To develop advanced hybrid membranes for cutting edge, next-generation fuel cells that are simpler, more affordable and able to operate at higher temperatures.	$1,500,000
Composite Technology Development, Inc.	SBIR/STTR - Optimizing the Cost and Performance of Composite Cylinders for H2 Storage using a Graded Construction	$154,991
FedEx Express	To develop a fuel cell delivery truck with a range of up to 150 miles per hydrogen fueling and test 20 of these trucks at FedEx facilities in Tennessee and California. Plug Power and Smith Electric Vehicles will join FedEx in this project.	$3,000,000
FuelCell Energy	Continue research and development on a demonstration sub-megawatt SOFC power plant.	$6,400,000
Gas Technology Institute	ARPA-E - Methane to Methanol Fuel: A Low Temperature Process	$772,897
Giner, Inc.	SBIR - Nanostructured Catalysts for Alkaline PEM Fuel Cells	$149,981
Giner, Inc.	SBIR - High-Performance, Long-Lifetime Catalysts for Proton Exchange Membrane Electrolysis	$999,983
LG Fuel Cell Systems, Inc.	To advance LG's SOFC technology and further develop the LGFCS laboratory	$5,100,000
Nanosonic, Inc.	SBIR/STTR - Cryogenically Flexible, Low Permeability Thoraeus Rubber H2 Dispenser Hose	$150,000
Nextgen Aeronautics, Inc.	SBIR/STTR - 4b Low-cost Integrated Nanoreinforcement for Composite Tanks (LINCT)	$149,949
Nuvera Fuel Cells	To demonstrate the use of hydrogen fuel cells to power transport refrigeration units (TRUs). Nuvera will work with Thermo King to integrate its Orion™ fuel cells in a refrigerated trailer that will run for at least 400 hours while supporting two sites, making deliveries for a Sysco food distribution facility in Riverside, California, and for H-E-B's food distribution center in San Antonio, Texas. The Sysco and H-E-B facilities already have fuel cell forklifts in operation with hydrogen infrastructure already in place, provided by Nuvera's PowerTap™ hydrogen generator and refueling system. PNNL will also oversee this demonstration.	$650,000
Plug Power	TRU demonstration. Plug Power's TRU fuel cells, based on its GenDrive™ system, will cool Carrier Transicold refrigeration units on trailers delivering products for a Sysco Corp. distribution center on Long Island. Each TRU will run for a minimum of 400 hours over the two-year contract period. Hydrogen will be supplied by Air Products. Researchers at the Pacific Northwest National Laboratory (PNNL) will oversee the program.	$650,000
Proton Energy Systems	SBIR - Economical Production of Hydrogen Through Development of Novel, High Efficiency Electrocatalysts for Alkaline Membrane Electrolysis	$1,000,000
Proton Energy Systems	STTR - Low-Noble-Metal-Content Catalysts/Electrodes for Hydrogen Production by Water Electrolysis	$1,000,000

Proton OnSite	Single Step Manufacturing of Low Catalyst Loading Electrolyzer MEAs	$150,000
Sprint	To deploy fuel cell-powered backup power systems for rooftop telecommunications equipment. The project will demonstrate modular and lightweight fuel cell systems that can be easily installed without heavy cranes and can be refueled from the ground, overcoming the need for transporting fuel to rooftops. Air Products, Altergy Systems, Burns & McDonnell Engineering Inc., CommScope Inc., First Element Energy LLC, IGX Group, Inc. and ReliOn Inc. will also participate in this project.	$250,000
Strategic Analysis	To analyze and evaluate potential cost-competitive pathways for producing and transporting hydrogen fuel.	$1,000,000
Texas A&M University - Engineering Experiment Station	ARPA-E - Generating Electricity from Waste Heat Using Metal Hydrides	$1,700,000
Treadstone Technologies	SBIR/STTR- Novel Structured Metal Bipolar Plates for Low Cost Manufacturing	$149,831
TOTAL		**$34,558,544**

State Policies and Funding

California continues to lead the United States with policies and funding programs that advance fuel cells and hydrogen infrastructure. In February, California issued the 2013 ZEV Action plan that identifies specific strategies and actions state agencies will take to meet a goal of 1.5 million ZEVs on the state's roadways by 2025. In September, the governor of California signed Assembly Bill 8 (AB8) into law.[47] AB8 provides funding for at least 100 hydrogen stations with a commitment of $20 million a year from the Alternative and Renewable Fuel and Vehicle Technology Program (ARFVTP). The funding comes from fees on motor vehicles, boat registrations, and new tires.

Prior to the passage and signing of AB8, in June, the California Energy Commission (CEC) approved $18.69 million in grants to build new and upgrade existing hydrogen fueling stations around the state. The companies receiving funding include the South Coast Air Quality Management District, Linde LLC, Hydrogen Frontier, Inc., Air Products and Chemicals, Inc., and Air Liquide Industrial US LP.[48]

To help pave the way for the commercialization and rollout of fuel cell electric vehicles (FCEVs), the governors of California, Connecticut, Massachusetts, Maryland, New York, Oregon, Rhode Island and Vermont signed a Memorandum of Understanding[49] to coordinate actions to support and ensure the successful implementation of their state's ZEV programs that support battery and FCEVs. The initial Signatory States have agreed to a collective target of having at least 3.3 million zero emission vehicles in their states by 2025 and pledged to work together to establish a fueling infrastructure that will adequately support this number of vehicles.[50]

Elsewhere, the New Jersey Economic Development Authority and the New Jersey Board of Public Utilities launched the second round of the Large Scale CHP/Fuel Cell Program in January 2013, with a goal to enhance energy efficiency through on-site power generation with recovery and productive use of waste heat, and to reduce existing and new demands on the electric power grid. The program supports CHP and standalone fuel cell projects with a generating capacity of greater than 1 MW with up to $3 million available per project.[51]

In response to power and system outages due to recent hurricanes and storms, Connecticut's Department of Energy and Environmental Protection (DEEP) Microgrid Pilot Program awarded $18 million to nine microgrid projects,

including two involving fuel cells. The city of Storrs will receive $2.14 million for a fuel cell and solar power project for the University of Connecticut, Depot campus, and the city of Woodbridge is slated for $3 million for a project including a natural gas turbine and a fuel cell for the police station, fire station, Department of Public Works, town hall and high school.[52] Connecticut also released its 2013 Comprehensive Energy Strategy, reporting that the state will need to increase the amount of class I energy resources (fuel cells, solar, wind) to meet the state's renewable portfolio standard (RPS) goal of 20% renewable generation by 2020.

International Activities

Overseas, the European Commission also proposed to renew and strengthen the Fuel Cell and Hydrogen Joint Undertaking (FCH JU) with a budget of €1.4 billion (US$1.8 billion) until 2024. This is a 27% increase in the government's commitment over the last phase of the program.[53,54]

The European Commission published the first part of its call for 2013 proposals for FCH JU, under the EU's Seventh Framework Programme. The call has a budget of €68.5 million (US$87.5 million) and consisted of 27 topics under five areas of research: transportation and refueling infrastructure; hydrogen production and distribution; stationary power generation and CHP; early markets; and cross-cutting issues such as social acceptance, education, performance test schemes, and guarantees of origin.[55]

Japan's 2013 research, development and deployment (RD&D) budget for fuel cells and hydrogen was ¥36.83 billion (US$363 million), almost double the 2012 budget.[56] In December, Japan's government allocated ¥7.2 billion (US$71 million) to build hydrogen fueling stations starting in FY2014.[57]

The U.K.'s Office of Low Emission Vehicles published ***Driving the Future Today – A Strategy for Ultra Low Emission Vehicles in the U.K.***, which recommends a funding commitment of more than £500 million (US$752 million) of new capital investment between 2015 and 2020 to continue to establish the U.K. as a premier market for ultra-low emission vehicles.

The U.K. and South Korea entered into a new Memorandum of Understanding in November 2013 to strengthen cooperation in hydrogen and fuel cell research.

The International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE) agreed to continue the partnership beyond the original ten year commitment. Japan took over as Chair with the United States and Germany as Vice Chairs.

Applications and Market Assessment

In several early markets, fuel cells are proving to be not only cost-effective, but often invaluable, due to the technology's ability to provide resilient, reliable power, flexible siting and long-running operation. Fuel cells now boast a long and impressive list of corporate heavyweights as customers, including many repeat customers that are purchasing and installing systems for multiple locations as well as in multiple applications.

In 2013, fuel cells were the go-to technology of choice for many customers to power large data centers, company headquarters, material handling equipment, telecommunications towers and networking equipment. The number of markets for fuel cells continues to grow, and promising demonstrations are under way, financed by DOE, involving zero-emission trucks at ports, power generation and mobile applications at airports, and power for refrigerated trailers used to transport food and other perishables.

Stationary Power

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

Prime Power

In 2013, several major corporations embraced fuel cells to support key data centers, with some even bypassing grid power to ensure reliability and resiliency. Several notable data center fuel cell installations were completed in 2013, including First National Bank of Omaha, eBay, Microsoft, and Equinix.

FuelCell Energy increased the annual production rate of its North American manufacturing facility by 25% during 2013, to 100 MW. In addition, total capacity was increased 11% to 100 MW as FuelCell Energy's team implemented process improvements utilizing lean manufacturing principles and six sigma practices.[58]

Table 7: Examples of Commercially Available Stationary Fuel Cells 2013

Prime Power and m-CHP			
Manufacturer	**Product Name**	**Type**	**Output**
Ballard Power Systems (Canada)	ClearGen	PEM	Multi-500 kW power banks
Bloom Energy (U.S.)	ES-5400	SOFC	100 kW
	ES-5700	SOFC	200 kW
	UPM-570	SOFC	160 kW
Ceramic Fuel Cells Ltd. (Australia)	BlueGen	SOFC	2 kW
	Gennex	SOFC	1.5 kW
ClearEdge Power (U.S.)	PureCell System Model 5	PEM	5 kW
	PureCell System Model 400	PAFC	400 kW
Elcore GmbH (Germany)	Elcore 2400	HT-PEM	300 watts (W)
ENEOS CellTech (Japan)	Ene-Farm	PEM	250-700 W
FuelCell Energy (U.S.)	DFC 300	MCFC	300 kW
	DFC 1500	MCFC	1,400 kW
	DFC 3000	MCFC	2,800 kW
	DFC-ERG	MCFC	Multi-MW
Fuji Electric (Japan)	FP-100i	PAFC	100 kW
Panasonic (Japan)	Ene-Farm	PEM	200-750 W
Toshiba (Japan)	Ene-Farm	PEM	250-700 W

Table 8: Summary of FuelCell Energy Projects 2013*

Location	Capacity	Notes
Dominion Fuel Cell Park, Bridgeport, CT	14.9 MW	Five 2.8 MW DFC3000® fuel cells. Connecticut Light & Power Co. (CL&P) will buy the electricity generated by the Dominion-owned facility under a 15-year, fixed-price energy purchase agreement.
Hartford Hospital, Hartford, CT	1 MW	Sold to Hartford Steam Company. Excess heat not used by the hospital will be supplied to the district heating system in Hartford that serves the Learning Corridor Corporation, a magnet school system.
Microsoft, Cheyenne, WY	300 kW	Data Plant pilot project – fuel cell will run on biogas generated from local Water Reclamation Facility and will operate grid-independent to provide continuous power to the data center in the event of a grid outage. Any excess power will be provided to the water reclamation facility to offset their electric costs.
NRG Energy, Montville, CT	5.6 MW	FCE entered into a co-marketing agreement with NRG Energy for the marketing and sales of its fuel cell power plants to NRG's customer base. NRG is installing 5.6 MW of FCE fuel cells and 2.3 MW of solar to create a renewable energy park.
Elektrizitaetswerke Zurich (ewz), Switzerland	300 kW	FCE will operate and maintain the power plant in collaboration with ewz and will supervise the plant from a European-based center staffed 24 hours a day.
Federal Ministry of Education and Research (BMBF), Germany	300 kW	Installed and manufactured by FCE, the fuel cell will provide approximately 40% of the electrical needs and 20% of the thermal needs of the facility.
Gyeonggi Green Energy Fuel Cell Park, Hwasung City, South Korea	59 MW	21 DFC3000® power plants make up the fuel cell park, delivering power to the electric grid and steam to a district heating system.
Tri-generation power plant, Vancouver, Canada	300 kW	Entered into contract to demonstrate a tri-generation stationary fuel cell power system utilizing landfill gas as the fuel source. The hot water created by the system will be supplied to Village Farms, a hydroponic greenhouse operator in British Columbia, and the renewable hydrogen will be exported for vehicle fueling or industrial applications.
TOTAL	**81.7 MW**	

* Based on publicly available data

Bloom Energy expanded its list of customers and installations in 2013. Most customers are located in California, but since opening its new manufacturing facility in Newark, Delaware, the company has seen interest and growth on the East Coast (Table 9).

Table 9: Summary of Bloom Energy Projects 2013*

Location	Capacity	Notes
AC Transit, Oakland, CA	400 kW	Fuel cells are fueled by biogas collected from landfills to supply electricity to the entire facility as well as to an electrolyzer to produce hydrogen for the agency's fuel cell buses.
American Honda, Torrance, CA	1 MW	Provides 25% of the electricity needs for 1.13 million square feet (sq. ft.) of office space, research, design and development operations, and parts distribution center.
Anaheim Ducks (Honda Center), Anaheim, CA	750 kW	The fuel cells will provide 80% of the venue's base load power and 25% during a Ducks game or concert. Financed by new leasing program with Bank of America Merrill Lynch.
AT&T, Numerous Sites, CA, CT	5.5 MW	Part of larger 17.5 MW order.
CenturyLink, Irvine, CA	500 kW	To power cloud, managed hosting and colocation services housed at data center.
eBay, South Jordan, UT	6 MW	Powers eBay's data center.
Delmarva Power, New Castle, DE	27 MW	Delmarva Power operates a total 30 MW of fuel cells at substations throughout Delaware, the largest utility-scale deployment of fuel cell technology in the U.S.
JPMorgan Chase, Morgan Christiana, DE	500 kW	Supporting data center.
Kaiser, Baldwin Park, CA	300 kW	Kaiser committed to installing 4 MW at seven sites in California.
Kellogg's, San Jose, CA	1 MW	Fuel cell will produce approximately half of the annual electrical consumption at an Eggo® bakery.
Life Technologies, Pleasanton, CA	1 MW	The fuel cells were installed in an uninterruptible power configuration to protect Life Technologies' labs, freezers, and critical experiments and provide 60% of the electricity needs for the facility. The company installed a 1 MW system at its Carlsbad, California, facility in 2012.
Macy's, Cheshire, CT	600 kW	Replaces most grid-produced power at distribution center.
New York City Hall, New York City, NY	100 kW	Installed as part of former New York Mayor Bloomberg's green initiative and $148 million multi-phase renovation of city.
Ramar Foods International, Pittsburg, CA	200 kW	The fuel cell will provide 65% of electricity needs of the food-manufacturing plant; the company expects to save at least $15,000 a month in electricity costs.
Roll Global, Los Angeles, CA	200 kW	Roll has installed a total of 4.6 MW of Bloom Energy fuel cells at various sites around California.

TaylorMade-adidas, Carlsbad, CA	300 kW	Fuel cell installed at manufacturing facility is financed by new leasing program with Bank of America Merrill Lynch.
Verizon, Los Angeles, San Jose, CA	1 MW	Two call-switching centers in Los Angeles and San Francisco and a data center in San Jose.
Walmart, Numerous sites	3.2 MW	Walmart installed its first Bloom Energy Server at its Lancaster, California store in 2009 and now has 35 installations at stores and distribution centers in California, totaling 11.4 MW.
SoftBank M-Tower, Fukuoka, Japan	200 kW	Bloom's first international installation, from the joint venture between Bloom and SoftBank, Bloom Energy Japan.
TOTAL	**81.7 MW**	

*Also includes installations from 2012 made public in 2013 and not included in the 2012 report. Based on publicly available data.

ClearEdge Power, which provided UTC's PureCell®Model 400 fuel cell systems under its own brand, saw sales in Korea as well as the U.S. in 2013 (Table 10).

Table 10: Summary of ClearEdge Power Projects 2013

Location	Capacity	Notes
First National Bank of Omaha, Omaha, NE	400 kW	First National Bank boasts one of the longest running fuel cell installations (since 1999) and was the first data center in the world to generate power via fuel cells. The new fuel cell is installed in the main floor of the building.
Lewis and Clark College	1 MW	Sold to Hartford Steam Company. Excess heat not used by the hospital will be supplied to the district heating system in Hartford that serves the Learning Corridor Corporation, a magnet school system.
Portland, OR	5 kW	Will be located at the Godfrey campus' Alternative Energy Production Center.
Verizon, Various sites in CA, NJ & NY	8 MW	Verizon is investing $100 million in a solar and fuel cell energy project and will install fuel cells at a mix of Verizon buildings, including corporate offices, call centers, data centers, and central offices.
Western Connecticut State University, Danbury, CT	400 kW	Powering the Science Building at University's Midtown campus. Expected to save $25,000 a year.
Busan International Finance Center's Landmark Tower, Busan, South Korea	400 kW	The fuel cell is installed in the basement and marks the fourth project on which ClearEdge Power has partnered with Samsung Everland and the first PureCell system installation in the city of Busan.

Ballard Power Systems has entered the large-scale stationary market with its 175 kW ClearGen™ fuel cell system. In 2013, Ballard sold one to the Blue Lake Rancheria Tribe of Humboldt County, California,[59] to integrate with a biomass gasifier and syngas purification unit. The system converts locally-grown timber by-products into hydrogen-rich syngas, using pyrolysis gasification technology. This syngas is purified, resulting in a high quality hydrogen stream, which is used to power the ClearGen™ fuel cell system. The plant will provide base load power for the Tribe's commercial enterprises; by-product heat will be used to warm the swimming pool in an adjacent hotel. Ballard also sold a 175 kW ClearGen™ system to Azure Hydrogen Energy Science and Technology Corporation,[60] its partner in China.

In Germany, Equinix installed a 100 kW Fuji Electric fuel cell system to generate energy for its data center in Frankfurt.[61] The fuel cell, supplied by N2telligence, is designed to also provide fire suppression by managing the oxygen level in the room, leaving enough oxygen for staff to breathe comfortably but not enough oxygen to support a fire.

GEI Global Energy Corp., a new high temperature fuel cell company created when Suja Minerals acquired Global Energy Innovations, entered into a Letter Of Intent with developer Owl Eco Group, to build a 100 MW (1,000 100 kW units) power plant in the natural gas shale fields of Western Pennsylvania.[62]

Another new company, Redox Power Systems LLC,[63] which spun out of the University of Maryland, has developed an SOFC system, the PowerSERG 2-80, also called "The Cube," and plans to release a 25 kW version of the fuel cell in 2014.

Widmer Brothers Brewing is testing a small-scale fuel cell developed by researchers at Oregon State University at its Portland brewery, using it to treat about 1,000 gallons of wastewater a day while generating electricity.[64] The project received a $150,000 grant from Oregon Built Environment & Sustainable Technologies (OregonBEST).

Solid Cell won a fourth grant ($200,000) from the New York State Energy Research and Development Authority (NYSERDA) to help develop its solid oxide fuel cell (SOFC) from prototype to commercialization.[65] Solid Cell will match the grant dollar-for-dollar with help from RocCera, a company specializing in advanced ceramic component manufacturing, and Alfred University's NanoMaterials Innovation Center.

Micro Combined Heat and Power

M-CHP fuel cell systems are making an inroad in the residential markets in Europe and Japan. Japan's Ene-Farm program has sold more than 65,000 units since it began in 2009.[66] Panasonic, one of the makers of Ene-Farm fuel cell units, announced that it will start to sell m-CHP fuel cells in Germany, in partnership with heating system manufacturer Viessmann, in 2014.

Panasonic and Tokyo Gas launched the latest version of their Ene-Farm residential fuel cell unit in April 2013. The fuel cell has a 60,000 hour lifetime and costs ¥1,995,000 (US$19,650), which is ¥760,000 (US$7,486) lower than its earlier Ene-Farm model.[67] The companies also have developed an Ene-Farm system for condominiums, with the fuel cell, hot water unit and backup heat source stored in the pipe shaft of the condominium.[68]

U.K. hospitality company Whitbread installed a Baxi Commercial fuel cell at its Glastonbury Premier Inn, which opened in early 2013, to provide approximately 20% of the total hot water demand. The Baxi fuel cell is the first U.K.-based trial under the EU's ene.field project, which plans to deploy 1,000 fuel cell systems from nine European manufacturers in 12 EU member countries.

Also part of the ene.field project, German fuel cell company Elcore installed its Elcore2400 unit in a German house. Elcore also entered into a partnership with the Thüga-Group, a network of municipal energy and water companies, and will initially install seven Elcore 2400 fuel cell systems around the country.

Another ene.field member, Bosch Thermotechnology, announced plans to launch a residential fuel cell m-CHP unit in 2014 in Germany, France, the U.K. and The Netherlands. It will purchase SOFC technology from Aisin Seiki and initially will be targeting one- and two-bedroom homes.

In Berlin, a fuel cell was installed at the Federal Ministry of the Environment (Bundesministerium für Umwelt, BMU) as part of the German Callux program, run by the National Innovation Program for Hydrogen and Fuel Cell Technology (NIP), and supported by NOW, the National Organization Hydrogen and Fuel Cell Technology.[69] The Callux program is another field test for fuel cell heating systems for domestic use, launched with partners from industry and supported by the German Federal Ministry of Transport and Digital Infrastructure. Up to 500 fuel cell heating appliances were to be installed by the end of 2013 and operated in some cases until 2015.[70]

In 2013, Australia's Ceramic Fuel Cells Limited (CFCL) began offering its BlueGen fuel cell m-CHP unit free to qualified schools and businesses in the U.K., using feed-in tariff income to allow for the fully funded installation.[71] The company also received a number of orders to provide units for installations and field trials across Europe (Table 11).

Table 11: Summary of Ceramic Fuel Cells Limited Projects 2013

Company or Project	Region	Notes
Alliander AG	Germany	Up to 600 BlueGen systems to be installed across Alliander's regional grids in Germany by 2015.
Energy Services Company (ESCo) iPower Energy Limited	U.K.	200 BlueGen units in 2013 and an additional 200 BlueGen units during 2014 for the social housing sector.
EWE	Germany	60 units to complete demonstration program.
National Grid Affordable Warm Solutions (National Grid AWS)	U.K.	National Grid AWS and CFCL have formed a partnership for the delivery of 10 BlueGEN m-CHP systems for installation at social housing partners in the U.K.
Novogaz SA	Switzerland	Agreement continues the companies' cooperation that began in 2010 with a BlueGen field testing exercise.
Solar Spirit	Belgium	Distribution agreement.
Synergy International OÜ	Baltic States, Scandinavia	Minimum of 1,000 BlueGen m-CHP units over two years.
Virtual Power Plant (VPP) Project	The Netherlands	45 BlueGEN fuel cell m-CHP appliances will generate electricity on the island of Ameland.

IE-CHP Ltd., the joint venture between Intelligent Energy (IE) and Scottish and Southern Energy (SSE), received CE certification for its 10 kW CHP fuel cell system.[72]

Korea may also present a new market for fuel cell m-CHP. U.K.-based Ceres Power Holdings plc signed a commercial and technical partnership with South Korean boiler manufacturer KD Navien Co. Ltd. to carry out trials of the Ceres 1-kW natural gas fuel cell at its facility in Seoul and engage in the first stages of design of a m-CHP product for Korea's residential market.[73]

Backup and Remote Power

Following the lead of major telecommunications companies in the U.S. such as AT&T, Sprint, and T-Mobile/ MetroPCS, there has been a recent surge in orders, sales and deployments of fuel cells in international markets– Latin America, the Caribbean, Indonesia, India, the Middle East, Africa, Japan and China. There has also been an increase in the number of fuel cell manufacturers and integrators introducing products and entering partnerships with telecommunications companies around the world.

Italian company Acta S.p.A. saw multiple orders from telecommunications companies and distributors in several countries (Table 12).

Table 12: Summary of Acta S.p.A. Backup Power Projects 2013

Partner	Country	Notes
Unnamed international mobile telecommunications company	Africa	Acta sold its first fuel cell backup system for a three-month onsite trial for base station.
Shanghai Sunwise Energy Systems Co. Ltd.	China	Distribution partnership for electrolyzers and back-up power systems in China.
MVS Energy Solutions	India	Acta signed distribution agreement for its electrolyzers in India.
Cascadiant	Indonesia	Acta received its first purchase order from Cascadiant for a rack-mounted 300 L/hr electrolyzer unit for evaluation for telecom backup in Indonesia.
Lead Core Technology Systems Inc.	Philippines	Trial of backup power system at telecom base station
SMS Global Technologies Inc.	Philippines	Two month trial of backup power system at telecom base station.
M-Business Resourcing Sdn Bhd	Southeast Asia – Indonesia, Malaysia, Singapore	Commercial sales partner.

Ballard Power Systems completed the commissioning of 796 ElectraGen systems and shipped 500 fuel cell stacks to customers in 2013. Table 13 summarizes new orders received by Ballard and its subsidiary, Dantherm Power, in 2013.

Table 13: Summary of Ballard/Dantherm Projects 2013

Partner/Country	# of Units	Notes
Acta S.p.A./Isle of Wight	1	Part of EcoIsland energy storage project. Acta is incorporating its EL500 electrolyzer with Dantherm's 5-kW fuel cell system to generate hydrogen directly from the solar panels on a home.
Azure Hydrogen Energy Science and Technology Corporation, China	220	Ballard and Azure signed an Equipment Supply Agreement for the supply of 220 ElectraGen™ fuel cell systems (120 ElectraGen™-H2 and 100 ElectraGen™-ME systems) to be deployed in Chinese telecom networks.
Idea Cellular, India	5+	For a pilot project in Idea Cellular's India telecom network, ElectraGen™-ME fuel cell systems will be utilized in combination with solar technology to generate continuous power at five wireless base station sites. Funding for a feasibility study as well as the pilot project made available through a grant from the United States Trade and Development Agency (USTDA).
Telestra/Australia	N/a	After several months of testing at base stations, including one in Tasmania, Telstra will deploy fuel cells as an alternative to back up battery arrays at mobile base stations and small telephone exchanges.
TOTAL	**226+**	

Other fuel cell companies entered agreements or selected partners to expand networks internationally:

- Heliocentris will supply fuel cells to one of the world's largest mobile network operators from the Middle East to upgrade its network, beginning with 240 sites.[74]
- Intelligent Energy and Microqual Techno Limited established a partnership to provide telecommunications infrastructure to existing power transmission towers in India.[75]
- Italian fuel cell company Electro Power Systems SpA (EPS), granted VP Energy, LLC , of Michigan exclusive rights to manufacture and distribute its ElectroSelf™ fuel cell product line in North America. EPS also selected Century Yuasa as its authorized distributor and installer for Australian and New Zealand markets.[76]

A number of other systems were announced or commissioned in 2013. VP Energy, LLC will install an ElectroSelf™ fuel cell system at the Lansing Board of Water and Light's new REO Town Headquarters and Cogeneration Plant in Michigan.[77]

Belgacom began powering a remote telecommunications antenna in Wemmel, Belgium, with an Axane (Air Liquide's subsidiary) fuel cell.[78]

Spanish fuel cell company Ajusa installed a 1.2 kW fuel cell to power a telecommunications site for Iberdrola and a 5 kW fuel cell uninterruptible power supply (UPS) unit at the offices of an Albacete television channel.

Fuel Cell Systems (FCS), a subsidiary of UPS Systems PLC, joined the 'Alkammonia' project funded by a €1.96 million (US$2.5 million) grant[79] from the FCH JU to test the efficiency of ammonia-fed, alkaline fuel cell systems for remote telecommunication base stations.

Canadian fuel cell manufacturer Hydrogenics received an order from its U.S.-based partner CommScope, Inc., for HyPM™ XR Series fuel cell power modules for an unnamed U.S. wireless operator.[80]

Spotlight on...

Methanol Fuel Cell Systems for Telecommunications

Many of the international fuel cell orders for telecommunications backup power in 2013 were for methanol-fueled systems, which are becoming a viable alternative to diesel generators (gensets) in remote areas that have limited access to hydrogen. Compared to hydrogen-fueled systems, fuel cells that utilize methanol are better suited for 'extended duration runtime' backup power requirements, lasting longer and needing less maintenance.

Diesel gensets are loud and smoky, and the diesel fuel in remote, rural regions is often a target of thieves. Hydrogen delivered to these areas typically comes as compressed gas in cylinders, in large bulk orders to achieve long run times. Often these are costly and inconvenient to transport. Methanol is moved more easily, in liquid form, which allows for larger and less frequent deliveries.

Ballard Power Systems has reaped the most from the international interest in methanol after acquiring fuel cell manufacturer IdaTech in August 2012. In January 2013, Ballard assumed management of IdaTech's 37,000 square foot Tijuana, Mexico, manufacturing facility where the ElectraGenTM-ME fuel cells are built. Ballard and its partners ship methanol systems to telecommunications operators in many countries.

In April 2013, Ballard shipped its 500th ElectraGen™-ME since the IdaTech acquisition, including more than 270 deployed in 16 Caribbean and Latin American (CALA) telecom networks.

In June, Ballard launched its next-generation ElectraGen™-ME backup power system, and by the end of the year, had commissioned more than 300 in Japan, 100 in China, and is participating in several pilot projects, demonstrations and commercial deployments in India, Australia, Indonesia and other countries.

Other manufacturers see the potential of expanding their portfolio to include a methanol-fueled system.

Hy9 and Clean Energy Investments (CEI) are integrating Hy9's HGS liquid methanol on-site hydrogen generators into CEI's fuel cells for African markets. Hy9 also entered into an agreement with Sankosha Corporation to do the same for Asian markets. In 2012, Hy9 began working with ReliOn to add methanol capability to their portfolio.

Direct methanol fuel cell company Oorja Protonics entered into an MoU with HySA/Catalysis, one of the three centers of competence for Hydrogen South Africa, to sell and distribute Oorja's products in the African market for telecommunications towers. Oorja also joined with Genersys Energia Solar Sabre (Genersys ESS) for a 3-year contract to focus on the Latin American telecom market.

CommScope also installed an 8-kW fuel cell backup system at Cable Television Laboratories, Inc. (CableLabs®), a non-profit research and development consortium, at its headquarters in Louisville, Colorado, to support the head-end and cable modem termination system.[81]

Bing Energy, working with Swedish fuel cell manufacturer PowerCell, unveiled its first product, a hydrogen fuel cell for telecommunications backup.[82]

Outside of the telecom industry, there was a lot of activity in portable/backup fuel cell development.

Engine manufacturer Cummins Inc. signed a five-year international supply agreement with fuel cell company Heliocentris. The company also joined with Ad Astra Rocket Company to power a Cummins-built electrical generator using mixtures of hydrogen and biogas.

The Colorado School of Mines received the world's first geothermic fuel cell (GFC), a modified solid oxide fuel cell, to test in extraction of oil from oil shale.[83] The 4.5 kW natural gas-fueled GFC was designed and built by Delphi for IEP Technology.

SFC Energy had a very busy year in 2013. The company launched new fully integrated outdoor power solutions for industrial applications–EFOY Pro Energy Solutions, which consists of the EFOY ProCube, EFOY ProCabinet, and EFOY ProEnergyBox.[84] The company also expanded its EFOY COMFORT for recreational applications to

Canada and the U.S.,[85] and signed a contract to acquire Simark Controls Ltd.,[86] a Canadian value added (VAR) distributing company. SFC also began selling EFOY fuel cartridges for EFOY COMFORT fuel cell generators in the Caribbean.

SFC Energy's fuel cells are now powering surveillance trailers for Canadian oil and gas company Convergint Technologies[87] and were used for undisturbed video observation of a pair of white-tailed eagles by The Royal Society for the Protection of Birds (RSPB).[88] SFC's system integration partner Antares Ltd., U.K., worked with RSPB, the National Trust for Scotland and SNH to install a fuel cell to power a camera on Shieldaig Island, in Wester Ross, Scotland, adjacent to the nest of a white-tailed eagle pair.

SFC is also working with Mastervolt International BV to integrate products for marine and RV markets.[89] Other companies now offering SFC's EFOY products into its catalogs include the Knaus Tabbert Group[90] (Eurostar caravans) and Leonardo Yachts (Eagle 36 and Eagle 44 luxury daysailers).[91]

Table 14: Examples of Commercially Available Backup and Remote Power Fuel Cells 2013

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
Altergy Systems (U.S.)	Freedom Power™	PEM	500 W, 1 kW, 5 kW & 7.5 kW
Axane (France)	CommPAC 500™	PEM	500 W-10 kW
Ballard Power Systems (Canada)/Dantherm Power (Denmark)	FCgen-1020ACS	PEM	1.5-3.6 kW
	FCgen-1300	PEM	2-11 kW
	ElectraGen-ME	PEM	2.5 & 5 kW
	ElectraGen-H2	PEM	1.7, 2.5 & 5 kW
Bing Energy (U.S.)/ PowerCell (Sweden)	S1	PEM	3 kW
Electro Power Systems S.p.A. (Italy)/VP Energy, LLC (U.S)	Electro™, ElectroSelf™	PEM	1.5 kW-10 kW
First Element Energy (U.S.)	Air-cooled/Water-cooled	PEM	2 kW-25 kW
Heliocentris Fuel Cells AG (Germany)	Nexa 1200	PEM	1.2 kW
Horizon Fuel Cell Technologies (Singapore)	H-Series	PEM	10W-5 kW
	Ecobox-MR	PEM	1-10 kW
	GreenHub Powerbox	PEM	500 W-2 kW
Hydrogenics (Canada)	HyPM XR Power Modules	PEM	4.5 kW-12.6 kW
	HyPM Rack	PEM	2-200 kW
	CommScope FC Cabinet	PEM	2-16 kW

Intelligent Energy (U.K.)/ Essential Energy (India)	Air-cooled	PEM	5 kW
Oorja Fuel Cells (U.S.)	Model T	DMFC	1.5 kW
ReliOn (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	90 W

Micro Fuel Cells

Several new micro fuel cell products were introduced into the market in 2013, including Lilliputian Systems' Nectar™ and Intelligent Energy's Upp™.

Nectar™ is a SOFC portable electronics charger. Retailer Brookstone will exclusively sell and distribute the product, which won the 2013 Consumer Electronics Show (CES) Innovations Award for Design and Engineering in the Portable Power category.[92] The device is approved for carry-on and use on board regular commercial aircraft.

Figure 15: Lilliputian Systems' Nectar SOFC Portable Charger
Source: ***www.nectarpower.com***.

Figure 16: Intelligent Energy's UPP Charger for Hand-held Devices
Source: Intelligent Energy

Upp™, a hydrogen-fueled personal energy device from Intelligent Energy, was launched at AfricaCom in Cape Town[93] after collaboration and substantial testing with Etisalat Nigeria and Cable & Wireless Communications.

Aquafairy, a Japanese fuel cell company, unveiled several new products at the CEATEC 2013 (Cutting Edge IT & Electronics Comprehensive Exhibition) show, including a 2.5 W portable fuel cell charger and a 200 W portable fuel cell that provides power in the aftermath of a disaster or during a power outage.[94] The company is aiming for a commercial launch in 2014.

Horizon Fuel Cells launched the i-H2GO, its most technologically advanced toy car; it runs on hydrogen and can be controlled via a Smartphone or tablet.[95]

Neah Power Systems, Inc. received a $172,000 order for multiple units of its PowerChip® product from the Indian Government's Defense Research and Development Organization.[96] The company opened an office in India in October 2013.

Transportation

Light Duty Vehicles

At the end of 2013, the next generation of FCEVs was on display at the array of international shows.

Toyota got a jump start on others by debuting its latest FCV-r Concept vehicle first at the Consumer Electronics Show in January and then later in the year at the Tokyo Auto Show.[97] The new FCEV has a redesigned 100-kW fuel cell stack and has a range of more than 400 miles per tank of hydrogen.[98] Moving from Toyota's previous SUV design, the FCV-r is a four-door, four-passenger sedan. Toyota also showcased the vehicle at the Los Angeles (L.A.) Auto Show, and at the Washington, DC, Auto Show.

Figure 17: Toyota FCV-R Concept
Source: Toyota

Figure 18: Hyundai Tucson Fuel Cell Vehicle
Source: Hyundai

Also in L.A., Hyundai unveiled its next-generation Tucson Fuel Cell vehicle, and announced plans to begin leasing the vehicle in Southern California in Spring 2014.[99]

Hyundai is also partnering with Enterprise Rent-A-Car to make the vehicle available to consumers at select locations in the Los Angeles/ Orange County region. This announcement followed Hyundai becoming the world's first automaker to begin assembly-line production of its ix35 FCEV,[100] aiming to build 1,000 by 2015 for lease to public and private fleets, initially in Europe. Hyundai is providing 17 for fleet customers in the cities of Copenhagen, Denmark and Skåne, Sweden. It delivered five to the U.K. as part of the London Hydrogen Network Expansion project and two to Air Liquide in France. After 2015, with lowered vehicle production costs and further developed hydrogen infrastructure, Hyundai plans to begin sales of hydrogen FCEVs to individual customers.

For its next generation FCEV showcased at the L.A. Auto Show, Honda improved on its FCX Clarity with a vehicle (as seen in Figure 19) that can seat five people comfortably and has a range of more than 300 miles. The concept car features a next generation, smaller fuel cell stack that provides more power.[101] Honda reaffirmed its intent to launch its FCEV in the U.S. and Japan in 2015.

Figure 19: Honda FCEV Concept
Source: Honda

Also at the Tokyo Auto Show, Diahatsu showcased its new light FCEV (as seen in Figure 20) called the "FC DECK".[102] The proprietary fuel cell system runs on a liquid fuel, hydrazine, which consists of hydrogen and nitrogen. Daihatsu has been working on fuel cells with Toyota since 1999 and displayed a similar FCEV at the 2011 Tokyo Motor Show. This new vehicle has a smaller battery and lower cost.

Figure 20: Daihatsu FC DECK
Source: Daihatsu

Audi announced that it was developing a fuel cell version of its A7 vehicle and began trials at the end of August.[103]

Spotlight on...

Automaker Collaborations

In 2013, many of the major automakers made headlines for their collaboration on R&D and FCEV commercialization efforts.

- Daimler AG, Ford Motor Co, and Nissan Motor Co. are developing a "common fuel cell system" with plans to build 100,000 FCEVs between them, to start selling in 2017.
- Honda and General Motors are working to develop a next-generation fuel cell system and hydrogen storage technologies by 2020.
- Toyota and BMW aim to develop a complete FCEV system by 2020.
- Volkswagen is working with Ballard Power Systems to design and manufacture a next-generation fuel cell for its HyMotion demonstration cars.

This work is in addition to the RD&D and commercialization plans of the individual companies involved. It is especially important to note that several of the companies – Nissan, Ford, Volkswagen and BMW – have previously focused primarily on battery-electric vehicles and other alternative fuels.

Table 15: Commercially Available Fuel Cells for Transportation 2013*

Manufacturer	Product Name	Type	Output	Vehicle Type
Ballard Power Systems (Canada)	FCvelocity-HD6	PEM	75 kW & 150 kW	Cars, buses
SymbioFC (France)	ALP®	PEM	80 kW-100 kW (full system)	Utility vehicles, trucks
US FuelCell**	Model 80 APU	PEM	80 kW	Cars, buses
	Model 150 APU	PEM	150 kW	Buses, trucks
	UTC's PureMotion®	PEM	120 kW, Legacy	Buses

*For the purposes of this chart, transportation includes light duty vehicles, trucks and buses. Many automakers are developing and manufacturing proprietary fuel cells for their fuel cell electric vehicles.

**In January 2014, US Hybrid (US FuelCell's parent company) entered a global licensing agreement with United Technologies Corporation (UTC) for UTC's PEM fuel cell technologies for the vehicle market.

Fuel Cell Buses

In 2013, the Federal Transit Administration (FTA) awarded more than $13.6 million in funding for eight projects around the country to advance the commercialization of American-made fuel cell buses for the transit industry (using primarily FY2012 funds) (Table 17).

Table 16: FTA National Fuel Cell Bus Program Awards 2013

Project	Amount	Lead/Partners	Project Overview
Fuel Cell Bus Fleet Extended Operation and Support	$1,808,340	Center for Transportation and the Environment (CTE, GA), AC Transit (Oakland, CA)	Continues operation of existing fuel cell buses at AC Transit in revenue service. This project provides critical information on long-term operation, performance and maintenance of fuel cell buses against technical targets.
American Fuel Cell Bus	$2,732,147	CALSTART, Greater Cleveland Regional Transit Authority (Cleveland, OH), ECA), BAE Systems (NY), Ballard Power Systems (MA)	Builds a next-generation fuel cell bus with latest fuel cell technology and demonstrates in transit service in greater Cleveland area for 2 years. This project builds on success of the American Fuel Cell Bus project, funded under National Fuel Cell Bus Program, with a less costly, more reliable system.
Battery Dominant Fuel Cell Hybrid Bus	$4,251,307	CALSTART, SunLine Transit Agency (Thousand Palms, CA), ElDorado National (CA), BAE Systems	Develops and demonstrates a battery-dominant fuel cell bus based on a commercial hybrid platform, and smaller, less expensive fuel cells. The bus will operate in similar service to the American Fuel Cell Bus, allowing direct comparison.
Central New York Fuel Cell Transportation Program	$3,164,950	CTE, Tompkins Consolidated Transit Authority (Ithaca, NY), ElDorado National,	Builds and operates a next-generation American Fuel Cell Bus in a cold, northeastern climate. This project builds on the success of first American Fuel Cell Bus Project with more reliable, less-costly technology.
Birmingham Fuel Cell Bus Program Operational Support	$238,987	CTE, Birmingham-Jefferson County Transit (AL)	Comprehensive testing of an existing fuel cell bus, essential for commercialization of fuel cell electric buses. This project will help develop consistent procedures and guidelines for testing all fuel cell buses.
Fuel Cell Bus Altoona Testing	$554,316	CALSTART, National Bus Testing Facility (PA)	Develops a best practices guide for transit agencies in hydrogen fueling and maintenance facilities.
National Fuel Cell Bus Program Education & Transit Outreach	$691,000	CTE	Conducts targeted education and outreach on the current state of the fuel cell bus technology and industry, and helps develop needed guidelines for fuel cell specific procurements.
TOTAL	**$13,009,146**		

There were several other deployments and orders of fuel cell buses around the U.S. in 2013:

- The University of Delaware announced it will add two new fuel cell buses to its existing fleet of two and install a fueling station at the school's Science Technology and Research campus.[104]
- Golden Gate Transit began operating a fuel cell bus as part of the Zero Emission Bay Area (ZEBA) fuel cell bus demonstration. ZEBA is comprised of five transit agencies (AC Transit, GGT, Santa Clara VTA, SamTrans, and Muni) that collectively are using a fleet of 12 third-generation fuel cell buses to provide service around the San Francisco Bay Area.[105]
- CTE finalized a deal with Connecticut Transit (CTTransit) to deliver the first commercially procured fuel cell transit bus.[106]

Ballard Power Systems, the fuel cell manufacturer for several of the buses listed above, also had a good year internationally with its FCvelocity power module in demand.

- The company was awarded a CAN$2.0 million (US$1.9 million) extension to a previous award from Sustainable Development Technology Canada to commercialize its FCvelocity™-HD6 150-kW fuel cell power module for use in the transit bus market.[107]
- Ballard also shipped eight systems to Van Hool, six to be used in the Aberdeen, Scotland bus fleet and two for buses in Cologne, Germany. The Cologne buses were procured by the government of North Rhine Westphalia (NRW) with funding support from the German NIP program. The Aberdeen buses are funded under the Fuel Cells and Hydrogen Joint Technology Initiative (FCH JTI) through the High V.LO-City and HyTransit programs.[108]
- In China, Ballard signed a non-binding MoU with its partner Azure Hydrogen Corporation of Beijing, extending the scope of their collaboration to include fuel cell buses. This MoU led to a multi-year, $11 million definitive agreement for Ballard to provide a license, associated equipment and Engineering Services to enable assembly of FCvelocity®-HD7 bus power modules by Azure in China.[109,110]

In late November, the FCH JU released its latest call for proposals, which includes around €15 million (US$19 million) to fund up to 24 fuel cell buses.[111]

Spotlight on...

Fuel Cell Material Handling in Europe

The success of fuel cell-powered forklifts and lift trucks in the U.S. has led to several small demonstration projects in Europe, including the HyLIFT-DEMO and HyLIFT-EUROPE projects, co-funded by the FCH JU. Both are in the demonstration phase.

Also during 2013:

- Global logistics provider DB Schenker received the first of 10 fuel cell-powered pallet trucks for a field test as part of a year-long "E-LOG Biofleet" research project. The indoor hydrogen refueling facility developed by OMV is the first in Europe to reform methane from biogas into hydrogen.
- BMW, with partners Linde Material Handling and Munich Technical University, was awarded €2.9 million (US$3.7 million) from the Federal Ministry of Transport, Building and Urban Development for a three-year research project to develop and test fuel cell-powered forklifts at BMW's plant in Leipzig, Germany.1
- Viessmann is using a hydrogen forklift truck at its Allendorf, Germany, factory as part of the state of Hesse's H2BZ Hydrogen and Fuel Cell Initiative. Viessmann plans to produce renewable hydrogen on site to fuel future vehicles.

In India, as part of a five-year research project, Tata Motors conducted test runs of the country's first hydrogen fuel cell-powered bus at the Liquid Propulsion System Centre of the Indian Space Research Organization.[112]

Two Mercedes-Benz Citaro FuelCELL Hybrid fuel-cell buses began shuttle service between the Karlsruhe Institute of Technology (KIT) campuses in Germany, fueling at a new hydrogen fueling station on KIT's North campus.[113]

Nuvera Fuel Cells supplied Dolomitech Srl with four fuel cell stacks to equip two minibuses that are in service in Val di Fiemme, Italy. The minibuses were initially used for the 2013 Nordic Skiing championship and have since been used in the snowy conditions of the Alps. The vehicles have traveled more than 18,000 miles without any cold weather issues.[114]

Material Handling

In 2013, the material handling sector continued to be an active market for the fuel cell industry, with a large majority of sales and deployments occurring in the U.S. Fuel cell manufacturer Plug Power is the major player in this area, with an estimated 80% of the market share. Other U.S. companies focused in this sector include Nuvera Fuel Cells and Oorja Protonics, with H2 Logic, a Danish company, leading the small number of deployments in Germany and Europe.

Table 17: Top Ten Fuel Cell Lift Truck Customers

1	Sysco	734+ forklifts at 7 sites
2	Walmart	523 forklifts at 3 sites*
3	Associated Wholesale Grocers	500+ forklifts at 2 sites
4	P&G	340 forklifts at 4 sites
5	BMW	275+ forklifts at 1 site
6	Central Grocers	234 forklifts at 1 site
7	WinCo Foods	200+ forklifts at 1 site
8	Lowe's	157 forklifts at 1 site
9	Kroger	150+ forklifts at 1 site
10	Wegmans	140+ forklifts at 1 site

*In March 2014, Walmart ordered 1,738 fuel cells for more than 1,500 forklift trucks at six distribution centers around the U.S. In July 2014, the company announced an additional site and 286 additional fuel cells.

Chart created by Breakthrough Technologies Institute.

Plug Power shipped 918 units and received 1,079 orders for GenDrive products during 2013. Three customers comprised 33.2% of Plug Power's 2013 total consolidated revenues, with Mercedes-Benz, Procter & Gamble, and Lowe's representing 11.6%, 11.2%, and 10.4% of total consolidated revenues, respectively. Backlog at December 31, 2013, for GenCare and GenFuel products was approximately $25 million.

Table 18: Notable Plug Power 2013 GenDrive® Sales

Customer	# of Units	Location of Deployment	Notes
Ace Hardware	65	Wilmer, TX	For newly constructed retail support center.
BMW	175+	Spartanburg, SC	With more than 100 vehicles already powered by fuel cells, BMW's fleet has become the largest fuel cell material handling fleet at a single location in North America and arguably in the world.
Mercedes-Benz US International, Inc.	123	Tuscaloosa, AL	Repeat order. Purchased 72 in July 2012 for new $70 million, 900,000 square-foot state-of-the-art warehouse.

In 2013, several new fuel cell products were introduced for the materials handling market.

- Plug Power's GenDrive 1900 is its highest power fuel cell designed as a drop-in replacement for lead-acid batteries on six-ton capacity, four-wheel, class-one counterbalanced forklift trucks. The new fuel cell features an optional second hydrogen tank. With both tanks installed, the system can store up to 3.4 kilograms (kg) of hydrogen with an energy capacity of 50 kilowatt-hours (kWh).
- Ballard's next generation FCgen™-1020ACS air-cooled fuel cell stack features enhancements designed to increase durability and lifetime of the product. Overall, the company shipped 2,325 stacks for material handling in 2013, a 15% year-on-year increase from 2012.
- Nuvera Fuel Cells' new Orion® fuel cell stack is designed for material handling and other industrial vehicle applications.

Toyota Industries (Toyota Shokki) revealed its new fuel cell powered forklift truck, co-developed with Toyoda Gosei Co., Ltd., which has a continuous power rating of 8 kW and maximum output of 32 kW. Two have been deployed at Toyoda Gosei's Kitakyushu site for testing until March 2014. The hydrogen supplied is a by-product of a nearby steel plant. Japan's Ministry of Economy, Trade and Industry (METI) funded the project as part of its "Kitakyushu Smart Community Creation Project." [115]

Table 19: Commercially Available Fuel Cells for Material Handling* 2013

Manufacturer	Product Name	Type	Output
Ballard Power Systems (Canada)	FCgen-1020ACS	PEM	1.5-3.6 kW
	FCvelocity-9SSL	PEM	4-19 kW
H2Logic (Denmark)	H2Drive	PEM	~10 kW
Hydrogenics (Canada)	HyPX Power Packs	PEM / hybrid	N/a
Infintium (U.S.)	EnerPac™ 48.1	PEM	40 kW
	EnerPac™ 24.3	PEM	14 kW
Nuvera Fuel Cells (U.S.)	Orion	PEM	10-30 kW
Oorja Protonics (U.S.)	OorjaPac Model III	DMFC	1.5 kW
Plug Power (U.S.)	GenDrive Series 1000	PEM	8–10 kW
	GenDrive Series 2000	PEM	8–10 kW
	GenDrive Series 3000	PEM	1.8–3.2 kW
Proton Motor GmbH (Germany)	HyRange® 8	PEM	8.2 kW
	PM400	PEM	Up to 30 kW
SymbioFC (France)	ALP®	PEM	5 kW-20 kW (range extender)

*For purposes of this chart, material handling includes forklifts, lift trucks and range extenders for battery-electric utility and commercial vehicles

Other Transportation Applications

Aside from light duty cars, buses and material handling vehicles, many companies, organizations and stakeholders are focused on integrating fuel cells into a wide range of specialty vehicles.

Trucks and Utility Vehicles

In Texas, DOE awarded $3.4 million to the Houston Galveston Area Council to demonstrate 20 heavy duty TYRANO™ hydrogen fuel cell-electric trucks from Vision Industries at the Port of Houston. Expected benefits of the project include displacement of 200,000 gallons of diesel annually and annual emissions reductions of 39 tons of nitrogen oxides and 0.8 tons of particulate matter. Hydrogen for the fuel cell trucks will be locally sourced from natural gas.[116]

Proton Motor Fuel Cell GmbH unveiled a battery-fuel cell hybrid electric commercial vehicle based on the battery-powered Newton vehicle built by Smith Electric Vehicles. Proton Motor integrated a HyRange 8-kW fuel cell system with the battery to increase range and power air conditioning and other equipment. The project was supported by funding from Germany's NIP program.[117]

French fuel cell manufacturer Symbio FCell announced that the French postal service, La Poste, is testing three Renault Kangoo Z.E. electric mail delivery vehicles fitted with the company's fuel cells. The vehicles will deliver mail in the Franche-Comté region in eastern France. The fuel cell will act as a battery range extender, doubling the range of the battery vehicles for the long, cold and sometimes treacherous routes.[118]

The Nilfisk-Advance Group showed off the first fuel cell-powered industrial combination floor cleaning vehicle at the ProMat 2013 conference in Chicago, Illinois. The Advance CS7000™ Combination Sweeper-Scrubber uses a Plug Power fuel cell.[119]

Two-Wheeled Vehicles

Three French companies, Cycleurope, Pragma Industries and Ventec, developed the ALTER BIKE, a fuel cell electric bicycle that stores its hydrogen in solid form, in recyclable canisters.[120]

SMILE FC System Corporation, a joint venture between Intelligent Energy and Suzuki Motor Corporation, established a ready-to-scale production plant for its fuel cell systems in Yokohama, Japan. The fuel cell stacks will be integrated into Suzuki vehicles.[121]

Also in Japan, Atsumitec Co. Ltd. integrated an SOFC and a thermoelectric conversion element onto a motorbike that is able to run off the exhaust and power onboard systems.[122]

In Taiwan, a year-long demonstration project of 80 fuel cell scooters was completed (see page 42).

Marine

Nuvera Fuel Cells announced it will deliver eight of its Orion™ fuel cell stacks (total power 260 kW) to be used as range extenders on Italian shipbuilder Fincantieri's luxury marine vessels.[123]

WATT Fuel Cell Corporation entered into a strategic licensing and supply agreement with Parker Hannifin Corp. to provide propane-fueled SOFC products for the recreational vehicle (RV), marine, over-the-road trucking and residential markets. The companies worked together to demonstrate the SOFC on a 36-foot sailboat.[124,125]

Unmanned Aerial Vehicles (UAVs)

EnergyOr Technologies Inc. demonstrated what is believed to be the first fuel cell-powered UAV flights in India, using EnergyOr's EPOD EO-310-XLE fuel cell system.[126]

A Washington State University (WSU) student team has been working a hydrogen-powered UAV, Genii (derived from the Latin "potentia hydrogenii" or the potential of hydrogen). The UAV is made of fiberglass-laminated plastic foam with a carbon-fiber wing spar, and has a wing span of 19 feet. Test flights of the battery-powered version were successful, and students are working to integrate a hydrogen fuel cell.[127]

Spotlight on...

Taiwan Hydrogen Fuel Cell Scooter Fleet Demonstration Project

A year-long verification project of fuel cell-powered scooters in Taiwan was completed in September 2013. In this trial, 80 fuel cell scooters from Asia Pacific Fuel Cell Technologies (APFCT) were offered free to the general public to ride around a 70 kilometer (km) closed loop in the beach resort area of Kenting in southern Taiwan. The scooters were equipped with two metal hydride hydrogen canisters providing a range of around 80 km.

Fifty-five scooters were placed at 10 hostels along the route with the other 25 placed at local police stations, health centers and elementary schools. The 360 hydrogen canisters were evenly distributed to seven exchange stations, including gas stations, 7-11 convenient stores, and police stations.

Over the course of the year, the scooters were ridden more than 10,900 times, accumulating 245,446 kilometers. A total of 453 kg of hydrogen were consumed during the project.

Each scooter was fitted with a GPS system that monitored and analyzed a variety of data throughout the year, including driving time, location, direction, altitude, cruising distance, voltage, current and the temperature of fuel cell stack.

In addition to the technical data gathered from the GPS and other testing equipment, riders were encouraged to complete a questionnaire that asked about performance, ease of use, safety, riding experience and expectations. A total of 104 users responded to the 15-question survey and a majority of riders were satisfied with the scooter's speed, range and handling, as well as the hydrogen canister exchange system.

More than half of the riders had more than 10 years experience riding motorcycles, mostly for general commuting or commuting to work and 32% said they would purchase a fuel cell-powered scooter in the future (40% said not sure). A majority (62%) preferred a price below NT40000 (US$1,325) for the scooter and NT30 (US$1) to pay for a hydrogen canister swap.

APFCT is using the data from these field trials to design a commercial-ready scooter. Focus will be placed on reducing the cost of fuel cell stacks and hydrogen canisters while increasing the size of the vehicle.

Hydrogen Infrastructure and Energy Storage

Hydrogen Fueling Infrastructure

To help support commercialization of fuel cell cars, buses and material handling vehicles, governments and industry are working together to establish the hydrogen infrastructure. In 2013, several new and upgraded hydrogen stations opened around the world.

The German "H2 Mobility" initiative, Japan's government and the state of California all announced funding commitments to increase the number of hydrogen stations to coincide with automakers' FCEV commercialization plans (see text box).

Following Germany's lead, three U.K. government departments and 11 companies started the UK H2Mobility initiative to evaluate the benefits of FCEVs. Since the launch, the group added three more government members.[128] In February 2013, UK H2Mobility released a roadmap to show how 1.6 million FCEVs could be on the road in the U.K. by 2030.[129]

Also in the U.K., the Aberdeen City Council released, ***A Hydrogen Economy for Aberdeen City Region***,[130] a platform for the city to build off the £20 million (US$30 million) Aberdeen Hydrogen Bus Project.

France followed suit as well, launching "Hydrogen Mobility France" with 25 regional, national and international, private and public partners managed by the French Association for Hydrogen and Fuel Cells (AFHyPaC) and supported by the Ministry of Ecology, Sustainable Development and Energy.[131]

In 2012, the Japanese government changed a regulation that had previously required all hydrogen fueling stations to be located in industrial areas, to allow hydrogen stations to be placed in residential areas and near gas stations. This led to Japan's first public hydrogen station in a non-industrial area, adjacent to a conventional gas station in Ebina, Kanagawa prefecture. The station was developed through a partnership of JX Nippon Oil & Energy Corporation and the New Energy and Industrial Technology Development Organization (NEDO).[132]

Figure 21: Ebina-Chuo Hydrogen Station, Japan
Source: Breakthrough Technologies Institute

Also in Japan, Air Liquide Japan and Toyota Tsusho Corporation signed a partnership agreement establishing a joint venture called "Toyota Tsusho Air Liquide Hydrogen Energy Corporation," where Toyota Tsusho will own 51% and Air Liquide Japan will own 49% of the company.[133] The first project is to build two public hydrogen stations in the Aichi area of Japan to be operational in 2014.

Air Liquide had several other station projects announced or completed in 2013, including several publicly-accessible refueling stations, as illustrated in Table 20. The company was also awarded funding from the CEC for a station in Anaheim, California.

Hydrogen Fueling Station Commitments

In September, the governor of California signed Assembly Bill 8 (AB8) into law. AB8 provides annual funding until 2024 for at least 100 hydrogen stations with a commitment of $20 million a year from the Alternative and Renewable Fuel and Vehicle Technology Program.

The H2 Mobility initiative partners (Air Liquide, Daimler, Linde, OMV, Shell and Total) announced in September that they plan to expand Germany's public hydrogen infrastructure to about 400 stations by 2023, with the first 100 stations planned over the next four years. The Initiative expects that a total investment of around €350 million (US$447 million) will be required.

In December, Japan's government said that it will propose ¥7.2 billion (US$71 million) in funding for hydrogen fueling station development in the next fiscal year. Plans for 19 stations were approved in June.

Table 20: Air Liquide Hydrogen Stations Opened or Ordered 201

City/Country	Pressure/Capacity	Notes
Brussels, Belgium	High capacity (40 fill-ups per day)	To be opened in 2014 as part of the Small 4-Wheel fuel cell passenger vehicle Applications in Regional and Municipal transport demonstration (SWARM).
Saint-Quentin-Fallavier, France	350 bar	Located at IKEA's distribution center to fuel around 20 fuel cell-powered forklift trucks.
Bremen, Germany	High capacity (40 fill-ups per day)	To be opened in 2014 as part of SWARM.
Birmingham,U.K.	High capacity (40 fill-ups per day)	To be opened in 2014 as part of SWARM.
Fukada, Toyota City, Japan	N/a	To be operational in 2014. Will be accessible by the public.
Atsuta, Nagoya, Japan	N/a	To be operational in 2014. Will be accessible by the public.
Rotterdam, Netherlands	350 and 700 bar	First Air Liquide station in Netherlands. Has the financial backing of the European Union as part of the Trans-European Transport Networks (TEN-T) program. Will be accessible by the public.
Lesce, Slovenia	20 kg/day	Will fuel a hydrogen-powered bus developed by Italian company Rampini.

In June 2013, CEC awarded more than $18 million in grants for hydrogen fueling station projects in California.[134]

- Linde – $4.5 million to install hydrogen fueling stations in the cities of Mountain View, Cupertino, and Foster City. The agreement includes a $3,069,948 match-funding requirement.
- Hydrogen Frontier, Inc. – $3 million to build a 100% renewable hydrogen fueling station at the Hyundai America Technical Center testing facility in Chino. The award agreement includes a $1,615,385 match-funding requirement.
- Air Products and Chemicals, Inc. – $2,999,172 to install hydrogen fueling stations in Woodland Hills and Mission Viejo and to automate two trailer loading operations for transporting hydrogen for fueling from a production facility in Southern California. The award agreement includes a $1,614,927 match funding requirement.
- Air Liquide – $1.5 million to build a hydrogen fueling station in Anaheim. The award agreement includes a $933,996 match-funding requirement.

In addition to the new station awards listed above, the South Coast Air Quality Management District (SCAQMD) was awarded $6,690,828 to evaluate, test and upgrade select public hydrogen fueling stations, primarily in the South Coast Air Basin.

Other stations announced or opened in 2013 include:

Table 21: Hydrogen Refueling Station Projects 2013

City/Country	Hydrogen Supplier	Pressure/ Capacity	Notes
Bolzano, Italy	Linde Group/ Hydrogenics	N/a	Station is part of the EU's Clean Hydrogen in European Cities (CHIC) project, and will provide fuel to both cars and buses.
Copenhagen, Denmark	H2 Logic	70MPa	Hydrogen is produced renewably onsite with electrolysis to fuel 15 Hyundai FCEVs.
Flanders/ Netherlands	Ballast Nedam	700 bar	Part of the cross-border 'Hydrogen Region Flanders-Netherlands' Interreg IVA program.
Helmond, Netherlands	Ballast Nedam	350 bar	Built on the AutomotiveCampusNL, this station produces hydrogen renewably and could be upgraded to 700 bar.
Houston, Texas, U.S.	Air Products	N/a	Hydrogen will come from an existing pipeline to fuel fuel cell electric hybrid trucks the Port of Houston as well as personal vehicles.
Leuna, Germany	Linde Group	500 bar	To demonstrate its new storage technology, Linde opened this fueling station at its Leuna facility.

In 2013, ITM Power joined both Swiss H2Mobility and Mobilité Hydrogène France to help develop the hydrogen infrastructure in those countries. ITM received a £1 million (US$1.5 million) grant award from the Welsh Government to establish a wholly owned subsidiary, ITM Motive, to help develop a hydrogen refueling infrastructure in Wales.[135] The company also launched ITM Power ApS[136] in Denmark as a wholly-owned subsidiary company. ITM also sold its reference plant based on its HPac platform to companies in Japan,[137] Russia,[138] and a U.K. government agency.[139]

After BMW added more than 170 new fuel cell-powered material handling vehicles to its fleet, Linde installed two new higher-throughput compressors, new storage tubes and distribution piping, and eight new hydrogen dispensers to the automaker's Spartanburg, South Carolina, manufacturing facility.[140]

In 2013, BMW also entered the second phase of its Landfill Gas-to-Hydrogen Pilot Project with the South Carolina Research Authority (SCRA) to use locally sourced methane fuel for the forklift fleet. In the final phase of this project, BMW is conducting side-by-side trials of its fuel cell-powered material handling vehicles using the landfill gas derived hydrogen versus commercially sourced hydrogen.[141]

Greenlight Innovation delivered three electrolyzer test stations to the Forschungszentrum Jülich energy research center in Jülich, Germany.[142]

IGX Group, a specialty distributor of high purity, industrial compressed gases, entered the hydrogen market in 2013 and performed the first on-site hydrogen fueling of a Multiquip fuel cell mobile lighting unit at San Francisco International Airport.[143] The lighting unit was powered by an Altergy Systems' fuel cell and part of a project led by Sandia National Laboratories and funded by Boeing and DOE. IGX also launched its hydrogen fueling services in California focused on the telecommunications industry, with a fleet of composite cylinder equipped trailers that store and deliver high-pressure hydrogen to fuel cell locations.[144]

Table 22: Examples of Commercially Available Hydrogen Generation Systems 2013

Manufacturer	Product Name	Type	Output
Acta S.p.A. (Italy)	EL 250	Alkaline solid polymeric electrolytic process	50 l/h
	EL 500		500 l/h
	EL 1000		1000 l/h
Element 1 (U.S.)	H-75 Hydrogen Generator	Reformer	9.7 kg/day
	H-110 Hydrogen Generator		14.3 kg/day
	H-150 Hydrogen Generator		19.5 kg/day
Hydrogenics (Canada)	HySTAT	Alkaline Electrolysis	8.6 kg-130 kg/day
	HyLYZER	PEM Electrolysis	1-2 Nm3/h
HyGear (Netherlands)	HGS-L	Reformer	42 Nm3/h
	HGS-C		84 Nm3/h
ITM Power (U.K.)	HPac 10	PEM Electrolysis	1.3-5.0 kg/day
	HPac 40		1.3-5.0 kg/day
	HFuel Hydrogen Station		5-100 kg/day
	HGas		25-400 kg/day
McPhy (France)	Baby PIEL	Alkaline Electrolysis	0.4 Nm3/h
	Standard model		1-10 Nm3/h
	MP Model		3-16 Nm3/h
Nuvera Fuel Cells (U.S.)	PowerTap	Reformer	50 kg/day
Plug Power (U.S.)	GenFuel	N/a	1 kg/minute
Proton OnSite (U.S.)	HOGEN S Series	PEM Electrolysis	0.57-2.27 kg/day
	HOGEN H Series		4.31-12.94 kg/day
	HOGEN C Series		21.6-65 kg/day

There was advancement in hydrogen production by other new companies as well in 2013:

Kawasaki Heavy Industries of Japan and Russian companies RAO Energy Systems of East and RusHydro entered an agreement outlining their intention to build a liquid hydrogen plant in Russia's Magadan Region.[145] The hydrogen will be sold in Japan and the East Asian markets.

Florida-based Chemergy Inc. partnered with Lawrence Livermore National Laboratory (LLNL) on a $1.75 million project, funded jointly by the California Energy Commission (CEC) and Chemergy, to demonstrate a bioenergy technology that converts wastewater treatment plant byproducts into hydrogen gas to use in fuel cells at the Delta

Diablo Sanitation District (DDSD) facility in Antioch, California.[146] DOE and the Department of Defense (DoD) Construction Engineering Research Laboratory (CERL) are also partners on the project.

Western Hydrogen Limited was awarded CAN$1.45 million (US$1.35 million) from Sustainable Development Technology Canada (SDTC) to continue piloting its "Molten Salt Gasification" hydrogen production technology.[147]

On the university side, Researchers at Ecole Polytechnique Fédérale de Lausanne and Technion–Israel Institute of Technology developed a photoelectrochemical cell that uses water and nano-structured iron oxide to produce low cost hydrogen.[148]

Japan's Kyushu University was the Grand Prize Winner of the 2012-2013 Hydrogen Energy Foundation's Hydrogen Student Design Contest,[149] developing hydrogen fueling infrastructure plans for the Northeast and mid-Atlantic for the 2013-2025 timeframe.

Energy Storage/Power-to-Gas

Hydrogen and fuel cells are becoming a viable energy storage option in many countries and regions that are generating excess energy via renewable resources such as solar and wind. Power-to-Gas projects, where the excess electrical energy is used to produce hydrogen or methane, which can be injected into existing natural gas pipeline infrastructure or diverted to a fuel cell, to be stored and used as needed, were on the rise in 2013.

Most of the Power-to-Gas and energy storage projects are occurring in Europe, mainly Germany. ITM Power, Acta and Hydrogenics are the main companies providing the electrolyzers to generate hydrogen from wind, solar or other resources.

Table 23: Power-to-Gas/Energy Storage Projects Announced or Completed in 2013

Project/Country	Companies Involved	Project Notes
CommONEnergy project, Europe	ITM Power, European consortium	Four year project funded under the EU's Seventh Framework Program to demonstrate energy efficient technologies and energy storage solutions for non-residential buildings such as shopping malls.
EcoIsland House trial, Isle of Wight, U.K.	Acta S.p.A, Dantherm Power	Three-month trial at residence on Isle of Wight.
Hydrogen Mini Grid System (HMGS), Rotherham, U.K.	ITM Power, Homes and Communities Agency (HCA)	Project consists of a 225 kW wind turbine coupled directly to an electrolyzer, 200 kg of hydrogen storage, a hydrogen dispensing unit and a 30-kW fuel cell system for backup power generation for nearby buildings.
Power-to-Gas, Falkenhagen, Germany	Hydrogenics, E.ON, Swissgas	Began operation in August 2013. The 2 MW plant uses wind power and an electrolyzer to convert water into hydrogen, which is then injected into the existing regional natural gas transmission system.
Power-to-Gas, Frankfurt, Germany	ITM Power, Thüga Aktiengesellschaft, Mainova AG, German consortium	The 360 kW plant will produce 125 kg/day of hydrogen gas. Situated at a Mainova AG site in the Schielestraße, Frankfurt in the state of Hessen.
Power-to-Gas, Hamburg, Germany	Hydrogenics, E.ON	Awarded in April 2013. The 1 MW system will use excess wind and solar to generate hydrogen. Funding was provided by Germany's NIP program.

Renewable Energy Storage, Singapore	Acta S.p.A, Nanyang Technological University	Installed at Raffles Lighthouse, the system will store renewable energy generated from solar and wind turbine electrolysis from rainwater.
Renewable Energy Storage Project, Chesire, U.K.	Acta S.p.A, Clean Power Solutions, Giacomini S.p.A	Will demonstrate the use of electrolyzers to produce hydrogen from rainwater, utilizing the excess energy produced by a domestic wind turbine on a farm.

Several Power-to-Gas consortiums were formed in 2013, joining together government agencies, industry and other stakeholders (utilities, universities):

- Hydrogen Power Storage & Solutions East Germany (HYPOS): This initiative will select projects to be funded with up to €45 million ($57 million) from the Germany Federal Ministry of Education and Research.[150]
- North Sea Power-to-Gas Platform: Eleven companies in Europe–DNV KEMA, Fluxys Belgium, Hydrogenics, Energinet.dk, Maersk Oil Alliander, Gasunie, TenneT, ITM Power, National Grid, and Open Grid Europe–focused on utilizing wind power in the North Sea region.[151]
- Mediterranean Power-to-Gas platform (MP2G): will develop projects based on the integration of wind and solar PV for Power-to-Gas energy storage across the Mediterranean region. Partners are ITM Power (U.K.) EDP (Portugal), REN (Portugal), Enagas (Spain), Gas Natural (Spain), GDF Suez (France), TIGF (France), Edison (Italy), Hydrogenics and SNAM (Italy).[152]

Also in 2013, McPhy Energy, a French hydrogen storage company, showcased its system coupling an industrial-scale hydrogen generator with a 100 kg solid hydrogen storage unit, the world's first it claims.[153]

Air Liquide made an equity investment in the Australian company HYDREXIA, a spin-off of the University of Queensland that has developed a magnesium alloy solid hydride hydrogen storage technology.[154]

Military

Despite publicly announcing only two new funding awards (Table 15), the U.S. military continued to invest in fuel cell development and testing for a range of applications.

The Naval Air Warfare Center Weapons Division (NAWCWD) Renewable Energy Office in China Lake, California, received a trailer-mounted regenerative fuel cell system from an unspecified provider, consisting of a fuel cell and an array of solar panels for testing and evaluation. During the day, the command center will be powered by solar energy. Excess energy is used to produce hydrogen. At night, the stored hydrogen is used by the fuel cell to generate electricity.[155]

Table 24: U.S. Military Project Funding 2013

Company	Agency	Project	Funding
SAFCell, Inc.	U.S. Army	To demonstrate a 50 W wearable power unit for the dismounted warrior. SAFCell will integrate its proprietary solid acid fuel cell (SAFC) stacks into UltraCell Inc.'s micro fuel cell systems and deliver to the Army for initial alpha testing in late 2014.	$1 million
SFC Energy, Inc.	U.S. Air Force	To further develop a portable 50 W fuel cell.	$1 million

The U.S. Naval Research Laboratory (NRL) with funding from SwampWorks at the Office of Naval Research (ONR) and the DoD Rapid Reaction Technology Office successfully launched an all-electric, fuel cell-powered, unmanned aerial system (UAS) from a submerged submarine.[156]

The Air Force Research Laboratory (AFRL) Advanced Power Technology Office is demonstrating small wind turbines and fuel cells in extreme arctic conditions. The fuel cell manufacturer was not named.[157]

GM expanded its collaboration with the U.S. Army Tank Automotive Research, Development & Engineering Center (TARDEC) via a new five-year Cooperative Research and Development Agreement. GM and TARDEC will jointly test new hydrogen fuel cell-related materials and designs to evaluate their performance and durability before assembling them into full scale fuel cell propulsion systems.[158]

SFC Energy AG launched its new EMILY 3000 fuel cell generator for vehicle-based defense applications, redesigned based on user experience and requests.

UltraCell released the GENiii XX55 portable fuel cell system that can operate using a range of field refillable fuel cartridges and comes with a targeted lifetime of 2,500 hours. The company also completed evaluation of the XX55 fuel cell and the CliC-It methanol filling station in conjunction with Eylex Pty Ltd, its Australian and New Zealand regional partner, and the New Zealand military.[159]

Cost Reduction

DOE's EERE Fuel Cell Technologies Office, and the fuel cell industry itself, have made significant achievements in fuel cell cost reduction. DOE reports that its funded research has enabled:[160]

- PEM fuel cell cost reduction of more than 50% since 2006, and more than 35% since 2008.
- A greater than 80% reduction in electrolyzer stack cost over the past 10 years.
- Reduction in the amount of platinum (Pt) used by a factor of five since 2005.
- A more than doubling of fuel cell durability since 2006.

Transportation Fuel Cells

Since 2006, DOE-supported research has reduced the cost of transport fuel cell systems by more than 50%, from an $108/kW in 2006 to $55/kW in 2012/2013 (Figure 22). These numbers are based on high volume projections of 500,000 units per year and a platinum price of $1,500/troy ounce. DOE's next target is a 2020 transport fuel cell system cost of $40/kW, with an ultimate target of $30/kW.[162]

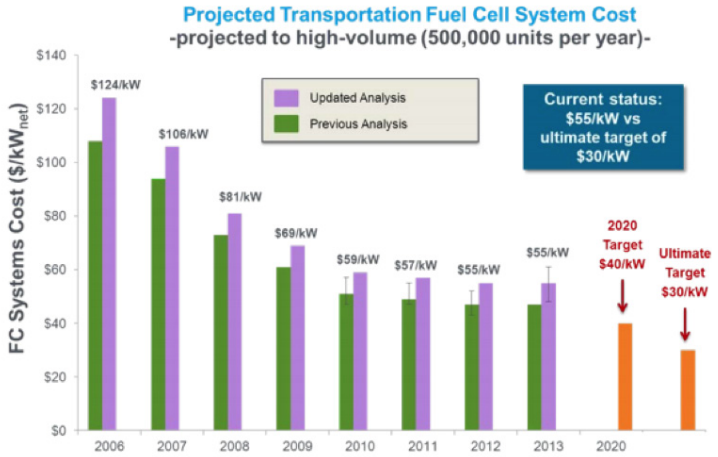

Figure 22: DOE's EERE Fuel Cell Technologies Office Transport Fuel Cell System Cost Status and Targets
Source: DOE

Toyota estimates that, since 2002, it has attained a 95% cost reduction in the powertrain and fuel tanks of the vehicle the company will launch in 2015, compared to the cost to build the original Highlander FCEV in 2002.

Stationary Fuel Cells

Cost reductions in small and large stationary fuel cell systems stem from a range of factors, including reductions in size and weight, components and the use of noble metals. Several manufacturers are also seeking supply agreements with lower cost, high quality, component manufacturers that will enable lower production costs as sales orders increase.

In Japan, manufacturers have lowered the cost of the Ene-Farm residential fuel cell system, from ¥8.0 million (US$78,800) in 2005 to less than ¥2 million (US$19,700) in 2013. These numbers factor in the government subsidy for the fuel cell system, which has helped to support 57,000 sales to consumers. By the time the subsidy program ends in 2015, sales are expected to grow significantly as the price continues to decline to less than ¥1.0 million (US$9,850) after 2015, and to ¥0.5-0.6 million (US$4,925-5,910) between 2020 and 2030.[162]

Figure 23 shows the cost reduction attained by FuelCell Energy for the company's MCFC, stated in terms of cost per kilowatt, showing a 75% decrease in costs–from almost $10,000/kW in 2003, to about $2,500/kW today. The company anticipates further cost reduction in the "mid-term."

Ballard Power Systems has reduced the cost of its FCvelocity-9SSL and FCvelocity-1020ACS fuel cell products, which power material handling equipment, by roughly 50% since 2008. The company continues to pursue cost reduction and anticipates that, with increased purchase order commitments, the "scale and cadence" of product shipments will contribute to increased manufacturing efficiency and further reductions in stack costs.[163]

Plug Power reports that their cost has been reduced by 25% since 2010 (Figure 24) through design simplification, changes to scale and sourcing alternative suppliers.

Materials and Components

Ongoing research continues to improve fuel cell stacks, often focusing on improved and more active catalysts as well as stack components and hydrogen generation techniques. A few examples are provided below.

Researchers at DOE's Brookhaven National Laboratory discovered a low-cost, stable, effective catalyst that could replace platinum in the production of hydrogen. The catalyst, made from soybeans and molybdenum metal, proved active and stable in testing.[164]

Researchers from Ulsan National Institute of Science and Technology (South Korea), Case Western Reserve University and University of North Texas report great progress with graphene nanoparticles as a fuel cell catalyst,

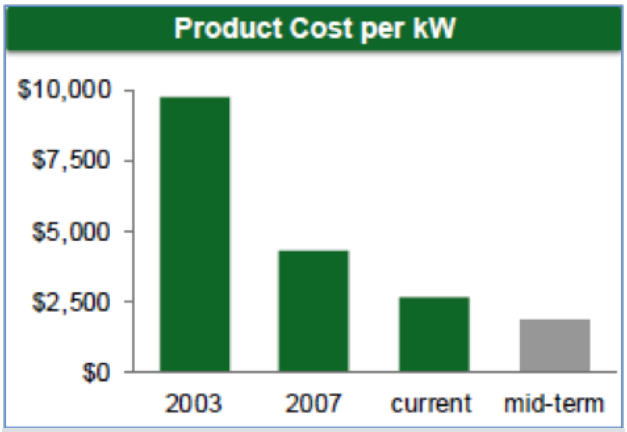

Figure 23: FuelCell Energy Product Cost per Kilowatt
Source: FuelCell Energy

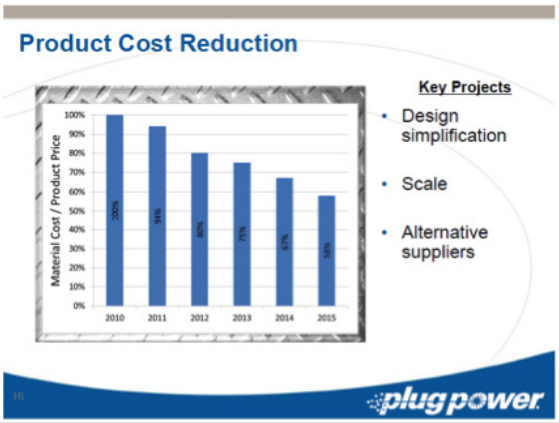

Figure 24: Plug Power – Product Cost Reduction
Source: Plug Power

performing better than platinum in oxygen-reduction reactions.[165] The catalyst material was tested in a wet cell, lab scale, set-up and not in a membrane electrode assembly.

Supported by DOE's Basic Energy Sciences program, researchers at the University of Wisconsin-Madison have achieved high performance with a new catalyst made of molybdenum disulfide, which they say could eliminate the platinum altogether. The group has produced milligram quantities of the catalyst. Plans are to experiment with scaling up and improving performance as well as exploring related compounds.[166]

Duke University engineers developed a method for producing clean hydrogen using a new catalytic approach–using nanoparticle combinations of gold and iron oxide (rust), but not in the traditional sense. Current methods depend on gold nanoparticles' ability to drive the process as the sole catalyst; Duke researchers made both the iron oxide and the gold the focus of the catalytic process.[167]

TÜV Rheinland completed the construction of a new testing laboratory in Pleasanton, California, to inspect and certify small- to mid-sized power inverter devices. The new facility joins TÜV Rheinland's laboratories in Germany, Italy, Hungary, China, Taiwan and Japan. The company is prepared to open a facility in the eastern U.S. to accommodate an expected increase in testing and certification demand.[168]

BASF announced that it is restructuring its fuel cell systems activities. As a result, BASF Fuel Cell, Inc., which produced membrane electrode assemblies for HT-PEM fuel cell systems, was closed in August 2013. BASF is now focusing on activities in the field of catalysts and absorbents for fuel cells.[169]

New Studies in 2013

DOE, national laboratories, and other stakeholders published several key reports in 2013, including:

Fuel Cell Buses in U.S. Transit Fleets: Current Status 2012 - 12-month status report that includes data collected from 18 fuel cell electric buses at three transit agencies. The report that shows the fuel economy of fuel cell electric buses is 1.8 to 2 times higher than conventional diesel buses and compressed natural gas buses.

State of the States: Fuel Cells in America 2013 - provides details on new state policies and funding, recent and planned U.S. fuel cell and hydrogen installations, and other related areas including university activity and international expansion. This report also singles out the Top 5 fuel cell states, three states to watch and spotlights six U.S. cities.

An Evaluation of the Total Cost Of Ownership of Fuel Cell Powered Material Handling Equipment - assesses the total cost of ownership of fuel cell materials handling equipment and compares it to traditional battery-powered equipment.

Vessel Cold-Ironing Using a Barge Mounted PEM Fuel Cell: Project Scoping and Feasibility - examines the feasibility of a hydrogen-fueled PEM fuel cell barge to provide electrical power to vessels at anchorage or at berth.

Status and Prospects of the Global Automotive Fuel Cell Industry and Plans for Deployment of Fuel Cell Vehicles and Hydrogen Refueling Infrastructure - automobile manufacturers leading the development of mass-market fuel cell vehicles were interviewed in Japan, Korea, Germany and the U.S.

Transportation Energy Futures - this study that finds the U.S. has the potential to reduce petroleum use and greenhouse gas (GHG) emissions in the transportation sector by more than 80% by 2050 with a comprehensive and inclusive approach.

DOE's EERE ***released peer-reviewed documentation*** detailing the updated well-to-wheels greenhouse gas (GHG) emissions and petroleum energy usage as well as the life cycle cost analysis for advanced technology vehicles.

The Breakthrough Technologies Institute released ***The Business Case for Fuel Cells 2013: Reliability, Resiliency & Savings***, which takes a look at new markets for fuel cells and the benefits they are providing customers. The report also highlights sales and installations of fuel cells to businesses in the past year.

The National Research Council (NRC) released ***Transitions to Alternative Vehicles and Fuels***, which found that by the year 2050, the U.S. may be able to reduce petroleum consumption and greenhouse gas emissions by 80% for light-duty vehicles (cars and small trucks) via a combination of more efficient vehicles; the use of alternative fuels like biofuels, electricity, and hydrogen; and strong government policies to overcome high costs and influence consumer choices.

The California Fuel Cell Partnership (CaFCP) released ***A Road Map for Fuel Cell Electric Buses in California: A Zero-Emission Solution for Public Transit***, which examines at the progress of fuel cell electric buses (FCEBs) in California and across the world, and offers recommendations to state and federal policy makers about actions they can take to put FCEBs on the path to full commercial readiness.

The ***2011-2012 Annual Report on World Progress in Hydrogen***, from the Partnership for Advancing the Transition to Hydrogen (PATH), the international coalition of national hydrogen associations, projects the global fuel cell and hydrogen energy market to be worth over $180 billion in 2050. The report also foresees revenues in the fuel cell sector growing at a rate of 26% annually over the next decade.

Zero emissions trucks: An Overview of State-of-the-Art Technologies and Their Potential, a report by CE Delft in the Netherlands and the German Aerospace Centre (DLR), commissioned by the International Council on Clean Transportation (ICCT), assesses zero emission drivetrain technologies for on-road heavy-duty freight vehicles. The report looks at CO2 reduction potential, the state of these technologies, expected costs in case of a technology shift, the role of policies to promote these technologies, and greenhouse reduction scenarios for the European Union (EU).

The New Energy World Industry Grouping (NEW-IG) Annual Report captures the key achievements and highlights of NEW-IG activities in 2012, including the Fuel Cells and Hydrogen Joint Undertaking and the Horizon 2020 program. The report presents NEW-IG efforts in securing a European R&D program for fuel cells and hydrogen and advocating market-deployment at EU policy level.

When the Grid Fails: Fuel Cells Power Critical Infrastructure in Disasters, a case study by Fuel Cells 2000, profiles industries that are beginning to adopt fuel cell systems for backup power and examines how the fuel cells performed in recent catastrophic weather events, including Superstorm Sandy, Hurricane Irene, and Winter Storm Alfred.

Appendix I: H_2USA Member Companies

2013, DOE, along with industry partners, launched H2USA - a public-private partnership focused on advancing hydrogen infrastructure to support more transportation energy options for U.S. consumers, including fuel cell electric vehicles. This partnership brings together automakers, government agencies, state coalitions, gas suppliers, and the hydrogen and fuel cell industries to coordinate research and identify cost-effective solutions to deploy infrastructure that can deliver affordable, clean hydrogen fuel in the United States.

Members of the H2USA partnership as of the end of 2013 included:

- American Honda Motor Company (CA)
- California Fuel Cell Partnership (CA)
- Hyundai Motor America (CA)
- Toyota Motor North America (CA)
- National Renewable Energy Laboratory (CO)
- Proton OnSite (CT)
- American Gas Association (DC)
- Association of Global Automakers (DC)
- Electric Drive Transportation Association (DC)
- Fuel Cell and Hydrogen Energy Association (DC)
- U.S. Department of Energy (DC)
- Argonne National Laboratory (IL)
- Massachusetts Hydrogen Coalition (MA)
- Nuvera Fuel Cells (MA)
- Chrysler Group LLC (MI)
- General Motors Holding (MI)
- Mercedes-Benz USA (NJ)
- Sandia National Laboratories (NM)
- Plug Power (NY)
- ARC: Hydrogen (SC)
- South Carolina Research Authority (SC)
- Nissan North America Research and Development (TN)
- Air Liquide (TX)
- Hydrogenics (Canada)
- ITM Power (U.K.)

Appendix II: Profiles of Public Fuel Cell Manufacturers Highlighted in the Report

Public Companies	Head-quarters/ Facilities	Annual Manu-facturing Capability	# of Employ-ees	Fuel Cell Type	Primary Fuels	Markets	Applications
Acta S.p.A. AIM: ACTA.L	Italy	2.4 MW	60	PEM	Water (system includes fuel cell and integrated electrolyzer)	Backup	Telecom Hydrogen generation, energy storage, power-to-gas
Ballard Power Systems[170] NASDAQ: BLDP TSX: BLD	Canada Other facilities: U.S. (Oregon), Denmark, Mexico	>150 MW	350	PEM	Hydrogen, methanol	Telecom, other stationary, material handling, transport	Telecom, forklifts in distribution centers, bus, automotive
Ceramic Fuel Cells, Ltd. AIM: CFU ASX: CFU	Australia	Unavailable	Unavailable	SOFC	Natural gas	Stationary	Residential & light commercial m-CHP
Ceres Power AIM: CWR	U.K.	Unavailable	65	SOFC	Natural gas, liquefied petroleum gas (LPG), butane	Stationary, portable, auxiliary	Residential m-CHP, truck APUs, off-grid, smart grid
Delphi NYSE: DLPH	U.S. (Michigan) Other facilities: Brazil, China, Luxembourg	Unavailable	Unavailable	SOFC	Natural gas, bio-diesel, diesel, propane, gasoline, military logistics fuel	Stationary, transport	Truck APUs, residential, commercial, military
FuelCell Energy[171] NASDAQ: FCEL	U.S. (Connecticut) Other facilities: South Korea, Germany	U.S.: 100 MW Europe: 20 MW Asia: 100 MW under construction, designed for expansion up to 200 MW	610 full-time employees (565 in U.S., 45 at foreign locations) and 34 temporary workers (U.S.)	MCFC	Natural gas, onsite biogas, directed biogas, propane	Large-scale stationary	Electric utilities and independent power producers, industrial operations, universities, water treatment facilities, government, businesses
Fuji Electric[172] 6504: Tokyo	Japan	2MW per year + (under expansion)	Unavailable	PAFC	Natural gas, propane	Large-scale stationary	Hospitals, schools, commercial sites

GEI Global Energy Corp. OTCBB: GEIG	U.S. (Michigan)	Unavailable	5	HT-PEM	Hydrogen, natural gas, methane, butane, propane, biofuels	Stationary, backup, auxiliary	Primary power for commercial business, telecom, backup emergency, APUs
Hydrogenics NASDAQ: HYGS	Canada Other facilities: Belgium, Germany, Russia	Up to 90 MW 30 MW if producing on one shift / 90 MW w/ 3 shifts - assuming 1) customer orders and 2) supplier materials are available	135 full time employees (62 in Canada, 73 in Belgium)	PEM PEM electro-lyzers	Hydrogen Water	Stationary, backup, motive Hydrogen fuel	Telecom, data centers, bus, material handling, utility vehicles Hydrogen production, storage, fueling, power-to-gas
ITM Power AIM: ITM	U.K.	Unavailable	75	PEM electro-lyzers	Water	Hydrogen fuel	Hydrogen production, storage, fueling, power-to-gas
Neah Power Systems OTCBB: NPWZ	U.S. (Washington)	Unavailable	Unavailable	PEM	Hydrogen	Portable	Consumer electronics, military, first responders, logistics
Panasonic NYSE: PCRFY	Japan	10,000 units/ year	Unavailable	PEM	Natural gas	Stationary	Residential
Plug Power NYSE: PLUG	U.S. (New York)	10,000 units/ year	230	PEM	Hydrogen	Motive	Material handling
SFC Energy AG F3CG.DE	Germany Other facilities: U.S., Canada, The Netherlands, Romania	Unavailable	256	DMFC	Methanol	Off-grid stationary, motive	Onboard devices (RVs, boats), remote equipment (telecom, traffic management, weather stations, environmental recorders, surveillance, lighting, pumps), military
Toshiba NYSE: TOSBF	Japan	Unavailable	Unavailable	PEM	Natural gas	Stationary	Residential

Appendix III: Profiles of Private Fuel Cell Manufacturers Highlighted in the Report

Public Companies	Head-quarters/ Facilities	Annual Manu-facturing Capability[173]	# of Employ-ees	Fuel Cell Type	Primary Fuels	Markets	Applications
ACAL Energy	U.K.	Unavailable	Unavailable	PEM	Hydrogen	Stationary, motive	Peak shaving, remote power, commercial scale CHP, transport
Aisin Seiki[174]	Japan	Unavailable	Unavailable	SOFC	Natural gas	Stationary	Residential CHP
Altergy Systems	U.S. (California)	Unavailable	Unavailable	PEM	Hydrogen, methanol	Backup	Telecom
AquaFairy	Japan	Unavailable	Unavailable	PEM	Calcium hydride/water	Portable	Consumer electronics
Axane[175]	France	Unavailable	Unavailable	PEM	Hydrogen	Backup, off-grid	Telecom
Baxi Innotech	Germany	Unavailable	Unavailable	PEM, SOFC	Natural gas	Stationary	Residential m-CHP
Bing Energy	U.S. (Florida)	Unavailable	Unavailable	PEM	Hydrogen	Backup	Telecom
Bloom Energy	U.S. (California) Other facilities: Delaware	Unavailable	Unavailable	SOFC	Natural gas, directed biogas	Large-scale stationary	Buildings (commercial, universities, arenas), data centers, utilities
Bosch Thermo-technology	Germany	Unavailable	Unavailable	SOFC	Natural gas	Stationary	Residential m-CHP
ClearEdge Power[176]	U.S. (California) Other facilities: Oregon, Connecticut	Unavailable	>250	PAFC PEM	Natural gas	Large-scale, small-scale stationary	Buildings (commercial, government, universities, hospitals), residential CHP
Dantherm Power[177]	Denmark	Unavailable	Unavailable	PEM	Hydrogen, methanol	Backup	Telecom
Elcore GmbH	Germany	Unavailable	Unavailable	PEM	Natural gas	Stationary	Residential CHP
Electro Power Systems	Italy Other facilities: U.S. (Michigan)	10 MW (1,000 units annually)	45	PEM	Hydrogen self-generated onsite	Backup, energy storage	Telecom, data centers and public infrastructure for energy storage
Eneos Celltech[178]	Japan	Unavailable	Unavailable	SOFC	LPG, kerosene	Stationary	Residential CHP

EnergyOr	Canada	Unavailable	Unavailable	PEM	Hydrogen	Motive	Niche civil, and military applications – UAVs, APUs Hydrogen fueling
Fuel Cell Systems[179]	U.K.	Unavailable	Unavailable	PEM	Hydrogen, methanol	Portable	Auxiliary power for marine, RV, industrial
Future E Fuel Cell Solutions	Germany	Unavailable	Unavailable	PEM	Hydrogen	Backup, stationary	Telecom, UPS, off-grid
H2 Logic	Denmark	10 hydrogen stations/year	35+	PEM	Hydrogen	Motive	Hydrogen fueling
Heliocentris	Germany Other facilities: Canada, South Africa, United Arab Emirates	Unavailable	Unavailable	PEM	Hydrogen	Backup	Telecom
Horizon Fuel Cell Technologies	Singapore Other facilities: U.S. (Illinois), Czech Republic, Australia, Brazil, China, India, Japan, South Korea, Thailand, Taiwan, U.K.	Unavailable	Unavailable	PEM	Hydrogen	Portable, backup, motive	Educational, consumer electronics, off-grid, military, vehicles, aerospace
Infintium Fuel Cell Systems	U.S. (Texas)	Unavailable	Unavailable	PEM	Hydrogen	Motive	Material handling
Intelligent Energy	U.K. Other facilities: USA (California), India, Japan	Unavailable	300+	PEM	Hydrogen	Portable, motive, backup	Consumer electronics, vehicles, telecom
LG Fuel Cell Systems[180]	U.S. (Ohio)	Unavailable	Unavailable	SOFC	Natural gas, coal syngas	Stationary	Large-scale utilities
Lilliputian Systems	U.S. (Massachusetts)	Unavailable	Unavailable	SOFC	Butane	Portable chargers	Consumer electronics
Novofuel[81]	U.S. (Indiana) Other facilities: Italy	Unavailable	Unavailable	PEM	Hydrogen	Portable, auxiliary, backup	Military, telecom, off-grid, emergency response, electro-medical devices, nautical APUs, industrial automation

Nuvera Fuel Cells	U.S. (Massachusetts) Other faciilties: Italy	32 MW	135	PEM	Hydrogen	Motive	Material handling, aerospace, automotive Hydrogen generation
Oorja Protonics	U.S. (California) Other facilities: China	Unavailable	Unavailable	DMFC	Methanol	Motive & backup, onsite hydrogen generation	Range extension for material handling & refrigerated trucks, telecom
PowerCell[182]	Sweden	10 MW (2,000 units/year)	25+	PEM	Diesel, CNG, hydrogen	Stationary, auxiliary	Telecom, truck APUs
Proton Motor GmbH	Germany	Unavailable	Unavailable	PEM	Hydrogen	Motive, stationary, backup	Telecom, data center, hospitals, office buildings, boats, range extender for buses and commercial vehicles
Proton OnSite	U.S. (Connecticut) Other facilities: Saudi Arabia[183]	2 MW	Unavailable	PEM electro-lyzers	Water	Onsite hydrogen generation	Military, aerospace, fueling, renewable energy industries
ReliOn	U.S. (Washington)	Scalable as needed through contract manu-facturers	45	PEM	Hydrogen, methanol	Backup	Telecom
SAFCell	U.S. (California)	20-30 kW	11	SAFC[184]	Methanol, propane, diesel	Portable, backup, remote	APUs, military
Solid Cell	U.S. (New York) Other facilities: Ireland	Unavailable	Unavailable	SOFC	Hydrogen, natural gas, propane, butane, ethanol, 87 octane gasoline, diesel	Stationary, portable, backup	Off-grid residential & light commercial, small scale CHP, remote continuous power, backup, mobile power generators, APUs for trucks, RV's, marine vessels, aircraft
Symbio FCell	France	Unavailable	Unavailable	PEM	Hydrogen	Motive	Range extender for electric vehicles
UltraCell[185]	U.S. (California) Other facilities: New York	100 kW	Unavailable	RMFC[186]	Methanol, propane	Portable	Military, off-grid

VP Energy[187]	U.S. (Michigan)	Unavailable	Unavailable	PEM	Hydrogen	Stationary, backup	Telecom, federal agencies, industry (buildings), emergency communications for state and local
Watt Fuel Cell Corp.	U.S. (New York)	Unavailable	Unavailable	SOFC	Natural gas, propane, JP-8, diesel, renewable fuels	Portable, backup	Military, emergency backup for municipal & first aid, battery charging for RVs & marine, remote sensor power, residential

Appendix IV: Endnotes

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170 In 2012, Ballard acquired key assets from IdaTech, including fuel cell product lines for backup power applications, distributor and customer relationships, and a license to intellectual property, in return for $7.7 million of Ballard common shares at a price of $1.08 per share (transferred to IdaTech's principal funder, Investec, a South African specialist bank and asset management company). Ballard had supplied IdaTech with fuel cell stacks for its methanol-fueled ElectraGen systems for several years.

171 In 2012, Fuel Cell Energy acquired Versa Power Systems, Inc., a global developer of solid oxide fuel cell technology (SOFC). Prior to this action, Fuel Cell Energy owned approximately 39% of Versa and partnered with Versa under the U.S. Department of Energy Solid State Energy Conversion Alliance (SECA) coal-based systems program.

172 Global Energy Innovations, Inc., was acquired by Suja Minerals Corp. in 2013, and changed name to GEI Global Energy Corp.

173 Unless otherwise specified. Some numbers are provided in kilowatts (kW) and are noted as such in the entries.

174 Aisin Seiki and Toyota worked jointly to develop the stationary SOFC fuel cell cogeneration system.

175 Axane is a wholly-owned subsidiary of the Air Liquide group.

176 ClearEdge Power acquired fuel cell manufacturer, UTC Power, in 2013.

177 Dantherm Power is a subsidiary of Ballard Power Systems Inc. Dantherm Power's fuel cells incorporate Ballard Power Systems' FCgen®-1020ACS fuel cell stack. Dantherm A/S and Azure Hydrogen hold non-controlling interests in Dantherm Power.

178 JX Nippon Oil and Sanyo Electric Company established Eneos Celltech as a joint company for stationary fuel cells.

179 Fuel Cell Systems Limited was formed as a subsidiary of UPS Systems plc.

180 In 2012, Rolls Royce sold 51% of its SOFC company, Rolls Royce Fuel Cell Systems, Inc., to South Korean multi-national corporation, LG. The company was re-named LG Fuel Cell Systems.

181 In November 2013, AlumiFuel Power Corporation announced that its wholly owned subsidiary, NovoFuel, Inc., signed an agreement with Genport, srl of Italy to combine and integrate their technologies, assets and operations into NovoFuel.

182 PowerCell is owned by Volvo Group Venture Capital, Fouriertransform, Midroc New Technologies and Finindus.

183 Proton Energy Arabia is a joint venture with SupplyCore Middle East.

184 Solid Acid Fuel Cell

185 UltraCell was founded in 2002. Bren-Tronics Inc. acquired certain IP and assets of the company in 2011, and formed UltraCell LLC.

186 Reformed Methanol Fuel Cell

187 VP Energy, LLC (Michigan) maintains the Exclusive Technology License to Operations, Manufacturing and Distribution to North America of the Electro Power Systems product line.

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DOE/Publication Number • November 2014