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

2011 FUEL CELL TECHNOLOGIES MARKET REPORT

July 2012

Authors

This report was a collaborative effort by staff of the Breakthrough Technologies Institute, Inc., in Washington, DC.

Acknowledgement

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APU	Auxiliary power unit	mpg	Miles per gallon
ARRA	American Recovery and Reinvestment Act	MW	Megawatt
CEP	Clean Energy Partnership	nm	Nanometer
CFCL	Ceramic Fuel Cells Limited	NOW	National Organization for Hydrogen, Germany
CHP	Combined heat and power	OEM	Original Equipment Manufacturers
CHIC	Clean Hydrogen in European Cities Project	OTC	Over the counter (investment)
CO2	Carbon dioxide	PAFC	Phosphoric acid fuel cell
DLA	Defense Logistics Agency	PE	Private equity
DoD	Department of Defense	PEM	Proton exchange membrane
DOE	Department of Energy	PIPE	Private investment in public equities
DFC	Direct Fuel Cell	PV	Photovoltaic
DMFC	Direct methanol fuel cell	R&D	Research and development
FCE	FuelCell Energy	RV	Recreational vehicle
FCEV	Fuel cell electric vehicle	SECA	Solid State Energy Conversion Alliance
gge	Gallon gasoline equivalent	SGIP	Self-Generation Incentive Program
GM	General Motors	SOFC	Solid oxide fuel cell
H2I	Hawaii Hydrogen Initiative	TGC	The Gas Company
K2	K2 Pure Solutions	UAV	Unmanned aerial vehicle
kg	Kilogram	UK	Uniter Kingdom
km/h	Kilometer per hour	US	United States
kW	Kilowatt	VC	Venture capital
kWh	Kilowatt-hour	W	Watt
MCFC	Molten carbonate fuel cell	Wh	Watt-hour
m-CHP	Micro-combined heat and power		

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 non-polluting sources.
There are three main markets for fuel cell technology: stationary power, transportation power, and portable power. Stationary power includes any application in which the fuel cells are operated at a fixed location, either for primary or for backup power, or for combined heat and power (CHP). Transportation applications include motive power for cars, buses, and other fuel cell electric vehicles (FCEV), specialty vehicles, materials handling vehicles (e.g. forklifts) and auxiliary power units (APUs) for highway and off-road vehicles. Portable power applications use fuel cells that are not permanently installed or fuel cells in a portable device.

This report provides an overview of trends in the fuel cell industry and markets, including product shipments, market development, and corporate performance in 2011. Trends include:

- Commercial markets expanded significantly, especially in the materials handling industry, where more than 3,000 fuel cell forklifts were either deployed or on order in the United States at the end of 2011.

- ReliOn and Plug Power were both named to Deloitte's Technology Fast 500, a ranking of the fastest growing technology, media, telecommunications, life sciences and clean technology companies – both public and private – in the United States and Canada.

- The use of power purchase agreements in the stationary market continued to increase, enabling customers to purchase fuel cell power and heat without owning the fuel cell itself.

- New, independent studies highlighted the key role hydrogen should play in balancing the grid of the future, quantified the benefits of federal research support for

Notable in 2011

Total, worldwide fuel cell shipments grew 37.5% between 2010 and 2011 and 214% between 2008 and 2011.

Venture capital and private equity investments in fuel cells and hydrogen increased worldwide by 276% between 2010 and 2011. Venture capital and private equity investments in US fuel cell companies grew by 553.5% during the same period.

A UTC Power fuel cell on a transit bus in California surpassed 10,000 operating hours in real-world service with its original cell stacks and no cell replacements.

Vision Motors provided the world's first fuel cell plug-in hybrid class 8 and terminal tractor trucks to the ports of Long Beach and Los Angeles.

A report by the Energy Department concluded that, in the long term, fuel cell electric vehicles offer the greatest potential to displace petroleum consumption in the transportation sector, and they can do so at a competitive cost.

FuelCell Energy secured a 70 MW order from POSCO Power in South Korea, the largest order ever received by the company.

fuel cells and hydrogen, and affirmed that fuel cells in the transportation sector provide the best opportunity in the long term to reduce petroleum consumption and greenhouse gas emissions.

- There was increased interest in Europe to use hydrogen and fuel cells for grid-scale energy storage, primarily to balance the intermittent and volatile nature of renewable power sources, such as wind and solar.

- California continued to build hydrogen stations for FCEVs, with two new public access hydrogen stations commissioned in 2011. As of the date of this report, California had nine public access stations, fourteen private access stations, and fourteen additional stations that were either funded or in development.

- Fuel cells continue to receive far more patents than other renewable energy technologies, with fuel cells receiving more than 950 patents in 2011 and solar receiving the second greatest number of patents, at roughly 550. However, Asia appears to be overtaking North America and, in particular, Japan appears to be overtaking the United States in terms of fuel cell patents issued. If this trend continues, it suggests that North America and the United States may cede leadership in the fuel cell industry to Asia and Japan, similar to what has occurred in other high technology industries.

Fuel cell technologies have made great progress in meeting cost reduction goals, system longevity and durability. However, progress on cost reduction for both fuel cells and hydrogen must continue, and the availability of public hydrogen fueling stations must substantially increase, especially stations that provide hydrogen produced from renewable sources. Performance and durability of fuel cells also must continue to improve, especially for transportation applications. Public awareness of hydrogen and fuel cells remains low, requiring further outreach and education from the industry. Finally, safety regulations and product standards in many countries need to be revised to reflect current experience and to ensure better harmonization.

The world's first "trigeneration" fuel cell facility opened in California, producing electricity, heat, and hydrogen from bio-gas produced at the Orange County Sanitation District's wastewater treatment plant in Fountain Valley. The fuel cell produces 250 kW of electricity and enough hydrogen to supply up to 50 FCEVs per day.

A plant opened in Germany that uses wind power to produce hydrogen through a 500 kW electrolyzer. The hydrogen is then co-fired with biogas to balance short term fluctuations in the wind power and also is used as fuel for hydrogen vehicles.

The Delaware Public Service Commission approved a plan whereby Bloom Energy will install 30 MW of fuel cells at two Delmarva Power substations and open a manufacturing facility at a former Chrysler plant.

Financial Data

This section provides information regarding fuel cell cost reduction as well as 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, this section discusses venture capital, private equity, and other investment activity within the industry.

Fuel cell companies continued to operate with significant though in some cases declining losses. Several companies are on the road to profitability, reached through aggressive cost cutting and increased economies of scale due to commercial sale of products.

Cost Reduction

Fuel cell costs continue to decline significantly for light duty vehicles, with projected volume costs reduced more than 80% since 2002 and 30% since 2008, according to the DOE.[1] Platinum content has been reduced by a factor of five and is currently at less than 0.2g/kilowatt (kW), with a DOE target of 0.125g/kW. Fuel cell durability has more than doubled.

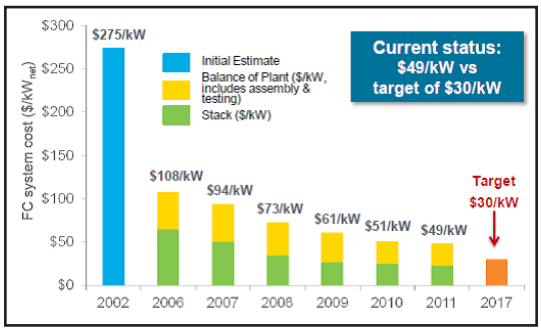

Figure 1: Projected Fuel Cell Transportation System Costs per kW, Assuming High Volume Production (500,000 units per year). Source: DOE

As shown in Figure 1, the projected cost per kW of a transportation fuel cell system dropped to under $50/kW for the first time in 2011. More than half of this cost is for balance of plant, not the fuel cell itself. Moreover, compared with 2007, the projected transportation system cost per kW in 2011 is significantly lower than it was in 2007 across a wide range of annual production rates. (See Figure 2).

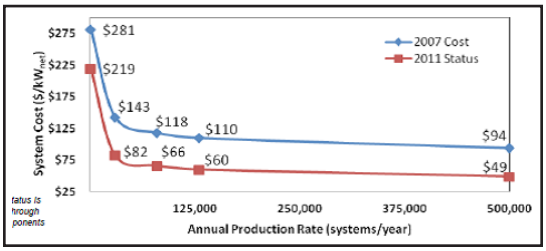

Figure 2: Projected Fuel Cell Transportation System Costs per kW Across a Range of Manufacturing Volumes, 2007 and 2011. Source: DOE

Ballard Power Systems reported that it decreased the cost of its materials handling fuel cell stacks by 55% since 2008. Ballard supplies its stacks primarily to Plug Power, which integrates the fuel cells systems into various materials handling vehicles.

Similar cost reductions are being realized with stationary fuel cells. For large stationary, UTC Power reports a nearly 50% cost reduction for its PureCell Model 400 in 2011 as compared with 2009.[2] FuelCell Energy has reduced costs from nearly $10,000/kW in 2003 to roughly $3,000/kW in 2011 (see Figure 3).[3]

Regarding small stationary fuel cells, ReliOn reported that it is achieving a 40% cost reduction with each new generation of a typical 4-kW fuel cell installed outdoors with hydrogen storage.[4] On April 1, 2011, Tokyo Gas introduced its 2011 model year residential fuel cell for the

ENE-FARM program, achieving a 30% manufacturing cost reduction compared with the previous model. The customer price was reduced by 21% to 2.76 million yen (roughly $34,000 US dollars).[5]

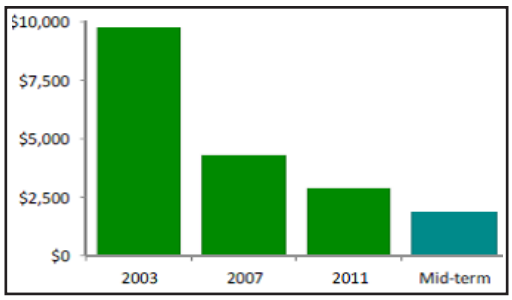

Figure 3: FuelCell Energy Cost Reduction. Source: FuelCell Energy.

The cost for producing and dispensing hydrogen also continues to decline. For distributed production, the projected cost of hydrogen (dispensed and untaxed) through natural gas reforming is now below $4 per gallon gasoline equivalent (gge), within DOE's target range of $2-$4/gge.[6] The projected cost of hydrogen (dispensed and untaxed) through electrolysis and bio-derived liquids is now around $6/gge, down from nearly $8/gge in 2006.

Revenues, Assets, and R&D Expenses

Fuel cell companies derive revenue from the sale of fuel cells and related equipment (such as hydrogen generators), support and maintenance contracts, and from contract research and development. A recent trend, especially in the large stationary market segment, is for companies to derive revenue through the sale of electricity and in some cases waste heat. This is typically accomplished through a power purchase agreement, whereby the end user agrees to purchase the electricity and/or heat generated by the fuel cell for a period of years, often at a fixed rate. The fuel cell company maintains ownership of the fuel cell and provides maintenance and support.

Tables 1 through 3 provide financial data for select public companies. These companies were selected because fuel cells are their primary product, and because they are traded on major stock exchanges. IdaTech was included in previous editions of this report but has been removed because it is no longer a publicly traded company.

As shown in Table 1, gross revenues of publicly traded fuel cell companies continue to increase. At the same time, however, the cost of revenue also tends to be increasing, although in some cases the difference between gross revenues and cost of revenues is declining, reflecting improved prospects for profitability.

Table 1: Gross Revenues and Cost of Revenue for Select Public Fuel Cell Companies
(Thousands USD except where noted)

North American Companies	2011		2010		2009	
	Gross Revenues	Cost of Revenue	Gross Revenues	Cost of Revenue	Gross Revenues	Cost of Revenue
Ballard Power Systems	76,009	62,124	65,019	54,887	46,722	40,795
FuelCell Energy [1]	122,570	135,180	69,777	88,430	88,016	118,027
Hydrogenics Corp.	23,832	18,344	20,930	15,504	18,841	15,113
Plug Power	27,626	36,901	19,473	29,482	12,293	19,680
TOTALS (USD)	**250,037**	**252,550**	**175,199**	**188,303**	**165,872**	**193,615**
Other Companies						
Ceramic Fuel Cells Ltd [2 3]	3,681	29,142	2,033	21,940	1,679	48,667
Ceres Power [2 4]	692	17,702	786	14,543	952	10,734
SFC Energy AG [5]	15,425	10,056	13,330	9,288	11,687	8,493

[1] Year ends October 31 [2] Year ends June 30 [3] $AUS Thousands [4] £ Thousands [5] € Thousands

As seen in Table 2, most companies continue to show decreases in R&D expenditures in 2011 over 2010. This continues the trend, as discussed in previous editions of this report, of companies focusing increasingly on product development and manufacturing, rather than R&D.

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

North American Companies	2011	2010	2009
Ballard Power Systems	21,623	23,766	26,628
FuelCell Energy [1]	7,830	10,370	10,994
Hydrogenics Corp.	2,934	3,445	5,219
Plug Power	5,656	12,901	16,324
TOTALS (USD)	**16,420**	**50,528**	**59,165**
Other Companies			
Ceramic Fuel Cells Limited [2 3]	15,127	10,257	9,861
Ceres Power [2 4]	12,869	9,907	6,308
SFC Energy AG [5]	2,537	1,891	1,507
[1] Period ending October 31 [2] Period ending June 30 [3] $AUS Thousands [4] £ Thousands [5] € Thousands			

Table 3 shows that some companies increased assets between 2010 and 2011, while others saw asset reductions. At the same time, most companies showed increases in liabilities over the same period. This continues a general trend cited in previous editions of this report.

Table 3: Total Assets and Liabilities for Select Public Fuel Cell Companies
(Thousands USD, unless footnoted)

North American Companies	2011		2010		2009	
	Assets	Liabilities	Assets	Liabilities	Assets	Liabilities
Ballard Power Systems	165,290	69,970	189,788	61,913	195,348	36,428
FuelCell Energy [1]	183,630	137,224	150,529	66,136	162,688	56,420
Hydrogenics Corp.	31,061	18,309	31,473	13,937	36,808	18,244
Plug Power	55,656	26,620	59,177	16,264	164,185	75,915
TOTALS	**436,049**	**247,661**	**430,967**	**158,160**	**559,029**	**188,091**
Other Companies						
Ceramic Fuel Cells Limited [2 3]	42,785	9,250	33,275	7,229	50,941	2,451
Ceres Power [2 4]	33,873	6,465	47,054	6,437	27,081	5,688
SFC Energy AG [5]	48,782	11,994	46,312	4,591	50,442	4,581
[1] Period ending October 31 [2] Period ending June 30 [3] $AUS Thousands [4] £ Thousands [5] € Thousands						

Venture Capital and Private Equity

Cumulative global investment in fuel cells and hydrogen totaled roughly $731.9 million between 2009 and 2011.[1] The vast majority of these investments ($671.4 million) were in fuel cell companies. Figure 4 provides a breakdown by quarter and by investment type.

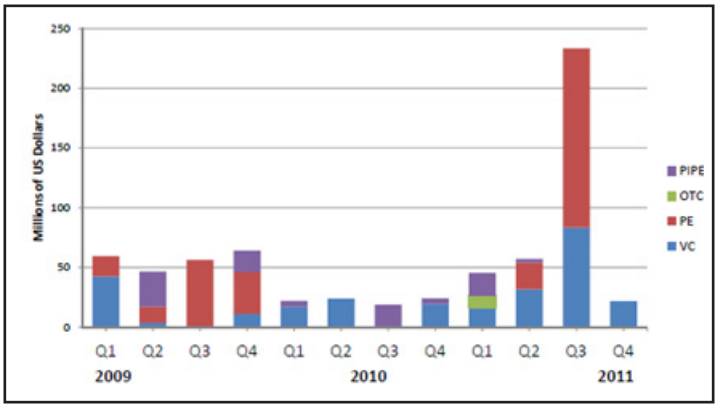

Figure 4: Worldwide Venture Capital (VC), Private Equity (PE), Over-the-Counter (OTC), and Private Investment in Public Equities (PIPE) Investments in fuel cell companies (2009 – 2011) Source: Breakthrough Technologies Institute using data from Bloomberg New Energy Finance

The $731.9 million invested between 2009 and 2011 represents an increase of nearly $102 million over the total fuel cell and hydrogen investment between 2008 and 2010, as reported in the 2010 edition of this report.[7] Moreover, global venture capital and private equity investments in hydrogen and fuel cells nearly quadrupled between 2010 and 2011 – rising from $86.5 million to $325.2 million.

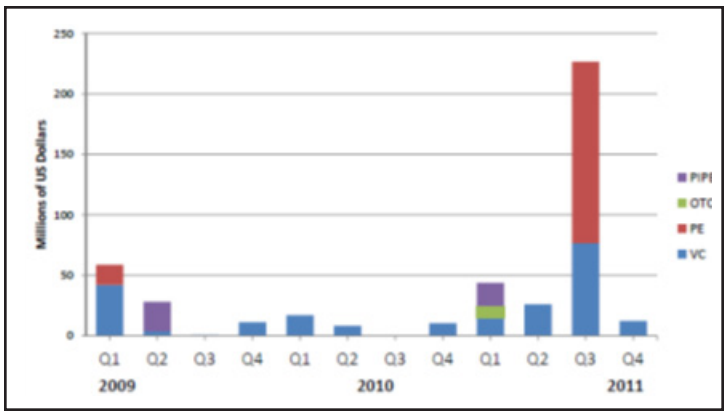

Figure 5: US Venture Capital (VC), Private Equity (PE), Over-the-Counter (OTC), and Private Investment in Public Equities (PIPE) Investments in fuel cell companies (2009 – 2011) Source: Breakthrough Technologies Institute using data from Bloomberg New Energy Finance

Much of the growth between 2010 and 2011 is due to $150 million in fuel cell private equity investments made in a US company or companies recorded in the third quarter of 2011. This was by far the most invested in fuel cells in any single quarter between 2006 and 2011. However, even if this $150 million is excluded from the 2011 total, global private equity and venture capital investment doubled between 2010 and 2011, suggesting broad growth in investment activity.

Venture capital and private equity investment in US fuel cell companies totaled $389.4 million between 2009 and 2011, more than half of the global total. Moreover, venture capital and private equity investment in US companies grew by more than six fold between 2010 and 2011, rising from $42.8 million to $279.7 million. If the $150 million investment in the third quarter of 2011 is excluded, venture capital and private equity investment in US companies tripled between 2010 and 2011, again suggesting broad growth in investment activity.

The growth in investment activity is reflected in Table 4, which shows the top ten disclosed venture capital and private equity investors in fuel cells and hydrogen in 2011. The total amount of private equity and venture capital investment for the top ten investors is nearly three times greater in 2011 ($113.2 million) than it was in 2010 ($36.9 million), as reported in the 2010 edition of this report. Moreover, with the exception of Intel Capital Corporation, all of the top ten investors shown in the table are new to the list in 2011, suggesting that the industry is attracting both new capital and new sources of that capital.

Table 4: Top Ten Disclosed Venture Capital and Private Equity Investors in Fuel Cells and Hydrogen, By Company and By Country (2011)

Top Ten Fuel Cell Investors	
Company	**Amount (millions USD)**
Artis Capital Management LP (US)	18.4
Gussing Renewable Energy GmbH (Austria)	18.4
Kohlberg Capital Corp (US)	18.4
Southern California Gas Co (US)	18.4
Intel Capital Corp (US)	10.5
Rockport Capital Partners LLC (US)	10.5
Scottish Enterprise (UK)	5.7
SSE PLC (UK)	5.7
CT Investment Partners, LLP (UK)	3.8
KTH Chalmers Capital AB (Sweden)	3.4
Total (top 10 only)	**$113.2**
Source: Bloomberg New Energy Finance	

Table 5 shows the top ten global investors in fuel cells and hydrogen between 2000 and 2011, as well as the countries with the highest level of investment during that period. Kleiner Perkins Caufield & Byers, a US firm, made the greatest cumulative investment during the period, followed by the World Gold Council, a United Kingdom (UK) firm. In aggregate, US investors made the greatest cumulative investment during the period, $815 million, followed by UK investors at $320.5 million. US and UK investors collectively comprised six of the top ten largest investors in the sector.

Table 5: Top Ten Venture Capital and Private Equity Investors in Fuel Cells and Hydrogen, By Company and By Country (Cumulative 1/1/2000 – 12/31/2011)			
Top Ten Fuel Cell Investors		**Top Ten Countries with Highest Levels of Private Investment in Fuel Cells**	
Company	**Amount (millions USD)**	**Country**	**Total All VC and PE Investment (millions USD)**
Kleiner Perkins Caufield & Byers (US)	66.4	US	815.0
World Gold Council (UK)	60.4	UK	320.5
Carbonics Capital Corp (US)	58.1	Canada	154.0
Investec (South Africa)	57.1	Germany	98.1
Chrysalix Energy LP (Canada)	53.2	South Africa	57.1
Mobius Venture Capital (US)	51.5	Singapore	50.0
EnerTek Singapore Ptd Ltd (Singapore)	50.0	Australia	46.5
Rolls Royce Plc (UK)	50.0	Sweden	33.2
Jolimont Ventures (Australia)	45.5	Switzerland	31.1
Meditor Capital Management (UK)	36.7	Netherlands	29.1
Subtotal (top 10 only)	**$528.9**	**Subtotal (top 10)**	**$1,634.6**
TOTAL (All Companies and Countries)			**1,828.5**
Source: Bloomberg New Energy Finance			

Shipments

The total number of fuel cell systems shipped continued to increase in 2011. As shown in Figure 6, total global shipments across all applications grew from roughly 16,000 units in 2010 to roughly 22,000 units in 2011, a 37.5% increase. Between 2008 and 2011, total global shipments increased from about 7,000 units to 22,000 units, a 214% increase.

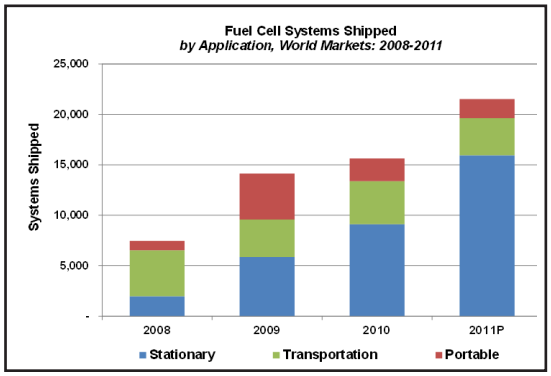

Figure 6: Fuel Cell Systems Shipped by Application, World Markets: 2008-2011. Source: Pike Research[8]

There also is a steady increase in MWs shipped for most of the period, but a slight decline between 2010 and 2011, primarily in the stationary market (See Figure 7). This is because the substantial growth in stationary unit shipments, as shown in Figure 6, is primarily attributable to residential units, which typically produce a few kilowatts of power each, a small fraction of the output of large stationary units. In other words, total stationary shipments in 2011 comprised a greater proportion of residential units than the total stationary shipments in 2010. This accounts for the increase in the number of units and the decrease in the MW shipped between 2010 and 2011. Similarly, portable MWs shipped each year total substantially less than 1 MW, even though there are a significant number of portable units sold each year.

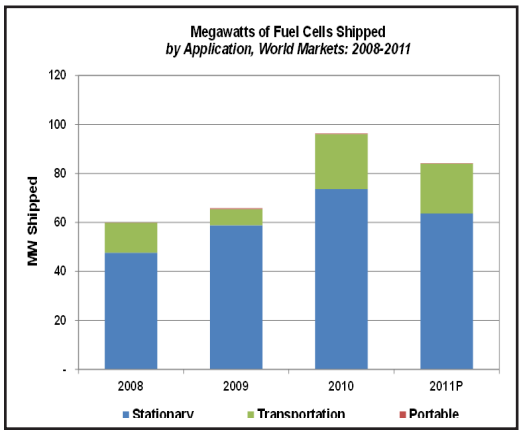

Figure 7: MW of Fuel Cells Shipped by Application, World Markets: 2008-2011. Source: Pike Research.

The location of manufacture for fuel cell systems shows a trend toward increased manufacturing activity in Asia as compared with North America. As shown in Figure 8, fuel cell manufacturing in North America increased substantially between 2008 and 2010, with growth in all three market segments (portable, transportation, stationary). In 2011, however, total units manufactured in North America declined to about 3,100 units, as compared with 3,600 units in 2010. The declines were in the stationary and portable market segments, with transportation showing a significant increase, due to increasing shipments for materials handling equipment.

In Asia, the trend between 2008 and 2011 has been a generally steady and sharp increase, rising from roughly 1,600 units in 2008 to roughly 12,500 units in 2011. All of the growth has been in the stationary market, primarily due to Japan's residential fuel cell program.

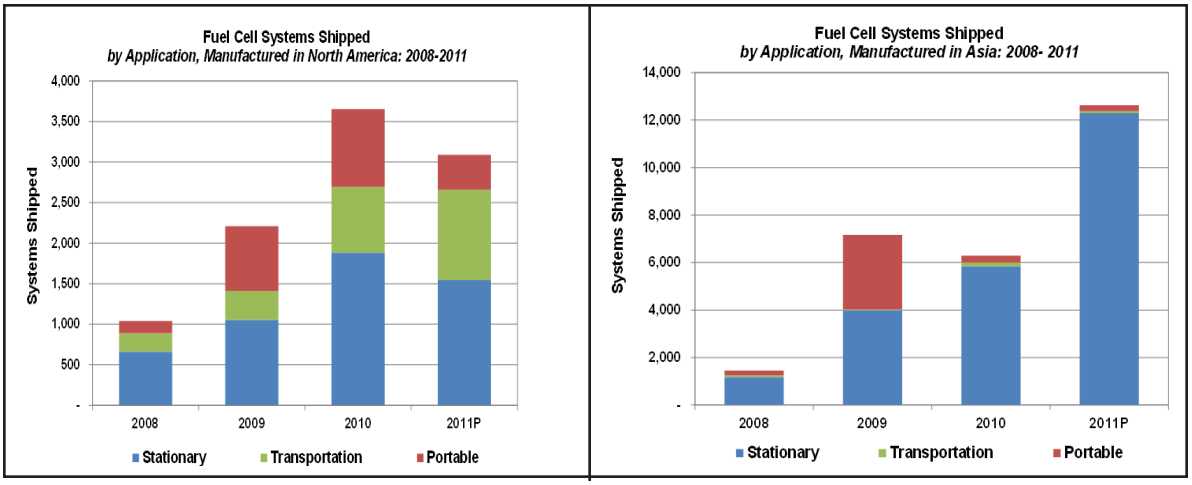

Figure 8: Fuel Cell Systems Shipped by Application, Manufactured in North America and Asia: 2008-2011. Source: Pike Research.

A breakdown of shipments by country of manufacture further reveals this trend. As shown in Figure 9, Japan experienced the greatest growth between 2008 and 2011 in terms of unit shipments. The United States also experienced growth between 2008 and 2010, but unit shipments declined 16 % between 2010 and 2011. Germany's unit shipments remained relatively constant during the period.

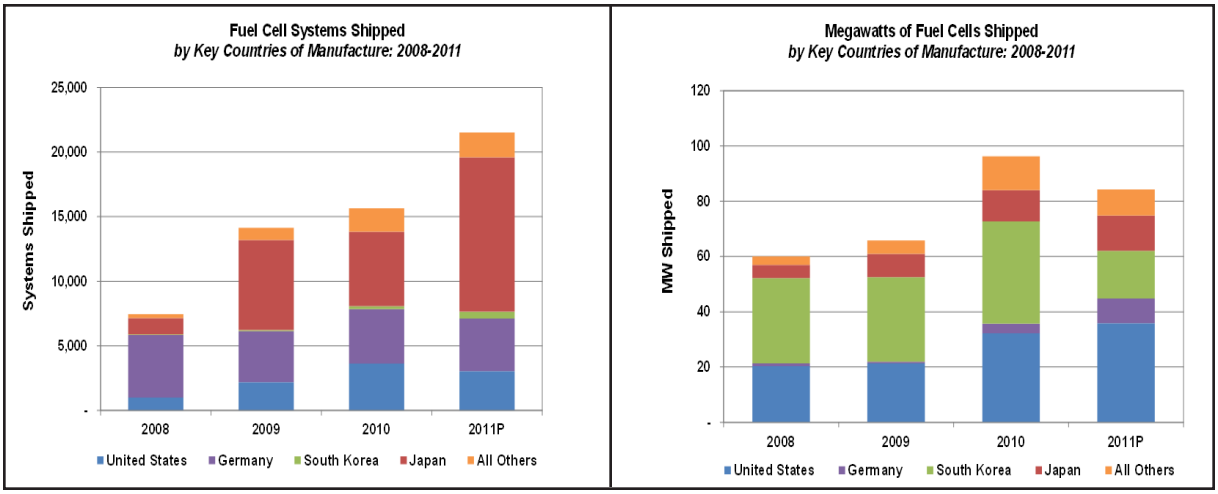

Figure 9: Fuel Cell Systems and MWs Shipped by Country of Manufacture: 2008-2011. Source: Pike Research.

In terms of MW shipped, the United States experienced steady growth between 2008 and 2011, largely because of increased sales of large stationary fuel cells. Japan also experienced growth, but its total MW shipped is less than the United States because of Japan's focus on the small stationary market. South Korea is notable for its substantial MW shipments, largely due to the manufacturing and sales agreement between FuelCell Energy and Posco Power. Germany significantly expanded MWs shipped between 2010 and 2011, much of which is attributable to the transportation market segment.

Finally, the number of units manufactured in Europe remained steady between 2008 and 2011, with a roughly 2% increase between 2010 and 2011 (see Figure 10). Most of the shipments were for transportation applications, although the number of stationary shipments continues to

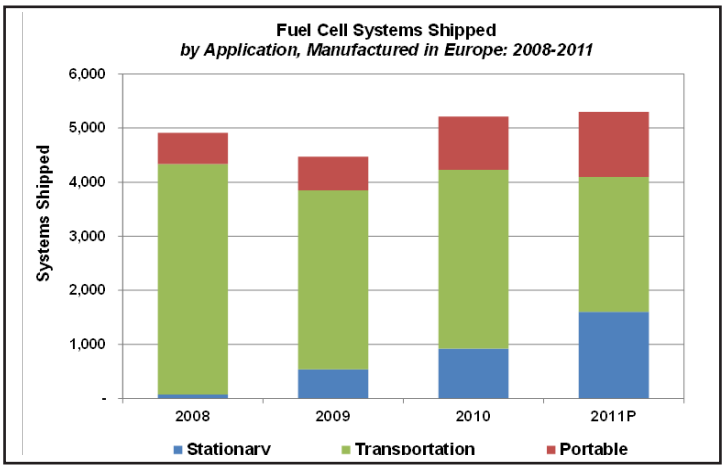

Figure 10: Fuel Cell Systems Shipped by Application, Manufactured in Europe: 2008-2011. Source: Pike Research.

rise, exceeding 1,500 units in 2011.

Government Policy, Standards, and Regulation

Enacted in 2009, the American Recovery and Reinvestment Act (ARRA) was a significant driver of fuel cell sales in 2010, providing $41.9 million through DOE and attracting $54 million in cost share. In 2011, much of the ARRA funding had been spent, but there was significant activity at the state level.

California enacted AB 14, which creates a Clean Energy Upgrade Program to subsidize property owners who borrow from financial institutions to install distributed generation renewable energy sources or energy or water efficiency improvements. The bill was intended to provide an alternative to the state's PACE program, which permits local governments and utility districts to provide property owners with up-front financing to install renewable energy (including fuel cells), or to make water or energy efficiency improvements.

In September 2011, the California Public Utilities Commission (CPUC) modified the Self-Generation Incentive Program (SGIP), including changing eligibility criteria, incentive amounts, and payment structures. SGIP funding is now based upon greenhouse gas (GHG) emissions reductions and a wide range of technologies are eligible, including fuel cells. The CPUC decision also extended the SGIP program until January 1, 2016.

The Connecticut Clean Energy Fund (which became part of the Clean Energy Finance and Investment Authority in July 2011) created the Alpha Program to fund development and testing of emerging clean energy technologies. Companies may apply for a total of $200,000 divided into two phases: a phase 1 grant of up to $50,000 for engineering design and development and a Phase 2 loan of up to $150,000 for prototyping. The grant requires a 25% funding match and the loan requires a one-third match. Eligible projects include fuel cells and hydrogen production.

Connecticut also authorized municipalities to exempt "Class I" renewable energy projects from paying building permit fees. Class I renewable energy projects include energy derived from fuel cells.

In May 2011, Indiana enacted legislation creating the Clean Energy Portfolio Standard (CPS), also known as the Comprehensive Hoosier Option to Incentivize Cleaner Energy (CHOICE) program. The program sets a voluntary goal of 10% clean energy by 2025, based on 2010 levels. Participation in CPS is open only to public utilities, which must meet renewable generation targets to receive incentives. These targets begin at 4% in 2013 and escalate to 10% in 2025.

Missouri enacted legislation that exempts qualified plug-in electric drive vehicles from state motor vehicle emissions inspection. A qualified plug-in electric drive vehicle is defined as a vehicle that, among other things, "can operate solely on electric power and is capable of recharging its battery from an on-board generation source and an off-board electricity source." Missouri already exempts hydrogen powered vehicles from the emissions inspection

requirement.

Missouri also amended its Enterprise Zone program to create "renewable energy generation zones," enabling local governments to reduce real property taxes for up to 25 years for renewable energy projects. Targeted industries include the renewably-powered fuel cell industry.

As of 2011, Nevada requires local governments to establish a parking program for qualified alternative fuel vehicles, enabling free parking at certain times and places. The state also authorized the use of qualified alternative fuel vehicles in high-occupancy vehicle lanes, regardless of the actual occupancy of the vehicle. A "qualified alternative fuel vehicle" may include a FCEV.

The New York State Energy Research and Development Authority (NYSERDA) announced an incentive program for large and small fuel cell installations. For large fuel cells (greater than 25 kW), the basic incentive is $1,000 per kW up to $200,000 per project, with additional incentives available for fuel cells serving essential public services (police, fire, health care, etc.) and for projects with an annual capacity factor of 50% or more. For small fuel cells, the incentive is up to $50,000, with a performance incentive of up to $20,000 per year for three years. Total program funding is $21.6 million, which will be available through 2015 unless exhausted earlier.

Other highlights include:

- Delaware enacted legislation to permit energy from Delaware-manufactured fuel cells to meet part of Delmarva Power and Light's renewable energy production requirements. The fuel cells must be capable of being powered by renewable fuels, which includes natural gas.
- Ohio amended its alternative fuels transportation grant program to add natural gas, liquefied petroleum gas or propane, hydrogen, electricity, and any fuel that DOE determines to be substantially not petroleum.
- Rhode Island enacted a feed-in tariff (FIT) for new distributed renewable energy generation. The FIT seeks an aggregate capacity of 40 MW by the end of 2014 and includes fuel cell projects that are less than or equal to 1 MW and that use renewable fuels.
- The federal tax credit for hydrogen fueling stations was reduced from a maximum of

$200,000 to a maximum of $30,000 per station, consistent with other alternative fuel infrastructure.

Applications and Market Assessment

Materials Handling

Materials handling continues to be a leading market for transport-related fuel cells. Large warehouses have found that fuel cells provide both an attractive alternative to battery-powered vehicles and an effective range extender for batteries. As a battery replacement, fuel cells provide nearly continuous operations (refueling takes less than five minutes), provide a continuous level of power (batteries lose power as charge levels decrease), and eliminate the need for battery changing facilities that use valuable warehouse space. As a range extender, fuel cells help maintain a constant state of charge, thus reducing or eliminating the need for battery recharging or replacement. The result is that the materials handling market provides a clear business case for fuel cell applications.

Many reports and analyses include materials handling within the transportation market segment for fuel cells. However, because materials handling is a niche application that operates primarily on private property, and because it is one of the first commercial applications for fuel cells, we have broken it out separately in this report. Table 6 provides a list of commercially available materials handling fuel cells in 2011. Manufacturers of materials handling equipment have developed dozens of models using these fuel cells for motive power.

Table 6: Commercially Available Materials Handling Fuel Cells 2011

Manufacturer	Product Name	Type	Output
H2Logic	H2Drive	PEM	~10 kW
Hydrogenics	HyPX Power Packs	PEM / hybrid	8–12 kW
Nuvera	PowerEdge CS25, CM25, CM32, RL25	PEM	25–31 kW
	PowerFlow PFV-5	PEM	5 kW
Oorja Protonics	OorjaPac	DMFC	5 kW
Plug Power	GenDrive Series 1000	PEM	8–10 kW
	GenDrive Series 2000	PEM	8–10 kW
	GenDrive Series 3000	PEM	1.8–3.2 kW

Currently, the United States is by far the world leader in fuel cell-powered forklift deployments, with more than 3,000 fuel cell forklifts either deployed or on order as of the end of 2011. By comparison, deployments in Europe total about 33 units. Government funding through ARRA was a catalyst in the United States for many early fuel cell forklift deployments.

Plug Power is one of the leading companies in this market, offering a range of products that replace batteries on existing materials handling equipment, including forklifts, pallet trucks, tow tractors, and counterbalance trucks. In 2011, Plug Power announced the next generation of its GenDrive® fuel cell products for electric lift trucks and committed to purchase a minimum of 3,250 fuel cell stacks by the end of 2012 from Ballard Power Systems. Ballard is the exclusive supplier of fuel cell stacks for Plug Power's GenDrive™ systems and Plug Power is the exclusive systems integrator for Ballard's fuel cell stacks in the materials handling market in North America. Ballard shipped 1,422 fuel cells to Plug Power in 2011, a 29% increase

over 2010.

Plug Power also announced its intent to partner with Axane, an Air Liquide subsidiary, to better penetrate the European forklift market, which the company estimates to include an installed base of 2,000,000 forklifts and 325,000 annual unit sales. Under the partnership, Plug Power will continue manufacturing in the United States and Axane will provide sales and distribution support.

Finally, Plug Power was listed on Deloitte's Technology Fast 500™, a ranking of the 500 fastest growing technology, media, telecommunications, life sciences and clean technology companies in North America. The rankings were based upon revenue growth between 2006 and 2010, during which period Plug Power grew 149 %.

Table 7: Notable Plug Power 2011 GenDrive® Sales

Customer	# of Units	Type	Location of Deployment
Procter and Gamble	200+	Lift trucks	California, Louisiana, North Carolina
Central Grocers	11	Lift trucks	Additional order for distribution center fleet in Joliet, IL, for total of 231
Kroger Co.	161	4 sit down counterbalanced trucks, 42 reach trucks and 115 pallet trucks	Food distribution center in Compton, CA
Sysco Corporation	315	mix of class-1 units for sit down counterbalanced trucks, class-2 units for reach trucks and class-3 units for rider pallet jacks	Boston, MA (160), Long Island, NY (42), and San Antonio, TX (113)
Coca-Cola Refreshments	37	Lift trucks	250,000 sq. ft. bottling and distribution center in San Leandro, CA
WinCo Foods	184	93 pallet jacks; 38 stand-up counterbalance trucks; and 53 European-style moving mast lift trucks	800,000 sq. ft. grocery distribution center in Modesto, CA

Table 7 shows major sales for Plug Power in 2011.
Oorja Protonics offers direct methanol fuel cells (DMFCs) as range extenders for battery-powered vehicles. In 2011, Oorja received the TiECON 50 award, which recognizes world leading technology startup companies. More than 1,600 companies were screened on a variety of criteria, including business model, customer references, number of users, executive team, prior experience of founders, intellectual property, and funding status.

Oorja also received a follow-on order from Martin-Brower for its Stockton, California, facility and provided 24 OorjaPac Model III fuel cell systems to EARP Distribution, converting EARP's entire fleet. Similarly, Oorja installed 20 units at Golden State Foods in Lemont, Illinois, converting the facility's entire fleet of class three pallet jacks to fuel cells. Oorja also sold fifty

units to Baldor Specialty Foods. In Europe, the European Union launched the HyLIFT-DEMO project to conduct a two-year demonstration of at least 30 fuel cell-powered forklifts and hydrogen refueling at three end-user sites throughout Europe. The goal is to bring a commercially viable product to market by 2013. The project is co-funded by the European Joint Undertaking for Fuel Cells and Hydrogen.

H2 Logic, a Danish company and a partner in HyLIFT-DEMO, introduced two hydrogen fuel cell systems for forklifts. The first is a battery replacement product, similar to Plug Power's GenDrive. The second is a range extender, similar to the product offered by Oorja Protonics.

Stationary Power

Stationary fuel cells cover a number of market segments, including megawatt-scale prime power plants, uninterruptable power supplies, and CHP. They come in a variety of types, including molten carbonate fuel cell (MCFC), solid oxide fuel cell (SOFC), phosphoric acid fuel cell (PAFC), and low and high temperature proton exchange membrane (PEM). They also generally exceed all other market segments in terms of annual megawatts shipped, with US companies such as FuelCell Energy, UTC Power, and more recently Bloom Energy accounting for the dominant share of shipped capacity. Table 8 provides a list of commercially available stationary

Table 8: Commercially Available Stationary Fuel Cells 2011

Prime Power and mCHP			
Manufacturer	**Product Name**	**Type**	**Output**
Ballard	FCgen-1300	PEM	2 – 11 kW
	CLEARgen	PEM	Multiples of 500 kW
Bloom Energy	ES-5400	SOFC	100 kW
	ES-5700	SOFC	200 kW
Ceramic Fuel Cells	BlueGen	SOFC	2 kW
	Gennex	SOFC	1 kW
ClearEdge Power	ClearEdge 5	PEM	5 kW
	ClearEdge Plus	PEM	5 – 25 kW
ENEOS CellTech	ENE-FARM	PEM	250 – 700 W
FuelCell Energy	DFC 300	MCFC	300 kW
	DFC 1500	MCFC	1,400 kW
	DFC 3000	MCFC	2,800 kW
Heliocentris Fuel Cells AG	Nexa 1200	PEM	1.2 kW
Horizon	GreenHub Powerbox	PEM	500 W – 2 kW
Hydrogenics	HyPM Rack	PEM	Multiples of 10, 20, and 30 kW
	FCXR System	PEM	150 kW
Panasonic	ENE-FARM	PEM	250 – 700 W
Toshiba	ENE-FARM	PEM	250 – 700 W
UTC Power	PureCell Model 400	PAFC	400 kW
Backup and Remote Power			
Manufacturer	**Product Name**	**Type**	**Output**
Altergy Systems	Freedom Power System	PEM	5 – 30 kW
Ballard	FCgen 1020A CS	PEM	1.5 – 3.6 kW
ClearEdge Power	ClearEdge CP	PEM	10 kW
Dantherm Power	DBX 2000	PEM	1.7 kW
	DBX 5000	PEM	5 kW
Horizon	H-100	PEM	100 W
	H-1000	PEM	1 kW
	H-3000	PEM	3 kW
	H-5000	PEM	5 kW
	MiniPak	PEM	100 W
Hydrogenics	HyPM XR Power Modules	PEM	4, 8, and 12 kW
IdaTech	ElectraGen H2-I	PEM	2.5 - 5 kW
	ElectraGen ME	PEM	2.5 - 5 kW
Microcell	MGEN 1000	PEM	1 kW
	MGEN 3000	PEM	3 kW
	MGEN 5000	PEM	5 kW
ReliOn	E-200	PEM	175 W
	E-1100/E-1100v	PEM	1.1 kW
	E-2500	PEM	2.5 kW
	T-1000	PEM	600 W – 1.2 kW
	T-2000	PEM	600 W – 2 kW
SFC Energy	EFOY Pro Series 600, 1600, 2200	DMFC	25, 65, and 90 W

fuel cells as of 2011.

Prime Power

The market for fuel cells as prime power is growing, although government support is still critical to help offset first costs. Fuel cells are providing clean, reliable power for commercial buildings, retail stores, multi-family residential buildings, and many other facilities. Fuel cells also are increasingly generating electricity from renewable fuel sources, such bio-gas produced as a by-product of wastewater treatment.

In 2011, fuel cell companies continued to cut costs and increase their geographic reach and partnerships. Companies also expanded the use of power purchase agreements, whereby customers agree to purchase the electricity generated by a fuel cell without purchasing the fuel cell itself. This has many advantages for customers, including the ability to lock-in rates and to use waste heat produced by the fuel cell.

In 2011, Bloom Energy announced that it expanded its manufacturing facility in Sunnyvale, California, increasing the company's footprint by four times and creating more than 1,000 new jobs. The company announced that it grew 525% over the previous four years, and that it will open a manufacturing facility at a former Chrysler plant in Delaware and install two clusters of fuel cell units at Delmarva Power substations. Bloom further announced a deal with AT&T, whereby it will install fuel cells at eleven AT&T sites in California, totaling 7.5 MW of power.

Bloom also introduced Bloom Electrons^{sm}, a power purchase arrangement that allows customers to lock in their electricity rates for 10 years, delivering fixed, predictable costs with no initial investment. Bloom manages and maintains the systems on the customers' sites and the customers pay only for the electricity consumed. The Power Purchase Agreement can

Table 9: Summary of Bloom Energy US Projects 2011

Location	Capacity	Notes
Kaiser Permanente, CA	4 MW	Seven facilities in California
NTT America, San Jose, CA	500 kW	Will use biogas (gas generated by decomposing organic material) produced at a California dairy farm
Sharks Ice, San Jose, CA	300 kW	Practice rink for the San Jose Sharks hockey team
AT&T, CA	7.5 MW	11 sites - Corona, Fontana, Hayward, Pasadena, Redwood City, Rialto, San Bernardino, San Diego, San Jose, and San Ramon, CA
Fireman's Fund, Novato, CA	600 kW	Fireman's Fund said it anticipates a return on investment plus $1.5 million in the next 10 years
Ratkovich Co., Alhambra, CA	500 kW	For an office park
Red Lion Energy Center, DE	13.5 MW	Planned project for a fuel cell-powered, grid-tied, base-loaded generating station
Washington Gas, Springfield VA	200 kW	First Bloom installation on the US east coast
Owens Corning, Compton, CA	400 kW	Power for a roofing and asphalt plant

save customers up to 20 percent on electricity costs, according to Bloom.
UTC Power secured sales from repeat customers and achieved 200,000 operating hours with its PureCell® Model 400. In May 2011, a 500-unit apartment community on Roosevelt Island in New York City became the first residential building in the State of New York to be powered and heated by a 400 kW fuel cell from UTC Power. The project was supported by $1.2 million in financial incentives from NYSERDA. In February 2011, the company announced that Cox Communications installed four, 400 kW fuel cells at Cox facilities in San Diego and Rancho Santa Margarita, California. Also in 2011, UTC Power selected Newmark Energy Solutions, LLC as an exclusive distributor of its fuel cells to commercial real estate markets across the United States.

Table 10: Summary of UTC Power US Projects 2011

Location	Capacity	Notes
Cox Communications, San Diego and Rancho Santa Margarita, CA	1.2 MW (two 400 kW units at two facilities)	Powered by a blend of biogas and natural gas
University of Connecticut	400 kW	Will supply energy, heat, and cooling to all of the buildings on the Depot campus
Whole Foods, Fairfield, CT	400 kW	Second Whole Foods in CT to receive a UTC fuel cell, fourth in US.
Octagon, Roosevelt Island, NY	400 kW	Provides electricity, heat, and hot water to LEED certified 500-unit apartment complex
Hamden High School, Hamden, CT	400 kW	Will provide 90% of the electricity needs and byproduct thermal energy will be used to heat the school and swimming pool

FuelCell Energy continued to secure international orders and funding for research and development (See Table 11). The world's largest fuel cell park is now operating in Daegu City, South Korea, providing 11.2 MW of power using four FuelCell Energy Direct Fuel Cell (DFC3000) power plants. In May 2011, FuelCell Energy secured an order from POSCO Power in South Korea for 70 MW for the South Korean market. This was the largest order ever received by FuelCell Energy, nearly doubling product sales and enabling continuation of an annual production rate of 55 MW, according to the company. The first shipment of a 2.8 MW unit was completed in October 2011, and monthly shipments are expected through October 2013. POSCO Power also purchased a unit for Indonesia and plans to expand the market into Thailand, Malaysia, and Singapore.

In December 2011, FuelCell Energy signed a partnership agreement with Abengoa S.A. Under the agreement, Abengoa will install a 300 kW unit at its headquarters in Seville, Spain, and will manufacture and market units targeting renewable biogas markets in Europe and Latin America. Abengoa also will develop a fuel processing system to enable FuelCell Energy units

Table 11: Summary of FuelCell Energy Projects 2011		
Location	**Capacity**	**Notes**
California State University, San Bernardino, CA	1.4 MW	Will be owned by Southern California Edison Company
Central Connecticut State University, New Britian, CT	1.4 MW	Sold to Greenwood Energy
London, England	300 kW	Will be installed in a 250,000 square foot, mixed-use redevelopment project by the Crown Estate
POSCO Power, South Korea	70 MW	2.8 MW have already been shipped
Water Park Resort, Jakarta, Indonesia	300 kW	Sold to POSCO Power

to operate using liquid biofuels.

FuelCell Energy received several government contract awards in 2011, including funding from the Solid State Energy Conversion Alliance (SECA) to develop a solid oxide fuel cell module operating on coal syngas and to evaluate the use of its fuel cells to capture

Table 12: Summary of FuelCell Energy Federal Agency Funding Awards 2011		
Agency/Project	**Amount**	**Partners/Notes**
DOE /SECA - To build and operate a scalable 60-kW SOFC module fueled by coal syngas	$11.7 million (cost-share, with $8.2 million funded by DOE)	Versa Power Systems
DOE - To demonstrate advanced biogas de-sulfurization technology	$1.6 million	TDA Research
DOE - To evaluate the use of its DFC® to capture carbon dioxide (CO2) from coal-fired power plants	$3 million	Three-year project for system design, cost analysis, and long-term testing of a multi-kilowatt DFC stack
DOE - To further develop and demonstrate a method for separating and compressing hydrogen using solid-state electrochemical hydrogen separation and compression (EHSC) technology	$1 million	Two-year project
EPA - To evaluate the effectiveness of DFC®s to efficiently separate CO2 from the emissions of industrial operations such as refineries, cement kilns and pulp and paper mills.	$100,000	Successful results may lead to a demonstration project

carbon dioxide (CO_2) from coal-fired power plants (See Table 12).

Ballard Power Systems announced several big projects and sales, including 1.25 MW of its FCgen®1300 fuel cells to Real Time Engineering PTE Ltd. (RTE). RTE intends to produce a 1 MW distributed power generator for deployment in Singapore. The company is also partnering with GS Platech to demonstrate waste-to-energy power generation using fuel cells and hydrogen produced from processing of municipal solid waste. The system will operate at a GS Platech pilot plant in Cheongsong, South Korea.

Ballard Power Systems also will deploy a 1 MW fuel cell to provide peak electrical

power and heat to the Toyota's sales and marketing headquarters in Torrance, California. Ballard's CLEARgen™ fuel cell system will use hydrogen produced by steam-reformation of renewable biogas generated at a landfill and will provide power to a number of locations on the 125-acre, multi-building campus, including Toyota and Lexus headquarters, a data center, and an employee fitness center.

Other 2011 stationary power highlights include:

- Nedstack delivered a 1 MW PEM fuel cell power plant to a chlorine plant in Antwerp, Belgium. The fuel cell will use byproduct hydrogen from the chlorine plant.

- A Nedstack PEM system recently completed 10,000 hours of operation with a 5 % performance loss at the end of the period. The stacks operate under industrial conditions, including exposure to air contaminants, multiple start-stop cycles, and emergency shut downs. The company expects the fuel cell system to last a total of 20,000 hours or more.

- Connecticut Transit was awarded $5,702,298 from the Federal Transit Administration (FTA) to install a stationary fuel cell at its New Haven Division Bus Maintenance Facility.

- The University of California, Davis, broke ground on the 8,000-square-foot Jess S. Jackson Sustainable Winery Building, which will be the first self-sustainable, zero-carbon teaching and research facility in the world. The building will sequester CO_2 captured from all fermentation and convert it into calcium carbonate, or chalk, which will be given to a plasterboard company. The building also will produce chilled water using solar electricity panels, generate hydrogen by electrolysis, and enable nighttime energy using a hydrogen fuel cell.

- VTT Technical Research Centre of Finland built a system that uses a single 10 kW planar SOFC stack to produce grid electricity from natural gas. According to VTT, this is the first time that a 10 kW power class planar SOFC fuel stack has been operated as part of a complete fuel cell system.

- The South Korean Ministry of the Knowledge Economy issued the final ruling providing the funding mechanism for new and renewable (NRE) power sources under the county's Renewable Portfolio Standard (RPS). Power produced from fuel cells will receive a premium price compared with power produced from other NRE power sources, thus recognizing the environmental advantages and high capacity factor of fuel cells.

- POSCO Power completed construction of its fuel cell stack manufacturing plant in the city of Pohang, South Korea. The facility now has the capacity to produce 100 MW of molten carbonate fuel cell stacks annually. In addition, the plant has a 2.4 MW fuel cell power plant, a research and development center, and a POSCO fuel cell gallery/show

room.

Micro Combined Heat and Power

An important component of the stationary prime power market is micro combined heat and power (mCHP). mCHP allows residences and small business to generate their own power and to use excess thermal energy from the fuel cell for heating and other purposes.

As highlighted in the 2010 edition of this report, much of the activity in this segment is in Japan, where mCHP products are marketed under the ENE-FARM brand. In 2011, there were increased orders for the ENE-FARM residential fuel cell, due in part to the earthquake, tsunami, and nuclear catastrophe. The Japanese government set aside funding sufficient to subsidize 8,000 residential fuel cells in fiscal year 2011, which ends in March 2012. Although the total subsidy allocation was roughly 60% greater than the previous year, it had been exhausted by July 2011. According to media reports, Osaka Gas sold roughly 1,300 fuel cells between March and June 2011, and Tokyo Gas Co. sold more than 4,000 fuel cells between April and July 2011. At the same time, retail prices were falling. Tokyo Gas and Panasonic introduced a new ENE-FARM fuel cell that costs roughly 20% less than previous models.

In the United States, ClearEdge Power added two new products to its portfolio. The ClearEdge Plus is modular and flexible protected load system that is designed to provide continuous power to a range of commercial applications. ClearEdge CP is a triple redundant base load system designed for customers that require mission critical power for their data and telecommunication needs.

The company received a competitive award from DOE's Pacific Northwest National Laboratory (PNNL) and is installing 15 fuel cell systems at different businesses in California and Oregon. ClearEdge also received $1 million from Southern California Gas to help develop its CHP stationary fuel cell for home and businesses in California. ClearEdge Power became the first fuel cell manufacturer to be awarded the Korean Gas Safety Corporation's (KGS) internationally recognized safety certification, which is mandatory to market fuel cells in Korea, and is recognized throughout Asia, including China, Japan, Thailand, Hong Kong, Singapore, Australia, Russia, and parts of Europe. ClearEdge also

Table 13: Summary of ClearEdge Power US Projects 2011

Location	Capacity	Notes
Cambrian Center, San Jose, CA	20 kW	Provides CHP to a senior and disabled adult housing facility
Irvine Unified School District (IUSD), Irvine, CA	60 kW	Woodbridge High School and University High School, each receiving six fuel cells
Portland Community College, Portland, OR	10 kW	Will be used as part of PCC's comprehensive alternative energy curriculum
Palace Hotel, Long Beach, CA	10 kW	Two units, combined with solar panels, will provide almost all the property's electric demand on-site
Stone Edge Farm, Sonoma County, CA	5 kW	Provides CHP to the winery's estate and vineyard
Universal Studios, Hollywood, CA	20 kW	Provides power and hot water to Universal production kitchen serving theme park

announced plans to expand its market to New York.
In Australia, Ceramic Fuel Cells Limited's (CFCL) sold hundreds of units in 2011 and signed distribution agreements with companies in the United Kingdom, the Netherlands, Australia, Germany, and Austria. The company's BlueGen® mCHP product received final product and factory accreditation in the UK, enabling BlueGen customers to benefit from the UK government's feed in tariff. BlueGen also won the Microgeneration UK 2011 Technical Innovation Award at the Microgeneration UK 2011 conference in London. Microgeneration UK 2011 brings together policymakers, investors, suppliers, and customers in the UK microgeneration industry.

In Australia, BlueGen was certified by the Australian Gas Association (AGA) for installation as a gas appliance. Finally, CFCL signed a Manufacturing Services Memorandum of Understanding (MoU) with Jabil Circuit, Inc. to scale up the manufacturing of CFCL's

Table 14: Summary of Ceramic Fuel Cells Limited International Sales 2011

Customer	# of units (and type)	Notes
Zestiq B.V.	100 BlueGen	For small commercial and residential customers in the Netherlands
E.ON UK	105 BlueGen	Addition to previous order of 41 fuel cells
Sanevo Lizenz-GmbH & Co.	100 BlueGen	Initial order for 100 units to be delivered in the first year, with a target minimum order of 500 units for delivery in the second year and a target of 2000 units in third
Ausgrid	25 BlueGen	To be installed in homes in Newcastle as part of Ausgrid's 'Smart Grid, Smart City' project
EWE	200 Gennex modules	German Government formally approved funding for an order of up to 200 modules for Gebrüder Bruns Heiztechnik GmbH to integrate and deliver to EWE. EWE will then install the units in homes in the Lower Saxony region in northern Germany
Eneco, Liander, GasTerra and Amsterdam Smart City	1 BlueGen	Installed at a 17th century canal house office building "De Groene Bocht" in the center of Amsterdam

Gennex fuel cell module and BlueGen systems.
Other 2011 mCHP highlights include:

- Wärtsilä and Versa Power Systems (VPS) entered into a cooperative agreement to develop and integrate Versa Power's SOFC technology into Wärtsilä CHP and power products for the distributed energy and marine markets.

- Ceres Power Holdings obtained CE safety approval for its wall-mounted fuel cell CHP product, which will be used in field trials under the residential CHP program with British Gas.

- Topsøe Fuel Cell of Denmark signed a MoU with South Korean company SK Holdings to work together on the commercialization of fuel cells for residential applications as well as larger stationary units for Asian markets.

- Microcell Corporation introduced a new, scalable 3 kW CHP unit, which can be scaled

up to several hundred kilowatts.

Backup and Remote Power

The backup and remote power market continued to be dominated in 2011 by US companies, primarily for the telecommunications market.

IdaTech announced the availability of Bio-HydroPlus renewable fuel, a mixture of bio-methanol and de-ionized water, which can be used to power its backup power fuel cell systems. T-Mobile® installed an IdaTech ElectraGen™ ME Fuel Cell System on its network in California, and is using Bio-HydroPlus fuel to power the system. IdaTech's ElectraGen® ME fuel cell system also provided power for cellular phone coverage during the United Nations Climate Change Conference (COP 17) held in Durban, South Africa.

ReliOn announced that is has deployed more than 3.9 MW of its fuel cell systems at approximately 1,350 customer sites globally. The company's E-2500 fuel cell system was designated a "Hot Product" by the Association of Public Safety Communications Officials (APCO) and was awarded third place in the Green Telecom & Smart Energy Solutions, Applications and Hardware category of the annual Emerging Technology (E-Tech) Awards. The E-Tech awards are given by CTIA, the industry association for the wireless telecommunications industry.

ReliOn was also ranked number 148 on Deloitte's Technology Fast 500™, a ranking of the 500 fastest growing technology, media, telecommunications, life sciences and clean technology companies in North America. The rankings were based upon revenue growth between 2006 and 2010, during which period ReliOn grew 695 percent. ReliOn also entered into a partnership with HOPPECKE, a German manufacturer of industrial batteries, to market ReliOn's fuel cell products under the HOPPECKE brand for backup power solutions throughout Europe, the Middle East, and Africa.

Altergy Systems' Freedom Product achieved 5 million operational hours in telecommunications and other applications worldwide. The company announced significant new projects, including providing telecom power in Jamaica and for the Union Pacific Railroad. Altergy also continued to expand its unique remote and indoor lighting applications, providing fuel cell lighting for various Hollywood award ceremonies and for the final lift off of the space shuttles Endeavour and Atlantis. Altergy's fuel cell lighting system was named the Grand Award Winner for the "Most Innovative Product" at the Rental Equipment Register's awards and took the top prize in the "Light Towers" category. The Innovative Product Award was established to honor "excellence in new product development in the equipment rental industry."

Ballard Power Systems, through its Dantherm Power arm, signed a collaboration agreement with Delta Power Solutions (India) to market fuel cell-powered backup power systems for the India telecommunications sector as well as commercial uninterruptable power supply (UPS) systems for data centers, industrial power solutions and distributed power generation. Delta ordered 30 Dantherm DBX2000 fuel cell systems to be installed at sites of a major telecom service provider in India. Dantherm Power will also supply a 150-kW fuel cell generator to Anglo American Platinum Limited for deployment at one of

Anglo American Platinum's mining operations in South Africa.
SFC Energy AG introduced several new products in 2011, including the EMILYCube 2500 – a portable charging station that combines a 100 W fuel cell with a Li-ion battery – and the EFOY COMFORT line power generators for mobile homes, sailing yachts and holiday cabins. The company is also working with Ensol Systems to integrate its EFOY Pro fuel cells into chemical injection, air compression, and independent power packages for oil and gas pipelines and facilities isolated from the grid.

UPS Systems, a supplier of several manufacturers' fuel cell systems, provided fuel cells to power telemetry and television equipment, camera equipment, and a weather monitoring station.

Other significant applications include:

- ACAL Energy will install its first FlowCath® fuel cell technology system to provide backup power for an environmental remediation plant.

- Meiningen, Germany began operating a new emergency power supply system based on Heliocentris Energy Solution AG's Nexa 1200 fuel cells.

- CommScope, Inc. will supply its hydrogen fuel cell system to the Society of Cable Telecommunications Engineers (SCTE), providing 64 hours of backup power to the data center.

- AFC Energy and N2telligence GmbH will to develop alkaline fuel cells for fire protection.

Transportation

The transportation market segment includes a wide range of applications, such as light and heavy duty vehicles, buses, small aircraft, and ships (materials handling is covered in a separate section of this report). Several large automakers continue to pursue fuel cells for light duty vehicle applications, with commercialization expected by 2015. The number of fuel cell buses continues to increase, in terms of both quantity and the number of countries where they are being deployed. The military has had particular success with fuel cells for unmanned aerial vehicles (UAVs).

Fuel cells for transportation are exclusively PEM fuel cells. In most applications, the fuel cells are coupled with a battery or other energy storage device. In this configuration, the fuel cell provides either prime power or power to the battery, which is the prime power source. Table 15 shows

Table 15: Commercially Available Fuel Cells for Transportation 2011

Manufacturer	Product Name	Type	Output
Ballard	FCvelocity-HD6	PEM	75 and 150 kW
Hydrogenics	HyPM HD Modules	PEM	4, 8, 12, 16, 33, and 100 kW
Nuvera	Andromeda Fuel Cell Stack	PEM	100 kW
	HDL-82 Power Module	PEM	82 kW
UTC Power	PureMotion 120	PEM	120 kW

the commercially available fuel cells for transportation in 2011.

Light Duty Vehicles

Fuel cell electric vehicles (FCEVs) have many advantages over conventional fuel and battery-powered vehicles. They have no tailpipe emissions and, if hydrogen is produced from renewable sources, can provide truly emission-free mobility. Unlike battery vehicles, their range is comparable to existing gasoline vehicles and they can be refueled in minutes. Although they are expensive and are available only in limited markets, several major automakers remain committed to producing commercial quantities by 2015. The increased volume, coupled with continued technology improvements, is expected to result in significant price reductions.

In July 2011, President Obama announced an agreement with thirteen major automakers to increase average fuel economy to 54.5 miles per gallon for cars and light-duty trucks by Model Year 2025. FCEVs were cited as important to achieving the new fuel economy standard. Rules to implement the agreement will be proposed by the US Environmental Protection Agency and the Department of Transportation.

As shown in Figure 11, DOE is seeking to reduce lifecycle costs of light duty vehicles roughly in half, from 53 cents per mile in 2010 to 28 cents per mile in 2020. The cost reduction is expected to result from increased volume manufacturing and technology improvements in both fuel cells and hydrogen production and storage.

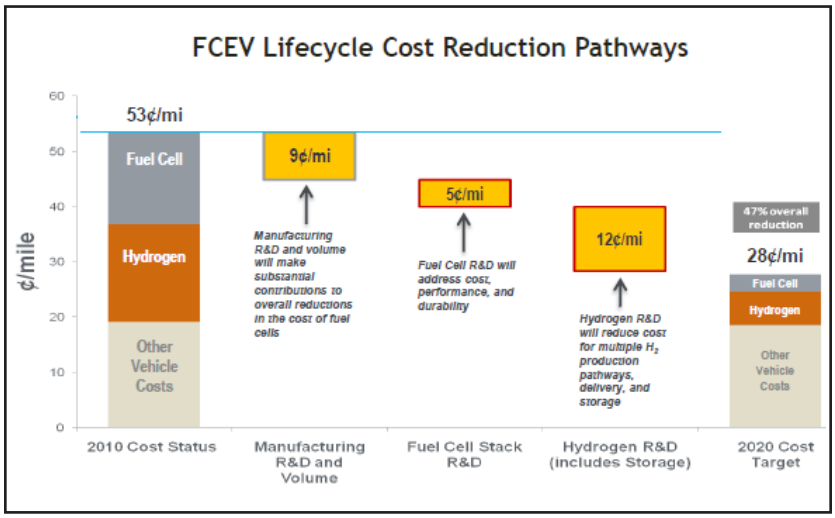

Figure 11: Cost Reduction Pathways for FCEVs. Source: DOE

Automakers continue to improve and test fuel cell vehicles. General Motors (GM) delivered 16 fuel cell Equinox vehicles to the US military as part of the Hawaii Hydrogen Initiative (H2I). Under this initiative, GM and 11 partners are seeking to make hydrogen-powered vehicles and a fueling infrastructure a reality in Hawaii by 2015, including installing up to 25 hydrogen stations in and around Oahu by the end of this decade.

Toyota delivered two of its FCHV-adv fuel cell vehicles to the town of Hempstead, New York and announced it would place more than 100 FCHV-adv vehicles with universities, private companies, and government agencies in both California and New York over the next three years. Toyota's FCHV-adv vehicles also were

Figure 12: Toyota FCV-R concept vehicle

deployed with All Nippon Airways Co., Ltd. and Welcome-Home Limousine Taxi Service at Narita Airport in Tokyo, Japan. The vehicles will be used to transport passengers returning to Japan from Europe and the US. At the Tokyo Motor Show, Toyota unveiled its latest FCEV, the FCV-R Concept, which will achieve a range of approximately 700 km (430 miles). The company announced a commercial launch date of 2015 for the vehicle.

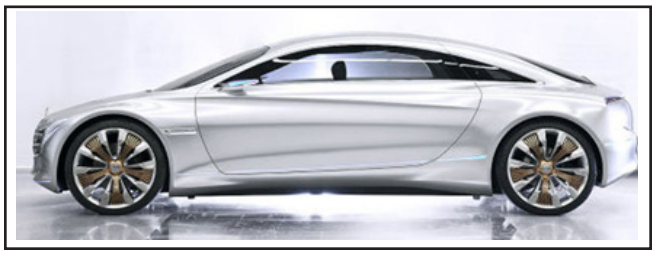

Figure 13: Mercedes F125! concept vehicle

In January 2011, Mercedes-Benz drove its F-CELL B-Class vehicles on the F-CELL World Drive, a 125-day journey through four continents, 14 countries, and a wide range of climates and driving conditions. An F CELL also is now working as a "follow me" vehicle at the Stuttgart airport in Germany. At the 2011 Frankfurt Auto Show, Mercedes-Benz unveiled its F125! concept car, which includes its F-CELL plug-in hybrid technology, boosting the range to around 620 miles with a fuel economy estimated at 105 mpg.

Hyundai Motor Group introduced two new FCEVs in 2011 - its third generation, the Tucson ix FCEV, which has a range of more than 400 miles and a gasoline equivalent fuel efficiency of more than 70 miles per gallon. Hyundai tested 50 of the Tucson ix FCEVs in 2011 in South Korea and announced plans to make a limited supply of the vehicle in 2012 and begin mass production in 2015 (Hyundai previously announced a goal of manufacturing 10,000 FCEVs in 2015.) The other vehicle, the Blue2 fuel cell concept vehicle, debuted at the Seoul Motor Show.

Hyundai also reinforced its commitment to bring its FCEVs and related infrastructure to Nordic countries, signing a MoU with stakeholders from Sweden, Denmark, Norway, and Iceland, as well as one with the City of Copenhagen, H2 Logic, and Hydrogen Link.

Honda joined Clean Energy Partnership (CEP), Europe's leading FCEV and hydrogen infrastructure demonstration project and provided two FCX Clarity FCEVs to the project. Honda also announced plans to introduce an electric power outlet-equipped FCX Clarity FCEV by the end of March 2012.

Other light duty highlights for 2011 include:

- A study by Germany's H2Mobility concluded that FCEVs are market ready and the best electric option for larger vehicles and longer trips.[9]

- Hydrogen Transport for European Cities (HyTEC) announced that it will deploy fifteen Intelligent Energy/Lotus London fuel cell taxi cabs. The cabs will help serve the 2012 Olympics.

- Intelligent Energy's fuel cell scooter achieved Whole Vehicle Type Approval (WVTA) and is approved for production and sale within Europe.

- ACAL Energy won £1 million (US $1.6 million) from the UK's Carbon Trust's Polymer Fuel Cell Challenge to help make its fuel cell system more affordable for the mass car market. ACAL is already working with a car manufacturer and hopes to help produce a commercial car engine by 2015.

Fuel Cell Buses

Fuel cell buses are expensive as compared with conventional fossil fuel buses, in part because they are not yet produced in commercial volumes. However, fuel cell buses offer zero tailpipe emissions and are much quieter than conventional buses – significant advantages for crowded urban areas with air pollution concerns.

Figure 14: CHIC fuel cell bus in London

In 2011, major programs were either initiated or continued to deploy fuel cell buses in the North America, Europe, and Latin America. In late 2010, the European Union launched the Clean Hydrogen in European Cities Project (CHIC) program, a project to deploy 26 fuel cell buses in five locations across Europe – Aargau (Switzerland), Bolzano/Bozen (Italy), London (UK), Milan (Italy), and Oslo (Norway). As of October 2011, five fuel cell hybrid buses had been deployed in London, operating up to 20 hours per day with refueling times of less than 15 minutes. Many of the buses in the CHIC program will be powered by Ballard Power Systems, which signed an agreement with Van Hool NV, Europe's fourth largest bus manufacturer, for 21 FCvelocity®-HD6 fuel cell power modules.

Hamburg, Germany deployed four Mercedes-Benz Citaro fuel cell buses under the German NaBuz program. NaBuz is part of the CEP, funded by NOW GmbH's National Innovation Programme (NIP), and is closely linked to the CHIC project. The Citaro buses have a 120 kW fuel cell and a battery hybrid system.

In the United States, a "Buy America"-compliant fuel cell bus was delivered to SunLine Transit Agency (California) by Ballard and consortium partners BAE Systems and ElDorado National Inc. The 40-foot transit bus uses a Ballard FC-velocity®-HD6 fuel cell module to provide primary power in combination with BAE Systems propulsion and power management systems. SunLine will receive two more fuel cell hybrid buses from the consortium, funded under the FTA's Transit Investments for Greenhouse Gas and Energy Reduction (TIGGER) program.

The city of Sao Paolo, Brazil, signed a letter of intent with Ballard Power Systems to purchase 25 fuel cells for city buses. It is anticipated that the buses will be deployed for the 2014 World Cup and 2016 Summer Olympic Games, both of which will be held in Brazil.

In Canada, the 20-bus fleet operated by BC Transit and powered by Ballard fuel cell modules surpassed 1 million miles in two years of service. Ballard and Simon Fraser University were awarded $4.05 million from the Automotive Partnership Canada (APC) to develop the next generation of fuel cell buses.

Other Transportation Applications

Most transport-related applications for fuel cells are in light duty vehicles and buses. In recent years, however, fuel cells have found a range of other transport applications, including heavy duty trucks, aviation, and utility vehicles.

Vision Motors provided the world's first fuel cell plug-in hybrid class 8 and terminal tractor trucks to the ports of Long Beach and Los Angeles, California, for a demonstration of the technology. Vision also received a Letter of Intent (LOI) from Total Transportation Services, Inc. to purchase one hundred of its trucks for approximately $27 million. The letters of interest also includes an option to purchase an additional three hundred trucks.

Figure 15: Vision Motors' Tyrano fuel cell electric truck

In aviation, fuel cells continued to be developed for various applications by the military and commercial companies, including propulsion power, auxiliary power, and motive power on the ground. For example:

- The first rolling tests of a fuel cell nose wheel were conducted in 2011 by the German Aerospace Center (DLA). The system is anticipated to reduce emissions produced by aircraft on the ground by up to 27% and to nearly eliminate noise during taxi operations.

- EnergyOr Technologies demonstrated a long endurance flight of more than 10 hours with its fuel cell-powered unmanned aerial vehicle using the company's EO-310-XLE fuel cell system.

- Horizon Energy Systems' AEROPAK fuel cell power system helped power the Elbit Systems Skylark® I-LE UAS (Unmanned Aircraft System) on a successful test flight in Israel.

- Lockheed Martin developed the Stalker eXtreme Endurance (XE) UAS, powered by Ultra Electronics' hybrid system that uses a propane fuel cell with a small, conventional lithium polymer battery to handle power peaks.

- AeroVironment's Global Observer™ UAS successfully completed its first flight powered by a hydrogen-fueled propulsion system. The flight lasted for four hours and reached an altitude of 5,000 feet.

- JBT AeroTech teamed with InnovaTek and EnerFuel to develop a fuel cell range extender for battery-powered airport ground support equipment. The multi-phase project is funded by a DOE Small Business Innovation Research (SBIR) Program grant.

- Airbus and Parker Aerospace are developing a fuel cell APU system for a single-aisle aircraft. The companies plan to build a technology demonstrator that can be flight tested around 2015.

Other notable transportation-related news in 2011 includes:

- Heliocentris Energiesysteme GmbH and FAUN developed a garbage truck powered by a 32 kW fuel cell which will be in everyday operation for two years in Germany.

- Asia Pacific Fuel Cell Technologies, Ltd. (APFCT) secured a contract from the Taiwan Board of Energy to build a fleet of 80 fuel cell scooters to be used in real world settings. APFCT also drove three fuel cell-powered scooters more than 900 miles as part of a road test.

- Students from Singapore won awards at the Shell Ecomarathon Asia in Malaysia for vehicles using Horizon Fuel Cell Technologies' 1 kW hydrogen fuel cell system. The event brought together 94 student teams from 12 countries all over Asia, to design and build energy efficient vehicles. The recipient of the E-Mobility Class Hydrogen award in the Prototype category set a new record in its class of 84.9 km/kWh.

- Germany's ATG Alster-Touristik GmbH (ATG) has been operating the world's first hydrogen powered ferry boat on a daily basis since the beginning of the 2011 summer season without any technical problems.

- Hydrogenics Corporation received a contract to deliver two HyPM HD 16 fuel cell power modules (33 kW) for a hybrid ferry in New York City.

- A boat using an SFC Energy EFOY 2200 fuel cell won the 2011 Azores and Back (AZAB) race. The fuel cell generated 90 W of electricity to power the boat's navigation and communication equipment.

- Suzuki's hydrogen-powered Burgman scooter became the first FCEV to get European Whole Vehicle Type Approval, enabling the company to begin mass production.

Hydrogen Infrastructure and Delivery

The number of hydrogen refueling stations worldwide increased modestly in 2011 and by year's end totaled roughly 215.[10] Another 122 are in final planning or construction and 100 are in preliminary planning.

The vast majority of stations support research and demonstration activities or bus operations and are not open to the public. However, the number of public stations is expected to increase significantly as markets prepare for commercial quantities of FCEVs in 2014 or 2015. Table 16 provides a list of commercially available hydrogen fueling systems in 2011.

Germany is a leader in hydrogen station development, with 12 public hydrogen stations operating in 2011, four more under construction, and plans announced for an additional 20. The fueling station effort is coordinated by the Clean Energy Partnership, a 15-member consortium of automakers and energy companies.

Table 16: Commercially Available Hydrogen Fueling Systems 2011

Manufacturer	Product Name	Type	Output
Avālence	Hydrofiller 15	PEM	¾ kg/day (12 scfh)
	Hydrofiller 50	PEM	3 kg/day (50 scfh)
	Hydrofiller 85	PEM	5 kg/day (85 scfh)
	Hydrofiller 175	PEM	10 kg/day (175 scfh)
Element One	H-Series Fuel Reformer	PEM	0.64 – 3.2 kg/hr
H2 Logic	Alkaline Electrolyzer Series	Alkaline and PEM Electrolysis	0.66 – 42.62 Nm3/hr
Hydrogenics	HySTAT Alkaline Electrolyzer	Alkaline Electrolysis	4 – 60 Nm3/hr
ITM Power	HPac 10	PEM Electrolysis	5.0 kWh/Nm^3
	HPac 40	PEM Electrolysis	4.8 kWh/Nm^3
Proton OnSite	HOGEN C Series	PEM	10 – 30 Nm3/hr
	HOGEN H Series	PEM	2 – 6 Nm3/hr
	HOGEN S Series	PEM	0.26 – 1.05 Nm3/hr

Germany has a goal of producing 50% of its hydrogen motor fuel from renewable sources by 2015. In 2011, a wind-to-hydrogen project near Berlin was inaugurated that will supply 100% renewable power to a fueling station at Berlin's new airport. Similarly, H2Mobility, a public-private partnership of about 13 members, has developed specifications for modular hydrogen stations of various capacities. Construction began in 2011 on a small station with 36 kilogram per hour capacity, scalable to double that capacity.

The Scandinavia region also is a leader in the deployment of hydrogen fueling stations. Through the Scandinavian Hydrogen Highway Partnership, a goal has been established to deploy 15 permanent stations plus another 30 mobile stations by 2015. Three stations are open in Norway and Sweden and two in Denmark. Three more are under construction. Hyundai has signed a strategic agreement with the three countries, plus Iceland, and hopes to deploy fuel cell fleet vehicles as early as 2012.

Other highlights from Asia include:

- In South Korea, there are 13 hydrogen stations operating, including nine in metropolitan Seoul.

- In Japan, there are about 12 stations using a variety of fuels and hydrogen generation strategies.

Three stations are under construction. The Research Association of Hydrogen Supply/ Utilization Technology (HySUT) is working with the Japanese Government to redraft hydrogen safety regulations, because stations now must meet standards developed for large industrial hydrogen facilities, which drives up cost and complicates deployment.

In the United States, there are 37 hydrogen fueling stations in California, including eight stations open to the public. Another 15 public stations are in development or under construction. In recent years the financing has come from the Alternative and Renewable Fuel & Vehicle Technology Program. The California Energy Commission (CEC) awarded $15.7 million for stations between 2008 and 2011 and has budgeted $18.7 million for stations in 2012.[11]

Figure 16: A customer fills up on hydrogen derived from renewable biogas at the Orange County Sanitation District , Fountain Valley, CA. The hydrogen is dispensed from the Energy Park built by Air Products.

The California legislature imposed a requirement that one-third of the hydrogen dispensed at the state funded stations be renewable. This target has been achieved but it adds to the cost, so California was considering a temporary reduction to 20% renewable in 2011.

The world's first fuel cell trigeneration facility opened in Fountain Valley, California, using renewable biogas. Using trigeneration, a portion of the hydrogen generated by a fuel cell power generation unit is diverted for use as a motor vehicle fuel. The system yields about 250 kW of electricity per hour, and about 100 kilograms of hydrogen per day, enough for 25 to 50 FCEVs. The project received $2.2 million in funding from DOE.

In South Carolina, the nation's first multi-use industrial park fueling station opened, at the Sage Mill Industrial Park in Graniteville, South Carolina, to supply hydrogen directly for industrial, commercial, and government use. The station already had a customer in Kimberly-Clark, which fuels 25 fuel cell-powered forklifts operating at its 450,000 square foot distribution in the Park. The fork lift fleet was funded in part by $1.1 million of a $6.1 million cost-share award made through ARRA.

Also in South Carolina, BMW Manufacturing Co. launched a $1 million multi-phase project to convert some of the methane it collects from Waste Management's Palmetto Landfill in

Wellford into hydrogen. BMW operates 101 fuel cell forklifts at its Spartanburg, South Carolina manufacturing plant and plans to convert its entire on-site forklift fleet to fuel cells.

Figure 17: Sage Mill refueling station, SC

Other notable US hydrogen station news in 2011 includes:

- A fueling station opened at the Joint Base Pearl Harbor-Hickam facility in Honolulu, Hawaii, is powered by solar panels and produces hydrogen through an electrolyzer;
- A Green Fuels Depot opened in Naperville, Illinois uses a gasifier to convert collected yard residue into three fuels (electricity, hydrogen, and ethanol);
- The Town of Hempstead, New York, installed a wind turbine to generate renewable hydrogen for the town's two Toyota fuel cell vehicles and a hydrogen/natural gas bus;
- Air Products began work on a hydrogen fueling station in Flint, Michigan, to supply a fuel cell bus owned by Flint's Mass Transportation Authority (MTA); and
- The number of fueling facilities that serve fuel cell forklifts is growing as is their use. The total number of fills in the United States surpassed 750,000 in 2011.[12]

Energy Storage

The concept of hydrogen as a bulk storage option is not new. Quebec Hydro examined shipping hydro-based hydrogen to Europe in the 1980s and more recently Norsk Hydro studied piping or shipping hydrogen to Europe. A 600 kW wind-to-hydrogen system has been operating in Norway since 2004.

What has changed is the realization that achieving renewable energy deployment goals will require hydrogen as part of a complex mix of large and small scale generation, storage, and delivery strategies. For example, Denmark typically produces around 20 percent of its electricity from wind turbines. However, the wind often becomes stronger when demand is low, such as at night, forcing the sale of excess electricity to Norway and Sweden. These countries use the electricity to store power in hydro projects, enabling them to resell the power to Denmark when demand is high and thus at a higher rate than what was originally paid for the electricity.[13] In effect, Denmark is paying Norway and Sweden to store excess wind power. This problem is expected to grow as Denmark adds more wind turbines to meet its goal of 100 % renewable power by 2050.

To address the challenge of managing intermittent and volatile power from renewable sources, Denmark and other countries are increasingly studying hydrogen storage. Unlike batteries and other storage technologies, hydrogen can be stored indefinitely or converted to other uses, such as motor fuel. Moreover, the storage capacity of hydrogen is virtually unlimited. According to Siemens, "hydrogen is the only viable option to store energy quantities greater than 10 gigawatt-hours."[14] Similarly, a 2011 analysis in Europe that concluded that, "high capacity and flexible electrolysis-systems are essential for hydrogen production for the EU wide increasing share of fluctuating renewable energies such as wind or solar – this technology development will be at the centre of future technology plans."[15]

Several renewable hydrogen projects were launched or expanded in 2011. On Ramea Island, Canada, hydrogen production from wind, as well as hydrogen storage and combustion, have been in use since 2009. New hydrogen capacity was added in 2011, which has allowed expansion of the wind farm.

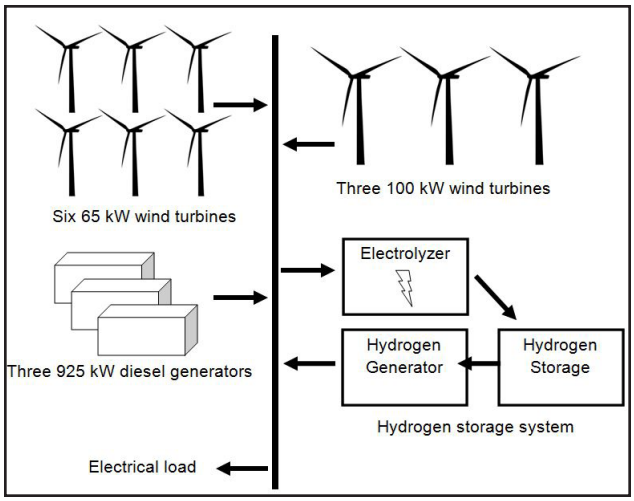

Figure 18: Block Diagram of Ramea Island Wind to Hydrogen System.

On Corsica, the MYRTE platform consists of a 560 kW photovoltaic power plant connected to an energy storage system comprised of an electrolyzer, hydrogen and oxygen reserves, and a fuel cell. MYRTE has been connected to the Corsican electrical grid since December, 2011. MYRTE phase 2 will involve installation of next generation hydrogen systems to increase the current system power.

In Prenzlau, Germany, Swedish utility Vattenfall, along with its project partners – French energy company Total, and Enertrag and Siemens from Germany – completed a facility that uses wind power to produce hydrogen gas which is then co-fired with biogas in on-site CHP units to balance short term fluctuations in three wind turbines. The plant generates heat and electricity, as well as fuel for hydrogen vehicles. (See the Spotlight on Germany section for details.)

Also in Germany, Hydrogenics is building a small scale, 50 kW wind-hydrogen plant in Herten. Wind energy will be used to electrolyze water, the hydrogen from which will be fed through a fuel cell to produce electricity when demand is high.

In the United States, hydrogen is not yet widely accepted as a mainstream storage option for intermittent power, although the European interest and experience has led to a fresh evaluation. However, the DOE has supported a test facility to demonstrate the production of hydrogen from wind and solar. Moreover, the DOE's Hydrogen and Fuel Cell Technology Advisory Committee launched an analysis early in 2011, with results expected sometime in 2012.

Most of the work in the United States in 2011 focused on small scale storage technologies, especially lightweight, high volume, affordable storage materials. For example:

- Lawrence Berkeley National Laboratory (LBNL) designed a new composite material for hydrogen storage consisting of nano-particles of magnesium metal sprinkled through a matrix of polymethyl methacrylate, a polymer related to Plexiglas. This pliable nano-composite rapidly absorbs and releases hydrogen at modest temperatures without oxidizing the metal.

- Cella Energy Limited received a $1 million investment by Space Florida to support the development of four proof-of-concept projects for Cella's hydrogen storage technologies and to expand operations hosted jointly by the UK and US space agencies.

- The National Institute of Standards and Technology (NIST) developed "molecular scale 'veins' of iron permeating grains of magnesium" to use for hydrogen storage. NIST scientists say the material can rapidly absorb and release hydrogen in sufficient quantities to enable a hydrogen storage tank for vehicles.

Military

The US military continued its support of fuel cell development in 2011, funding research as well as installations. As discussed in the transportation section of this report, a significant focus area continues to be fuel cells for UAVs. Fuel cells are much quieter than internal combustion engines, a significant stealth advantage. They also provide much greater range and endurance than battery-powered UAVs.

The Department of Defense (DOD) also joined with DOE to install 18 fuel cell backup power systems at eight military installations across the United States. LOGANEnergy Corporation is managing the project and has contracted with several fuel cell manufacturers, including Altergy Systems, Hydrogenics Corporation, IdaTech LLC, and ReliOn Inc. The first eight fuel cells were installed in November 2011, at Aberdeen Proving Ground in Maryland.

In 2011, Ultra Electronics, Adaptive Materials (AMI) shipped 15 of its 300-watt SOFCs to the US Army for field testing, with several of the fuel cells ultimately headed to Afghanistan for use by soldiers in the field. The company was also the first SOFC manufacturer to earn ISO 9001:2008 (w/ design) certification.

Table 17 shows major fuel cell projects funded by the US military in 2011.

Table 17: US Military Fuel Cell Projects Funded in 2011				
Company	**Agency**	**Project**	**Funding**	**FC Type**
Ultra Electronics, AMI	Army	Provide 30 fuel cells to recharge batteries and provide primary power for communications and information systems	$870,000	SOFC
Ultra Electronics, AMI	Army	To advance a 150-watt fuel cell system for the Coalition Warfare Program (CWP)	$999,999	SOFC
Dewey Electronics	Army	To integrate a JP-8 fueled, 10-kW fuel cell APU for military ground combat vehicles	$1.1 million subcontract	N/a
Proton OnSite	Army	To develop and build a fully commercialized version of its FuelGen® 65 Electrolyzer	$1.7 million	N/a
Optomec	Air Force	To enhance its Aerosol Jet system	$500,000 contract extension	SOFC
Innovatek	DOD	To miniaturize a fuel processor that produces hydrogen from butanol	$750,000	N/a
Auburn University	Office of Naval Research	To study and develop advanced air filters for fuel cell systems	$3.2 million	N/a

Portable/Micro

The portable/micro market segment is characterized primarily by fuel cell kits and toys, by devices for consumer electronics, and by small battery chargers. The kits and toys continue to be successful and to account for the largest proportion of annual fuel cell shipments by unit. However, their relatively small power output per unit means that they account for a small proportion of the market in terms of megawatts shipped. Table 18 provides a list of commercially available portable and micro fuel cells in 2011.

Table 18: Commercially Available Portable and Micro Fuel Cells 2011			
Manufacturer	**Product Name**	**Type**	**Output**
Horizon	MINIPAK	PEM	100 W
	HYDROPAK	PEM	50 W
	HYMERA	PEM	150 – 200 W
myFC	PowerTrekk	PEM	2.5 – 5 W
SFC Energy	EFOY COMFORT Series 80, 140, 210	DMFC	40, 72, and 105 W

The market for fuel cells in consumer electronics continues to face challenges, primarily related to miniaturization, the relative effectiveness of modern batteries, and the ability of device manufacturers to improve efficiency. However, there were some interesting developments in 2011. Fluid Computer Systems unveiled a fuel cell powered Windows 7 tablet computer at the 2011 Consumer Electronics Show. The fuel cell was provided by Horizon Fuel Cell Technologies. Also, Apple is reported to have filed at least two fuel cell patents in 2011: *Fuel Cell Systems to Power Portable Computing Device* and *Fuel Cell System Coupled to a Portable Computing Device*. The apparent goal is to extend battery life.

Other portable/micro news in 2011 includes:

- myFC introduced its Powertrekk fuel cell charger in 2011, which combines a portable battery pack with a fuel cell. Users simply insert a fuel pack and add water. The company raised $6.7 million to commercialize and launch the Powertrekk.

- The Danish Technological Institute is developing a methanol replacement for batteries in hearing aids. The fuel cell could be recharged in as little as 30 seconds and would significantly extend running time.

New studies in 2011

Various reports, studies, and technical documents continue to be published that highlight the benefits of fuel cell technology in developing low carbon economies and reducing fossil fuel consumption. This section highlights studies and reports that were published in 2011 and that are publicly available free of charge.

In September, the DOE published *Pathways to Commercial Success: Technologies and Products Supported by the Fuel Cell Technologies Program*.[16] The report describes the link between US government research and commercial success in the fuel cell and hydrogen industry. The report found that research resulted in 313 patents between 1977 and 2011, with more than 150 of these patents issued after 2005. The report also found that 30 commercial products entered the marketplace during the same period, 29 of which remained commercially available at the time of the report. 14 of the patents identified in the report were being used in these commercial products.

The Sandia National Laboratory published *Proton Exchange Membrane Fuel Cells for Electrical Power Generation On-Board Commercial Airplanes*.[17] The report found that a fuel cell system performing to DOE target specifications could generate electricity using over 30% less fuel than existing aircraft, and that a fleet of 1,000 airplanes equipped with fuel cells could save over 20,000 metric tons of CO_2 annually.

The New Energy World Industry Grouping (NEW-IG), an industrial association representing fuel cell and hydrogen companies that works with the European Commission and the research community, released *Fuel Cell and Hydrogen technologies in Europe: Financial and Technology Outlook on the European sector ambition 2014-2020*.[18] The report is designed to guide the development of Europe's post-2014 hydrogen and fuel cell research program.

The report called upon European governments to increase their investment in fuel cells and hydrogen or risk losing leadership to North America and Asia. A roadmap was proposed involving substantial public/private partnerships and €17.9 billion in research and development, demonstration programs, and commercialization support for the 2014-2020 period. NEW-IG recommended that most of the investment (€11.48 billion) be geared toward commercialization support, recognizing the commercial readiness of many fuel cell and hydrogen technologies.

In July 2011, the DOE released a report entitled *Light-Duty Vehicle Fuel Consumption Displacement Potential up to 2045*.[19] The report found that a wide range of technology improvements will lead to a significant reduction in fuel-consumption and thus significant fuel displacement over the next few decades. Moreover, as shown in Table 19, the report found that the use of a fuel cell in various electric vehicle configurations will result in the greatest percentage reduction in gasoline consumption as compared with 2010 gasoline powertrains. The report concluded that battery electric vehicles "are likely to remain expensive and range limited in the near future" and that "[f]or the long term, fuel cell vehicles demonstrate very high fuel displacement potential at a competitive cost."[20]

Fuel\Powertrain	Conventional	HEV	PHEV10	PHEV40
Gasoline	2-43	37-64	49-70	64-81
Diesel	16-42	42-62	51-69	65-80
Hydrogen Internal Combustion Engine (ICE)	4-41	50-67	56-73	69-82
Ethanol	1-47	32-62	46-69	62-80
Fuel Cell		57-70	62-75	77-84

Table 19: Percentage Fuel-Consumption Reduction (mi/gal gasoline equivalent or MPGGE) by 2045, Compared to 2010 Gasoline Conventional Powertrain. (Electrical consumption is not taken into account for PHEVs). Source: DOE

In November, the Breakthrough Technologies Institute, with support from the DOE, published *The Business Case for Fuel Cells 2011: Energizing America's Top Companies.*[21] The report is a follow on to a similar report published in 2010. It highlights 34 companies that collectively have purchased more than 250 fuel cells totaling more than 30 megawatts of power. Many of the highlighted companies are major brand names and are repeat customers for fuel cells, including AT&T, Coca-Cola, Cox Enterprises, Price Chopper, Sysco Corporation, Whole Foods Market, and Walmart.

The Breakthrough Technologies Institute also published *State of the States: Fuel Cells in America*, a follow on to a report by the same name published in 2010.[22] The report, which includes a foreword by Connecticut Governor Dannel P. Malloy, highlights progress that US states are making regarding fuel cell policies and installations. Among other things, the report found that in just over a year since the previous edition had been published, more than 50 MW of stationary power had been either installed or purchased, more than 1,500 forklifts had been deployed or ordered, 30 fuel cell buses had been put on the road or planned for deployment, and Honda and Daimler had begun leasing fuel cell light duty vehicles in California.

Intellectual Property

The granting of a patent measures both the level of innovation within a particular industry and the success of research and development programs. As shown in Figure 19, the fuel cell industry continues to be a clear leader in patent awards among clean energy technologies, with roughly 950 patents granted by the US Patent and Trademark Office in 2011. The next closest industry is solar, with roughly 540 patents. As also shown by Figure 19, the fuel cell industry has consistently led the clean technology sector in terms of patent awards since 2002.

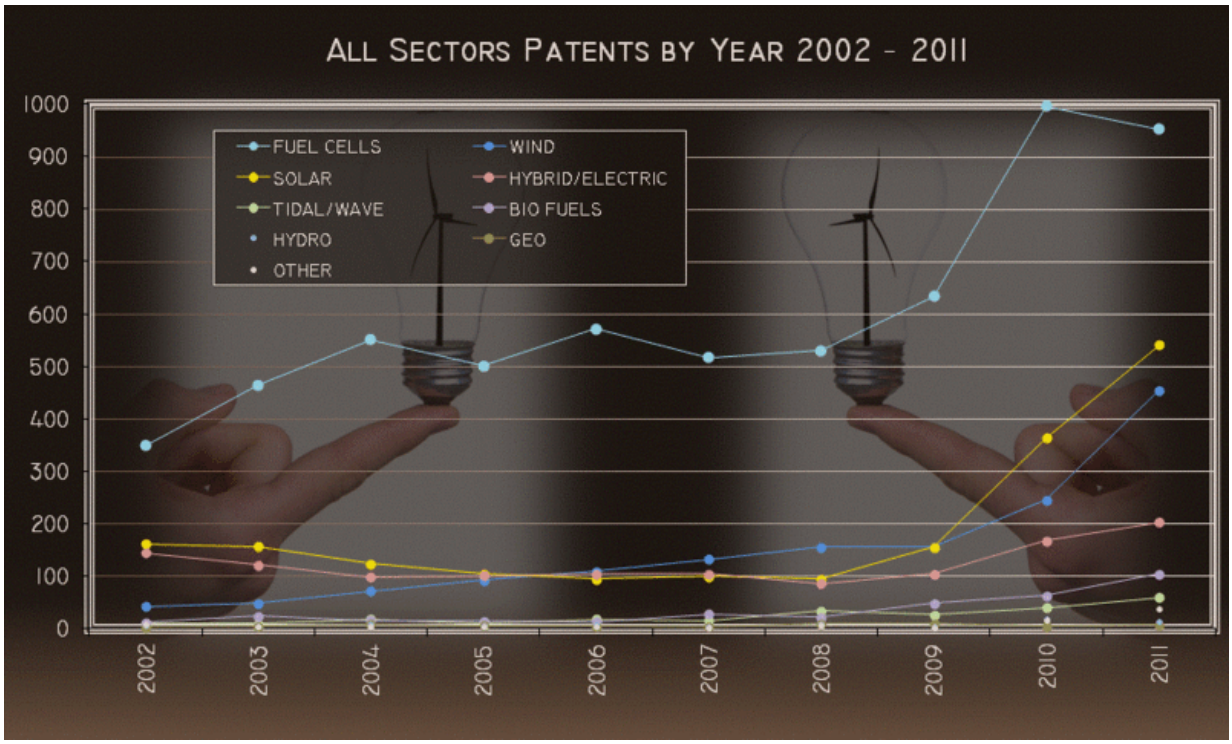

Figure 19: US Patent and Trademark Office Clean Energy Patent Awards By Sector, 2002-2011. Source: Heslin Rothenberg Farley & Mesiti P.C.

As shown in Figure 20, the automakers, especially GM, Honda, and Toyota, had the most number of fuel cell patents between 2002 and 2011. However, in 2011, Samsung Electronics Corporation had the most fuel cell patents, perhaps indicating a substantial effort to develop and commercialize fuel cells for consumer electronics.

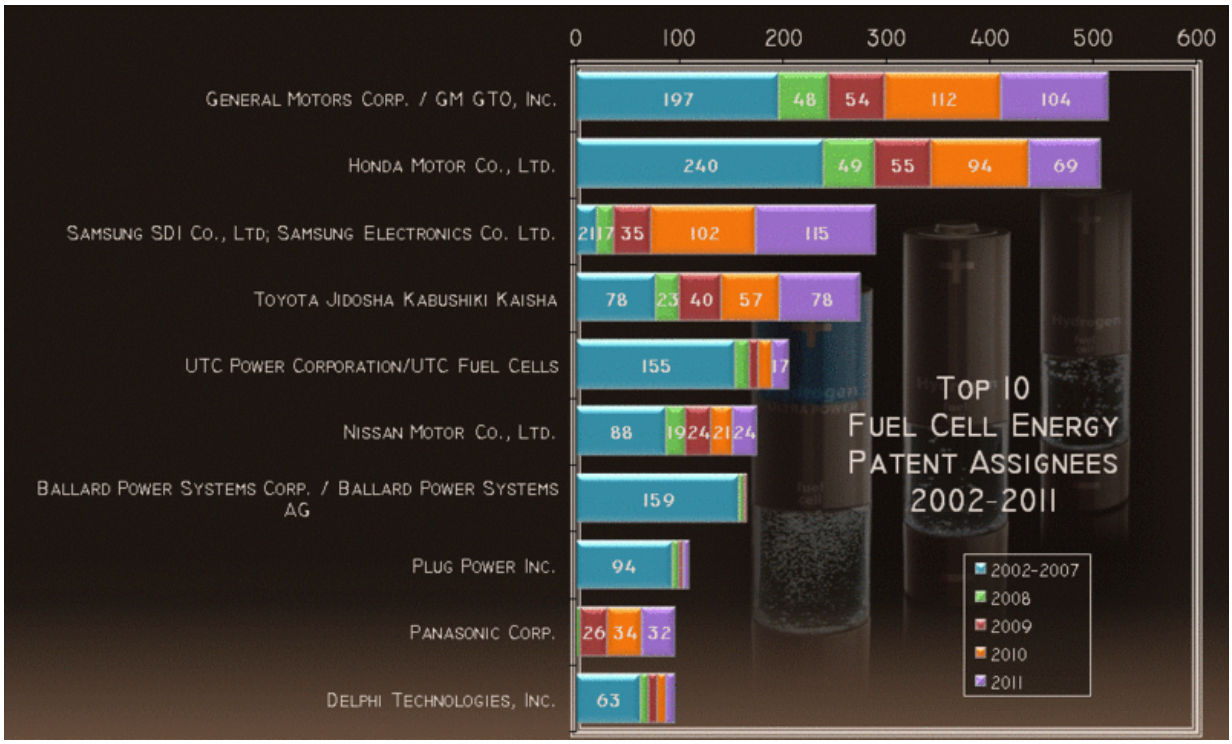

Figure 20: Top Ten US Patent and Trademark Office Fuel Cell Patent Assignees, 2002-2011. Source: Heslin Rothenberg Farley & Mesiti P.C.

In 2011, FuelCellToday published *The 2011 Fuel Cell Patent Review.*[23] Among other things, the review analyzed fuel cell patents by country and region of origin between 2000 and 2010. North America and the United States clearly led the world in terms of fuel cell patent awards in 2000 and 2005 (See Figure 21). However, in 2010, Japan eclipsed the United States by a slight margin and Asia eclipsed the North America by a significant margin. If this trend continues, it suggests that Asia and Japan will become leaders in fuel cell innovation and that North America and the United States is ceding the industry to Asian competitors, similar to what has occurred in other high technology industries.

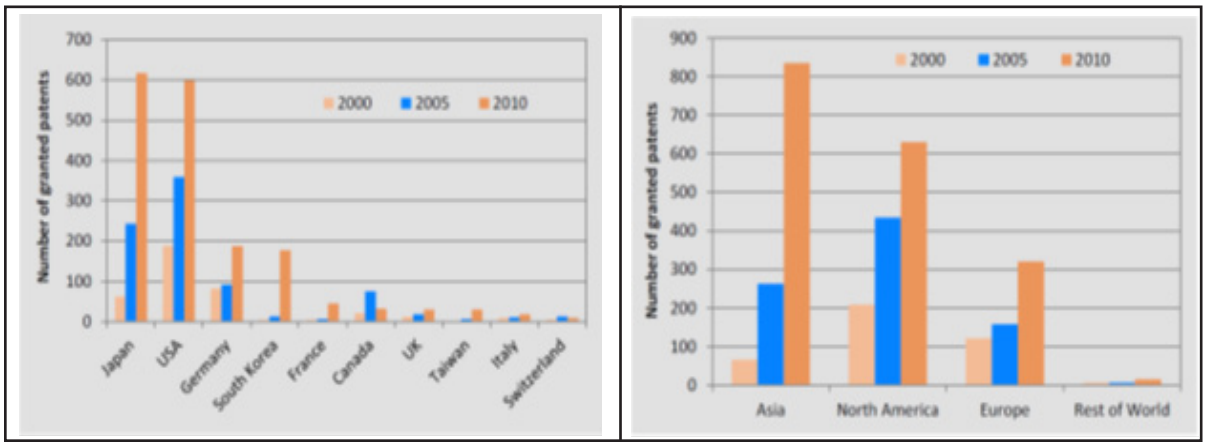

Figure 21: Fuel Cell Patents by Country (Top Ten) and by Region. Source: FuelCellToday

Spotlight on Germany

Germany is the leading laboratory in Europe for fuel cell development and demonstration and the first and largest commercial market for fuel cell passenger vehicles. Germany is home to active commercialization efforts in power generation, vehicles, specialty power, and defense systems.

The focus of German activity is the National Organization for Hydrogen, or NOW.[24] NOW was conceived as a public-private collaboration and is managed by a board that includes major industrial and public sector institutions. It was given a national mandate by the German government in 2005, with 10-year funding that provides certainty and stability.

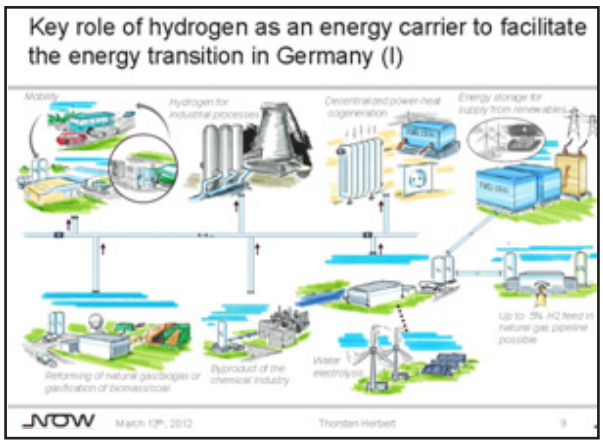

Figure 22: NOW Sees Hydrogen Playing a Key Role in Germany's Energy Future

NOW coordinates the National Innovation Program for Hydrogen and Fuel Cells (NIP), which has grown into a €1.4 billion ($1.87 billion[25]) program, with roughly 30% of the funds spent on research and 70% on demonstration programs. Just over half of NIP funding supports transportation applications, about one-third supports applications for homes and businesses, and the remaining 10% supports development for specialty markets.

Vehicle and infrastructure programs are overseen by the Clean Energy Partnership (CEP), a 13-member consortium; residential fuel cell demonstrations are overseen by Callux, an 11-member consortium. NOW also coordinates the Model Regions Electric Mobility,[26] an electric vehicle and infrastructure seed money project in eight German urban areas.

NOW is a central player in H2Mobility, an industry coalition with a mandate to develop a business plan for infrastructure deployment in Germany. H2Mobility financed an influential study on fuel cell powertrains for Europe, published in 2010. H2Mobility also developed specifications for modular designs for hydrogen vehicle refueling. Although these studies have not been published, the first station to be built is under construction in Hamburg.[27] By the end of 2011, parallel H2Mobility efforts had been announced in France and the United Kingdom.

Germany's fuel cell programs are notable for their breadth and level of organization. Demonstration projects include buses, a passenger ferry, passenger cars, a garbage truck, residential, and commercial fuel cells for power generation, industrial vehicles such as forklifts and airport ground support equipment, aircraft prime power and APUs, and various military applications. Early commercial sales include a range of products from battery chargers for recreational vehicles to fuel cell power for submarines. The following is a brief discussion of some key areas of German fuel cell development.

Hydrogen and the Grid

Germany's aggressive support programs for solar and wind power has had the perverse effect of creating a surplus of renewable power. Peak wind generation is not well matched with peak energy demand, similar to the situation in Denmark discussed in the Energy Storage section of this report.

Germany therefore is assessing the potential of hydrogen for large scale wind storage. Fuel cell companies in Europe are also examining smaller scale strategies that use batteries, wind or solar power, and fuel cells as building blocks in integrated distributed generation systems. At the other end of the scale, Siemens, the German industrial giant, has launched a research project to design a MW-scale electrolyzer.

As discussed in the Energy Storage section of this report, an integrated wind-to-hydrogen facility began operations in 2011 near Prenzlau. The system used hydrogen to balance the power output of three wind turbines and ships excess hydrogen to Berlin to supply fuel cell vehicles. The system involves about 7.5 MW of wind power coupled to a 600 kW electrolyzer that uses electricity from the wind turbines to covert water into hydrogen. The hydrogen is blended with biogas to improve the quality of the biogas, and then combusted to provide a base of power that overcomes the natural short-term fluctuations in wind generation. Enertrag, the system operator, hopes to use fuel cell power to replace the combustion system, and is looking for suitable fuel cell systems. Excess hydrogen is trucked to Berlin, but plans call for a pipeline.

Commercial Aircraft and Airports

Germany is the world leader in adapting fuel cell power to the needs of modern airports. Demonstrations and research date back to at least 2005, involving fuel cell powered ground support equipment and fuel cells for power onboard aircraft. The Munich, Hamburg and Berlin airports offer hydrogen to the public.

The German Aerospace Agency (DLR) is working with Airbus and Michelin to use fuel cells for a number of on-board and off-board auxiliary functions. Fuel cells are of interest due to their high efficiency, fuel flexibility, zero emission capability, low noise output, and ability to be installed in a variety of configurations and sizes.

Fuel cells are one of the most promising 'step change' technologies and Airbus sees high potential in fuel cell applications towards a further significant reduction of emissions, fuel consumption and external noise. – Airbus website

Airbus considers fuel cell technology as a key contributor to meeting the ACARE 2020 goals, which foresee the reduction of CO2 emissions by 50%, NOx emissions by 80% and noise by 50%. – Airbus

DLR has identified a number of potential fuel cell applications in aircraft.[28] Fuel cell systems can provide on-board power; emissions-free ground operations, including autonomous taxiing and support vehicles; electrical main engine start; electrical environmental control system supply (air conditioning); water generation for drinking and

for toilets; heat generation for ice prevention and hot water; explosion, fire prevention and suppression via inerting of the tanks, cargo and electrical bay compartment; and cockpit and cabin air humidification. Using a fuel cell in multiple applications may reduce a plane's payload, lower maintenance costs and reduce emissions, potentially justifying the present higher cost of fuel cells compared to current technologies.

A fuel cell may also be superior to the current Ram Air Turbine (RAT) emergency power technology, which cannot be retracted if main engine power is restored. A fuel cell emergency power system could be switched off if the main engine function was restored, and would require less maintenance than current technology.

Figure 23: A Fuel Cell-powered Nosewheel

Airbus and the German Aerospace Agency have developed a fuel cell wheel motor that would replace ground tugs in docking aircraft. Its first real world test in 2011 was called a success. Aircraft in short haul operations can spend two hours per day moving on the ground, a fuel-intensive operation. Switching from on-board power to conventional ground power would reduce conventional emissions by 75% and CO_2 by 40%, with substantial additional reductions possible using fuel cell ground power units.

> *"The potential saving at Frankfurt Airport from the use of electrically-driven nose wheels for Airbus A320 class aircraft is about 44 tons of kerosene [jet fuel] per day."*
> - Thorsten Mulhouse, DLR Institute of Flight Guidance.

DLR and Lange Aviation have developed a fuel cell test bed, the Antares DLR-H2, which made its maiden flight in Hamburg, Germany, in July 2009. The fuel cell's efficiency is 52 %, and overall drive system efficiency (tank to power train, including propeller) is about 44 %, twice as efficient as conventional propulsion.

In 2011, Airbus and Parker Aerospace announced a partnership to develop a fuel cell technology demonstrator for on-ground and in-flight power supply. A test flight is anticipated by mid-decade.

Appendix I: Company Profiles

Public Companies

Ballard Power Systems, Inc.

Ballard Power Systems Percentage of Total Revenues by Segment		
	2011	2010
Fuel Cell Products	61.1%	52.7%
Contract Automotive	12.2%	15.1%
Material Products	26.6%	32.2%

Ballard Power Systems, Inc. was founded in 1979, under the name Ballard Research Inc., and in 1983 began developing fuel cells. The company's principal business is the design, development, manufacture, sale and service of fuel cell products for a variety of applications, focusing on motive power (materials handling and buses) and stationary power (backup power and distributed generation) markets, and also provides engineering services for a variety of fuel cell applications. To date, Ballard has designed and shipped almost 150 MW of hydrogen fuel cell technology. Ballard has four principal subsidiaries and affiliates: Ballard Material Products Inc., located in Lowell, Massachusetts, develops and manufactures carbon fiber products for use in the automotive and fuel cell markets; Dantherm Power A/S, a Denmark-based corporation jointly owned with Danfoss Ventures A/S and Dantherm A/S that develops clean energy backup power systems across Europe; AFCC Automotive Fuel Cell Cooperation Corp., a British Columbia corporation that develops fuel cell products for the automotive fuel cell market; and BDF IP Holdings Ltd., a Canadian corporation that holds intellectual property assets.

Ballard Power Systems www.ballard.com	
Company Type	Public: TSX:BLD, NASDAQ:BLDP
Headquarters	Burnaby, Canada
Employees	440
Fuel Cell Type	PEM
Market Application	Backup power, distributed generation, material handling, buses
Manufacturing Capability	20,000 stacks/year

Notable 2011 Activities:

- Revenue increased 17% on a full year basis, to $76 million.
- Fuel cell product revenue grew 36%, representing 61% of total revenue.
- Material handling shipments to Plug Power totaled 1,422 fuel cells, a 29% increase over 2010 levels; received purchase order from Plug Power for minimum of 3,250 fuel cell stacks by the end of 2012.
- Fuel cell stack shipment to backup power customer totaled 1,447 units, down 13% from last year.
- Letter of Intent with São Paulo in support of a 10 to 30 fuel cell bus RFP, supply agreement with Van Hool NV for up to 21 fuel cell modules.
- Agreement to deploy 1-MW CLEARgen™ fuel cell system for peak power and heat at the Toyota Motor Sales USA facility in Torrance, California.
- Received US Department of Energy's 2011 Annual Merit Review Award for success in reducing the manufacturing cost of gas diffusion layer (GDL) material.

Ceramic Fuel Cells Limited

Ceramic Fuel Cells Limited (CFCL) was formed in 1992 by Australia's CSIRO (Commonwealth Science and Industry Research Organization) and a consortium of energy and industrial companies. CFCL offers a natural gas-powered micro-CHP SOFC 'modular generator' product called BlueGen®; which uses the Company's Gennex® fuel cell module and shares many balance of plant components, allowing CFCL and its partners to create different products and customer offerings from the same core technology platform. In addition to BlueGen, CFCL is developing fuel cell power and heating products with energy companies E.ON UK in the United Kingdom, GdF Suez in France, and EWE in Germany.

As of 31 December 2011, CFCL has sold 614 units to customers in: Germany, the United Kingdom, France, Switzerland, the Netherlands, Italy, Japan, Australia, and the United States. The company also operates a ceramic manufacturing plant in the UK and a 40,000 sq. ft (4,200 square meter) high-volume fuel cell assembly plant in Germany.

Ceramic Fuel Cells Limited www.cfcl.com.au	
Company Type	Public: AIM/ASX:CFU
Headquarters	Melbourne, Australia
Employees	150 world-wide
Fuel Cell Type	SOFC
Market Application	Stationary, micro-CHP
Notable 2011 Activities: • 73% increase in sales revenue (to AUD 4.4 million). • Product sales in nine countries worldwide, orders for 614 units. • Follow-on orders from utility customers in Australia and Germany. • Agreements signed with BlueGen service and distribution partners in Australia, the UK, the Netherlands and Germany.	

FuelCell Energy, Inc.

FuelCell Energy - which was formed in 1969 as Energy Research Corporation (ERC) and renamed FuelCell Energy in 1999 - manufactures Direct Fuel Cell® (DFC®) MCFC stationary fuel cell power plants that can be used for on-site power generation, cogeneration, CHP, and distributed energy grid support. The power plants internally reform readily available fuels such as natural gas and anaerobic digester gas into the hydrogen gas required to power the fuel cell system. Customers include electric utilities, universities, industrial operations, food processors, municipal water treatment facilities, government installations and others, with 182 MW of plants installed or are in backlog, and more than one billion kWh of power generated since 2003.

FuelCell Energy Product Sales and Revenues		
	Fiscal Year Ended October 31, 2011	**Fiscal Year Ended October 31, 2010**
2011 - Sale of complete power plants, modules and components 2010 - Sale of power plants, fuel cell modules, and other fuel cell power plant components	$88.0 million	$46.5 million
2011 - Revenue primarily from design and delivery of capital equipment to POSCO Power for their fuel cell module assembly facility, and construction and installation services. 2010 - Sale of stack module assembly and conditioning equipment to POSCO and for site engineering and construction work for projects where FuelCell Energy was responsible for complete power plant system installation	$15.0 million	$3.6 million
2011 - Service and power purchase agreements 2010 - Service agreements, component sales and PPAs	$12.1 million	$9.1 million
Total FY 2011 Revenues (year ending October 31, 2011)	**$115.1 million**	**$59.2 million**

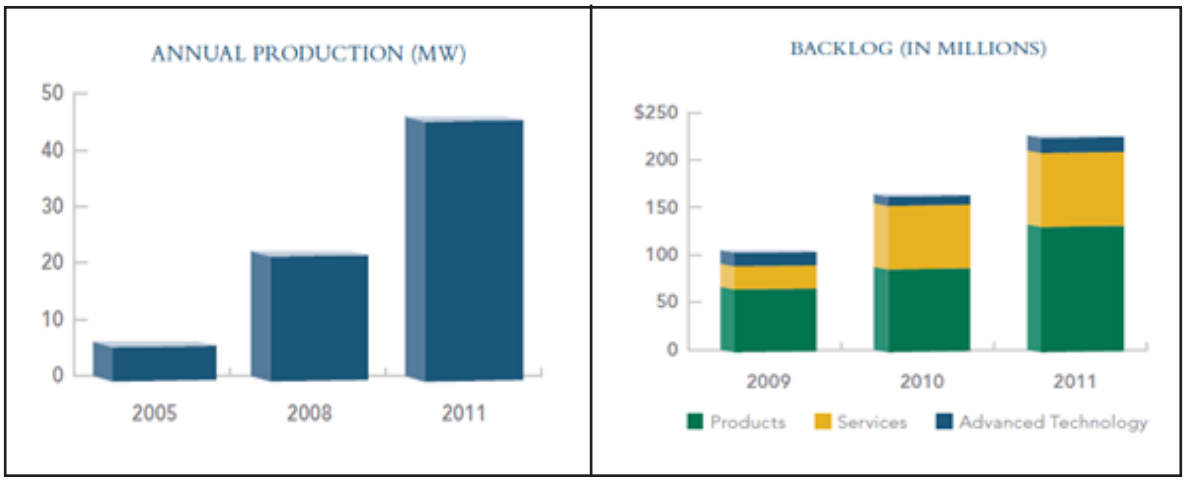

Image Source: FuelCell Energy 2011 Annual Report

FuelCell Energy www.fuelcellenergy.com	
Company Type	Public: NASDAQ:FCEL
Headquarters	Danbury, Connecticut
Employees	400+
Fuel Cell Type	MCFC
Market Application	Large stationary power
Manufacturing Capability	Up to 90 MW depending on product mix

Notable 2011 Activities:

- Product sales and revenues increased $55.9 million, or 94 %, in the fiscal year ended October 31, 2011 to $115.1 million compared to $59.2 million for the prior year period.
- Quarterly gross profit was achieved for the third and fourth quarters of 2011, a first for the company since beginning to commercialize power plants.
- Increase in revenues is attributable to increased order flow from the Korea and California markets and resulting increase in production over the prior year and enabling cost reductions.
- Installed base and backlog grew at a compounded annual growth rate in excess of 45% over the past five years.
- $129 million, 70 MW order from POSCO Power (South Korea) enabled production at an annual run-rate of 56 MW for the second half of 2011, more than double the production level in 2010.
- Partnership Agreement with Abengoa (Spain) to develop localized fuel cell power plants for Europe and Latin America, targeting renewable biogas markets. Abengoa will develop, manufacture and market stationary fuel cell power plants using fuel cell modules provided by FuelCell Energy.
- First direct sale into the UK market with a showcase installation in central London.
- Shipment of 12.4 MW of DFC plants to California during fiscal 2011.

Hydrogenics Corporation

Hydrogenics Revenues for the Year Ended December 31, 2011	
Onsite Generation business	$19.7 million
Power Systems business	$4.1 million
Total 2011 Revenues	$23.8 million

Hydrogenics Corporation began its fuel cell technology development business in 1995. The company's products span a range of applications, including hydrogen generators for industrial processes and fueling stations; hydrogen fuel cells for electric vehicles, such as urban transit buses, commercial fleets, utility vehicles, and electric lift trucks; fuel cell installations for freestanding electrical power plants and uninterrupted power supply (UPS) systems; and hydrogen storage and power systems for optimizing solar and wind systems during lulls and peaks. Company headquarters are located in Mississauga, Canada, with satellite offices in the US and Russia, and a sales office in China. The company's OnSite Generation business segment, which is based in Oevel, Belgium, manufactures water electrolyser products for industrial gas, hydrogen fueling and energy storage markets, while the Power Systems business segment, based in Mississauga, Canada, with a satellite facility in Gladbeck, Germany, manufactures fuel cell products for backup, stationary and motive power applications.

Hydrogenics www.hydrogenics.com	
Company Type	Public: TSX:HYG, NASDAQ:HYGS
Headquarters	Mississauga, Canada
Employees	118
Fuel Cell Type **Electrolyser Type**	PEM Alkaline and PEM
Market Application	Hydrogen generation, Energy storage, fueling stations, transportation, backup power.

Notable 2011 Activities:

- Revenues were $23.8 million, an increase of 14%, reflecting increased order bookings in OnSite Generation driven by growth in industrial, fueling and renewable energy storage markets.
- Backlog stands at approximately $29.1 million, up 70% over 2010.
- 44% of revenues derived from Europe, 25% from North and South America, 3% from Asia, and the remaining 28% were derived from other foreign jurisdictions.
- Contracted to deliver two HyPM HD 16 fuel cell power modules for the 600-passenger Hornblower Hybrid ferry.
- Received orders to deliver HySTAT™ electrolyzers to customers in Europe, Asia, Africa and South America, including a 1-MW electrolyzer for an industrial-scale renewable energy project in Germany.
- Selected by Herten, Germany, to provide a wind-hydrogen energy storage solution.
- Chosen to supply a complete electrolysis-based hydrogen fueling station in Istanbul, Turkey that will be used for land and sea transportation applications.

ITM Power

UK-based ITM Power designs and manufactures hydrogen energy systems for energy storage and clean fuel production based on water electrolysis. The company currently offers four small and medium-size electrolyzer products – including two PEM electrolyzers - and is working on the development of a large PEM electrolyzer for return-to-depot vehicle refuelling applications and electrolyzer solutions for home refuelling of hydrogen cars. Application areas include: hydrogen homes (power, heat, cooking); hydrogen vehicle refueling (cars, vans and forklifts); off-grid Hydrogen Generation; renewable energy storage (solar, wind, micro-hydro); oxy-hydrogen combustion (dental laboratories, workshops); and gas chromatography and analytical systems. ITM established a wholly-owned subsidiary, ITM Power GmbH, in July 2011 to further develop the Group's interests in the German market.

ITM Power www.itm-power.com	
Company Type	Public: AIM:ITM
Headquarters	Sheffield, England
Employees	55
Fuel Cell Type	PEM
Market Application	Hydrogen generation (PEM-based), hydrogen fueling, energy storage
Manufacturing Capability	Not reported
Notable 2011 Activities: • Sold first HFuel© small-scale PEM electrolyzer in April 2011. • Posted year-end orders of £0.43m. • Pilot agreement with Marks & Spencer to deliver the UK's first fuel cell materials handling trial using onsite hydrogen generation on a commercial basis. • Dutch Fuel Cell Consortium MoU signed for the Benelux countries (Benelux = Belgium, Netherlands, Luxembourg). • UKH2Mobility MoU signed with the UK government, Daimler, GM, Hyundai-Kia, Nissan, Tata Motors, Toyota, Air Liquide, Air Products, BOC/Linde, SSE, Intelligent Energy, Johnson Matthey. • Hydrogen On Site Trials (HOST) of the transportable high pressure refueling unit (HFuel) launched at Stansted Airport.	

Panasonic

Panasonic was founded in 1918 as the Matsushita Electric Industrial Co., Ltd. and is headquartered in Osaka, Japan. The company has grown to become one of the largest electronic product manufacturers in the world, comprised of over 680 companies. In 2006, Matsushita Battery Industrial, a branch in the Panasonic Corporation, showed a DMFC laptop at the International Consumers Electronic Show. Panasonic has also been developing residential micro-CHP fuel cells since 1999 and, along with several partners (including Toshiba), launched the residential ENE-FARM fuel cell brand in the Japanese market in 2009. The 2011 ENE-FARM model features significant simplification of the fuel cell unit and miniaturization of core components, making the price more affordable. The company now plans to follow on the ENE-FARM success by extending its operations into Europe. Panasonic opened its Fuel Cell Development Office Europe in Langen, Germany in July 2011 to focus on developing residential fuel cells for the European market in close collaboration with leading European utility companies.

Panasonic http://panasonic.net	
Company Type	Public: TYO:6752, NYSE:PC
Headquarters	Osaka, Japan
Employees	Not reported
Fuel Cell Type	DMFC, PEM
Market Application	Residential, consumer electronics
Manufacturing Capability	Not reported
Notable 2011 Activities: • Launched updated ENE-FARM product in April 2011, with improved efficiency, simplified fuel cell system configuration and downsized core, permitting a significantly lower recommended retail price for the new system. • Opened Panasonic Fuel Cell Development office in Germany.	

Plug Power

Plug Power is involved in the design, development, commercialization, and manufacture of PEM fuel cell systems in the material handling market. The company was incorporated in 1997 as a joint venture between Edison Development Corporation and Mechanical Technology Inc. and, in 2007, acquired Cellex Power Products and General Hydrogen Corporation. Plug Power currently is focusing on its GenDrive® product line, a hydrogen-fueled PEM fuel cell system designed for industrial vehicles, especially materials handling and automated guided vehicles at high volume manufacturing and distribution facilities. To date, more than 2,000 Plug Power units have been deployed worldwide, accumulating over 5.5 million hours of runtime. The company reports 2011 orders

Plug Power Revenues		
	2011	**2010**
Products and Services	$23.2 million	$15.7 million
Research and development contracts	$3.9 million	$3.6 million
Total 2011 Revenues	**$27.6 million**	**$19.5 million**

increased five-fold over 2010, with more than 2,500 units ordered. Units shipped during the fourth quarter include Plug Power's next-generation GenDrive - the simplified unit features 30 % fewer components and is designed to increase reliability and improve lift and towing capacity.

Plug Power www.plugpower.com	
Company Type	Public: NASDAQ:PLUG
Headquarters	Latham, New York
Employees	125
Fuel Cell Type	PEM
Market Application	Materials handling

Notable 2011 Activities:

- Received orders for $46.1 million from material handling customers. 2,503 GenDrive units were ordered, almost a five-fold increase over the 543 GenDrive orders placed in 2010.
- First time customers in North America: Associated Wholesale Grocers, Procter and Gamble, Kroger.
- Repeat North American customers: Walmart Canada, Walmart USA, Sysco, Coca-Cola, Wegmans, BMW.
- Global expansion into Europe: Air Liquide, who received Plug Power's first CE-certified products.
- Formed a joint venture with Axane, an Air Liquide subsidiary to develop the European market for fuel cell powered forklift trucks.

SFC Energy AG

SFC Energy Sales by Region (in T€)		
	Jan-Sept 2011	**Jan-Sept 2010**
Germany	3,123	2,668
Europe (excluding Germany)	3,976	4,982
North America	2,660	985
Asia	496	147
Rest of world	248	83
Total Sales	**10,503**	**8,865**

Founded in 2000, SFC Energy produces DMFC fuel cell technologies for mobile and off-grid power applications serving the leisure, industrial, and defense markets. The company's products generate power for mobile homes, yachts, vacation cabins, traffic-monitoring systems, observation stations, metering and early-warning devices, electric cars, and more. SFC has alliances with leading companies in a wide range of industries and has shipped more than 24,000 fully commercial products to industrial and private end users for more than five years. SFC's fuel cells and fuel cartridges are manufactured in Germany at the company headquarters near Munich, which is also the site of the company's research and development department, and has a US sales and technical service office located in Maryland. The company recently signed a contract to acquire PBF Group B.V., a Dutch worldwide operating company specializing in switched mode power supplies and higher level power management solutions. The new alliance is expected to increase both companies' presence in existing markets and extend the customer base into new markets, such as medical equipment, as well as significantly

reduce the impact on SFC of seasonal fluctuations in the leisure business and on the defense segment's traditionally low predictability.

SFC Energy Sales by Segment (in T€)		
	Jan-Sept 2011	Jan-Sept 2010
A Series (leisure market)	7,394	7,045
C Series (manufacturing of miniaturized fuel cells)	235	389
JDAs (joint development agreements)	1,622	648
Power manager product	493	153
Other (includes methanol fuel cartridges, testing equipment)	759	630
Total Sales	**10,503**	**8,865**

SFC Energy AG www.sfc.com	
Company Type	Public: DBPS:WKN 756857
Headquarters	Brunnthal, Germany
Employees	190
Fuel Cell Type	DMFC
Market Application	Leisure, motive, industrial and defense
Manufacturing Capability	More than 20,000 units/year

Notable 2011 Activities:

- 19.2% increase in sales compared to the same period in 2010 (Jan-Sept).
- Greater than 100% growth in orders outside of Europe (North America, Asia, rest of world) between Jan-Sept 2011.
- Partnership with RV Care to make EFOY fuel cell generators available for recreation vehicles in Canada.
- Cooperative agreement with Canadian Oil & Gas system integration specialist Ensol Systems Inc. Ensol integrates EFOY Pro fuel cells into chemical injection, air compression and independent power packages for oil and gas pipelines and facilities isolated from the grid.
- Acquired PBF Group B.V. (PBF), a Dutch worldwide company specializing in switched mode power supplies and higher level power management solutions.
- SFC sells 20,000th EFOY fuel cell.
- Order from Jenoptik Defense and Civil Systems to supply power to the NYXUS observation platform.

Toshiba

Toshiba was founded in 1939 by the merging of two companies, Shibaura Seisakusho (formerly Tanaka Seisakusho) and Tokyo Denki (formerly Hakunetsushua). In 1984, Toshiba operated an experimental 50 kW fuel cell power plant, which was the first and largest power plant in Japan at the time. Since the early 1990's, the company has been conducting R&D on both active and passive DMFC technology, achieving several milestones and achievements showcasing its technology in consumer electronics products before the official commercialization launch in Japan of its Dynario™ product in 2009. In 2001, Toshiba entered a joint venture with UTC Power to form Toshiba International Fuel Cells Corporation (TIFC), focusing on the development of PAFC and PEM fuel cells for residential and transport applications. The company has been developing a 1 kW residential fuel cell system since 2000 and in 2003, Toshiba was one of four companies selected by Osaka Gas to jointly develop residential PEM CHP systems as part of the ENE-FARM program (Panasonic is a partner in this venture). ENE-FARM sales began in 2009; a new ENE-FARM model was released in 2011 that features significant simplification of the fuel cell unit and miniaturization of core components.

Toshiba **www.toshiba.co.jp**	
Company Type	Public: TYO:6502, NASDAQ:TOSBF
Headquarters	Tokyo, Japan
Employees	Not reported
Fuel Cell Type	DMFC, PEM
Market Application	Consumer electronics, residential
Manufacturing Capability	Not reported
Notable 2011 Activities: • Limited release in Japan of 3,000 Dynario DMFC external power sources with refueling cartridge for mobile digital consumer products. • Launched updated ENE-FARM product in April 2011 with improved efficiency, simplified fuel cell system configuration, downsized core, and lower recommended retail price.	

UTC Power

UTC Power, a unit of United Technologies Corp., develops and manufactures fuel cells for building, transit bus, automotive, space, and marine applications. The company was formed in 1958 when Pratt & Whitney Aircraft's Advanced Power Systems Group began to explore new power generation concepts, and the company's fuel cells have provided electric power and drinking water for astronauts on every manned space flight since the Apollo program. Since the early 1990s, more than 300 UTC Power stationary fuel cell power plants have been installed in 19 countries on six continents at locations such as educational institutions, hospitals, manufacturing facilities, office buildings, and supermarkets. UTC's earlier generation stationary fleet, the PureCell® Model 200 System, has accumulated more than 9.4 million operating hours and attained over 80,000 hours of operation (more than nine years) without need for a cell stack replacement. The company's PureMotion 120 power plants are presently used in revenue service in transit bus applications in Connecticut, California, and Europe. UTC Power is currently developing PEM fuel cells for submarine applications.

UTC Power www.utcpower.com	
Company Type	Public: NYSE:UTX
Headquarters	South Windsor, Connecticut
Employees	450
Fuel Cell Type	PAFC, PEM
Market Application	Large stationary, automotive, transit buses, aerospace, defense
Manufacturing Capability	150 MW/year
Notable 2011 Activities: • UTC Power's stationary PureCell® Model 400 System fleet attained 200,000 hours of field operation in 2011. • A PureMotion® System Model 120 fuel cell power plant for hybrid-electric transit buses has surpassed 10,000 operating hours with its original cell stacks and no cell replacements. The unit has been operating in real-world bus service with California transit operator, AC Transit. • Signed exclusive agreement with Newmark Energy Solutions to sell UTC Power fuel cells to power buildings. • 2011 stationary fuel cell sales and installations include two Connecticut supermarkets (Whole Foods Market, Stop & Shop), Cox Communications (CA), a high school (CT), and a residential apartment building (NY).	

Private Companies

Bloom Energy

Founded in 2001 and headquartered in Sunnyvale, California, SOFC manufacturer Bloom Energy shipped its first 5 kW field trial unit to the University of Tennessee, Chattanooga, in 2006. Following field trials in Tennessee, California, and Alaska, the first commercial 100 kW products were shipped to Google in July 2008. Since that time, Bloom Energy Servers have been deployed at California sites of corporate customers such as Adobe, Bank of America, Coca-Cola, Cox Enterprises, eBay, Google, FedEx, Staples, and Walmart. In 2011, Delaware's Public Service Commission approved a plan for Bloom to build a fuel cell manufacturing center in Newark and deploy 30 MW of power at two Delmarva Power substations, funded in part by a monthly renewable energy tariff to be paid by Delmarva Power customers.

Bloom Energy www.bloomenergy.com	
Company Type	Private
Headquarters	Sunnyvale, California
Employees	Not reported
Fuel Cell Type	SOFC
Market Application	Stationary power
Manufacturing Capability	Not reported
Notable 2011 Activities: • Expanded Sunnyvale, CA manufacturing facility, quadrupling the size of manufacturing operations and providing over 1,000 new California jobs. • Delaware regulators approved plan to locate a Bloom Energy manufacturing facility in Delaware, and to provide 30 MW of fuel cells to deliver electricity to the Delmarva Power grid. • Announcement of Bloom Electrons PPAs with Walmart, Staples, Coca-Cola, Caltech, Kaiser Permanente, and BD, among others. • AT&T to power 11 California Sites with Bloom Energy fuel cells. Other customers include NTT America, Fireman's Fund, Cox Enterprises, and Sharks Ice.	

ClearEdge Power

Located in Oregon and founded in 2003, ClearEdge Power is a global, privately held technology company that provides distributed energy generation solutions to commercial, institutional, and residential customers around the world. The company designs, manufactures, and sells a family of continuous onsite power systems – enabled by fuel cell technology – that offer localized, controllable, predictable, clean sources of energy. Continuous onsite power systems use natural gas to locally generate energy, enabling the constant flow of power and heat. In doing so, they are ideal for any customer that wants to maintain essential/critical circuits during grid disturbances; reduce operating costs; lessen their dependency on the grid; or contribute to corporate sustainability goals.

The company's natural gas-powered, 5 kW ClearEdge5 CHP fuel cell system has been deployed with more than 100 customers on three different continents across a range of vertical markets including education, hospitality, and multi-tenant housing. Operating costs for the ClearEdge5 can be as low as 6 cents per kWh, which may decrease customer electricity bills by as much as 50 % for buildings spending $1,000 or more a month on electricity or using at least 43,000 kWh a year. Customers can also scale the platform to meet their individual and evolving power needs, with systems that range from five to 100 kW. This modular design approach provides an alternative to the fixed dimensions of other fuel cells available today.

To further address the diverse needs of its customers, in 2011 ClearEdge Power expanded its product line with two distinct designs in an array of options: the ClearEdge Plus, a modular and flexible protected load system that is designed to provide continuous power to a range of commercial applications; and the ClearEdge CP, a triple redundant base load system designed for customers that require mission critical power for their data and telecommunication needs.

ClearEdge Power www.clearedgepower.com	
Company Type	Private
Headquarters	Hillsboro, Oregon
Employees	As a privately-held company, ClearEdge Power does not discuss its investments, financials or business performance.
Fuel Cell Type	PEM
Market Application	Stationary power generation
Notable 2011 Activities: • January 2012 – ClearEdge Power enters the European market through a partnership with Güssing Renewable Energy GmbH. • Throughout 2011, ClearEdge Power secured deals in a variety of different verticals with customers such as Universal Studios (CA), StoneEdge Farm Winery (CA), and Portland Community College (OR). • November 2011 – ClearEdge Power expands its portfolio of continuous onsite power systems, including industry-first innovations in areas such as reliability, scalability and flexibility. • August 2011 – ClearEdge Power successfully completes a $73.5 million Series E financing round • June 2011 – ClearEdge Power receives a $2.8 million U.S. Department of Energy grant to deploy fuel cells in a variety of commercial buildings, including a grocery store, greenhouse, hotel and community college. • January 2011 - Southern California Gas Co. (SoCalGas) announced $1 million investment in ClearEdge Power.	

Horizon Fuel Cell Technologies

Singapore-based Horizon Fuel Cell Technologies was founded in 2003 and currently owns five international subsidiaries, including a new subsidiary in the United States. The company began by commercializing small and simple products while preparing for larger and more complex applications. In 2006, Horizon launched its "H-Racer" toy fuel cell car, named by TIME Magazine as one of the best inventions of the year. As a result the company began commercial sales of various micro-fuel cell powered toys which have shipped in the hundreds of thousands of units to over 60 countries. In 2009, the company started Horizon Energy Systems, a separate company in Singapore which applies its ultra-light fuel cell technologies for customers in aerospace and defense. In 2008, Horizon unveiled the first version of its Hydropak, a portable fuel cell power system capable of producing 60 - 100 W using ultra-light 150 watt-hour (Wh) chemical hydride cartridges, as well as the first version of a small 2 W micro-fuel cell power extender for consumer devices called MiniPAK, using 12 Wh metal hydride cartridges. In 2010, Horizon began work on a new easy to use and simplified version of the Hydropak with proprietary and lower cost cartridge technologies.

Horizon Fuel Cell Technologies www.horizonfuelcell.com	
Company Type	Private
Headquarters	Singapore
Employees	150
Fuel Cell Type	PEM
Market Application	Consumer electronics, portable power, educational, stationary power, military, electric vehicles
Manufacturing Capability	500,000 micro fuel cells/year; One thousand 100W to 5kW fuel cell stacks/year
Notable 2011 Activities: • Announced strategic partnership with Pilus Energy, a developer of clean technologies and biogas solutions, to combine Horizon's hydrogen fuel cells to Pilus Energy's renewable hydrogen production platform. • Introduced the 2 W MiniPak Personal Power Center in December 2011 to power cell phones, smart phones, GPS handhelds, MP3 players, and all USB gadgets such as USB lighting devices, USB fans, and USB speaker systems for MP3 players or smart-phones.	

IdaTech

IdaTech, founded in 1996, designs and manufactures ElectraGen fuel cell systems for telecommunications and other critical backup power applications. The company offers 250 W, 3 kW and 5 kW fuel cell products that provide solutions for stationary power applications requiring 100 W to 15 kW, providing extended run backup power to mobile network sites when there is loss of electrical power due to severe weather conditions or limited grid capacity. The company is also developing prime power systems to provide the primary source of energy for off-grid sites. IdaTech's PEM fuel cells use proprietary liquid fuel reforming for generating hydrogen onsite and on demand. IdaTech was acquired by Investec, a diversified UK based bank, in 2006 and went public on the London AIM exchange in 2007, but delisted in 2011. The company is headquartered in Bend, Oregon, with operations in the U.S., India, Mexico, Asia, and Europe.

IdaTech **www.idatech.com**	
Company Type	Private
Headquarters	Bend, Oregon
Employees	65
Fuel Cell Type	PEM
Market Application	Telecommunications backup power
Manufacturing Capability	Up to 5,000 units
Notable 2011 Activities: • Announced availability of Bio-HydroPlus renewable fuel, a mixture of bio-ethanol and de-ionized water • Installed an ElectraGen™ ME fuel cell system in T-Mobile's California network using Bio-HydroPlus fuel to power the system. • Provided power to a Base Transceiver Site supplying cellular phone coverage during the COP 17 meeting in Durban, South Africa, using an ElectraGen™ ME fuel cell system.	

Intelligent Energy

Intelligent Energy is located in the UK (Loughborough and London) and the United States (Long Beach, California), with offices in Japan and India. The company was founded in 2001 after acquiring APS, a Loughborough University spin-off company, and subsequently acquired US-based Element One Enterprises (2003) and MesoFuel Inc. (2004), both now part of the company's Long Beach operation. The company partners with global companies in the transportation, aerospace, distributed generation, backup, and portable power markets, including the Suzuki Motor Corporation, with whom Intelligent Energy built the Burgman Fuel Cell Scooter. It also supplied the fuel cell to Boeing which powered the world's first manned fuel cell aircraft.

Intelligent Energy www.intelligent-energy.com	
Company Type	Private
Headquarters	Loughborough, United Kingdom
Employees	Over 250
Fuel Cell Type	PEM
Market Application	Aerospace, defense, distributed power, generation portable power, motive, hydrogen generation
Manufacturing Capability	Not reported
Notable 2011 Activities: • Intelligent and the Suzuki Motor Corporation created of a joint venture company called SMILE FC System Corporation to develop and manufacture air-cooled fuel cell systems for a range of industry sectors. • Suzuki Burgman Fuel Cell Scooter obtains European Whole Vehicle Type Approval, the first fuel cell vehicle to achieve this level of certification and qualifying it as safe to use on public roads without having to be inspected and tested individually. • Intelligent Energy-powered Fuel Cell Black Cabs debut in London. A fleet of Fuel Cell Black Cabs will be delivered to London in time for the 2012 Olympics.	

Microcell Corporation

Incorporated in 2000, Microcell Corporation manufactures and sells packaged hydrogen-fueled PEM fuel cells in the 1 to 5 kW size range and power plants in the range 50 to 100 kW and higher. The company's patented extrusion technology produces high efficiency fuel cells that are low cost, easy to repair in the field, compact, and scalable. While Microcell fuel cells can be configured for any application suitable for PEM technology, the company is presently focusing on back-up power applications including disaster recovery, data centers, and electric utility/telecommunications applications.

Microcell Corp.'s partners include five of the nation's largest investor-owned utilities, the second largest electric generation and transmission cooperative and Curtiss-Wright Flow Control (CWFC), a subsidiary of Curtiss-Wright Corp.

Microcell www.microcellcorp.com	
Company Type	Private
Headquarters	Raleigh, North Carolina
Employees	30
Fuel Cell Type	PEM
Market Application	Distributed generation, CHP, backup power
Notable 2011 Activities: • Introduces new fuel cell module design allowing for scalable power plants of 100kw+ operating on direct hydrogen or natural gas. • Introduces the 3-kW MGEN 3000 CHP fuel cell unit. • Installs MGEN 1000 units at a variety of North Carolina Electric Cooperative locations.	

Nedstack

Nedstack is a fuel cell stack provider for integrators who deliver energy systems for telecom, rail and utilities applications, and transport purpose, in applications ranging from stationary backup devices, to buses, forklifts, boats, and trucks. Nedstack also builds PEM power plants to co-generate energy from hydrogen produced in chlor-alkali plants. The company originated from Netherlands-based AkzoNobel Research, which started PEM fuel cell development in 1989; Nedstack was founded in 1998 when seven development engineers got the opportunity to take over AkzoNobel's PEM activities. About 1,000 Nedstack fuel cells are in commercial operation world-wide, mostly in backup power applications, some in use since 2006. In 2007, Nedstack installed a 70 kW PEM power plant at AzkoNobel's chlor-alkali plant in the Netherlands, and in 2011 installed a 1 MW unit at Solvay's chlorine production site in Belgium.

Nedstack **www.nedstack.com**	
Company Type	Private
Headquarters	Arnhem, The Netherlands
Employees	50
Fuel Cell Type	PEM
Market Application	Stationary power, backup power, materials handling, buses
Manufacturing Capability	3,000 stacks/year
Notable 2011 Activities: • PEM stacks operating at AzkoNobel's chlor-alkali plant attained 10,000 hours of operation with an extremely low degradation rate - performance loss over 10,000 hours is only 5%, suggesting this generation of cells will attain lifetime of over 20,000 hours. • Installed a 1-MW PEM power plant at Solvay's chlorine plant located near Antwerp, Belgium.	

Nuvera Fuel Cells

Nuvera Fuel Cells' development and commercialization activities focus on OEM fuel cell products for transportation applications (including industrial vehicles, automobiles, and buses) as well as on its PowerTap™ line of hydrogen generation and refueling equipment for FCEVs. Nuvera was the first to demonstrate a gasoline fuel cell engine for cars, which Newsweek magazine highlighted as one of the most notable inventions of the 20th century. Its fuel cell manufacturing capability is 3,000 units per year. Nuvera was formed in 2000 through the merger of Epyx Corporation (a subsidiary of Arthur D. Little, Inc.) of Massachusetts, and DeNora Fuel Cells, a subsidiary of Gruppo DeNora of Italy. World headquarters is located in Billerica, Massachusetts, where the company employs 100 people. Nuvera Fuel Cell Europe is based in Milan and has 15 employees. Hess Corporation is the majority shareholder of Nuvera.

Nuvera Fuel Cells www.nuvera.com	
Company Type	Private
Headquarters	Billerica, Massachusetts
Employees	115 worldwide
Fuel Cell Type	PEM
Market Application	Hydrogen generation and fueling, fuel cell stacks and subsystems for mobility applications

Notable 2011 Activities:

- Signed license and engineering service agreement with Xebec Adsorption Inc. for the development of two rapid cycle hydrogen purification units for use in hydrogen refueling and merchant hydrogen applications.
- Received a follow-on order from the Defense Logistics Agency (DLA) for 18 PowerEdge RL25 fuel cell units to operate at the Susquehanna Defense Distribution Supply Depot (DDSP) in New Cumberland, Pennsylvania.
- Twenty fuel cell systems powered by Nuvera's technology have been in service at DDSP since 2009.
- Achieved ISO 9001:2008 certification for Nuvera's Billerica, Massachusetts headquarters, indicating that Nuvera's Quality Management System meets International Organization for Standardization (ISO) criteria.
- Nuvera demonstrated its PowerTap Hydrogen Station to refuel a Chevy Equinox fuel cell vehicle as part of the GM Northeast Hydrogen Infrastructure Rally.

Oorja Protonics

Oorja Protonics, founded in 2005, produces DMFC systems for materials handling vehicles. The company's OorjaPac fuel cell product operates as an on-board battery charger for materials handling vehicles. OorjaPac features on-board sensors that keep the vehicle's battery at a constant state of charge, eliminating the need for battery swapping and rapid charging. Oorja Protonics also offers the OorjaRig™, a refueling system that stores and delivers methanol to the OorjaPac™ on-board charging system that is designed for indoor use in commercial and industrial environments. Oorja's customers include Golden State Foods, Martin-Brower, Nissan, Super Store Industries, Unified Grocers, and US Foodservice.

Oorja Protonics www.oorjaprotonics.com	
Company Type	Private
Headquarters	Fremont, California
Employees	30
Fuel Cell Type	PEM
Market Application	Materials handling
Manufacturing Capability	2,000-3,000 units/year; 4-6 MW/year
Notable 2011 Activities: • Second purchase order in six months by Martin-Brower of the OorjaPac Model III fuel cell for use at its distribution facilities. • Announced that it will install 50 OorjaPac fuel cells for materials handling equipment at Baldor's Bronx, NY facility. • Installed 24 OorjaPac fuel cells for powering pallet jacks at EARP Distribution's Kansas warehouse, and 20 OorjaPacs to power pallet jacks at Golden State Foods' Illinois facility.	

ReliOn, Inc.

ReliOn develops and markets a range of modular, fault-tolerant, PEM stationary fuel cells for emergency and backup power requirements, uninterruptible power supplies, grid support, digital power needs and a variety of off grid power requirements. ReliOn has sold more than 4.2 MW of fuel cells in the United States, Europe, South America, Australia, Africa, and Asia, with customers that include major telecommunications providers, government communication sites, and railroads. Based in Spokane, Washington, the company was incorporated in 1995 as Avista Laboratories, Inc., and renamed ReliOn, Inc. in 2004. The company's products range from 175 W to 2.5 kW and are configured to meet power requirements up to 20 kW.

ReliOn, Inc. www.relion-inc.com	
Company Type	Private
Headquarters	Spokane, Washington
Employees	47
Fuel Cell Type	PEM
Market Application	Backup power
Notable 2011 Activities: • Agreement with HOPPECKE, a manufacturer of industrial batteries, charging equipment and energy systems, to market ReliOn's fuel cell products under the HOPPECKE brand for backup power solutions throughout Europe, the Middle East and Africa. • ReliOn ranked number 148 fastest growing company in North America on Deloitte's 2011 Technology Fast 500™, and ReliOn's E-2500 fuel cell system chosen as "Hot Product" by the Association of Public Safety Communications Officials. • Announced that a ReliOn customer with 56 cell towers backed up by fuel cells experienced 45 sites with grid power outages in excess of six hours during Hurricane Irene; ReliOn's fuel cell systems successfully provided power to the communications equipment for a cumulative outage time of 725 hours. Average duration per site was 16 hours, with the maximum single outage duration being 50 hours.	

Ultra Electronics, AMI

Adaptive Materials, developer and manufacturer of portable, propane-powered SOFCs, was acquired by UK-based Ultra Electronics Holdings plc. in 2011. Ultra Electronics Adaptive Materials Inc. (Ultra Electronics, AMI) will continue to develop and manufacture fuel cell systems from its current Ann Arbor, Michigan facility, including its work in for the US military, where it has, in recent years, been awarded over $45 million from the DOD and other research agencies. The company offers 50 and 250 W fuel cell systems powered by propane, butane, and LPG. Adaptive Materials' fuel cell system provides portable power to the military, and to the leisure, remote monitoring, and medical devices industries.

Ultra Electronics AMI www.ultracellpower.com	
Company Type	Private
Headquarters	Ann Arbor, Michigan
Employees	Not reported
Fuel Cell Type	SOFC
Market Application	Portable power
Manufacturing Capability	Not reported

Notable 2011 Activities:

- Adaptive Materials acquired by Ultra Electronics (UK).
- Ultra Electronics, AMI certified to the ISO 9001:2008 (with design) International Quality System Standard.
- Shipped fifteen 300-W solid oxide fuel cells to the US Army's Communications-Electronics Research, Development and Engineering Center (CERDEC) for field testing.
- Secured a $870,000 contract to provide 30 SOFCs to the US Army's Rapid Equipping Force. Soldiers in the field will use the Ultra Electronics, AMI 300-W fuel cells to recharge batteries and provide primary power to communications and information systems.
- In collaboration with Lockheed Martin, announced a new, ruggedized version of the Stalker Unmanned Air System (UAS), called the Stalker eXtreme Endurance (XE) UAS. The Stalker XE system, powered by Ultra Electronics' fuel cell, quadruples Stalker's flight endurance to eight-plus hours without impacting the mobility or capabilities of the unmanned system.

Auto Manufacturers

Daimler AG

Daimler AG, headquartered in Germany, is one of the largest manufacturers of commercial vehicles in the world, with production facilities on five continents and product sales in nearly every country. The company began developing fuel cell motive technology in 1994 and has 180 patent applications in this field. A total of 100 fuel cell passenger cars, buses, and vans placed in everyday use with customers have accumulated more than 2.8 million miles, providing feedback to Daimler for ongoing technology development. Daimler's first series-produced FCEV, the Mercedes-Benz B-Class F-CELL, was debuted in late 2009. Two hundred F-CELL vehicles were produced and delivered to selected customers in the US and Europe during 2010.

Daimler AG www.daimler.com	
Company Type	Public: DAI
Headquarters	Stuttgart, Germany
Employees	Approximately 250
Fuel Cell Type	PEM
Market Application	Passenger vehicles and transit buses, with fuel cell vehicle commercialization anticipated in 2015
Notable 2011 Activities: • Announced Daimler and Linde joint project to build 20 hydrogen filling stations in Germany. • Announced that fuel cell stacks will be built in Vancouver, Canada starting in 2013. • Sent three B-Class F-CELL vehicles on a 18,750-mile world tour to show the technical maturity of Daimler's fuel cell technology.	

General Motors

General Motors (GM), one of the world's largest automakers, sells vehicles in 140 countries with the largest national markets in the United States, China, Brazil, Germany, the United Kingdom, Canada, and Italy. GM has extensive fuel cell research and product development facilities located in the United States and Europe and produced the industry's first operational fuel cell-powered passenger vehicle in 1968. GM launched Project Driveway in 2008, the first large-scale market test of FCEVs using a fleet of over 100 fuel cell electric Equinoxes that accumulated over 2 million miles. GM continues to work on developing and improving fuel cell technology.

GM **www.gm.com**	
Company Type	Public: GM
Headquarters	Pontiac, Michigan
Employees	Approximately 400
Fuel Cell Type	PEM
Market Application	Passenger vehicles, with fuel cell commercialization anticipated after 2020
Notable 2011 Activities: • GM Global Technology Operations assigned a patent for relative humidity control for a fuel cell. • Five GM Equinox fuel cell vehicles delivered to Marine Corps Base Hawaii, with more deliveries to the state planned in 2012. The vehicles are part of the Hawaii Hydrogen Initiative (H2I) to deploy fuel cell vehicles and develop hydrogen fueling stations in the state.	

Honda

Honda is a global producer of automobiles, motorcycles, and other power equipment, such as outboard motors and generators. Honda believes that fuel cell electric vehicle technology offers the "ultimate zero emission car"[29] and that their FCEVs have already proved to be "full function" [5,30] alternative fuel vehicles. Honda plans to begin mass production of FCEVs in 2018 and anticipates that the retail price will be comparable to luxury gasoline-fueled cars by 2020. Honda's fuel cell research program was first established in 1989 and, in 2008, Honda commissioned the world's first dedicated fuel cell vehicle production facility for the FCX Clarity. Two hundred Clarities were produced for lease to select customers in Japan and southern California. Honda also has developed two hydrogen refueling stations: 1) a home energy station that generates hydrogen from natural gas to provide heat and electricity for a home and hydrogen fuel for a vehicle, and 2) a solar-hydrogen station.

Honda **www.honda.com**	
Company Type	Public: HMC
Headquarters	Minato, Japan
Employees	Not reported
Fuel Cell Type	PEM
Market Application	Passenger vehicles and hydrogen fueling stations, with fuel cell vehicle commercialization anticipated in 2018
Notable 2011 Activities: • Joined Germany's Clean Energy Partnership (CEP) fuel cell vehicle and hydrogen infrastructure demonstration project. • Honda and ANA (All Nippon Airways) debut a FCX Clarity fuel cell vehicle that serves as a limousine service for passengers on international flights at Tokyo's Narita International Airport. • Honda opened a hydrogen refueling station in Swindon. UK. • Opened the first hydrogen fueling station in the US fed directly from an active industrial hydrogen pipeline in a collaborative effort between Toyota, Honda, Air Products, Shell, South Coast Air Quality Management District (SCAQMD) and the Department of Energy (DOE). Provides hydrogen for the Toyota fuel cell hybrid demonstration program vehicles and other manufacturers' fuel cell vehicle fleets in the Los Angeles area. • Honda Clarity FCX debuted in the UK at the EcoVelocity Festival. • Honda FCX Clarity served as pace car for the 2011 Honda Grand Prix of St. Petersburg, Florida.	

Hyundai Motor Company

Hyundai, founded in South Korea in 1947, sells cars in 28 European countries across 2,500 outlets. Hyundai began its FCEV research in 1998 and showcased its first vehicle, the FCEV Santa Fe in 2000, working with UTC Power on the fuel cell engine. In 2004, the company unveiled a fuel cell-powered Tucson and Sportage as part of the DOE Technology Validation program. From 2004-2010 Hyundai participated in the DOE Technology Validation program, partnering with UTC Power and Chevron in a learning demonstration that included testing, demonstrating, and validating of 32 of its FCEVs. The company announced a public lease program of a few thousand vehicles globally through 2014, and to increase its FCEV production capabilities to 10,000 vehicles by 2015.

Hyundai Motor Company www.hyundai.com	
Company Type	Public: HMC
Headquarters	Seoul, South Korea
Employees	Not reported
Fuel Cell Type	PEM
Market Application	Passenger vehicles, with capability for large-scale fuel cell vehicle production in 2015

Notable 2011 Activities:

- Signed a memorandum of understanding (MOU) with Norway, Sweden, Denmark and Iceland to operate a test fleet of fuel cell vehicles in the European market (Scandinavian Hydrogen Highway Partnership).
- Hyundai joined 'H2moves Scandinavia' to demonstrate fuel cell vehicles in Norway and Denmark, the first 'Lighthouse Project' of the European Commission-backed Fuel Cells and Hydrogen Joint Undertaking (FCH JU).
- Hyundai ix35 fuel FCEV was selected by the European Commission-backed Fuel Cells and Hydrogen Joint Undertaking (FCH JU) to be used as a demonstration vehicle to test and promote hydrogen fuel cell technology in a real-world environment - the ix35 FCEV was made available for Members of European Parliament, Commissioners, EU officials and other policymakers to test drive until March 2012.
- Interbrand ranked Hyundai as one of the world's greenest brands, citing the automaker's Blue Drive eco-friendly strategy and its industry leadership in zero-emissions hydrogen fuel cell vehicle development.
- Hyundai ix35 FCEV debuts in the UK at the EcoVelocity Festival.
- Hyundai Tucson FCEV traveled 4,500 miles between San Francisco and New York promoting awareness of childhood cancer and the need for a US hydrogen fueling infrastructure.

Toyota Motor Co., Ltd.

Toyota, established in 1937, is home to the Toyota, Lexus, and Daihatsu brands of passenger vehicles, the Hino brand of heavy duty trucks and buses, and also pursues non-automotive applications. From the start of its FCEV effort in 1992, Toyota has pursued development of its own fuel cell stack and system and manufactures the vehicle's 10,000 psi carbon fiber hydrogen tanks in-house. Toyota also is pursuing the stationary fuel cell market, focusing on development of PEM and SOFC cogeneration units for residential applications.

Toyota **www.toyota.com**	
Company Type	Public: TM
Headquarters	Toyota City, Japan
Employees	Not reported
Fuel Cell Type	PEM, SOFC
Market Application	Passenger vehicles and buses, with fuel cell vehicle commercialization anticipated in 2015, and stationary power generation
Notable 2011 Activities: Opened the first hydrogen fueling station in the US fed directly from an active industrial hydrogen pipeline in a collaborative effort between Toyota, Honda, Air Products, Shell, South Coast Air Quality Management District (SCAQMD) and the Department of Energy (DOE). Provides hydrogen for the Toyota fuel cell hybrid demonstration program vehicles and other manufacturers' fuel cell vehicle fleets in the Los Angeles area. Toyota and ANA (All Nippon Airways) debut a FCHV-adv fuel cell vehicle that serves as a limousine service for passengers on international flights at Tokyo's Narita International Airport. Debuts FCV-R concept vehicle at the Tokyo Motor Show. Announces that Ballard Power Systems will deploy a 1-MW fuel cell to provide power and heat at Toyota Motor Sales' Torrance, California headquarters. The system will generate hydrogen from biogas generated at a landfill.	

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[24] Nationale Organisation Wasserstoff- und Brennstoffzellentechnologie
[25] Dollar amounts are calculated using the annual average conversion rate for 2011 published by the US Internal Revenue Service.
[26] Modellregionen Elektromobilität

[27] See the discussion of hydrogen infrastructure for more information about this project and Germany's hydrogen infrastructure deployment programs.
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