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

2010 FUEL CELL TECHNOLOGIES MARKET REPORT

JUNE 2011

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
CARB	California Air Resources Board	Nm	Nanometer
CFCL	Ceramic Fuel Cells Limited	NOW	National Organization for Hydrogen and Fuel Cell Technology (Germany)
CHP	Combined heat and power	OEM	Original Equipment Manufacturers
CO_2	Carbon dioxide	OTC	Over the counter (investment)
DLA	Defense Logistics Agency	PAFC	Phosphoric acid fuel cell
DoD	Department of Defense	PE	Private equity
DOE	Department of Energy	PEM	Proton exchange membrane fuel cell
DMFC	Direct methanol fuel cell	PIPE	Private investment in public equities
FCE	FuelCell Energy	PV	Photovoltaic
FCEV	Fuel cell electric vehicle	R&D	Research and development
GHG	Greenhouse gas	RV	Recreational vehicle
HEV	Hybrid electric vehicle	SECA	Solid-State Energy Conversion Alliance
JHFC	Japan Hydrogen and Fuel Cell	SGIP	Self-Generation Incentive Program
K2	K2 Pure Solutions	SOFC	Solid oxide fuel cell
kg	Kilogram	TGC	The Gas Company
km/h	Kilometer per hour	UAV	Unmanned aerial vehicle
kW	Kilowatt	U.K.	United Kingdom
kWh	Kilowatt-hour	U.S.	United States
MCFC	Molten carbonate fuel cell	VC	Venture capital
m-CHP	Micro-combined heat and power	W	Watt
METI	Ministry of Economy, Trade, and Industry, Japan	Wh	Watt-hour

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 passenger vehicles, 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 2010. A clear trend in 2010 was continued growth in commercial deployments, largely in the material handling, power, CHP, and back-up and APU sectors. Several of these applications are becoming cost competitive with incumbent technologies in some duty cycles. As commercial deployments grow, many fuel cell companies are moving away from being primarily development stage enterprises. For example, as of April 2010, Plug Power was no longer considered a development stage company because it receives significant revenue from sales and has a considerable order backlog and repeat customers.

The U.S. fuel cell industry was an active participant in the worldwide marketplace. The number of fuel cell units shipped from North America quadrupled between 2008 and 2010 and the US was a global leader in terms of total megawatts (MW) shipped in 2010.[1] Grocery stores and high-tech industries remain strong customers, with well-known companies like eBay, Google, Bank of America, Safeway, Walmart, and FedEx using fuel cells. One customer saves $1 million annually.[2]

Notable in 2010

Sales continue to grow; fuel cell units shipped from North America quadrupled between 2008-2010.

Japan unveiled a plan to sell two million fuel cell vehicles by 2025, and install 1,000 hydrogen fueling stations to support them.

Ballard Power Systems surpassed one million membrane electrode assemblies produced.

McKinsey & Co. study concluded FCEVs are “the best low-carbon substitute” in medium- and large-car segments, which account for 50% of cars and 75% of CO_2 emissions.

In China, More than 200 fuel cell EVs helped supply transport at the 2010 Shanghai World Expo.

Germany and the **European Union** entered their peak year of multi-year fuel cell R&D programs.

DOE’s fleet of 152 FCEVs surpassed 2.8 million road miles and 114,000 hours of operation.

Taiwan unveiled a $10,000 per kilowatt support program for stationary fuel cell demonstrations.

Volume cost of a fuel cell stack declined again in 2010 to an estimated $51 per kilowatt – an 80% reduction since 2002.

AC Transit’s bus fleet has operated for over 255,000 miles, with average fuel economy 63% better than diesel; one bus passed 7,000 hours operations on one stack.

Patents for fuel cells grew 57% in 2010, outpacing other advanced energy technologies.

The American Recovery and Reinvestment Act (ARRA) provided a substantial boost for the U.S. industry. ARRA allocated $41.9 million for fuel cell commercialization activities and attracted $54 million in cost-share. In 2010, ARRA funding resulted in deliveries of 206 forklift trucks and 24 telecommunications back-up systems, with a significantly higher number of shipments anticipated for 2011 and up to 1,000 units to be deployed overall.

At the state level, California's Self Generation Incentive Program (SGIP) stimulated commercial and residential fuel cell demand, with some systems generating 100 percent renewable energy using biogas from waste digesters. In Ohio, testing was completed on a megawatt-scale PEM system.

Worldwide, governmental policies resulted in a significant increase in research and development (R&D) and market activity. Sales of residential fuel cell systems in Japan exceeded 5,000 units in 2010, bringing the installed total to more than 13,000. More than 20 MW of fuel cell power generation are on-line in Korea.[3] Taiwan enacted a $10,000 per kilowatt (kW) grant program for fuel cell demonstrations.

Fuel cell electric vehicle (FCEV) commercialization is anticipated in Europe in 2015, led by Germany, and in Asia, led by Japan and Korea. Production is expected to be in the hundreds of units in 2011 and 2012 and in the thousands of units by 2015. Other fuel cell vehicle highlights for 2010 include:

- Japan unveiled a plan to sell two million FCEVs by 2025 and to install 1,000 hydrogen fueling stations, beginning with 50 to 100 stations in four metropolitan areas, linked by stations on intercity highways.[4]

- A McKinsey & Co. analysis concluded that FCEV technology will be commercial-ready and will be cost competitive by 2020 or 2025. McKinsey also concluded that FCEVs are "the best low-carbon substitute" in medium- and large-car segments, which account for 50 percent of cars and 75 percent of carbon dioxide (CO_2) emissions.[5]

- China's latest five-year energy plan includes hydrogen and fuel cells and 200 vehicles helped provide transportation at the Shanghai World Expo in 2010.[6]

- AC Transit's fuel cell bus fleet passed a durability milestone: one bus achieved 7,000 hours operation on a single fuel cell stack.[7]

- Two Chevrolet Equinox FCEVs used by the U.S. Postal Service have delivered more than one million pieces of mail since entering service.

- GM introduced its "production intent" FCEV and restated its plan to introduce a commercial vehicle by 2015.

- California funded another 11 hydrogen fueling stations, bringing the number of public stations to 20 expected by the end of 2011.[8]

Research continues to further fuel cell innovation. The number of worldwide fuel cell patents grew by more than 57 percent in 2010. Fuel cells lead in the clean energy field, as has been the case since 2002, with 996 fuel cell patents registered in 2010. The U.S. holds 47 percent of fuel cell patents registered between 2002 and 2010.[9]

Figure 1: Altergy Systems' Freedom Power System™ lit up the Golden Globe Awards in January 2011. *Photo credit: Altergy Systems*

Although fuels cells are present in many aspects of our daily lives, including homes, grocery stores, warehouses, commercial and industrial buildings, and even the Golden Globe Awards, challenges remain to ensure more widespread adoption. Costs must be further reduced and performance and durability must continue to improve, enabling fuel cells to be fully competitive with incumbent technologies. Government support remains critical to achieving these goals.

Similarly, despite significant recent progress, the cost of hydrogen production and storage need to be further reduced to compete with incumbent fuels, and improvements are required in low carbon hydrogen production. Safety regulations and product standards need revision to reflect current experience and to ensure better harmonization among jurisdictions. Finally, public awareness of hydrogen and fuel cells remains low, requiring further outreach and education.

Despite these challenges, the outlook for fuel cells and hydrogen remains very positive. Market penetration is increasing, costs are coming down, and performance and durability are improving. With continued support, these trends should continue into 2011 and beyond.

Financial Data

Fuel cell companies continued to operate with significant though 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. Costs for fuel cell systems and components, as well as hydrogen production and distribution, also are decreasing.

Fuel Cell and Hydrogen Costs

Government sponsored and private industry research and development continues to reduce fuel cell cost and improve durability and performance. Brookhaven National Laboratory, Los Alamos National Laboratory, Argonne National Laboratory, and 3M each developed innovative catalysts with little or no platinum. The Solid State Energy Conversion Alliance (SECA) made considerable progress in 2010, including meeting 2010 cost targets. Case Western Reserve University and 3M developed membranes that achieve high conductivity at higher temperatures, thus helping to improve cost-effectiveness. A new process for making nano-fiber composite membranes was developed and demonstrated by Vanderbilt University, which could increase the durability of polymer-based membranes without compromising performance.

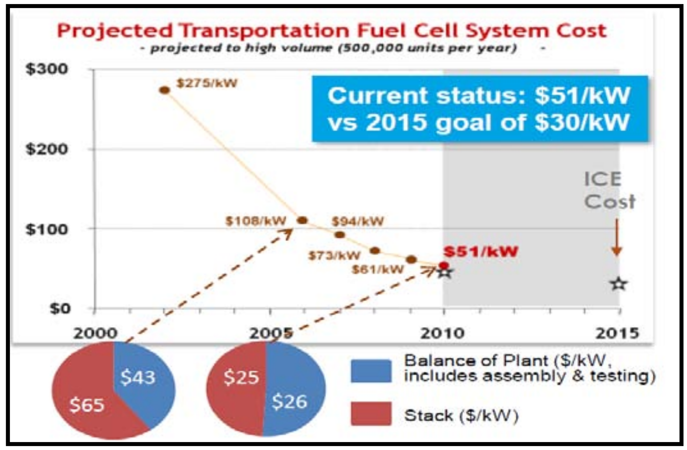

Figure 2: DOE Projected Transportation Fuel Cell System Cost

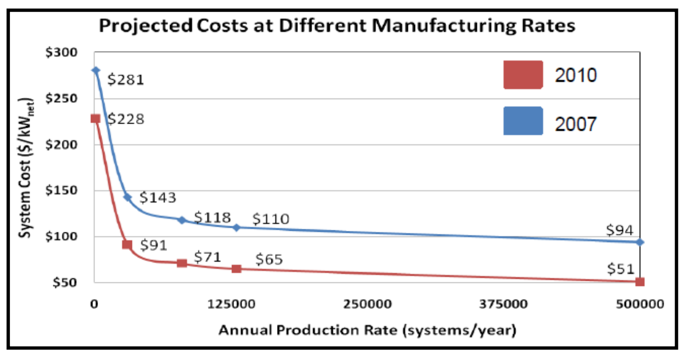

Figure 3: DOE Projected Costs at Different Manufacturing

The estimated cost of a transportation fuel cell system (2010 technology) for high volume manufacturing (500,000 units per year) is $51/kW (Figure 2). This is a reduction of more than 80 percent since 2002 and approaches the target of $30/kW established for 2015. Research and development efforts appear to be on track to achieve cost-competitiveness with internal combustion engines within the next few years.[10] Low volume cost reductions are following a similar trajectory (Figure 3).

The cost of hydrogen dispensed for motor fuel has decreased due to DOE sponsored research, with significant improvements in electrolyzer and reformer technology. Advances also were made in hydrogen production from photosynthetic algae. Hydrogen transport cost estimates have declined more than 30 percent since 2005.

Revenues, Assets, and R&D Expenses

Fuel cell companies derive revenue from the sale of fuel cells, related equipment (such as hydrogen generators), sales of material products related to fuel cells, support and maintenance contracts, and from contract research and development. Companies with strong patent positions derive significant income from license fees.

Table 1: Gross Revenues for Select Public Fuel Cell Companies[11] (Thousands USD except where noted)				
North American Companies	**2010**	**2009**	**2008**	**2007**
Ballard Power	65,019	46,722	59,580	65,532
FuelCell Energy	69,777	88,016	100,735	48,234
Hydrogenics Corp.	20,930	18,841	39,340	37,990
IdaTech	4,500	6,550	5,930	5,076
Plug Power	19,473	12,293	17,901	16,271
TOTALS (USD)	**179,699**	**172,422**	**223,486**	**173,049**
Other Companies	**2010**	**2009**	**2008**	**2007**
Ceramic Fuel Cells Ltd[1]	2,033	1,679	617	4,420
Ceres Power [2]	786	952	722	98
SFC Energy AG [3]	13,330	11,687	14,553	14,351
[1]$AUS Thousands [2]£ Thousands [3]€ Thousands				

Tables 1 through 3 provide financial information from select public companies. These companies were selected because fuel cells are their primary product, and because they are traded on major stock exchanges. As shown in Table 1, gross revenues of publicly traded fuel cell companies are returning to pre-recession levels. In some cases, this reflects growing commercial sales. Out of the selected companies, only Ceres Power remains primarily a research and development company and its decrease in revenue in 2010 reflects the receipt of a significant milestone payment in 2009.

Table 2: R&D Expenditures for Select Public Fuel Cell Companies (Thousands USD, unless footnoted)				
North American Companies	**2010**	**2009**	**2008**	**2007**
Ballard Power Systems	23,812	26,628	37,179	58,478
FuelCell Energy	10,370	10,994	16,059	13,438
Hydrogenics Corp.	3,445	5,219	7,296	9,690
IdaTech	11,500	17,708	7,835	5,990
Plug Power	12,900	16,324	34,987	39,218
TOTALS (USD)	**62,027**	**76,873**	**103,356**	**126,814**
Other Companies	**2010**	**2009**	**2008**	**2007**
Ceramic Fuel Cells Limited [1]	10,257	9,861	12,310	12,050
Ceres Power[2]	9,907	6,308	5,748	4,922
SFC Energy AG [3]	1,891	1,507	777	631
[1]$AUS Thousands [2]£ Thousands [3]€ Thousands				

As seen in Table 2, most companies show slight decreases in R&D expenditures in 2010 over 2009. This continues the trend from 2008 as companies focus increasingly on product development and manufacturing, rather than R&D.

Table 3 shows that most companies in our sample showed asset reductions between 2009 and 2010. At the same time, most companies showed increases in liabilities over the same period. This continues a general trend over the most recent four-year period.

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

North American Companies	2010		2009		2008		2007	
	Assets	Liabilities	Assets	Liabilities	Assets	Liabilities	Assets	Liabilities
Ballard Power Systems	189,788	61,913	195,348	36,428	208,443	49,956	298,691	40,502
FuelCell Energy	150,529	66,136	162,688	56,420	185,476	65,161	253,188	42,318
Hydrogenics Corp.	31,473	13,847	36,808	19,328	47,579	22,083	67,940	27,208
IdaTech	50,633	74,030	44,475	43,377	50,567	18,786	61,952	12,003
Plug Power	59,177	16,264	164,185	75,915	209,112	83,247	268,392	19,491
TOTALS	**481,600**	**232,190**	**603,504**	**231,468**	**701,177**	**239,233**	**950,163**	**141,522**
Other Companies	**2010**		**2009**		**2008**		**2007**	
Ceramic Fuel Cells Limited [1]	33,275	7,229	50,941	2,451	30,649	3,640	70,276	3,933
Ceres Power [2]	47,054	6,437	27,081	5,688	30,455	1,825	13,665	788
SFC Energy AG [3]	46,312	4,591	50,442	4,581	54,839	5,204	59,945	8,032
[1]$AUS Thousands [2]£ Thousands [3]€ Thousands								

Venture Capital and Private Equity

Cumulative global investment in fuel cells and hydrogen totaled roughly $630 million between 2008 and 2010. This is almost identical to the total level of investment in the 2007-2009 period, as reported in the 2009 edition of this report.

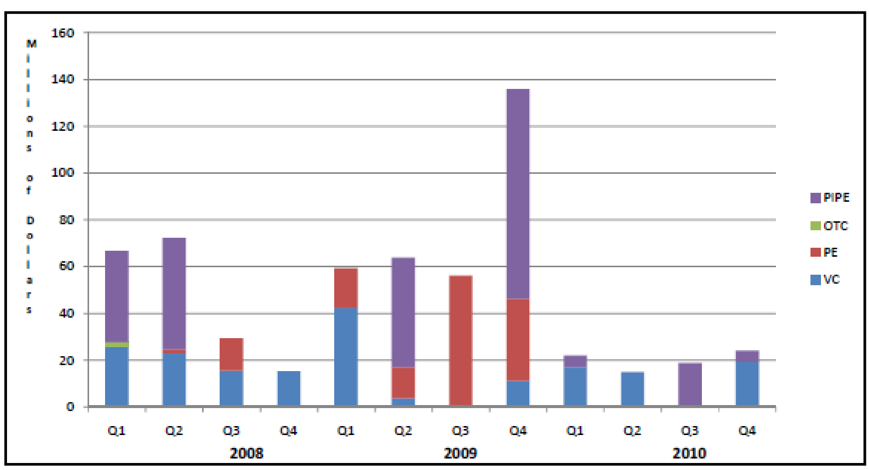

Figure 4: Worldwide Venture Capital (VC), Private Equity (PE), Over-the-Counter (OTC), and Private Investment in Public Equities (PIPE) Investments in Fuel Cell Companies (2008 – 2010) Source: New Energy Finance

Global private investment in fuel cell companies (excluding hydrogen) totaled $578.3 million between 2008 and 2010. As shown in Figure 4, investments in 2010 were significantly lower than in 2008 and 2009, comprising less than 14 percent of the three year total.

Investment in U.S. fuel cell companies totaled $242.1 million between 2008 and 2010, roughly half of the global total. Investment in U.S. companies declined significantly in 2010 (Figure 5). All of the U.S. activity in 2010 was venture capital.

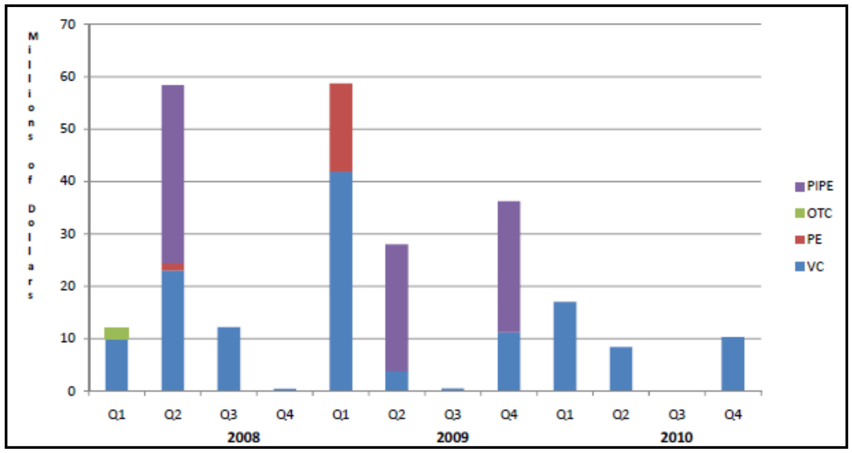

Figure 5: U.S. Venture Capital (VC), Private Equity (PE), Over-the-Counter (OTC), and Private Investment in Public Equities (PIPE) Investments in Fuel Cell Companies (2008 – 2010) Source: New Energy Finance

Table 4 shows the top ten global investors in fuel cells and hydrogen between 2000 and 2010. U.S. investors made the greatest cumulative investment during the period, $774.4 million, followed by United Kingdom (U.K.) investors, at $297.3 million. U.S. and U.K. investors collectively comprised six of the top ten largest investors in the sector.

Table 4: Top Ten Venture Capital and Private Equity Investors in Fuel Cells and Hydrogen, By Company and By Country (Cumulative 1/1/2000 – 12/31/2010)†

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 (U.S.)	$66.4	U.S.	$774.4
World Gold Council (U.K.)	$60.4	U.K.	$297.3
Carbonics Capital Corp (U.S.)	$58.1	Canada	$153.3
Investec (South Africa)	$57.1	Germany	$98.3
Mobius Venture Capital (U.S.)	$51.5	South Africa	$57.1
Chrysalix Energy LP (Canada)	$50.5	Singapore	$50.0
EnerTek Singapore Ptd Ltd (Singapore)	$50.0	Australia	$46.5
Rolls Royce Plc (U.K.)	$50.0	Switzerland	$28.8
Jolimont Ventures (Australia)	$45.5	Netherlands	$27.7
Meditor Capital Management (U.K.)	$34.0	Sweden	$26.5
Subtotal (top 10 only)	**$523.5**	**Subtotal (top 10)**	**$1,559.9**
TOTAL (All Companies and Countries)			**1,725.1**
†Cumulative investment reported for 2000-2010 is less than the cumulative total reported last year for 2009-2010. This is because investments are reported as estimates and are adjusted over time as new information becomes available.			

Source: New Energy Finance

Table 5: Top Ten Disclosed Venture Capital and Private Equity Investors in Fuel Cells and Hydrogen, By Company and By Country (2010)†			
Top Ten Fuel Cell Investors		**Countries with Highest Level of Private Investment in Fuel Cells and Hydrogen**	
Company	**Amount (million USD)**	**Country**	**Total All VC and PE Investment (million USD)**
Intel Capital Corp. (U.S.)	$6.3	U.K.	$15.4
Polaris Venture Partners (U.S.)	$4.8	U.S.	$13.7
Tata Ltd (U.K.)	$4.8	France	$10.1
Amundi Group (Hong Kong)	$3.4	Hong Kong	$5.1
Areva SA (France)	$3.4	Belgium	$5.1
Emertec Gestion (France)	$3.4	Switzerland	$1.0
GimV (Belgium)	$3.4	Israel	$1.0
Sofinnova Partners (France)	$3.4	Canada	$0.7
Intelligent Energy Holdings PLC (U.K.)	$2.0	Malaysia	$0.7
Scottish and Southern Energy PLC (U.K.)	$2.0		
Subtotal (top 10 only)	**$36.9**	**Subtotal (top countries)**	**$52.8**
TOTAL (All Companies and Countries)			**$52.8**
†There were $24.8 million in VC and PE investments in 2010 where the investor's identity was not disclosed.			

Source: New Energy Finance

Table 5 shows the top ten investors in fuel cells and hydrogen in 2010. The U.S. and the U.K. traded the top two spots, with the U.K. investing $15.3 million in 2010, while the U.S. invested $13.7 million. In 2010 more European-based companies made the top ten list, which was dominated by the U.S. and the U.K. last year. France, which did not make the list in 2009, has three companies investing in fuel cells and hydrogen, suggesting a growing interest in the country and Europe in general.

Shipments

The number of fuel cell shipments continued to grow in 2010, reflecting the ongoing trend toward commercialization. The trend is particularly noteworthy given the global financial crisis that began in 2008. This section examines both the number of units shipped and the total megawatts shipped.

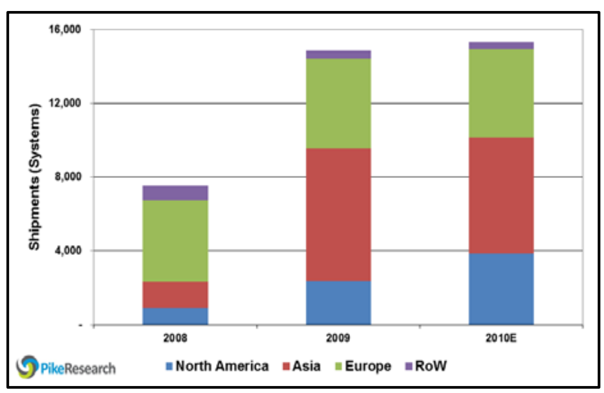

Figure 6: Global Fuel Cell Shipments by Region (2008-2010). Source: Pike Research (www.pikeresearch.com)

The total number of annual shipments of fuel cell systems has more than doubled since 2008, with a large proportion of the increase attributable to Asia

(Figure 6). Most of these Asian shipments were residential fuel cell units installed as part of the Japanese residential fuel cell program, which is discussed in greater detail in the Spotlight on Japan section. Shipments from North America nearly doubled between 2009 and 2010. A significant portion of the growth is attributable to continuing commercialization in the stationary sector. As discussed in the Government Policy Section, some of the North American growth is attributable to the ARRA.

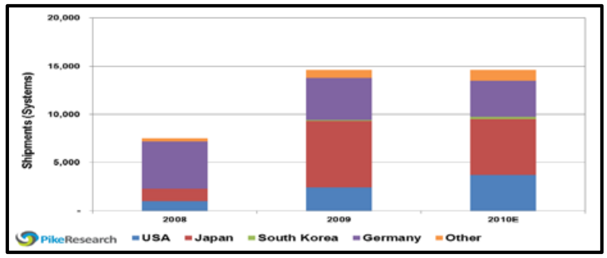

Figure 7: Units shipped by Key Fuel Cell Producing Countries (2008-2010) Source: Pike Research (www.pikeresearch.com)

Figure 7 breaks down shipments by key fuel cell producing countries. Japan has experienced a large increase in shipments due to its residential fuel cell program. The United States also experienced a major increase in shipments, while German shipments experienced a slight decline.

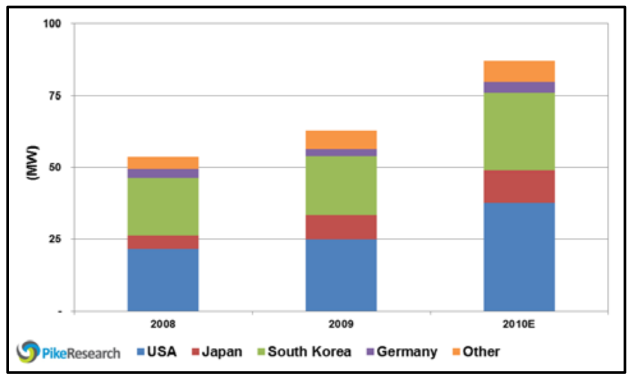

Figure 8: Megawatts shipped by Key Fuel Cell Producing Countries (2008-2010)
Source: Pike Research (www.pikeresearch.com)

Figure 8 provides national shipment data by MW. Here, the U.S. and South Korea lead, primarily because of molten carbonate fuel cells (MCFC) produced by FuelCell Energy and its South Korean partner, POSCO Power. Although Japan ships a larger number of stationary fuel cells for its residential program, the power output of these systems is small compared with the molten carbonate units.

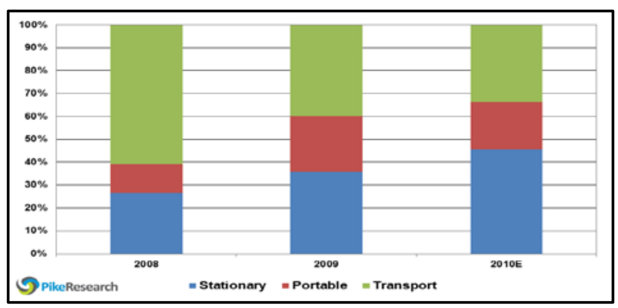

Figure 9: Percentage of Global Fuel Cell Shipments by Application (2008-2010)
Source: Pike Research (www.pikeresearch.com)

Figure 9 provides global fuel cell shipments by application. Stationary applications surpassed transport applications in terms of number of units shipped, and portable applications increased as a percentage of total global shipments. The increase in stationary shipments was primarily due to increases in residential and backup power applications. For transport, the growth was primarily in fuel cell forklift equipment, while for portable applications, the growth was primarily in external battery chargers, military applications, and remote monitoring.

Figure 10 breaks down global shipments by application and MW. Here, stationary applications dominate, because stationary units have the highest output per unit shipped. MCFCs, for example, are sold in systems of up to three MW.

There was a significant increase in the MW of transport shipments in 2010. This was due to shipments of industrial equipment and to a relatively large number of fuel cell buses, cars, and other vehicles delivered in 2010, including fuel cell buses in Canada and Europe, as well as 200 fuel cell vehicles used at the World Expo in Shanghai.

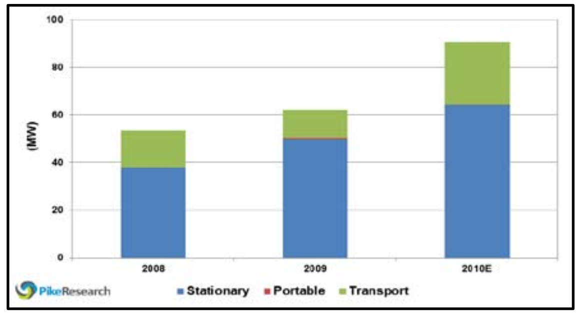

Figure 10: Total MW's Shipped by Application (2008-2010)
Source: Pike Research (www.pikeresearch.com)

As seen in Figure 11, the total number of fuel cell shipments in North America quadrupled between 2008 and 2010. Significant growth occurred in each market segment, but growth was especially strong in stationary and portable applications.

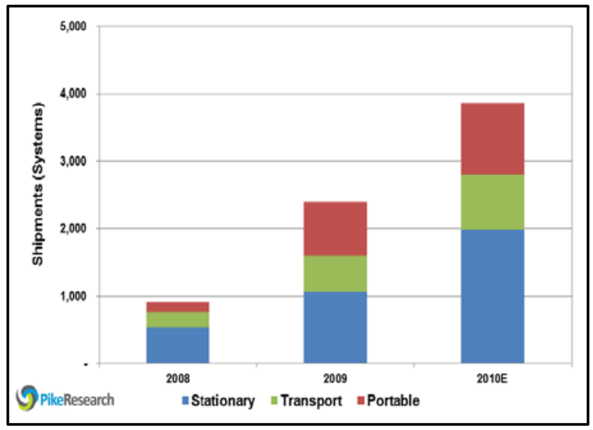

Figure 11: North America Fuel Cell Shipments by Application (Thousands of Units) (2008-2010).
Source: Pike Research (www.pikeresearch.com)

Asian fuel cell shipments also grew substantially between 2008 and 2010, but a slight decline occurred between 2009 and 2010, due to reductions in portable shipments for consumer electronics. As shown in Figure 12, the greatest growth in Asia was in the stationary segment, again largely due to the residential fuel cell program in Japan.

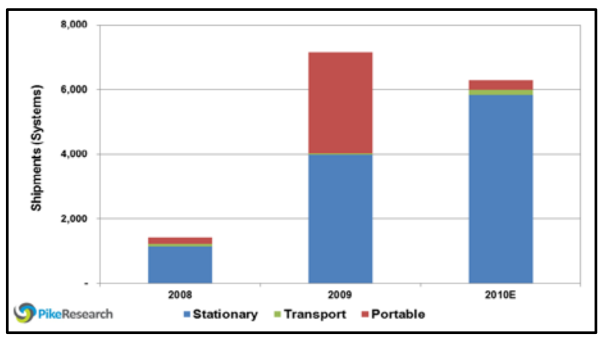

Figure 12: Asia Fuel Cell Shipments by Application (Thousands of Units) (2008-2010).
Source: Pike Research (www.pikeresearch.com)

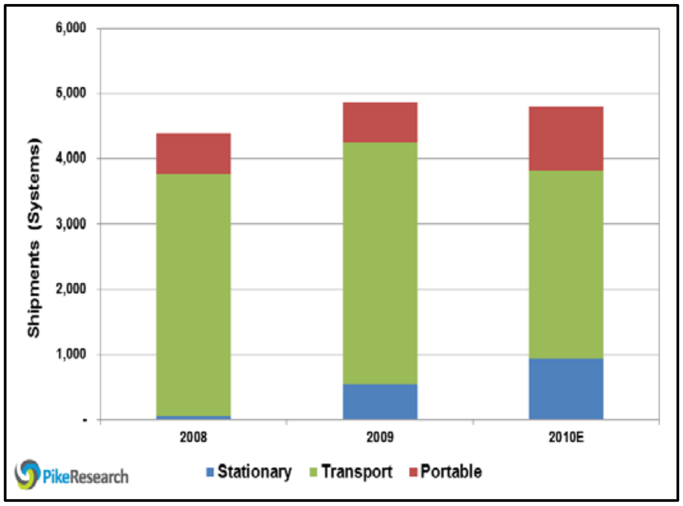

Figure 13: Europe Fuel Cell Shipments by Application (Thousands of Units) (2008-2010).
Source: Pike Research (www.pikeresearch.com)

Unlike North America and Asia, European fuel cell shipments remained flat between 2009 and 2010 (Figure 13). Although transport remains the predominant application, both stationary and portable systems increased as a percentage of overall European shipments. The transport systems in Europe are mostly APUs for luxury vehicles, such as recreational vehicles and boats.

Government Policy, Standards, and Regulation

The ARRA was an important driver of U.S. fuel cell sales. ARRA allocated $41.9 million for fuel cell commercialization activities and attracted $54 million in cost-share. The DOE nearly doubled its target installations in 2010, with 24 telecommunications backup systems and 206 lift trucks. (See Figure 14) Private sector participants include major U.S. companies such as Federal Express, Sysco, and AT&T.

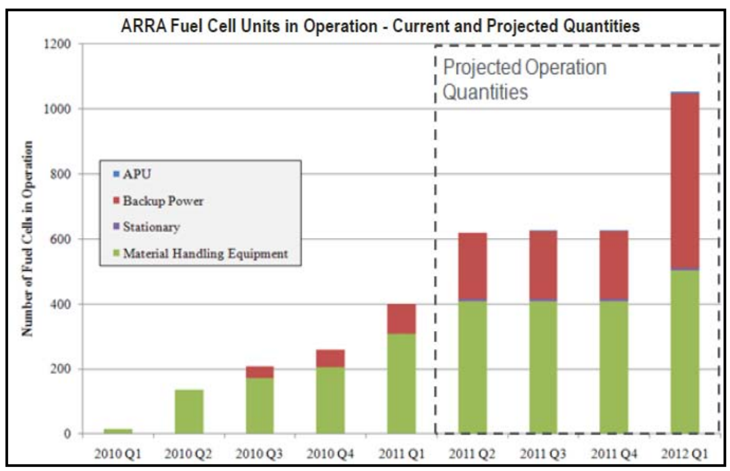

Figure 14: DoE ARRA Fuel Cells in Operation
http://www.hydrogen.energy.gov/pdfs/htac_overview_satyapal.pdf

The following is a summary of major projects that received DOE funding in 2010:

- $5 million to the Sacramento Municipal Utility District (SMUD) for various projects, including a MCFC.[12]

- $2.5 million to the University of California for a system to generate power from a renewable biogas fed to a 300-kW fuel cell.[13]

- $5.3 million in tax credits for UTC Power to open a new fuel cell manufacturing facility.[14]

- $8.4 million to Nuvera Fuel Cells to increase the durability and performance of fuel cell stacks.[15]

- $2.8 million to FuelCell Energy to demonstrate the hydrogen production capacity of a 300-kW Direct FuelCell[16], and $2 million to further develop a highly efficient method for compressing hydrogen.[17]

- Several Advanced Research Projects Agency-Energy (ARPA-E) projects involving advanced hydrogen generation and fuel cells.

Many organizations are working to develop consistent, harmonized codes and standards for fuel cells and hydrogen. Significant progress has been made in the last five years, in part due to DOE's research, coordination, and information-sharing activities. For example, the National Fire Protection Association published the 2010 code for compressed gases and cryogenic fluid, based upon data developed by Sandia National Laboratory. The DOE Hydrogen Program supported workshops that reached more than 300 code officials and published several online courses.

States also continued to adopt policies and programs supportive of fuel cells in 2010. Delaware expanded the state's net-metering policy to include fuel cells using non-renewable fuels. California launched a new clean vehicle rebate program, offering rebates of up to $5,000 to purchase or lease new, zero-emission or plug-in hybrid electric vehicles.[18] The Connecticut Clean Energy Fund (CCEF) launched a new program to invest in renewable energy technologies, including fuel cells and hydrogen. The program will provide incentives of up to $200,000. The New York State Energy Research and Development Authority (NYSERDA) implemented a fuel cell rebate and performance incentive, offering up to $50,000 for systems smaller than 25 kW and up to $1 million for larger systems.

Applications and Market Assessment

Materials Handling

The materials handling market showed particular strength, with increasing sales volumes, cost reductions, and a strong track record of operating success.

For example, Plug Power reported sales of more than 400 lift trucks in the fourth quarter of 2010 alone. Plug Power reports that its fuel cell forklift operators achieved more than 44,000 refueling events at 12 forklift refueling facilities, dispensing almost 24,000 kilograms (kg) of hydrogen. Table 6 shows some of Plug Power's notable sales in 2010.

Table 6: Notable Plug Power 2010 GenDrive™ Sales

Customer	# of Units	Type	Location of Deployment
GENCO Supply Chain Solutions	25	Lift Truck	Kimberly-Clark distribution center, Graniteville, South Carolina
Sysco	100	Pallet and Fork Trucks	Front Royal, Virginia distribution center
Walmart Canada	80+	Lift Trucks	Walmart sustainable refrigerated distribution center in Alberta, Canada
BMW	86	Forklifts, Tuggers, Stackers	Spartanburg, South Carolina manufacturing plant, installing six Linde hydrogen dispensers that will use the hydrogen by-product of a sodium chlorate plant that is purified, compressed and liquefied by using electricity produced from renewable hydropower
United Natural Foods Inc.	29 new, 36 retrofits	Lift Trucks	Sarasota, Florida distribution center

In addition, companies are beginning to place follow-on orders to 2009 deployments of fuel cell powered forklifts. For example, both GENCO and Sysco received ARRA funding in 2009 to deploy fuel cells for materials handling, and in 2010 both companies made additional, non-ARRA funded purchases.

Companies using fuel cell forklifts are reporting significant benefits. Nissan North America saved 35 hours per day of staff time in its Smyrna, Tennessee, plant by avoiding time spent changing and recharging batteries. Nissan also eliminated more than 70 electric battery chargers that used almost 540,000 kilowatt-hours (kWh) of electricity annually.

Other significant developments in materials handling include:

- Crown Equipment Corporation qualified 20 of its electric forklift models to operate with various fuel cells, bringing its total of qualified combinations of fuel cell packs and trucks to 29.[19]
- Oorja Protonics sold 15 of its OorjaPac Model III methanol-powered fuel cells to Martin-Brower for its Stockton, California, food distribution facility.[20] U.S. Foodservice also purchased 40 OorjaPacs to power pallet jacks in its Livermore, California, food distribution facility. The purchase came after a month-long trial period where U.S. Foodservice experienced increased productivity using the fuel cells.[21]
- The Defense Logistics Agency (DLA), an agency of the U.S. Department of Defense (DoD) awarded $6 million to the Center for Transportation and the Environment and partners to

develop a hydrogen fuel cell pilot program at DLA Distribution San Joaquin, CA. The project is a collaboration with the DOE. The scope includes 20 hydrogen-powered forklifts for warehousing activities and an electrolysis-based hydrogen generation system using renewable energy.[22]

- DLA Distribution Susquehanna, PA, with support from DOE, placed an additional order for 18 PowerEdge RL25 fuel cell units from Nuvera Fuel Cells, to power 15 forklifts, under a firm fixed price contract, a sign of the commercial maturity of the transaction. These forklifts are part of an ongoing deployment of both new and retrofit fuel cell systems at the distribution center.

- The Toro Company was selected to help design and build two fuel cell utility vehicles with a solid hydrogen storage system for the Naval Surface Warfare Center, Crane Division.[23]

Back-up and Remote Power

ARRA grants increased sales and installations of fuel cell backup and remote power systems in the United States. Companies like Sprint, AT&T, and PG&E installed more than 50 fuel cell back-up power units at U.S. cell tower sites, and an army base in South Carolina installed 10 systems. T-Mobile placed fuel cells at 35 sites in Florida, and Motorola deployed more than 100 in Denmark.

Figure 15: IdaTech PEM Back-up Unit ***Photo courtesy of IdaTech LLC, NREL/PIX 19192.***

Developing countries also increasingly used fuel cells for back-up and remote power. Wireless TT Info Services in India purchasing 200 Plug Power systems. IdaTech continued its focus on Indonesia, receiving an order for 154 ElectraGen™ H2 fuel cell systems, adding to the more than 100 IdaTech fuel cell systems already installed across Indonesia for telecommunications backup power.[24]

Other highlights include:

- EnerSys® installed a 300-kW hydrogen fuel cell system at a Time Warner Cable facility in Southern California, providing backup power for digital telephone, internet and video services.[25]

- SFC Energy AG and Evergreen Energy Technologies Inc. joined forces to market a fuel cell stand-alone power solution for remote monitoring and service of oil and gas well sites in Canada. SFC also launched the EFOY Pro 2200 XT, specifically developed for traffic management and security systems.[26]

Stationary Power

Companies such as Whole Foods, Albertsons, Coca-Cola, FedEx, UPS, Adobe, Walmart, Cox Enterprises, Bank of America, Safeway, Cypress Semiconductor, eBay, Google, and Price Chopper use stationary fuel cells for primary and back-up power and for heating and cooling. Tables 7 and 8 summarize projects in 2010 by the two U.S. manufacturers of large stationary fuel cell systems.

Table 7: Summary of FuelCell Energy U.S. Projects 2010

Location	Capacity	Notes
San Diego, CA	2.8 MW	Will use wastewater treatment biogas
San Diego, CA	1.4 MW	Will use wastewater treatment biogas
Point Loma, CA	300 kW	Will use wastewater treatment biogas
San Jose, CA	1.4 MW	Will use biogas
Rancho, CA	1.4 MW	Will power a pumping station
Riverside County, CA	600 kW	Will use biogas
Chino, CA	2.8 MW	Will use biogas
Tulare, CA	300 kW	Fourth fuel cell brings plant's total to 1 MW
French Camp, CA	1.4 MW	Will utilize renewable biogas generated from chicken waste
Hayward Hills, CA	1.4 MW	Utility-owned at CSU-East Bay
San Francisco, CA	1.4 MW	Utility-owned at San Francisco State University
Long Beach, CA	1.4 MW	Utility-owned at CSU-Long Beach
San Bernardino, CA	1.4 MW	Utility-owned at CSU-San Bernadino
Dublin, CA	300 kW	U.S. Army Camp Parks Reserve Forces Training Area
South Windsor, CT	300 kW	Frozen food processing facility
Groton, CT	600 kW	U.S. Naval Submarine base

In 2010, Whole Foods installed its third fuel cell for combined heat and power – a 400-kW UTC Power fuel cell with an 80,000-hour warranty. Similarly, the use of fuel cells in single- and multi-family residential buildings is expanding. In May 2010, Barksdale Air Force Base began using a FuelCell Energy unit to provide electricity, heat, and hot water at one of the dormitories on base. Two apartment buildings, one in New York and one in Connecticut, became the first large-scale residential buildings powered by fuel cells in the U.S., reducing residents' utility bills by 50 percent compared to a traditional building. Federal and state grants enable the developers to pay back the capital costs within five years.

In Japan, residential applications continue to be a priority. Thousands of residential CHP units have been sold, and Toyota continues developing solid oxide fuel cells (SOFC) for residential use. In South Korea, a new government program is supporting up to 80 percent of the installed costs of a residential fuel cell, with the goal of installing at least 1,000 systems by 2012. By 2020, the program aims to install more than 100,000 residential fuel cells.

Table 8: Summary of UTC Power U.S. Projects 2010

Location	Capacity	Notes
San Jose, CA	400 kW	CHP, providing 90 percent of grocery store electricity
San Diego, CA	400 kW	CHP, providing 90 percent of grocery store electricity
New Haven, CT	400 kW	Fuel cell will power to two schools
Torrington, CT	400 kW	CHP, providing 94 percent of grocery store electricity and 70 percent of its space heating requirements
New Haven, CT	400 kW	CHP, providing nearly all of the electricity for apartments, stores and common areas and hot water for a swimming pool
White Plains, NY	200 kW	CHP, providing 20 percent of the building's electricity
New York, NY	2.4 MW	Six fuel cells (out of 12) delivered to World Trade Center site
Sturtevant, WI	400 kW	Main headquarters

In mid-2010, the U.K. announced a feed-in tariff for low-carbon residential generation up to five kW that will pay British homeowners for every unit of low-carbon power generated or sold to the grid.

Fuel cells also are making inroads in markets for baseload power. POSCO Power of Korea has installed more than one-third of its planned 68 MW of fuel cells. In Canada, Enbridge and FuelCell Energy are demonstrating a hybrid fuel cell power plant that will serve about 1,700 homes. Bloom Energy launched its Bloom Energy Server, including 12 units installed at Adobe System's headquarters in San Jose, California. Bloom also announced a number of other major customers, including Bank of America, Coca-Cola, Cox Enterprises, eBay, FedEx Corp., Google, Staples, and Walmart.

Other developments include:

- FuelCell Energy certified its 2.8 MW DFC3000 power plant under the California Air Resources Board's (CARB) distributed generation emission standards. Certification enables local governments to exempt users from local clean air permitting.[27]

- FuelCell Energy and UTC Power received certification for CHP units under American National Standards Institute/CSA American Standard for Stationary Fuel Cell Power Systems.

- Ceramic Fuel Cells Limited (CFCL) sold its first BlueGen generator in the U.S.[28] and met the pre-conditions for an order for 30 BlueGen fuel cells to be installed in public housing in Australia.[29]

- Ballard Power Systems completed testing of a 1 MW utility-scale distributed generation proton exchange membrane (PEM) fuel cell system that was installed at FirstEnergy Generation Corp's Eastlake Plant in Ohio.[30] Ballard also finalized a sales agreement with K2 Pure Solutions for deployment of Ballard's CLEARgen™ fuel cell system to be sited at a K2 bleach plant in Pittsburg, California.

Figure 16: FuelCell Energy facility at the Tulare, California Wastewater Treatment Plant.
Photo courtesy of FuelCell Energy, Inc., NREL/PIX 19193

- ClearEdge Power entered into an exclusive, three-year distribution agreement to supply more than 800 units in South Korea.[31]

- Japan expanded its national fuel cell program by adding a SOFC demonstration program, in which Toyota Motor Corporation and Aisin Seiki Co. Ltd. will provide 60 residential SOFC units.[32]

- Topsoe Fuel Cell A/S and Risø DTU received a €7.3 million (U.S. $10.8 million) grant from the government of Denmark for SOFC development.[33] Topsoe and Risø DTU also received DKK 8.6

million (U.S . $1.5 million) in European Union and state funding to develop a methanol-fueled 500 watt (W) micro-CHP (m-CHP) plant.

- AFC Energy's alkaline fuel cell technology was chosen as the key component in a 500-MW carbon capture and storage project based in the North East of England. AFC Energy also signed a letter of intent to install up to 300 MW of fuel cells at an integrated gasification combined cycle power station.

Fuel Cell Vehicles

Fuel cell cars continue to make substantial gains in performance and cost reduction. Projected high-volume transportation fuel cell system cost, using 2010 best available technology, decreased to $51/kW, based upon the Department of Energy's cost model. This represents a 30 percent reduction since 2008 and an 80 percent reduction since 2002. These reductions are largely due to R&D efforts that enabled reduced platinum group metal content, increased power density, and simplified balance of plant. For example, General Motors' next-generation FCEV is expected to have a fuel cell system that is 50 percent smaller, 220 pounds lighter, and uses less than half the precious metal of the current Equinox FCEV. Significant additional reductions are required to meet the 2015 target of $30/kW.

Automakers continue to project commercial production in 2015. Thirteen Japanese companies (three automakers and 10 energy companies) formed a partnership in 2010 to develop a hydrogen station network. The companies plan to build 50 to 100 filling stations by 2015 in four major Japanese cities and along linking highways. The Japanese Ministry of Economy, Trade, and Industry (METI) pledged to support the revision of hydrogen infrastructure regulations ahead of vehicle deployment.

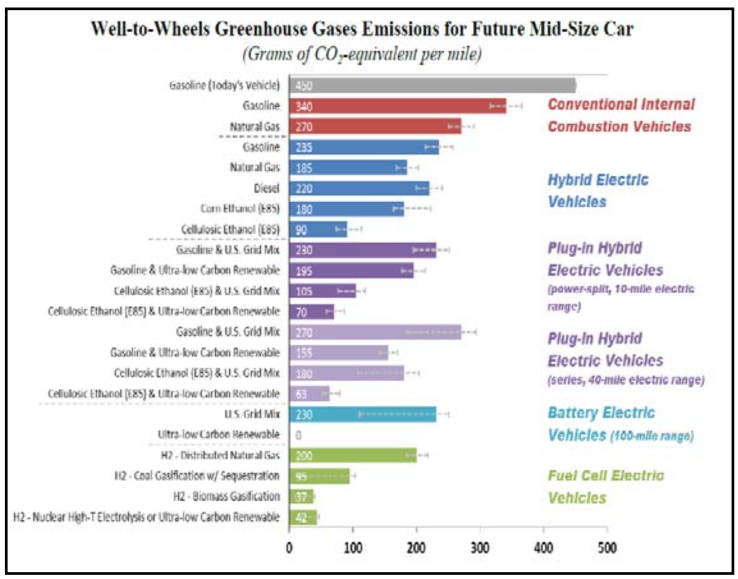

Figure 17: Well-to-wheels Greenhouse Gas Emissions for Mid-Sized Light-Duty Vehicles. GHG Emissions of Various Vehicle Fuel and Technology Combinations. Source: US Department of Energy http://hydrogen.energy.gov/pdfs/10001_well_to_wheels_gge_petroleum_use.pdf

McKinsey & Company examined various vehicle technology pathways and found, among other things, that fuel cell vehicles provide the best low carbon solution in the medium- and large-car segments, which account for 50 percent of all cars and 75 percent of carbon dioxide emissions.[34] Similarly, Argonne National Laboratory and the National Renewable Energy Laboratory prepared an updated well-to-wheels analysis for the DOE, finding that fuel cell vehicles offer one of the best strategies available to reduce petroleum use and greenhouse gas emissions from the transportation sector. (See Figure 17).

DOE's Technology Validation program continues to provide valuable data. The program includes 152 fuel cell vehicles that have accumulated 114,000 hours and 2.8 million miles of real-world driving, demonstrating ranges of over 400 miles and fuel cell efficiencies of up to 59 percent. The program's 24 fueling stations have produced and/or dispensed over 134,000 kg of hydrogen. The third biannual National Research Council review of the FreedomCAR and Fuel Partnership concluded that the U.S. hydrogen fuel cell research program is an effective public research effort that should continue.

Figure 18: Truck Featuring a Delphi SOFC APU. ***Photo courtesy of Delphi, NREL/PIX 19192***

Other U.S. government agencies also continued hydrogen vehicle demonstrations in 2010. The DoD's Army Tank Automotive Research, Development, and Engineering Center (TARDEC) operated 11 hydrogen FCEVs and 10 hydrogen internal combustion engine vehicles at four locations in 2010, reporting a very high rate of customer satisfaction.

Additional vehicle-related announcements in 2010 include:

- Hyundai signaled that it intends to take the lead in commercializing fuel cell electric vehicles, with production beginning in 2011. Targets include 2,000 vehicles per year by 2012 or 2013 and 10,000 per year in 2015 – to be offered at a cost below $50,000.
- General Motors introduced its "production intent" FCEV system and restated its plan to introduce a commercial vehicle by 2015.
- Daimler began small-series production of its Mercedes-Benz B-Class F-Cell vehicle and plans to increase production to tens of thousands of vehicles by 2015–2017. Twenty Mercedes-Benz B-Class F-CELL vehicless were delivered to DOE and Mercedes announced its intention to deploy 70 F-CELLs in California by 2012.[35]
- Toyota delivered 10 of its fuel cell-powered FCHV-adv vehicles to Proton Energy Systems in Wallingford, Connecticut. Toyota plans to introduce a fuel cell sedan in 2015, priced to sell at $50,000. Toyota also joined the German hydrogen fuel cell vehicle partnership, National Organization for Hydrogen and Fuel Cell Technology (NOW).
- BMW showcased a new hybrid electric vehicle that uses a 5-kW UTC Power fuel cell system to supplement a battery and traditional gasoline engine.[36]

Hydrogen Infrastructure and Delivery

Hydrogen infrastructure to support vehicle deployments advanced in 2010 and the cost of hydrogen delivery continued to decline. The DOE projected that hydrogen will be competitive with gasoline in hybrid electric vehicles (HEVs) in 2020, if the consumer cost of the hydrogen is between $2.00–$4.00/gallon gas equivalent (untaxed).[37] For some hydrogen delivery options, such as distributed natural gas reforming and biomass gasification, estimated costs, assuming high volume production, are already at or near this target.

Moreover, the projected cost of hydrogen delivery dropped by as much as 30 percent between 2005 and 2010, largely because of technical improvements, such as new materials for tube trailers and pipelines, process improvements, and improved compressor technology. In 2010, both Linde North America and Air Products introduced new hydrogen compression technologies.

Progress also was made on cost reduction for hydrogen produced from renewable sources. For example, research helped reduce electrolyzer cell costs by over 20 percent and improve photosynthetic solar-to-chemical energy conversion from three percent to 25 percent.

In July 2010, DOE created the Joint Center for Artificial Photosynthesis to find new ways to generate fuels from sunlight. The Center will receive up to $122 million over five years, and one of the anticipated outcomes is new ways to extract hydrogen from water.

Various states continued to invest in hydrogen fueling infrastructure:

- In California, 16 hydrogen stations were either funded or under construction in 2010, which will bring the number of public stations to about 20 by the end of 2011.

- In Hawaii, GM and The Gas Company (TGC) announced plans to build 20-25 retail hydrogen stations on Oahu by 2015. TGC will distribute hydrogen via its existing gas pipeline system.[38]

- SunHydro opened its first renewable solar array hydrogen fueling station in Wallingford, Connecticut.[39] A second station will be opened in Claymont, Delaware.[40]

- Air Products installed hydrogen fueling stations in Sarasota, Florida and Pottsville, Pennsylvania. The stations will supply fuel to more than 100 fuel cell-powered lift trucks at food distribution centers.

Internationally, Germany, Japan, and South Korea anticipate more than 300 stations combined by 2017. As of November 2010, Germany had 27 stations, and about 13 public stations are expected by the end of 2011. Japan currently operates 14 hydrogen stations and one hydrogen liquefaction facility, with plans for as many as 100 fueling stations in four cities by 2015. South Korea continues developing a hydrogen highway, with 13 stations anticipated by the end of 2011, and announced plans to build the world's first fueling station generating hydrogen from landfill gas.[41] Also in South Korea, Air Liquide was selected to supply hydrogen filling stations for a demonstration project at the Korea Institute of Energy Research, led by Hyundai Motors, and for the Korea Automobile Testing and Research Institute.[42]

Other noteworthy infrastructure developments in 2010 include:

- West Virginia University received a $1.15 million grant from the National Alternative Fuels Training Consortium to develop the state's second hydrogen fueling station.

- DLA Distribution Warner Robins, GA opened a new hydrogen fueling station, which will be used to power 20 fuel cell forklifts at the warehouse.[43]
- Ballard Power Systems launched a new center of excellence for fuel processing technology at the University of Maryland. The goal is to develop technologies enabling fuel cells to operate with fuels such as JP-8, diesel, natural gas as well as liquefied petroleum gas. [44]
- ITM Power was awarded a contract to design a prototype small-scale hydrogen fueling system for 70Mpa (700 bar) refueling.[45]
- Proton Energy Systems unveiled a new hydrogen generation system that can produce ultra-high purity hydrogen at rates up to 30 Nm^3/hr and 30 bar delivery pressure.

Fuel Cell Buses

Demonstration projects continue to show the potential of fuel cell buses and several new demonstrations were unveiled. In California, an AC Transit bus running on a UTC Power fuel cell exceeded 7,000 operating hours with its original fuel cell stacks and no cell replacements.[46] Compared with diesel, a fleet of three fuel cell buses achieved 60 percent better fuel economy, an 80 percent reduction in maintenance costs, and a 43 percent reduction in greenhouse gas emissions.

British Columbia, Canada, deployed 20 fuel cell buses for the 2010 Winter Olympics, the largest fleet of fuel cell buses deployed to date. A fleet of fuel cell buses also was used at the 2010 World Expo in Shanghai. A new project under the European Fuel Cell and Hydrogen Joint Technology Initiative, known as the “Clean Hydrogen in European Cities” (CHIC) project, will deploy up to 28 hydrogen fuel cell buses in five major European cities.

Other fuel cell bus milestones in 2010 include:

- CTTransit received four new UTC Power fuel cell-powered hybrid-electric transit buses, bringing its fleet’s fuel cell bus total to five.[47]
- The City of Burbank, California received a fuel cell/plug-in hybrid bus from Proterra.[48]
- Singapore used its first hybrid fuel cell-battery bus to transport athletes and officials during the Youth Olympic Games.[49]
- Ballard Power Systems was awarded up to CAN$4.8 million to further develop fuel cell power module technology for the transit bus market. The company also received a sales order for five Fcvelocity™ HD6 power modules from Advanced Public Transportation Systems (ATPS), a specialty bus manufacturer in the Netherlands.

- BAE Systems is developing a zero-emissions fuel cell bus for SunLine Transit in California. The bus is scheduled for delivery in December 2011.[50]

- Japan's METI announced a "Hydrogen Highway Project" providing Tokyo's Haneda and Narita Airports and Shinjuku train station with a fuel cell bus in regular daily service.

Other Transportation Applications

Fuel cells continued to find roles in specialty transportation applications. Fuel cells are replacing batteries in unmanned aerial vehicles (UAVs), setting new records for performance and durability in electric-powered flight. Horizon Energy Systems began commercial sales of its new AEROPAK hydrogen fuel cell power system, and Israel Aerospace Industries announced that it is equipping its most advanced UAV with the Horizon system, providing 250 percent more endurance than lithium batteries with no increase in take-off weight. In Italy, a fuel cell aircraft set new speed and endurance records for an electrically-powered Class C airplane, recording speeds of 145-150 km/h with an endurance of 45 minutes.

Fuel cells also are showing promise as APUs in truck, recreational vehicle (RV), and marine applications. Wärtsilä installed its WFC20, 20-kW methanol-fueled SOFC unit to provide auxiliary power onboard a Swedish ferry ship. SFC Energy's EFOY fuel cells became option equipment in Notin motorhomes and standard equipment in in Rapido SAS motorhomes. SFC is also working with Sortimo International GmbH to develop a stand-alone, modular energy supply solution for special-purpose vehicles.

Other notable transportation-related activity in 2010 includes:

- Hydrogenics Corporation was awarded a contract to supply fuel cell modules for several German aircraft projects,[51] as well as a contract to develop a fuel cell power system to be used on the moon.[52]

- Acta unveiled the world's first hydrogen-powered tender boat at the European Sailing Championships in Viareggio, Italy.[53]

- Amsterdam entered the first fuel cell-powered canal boat into revenue service.[54]

- SFC Energy began offering its EFOY marine fuel cells to Swedish yacht and boat builders.[55]

- Heliocentris Fuel Cells announced that it is incorporating a 32-kW fuel cell into a Rotopress garbage collection vehicle for extensive testing under real world operating conditions.[56]

- SiGNa Chemistry, Inc. developed a cartridge containing sodium silicide, which produces hydrogen when put in contact with water. According to the company, one cartridge can power a bicycle for a range of up to 60 miles without pedaling.[57]

- Adaptive Materials was awarded $3 million through the Centers of Energy Excellence Program to support the commercialization of its 250-W fuel cells for the RV and consumer leisure market.
- Delphi Automotive demonstrated its SOFC APU for the first time at the Hybrid Truck Users Forum in Dearborn, Michigan.[58]
- Cummins demonstrated a tubular SOFC and battery to power truck "hotel loads," thus enabling the diesel engine to be switched off when the truck is not in motion.[59]
- Proton Power Systems completed initial testing of a fuel cell range extender for battery vehicles.
- Intelligent Energy announced it will supply a fleet of fuel cell black cabs for the London 2012 Olympics.

Energy Storage

Fuel cells are playing an increasing role in energy storage. The Naval Air Warfare Center in China Lake, California, is developing a system that will use solar power to create hydrogen for use in a fuel cell during periods with insufficient sunlight. In Canada, a partnership between the federal government, BC Hydro, Powertech, and General Electric is converting excess off-peak electricity into hydrogen, reducing diesel consumption by an estimated 200,000 liters per year and greenhouse gas (GHG) emissions by an estimated 600 tons per year. Germany's Enertrag AG, one of the world's largest wind power companies, is building a facility to use excess wind energy to produce hydrogen for energy storage and for transport applications.

Military

Fuels cells continued to be developed in 2010 for a wide range of military applications, primarily because they are lighter, quieter, and enable longer run-time than incumbent technologies.

For example, modern soldiers carry extensive electronic equipment resulting in a heavy load of batteries that require frequent replacement and/or recharging.[60] Fuel cells are being tested to provide individual, team or squad power using a variety of operating fuels, including methanol and military or locally-available fuels (i.e., JP-5, JP-8, kerosene, propane, biofuels). UltraCell Corporation provided several of its fuel cell systems for Portable Power Excursion tests at Fort Riley in Kansas. UltraCell also shipped its Snorkel fuel cell system with an ultra-rugged two-gallon fuel tank to the U.S. military. SFC Energy AG received additional orders from the German army for its JENNY soldier power system. The system includes a portable fuel cell, power manager, battery, and solar panel.[61] SFC also launched its JENNY ND Terra product internationally[62] is now offering its fuel cell systems on the U.S. government's General Services Administration Schedule.[63]

In 2010, the Center for Electromechanics at The University of Texas at Austin delivered two fuel cell extended range utility vehicles for a 12-month demonstration at a defense distribution depot. The vehicles use an 8.5-kW fuel cell hybrid system, with a range of more than 300 miles. Nuvera Fuel Cells delivered 18 additional fuel cells for forklifts to operate at the DLA Distribution Susquehanna, PA. The site has operated 40 fuel cell powered forklifts since 2009, including 20 fuel cell systems powered by Nuvera's technology and 20 powered by Plug Power's fuel cell technology.

Other military applications for fuel cells include:

- improving system efficiency onboard naval ships and submarines;
- powering unmanned systems (unmanned ground vehicles and unmanned aerial vehicles);
- generators for Silent Camp operations;
- auxiliary power for vehicles and towable power;
- mobile power, including passenger vehicles, buses, forklifts utility vehicles and locomotives;
- smart grid (Smart Power Infrastructure Demonstration for Energy Reliability and Security – SPIDERS) to reduce the risk of extended electric grid outages by developing the capability to "island" installations; and
- residential and small building power and CHP.

Table 9: U.S. Military Fuel Cell Projects Funded in 2010

Company	Agency	Project	Funding	FC Type
Adaptive Materials	Army	Fuel cell component manufacturing	$1 million	SOFC
Adaptive Materials	Navy	Develop fuel cells powered by existing fuels, including JP-5	$150,000 with two options	SOFC
Adaptive Materials	DOD	Portable battery charger	Up to $5.6 million	SOFC
Adaptive Materials	DARPA	Portable fuel cell systems powered by JP-8	$1.5 million	SOFC
Proton Energy Systems	Hamilton Sundstrand Corporation	Equipment supply for submarines	N/A	Electrolysis cell stacks
Protonex	Air Force	Soldier-worn portable power managers	$3 million	SOFC
Protonex	Army	Portable battery charger/APU fuel cell systems	Up to $6.4 million	SOFC
Protonex	Army	Portable power systems and integrated fueling	$345,000	SOFC and PEM
Protonex	Lockheed Martin	Power supply for robotic exoskeleton	Unknown	SOFC
University of North Florida	Army	Laptop computer power supply	$3.2 million	DMFC
University of South Carolina	DOD	Portable power packs	$3.6 million	PEM and SOFC

Table 9 summarizes U.S. military fuel cell projects funded in 2010.

Portable/Micro

Several companies continue to develop portable fuel cells, primarily as battery chargers for consumer electronics. Lilliputian Systems received $5 million to help buy equipment for its Wilmington facility, which will produce USB charging systems, and Intel Capital took an equity stake in Lilliputian.[64]

Horizon Fuel Cell Technologies began shipments of the world's first miniaturized hydrogen fuel cells and refueling stations for use in model hobby radio controlled vehicles. The company also launched its new pocket-size fuel cell battery charger for the portable consumer electronics markets.

Panasonic became an approved partner of SFC Energy, which includes the certification of Panasonic's Toughbook products for operation with SFC's fuel cells.[65] Neah Power Systems announced that it will produce a hybrid fuel cell technology that recharges lithium ion batteries in consumer electronics.

Intellectual Property

The number of fuel cell patents continues to grow, according to the Clean Energy Patent Growth Index[66]. Worldwide the number of fuel cell patents grew more than 57 percent in 2010. Since 2002, the fuel cell industry has registered more patents than any other clean energy field by almost 200 percent. The solar industry came in second with only 363 patents (Figure 19).

The U.S. continues to be a leader in fuel cell intellectual property, holding 47 percent of patents registered between 2002 and 2010. Other leaders include Japan, 31 percent, Germany, seven percent, and Korea, five percent (Figure 20). Fuel cell patents originated from 30 states. Michigan was the leader with 136 patents (30 percent), followed by California with 59 patents, New York with 24 patents and Connecticut with 22 patents.

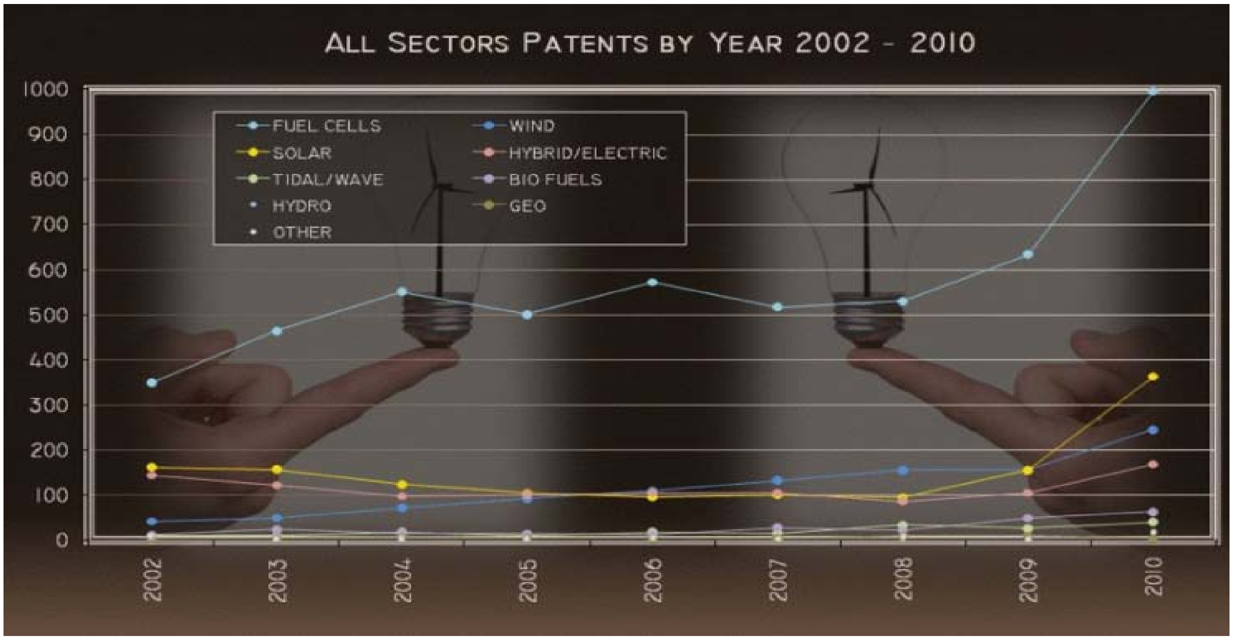

Figure 19: All Sector Patents by Year. Source: Cleantech Group of Heslin Rothenberg Farley and Mesiti P.C.
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Fuel cell patent leaders include General Motors, followed by Samsung and Honda in second and third place. Other top patent holders include Toyota, Panasonic, Nissan, Hyundai, IdaTech, United Technologies, Samsung, Delphi, Plug Power, Matsushita, Canon, Toshiba and Bloom Energy. Eighteen other companies held five or more fuel cell patents including Sanyo, Delphi, General Electric, Honeywell, Daimler, and 3M.

Percent Distribution of Fuell Cell Patents in U.S. and Worldwide

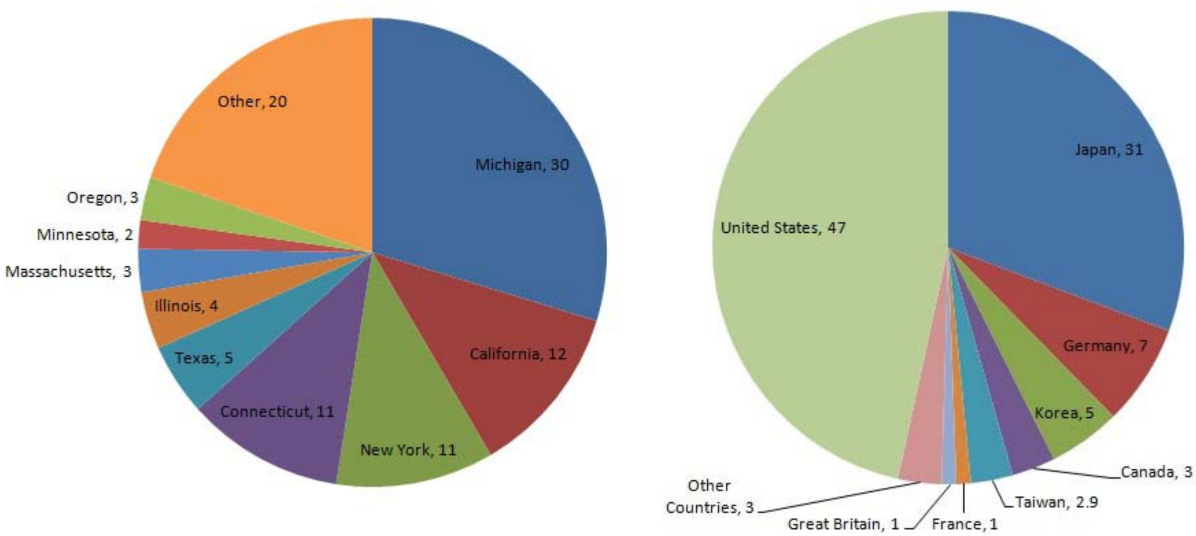

Figure 20: Percent Distribution of Fuel Cell Patents in the U.S. and Worldwide. Data from Cleantech Group of Heslin Rothenberg Farley and Mesiti P.C.

Spotlight on Japan

Fuel cells have been on Japan's research agenda since at least the early 1970's. In 2002, Japan completed a 10 year, ¥18 billion fuel cell research program and launched one of the world's most extensive residential fuel cell programs. The Japanese auto industry also launched an ambitious fuel cell vehicle research program, shaped substantially by California's ZEV motor vehicle regulations.

Consumer Savings

Osaka Gas is installing integrated solar-grid-fuel cell systems in new homes in Japan. The systems nearly eliminate household CO_2 emissions and also generate cash for the home owner, who can sell solar PV power back to the grid in a program called Double Power Generation. Osaka Gas can even set up the home system to give priority to the fuel cell system for home demand, freeing up the maximum amount of solar power to be sold back to the grid. Osaka Gas estimates a home owner can reduce energy bills by 80 to 90 percent.

In 2007, Japan's Prime Minister announced the "Cool Earth 50"[67] initiative that established a goal of cutting greenhouse gas emissions by half by 2050. As part of this initiative, the Cool Earth-Innovative Energy Technology Program[68] was launched in 2008. The program focused upon developing 21 technologies, including fuel cell vehicles, stationary fuel cells, and hydrogen production and storage technologies.[69]

Residential

Following the completion of the government's 10-year research program in 2002, a residential fuel cell demonstration project commenced. The first phase deployed 110 fuel cell units in a three-year demonstration involving five fuel cell companies and six gas companies. A second phase began in 2005, resulting in the installation of 3,307 units through 2008, with steadily improving operating results that convinced several manufacturers to move to low volume commercial production.

A total of ¥8.4 billion was allocated from FY2005-FY2008 for this residential fuel cell demonstration.[70] The program provided a declining level of support for installation of units, from ¥6 million per unit in 2005 to ¥2.2 million per unit in 2008. The manufacturers were ENEO Celltech, EBARA Ballard (now EBARA), Toshiba Fuel Cell Power System Corp., Panasonic Corp., and Toyota Motor Corp. Gas companies were Tokyo Gas, Osaka Gas, Toho Gas, Saibu Gas, Atmos Energy and Hokkaido Gas.[71]

Commercial sales began in 2009, supported by a government subsidy of about 40 percent of the installed cost of the units. The national program budget was ¥8.1 billion in 2009, and ¥6.8 billion in 2010. The budget for 2011 is ¥8.7 billion.[72]

Industry took the extraordinary step of establishing a common brand name for the Japanese residential CHP units – ENE-FARM. The joint marketing campaign has been a great success, achieving more than 85 percent name recognition after a media blitz in 2009. ENE-FARM is sold to customers on the basis that it will help them reduce their CO_2 emissions while also lowering their utility bill. Sales of ENE-FARM continue to exceed targets set by the individual companies.

Smart Meters

The ENE-FARM units include smart meters that can automatically select the optimal service level and hours of operation, thus ensuring optimal efficiency and energy savings. Each Smart Meter also has a user interface to monitor energy consumption and get tips on how to further conserve energy. Cell phone and computer applications allow customers to access Smart Meters remotely, enabling customers to turn appliances on or off and to control gas entering the system.

More than 10,000 residential units were sold in Japan between 2009 and 2010, a great majority of which were PEM fuel cells operating on propane or "town gas," a hydrogen-rich methane common to homes in parts of Japan. Japanese officials project up to 8,000 sales in 2011. The units carry a 40,000 hour warranty –

Table 10: ENE-FARM PEM Demonstration Units Installed as of 2008[73]

PEFC Maker	LPG	City Gas (Natural Gas)	Kerosene	Total
ENEOS Celltech Co. Ltd.	1,062	191	0	1,253
Ebara Corporation	0	396	314	710
Toshiba Fuel Cell Power System Corporation	554	194	0	748
Panasonic Corporation	0	520	0	520
Toyota Motor Corporation	0	76	0	76
Total	1,616	1,377	314	3,307

a level of durability once thought to be impossible for PEM systems. Systems are designed to work interactively with grid power and often include solar photovoltaic (PV) arrays. Table 10 provides the ENE-FARM installations since 2008.

Prices are subsidized by the Japanese government, which provides up to half the cost of the unit and installation costs. The subsidy is justified by the rapid increase in residential energy use (up 25 percent between 1990 and 2010) and CO_2 emissions (up nearly 30 percent). Tokyo Gas estimates that its units reduce home energy consumption by 33 percent and CO_2 emissions by 45 percent compared to conventional systems. The home owner saves about ¥70,000 per year.

Japanese fuel cell companies see continued growth in demand for residential fuel cell systems and hope to take advantage of a shift in the Japanese residential housing market toward single family homes. For example, in 2009, Panasonic established a new manufacturing center for mass production of units.[74] By 2015 Panasonic hopes to have sold between 60,000 – 100,000 units. Several residential construction companies are participating in the marketing and installation program.

Unit costs have declined from about ¥8 million in 2002 to ¥3.2 million in 2010. The cost target for 2015 is ¥500,000 to ¥700,000 yen, with a long term cost goal of about ¥400,000. Cost reduction pathways include high volume production and material cost reduction and redesign. Significant progress is being made. The latest generation from Panasonic is 50 percent smaller, 20 percent lighter, and costs 21 percent less than the previous system.[75] The smaller size is important, because heating and hot water units in Japan typically are installed outside, often in tight spaces between houses. Additionally, the new design rationalizes the balance of plant, making maintenance on the unit much simpler -- the system now has one access point for maintenance, rather than four.[76]

Japan also has funded SOFC research. Between FY2007 and FY2010, a ¥720 million SOFC demonstration project was undertaken and SOFC units were installed at a variety of locations with differing load environments, including residences. With the success of these demonstrations, SOFC ENE-FARM residential units have been developed and are beginning to be sold commercially by Osaka Gas which expects the units to enter into the apartment market.

Vehicles: Two Million FCEVs by 2025

The auto and oil industries unveiled a plan to begin commercial sales of fuel cell vehicles in Japan in 2015. If the announced timetable materializes, Japan will lead the world in FCV deployment by 2025 (See Figure 21).

Similarly, a coalition of 13 auto and energy companies issued a joint statement committing to up to 1,000 fueling stations by 2025, with 50 to 100 fueling stations planned in four major metropolitan areas by 2015, linked by stations along the major connecting highways. The stations would serve an initial production of one thousand to “several thousand” FCEVs in 2015. As is the case in other markets, the key unresolved issue is financing. The first stations will not be profitable, at least not for many years, and the extent of Japanese government financial support is not clear. The auto companies committed are Toyota, Nissan and Honda. Petroleum companies involved include JX Nikko Nisseki Energy, Idemitsu

Kosan, Showa Shell, and Cosmo. City gas companies include Tokyo Gas, Osaka Gas, Toho Gas, and Seibu Gas. Industrial gas companies Iwatani Sangyo and Taiyo Nissan are also in the partnership.

Toyota affirmed its commitment to commercial production of FCEV's in 2015 in Japan, Europe and the United States, via a speech by Executive Vice President Takeshi Uchiyamada at the Detroit Auto Show. "I have high expectations for fuel-cell vehicles as a candidate for next-generation cars," he said. "Over the past several years, we've seen many of the outstanding technical issues solved." He further said that Toyota is confident it can achieve a competitive price for its fuel cell vehicle, of about $50,000 and perhaps less, competitive with today's large luxury sport utility vehicles.

Toyota also joined the National Organization for Hydrogen and Fuel Cell Technology (NOW) in Germany. NOW is managing a 10-year $1.7 billion public-private partnership to commercialize fuel cell electric vehicles and deploy infrastructure beginning in 2015, when German auto makers also plan to begin commercial sales.

The Japan Hydrogen and Fuel Cell (JHFC) Demonstration Project finished its second phase in 2010 and began preparing to support commercialization. Over eight years, JHFC tested 135 passenger cars over more than 1 million km of road use, and tested 13 buses that traveled more than 400,000 km. JHFC reported bench test efficiencies of 60 percent and on-road fuel economy of up to 70 miles per gallon in the newest passenger cars. Figure 21 shows the progress JHFC has made on FCEV performance over time[77], achieving the 2015 practical use level for driving range, efficiency, low temperature performance, and refueling time targets, while durability and vehicle cost remain critical areas for achievement.

Japan's Hydrogen Town of Fukuoka took shape in 2010. Workers laid a pipeline from the Kita-Kyushu Hydrogen Station to nearby residential, commercial sites, and public facilities. Among the technologies and strategies being demonstrated are odorizing and deodorizing, gas measurement, and operability of pure hydrogen fuel cells. Demonstrations are scheduled to start January 15, 2011. In addition, a new fuel cell bus route began operating in December 2010 between Tokyo's two airports and its busiest train station. Finally in 2010, Japan announced that it will review existing hydrogen regulations including tank pressure limits and building and fire safety codes.

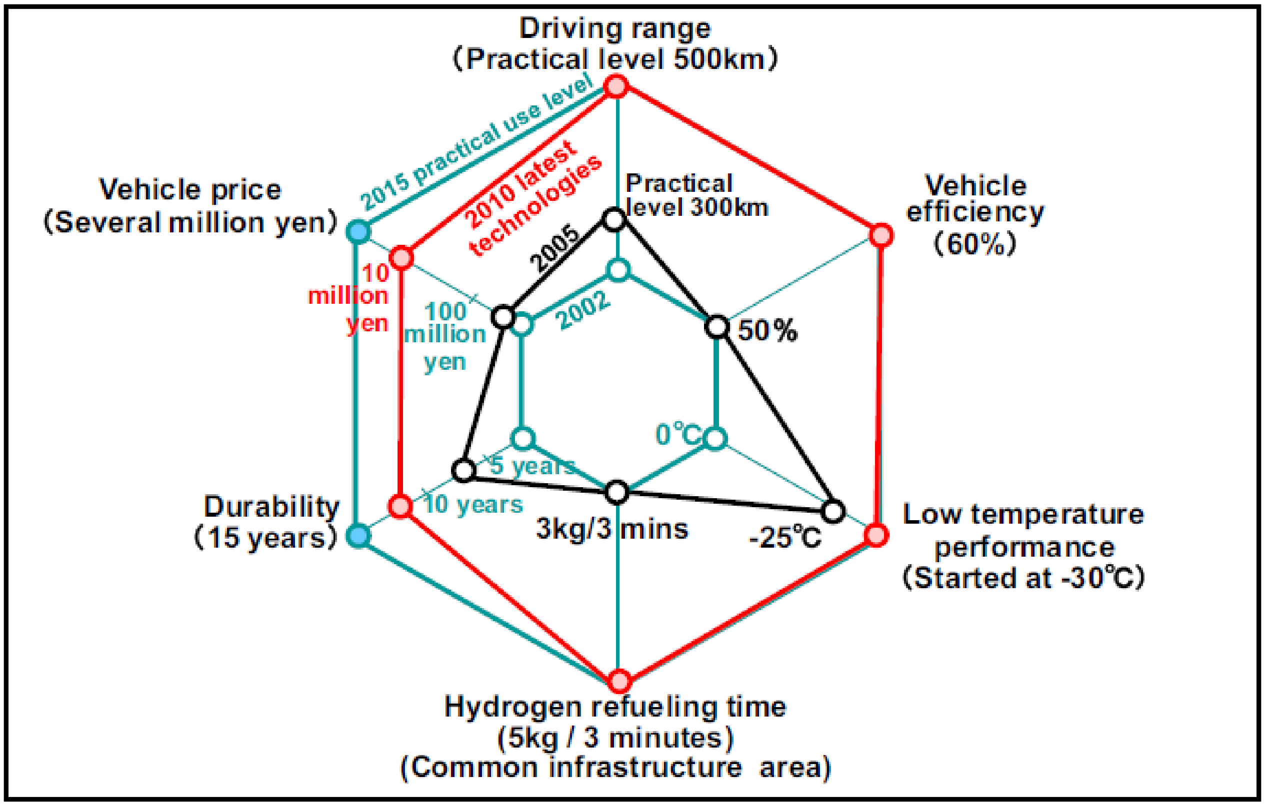

Figure 21: JHFC Status Report on Fuel Cell Electric Vehicle Performance, 2010

Appendix 1: Select Company Profiles

There are hundreds of companies involved in various aspects of the fuel cell industry, including original equipment manufacturers (OEMs), component suppliers, and integrators. This section provides an overview of select fuel cell OEMs and other significant players in the industry, and updates their fuel cell activities in 2010.

Public Companies

Ballard Power Systems Inc.

Ballard Power Systems operates in three segments: Backup and Supplemental Power, Motive Power, and Distributed Generation. The company's corporate headquarters and fuel cell manufacturing facility are located in Burnaby, BC, Canada and the company also operates a Lowell, Massachussetts manufacturing facility that produces carbon fiber products, including gas diffusion layers for fuel cells.

Ballard Power Systems	
Company Type	Public (Symbol: BLDP)
Fuel Cell Type	PEM
Primary Market Interest	Backup power, distributed generation, material handling, and buses
Employees	Approximately 400
Manufacturing Capability	20,000 stacks per year
Headquarters	Burnaby, Canada

Ballard focuses on PEM fuel cell technology, providing fuel cell stacks to leading fuel cell companies including IdaTech, LLC, Plug Power Inc., Baxi Innotech GmbH, Heliocentris Fuel Cells AG and FutureE Fuel Cell Solutions GmbH. These manufacturers of buses, lift trucks, backup power and cogeneration systems integrate Ballard's fuel cell stacks into end-user products. Ballard also provides power modules to system integrators seeking a 'plug-and-play' approach including, for example, ISE Corporation which integrates Ballard power modules with hybrid electric drives on transit buses.

In 2010, Ballard continued to play a major role in commercializing fuel cells for transportation buses. In January the company received an order for five fuel cell power systems by Advanced Public Transportation Systems BV, a bus manufacturer in the Netherlands. In March, Ballard entered into an agreement to provide the fuel cell power supply for new buses at the SunLine Transit Agency. Transportation for London has ordered three fuel cell power systems for buses to be used during the 2012 Olympic Games. Additionally, Ballard will participate in four projects under the Federal Transit Administration's National Fuel Cell Bus program.

Ballard achieved significant technological milestones in 2010. In July the company successfully completed factory testing of a utility-scale distributed generation fuel cell power system, based on their PEM technology. Ballard then installed the unit at FirstEnergy in Ohio for a multi-year demonstration. The installation is considered to be the largest PEM power generator in the world, at 1 MW. Additionally, in December Ballard announced they had produced their one millionth membrane electrode assembly.

Total Shipments by Unit				
Ballard Products	**2010**	**2009**	**2008**	**2007**
Material Handling	1100	182	508	204
Back-up power	1716	1225	720	200
Automotive & Others	198	69	627	631
Total Shipments	**3014**	**1476**	**1855**	**1035**

As with many in the fuel cell industry, the global economic down-turn in 2009 adversely impacted business. To deal with the reality of a harsh economic climate, Ballard focused on its commitment to profitability in the near term by cost cutting. Ballard ended 2009 with significant momentum going into the new year. The company entered into a supply agreement with Daimler to provide fuel cell stacks for cars and buses, with the potential of $24 million dollars in revenue. Ballard continues its work with IdaTech to develop backup power supply units for the telecommunications industry in India. Ballard also acquired controlling equity in Dantherm Power, located in Denmark.

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 leading energy and industrial companies. The Company is based in Australia, with offices located in the United Kingdom and a 40,000 sq. ft (4,200 square meter) fuel cell stack assembly factory in Germany.

Ceramic Fuel Cells Limited	
Company Type	Public (ASX and London AIM)
Fuel Cell Type	SOFC
Primary Market Interest	Stationary power
Employees	131
Manufacturing Capability	Germany: 20 MW per year Melbourne: 0.4 MW per year
Headquarters	Melbourne, Australia

CFCL's business goal is to supply SOFC products that integrate with distributed generation networks for global markets. The company is working towards this goal with two product strategies:

1. Development of integrated m-CHP appliances.
   Working with European utilities and appliance manufacturers, CFCL is delivering SOFC components enabling European style heating systems to operate as micro-CHP unit.

2. Production and sales of BlueGen® modular generation units.
   BlueGen® is a modular SOFC generator that is suitable for a number of markets and applications - either configured as a parallel grid connected generator or, optional connection to a hot water tank as part of a co-generation system.

CFCL began selling their BlueGen units in April 2010, and by the end of 2010 more than 50 units had been sold. In fiscal year 2009 - 2010 (July 1 through June 30), CFCL opened a new plant in Heinsberg, Germany, for volume assembly of fuel cell stacks.

In December 2010 CFCL and German utility EWE have agreed to an order for up to 200 European style integrated m-CHP units to be deployed over a two year period beginning in 2011. Additionally, CFCL installed a BlueGen unit as part of an electric vehicle recharging station at the Adelaide central markets in South Australia. The trial will evaluate and promote fuel cell technology as part of meeting the increasing demands for low-emission electromobility.

Ceres Power

Ceres Power was established in May of 2001 to commercialize fuel cell research from the Imperial College, London. The company's intellectual property is based on metal supported SOFC systems for small scale, combined heat and power systems.

Ceres Power	
Company Type	Public (Symbol: CWR)
Fuel Cell Type	SOFC
Primary Market Interest	Residential CHP, Portable Power, Auxiliary Power Units
Employees	130
Manufacturing Capability	Not reported
Headquarters	Horsham, West Sussex, United Kingdom

Since its founding, Ceres Power has operated with a "design for manufacture" development process. This process allows for simultaneous design, product engineering, and manufacturing activities, reducing time to commercialization, and allows the company to deal with barriers to manufacturing early on in the design process.

Ceres Power focuses on microgeneration fuel cell systems to improve the efficiency of electricity generation. SOFCs are already highly efficient, and using the waste heat from the system can bring system efficiencies up to 80 – 90 percent. In the United Kingdom, by the time electricity is generated and transmitted to a home, up to 65 percent of the energy is lost. The housing stock in the country contributes 27 percent of all UK carbon emissions. The company sees its products as having a strong place in helping reduce carbon emissions through improved energy efficiency.

A strong market for Ceres' fuel cell products is the residential market. The company's SOFC systems can run off of natural gas mains, or packaged fuels. Alpha tests of a 1-kW residential CHP unit were successfully completed in 2009 with partner company British Gas, and beta tests continued in 2010. In 2010, Ceres Power installed two units in unoccupied houses, and gained valuable knowledge about the systems from this demonstration. Following the completion of the CE certification process, Ceres commenced its Beta field trials in early 2011, installing the wall mounted CHP units in occupied homes.

FuelCell Energy

FuelCell Energy (FCE) manufactures and installs high temperature MCFCs, some of which operate at efficiencies almost twice that of conventional fossil fuel power plants. FCE products reform natural gas internally, or use industrial and municipal wastewater treatment gas, biogas, propane, or coal gas to produce both electricity and substantial amounts of heat for use in combined heat and power applications. FCE products have been certified

FuelCell Energy	
Company Type	Public (Symbol:FCEL)
Fuel Cell Type	MCFC
Primary Market Interest	Large stationary power
Employees	450
Manufacturing Capability	Up to 90 MW depending on product mix
Headquarters	Danbury, Connecticut

as “ultra-clean” under CARB standards.

FCE focuses on the stationary market with its line of high temperature carbonate fuel cells, marketed as “Direct Fuel Cells” (DFC). FCE offers four models: a 300 kW, 1.4 MW and a 2.8 MW power plant, with 47 percent electrical efficiency, and a hybrid multi-megawatt system for natural gas letdown facilities, with approximately 60 percent electrical efficiency. 80 FCE DFC power plants are operating at 50 locations worldwide, and have generated over 650 million kWh of energy.

FCE is focusing on the utilities market in Korea, with their partnership with POSCO Power. In fact, by the end of 2009 nearly half of FCE’s installed base was located in Korea.

The company also focuses upon using biogas from wastewater treatment facilities. The City of Tulare, California, purchased a fourth FCE DFC300 series fuel cell to bring the city’s installation up to one MW. The fuel cell power plant now generates enough electricity for more than 40 percent of the wastewater treatment plant’s operations. Additionally, in July 2009 a FCE fuel cell system was unveiled at Gills Onions in Oxnard, California. The onion grower and processor is using the nearly 300,000 pounds of onion waste generated each day to produce digester gas to power the two 300-kW fuel cells, saving up to 30,000 tons of CO_2 each year.

In 2010, FCE saw large orders taking place in California associated with the expansion of the SGIP. The Eastern Municipal Water District placed a follow on order, after an initial order in 2007. In November, the company announced the sale of 4.5 MW of DFC power plants to help provide primary power around San Diego. These units will be installed at three locations around the city, and will run on piped in biogas generated from a local wastewater treatment plant.

In the face of the global economic downturn, FCE has continued to focus on cost reductions. Since the commercialization of their MW class of fuel cells, the company has realized more than a 60 percent unit cost reduction. The margins for product sales increased over $14 million over 2009. Additionally, an increase in orders and order backlogs has allowed the company to increase production and manufacturing capacity.

FCE also conducts contract research and development that has targeted biofuels, carbon sequestration, logistic fuels, hybrid power systems, hydrogen co-production, and SOFCs. The company has contracts with several U.S. government organizations, including the U.S. Navy for marine applications of DFC technology, the DoD, and the DOE.

Hydrogenics

Hydrogenics designs, manufactures, and installs industrial and commercial fuel cell and hydrogen generation systems. Over the last 60 years, the company has installed more than 1,700 hydrogen products in more than 100 countries. Since 2007 the company has reorganized, and focused its mission on power generation. At the end of 2007 the company announced plans to end its test systems business, to focus instead on on-site generation and power systems. In 2009 the company employed over 130 full time people, across their two business units. Hydrogenics Corporation is a publicly listed company on the Nasdaq Global Market (stock symbol HYGS) and the TSX (stock symbol HYG). The corporate headquarters are in Mississauga, Canada. Hydrogenics has other corporate and sales offices, and hydrogen installations, operating in countries around the world.

Hydrogenics	
Company Type	Public (Symbol: HYGS)
Fuel Cell Type	PEM
Primary Market Interest	Renewable energy storage, transportation, back-up power, hydrogen generation
Employees	130
Manufacturing Capability	160 MW per year fuel cell units 25 MW per year hydrogen generation units 25 MW per year Renewable Energy systems
Headquarters	Mississauga, Canada

In January 2010 Hydrogenics announced a contract to develop a next generation power supply for surface mobility on the moon from the Canadian Space Agency. In February the company announced an order for six power modules from the United Nations Industrial Development Organization for use in a boat project. The company will also provide hydrogen storage tanks and components over the next two years. Additionally, 2010 was a strong year for Hydrogenics' electrolyzer market, with orders on three continents. Four orders for electrolyzers were placed from Argentina and Viet Nam. The Linde Group ordered two electrolyzers for a hydrogen fueling station in Germany, and the company received an order for an electrolyzer for a fueling station in Belgum.

Hydrogenics Sales (Millions)					
Product or Service	**2010**	**2009**	**2008**	**2007**	**2006**
Hydrogen Generation		$12.3	$31.2	$19.6	$12
Power Systems		$6.5	$5.6	$6.1	$7
Fuel Cell Test Equipment		$0.0	$2.5	$12.3	$11.1
TOTAL SALES		**$18.8**	**$39.3**	**$38**	**$30.1**

IdaTech

IdaTech designs and manufactures backup power fuel cell products for the telecommunications market and other critical applications. Founded in 1996, IdaTech was acquired by IDACORP in 1999 and sold to South African firm, the Investec Group, in 2006 before going public on the London Stock Exchange in 2007.

IdaTech	
Company Type	Public (Symbol:IDA London Stock)
Fuel Cell Type	PEM
Primary Market Interest	Backup power for telecommunications
Employees	90
Manufacturing Capability	Up to 5,000 units
Headquarters	Bend, Oregon

IdaTech offers backup power fuel cell systems which can be powered by direct hydrogen gas or a methanol-water mix unique to the industry. The ElectraGen™ ME system is available in 2.5 and 5 kW outputs. The ME is unique in that the unit has a fuel reformer which can power the system on site, negating the need for on-site storage of hydrogen gas, which can be useful for applications requiring long backup durations. The ElectraGen ™ H2 system is available in 2.5 and 5 kW outputs, and uses compressed hydrogen as a fuel. The H2 systems are best for applications with short backup duration needs.

The ElectraGen™ ME system, the next generation of IdaTech 's family of backup power fuel cell products, was launched in 2010 and is targeted toward telecommunication networks. During the year, IdaTech received orders for over 70 ElectraGen™ ME systems which began shipping to customers in December. Overall, the total number of commercial fuel cell systems sold in 2010 was 350 units.

Another key milestone for the year is that IdaTech received orders for over 150 ElectraGen™ systems for use as telecommunications backup power in Indonesia. Also in 2010, IdaTech acquired Plug Power's GenSys LPG off-grid and GenCore backup power stationary fuel cell product lines.

ITM Power

ITM Power is an AIM-listed company based in Sheffield, England, with two facilities there. Their aim is clean energy using hydrogen and to target new and existing markets in a global perspective.

ITM Power	
Company Type	Public (Symbol: ITM London Stock AIM)
Fuel Cell Type	PEM, electrolyzers
Primary Market Interest	Backup power for telecommunications
Employees	55
Manufacturing Capability	Not Reported
Headquarters	Sheffield, England

ITM has developed its own polymeric ion-conducting materials for hydrogen generation by water electrolysis. The company is developing engineering solutions for zero-carbon hydrogen generation. ITM has 5 patents granted with 23 more in the application process

ITM Power currently has five small and medium size electrolyzer products (HLab, HBox, HFlame, HPac and HFuel). The company is currently working on the development of a large PEM electrolyzer for return-to-depot vehicle refueling applications and electrolyzer solutions for home refueling of hydrogen cars. ITM also has a suite of cross-linked ion exchange membrane materials of ionic materials that is equally suited to use in both electrolyzer and fuel cells.

ITM has developed systems design and integration expertise covering the compression, storage and dispensing of high pressure gaseous hydrogen up to 350 bar. At its site in Sheffield, ITM has constructed a small hydrogen refueling station based on its electrolyzer technology. This is designed to refuel 1 – 2 vans or cars per day with 350 bar hydrogen. It is a demonstrator intended to indicate the pathway for deploying larger return-to-depot refuelers by companies with urban vehicle fleets.

The Hydrogen On Site Trials (HOST) of ITM Power's Transportable Hydrogen Refueling Station (HFuel), a self-contained module suitable for refueling hydrogen-powered road vehicles and forklift trucks, was launched in September 2010 to begin in 2011. The HFuel will fuel two HICE Ford Transit vehicles. Many different agencies and partners signed up for the HOST program.

Panasonic

Panasonic was founded in 1918 as the Matsushita Electric Industrial Co., Ltd. and is headquartered in Kadoma, Osaka, Japan. The company has grown to become one of the largest electronic product manufacturers in the world, comprised of over 680 companies. Its main focus is electronics manufacturing and it produces products under several brand names including Panasonic and Technics.

Panasonic	
Company Type	Public
Fuel Cell Type	DMFC, PEM
Primary Market Interest	Residential, consumer electronics
Employees	Not Reported
Manufacturing Capability	Not Reported
Headquarters	Osaka, Japan

Panasonic was ranked the 89th-largest company in the world in 2009 by the Forbes Global 2000 and is among the Worldwide Top 20 Semiconductor Sales Leaders. In the late 1990s Panasonic began to develop fuel cells. In 2006, Matsushita Battery Industrial, a branch in the Panasonic Corporation showed a DMFC laptop at the International Consumers Electronic Show. Using this technology, Panasonic aims to develop a 100 W-class portable generator and start field testing in fiscal 2012 ending in March 2012.

Panasonic is also involved with the ENE-FARM residential fuel cell project, working with Tokyo Gas on developing the unit and building a new fuel cell manufacturing plant in 2008 in Kusatsu. Sales of ENE-FARM began in 2009 and the new model developed by Panasonic and Tokyo Gas will began sales in 2011.

Plug Power

Plug Power is a provider of alternative energy technology and is involved in the design, development, commercialization and manufacture of PEM fuel cell systems in the material handling market. More than 1,400 Plug Power units have been deployed worldwide with the majority in the North America market. The company was incorporated in 1997 as a joint venture between Edison Development Corporation and Mechanical Technology Inc. and, in 2007, merged with Cellex Power Products and General Hydrogen Corporation.

Plug Power	
Company Type	Public
Fuel Cell Type	PEM
Primary Market Interest	Materials handling, Motive Power
Employees	145
Manufacturing Capability	10,000 units/year
Headquarters	Latham, New York

Plug Power currently is focusing on its GenDrive®product line, a hydrogen-fueled PEM fuel cell system designed for industrial vehicles, especially material handling and automated guided vehicles at high volume manufacturing and distribution facilities. Customers include Walmart, BMW, Wegmans, Bridgestone Firestone, Nestle Waters, Central Grocers, and Sysco Foods.

Plug Power Shipments and Orders				
Product	**2010**	**2009**	**2008**	**2007**
GenDrive (Forklifts)	650			
Shipments		271	131	77
Orders	543	584	358	94
GenSys (Backup Power)				
Shipments		1	5	
Orders		200	5	
GenCore				
Shipments	10	31	146	180
Orders		2	109	160
Total				
Shipments	660	303	278	257
Orders	543	786	467	200

In 2010, demand for the GenDrive® system increased substantially, with orders increasing by over 100 percent. Plug Power's systems can operate at freezing temperatures, an advantage over battery competitors. Sysco deployed 98 units in forklifts in a freezer warehouse in Houston, Texas. Walmart ordered units for a freezer facility in Canada. United Natural Foods Inc. ordered 65 GenDrive® units, and BMW deployed 86. Plug Power named materials handling vehicle manufacturer Raymond Corp. an independent distributor of the GenDrive® system. In addition, Raymond will provide warranty and maintenance services, as well as parts. Additionally, Plug Power sold units to high profile American companies:

- Whole Foods Markets purchased 61 fuel cells for a distribution center in Maryland.
- Coca-Cola purchased 40 fuel cells for a facility in North Carolina and another 37 units for Coca-Cola San Leandro, California.
- Nestlé-Waters purchased 32 fuel cell systems.
- GENCO purchased 307 GenDrive units with funding support from the DOE's ARRA program.

SFC Energy AG

SFC Energy AG	
Company Type	Public (Symbol: F3C.DE)
Fuel Cell Type	DMFC
Primary Market Interest	Portable, Mobil, Small Stationary, APUs
Employees	100
Manufacturing Capability	More than 20,000 units per year
Headquarters	Brunnthal, Munich, Germany

SFC Energy (formerly SFC Smart Fuel Cell) manufactures mobile and remote power solutions based on DMFC fuel cell technology. Founded in 2000, the company is based in Germany and listed in the Prime Standard on the German stock exchange.

SFC targets the consumer, industrial, defense, and mobile APU markets. SFC has deployed more than 20,000 commercial units around the world in a variety of applications, including recreational vehicles, yachts, vacation homes, traffic monitoring systems, observation stations, measurement and early warning stations, soldier power and special and emergency vehicles. Typically, SFC products operate in hybrid configurations with one or more other power sources, such as batteries and solar panels.

SFC's main product line is the "EFOY" ("energy for you") brand fuel cell for the consumer markets and offers five models, the EFOY 600, 900, 1200, 1600, and 2200 with charging capacities ranging from 600 to 2200 watt hours/day. The EFOY fuel cell is offered as standard or optional equipment by 50 international motor home manufacturers. In 2010 two yacht manufacturers, Arcona and Ridas Yachts, started offering EFOY as a standard option on all models. Rapido SAS, one of Europe's biggest motorhome manufacturers, is now offering EFOY as a standard option on its Series 10 models, and Notin, a French manufacturer, is pre-wiring all models for EFOY, and will install one for no additional cost.

SFC also offers the EFOY Pro Series, which is designed to meet the needs of professional and government users. EFOY Pro Series fuel cells are sold exclusively to professionals for use in remote mobile and stationary applications where they deliver power for traffic control, security and surveillance, among other applications. In 2010, the company launched a new model, the EFOY 2200 Pro XT, which provides a week of constant power without requiring any user intervention. Also in 2010, Altec announced is has integrated EFOY power supplies into their Sentinelle visual and thermal camera systems, where it will provide 20 days of unattended constant power. Since 2009 the German Federal Office for Goods Transport is using EFOY Pro in their official vehicles, negating the need to come back and plug in to power on-board electronics.

SFC also focuses on the defense market. However, both the European and U.S. defense markets delayed programs as a consequence of the worldwide economic crisis. Despite that difficult situation, SFC succeeded in making the leap from development partner to supplier of standard systems for defense applications in 2010 - which lead to tripled defense sales growth in 2010 compared to 2009. With a commercial order for a system solution combining a portable JENNY fuel cell, the SFC Power Manager, a hybrid battery and a solar panel, the German Bundeswehr introduced this efficient energy network as an independent source of power for soldiers in the field. The order gave a further strength to SFC's market position as a leading supplier of stand-alone power supply solutions for defense applications. In 2010 SFC launched the next generation JENNY ND Terra, a portable fuel cell system that can also be used as standalone power source, also underground, if required for specific operations. SFC products are now available on the U.S. General Services Administration Schedule, allowing the U.S. military and government agencies to purchase SFC products, through MaxaVision Technologies.

For mobile on board power generation in mobile offices and special and emergency vehicles, SFC offers off-grid EFOY Pro power solutions, ensuring that all equipment on board can be used anywhere, anytime without requiring an idling engine for battery charging.

With the establishment of the dedicated SFC sales and service subsidiary in the state of Maryland on the East Coast of the United States SFC is now in an excellent position to quickly and efficiently serve the North and South American markets with intelligent green power solutions. While the defense and off-grid industrial markets continue to be the focus here, the launch of the EFOY fuel cells in the Canadian motorhome market in early 2010 was an initial step toward the development of the region's consumer markets.

Toshiba

Toshiba was founded in 1939 by the merging of two companies, Shibaura Seisakusho (formerly Tanaka Seisakusho) and Tokyo Denki (formerly Hakunetsushua). The merger created a new company called Tokyo Shibaura Denki (Tokyo Shibaura Electric) nicknamed Toshiba, but it was not until 1978 that the company was officially renamed Toshiba Corporation.

Toshiba	
Company Type	Public (Stock Code: 6502 Tokyo Stock Exchange)
Fuel Cell Type	DMFC, PEM
Primary Market Interest	Consumer electronics, residential
Employees	Not Reported
Manufacturing Capability	Not Reported
Headquarters	Tokyo, Japan

In 1984, Toshiba started operation of an experimental 50-kW fuel cell power plant, which was the first and biggest 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. The ENE-FARM units began sales in 2009.

UTC Power

UTC Power	
Company Type	Public (Symbol: UTX)
Fuel Cell Type	PAFC, PEM
Primary Market Interest	Large stationary, transportation, aerospace
Employees	528
Manufacturing Capability	153 MW PAFC/PEM
Headquarters	South Windsor, Connecticut

UTC Power, a United Technologies Corp. (NYSE:UTX) company, is a leading developer and producer of fuel cells that generate energy for buildings, transportation, defense and space applications. The company has been involved with fuel cell technology since the 1950s, when it first launched fuel cells to provide electric power, heat, and drinking water on U.S. manned space flights.

UTC Power manufactured the first commercially available stationary fuel cell to provide on-site building power in 1991. Since then, UTC Power has designed, manufactured and installed more than 300 phosphoric acid stationary fuel cell power plants in 19 countries on six continents. The fuel cells are located at diverse locations, including supermarkets, hotels, educational institutions, hospitals, manufacturing facilities, mixed-use office/residential/retail buildings, and bottling facilities.

UTC Power's stationary fuel cell product, the PureCell® System, is a CHP system. Compared to typical central generation and other fuel cell offerings, UTC Power's PureCell System offers customers lower energy costs and reduced emissions. The PureCell System can help individual customers achieve secure power through on-site power solutions that operate independent of or in parallel to the electric grid. UTC Power's fleet of PureCell Systems is providing power to some of the world's most progressive and recognizable companies, and many are repeat customers.

The company's previous generation stationary fleet, the PureCell System Model 200, has accumulated more than 9.4 million operating hours, unmatched in the industry. In 2009, UTC Power launched its next-generation stationary fuel cell, the PureCell System Model 400. The Model 400 produces 400 kilowatts of assured power and up to 1.7 million British thermal units (BTU)/hr of heat for CHP applications. Its cell stack life has twice the durability of the previous generation and three to four times more durability than other competing commercial fuel cell technologies. It has a 10-year cell stack life, 20-year product life and an industry-leading 90 percent system efficiency.

In 2010, UTC Power installed Model 400 units at Diversey Inc.'s global headquarters in Sturtevant, Wis., an Albertsons' grocery store in San Diego, Calif., a Coca-Cola bottling facility in Elmsford, N.Y., a Whole Foods Market in San Jose, Calif., and an elementary school in New Haven, Conn. In late 2010, UTC Power secured more orders for the PureCell 400 across the country. Stop & Shop placed an order for their first fuel cell power system to be installed at a store in Torrington, Conn. Cox Communications ordered four Model 400s for its locations in San Diego and Santa Margarita, Calif.

The company's transportation PEM fuel cell product, the PureMotion® System Model 120, is powering transit buses in commercial service in California and Connecticut. In 2010, the UTC Power fuel cell buses used by Alameda-Contra Coast Transit (AC Transit) District surpassed previous durability limits, with one bus operating more than 8,000 hours without any stack or cell changes. In October of 2010, four next-generation fuel cell-powered hybrid-electric transit buses were delivered to Connecticut Transit in Hartford, Conn. The new buses are part of the Federal Transit Administration's national Fuel Cell Bus Program.

Private Companies

Adaptive Materials

Ultra Electronics acquired Adaptive Materials in 2010. The new entity, Ultra Electronics AMI is based in Ann Arbor, Michigan and designs, tests and manufactures solid oxide fuel cells for the military, leisure and emergency markets.

Adaptive Materials	
Company Type	Private
Fuel Cell Type	SOFC
Primary Market Interest	Military, emergency, and leisure
Employees	66
Manufacturing Capability	Not Reported
Headquarters	Ann Arbor, Michigan

Ultra Electronics, AMI offers three products: Power pods for unmanned vehicles, a 300w fuel cell and the Power Manager. Ultra Electronics, AMI's products run on propane. Ultra Electronics AMI has received numerous funding awards from the U.S. military to develop fuel cells for unmanned aerial and ground vehicles. Ultra Electronics AMI's fuel cells are also being used to provide power to recreational vehicles, boating and humanitarian missions, and industrial markets.

Ultra Electronics, AMI has several partners; CERCEC, DARPA, Marine Corps, NASA, SOCOM, U.S. Army, U.S. Navy and TARDEC.

Bloom Energy

Bloom Energy was founded in 2001 and is headquartered in Sunnyvale, California. The privately held company has investors such as Kliner Perkins. The company develops SOFC for distributed power generation and has roots in technology developed for the NASA Mars program.

Bloom Energy	
Company Type	Private
Fuel Cell Type	SOFC
Primary Market Interest	Distributed Power Generation
Employees	Unknown
Manufacturing Capability	Not reported
Headquarters	Sunnyvale, California

In 2006, Bloom Energy delivered its first five-kW test unit to the University of Tennessee, Chattanooga. The successful trial lasted two years, and in 2008 the first commercial unit, a 100-kW system, was delivered to Google in Palo Alto, California. Originally dubbed the "Bloom Box", these fuel cell power units are now marketed as Energy Servers. Bloom's customers now include many high profile companies such as Walmart, Staples, ebay, Cox Enterprises, FedEx, Bank of America, and Coca-Cola Enterprises. In 2010 Bloom continued the trend of installing units at high profile companies, with the installation of 12 Bloom Energy Servers at Adobe's headquarters in San Jose, California.

ClearEdge Power

ClearEdge Power	
Company Type	Private
Fuel Cell Type	PEM
Primary Market Interest	Residential and small commercial applications
Employees	185
Manufacturing Capability	Over 6,000 units per year
Headquarters	Hillsboro, Oregon

ClearEdge Power was formed in 2003 as Quantum Leap Technology to design and build combined heat and power fuel cell systems. The company changed its name to ClearEdge Power in 2005 and started installing products with customers in late 2009.

ClearEdge Power manufactures and markets the ClearEdge5 (CE5), a compact, five-kW combined heat and power PEM fuel cell energy system for use in residential and light commercial buildings like small hotels, restaurants, home owner association community centers and health clubs. The company is now expanding their solution set into the fault tolerant server center/data center market. The CE5 operates at up to 90 percent efficiency, generating 3,650 kWh per month and 20,000 BTUs per hour.

The CE5 is designed to operate 24 hours per day, seven days per week, either indoors or outdoors, and can use natural gas. The company claims that operating costs are as low as six cents per kWh based on $1.20 per therm for natural gas, assuming full electrical and heat load utilization. The purchase price of the CE5 is in the $56,000-$70,0000 range depending on the application and before state and federal incentives. This includes maintenance and warranty for the first five years. The CE5 is designed to run for more than 10 years, with servicing of the fuel cell stack and fuel processor required about every five to seven years.

In 2010, ClearEdge continued selling units to residential and light commercial customers. The company grew from 32 employees in February 2009 to 185 employees in 2010, with plans to continue this pace of growth. ClearEdge claims that the CE5 can reduce residential carbon dioxide (CO_2) emissions by more than 38 percent and can reduce utility bills by up to 50 percent.[1]

ClearEdge is targeting the California market; California utilities charge higher per kWh rates as energy consumption rises above a certain baseline, to discourage consumption at those levels. The company advertises that the CE5 reduces customer exposure to the top tier rates, saving an average of $8,000 annually in energy costs. The CE5 is eligible for California Self Generation Incentive Program (SGIP) instant rebate totaling $12,500 as well as a federal ITC in the $5,000-$15,000 range. The company aims to enter into new residential and commercial markets in 2011.

[1] See http://www.clearedgepower.com/categories/home-owner/pages/home

Horizon Fuel Cell Technologies

Horizon Fuel Cells	
Company Type	Private
Fuel Cell Type	PEM
Primary Market Interest	Consumer products, portable power, aerospace, small stationary, electric vehicles.
Employees	110
Manufacturing Capability	500,000 micro-fuel cells per year 1000 100W-5kW fuel cell stacks per year
Headquarters	Singapore

Horizon Fuel Cell Technologies was founded in 2003. The company produces a variety of fuel cells (0.5-5 W micro fuel cells, 10 W-5kW industrial grade stacks, and 10W-2kW aerospace grade systems), fuel cell system components and peripherals, as well as novel hydrogen storage and generation systems. Horizon's strategy was to start with small and simple products, such as fuel cell educational kits and toys, then progressively expand into larger, more complex, applications. The company is currently active in three business sectors (education/toys/hobby, portable power, and aerospace/defense) and has launched over 20 products which are now selling commercially. After securing success in these sectors and as experience continues to grow, the company plans to enter larger applications such as stationary and transport.

In 2005, Horizon began applying its fuel cell technology to consumer products and, in 2006, launched its "H-Racer" toy fuel cell car. TIME Magazine named the H-Racer one of the best inventions of 2006. As a result the company began commercial sales of various micro-fuel cell powered toys which have already shipped in the hundreds of thousands of units to over 60 countries. In 2007, Horizon unveiled the H-Cell, a power kit for 1:10 scale remote controlled hobby cars, and has since developed over 12 fuel cell and clean energy science kits.

In 2007, the company announced that a five kg UAV powered by a Horizon fuel cell flew for 78 miles, a world record for electric-powered aircraft of this category, according to the World Records Academy and the FAI (Federation Aeronautique Internationale). Its fuel cells also powered the world's first fuel cell electric jet-wing UAV (HY-Fish), in a development led by DLR in Germany. After continued success in demonstration tests, Horizon launched a new subsidiary in Singapore "Horizon Energy Systems" in 2009, and in 2010 the company announced that the AeroPak fuel cell system for mini-UAV's is ready for evaluation/testing. Among other UAV makers, Israeli Aerospace Industries has selected AeroPak as the next-generation power source for the Bird Eye 650 UAV.

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.

Intelligent Energy

Intelligent Energy	
Company Type	Private
Fuel Cell Type	PEM
Primary Market Interest	Automotive, aerospace, backup power, defense, distributed power generation, portable power, , distributed hydrogen generation
Employees	More than 150
Manufacturing Capability	N/a
Headquarters	UK

Intelligent Energy is a privately-owned clean power systems company. The company's headquarters and main operating site is located in Loughborough, UK with a further delivery site in Long Beach, California and offices in London, Japan, and India. Intelligent Energy was founded in 2001, when it acquired Advanced Power Sources (APS) Ltd., a Loughborough University spin-out company working on the early prototyping of PEM fuel cell products and on the pre-commercial development of its proprietary fuel cell technology. In December 2010, the company announced the commissioning of a new semi-automated assembly line for its advanced fuel cell stacks at its Loughborough site.

Intelligent Energy's current partners and customers include Scottish & Southern Energy plc with whom the company has formed a joint venture to commercialize fuel cell CHP systems, and The Suzuki Motor Corporation. Intelligent Energy's successes in recent years include the development of the world's first hydrogen fuel cell motorbike and supplying the fuel cell system to Boeing which powered the world's first manned fuel cell aircraft. The company has supplied Airbus with a multi-functional fuel cell APU aimed at on-board power and other loads in future commercial airliners and is also working in conjunction with Lotus Engineering, LTI Vehicles and TRW Conekt, on a program to deliver a fleet of the zero emission, Fuel Cell Black Cabs to the streets of London by 2012.

Microcell

Microcell	
Company Type	Private
Fuel Cell Type	PEM
Primary Market Interest	Stationary power, CHP
Employees	32
Manufacturing Capability	3 MW/year
Headquarters	Research Triangle, North Carolina

Microcell was formed in 2000, after receiving initial seed funding from Advanced Energy Corporation. Subsequent to developing the first laboratory prototypes, the company received $2 million in funding from the National Institute of Standards and Technology – Advanced Technology Program followed by an investment from Pepco Holdings, Inc. in 2001. Microcell is located in Research Triangle Park, North Carolina, and in 2007, the company acquired an 80,000 square foot manufacturing facility in Robersonville, North Carolina.

Microcell currently offers m-CHP products for backup power applications, incorporating a novel extrusion-based PEM fuel cell technology that operates on a Micro- tubular platform in its line of MGEN products. The three different versions are based on power output: the MGEN 500, the MGEN 1000 and the MGEN 3000.

In March of 2010, Microcell created a new company, "First Hydrogen, Inc." to pursue the development and commercialization of a novel renewable hydrogen generation technology based on a new class of nano-cells capable of producing hydrogen fuel suitable for low temperature PEM fuel cells from a wide range of commonly available, renewable, and non-fossil feedstock.

NedStack

NedStack Fuel Cell Technology produces PEM fuel cell stacks and power plants. NedStack is an independent, privately owned company, founded in 1998 to continue the fuel cell activities of AKZO Nobel, a multi-national chemicals company. Having started as a small R&D lab, NedStack holds more than 20 patents and patent applications. Today, it is the second largest PEM fuel cell producer in the world.

NedStack	
Company Type	Private
Fuel Cell Type	PEM
Primary Market Interest	Small stationary, large stationary, backup, heavy duty transport
Employees	50
Manufacturing Capability	3,000 stacks per year
Headquarters	Arnhem, Netherlands

NedStack fuel cell stacks are known for their reliability, durability and ease of integration. The stacks are available from 1 kW up to 10 kW and can be integrated into systems from a few kW up to several MW. Customers apply the stacks for continuous power generation, back-up power, auxiliary power, material handling and in larger automotive and marine drive trains. In 2010 the company received its largest order in company history for a 1 MW fuel cell power plant.

Nuvera Fuel Cells

Nuvera Fuel Cells was formed in April 2000 through the merger of Epyx Corporation and De Nora Fuel Cells. Hess Corporation is the majority shareholder of Nuvera. Nuvera focuses on the development of multi-fuel processing and fuel cell technology for the industrial utility vehicle market and transportation applications. Nuvera was the first company in the world to successfully demonstrate a gasoline fuel cell system.

Nuvera	
Company Type	Private (subsidiary of Hess Corporation)
Fuel Cell Type	PEM
Primary Market Interest	Materials handling, transportation, hydrogen generation and delivery
Employees	110
Manufacturing Capability	3,000 units per year
Headquarters	Billerica, Massachusetts

Nuvera is focused on the materials handling industry, and has developed the Total Power Solution™, a set of motive power and hydrogen refueling products that maximize productivity, minimize lifecycle costs and reduce greenhouse gas emissions. TPS features PowerEdge™, a hybrid fuel cell system for electric lift trucks and PowerTap™, an on-site hydrogen generator and refueling station.

In 2010, the company received $8.4 million dollars from the Department of Energy for research into increasing the durability and performance of fuel cell stacks designed to meet DOE's 2015 cost and durability targets. Nuvera also signed a multi-year supply agreement with Xebec Adsorption Inc. (TSX: XBC) ("Xebec"), a provider of biogas upgrading, natural gas and hydrogen purification solutions for the clean energy market.

Oorja Protonics

Oorja Protonics produces direct methanol fuel cell systems for materials handling vehicles. The company is privatly held by venture capital companies including McKenna Management, Spring Ventures, Sequoia Capital, and DAG Ventures.

Oorja Protonics	
Company Type	Private
Fuel Cell Type	DMFC
Primary Market Interest	Materials handling
Employees	32
Manufacturing Capability	2,000 – 3,000 units per year, 4-6 MW per year
Headquarters	Fremont, California

The main product from Oorja is the OorjaPac, an onboard fuel cell system that charges the battery of the vehicle while in use. This is different from the PEM fuel cell systems offered by other companies, which replace the battery pack. The OorjaPac runs on liquid methanol, and a five gallon tank can fully power two shifts.

In 2010, Martin-Brower orded OorjaPacs for their facility in Stockton, California and U.S. Food Service purchased 40 OorjaPacs for their Livermore, California facility. Testa Produced ordered 20 OorjaPacs and expects to save almost 1,000 man hours a year, due to reduced need to swap out batteries for recharge.

Protonex

Protonex develops PEM and SOFC systems for the portable power, remote power, and mobile power markets, in the 100 – 1,000 watt range. Both technology types can run on a variety of fuels including hydrogen, chemical hydrides, methanol, and propane. The company markets their products to both military and commercial users. Protonex is developing products for vehicle auxiliary power, portable/back-up power, and chargers that could replace batteries and generators. The company was founded in 2001, and in April of 2007 acquired Mesoscopic Devices, based in Broomfield, Colorado. Their strategic partners include Parker Hannifin, Northrop Grumman, Cummings Power Generation, Raytheon, Foster-Miller, and UltraCell.

Protonex	
Company Type	Private
Fuel Cell Type	PEM and SOFC
Primary Market Interest	Portable Power, Remote Power, Mobile Power
Employees	95
Manufacturing Capability	Not reported
Headquarters	Southborough, Massachusetts

In 2010, Protonex continued its work on military applications of fuel cells. In January the company received a contract from the U.S. Army Communications-Electronics (CECOM). The award was for $1.85 million dollars, as part of the ARRA, to develop and deliver portable battery chargers and APU fuel cell systems. The contract had three option phases, the first of which was exercised early in February. This option increased the award an additional $1.49 million, to further develop these systems. In February Protonex was chosen to develop a power supply concept for the Lockheed Martin HULC robotic exoskeleton. The system must be able to power the robot for missions beyond 72 hours, as well as power the robot while at rest.

On June 11th, 2010 Protonex shareholders voted to cancel the company's public listing on the London Stock Exchange's Alternative Investment Market. The capital stock in the company is now held by venture capital and investment firms, strategic investors, and other companies.

ReliOn

ReliOn	
Company Type	Private
Fuel Cell Type	PEM
Primary Market Interest	Back-up Power
Employees	46
Manufacturing Capability	Scalable as needed through contract manufacturers
Headquarters	Spokane, Washington

ReliOn focuses on modular, fault-tolerant PEM technologies for small scale backup and emergency power for customers including the telecommunications, security, and government industries. Investors include PCG Clean Energy & Technology Fund, Robeco, Enterprise Partners Venture Capital, Oak Investment Partners, Chrysalix Energy LP, Wall Street Technology Partners, Montlake Capital, and Avista Corp.

ReliOn offers two product lines designed around its patented modular, fault-tolerant architecture. The E-series offers three products: the E-200 (175 W), E-1100 (1,100 W) and E-2500 (2,500 W) fuel cell systems. The E-series offers higher power in a smaller footprint, meeting the needs of customers with space issues. The T-series offers two products: the T-1000 (1,200 W) and the T-2000 (2,000 W). The T-series offers an increased feature set designed around hot-swappable maintenance. Both product lines are exempt from many air quality standards, even those set by CARB. ReliOn products meet customer power requirements between 50 W and 20kW. In 2010, ReliOn worked with industry hydrogen providers to roll out a bulk hydrogen refueling solution for their fuel cell systems. Bulk hydrogen storage allows installations even greater run time between refueling. Additionally, longer run times opens up new market opportunities for ReliOn's suite of products.

Trenergi

Trenergi was founded in 2009, and is located in Hopkinton, Massachusetts. The company is focusing on microCHP solutions for residential and small business use. In 2010, Trenergi successfully completed the proof-of-concept development phase of its Trion™ product which it will offer in 1 kW, 3 kW and 5 kW versions to provide electricity, heat and hot water from natural gas or other readily available fuels.

Trenergi	
Company Type	Private
Fuel Cell Type	HTPEM
Primary Market Interest	Small stationary
Employees	6
Manufacturing Capability	Not Reported
Headquarters	Hopkinton, Massachusetts

UltraCell

UltraCell was founded in 2002 in Livermore, California, to commercialize the advanced Reformed Methanol Micro Fuel Cell (RMFC) technology invented at the U. S. Department of Energy's Lawrence Livermore National Laboratory (LLNL).

UltraCell	
Company Type	Private
Fuel Cell Type	RMFC
Primary Market Interest	Military, Back-up Power
Employees	Not Reported
Manufacturing Capability	Not Reported
Headquarters	Livermore, California

UltraCell's RMFC technology enables clean renewable energy to power portable electronics. The company is focused on military, emergency response, mobile computing, remote surveillance and mobile satcom markets. UltraCell has an exclusive license with LLNL for micro fuel cell technology based upon reforming methanol into hydrogen reformate using proprietary technology in the fuel reformer and hydrogen fuel cell stack.

The company's main product, the XX25™ micro fuel cell system, has undergone extensive Military Specification qualification testing and field trials, achieving Technology Readiness Level (TRL) 7 status, a significant U.S. Army milestone and certification for military use and commercial production. UltraCell also introduced the XX55™ reformed methanol fuel cell, delivering 50 watts of continuous power and up to 85 watts of peak power. It can run continuously off the grid for up to two weeks with a single hot swappable fuel tank.

The company has received several funding awards from the U.S. and the UK military to develop its fuel cells for soldier power packs and battery recharging. UltraCell is also working with both corporate partners and a network of resellers.

Automotive Companies

Daimler AG

Daimler AG	
Type	Public (Symbol:DAI)
Product (s)	Fuel cell vehicles
Primary Market Interest	Passenger cars and transit buses with commercialization by 2015
Employees	Approximately 250
Headquarters	Stuttgart, Germany

Daimler AG is one of the largest manufacturers of commercial vehicles in the world. Daimler sells its products in nearly every country and has production facilities located on five continents.

Daimler has been investigating the use of fuel cell technology to power road vehicles since 1994 and has produced over 20 concept vehicles and prototypes. The Group's pioneering achievements are underscored by 180 patent applications in this field of technology. Over the course of broad-based practical trials with fuel cell vehicles, a total of 100 passenger cars, buses, and vans have been on the move in everyday use with customers, and have covered more than 2.8 million miles and provided important insights for the ongoing development of the emission-free drivetrain.

Mercedes-Benz introduced the B-class F-CELL series of vehicles in August 2009 and small-scale production (200 in total) began at the end of that year and were delivered to selected customers in Europe and the USA in 2010. Twenty of Mercedes-Benz B-Class F-CELL fuel cell vehicles were delivered to the U.S. Department of Energy (DOE) for its Technology Validation project in the Fuel Cell Technologies Program. In 2010, Mercedes also announced its intention to deploy 70 F-CELLs in California by 2012. The vehicles will cost $849 per month for a 36-month lease that includes both insurance on the car and the cost of fuel.

The latest fuel cell technology is also used in the Mercedes-Benz Citaro FuelCELL-Hybrid city bus. Daimler Buses will initially produce a small series of about 30 of these new generation vehicles for European public transport operators. The new bus is the latest installment of a successful tradition- since 2003, 36 Mercedes-Benz Citaro buses with fuel cell drive have been demonstrated with twelve transport companies on three continents in the Clean Urban Transport for Europe (CUTE) program. With a total of 135,000 completed operating hours and more than 1.2 million miles covered, they have demonstrated their suitability for everyday use. Daimler won the F-Cell Award for the innovative use of fuel cell technology for the bus in Stuttgart, Germany in September. Daimler will continue its participation with the Clean Hydrogen in European Cities (CHIC) program, a continuation of CUTE, and provide fuel cell buses for selected cities in Europe.

General Motors

General Motors Co.	
Type	
Product (s)	Fuel cell vehicles
Primary Market Interest	Passenger cars, cross-over vehicles, and trucks
Employees	Approximately 400
Headquarters	Pontiac, Michigan

General Motors (GM), one of the world's largest automakers, traces its roots back to 1908. GM sells and services 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 in the U.S. and Europe, employing nearly 400 people.

GM's fuel cell research and product development is organized as follows:

- Honeoye Falls, New York – Fuel cell system research, product, and manufacturing development
- Mainz-Kastel, Germany - Fuel cell propulsion system integration and hydrogen storage product development
- Torrance, California - Electric drive research and development (motor and power electronics)
- Warren, Michigan - Base R&D
- Milford, Michigan - Vehicle testing, hydrogen refueling tests
- Pontiac, Michigan - Sector leadership and program management

GM produced the industry's first operational fuel cell-powered passenger vehicle in 1968. In 1991, GM and the DoE co-founded the Los Alamos–General Motors Joint Development Center to conduct fuel cell R&D. In the late 1990s, GM introduced the first drivable fuel cell concept passenger vehicle, the Opel Zafira minivan (1998). In the following decade, a number of concept and demonstration fuel cell vehicles were developed, including; Sequel, Hy-Wire, AUTOnomy, HydroGen1, HydroGen3, and Precept. These vehicles are credited with setting numerous milestones, including the first hydrogen fuel cell vehicle to achieve a 300 mile range.

GM launched Project Driveway in 2008, the first large-scale market test of hydrogen fuel cell vehicles. Project Driveway amassed more than 1.9 million miles, with individual vehicles accumulating more than 40,000 miles. Project Driveway also accumulated over 20,000 refueling events and has performed through 3 winters. In 2010, two vehicles being tested by the Postal Service in California and Washington, D.C., surpassed 1 million pieces of mail delivered since entering service. Also in 2010, GM partnered with Hawaii's energy company, The Gas Company, to form the Hawaii Hydrogen Initiative. This partnership will focus on enabling hydrogen refueling infrastructure throughout the island of Oahu.

Honda

Honda is a global producer of automobiles, motorcycles and other power equipment, such as outboard motors and generators. Honda is known for making fuel-efficient vehicles, maintaining the highest automobile fleet-average fuel efficiency of any U.S. automaker over the past 15 years.[3]

Honda Motor Co.	
Type	Public (Symbol: HMC)
Product (s)	Fuel cell vehicles, PEM home energy station
Primary Market Interest	Passenger cars (mass production in 2018), home energy stations
Employees	N/A[2]
Headquarters	Minato, Japan

Honda is focusing its R&D efforts on technologies that minimize environmental impacts, especially carbon dioxide emissions. Although the company is pursuing a variety of technologies, it believes that fuel cell electric vehicle technology offers the "ultimate zero emission car"[4] and that their fuel cell vehicles have already proved to be "full function" alternative fuel vehicles.[5] Honda has announced plans to begin mass production of fuel cell vehicles 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. In 1999, the company built fuel cell vehicles that reformed methanol onboard and that stored hydrogen in a metal alloy. Honda's current flagship fuel cell electric vehicle is the FCX Clarity, a hybrid powered by the 100 kW Honda V Flow fuel cell stack and Lithium Ion battery. In 2008, Honda commissioned the world's first dedicated fuel cell vehicle production facility for the Clarity, and 200 Clarities are being produced over three years for lease to select customers in Japan and southern California. In 2010, California included the Honda FCX Clarity in its Clean Vehicle Rebate Act Project (CVRP), offering up to a $5000 tax rebate for consumers who purchase one.

Honda also has developed two hydrogen refueling stations. One is the home energy station, developed in partnership with Plug Power. Currently in its fourth generation, this system reforms natural gas to provide hydrogen for the Clarity and produces both heat and electricity for the home. Honda estimates that CO_2 emissions for a home using its energy station and a fuel cell vehicle would be 30 percent lower than a home using a gasoline car and conventionally-supplied electricity and heat. The second station is a solar powered water-electrolysis unit, providing hydrogen made from renewable, zero CO_2 electricity via its own Honda Soltec photovoltaic panels.

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[2] Employment data solely for fuel cell activities not available.
[3] Average sales-weighted fuel consumption for 1992-2007 mid-model year passenger-car and light-truck fleets sold in the U.S. based on final CAFE reports through 2006 and 2007 mid-year reports.
[4] http://www.bloomberg.com/apps/news?pid=20601087&sid=afMZ1CSLb2EQ#
[5] "Future of Transportation in the Carbon Constrained Environment Technical and Political Perspectives of American Honda Motor", Ichiro Sakai, Assistant Vice President, Product Regulatory Office, American Honda Motor, PowerPoint presentation at Johns Hopkins University, School of Advanced International Studies, March 25, 2009.

Hyundai

Hyundai	
Type	Public
Product (s)	Fuel cell vehicles
Primary Market Interest	Passenger cars
Employees	78,000 (Company-wide)
Headquarters	Seoul, South Korea

Hyundai was founded in South Korea in 1947, starting as Hyundai Motor Company in 1967. In 1998, the company acquired Kia Motors.

Hyundai began research into FCE 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, working with UTC power.

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 Hyundai-Kia's fuel cell vehicles. It has announced that it will begin a public lease program of a few thousand vehicles globally through 2014. Hyundai plans to increase its FCEV production capabilities to 10,000 vehicles by 2015.

Toyota

Toyota Motor Co.	
Type	Public (Symbol:TM)
Product (s)	Fuel cell vehicles, PEM and SOFC for residential applications
Primary Market Interest	Passenger cars, transit buses, materials handling, residential
Employees	N/A[6]
Headquarters	Toyota City, Japan

Toyota Motor Co., Ltd. was established in 1937. Brands include the Toyota, Lexus and Daihatsu passenger vehicles and Hino heavy duty trucks and buses. Non-automotive applications focus on housing, financial activities, ITS (Intelligent Transport System for safe vehicles), GAZOO (multi-media kiosk for e-commerce), marine, biotechnology and afforestation, and new business enterprises.

From the start of its fuel cell vehicle effort in 1992, Toyota has pursued development of its own fuel cell stack and system. In December 2002, the company started limited marketing of hybrid fuel cell vehicles in the United States and Japan. In September 2008, Toyota began leasing an improved vehicle, the FCHV-adv, based on the production Toyota Highlander Hybrid vehicle. Over 50 are currently in use in the US, including 10 delivered to Proton Energy Systems in Wallingford, Connecticut over the last year. In 2009, DoE (through the National Renewable Energy Laboratory and the Savannah River National Laboratory) verified through on-road tests that Toyota's Highlander fuel cell vehicle can achieve an estimated 431 miles on a single tank of compressed hydrogen, for an average fuel economy of 68.3 miles per gallon equivalent.

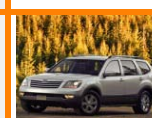
In addition to the fuel cell stack and major system components, Toyota manufactures the vehicle's

[6] Employment data solely for fuel cell activities not available.

10,000 psi carbon fiber hydrogen tanks in-house. This in-house design and manufacturing helped meet aggressive internal cost and durability targets, leading to the company's announcement of a commercial fuel cell vehicle in the 2015 time frame.

Toyota also is pursuing the stationary fuel cell market, focusing on development of PEM and SOFC cogeneration units for residential applications. The company participated in the Japanese government's Stationary Fuel Cell Demonstration Project from 2002-2004, and the Large-scale Stationary Fuel Cell Demonstration Project from 2005-2008. In December Toyota announced they will provide 30 SOFC cogeneration residential fuel cells with partners Aisini Seiki and Osaka Gas.

Appendix 2: Examples Fuel Cell Vehicles from Major Auto Manufacturers[7]

Automaker	Vehicle Type	Engine Type	Fuel Cell Size/type	Fuel Cell Mfr.	Range (mi/km)	MPG Equivalent*	Details	Picture
Daimler	B-Class F-Cell	Fuel cell/ battery hybrid	90 kW/ PEM	N/a	239 mi 385 km	54 mpg 23 km/l	Small series production started in 2009. 70 to be deployed in LA & SF by 2012 and will cost $849 per month for a 36-month lease that includes both insurance on the car and the cost of fuel.	
	A-Class F-Cell	Fuel cell/ battery hybrid	85kW/ PEM	Ballard Mark 900 Series	90mi 145km	56 mpg 24 km/l	60 fleet vehicles in U.S., Japan,Singapore, and Europe startedin 2003 – small fleet in Michigan operated by UPS.	
Ford	Advanced Focus FCV	Fuel cell/ battery hybrid	85kW/ PEM	Ballard Mark 900 Series	180mi 290km	~50 mpg 21 km/l	3-year demo in Vancouver from 2004-2007. Tested 18 vehicles in Sacramento, Orlando, Detroit and Iceland as part of DOE Technology Validation program.	
GM	Equinox FCEV	Fuel cell/battery hybrid	93kW/ PEM	N/a	200mi 320km	~39 mpg 17 km/l	"Project Driveway" put 100 vehicles in CA, NY, DC. In Berlin, leased as "HydroGen4" to 9 companies from 2008 on. 20 will be provided to the Hawaii Hydrogen Initiative starting in 2011.	
Honda	FCX Clarity	Fuel cell/battery hybrid	100kW/ PEM	Honda	354mi 570km	N/a	Small scale production of 200 vehicles between 2008-2010. Leasing in southern California and Japan.	
Hyundai	Tucson ix35 FCEV	Fuel cell/ battery hybrid	100 kW PEM	N/a	404 mi 650 km	73 mpg 31 km/l	Testing in 2011, production in 2015.	
	Tucson	Fuel cell/ battery hybrid	100 kW PEM (2007 version)	Kia	230 mi 370 km	63.5 mpg 27 km/l	Demonstrated 33 Hyundai Tucsons and Kia Sportage FCVs in the U.S. between 2004-2009 and in Korea between 2006-2010.	
Kia	Borrego/ Mojave FCEV	Fuel cell/ battery hybrid	115kW/ PEM	Kia	426mi 685km	54 mpg 23 km/l	Leasing to Seoul, Korea residents starting in 2009.	
Nissan	X-TRAIL (SUV)	Fuel cell/ battery hybrid	75kW/ PEM	UTC Power (Ambient-pressure)	N/a	N/a	Approved for Japanese Public road testing – 3 leased to Japanese government.	
Toyota	FCHV-adv	Fuel cell/ battery hybrid	N/a	Toyota	515mi 830km	N/a	Limited leasing in Japan started in 2008. 10 delivered to CT in 2010. Will place more than 100 with universities, private companies and gov. agencies in CA and NY in the next 3 years.	

[7] Compiled by Fuel Cells 2000. For a more detailed chart, including the most recent vehicles, see http://www.fuelcells.org/info/charts/carchart.pdf

Appendix 3: Examples of Commercially Available Fuel Cell Products

Current Commercially Available Fuel Cell Products[8]				
Manufacturer	**Product Name**	**Application**	**Type**	**Output**
Ballard	FCVelo City 9SSL	Materials Handling Forklifts Classes I, II, and III	PEM	4.4 - 19.3 kW
	FCGen 1030	Residential Cogeneration	PEM	1.2 kW
	FCGen 1020A CS	Back-up power	PEM	0.3 – 3.4 kW
	FCVelo City	Bus and Heavy Duty Trucks	PEM	75 and 150 kW
Ceramic Fuel Cells Limited	Gennex	Micro-CHP	SOFC	1kW
	BlueGen	Small Scale Electricity Generation	SOFC	2 kW
ClearEdge Power	CE5	Residential CHP	PEM	500 W
FuelCell Energy	DFC 300	Stationary	MCFC	300 kW
	DFC 1500	Stationary	MCFC	1,400 kW
	DFC 3000	Stationary	MCFC	2,800 kW
Horizon	H-100	Uninterrupted Power Supply	PEM	100 W
	H-1000	Uninterrupted Power Supply	PEM	1 kW
	H-3000	Uninterrupted Power Supply	PEM	3 kW
	GreenHub	Uninterrupted Power Supply	PEM	500 w – 2 kW
	MiniPak	Portable Battery Charger	PEM	100 W
Hydrogenics	HyPM XR Power Modules	Stationary	PEM	4, 8, 12 kW
	HyPM Rack	Stationary	PEM	Multiples of 10, 20, 30 kW
	FCXR System	Stationary	PEM	150 kW
	HyPM HD Power Modules	Mobility	PEM	4, 8, 12, 16 kW
	HyPX Power Packs	Class 1 Forklift Trucks	PEM / hybrid	8 - 12 kW

[8] Complied by Fuel Cells 2000, with input from the U.S. Fuel Cell Council's Commercially Available Product List http://www.usfcc.com/download_a_file/download_a_file/GAWG-FuelCellProducts-8-09.pdf

	HySTAT Hydrogen Generator	Hydrogen Refueling	Alkaline Electrolysis	4 - 60 Nm3/hr
IdaTech	ElectraGen™ 3	Backup Power for Telecom	PEM	3 kW
	ElectraGen™ 5	Backup Power for Telecom	PEM	5 kW
	ElectraGen™ H2-I	Backup Power for Telecom	PEM	2.5 - 5 kW
	iGen™	Portable, Backup Power for Telecom	PEM	250 W
	ElectraGen ™ ME	Backup Power for Telecom	PEM	2.5 - 5 kW
Medis	Medis Power Pack	Portable	Direct Borohydride	1 W
Morphic Technologies	Mira 6	Boats, Forklifts, APU	PEM	6 kW
	Max-E 3600	Battery Charger for RV	PEM	150 w
	Polaris TLC	Backup Power for Telecom	PEM	5Kw
	Polaris 5	APU	PEM	5 kW
	Orion5	APU	PEM	5 kW
	Orion1	Residential CHP	PEm	Unknown
Nuvera	PowerEdge CS25, CM25, CM32, RL25	Counterbalance Lift Trucks and Reach Trucks	PEM	25 kW – 31 kW
	PowerFlow PFV-5	Industrial Vehicles	PEM	5 kW
	Andromeda Fuel Cell Stack	Transportation	PEM	100 kW
	HDL-82 Power Module	Transportation	PEM	82 kW
Oorja Protonics	OorjaPac	Materials Handling Vehicles	DMFC	Unknown
Plug Power	GenDrive 160	Materials Handling Vehicles	PEM	8.7 kW
	GenDrive 170	Materials Handling Vehicles	PEM	10.1 kW
	GenDrive 240	Materials Handling Vehicles	PEM	10.5 kW
	GenDrive 312	Materials Handling Vehicles	PEM	2.6 kW
	GenCore® 5T Series	Backup -Telecom	PEM	5 kW
	GenCore® 5U Series	Backup -Utilities	PEM	5 kW
	GenCore® 5B Series	Backup - UPS	PEM	5 kW
	GenSys 6U48	Residential CHP, Backup Power	PEM	6 kW
Protonex	M300-CX	Portable Battery Charger	PEM or SOFC	300 W
	UAV-C250	UAV Power Source	PEM or SOFC	250 W
	UGV-C250	UGV Power Source	PEM or SOFC	250 W

Relion	T-1000	Backup	PEM	600 - 1200 W
	T-2000	Backup	PEM	600 W - 2kW
	I-1000	Backup	PEM	1 kW
SFC Smart Fuel Cell	EFOY Series 600, 900, 1200, 1600, 2200	APU for mobile homes, power for leisure markets	DMFC	25, 38,50, 65, 90 W
	EFOY Pro Series 600, 1200, 1600, 2200	Portable, Backup power for security markets	DMFC	25 – 90 W
Trulite	KH4 Power System	Portable	PEM	150 W - 250 W
UltraCell	XX25	Micro /Portable	RMFC	25 W
UTC Power	PureCell® System Model 400	Stationary	PAFC	400 kW
	PureMotion® 120 System	Transportation	PEM	120 kW
	PureCell® System Model 5	Backup	PEM	5 kW

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On the Cover

Two 400 kW PureCell® stationary fuel cells from UTC Power provide power and thermal energy to the Coca-Cola Refreshments bottling facility in Elmsford, NY. The highly efficient fuel cells lower the facility's energy costs and contribute to the company's sustainability mission through reduced carbon emissions.

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