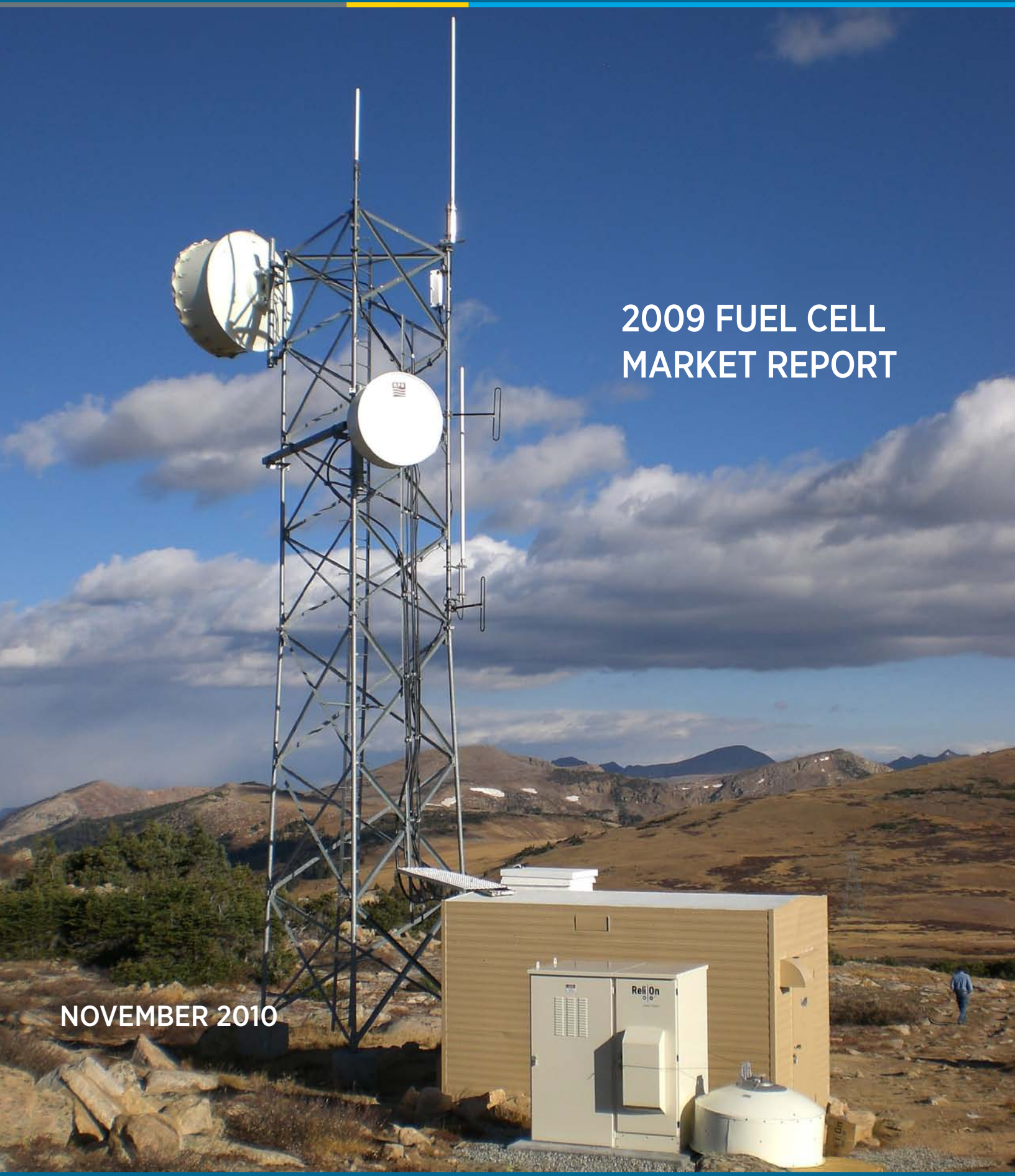
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy



2009 FUEL CELL MARKET REPORT

NOVEMBER 2010

Authors

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Acknowledgement

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APU	Auxiliary power unit
ARRA	American Recovery and Reinvestment Act
BTU	British thermal unit
CARB	California Air Resources Board
CFCL	Ceramic Fuel Cells Limited
CHP	Combined heat and power
CO_2	Carbon dioxide
DDSP	Defense Depot Susquehanna, Pennsylvania
DFC	Direct Fuel Cell
DLA	Defense Logistics Agency
DoD	Department of Defense
DoE	Department of Energy
DoT	Department of Transportation
DMF	Direct methanol fuel cell
EPA	U.S. Environmental Protection Agency
FCE	FuelCell Energy
FCEV	Fuel cell electric vehicle
FCV	Fuel cell vehicle
FTA	Federal Transit Administration
GBP	Great British Pound
ILEV	Inherently low emission vehicle
ITC	Investment Tax Credit
kg	Kilogram
kW	Kilowatt
kWh	Kilowatt-hour
LPG	Liquefied petroleum gas
MCFC	Molten carbonate fuel cell
m-CHP	Micro-combined heat and power
mpg	Miles per gallon
MW	Megawatt
OEM	Original equipment manufacturer
OTC	Over the counter (investment)
PAFC	Phosphoric acid fuel cell
PE	Private equity
PEM	Proton exchange membrane fuel cell
PIPE	Private investment in public equities
R&D	Research and development
RD&D	Research, development and demonstration
RPG	Residential power generation
SGIP	Self-Generation Incentive Program
SOFC	Solid oxide fuel cell
UAV	Unmanned aerial vehicle
UGV	Unmanned ground vehicle
VC	Venture capital
Wh	Watt-hour
ZEV	Zero Emission Vehicle

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. Fuel cell systems can be a truly zero-emission source of electricity, if 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 vehicles (FCV) and auxiliary power units (APUs) for highway and off-road vehicles, as well as specialty vehicles (e.g. forklifts). Portable power applications include the use of fuel cells not permanently installed or fuel cells in a portable device.

There are an exceptional number of fuel cell applications being developed or demonstrated worldwide to improve the efficiency of electricity generation and to reduce fossil fuel consumption and air pollution, including carbon dioxide emissions. This report provides an overview of trends in the fuel cell industry and markets, including product shipments, market development, and corporate performance.

Notable Fuel Cell Events in 2009

The Honda FCX Clarity was named the 2009 World Green Car at the New York International Auto Show.

Plug Power booked 786 total orders, including 584 orders for its GenDrive materials handling product.

IdaTech shipped more than 445 systems, selling more than five times its 2008 volume.

FuelCell Energy signed a license agreement with South Korea's POSCO Power, whereby POSCO will manufacture components, assemble, and sell FuelCell Energy's stationary fuel cells. The agreement includes an upfront $10 million dollar licensing fee and a $25 million dollar purchase of FuelCell Energy common stock. To date POSCO Power has ordered 68 megawatts (MW) of fuel cell systems from FuelCell Energy.

Two DoE National Laboratories verified that a Toyota fuel cell vehicle can achieve an estimated range of 431 miles on a single tank of compressed hydrogen gas, with an average fuel economy of 68.3 miles per gallon.

Executive Summary

The fuel cell industry faced a dynamic environment in 2009. The global economic recession and political uncertainty regarding fuel cell vehicle policies in the United States created unusual challenges. At the same time, many industry segments showed exceptional strength and promise, and a fresh commercialization commitment was made by the international auto industry. Commercial sales grew significantly, especially in the materials handling industry and residential CHP applications, and worldwide shipments of fuel cell systems increased by more than 40 per cent compared with 2008.

United States

North American fuel cell manufacturers increased shipments significantly in 2009 (see Figure ES1). Plug Power booked 786 total orders, including 584 orders for its GenDrive materials handling product, a 40 percent increase over 2008. IdaTech shipped more than 445 systems, five times greater than its 2008 volume. FuelCell Energy secured 30.8 MW in fuel cell orders from POSCO Power in Korea, and 1.65 MW in orders in California, on par with orders from 2008.

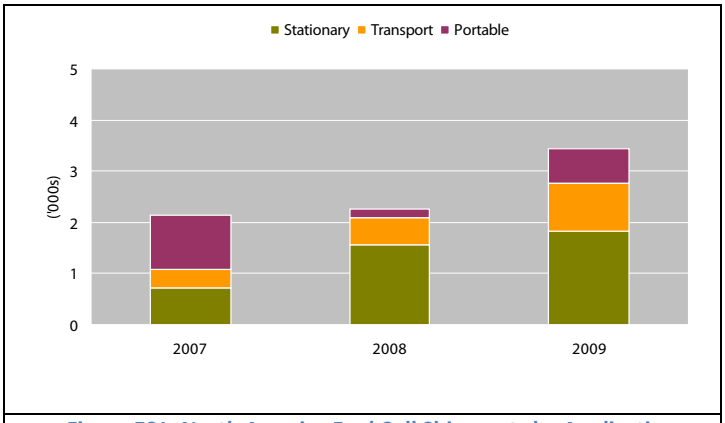

Figure ES1: North America Fuel Cell Shipments by Application (Thousands of Units) (2007-2009) Source: Fuel Cell Today (Copyright 2010)

The Department of Energy's (DoE) funding for fuel cells, hydrogen, and related materials research totaled $380 million in FY2009, including $41.9 million in American Recovery and Reinvestment Act (ARRA) funding to accelerate the commercialization of fuel cells. The ARRA funding alone is projected to result in nearly 1,000 fuel cell deployments for backup power and material handling applications and was matched by approximately $51 million in industry cost-share. The ARRA also expanded existing tax credits for fuel cell and fueling infrastructure deployment, including raising the cap on the hydrogen fueling facility credit to $200,000, creating a 30 percent tax credit for investment in property used in manufacturing, and raising the investment tax credit (ITC) cap for residential fuel cells in joint occupancy buildings to $3,334/kilowatt (kW).

The DoE's cost assessment for an 80-kW automotive fuel cell system was reduced from $73/kW in 2008 to $61/kW in 2009, assuming a manufacturing volume of 500,000 units per year, with comparable reductions at lower volumes. DoE also reported that fuel cell passenger vehicle durability had achieved 75,000 miles.

The Honda FCX Clarity was named the 2009 World Green Car of the Year at the New York International Auto Show. The jurors selected the Clarity from among 22 contenders, stating that the Clarity "provides

the amenities people expect in a premium car with 430 km range, fuel consumption of about 3.3 liters/100 kilometer (72 miles per gallon [mpg] U.S.) equivalent and zero tailpipe emissions."

As part of the 2009 Hydrogen Road Tour, eight fuel cell vehicles from eight different automakers were driven 1,700 miles through 28 cities in the U.S. and Canada. One of the tour's sponsors, the California Fuel Cell Partnership, published an Action Plan designed to deploy a fueling infrastructure for an estimated 50,000 fuel cell vehicles by 2017.

There were significant orders for, and deployments of, fuel cell forklifts in the private sector. For example, Central Grocers of Illinois purchased 220 fuel cells to replace batteries in electric forklifts and Nestlé Waters installed 32 Plug Power fuel cell forklifts at a bottling facility in Dallas, Texas.

The Defense Logistics Agency (DLA) installed 40 fuel cell forklifts at its Susquehanna, Pennsylvania supply depot, the largest and most active Defense Department depot in the United States. DLA also installed 20 fuel cell forklifts at a depot in Georgia. These forklifts were the first installment of a total of 100 forklifts that DLA is deploying in four of its high-volume distribution centers across the country. In 2009, DLA surpassed 7,000 hydrogen refuelings at the Susquehanna facility,[1] generating significant knowledge about hydrogen refueling and demonstrating the ability to frequently refuel fleets of fuel cell vehicles.

The military continued to demonstrate success with fuel cells in other applications. For example, military vehicles powered by fuel cells achieved mission times that far exceed the times achieved by advanced batteries, including an unmanned aerial vehicle that set a flight endurance record roughly seven times that of batteries.[2]

Global Competition Strengthens

Although the U.S. fuel cell industry is experiencing considerable success, growth by non-U.S. companies is occurring at a faster pace. For example, as shown in Figures ES2 and ES3, non-US companies are experiencing significantly faster growth than US companies, both in terms of total number of units shipped and total generating capacity of those shipments. Between 2007 and 2009, the total share of U.S. shipments clearly declined as a proportion of the global fuel cell market. Indeed, at least one U.S. company, FuelCell Energy, continued a move toward manufacturing overseas, signing an agreement with POSCO Power to assemble FuelCell Energy units and produce components in Korea.

[1] http://apps1.eere.energy.gov/news/progress_alerts.cfm/pa_id=228

[2] Protonex set an unofficial flight endurance record of more than 23 hours. See pages 23 and 24 for more information about military applications of fuel cells.

In part, the strengthening of the industry outside of the United States is due to strong government support in several countries. For example, the Republic of Korea (South Korea) is seeking to become a global leader in fuel cell technology, with plans to capture at least 20 percent of global market share and generate 560,000 domestic jobs, primarily through exports of fuel cells. The national government announced a program to pay 80 percent of the cost of a residential fuel cell. The Seoul municipal government announced that it intends to generate half of its renewable energy from fuel cells and will pay an additional 10 percent of the cost of new residential fuel cell units.

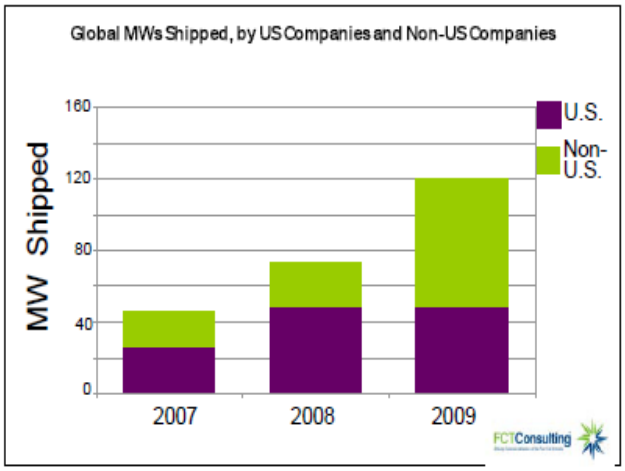

Figure ES2: Global MWs Shipped, By US Companies and Non-US Companies.
Source: Fuel Cells Today

In Germany, eight major companies,[3] with support from the federal Ministry of Transport, Building, and Urban Development, launched the H2 Mobility initiative to promote the development of a nationwide hydrogen fueling infrastructure and the commercial deployment of fuel cell vehicles by 2015. Daimler began small series production of its Mercedes-Benz B-Class F-Cell vehicle, with plans to increase to tens of thousands of vehicles in the 2015-2017 timeframe. Daimler also unveiled its new Mercedes-Benz Citaro FuelCELL Hybrid bus, which will undergo a fleet test in several European cities.

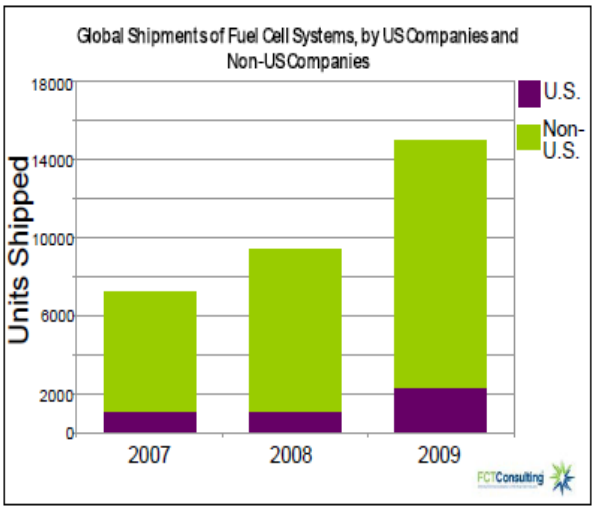

Figure ES3: Global Shipments of Fuel Cell Systems, by US Companies and Non-US Companies.
Source: Fuel Cells Today

Additionally, a German-Dutch consortium announced plans to develop a fuel cell-battery-hybrid bus for public transport service in Cologne and Amsterdam, and two additional Hydrogenics' fuel cell hybrid MidiBuses were placed in operation in Germany, bringing the total number to ten. A larger Hydrogenics fuel cell bus was commissioned in Gladbeck, Germany for testing. Australian company Ceramic Fuel Cells Limited opened a high volume manufacturing plant in Germany for the production of solid oxide fuel cell (SOFC) stacks.

[3] Daimler, EnBW, Linde, OMV, Shell, Total, Vattenfall, and the NOW GmbH National Organization Hydrogen and Fuel Cell Technology.

Significant fuel cell developments also occurred in Japan in 2009. An association of 13 major companies[4] formed a research alliance to develop hydrogen fueling technologies, and the Ministry of Economy, Trade and Industry announced a program to provide roughly $12 billion to install hydrogen fueling stations by 2015 and to build hydrogen pipelines. Six Japanese companies began selling a residential fuel cell system under the ENE-FARM brand and increased the target number from 1,500 units to 2,100 units because sales exceeded expectations. As of March 2009, over 3,000 units have been installed, and an additional 2,000 had been sold by years end. Toyota entered the residential arena in 2009, working with partners to develop a fuel cell system.

Conclusion

It appears likely that 2009 will be remembered as a pivotal year for the fuel cell industry. Despite significant challenges, the industry continued to move toward wider commercialization, and many purchases and programs were announced that will contribute to continued improvement in 2010. Moreover, support for fuel cell technology, on balance, continued to grow, with committed leadership intensifying in Europe and Asia, especially Germany, Korea and Japan. Industry outside of the U.S. continued a trend of increasing its share of the global fuel cell market as compared with U.S. companies.

[4] Nippon Oil, Idemitsu Kosan, Cosmo Oil, Japan Energy, Showa Shell Sekiyu, Tokyo Gas, Osaka Gas, Toho Gas, Saibu Gas, Iwatani, Taiyo Nippon Sanso, Air Liquide Japan, and Mitsubishi Kakoki Kaisha.

Financials

Fuel cell companies typically derive revenue from the sale and support of fuel cells and related equipment, such as hydrogen generators, and from contract research and development. Many fuel cell companies are development stage enterprises, focusing most of their efforts on research and product development. In 2009, the trend away from the development stage to the commercial stage continued, with companies like IdaTech, FuelCell Energy, and Plug Power continuing to increase commercial sales. This section provides financial information for selected publicly traded fuel cell companies. It does not include private companies or companies for which fuel cells are not the primary business.

Table 1. Gross Revenues for Select Public Fuel Cell Companies (Thousands USD, unless footnoted)

North American Companies	2009	2008	2007	2006
FuelCell Energy	88,016	100,735	48,234	33,288
Plug Power	12,293	17,901	16,271	7,836
Ballard Power	46,722	59,580	65,532	49,832
Hydrogenics Corp.	18,841	39,340	37,990	30,059
IdaTech	6,550	5,930	5,076	4,709
Protonex	7,101	7,851	5,990	2,316
TOTALS (USD)	**179,523**	**231,337**	**179,093**	**128,040**
Other Companies	**2009**	**2008**	**2007**	**2006**
SFC Smart Fuel Cell AG [1]	11,687	14,553	14,351	7,024
Ceres Power [2]	952	722	98	110
Ceramic Fuel Cells Limited[3]	1,679	617	4,420	2,077
[1]Euro [2]UK Pound, [3]Australian Dollar				

Table 1: Gross Revenues for Select Public Fuel Cell Companies
Source: Fuel Cells 2000

As shown in Table 1, the global recession had a significant impact on fuel cell companies, reversing recent gains in revenue growth. However, revenues generally were higher than in 2006, and two companies showed revenue increases compared with 2008.

- IdaTech increased total sales by 12 percent compared with 2008 and increased revenue from product sales by nearly 100 percent.

- Ceres Power increased revenue because it received a milestone payment from British Gas following the successful test of its 1kW SOFC residential CHP product.

Fuel cell companies continued to operate with significant losses, although some trimmed their losses in 2009.

- FuelCell Energy reported a net loss of $68.7 million in 2009, a significant reduction from the net loss of $93.4 million reported in 2008, with gross revenues of $88 million in 2009.

- Plug Power reported a net loss of $40.7 million in 2009 as compared with a net loss of $121.7 million in 2008, with gross revenues of $12 million in 2009.

- Hydrogenics reported a net loss of $9.38 million compared with the net loss of $14.32 million reported in 2008, with gross revenues of $18 million in 2009.

- Ballard Power Systems slipped from positive net income of $31.46 million in 2008 to a net loss of $3.26 million in 2009.

- IdaTech's before tax operating loss increased from $21.9 million to $33.5 million, largely because the company cancelled the current version of its iGen product and because it unexpectedly lost a tax credit from the State of Oregon.

It is interesting to note that FuelCell Energy, Plug Power, and Hydrogenics each cut their net losses in 2009 while, at the same time, experiencing significant revenue declines. In some cases, this appears due to continued aggressive product cost-cutting. For example, FuelCell Energy claims to have achieved more than 60 percent unit cost reduction since first commercializing its molten carbonate (MCFC) power plants. The company's most recent, cost-reduced unit went into production in 2009 and is expected to be profitable on a unit-by-unit basis with production volumes between 35 and 70 MW.

In other cases, the change in net losses may be due primarily to restructuring and one-time charges. For example, Plug Power cut research and development expenses in 2009 by 53.3 percent through workforce and other reductions. Plug Power also took a $45.8 million charge for goodwill impairment in 2008 that did not recur in 2009, significantly reducing the size of the loss in 2009. Similarly, Hydrogenics recorded a one-time, $10.4 million recovery of income taxes in 2009 as a result of a restructuring completed in 2009.

Ballard's net loss was attributed to a number of factors, including restructuring and related expenses and the weak economic situation. As part of its restructuring, Ballard cut annual operating expenses by 30 percent, reducing the workforce, simplifying its structure, and cutting discretionary costs. Ballard also found ways to secure more funding, including increased government support and a sale-leaseback arrangement of its headquarters in Burnaby, British Columbia.

Table 2 shows that all but one company in our sample showed significant reductions in assets between 2008 and 2009. In a few cases, however, assets have increased since 2006. Most companies offset the loss in assets with significant reductions in liabilities between 2008 and 2009, and many also show reductions in liabilities between 2006 and 2009.

Finally, as shown in Table 3, most companies have continued trimming their R&D expenditures in 2009, or R&D expenditures have remained flat. In some cases, this may be a reflection of a transition to increased manufacturing and commercialization. For example, Plug Power announced it plans to enter the commercial phase of its GenDrive™ and GenSys® products in 2010, shifting resources to marketing and service activities.

Table 2. Total Assets and Liabilities for Select Public Fuel Cell Companies (Thousands USD, unless footnoted)								
North American Companies	**2009**		**2008**		**2007**		**2006**	
	Assets	**Liabilities**	**Assets**	**Liabilities**	**Assets**	**Liabilities**	**Assets**	**Liabilities**
FuelCell Energy	162,688	56,420	185,476	65,161	253,188	42,318	206,652	29,402
Plug Power	164,185	75,915	209,112	83,247	268,392	19,491	307,920	13,391
Ballard Power Systems [1]	195,348	36,428	208,443	49,956	298,691	40,502	350,038	51,175
Hydrogenics Corp.	36,808	19,328	47,579	22,083	67,940	27,208	97,173	30,189
IdaTech	44,475	43,377	50,567	18,786	61,952	12,003	46,509	12,056
Protonex	25,348	2,495	36,663	2,066	46,003	1,706	19,880	699
TOTALS	**628,852**	**233,963**	**737,840**	**241,299**	**996,166**	**143,228**	**1,028,172**	**136,912**
Other Companies	**2009**		**2008**		**2007**		**2006**	
SFC Smart Fuel Cell AG [1]	50,442	4,581	54,839	5,204	59,945	8,032	14,986	9,390
Ceres Power [2]	27,081	5,688	30,455	1,825	13,665	788	16,498	438
Ceramic Fuel Cells Limited [3]	50,941	2,451	30,649	3,640	70,276	3,933	88,588	2,834
[1]Euro [2]UK Pound, [3]Australian Dollar								

Table 2: Total Assets and Liabilities for Select Public Fuel Cell Companies
Source: Fuel Cells 2000

Table 3. R&D Expenditures for Select Public Fuel Cell Companies (Thousands USD, unless footnoted)				
North American Companies	**2009**	**2008**	**2007**	**2006**
FuelCell Energy	10,994	16,059	13,438	24,714
Plug Power	16,324	34,987	39,218	41,577
Ballard Power Systems	26,628	37,179	58,478	52,274
Hydrogenics Corp.	5,219	7,296	9,690	9,379
IdaTech	17,708	7,835	5,990	4,076
Protonex	14,185	13,858	10,503	5,038
TOTALS (USD)	**91,058**	**117,214**	**137,317**	**137,058**
Other Companies	**2009**	**2008**	**2007**	**2006**
SFC Smart Fuel Cell AG [1]	1,507	777	631	438
Ceres Power [2]	6,308	5,748	4,922	3,104
Ceramic Fuel Cells Limited [3]	9,861	12,310	12,050	10,765
[1]Euro [2]UK Pound, [3]Australian Dollar				

Table 3: R&D Expenditures for Select Public Fuel Cell Companies
Source: Fuel Cells 2000

Venture Capital and Private Equity

Cumulative global investment in fuel cell companies, based on venture capital (VC) and private equity (PE) totaled roughly $631 million between 2007 and 2009 (see Figure 1). Roughly 51 percent of this amount was venture capital and 24.2 percent was private equity.

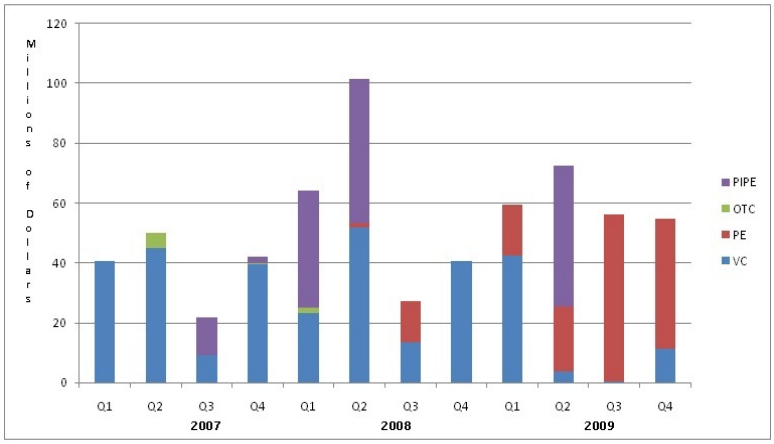

Figure 1: Worldwide Venture Capital (VC), Private Equity (PE), Over-the-Counter (OTC), and Private Investment in Public Equities (PIPE) Investments in Fuel Cell Companies (2007 – 2009)
Source: New Energy Finance

As shown in Figure 2, total investments increased each year, rising from roughly $155 million in 2007 to more than $233 million in 2008 and $242 million in 2009. Most of the increase in 2008 and 2009 is attributable to venture capital and private equity (Figure 1). Private Investment in Public Equities (PIPE) activity appears to have slowed in 2009, replaced largely by private equity. PIPE deals provide companies with quick access to cash, because they enable private investors to purchase securities directly from publicly traded companies, usually at a discount to the market price. Typically, PIPE transactions involve hedge funds investing in small companies that do not have access to other forms of financing. The fact that private equity financing has replaced a significant amount of PIPE financing in 2009 suggests that at least some fuel cell companies are able to access more traditional forms of finance.

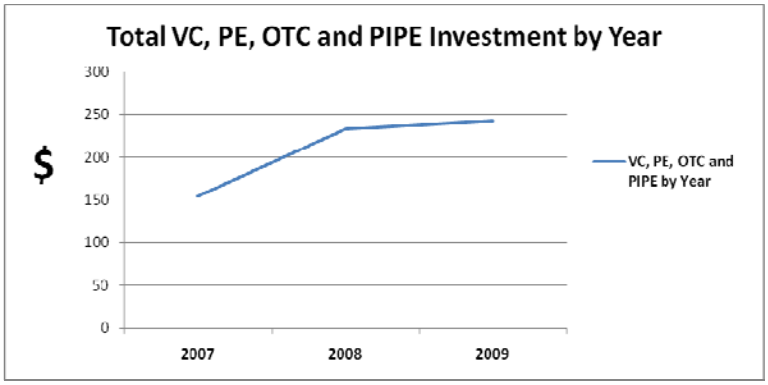

Figure 2: Total VC, PE, OTC, and PIPE Investments by Year
Source: New Energy Finance

Table 4 shows the top ten global investors in fuel cells over the last decade. U.S. investors made the greatest cumulative investment in fuel cells and hydrogen during that period, totaling $824.9 million, followed by United Kingdom (UK) investors, at $270.3 million. U.S. and UK investors collectively comprised six of the top ten largest fuel cell and hydrogen investors during the decade.

Table 4. Top Ten Venture Capital and Private Equity Investors in Fuel Cells and Hydrogen, By Company and By Country (Cumulative 1/1/2000 – 12/31/2009)			
Top Ten Fuel Cell Investors		**Top Ten Countries with Highest Levels of Private Investment in Fuel Cells**	
Company	**Amount (millions USD)**	**Country**	**Total All VC and PE Investment (millions USD)**
Kleiner Perkins Caufield & Byers (US)	$66.4	US	$824.9
World Gold Council (UK)	$60.4	UK	$270.3
GreenShift Corp (US)	$58.1	Canada	$161.1
Investec (South Africa)	$57.1	Germany	$106.8
Chrysalix Energy LP (CAN)	$51.5	South Africa	$57.1
Mobius Venture Capital (US)	$51.5	Singapore	$50.0
EnerTek Singapore Ptd Ltd (Singapore)	$50.0	Australia	$46.5
Rolls Royce Plc (UK)	$50.0	Denmark	$29.3
Jolimont Ventures (AUS)	$45.5	Netherlands	$28.5
Meditor Capital Management (UK)	$34.0	Switzerland	$27.8
TOTAL	**$524.5**	**TOTAL**	**$1,602.3**

Table 4: Top 10 VC and PE Investments by Country and Company (2000-2009)
Source: New Energy Finance

Table 5 provides investment information just for 2009. Again, both U.S. and UK investors lead the pack in terms of the total venture capital and private equity and the national origin of the investors. However, five new countries (Sweden, Belgium, Malaysia, Portugal, and Japan) appear in the 2009 top ten list of countries, suggesting a growing interest in fuel cell and hydrogen by investors in those countries.

Moreover, Table 5 shows that Swedish investors comprise three of the top ten fuel cell and hydrogen investors in 2009. The Volvo Group, one of the investors, is seeking to develop fuel cell auxiliary power units (APUs) for diesel trucks through PowerCell Sweden AB, a Swedish company established by Volvo. Investors in PowerCell Sweden include the Volvo Group as well as Midroc New Technology and OCAS, both of which also are among the top ten fuel cell investors for 2009. Midroc is Swedish and OCAS is located in Belgium.

Table 5. Top Ten Venture Capital and Private Equity Investors in Fuel Cells and Hydrogen, By Company and By Country (2009)			
Top Ten Fuel Cell Investors		**Top Ten Countries with Highest Level of Private Investment in Fuel Cells**	
Company	**Amount (million USD)**	**Country**	**Total All VC and PE Investment (million USD)**
Meditor Capital Management (UK)	$24.0	US	$65.9
New Enterprise Associates (US)	$16.8	UK	$37.8
Altira Group, LLC (US)	$7.7	Sweden	$19.2
Chrysalix Energy LP (CAN)	$6.8	Canada	$8.4
Midroc New Technology (SWE)	$6.4	Belgium	$6.4
OCAS (BELGIUM)	$6.4	Germany	$5.4
Swedish Energy Agency(SWE)	$6.4	Netherlands	$5.2
Volvo Group (SWE)	$6.4	Malaysia	$1.4
F&C Investments plc (UK)	$6.0	Portugal	$1.0
Applied Ventures LLC (US)	$5.5	Japan	$0.7
TOTAL	**$92.4**	**TOTAL**	**$151.4**

Table 5: Top 10 VC and PE Investors in Fuel Cells and Hydrogen, by Country and Company (2009)
Source: New Energy Finance

Detailed Discussion by Application

Shipments

The number of fuel cell shipments continued to increase in 2009, reflecting the ongoing trend toward commercialization. As shown in Figure 3, much of this growth occurred in Asia. Figure 4 shows that global growth occurred in the stationary and portable sectors, while transportation shipments declined roughly 10 percent. The total MW of stationary power shipped per year roughly tripled between 2007 and 2009, while the MW shipped of transportation declined (Figure 5). Portable does not show up on this chart because the output of each portable unit is small so that, despite large volumes shipped, total generating capacity from portable is low small.

There appear to be at least two reasons for the large growth in shipments in Asia. First, Japan and Korea have both embraced fuel cells, especially for residential CHP applications. Figure 6 shows that the number of stationary fuel cell shipments more than doubled in Asia between 2007 and 2009. Second, there has been a substantial increase in the shipment of portable fuel cells in Asia (Figure 6). These shipments are largely for fuel cell educational products, such as miniature fuel cell cars for classrooms.

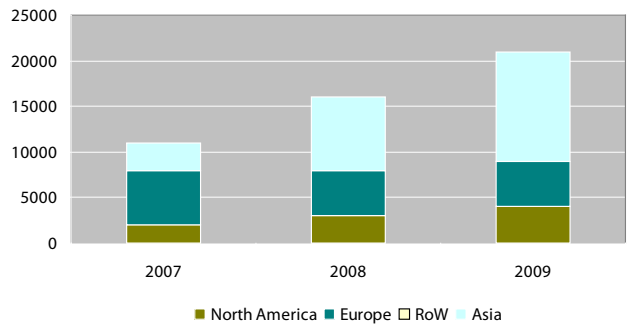

Figure 3: Global Fuel Cell Shipments by Region (2007-2009) Source: Fuel Cell Today (Copyright 2009)

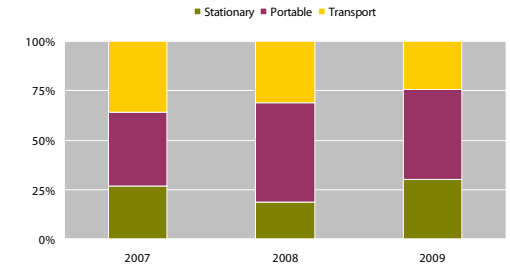

Figure 4: Percentage of Global Fuel Cell Shipments by Application, Global (2007-2009) Source: Fuel Cell Today (Copyright 2010)

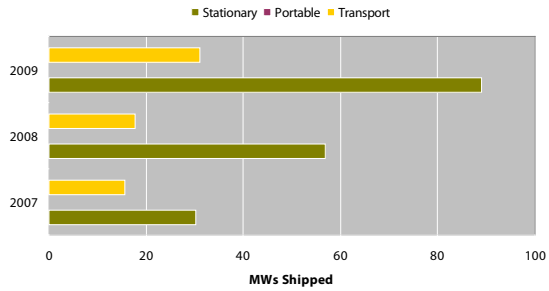

Figure 5: Total MW's Shipped by Application (2007-2009) Source: Fuel Cell Today (Copyright 2010)

The number of North American shipments also is growing, primarily for stationary and transport applications, as can be seen in Figure 7. Stationary growth is primarily related to the continued strength in the telecommunications backup power market and in some distributed generation applications, especially in California. The transportation growth is primarily related to the increasing demand for fuel cell materials handling equipment, such as forklifts.

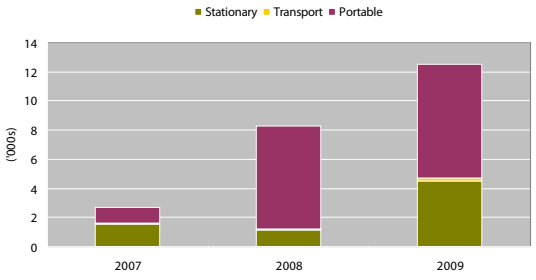

Figure 6: Asia Fuel Cell Shipments by Application (Thousands of Units) (2007-2009). Source: Fuel Cell Today (Copyright 2010)

Europe is the one region where fuel cell shipments did not increase. As shown in Figure 8, the change in shipments appears primarily due to declines in the portable and transportation markets. Also, unlike Asia and North America, transportation applications comprise the majority of fuel cell shipments in Europe. Europe has developed a market niche for fuel cells as auxiliary power units (APU) on vehicles, and many of the transportation shipments are APUs that charge batteries in recreational vehicles or on boats. One European company, PowerCell AB, is developing an APU application for heavy duty trucks and has raised significant venture capital and other financing.

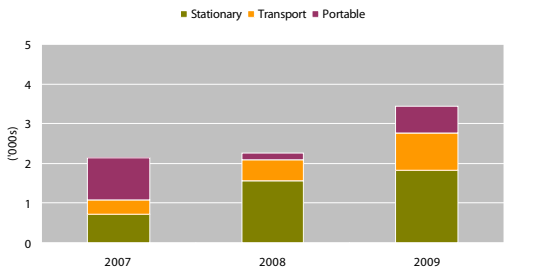

Figure 7: North America Fuel Cell Shipments by Application (Thousands of Units) (2007-2009). Source: Fuel Cell Today (Copyright 2010)

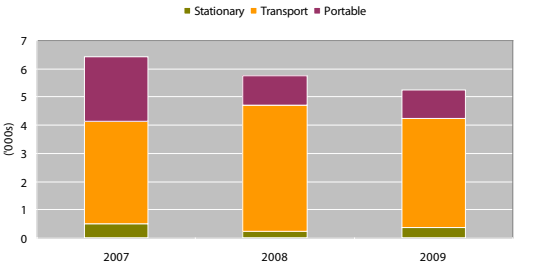

Figure 8: Europe Fuel Cell Shipments by Application (Thousands of Units) (2007-2009). Source: Fuel Cell Today (Copyright 2010)

Stationary Fuel Cells

There were substantial developments in 2009 in distributed generation, residential CHP, and back-up power. Significant new fuel cell installations occurred across the U.S., especially in the Northeast states and California, and international programs showed strong growth.

Large Stationary

U.S.-based FuelCell Energy (FCE) and UTC Power continue to be the major companies providing large stationary fuel cells. At the end of 2009, FCE had installations in more than 55 locations worldwide and their products had generated more than 400 million kilowatt-hours (kWh) of power using wastewater gas, food and beverage waste, natural gas, and other hydrocarbon fuels. FCE announced a significant number of new installations and approvals in 2009, including expansion of its unique DFC-ERG product, which harnesses energy lost during pressure reductions in natural gas transmission networks to power a turboexpander, thus generating additional electricity.

Figure: 9 FuelCell Energy unit installed at Gills Onions. Photo Courtesy of Gills Onions

FuelCell Energy also signed license and purchase agreements with Korea's POSCO Power. POSCO will manufacture fuel cell systems from components provided by FCE and will combine the stacks with balance-of-plant components manufactured in South Korea. In return, POSCO provided a one-time

Table 6. Summary of FuelCell Energy 2009 Projects

Location	Generation Capacity	Notes
California (San Diego)	2.8 MW	$11 million provided through California's Self Generation Incentive Program (SGIP), the largest amount ever awarded by the California Public Utilities Commission for a renewable energy project. The project will operate on landfill gas and will be combined with a 2.8 MW energy storage system, enabling storage of off-peak power.
California (Sonoma County)	1.4 MW	$3 million grant through SGIP. Waste heat will replace approximately half of the natural gas currently purchased on-site.
Connecticut (multiple locations)	27.3 MW	Five projects approved in 2009 under the state's Project 150, all of which were FuelCell Energy fuel cells: • 3.4 MW at a natural gas letdown station in Bloomfield; • 3.2 MW at a natural gas substation in Danbury; • 14.3 MW in Bridgeport; • 3.2 MW in Trumbull; and • 3.2 MW in Glastonbury.
Korea (multiple locations)	30.8 MW	Includes licensing agreement with POSCO Power, which is building a manufacturing facility in Korea.

Table 6: Summary of FuelCell Energy 2009 Projects
Source: Fuel Cells 2000

license fee, agreed to pay royalties on POSCO's sales of fuel cell stack modules, and purchased $25 million in FCE common stock, increasing its ownership in the company to approximately 13 percent. POSCO also agreed to purchase 30.8 MW of stack modules and components for delivery in 2010 and early 2011. Table 6 provides a summary of major FCE projects in 2009.

UTC Power shipped its first 400-kW CHP unit with an 80,000 hour guarantee. UTC Power also made a number of notable sales in 2009, which are set forth in Table 7.

Table 7. Summary of UTC Power 2009 Projects

Location	Generation Capacity	Notes
New York (Hauppauge)	200 kW	Installed at a state office building, providing about 25 percent of the building's electricity requirements. Funding was provided by the New York State Energy and Development Authority, Long Island Power Authority, U.S. Department of Energy, Petroleum Overcharge Restitution program, and the New York Power Authority.
Massachusetts (Dedham)	400 kW	Fuel cell provides roughly 90 percent of the electricity and nearly 100 percent of hot water for a new Whole Foods Market.
Connecticut (Hartford)	200 kW	The Connecticut Science Center will be the nation's first museum or science center to use a fuel cell for most of its power needs.
New York (Elmsford)	800 kW	Coca-Cola Enterprises will install two 400 kW fuel cell systems, which will be owned, operated and maintained by UTC Power under an energy services agreement.

Table 7: Summary of UTC Power 2009 Projects
Source: Fuel Cells 2000

Other significant distributed generation projects and developments in 2009 include:

- Ballard Power Systems signed a contract with FirstEnergy Corp. to deliver its 1 MW FCvelocity™ fuel cell system to provide peaking capacity and load management.
- Microcell Corporation's MGEN1000 fuel cell system was installed at an electric cooperative in North Carolina to provide peak shaving.
- The Environmental Energy Technology Centre in Rotherham, England, announced that it is developing a Hydrogen Mini Grid System (HMGS), designed to be the largest wind-to-hydrogen installation in the U.K and the first to generate hydrogen for both vehicle refueling and electricity generation. Hydrogenics is providing three 12-kW fuel cells for the project, which is expected to open in early 2010.
- The Erdinger Weißbräu brewery in Germany installed MTU's HotModule HM300 MCFC to generate electricity from biogas. The thermal energy will heat the brewery's buildings and will provide hot water.

- Hydrogenics received an order for HyPM Rack fuel cell power modules that will used by Greenland's national energy company, Nukissiorfiit, for a renewable energy project designed to assess the potential of using hydrogen for energy storage and management.

- The World Economic Forum selected Bloom Energy as one of 26 Technology Pioneers in 2009. Several corporations began testing Bloom's fuel cells during 2008 and 2009, including five 100-kW units deployed at eBay's San Francisco headquarters.

Small Stationary

Back-up power for the telecommunications industry also continued to show strong sales, with hundreds of units ordered or deployed in several countries. Moreover, the DoE ARRA funding provided $18.6 million for telecommunications backup power, which is discussed in more detail below in the Government Policy section.

Residential CHP continued to advance toward greater commercialization, especially in Asia and to some extent in the United States. ClearEdge Power grew from 40 to 150 employees and expanded its manufacturing facility in Oregon. The company sold four fuel cells to Universal Studios and made other significant sales, including to the wife of country music legend Gene Autry and to a McDonald's restaurant in Oregon. The company has an order backlog of 300 units, and CEO Russell Ford stated that he expects ClearEdge to grow to 300 employees and $50 million in sales in 2010.

Figure 10: ClearEdge CS5 unit. Photo Courtesy of ClearEdge Power

Korea Gas is winding down the monitoring and evaluation phase of a 1 kW residential fuel cell program, testing 210 units from three manufacturers. The company anticipates beginning demonstrations in 2010, with a goal of 2,000,000 installed by 2020. Also in Korea, ClearEdge Power announced an exclusive distribution agreement with LS Industrial Systems, with is expected to be worth $40 million and result in the sale of up to 800 ClearEdge5 units in Korea.

Six Japanese utilities began selling residential PEM fuel cell systems, via a marketing consortium called ENE-FARM, with a goal of 5,000 units in the first year[5]. The fuel cells are produced by three companies (Panasonic, Toshiba Fuel Cell Systems, and ENEOS Celltech). More than 5,000 units were sold in 2009, and a similar number is expected to be sold in 2010.

Finally, Ballard announced that it plans to discontinue EBARA Ballard Corporation, a joint venture with EBARA Corporation focused on the development, manufacture, sale, and servicing of stationary power systems for the residential cogeneration market in Japan. Ballard noted that it still sees opportunities

[5] http://www.istockanalyst.com/article/viewiStockNews/articleid/2990159 Companies include Tokyo Gas, Osaka Gas, Nippon Oil, Toho Gas, Saibu Gas, and Astomos Energy

for growth in the residential cogeneration market, but that the timeline for commercialization is longer than Ballard had initially anticipated.

Other major developments or announcements regarding small stationary in 2009 include:

- Plug Power installed a GenSys® unit at Union College and was awarded $1.4 million to install three GenSys® fuel cells in New York homes. Plug Power also agreed to supply 200 GenSys® fuel cells for cell towers in India and to produce the fuel cells in India.
- IdaTech received an order for 30 fuel cells from b+w Electronic Systems GmbH and deployed 43 fuel cells for the cellular network in Mexico.
- CFCL, an Australian Company, opened a high volume SOFC stack manufacturing plant in Germany with a manufacturing capacity of 10,000 stacks per year.
- Ceres Power, a UK company, will develop liquefied petroleum gas (LPG) fuel cells for Calor Gas, and Calor placed an order for 20,000 of the units, conditional upon successful development. Ceres entered into a similar agreement with an Irish energy company for natural gas units.
- Toyota announced that it will develop a residential SOFC.
- Ballard announced that its 1.6 kW fuel cells will be used for back-up power for the emergency radio network in Denmark.
- Dantherm Power installed a fuel cell backup power system for a municipal radio system in Columbia, South Carolina.
- ReliOn introduced the Eco-200 PEM fuel cell power system, a 175-W system that can provide back-up power for days, rather than hours for battery powered systems.
- Horizon Fuel Cells introduced the GreenHub line of PEM uninterrupted power systems, which range from 500 W to 2 kW.
- SFC Energy AG introduced its new EFOY Pro 2200 fuel cell for off-grid industrial applications, such as security cameras.

Transportation Applications

Transportation applications continued to be high profile in 2009, most notably for developments in light duty vehicles and in the materials handling industry. The Honda fuel cell-powered Clarity FCX was awarded the "World Green Car of the Year' award at the New York International Auto Show.[6] Shortly thereafter the DoE proposed eliminating funding for its applied R&D for hydrogen in light duty vehicles, and to focus instead on battery and other advanced vehicle funding. Congress eventually restored most of the hydrogen fuel cell vehicle funding, based in part upon the progress demonstrated by industry. However, the lack of a hydrogen refueling infrastructure continues to be widely regarded as a significant obstacle to fuel cell vehicle commercialization.

Figure 11: Honda Clarity
Photo Courtesy of Honda

A nine-day Hydrogen Road Tour, which started in Chula Vista, California and ended in Vancouver, British Columbia, Canada, was organized by the California Air Resources Board (CARB) and sponsored by the California Fuel Cell Partnership, National Hydrogen Association, U.S. Fuel Cell Council and Powertech Labs, Inc. (on behalf of British Columbia, Canada). The Tour spanned 28 cities and covered roughly 1,700 miles. Participating automakers included GM, VW, Daimler, Honda, Nissan, Toyota and Hyundai. The Tour was designed to highlight communities where hydrogen stations are deployed and fuel cells are entering early commercial markets.

In 2009, the automakers re-affirmed their commitment to commercialization goals. Daimler began small series production of its F-Cell vehicle with plans to increase to tens of thousands of vehicles in the 2012-2015 timeframe. Similarly, Hyundai-Kia announced plans to produce 1,000 fuel cell vehicles per year in 2012, increasing to 10,000 a year by 2015.

In Europe, seven automakers signed a joint letter affirming that "from 2015 onwards a quite significant number" of fuel cell vehicles could be on the road in Europe, conditional upon sufficient fueling infrastructure. Fuel providers responded by establishing their own planning entity, H2 Mobility, to promote that infrastructure.

South Korea had six hydrogen stations in operation and four more planned at the end of 2009. The California Fuel Cell Partnership published a plan to prepare the fueling infrastructure in California for an estimated 50,000 fuel cell vehicles by 2017.

Fuel cell vehicle performance continues to improve. Two DoE National Laboratories verified that the Toyota Highlander fuel cell vehicle can achieve an estimated range of 431 miles on a single full tank of compressed hydrogen, with an average fuel economy of 68.3 miles/gallon. Through DOE's Technology

[6] http://world.honda.com/news/2009/4090409FCX-Clarity/

Validation efforts, fuel cell vehicles have travelled a total of 2.5 million miles and achieved 75,000 mile durability.

Other light duty vehicle and bus highlights from 2009 include:

- The General Motors (GM) Project Driveway demonstration surpassed one million miles in September 2009, with more than 5,000 participants.
- GM and its Chinese partner Shanghai Automotive Industry Corp. launched the Shanghai Brand Fuel Cell Vehicle, powered by GM's fourth-generation fuel cell. Ten vehicles will be built and used to shuttle VIPs at World Expo 2010 Shanghai.
- Sacramento Coca-Cola Bottling Co., Inc. began leasing a Nissan X-TRAIL fuel cell vehicle for sales calls and public events.

Fuel cell buses also made significant advances in 2009. The Van Hool 40-foot fuel cell hybrid, powered by a UTC Power fuel cell, won the Grand Environment Award at Busworld Europe Kortrijk 2009. In addition, Ballard provided 20 fuel cell buses for the 2010 Winter Olympics in British Columbia. The buses, which will continue in service after the Olympics, can operate at freeway speeds and climb a 20 percent grade. Other significant fuel cell bus developments include:

Figure 12: Hydrogenics Fuel Cell Power Lift Truck

- Alameda-Contra Costa Transit District ordered four additional UTC Power fuel cells systems for its hybrid-electric fuel cell bus fleet, bringing its total order to twelve.
- Daimler unveiled its new Citaro FuelCELL Hybrid bus, which will undergo a large-scale fleet test in several European cities.
- A 40-passenger Hydrogenics fuel cell bus was commissioned in Gladbeck, Germany. Hydrogenics also received contracts to provide fuel cell power modules to bus manufacturers Proterra and EVAmerica.
- São Paulo, Brazil debuted Latin America's first fuel cell bus, with a goal of deploying four buses by June 2010.
- A European consortium began development of an 18-meter long fuel cell hybrid bus for use in Cologne, Germany, and Amsterdam, Netherlands.
- The U.S. Federal Transit Administration (FTA) released "A Report on Worldwide Hydrogen Bus Demonstrations, 2002-2007".[7]

[7] http://www.fta.dot.gov/documents/ReportOnWorldwideHydrogenBusDemonstrations_2002to2007.pdf.

- The world's first triple-hybrid fuel cell passenger bus, incorporating a Proton Motor Fuel Cells GmbH 50-kW fuel cell system, batteries and ultracapacitors, was placed into service in Prague.

The materials handling industry continued to show significant strength for fuel cells as battery replacements or battery chargers, with approximately 500 systems in operation around the world and roughly 500 fuel cell-forklifts on order. As detailed in the Government Policy section below, the DoE's ARRA funding allocated roughly $10 million to deploy more than 300 fuel cell-powered forklifts. Plug Power was selected to provide 19 fuel cell power units for a two-year, $1.5 million demonstration project funded by the Department of Defense. The DoD achieved more than 7,000 hydrogen refueling in seven months at the DLA depot in Susquehanna, Pennsylvania, the largest defense depot in the country. (See page 24 for more on fuel cell forklifts at the DoD.)

Private industry continued to invest significantly in fuel cell forklifts, with well over 300 units sold or ordered, including:

- Central Grocers, Inc. purchased 220 Plug Power GenDrive™ fuel cell units to power the entire lift truck fleet at its facility in Joliet, Illinois.
- Nestlé Waters North America installed 32 Plug Power GenDrive™ fuel cell lift trucks at its Dallas, Texas bottling facility.
- Oorja Protonics sold its methanol fuel cells to a dairy products distribution company for use as on-board battery chargers on battery lift trucks in California.
- Nissan North America deployed 60 methanol fuel cells from Oorja Protonics to power its material handling equipment in Tennessee.
- Coca-Cola ordered 40 Plug Power GenDrive™ fuel cell systems to power forklifts in Charlotte, North Carolina.

Figure 13: Plug Power GenDrive Fuel Cell Powered Forklift. Photo Courtesy of Plug Power.

Figure 14: IdaTech Back-up Fuel Cell

At least two companies were focused on developing APUs for trucks, which can substantially reduce air pollution and fuel consumption by enabling trucks to shut down their diesel engines while maintaining power for electrical equipment. Delphi Automotive received $2.4 million in ARRA funds to demonstrate a SOFC fuel cell APU, and PowerCell Sweden AB received $25 million from the Swedish Energy Agency to develop an APU powered by diesel reformed on the truck. Hydrogenics Corporation received a contract to provide fuel cells for use in plug-in fuel cell powered trucks to be demonstrated at the ports of Los Angeles and Long Beach in California.

There was significant fuel cell activity in the marine, recreation, and other markets in 2009, including fuel cells on a ferry in Sweden, a trawler in Australia, and in numerous recreation vehicles.

Military and Portable Applications

The military has been focused primarily on small PEM, SOFC, and direct methanol fuel cells (DMFC). Applications include unmanned vehicles (both aerial and ground), soldier power, and materials handling equipment, such as forklifts. Table 8 summarizes major military fuel cell projects, by company, in 2009.

Table 8. Summary of 2009 Military Funded Fuel Cell Projects

Company	Agency	Project	Funding Level	Technology Type
IdaTech	United States Army	14 EletroGen fuel cell systems for back-up power on voice and data networks in Germany	N/A	PEM
Adaptive Materials	United States Air Force	60-watt, propane-fuelled system for communications, soldier power, and other small applications[8]	$3 million	SOFC
Protonex	United States Army	Liquid- fueled fuel cell systems for APUs, portable generators, and field battery chargers, with a 60 – 80 percent weight reduction over battery powered system[9]	$2 million	SOFC
Protonex	United States Naval Research Laboratory	Develop fuel cell systems for UAVs, Ion Tiger project	$500,000	PEM
Protonex	United States Department of Defense	Fuel cell systems for unmanned aerial vehicles (UAV)	$3.3 million	PEM and SOFC
Protonex	United States Army	SOFC power solutions	$1.5 million	SOFC
Protonex	United States Army	Portable power systems and integrated fueling	$345,000	SOFC and PEM
Jadoo Power	United States Air Force and Army	Develop ammonia borane for fuel stock, to reduce weight of systems	Unknown	For use in SOFC systems
DuPont and SFC Smart Fuel Cell	United States Army	Portable Power units to extend mission times by 72 hours or more	$3 million	DMFC

Table 8: Summary of 2009 Military Funded Fuel Cell Projects
Source: Fuel Cells 2000

[8] http://www.adaptivematerials.com/adaptive-materials-wins-3-million-air-force-contract-to-manufacture-60w-fuel -cells

[9] http://www.protonex.com/_assets/pressrelease/eaaa7b30-ba16-43b2-b4db-0064d9ebde6c.pdf

Fuel cells have substantial value in military applications. Compared with batteries, fuel cells offer smaller package size and weight, longer running times, and a lower heat signature, making them more difficult to detect by infrared scanning. Fuel cells also deliver constant power output over time and can be refueled much more quickly than a battery can be recharged.

In 2009, the DoD announced a PEM fuel cell backup power demonstration project.[10] This program will utilize fuel cells manufactured in the United States for two year demonstrations at bases. In early 2009, the Army Corps of Engineers announced that it will install ten fuel cells at Fort Jackson in South Carolina.[11] In November 2009, DoD issued a Broad Agency Announcement seeking proposals to site fuel cells at 12 federal and military locations. Table 9 shows the proposed host sites.[12]

Table 9: U.S. Army Corps of Engineers Broad Agency Announcement for PEM Backup Power Demonstration

Host Site	Number of Fuel Cells, Total System Power Output
Argonne National Laboratory (Illinois)	3 fuel cells, 30 kW
Cheyenne Mountain Air Force Stations (Colorado)	2 fuel cells, 23 kW
U.S. Army Aberdeen Proving Ground (Maryland)	3 fuel cells, 42.5 kW
U.S. Army Fort Bragg (North Carolina)	1 fuel cell, 15 kW
U.S. Army Fort Hood (Texas)	3 fuel cells, 18 kW
U.S. Army Fort Irwin (California)	7 fuel cells, 45 kW
U.S. Army National Guard/Ohio National Guard (Ohio)	2 fuel cells, 40 kW
U.S. Army Picatinny Arsenal (New Jersey)	4 fuel cells, 20 kW
NASA AMES Research Center (California)	Unspecified
U.S. Marine Corps Air Ground Combat Center 29 Palms (California)	5 fuel cells, 49.56 kW
U.S. Military Academy West Point (New York)	2 fuel cells, 40 kW
U.S. Army Fort Richardson (Alaska)	3 fuel cells, 60 kW

Table 9: U.S. Army Corps of Engineers Broad Agency Announcement.

[10] http://dodfuelcell.cecer.army.mil/backup/index.php
[11] http://www.swampfox.ws/2009/01/16/scras-ati-install-fuel-cells-ft-jackson-sc-0
[12] http://dodfuelcell.cecer.army.mil/FY10_PEM_FC_BAA.pdf

Military fuel cells achieved significant milestones in 2009 as battery replacements.

- Adaptive Materials demonstrated a SOFC-powered unmanned ground vehicle (UGV) that operated for 12 hours in real world conditions, using three 8 oz canisters of commercially available propane gas. The fuel cell increased range and mission time and powered all onboard electronics at a fraction of the cost of other systems. In a comparison test, a battery powered UGV operated for 40 minutes.

- A fuel cell-powered robot using a Protonex hybrid system achieved three times the range of a similar robot powered by batteries alone.

- A small UAV powered by a Protonex fuel cell system set an unofficial endurance record of more than 23 hours, roughly seven times the endurance capability of advanced batteries.

In addition, SFC Smart Fuel Cell released three fuel cell products for military use in 2009: The JENNY, a portable DMFC soldier power pack that can reduce weight by 80 percent compared to battery systems; the Joint Power Manager, which can charge four batteries simultaneously and harmonize all of a soldier's power sources and devices; and the EMILY, an in-field fuel cell generator that can be used as a vehicle APU.

Figure 15: JENNY Portable Power Unit. Photo Courtesy of SFC Smart Fuel Cells

The materials handling market is also an area of focus for fuel cells for the DoD. DLA, which operates military warehouses and supply chains as large as some Fortune 500 companies, deployed 60 fuel cell-powered forklifts at two of its distribution warehouses (Pennsylvania and Georgia) during 2009 to evaluate the business case for fuel cell forklifts, foster competition in the marketplace, and provide early market demand.[13] Fuel cells used in the two-year trials were manufactured by Plug Power, Nuvera, and Hydrogenics. [14] DLA plans additional fuel cell-powered forklift deployments at two more DLA warehouses during 2010. DLA also announced plans to demonstrate 19 PEM fuel cell systems running on wastewater digester gas and 20 fuel cell vehicles using a solar array to generate hydrogen.

Non-military portable and micro fuel cell applications include:

- Two German companies are developing mobile wards and medical trolleys that use fuel cells rather than batteries to power all the necessary computer technology.

- UltraCell demonstrated fuel cells as power sources for modular recognition terminals during a humanitarian training exercise in the Dominican Republic.

- Adaptive Materials introduced a 250 W SOFC system which can recharge batteries.

[13] http://www.dla.mil/
[14] http://www.dla.mil/DLAPublic/DLA_Media_Center/TopStories.aspx?ID=701

- MTI entered into an agreement to test their Mobion DMFC fuel cell in cordless tools for industrial applications.
- Toshiba launched a limited production run of 3,000 Dynario fuel cell chargers in October, offering the unit for sale by winter at about $330 dollars.[15] The charger runs on methanol and can charge two telephones per cartridge.

[15] http://www.techchee.com/2009/10/24/portable-fuel-cell-charger-toshiba-dynario/

Government Policy, Standards and Regulation

In April 2009, DoE allocated $41.9 million from the ARRA to accelerate the commercialization of fuel cells. The funding was matched with approximately $51 million in cost-share, bringing the total to more than $92.9 million. Table 10 provides a summary of the awards and projects:

Table 10. Summary of 2009 American Recovery and Reinvestment Act Fuel Cell Awards

Company	State	Project
FedEx Freight East	Arkansas	$1.3 million to deploy 35 fuel cell systems as battery replacements for a complete fleet of electric lift trucks at FedEx's existing service center in Springfield, Missouri.
Jadoo Power	California	$1.8 million to demonstrate a 1-kW fuel cell.
University of North Florida	California	$2.5 million to further integrate and miniaturize the components of a portable power system for use in mobile computing. Originally awarded to PolyFuel.
Nuvera Fuel Cells	Massachusetts	$1.1 million to deploy 10 fuel cell forklifts.
Delphi Automotive	Michigan	$2.4 million to develop, test and demonstrate a 3- to 5-kW SOFC auxiliary power unit (APU) for heavy duty commercial class 8 trucks.
MTI Micro	New York	$2.4 million to demonstrate a 1-watt consumer electronics power pack.
Plug Power	New York	$3.4 million to validate the durability of Plug Power's 5-kW stationary combined heat and power fuel cell system.
Plug Power	New York	$2.7 million to demonstrate the GenCore® rack-mounted fuel cell back-up power product.
GENCO	Pennsylvania, South Carolina, Ohio	$6.1 million to deploy 156 fuel cell systems as battery replacements for fleets of electric lift trucks at six of GENCO's existing distribution centers.
Sysco	Texas	$1.2 million to deploy 90 fuel cell systems as battery replacements for a fleet of pallet trucks at Sysco's new distribution center in Houston, Texas.
Sprint	Virginia	$7.3 million to demonstrate 1-kW to 10-kW fuel cell systems with 72 hours of on-site fuel storage for backup power to communication infrastructure used by state and local first responders and by public safety answering points (911 centers).
ReliOn	Washington	$8.6 million to deploy 180 fuel cells with a new refillable 72-hour fuel system to locations across the AT&T Mobility Network.

Table 10: Summary of 2009 American Recovery and Reinvestment Act Fuel Cell Awards
Source: Fuel Cells 2000

The ARRA also expanded existing tax credits to 2016 for fuel cell and fueling infrastructure deployment that were scheduled to expire at the end of 2008. The credit raises the cap on the hydrogen fueling facility credit to $200,000, creates a 30 percent tax credit for investment in property used in manufacturing, and raises the ITC cap on fuel cells from $1,000/kW to $3,000/kW ($3,334/kW for residential fuel cells in joint occupancy buildings). The ARRA also created a temporary Grant-in Lieu of Tax Credit program for specified energy properties, which includes fuel cells.

California extended its Self-Generation Incentive Program (SGIP) through 2016, which provides incentives to install distributed generation, including fuel cells, on the customer side of the meter. Fuel cells operating on renewable fuels, such as landfill gas, are eligible for an incentive of up to $4.50 per watt.

In January 2009, the U.S. Department of Transportation (DoT) Pipeline and Hazardous Material Safety Administration issued a final rule harmonizing U.S. regulations with United Nations recommendations to allow transport of fuel cells and a wide range of fuels on board U.S. passenger aircraft as carry-on baggage. The rule also allows routine cargo shipment of fuel cells and fuel cell cartridges by road and rail, as well as international ocean shipment in bulk. Fuels used to power fuel cells allowed as carry-on baggage had previously been limited to only liquid and liquefied gases. The broadening of the regulations to include other fuels removed a barrier to fuel cell deployment on board aircraft for many developers.

In South Korea, the national government committed to pay 80 percent of the cost of purchasing and installing residential fuel cells until 2012. The subsidized percentage will drop to 50 percent from 2013 to 2016, and to 30 percent in the last three years leading up to 2020. The goal is to install 2,000,000 residential fuel cells by 2020 and to decrease the cost of the fuel cell from 50 million Won ($40,000 U.S.) to 10 million Won ($8,000 U.S.) in 2015 and 5 million Won ($4,000 U.S.) by 2018. More details on fuel cells in Korea are available below.

In Japan, the national government is supporting commercialization of residential fuel cell systems by subsidizing 50 percent of the user's system and installation costs. Six Japanese companies began selling residential fuel cell systems under the ENE-FARM brand name and increased their sales target from 1,500 units to 2,100 units because of strong demand.

Phase one of Germany's H_2 Mobility project was initiated in 2009, starting the process of nationwide roll-out of hydrogen fueling stations that will support introduction of series-produced hydrogen powered vehicles in 2015. Leading German industrial companies signed a memorandum of understanding in 2009 to foster development of hydrogen vehicles and infrastructure (Daimler, EnBW, the Linde Group, NOW, OMV, Shell, TOTAL, and Vattenfall), while major auto manufacturers (Daimler, Ford, GM, Opel, Honda, Hyundai, Kia, Renault, Nissan and Toyota) signed a letter of understanding that anticipates, from 2015 onwards, commercialization of a "significant number" of fuel cell vehicles and supporting the build-up of hydrogen infrastructure in Europe, and eventually worldwide, with Germany as a starting point.

Additionally, the UK announced a feed-in tariff (FIT) for residential generation up to five kW. The FIT is designed to help meet the UK's target of 15 percent renewable by 2020, and fuel cells fed by either natural gas or LPG qualify.

Spotlight on Korea

In the last few years, South Korea has emerged as a global player in the fuel cell industry. The country has committed itself to capturing 20 percent of the global fuel cell market and to creating 560,000 domestic jobs.[16] It has committed to substantial fuel cell deployments, including the deployment of 100,000 residential fuel cells by 2012[17] and to using fuel cells to provide roughly half of all renewable energy consumed in Seoul, one of the world's largest cities.

To accomplish this, South Korea is developing domestic fuel cell technology, acquiring intellectual property and products developed in the United States, focusing on low cost manufacture through domestic sourcing wherever possible, and providing aggressive incentives to consumers for the adoption of fuel cells. In other words, developing a domestic, export-oriented fuel cell industry has become a national priority, and the policies, funding, and strategies are in place to make that priority a reality.

Background

South Korea is slightly larger than the state of Indiana and ranks 108th in the world in terms of total national land area. South Korea has a relatively high population density, ranking 26th in terms of national population, with 48.6 million residents in 2010. Moreover, 81 percent of the population is in urban areas, with the Seoul National Capital Area accounting for roughly half of the national population. South Korea is the tenth largest consumer of energy in the world but has few domestic energy resources, so the country is highly dependent upon imports.

South Korea is widely considered a modern economic success story. Impoverished and devastated after the Korean War ended in 1953, the country is now among the world's twenty largest economies, with a GDP per capita roughly equivalent to Israel, Slovenia, and New Zealand. Korean conglomerates such as Samsung and LG have become global leaders in a variety of markets, including cell phones, televisions, computer chips, and consumer appliances. Hyundai is now the fifth largest automaker in the world, and South Korea is ranked fifth among auto-making nations in terms of annual production.

South Korea's success has been built substantially as an export economy. In 2009, South Korea was the world's ninth largest exporter, with total exports of nearly $374 billion. A recent and significant depreciation of the Korean won vis-à-vis the U.S. dollar has helped boost Korean exports.

[16] Park, Dal-Ryung. "Roadmap-Commercialization of Fuel Cell Technologies in KOREA". Given at Fuel Cell Expo 2010, Tokyo Japan.
[17] Park, Dal-Ryung. "Current Status of Demonstration for Stationary Fuel Cells in Korea".

Energy Sector

South Korea is the world's fifth largest importer of oil and second largest importer of liquefied natural gas. Table 11 shows the energy consumption by type in South Korea, and Table 12 shows electricity generation, by type.

Table 11. South Korea Energy Consumption, by Type (2004)	
Type	**Percentage**
Oil	50%
Coal	24%
Nuclear	14%
Natural Gas	12%
Renewable	<1%

Table 11: South Korea Energy Consumption, by Type (2004) Source: U.S. Department of Energy, Energy Information Administration

Retail electricity rates in Korea are subsidized and are relatively low, ranging from $0.06 per kilowatt hour (excluding tax) for industrial customers to $0.089 per kilowatt hour (excluding tax) for households.[18] By contrast, natural gas tends to trade at market prices and is relatively expensive, with an average price of approximately $0.58 per cubic meter for households, $0.45 for industrial customers, and $0.61 for electricity generation in 2008.[19] The result is that, for fuel cells to be economically competitive in Korea at the present time, they must have relatively low capital and operating costs and relatively high electrical and thermal efficiency, with a valuable use for the waste heat.

Table 12. South Korea Electricity Production, by Type (2008)	
Type	**Percentage**
Nuclear	39%
Coal	38%
Natural Gas	13%
Oil	8%
Hydro	1.7%

Table 12: South Korea Electricity Production, by Type (2009) Source: Hyundai-Kia Motor Company

Government Policy and Programs

In 2003, the government issued a 10-year plan for the development of the new and renewable energy industry. Between 2004 and 2008, roughly $500 million was invested in fuel cell R&D, and demonstration programs were established for residential applications and vehicles.[20]

In 2008, the government announced a revised plan, with the primary goal of accelerating commercialization. Under this plan, fuel cells were selected as one of the nation's "new growth engine" technologies, with specific emphasis on small stationary (residential fuel cells), large stationary (fuel cell power plants), and vehicles. The goal is to have approximately 10 percent of the nation's renewable electricity generated from fuel cells by 2030. The Seoul metropolitan area has established a more aggressive goal, seeking to achieve 50 percent of its renewable electricity generation from fuel cells by 2030.[21]

The plan has three phases designed to lead to a fully developed commercial market for fuel cells by 2030:

[18] http://www.eia.doe.gov/emeu/international/elecprih.html
[19] Calculated by Fuel Cells 2000 from data available at the Energy Information Agency. http://www.eia.doe.gov/emeu/international/gasprice.html
[20] Butler, Johnathan. FuelCell Today. "2010 Survey of Korea" p. 11. http://www.fuelcelltoday.com/media/pdf/surveys/Korea-Report-Free.pdf
[21] "Seoul to become a Global Climate-Friendly City by 2030:-Reduce Carbon by 40 percent, Create 1 million Green jobs".

- Phase I (2009-2012) focuses upon research, development, and demonstration of components and high value added applications. Current activities include developing domestic production of fuel cell stacks, core components, and balance of plant, as well as additional demonstrations, especially of residential fuel cells and vehicles.

- Phase II (2012 – 2020) consists of early commercialization and market penetration for fuel cell power plants, residential fuel cells, and vehicles. There appears to be a particular emphasis on establishing export-oriented businesses.

- Phase III (2020 – 2030) focuses upon market expansion, with the goal of achieving a hydrogen economy.

A wide range of programs and incentives have been implemented to support the development of the Korean fuel cell industry. These include:

- a feed-in-tariff of roughly $0.10/kWh for up to 50MW of fuel cell distributed generation installed between 2008 and 2011;

- a renewable portfolio standard that, beginning in 2012, requires 350 MW of additional renewable energy per year through 2016 and 700 MW per year through 2022. The goal is to achieve 10 percent generation capacity from renewable sources by 2022;

- an 80 percent subsidy from the national government for residential fuel cells, decreasing to 50 percent by 2013;

- a 10 percent subsidy by local government for residential fuel cells;

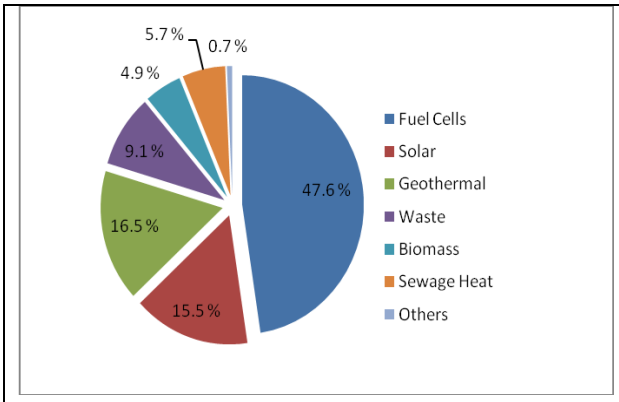

Figure 16: Anticipated Renewable Energy Generation (Percent) in Seoul, Korea by 2030. Source: Municipal Government of Seoul

- a requirement that new public buildings larger than 3,000 square meters invest at least five percent of construction costs in new and renewable energy; and

- a policy by Seoul city to create one million green jobs and reduce CO_2 emissions by 40 percent by 2030. The policy will be implemented by, among other things, ensuring that 20 percent of energy consumed in Seoul will be from new and renewable sources. Of this 20 percent, Seoul anticipates that nearly half will be derived from fuel cells, with the remainder divided among solar, geothermal, and other renewable sources. (See Figure 16)

The focus in Korea currently is on PEM residential fuel cells, known locally as residential power generators (RPG's). There also is development work on SOFC RPGs underway. The short term (2012) technical targets are to achieve electrical efficiency of 38 percent, thermal efficiency of 48 percent,

durability of 40,000 hours, and a cost of $20,000.[22] The long term (2030) technical targets are to achieve electrical efficiency of 40 percent, thermal efficiency of 50 percent, durability of 90,000 hours, and a cost between $3,000 – $5,000.

Korea Gas is completing a three-year evaluation of 1 kW natural gas RPGs from three companies: GS Fuel Cell, FuelCell Power, and Hyosung. At the end of the second year, the average electrical efficiency was 33.5 percent and the average thermal efficiency was 46.3 percent. Two of the companies in the program had achieved durability of at least 20,000 hours. Moreover, at the end of the second year, most of the failures were the result of problems with balance of plant, such as pumps and valves, not the fuel cell stack itself.

Korea also is working to develop large stationary CHP power plants, primarily using MCFC. The Korea Electric Power Corporation (KEPCO) has been developing its own MCFC but does not appear to be as advanced as POSCO Power, which licensed FuelCell Energy's molten carbonate fuel cell. Several FuelCell Energy units are operating in the country, and POSCO is building a new factory to assemble stacks and balance of plant. In addition, Samsung has imported UTC Power large stationary fuel cells for a power plant near Seoul.

According to the city government, fuel cells have significant advantages over other renewable energy technologies in a large, dense urban area such as Seoul. Among other things, fuel cells provide constant power as well as hot water, which can be used for district heating and cooling. Fuel cells also require less space than solar and are less intrusive than a large wind farm. Thus, as discussed above, the city hopes to generate half of its renewable energy from fuel cells.

Hyundai-Kia has been a global leader in fuel cell vehicles, developing 100-kW and 115-kW stacks for cars and a 200-kW stack for buses. Hyundai's Chairman, Mong-Koo Chung, has made the commercialization of fuel cell vehicles a top priority. In 2012, Hyundai will release the Tucson iX, its next generation vehicle that Hyundai claims will achieve more than 400 miles on a single tank of 700 bar hydrogen. The Tucson iX will have a 100-kW stack with a durability target of 5,000 hours.

There is relatively little activity in Korea on portable fuel cells. One exception is Samsung which, under contract with the U.S. Department of Defense, is developing portable DMFC's for soldier power and is preparing to enter field testing. Among other things, the fuel cells are expected to run for three days on a single methanol cartridge and to operate regardless of their physical orientation.

[22] Park, Dal-Ryung. "Roadmap-Commercialization of Fuel Cell Technologies in KOREA." Fuel Cell Expo 2010, Tokyo Japan.

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 a snapshot of select fuel cell OEMs and other significant players in the industry, and updates their fuel cell activities in 2009.

Public Companies

Ceres Power

Ceres Power	
Company Type	Public (Symbol: CWR)
Fuel Cell Type	SOFC
Primary Market Interest	Residential CHP, Portable Power, Auxiliary Power Units
Employees	Approximately 85
Manufacturing Capability	Not reported
Headquarters	Horsham, West Sussex, United Kingdom

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 SOFC systems for small scale, combined heat and power systems.

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. In 2009 Ceres Power leased a new manufacturing facility in Horsham. The 50,000 square foot facility will be used to assemble fuel cell stacks and modules and the first production line began in December. The company continued to grow in 2009, adding nearly 30 new staff members in manufacturing, product development, supply chain management, and product testing.

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, up to 65 percent of the energy is lost. The housing stock in the country contributes 27 percent of all 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 have already begun. In January 2009 the company entered into a distribution agreement with Calor Gas to help develop units that could run off of LPG. The company has also entered into an agreement with Bord Gais in Ireland.

Ballard Power Systems

Ballard Power Systems, Inc. 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 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.

Ballard Power Systems	
Company Type	Public (Symbol: BLDP)
Fuel Cell Type	PEM
Primary Market Interest	Backup power, supplemental power, distributed generation, material handling, heavy duty
Employees	Approximately 400
Manufacturing Capability	17,000 stacks per year
Headquarters	Burnaby, Canada

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 the year with significant momentum going into 2010. 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.

Ballard Products	2009	2008	2007
Material Handling	182	508	204
Back-up power	988	720	200
Residential Cogeneration		403	445
Automotive & Others		224	186
Total Shipments		**1855**	**1035**

Ballard has continued decreasing its participation in the automotive fuel cell market. In early 2008, the company sold its automotive fuel cell research and development assets to Daimler AG and Ford Motor Company, and is no longer directly involved in automotive fuel cell research and development. Ballard remains a 19.9 percent shareholder in AFCC, a joint venture among the three companies to develop fuel cell stacks for automotive applications.

Additionally, Ballard discontinued its operations with the EBARA Corporation in May. Previously, Ballard had been involved in systems development for the residential cogeneration market through a joint venture with the EBARA Corporation of Japan.

Ceramic Fuel Cells Limited

Ceramic Fuel Cells Limited	
Company Type	Public
Fuel Cell Type	SOFC
Primary Market Interest	Stationary power
Employees	Not reported
Manufacturing Capability	Germany: 20 MW per year Melbourne: 0.4 MW per year
Headquarters	Melbourne, Australia

Ceramic Fuel Cells Limited (CFCL) is a developer of SOFC products for small-scale micro combined heat and power (m-CHP) applications, and distributed generation units that cogenerate electricity and heat for domestic use. 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.

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

1. Development of integrated micro-Combined Heat & Power (micro-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.

To implement this strategy, CFCL has established a plant in the UK to produce ceramic powders and has established a fuel cell stack manufacturing plant in Germany to enable large scale manufacturing of its fuel cells - up to 10,000 fuel cell stacks per year, and the plant can be extended to produce up to 160,000 fuel cell stacks/year. In 2009, The Company exceeded technical objectives with CFCL's fuel cell technology delivering 60 percent electrical efficiency for customer units installed in 2009 and 2010

During 2009, CFCL extended several agreements to further develop and deploy fuel cell m-CHP units in Europe and Australia:

- CFCL and energy company EON extended their agreement to collaborate on a joint development project to commercialize mCHP units designed specifically for the Great Britain market. The commercialization project is scheduled to run from 2009 to 2012, in a number of stages subject to performance criteria, followed by market launch in Great Britain.

- CFCL and energy company GDF Suez extended their agreement to develop and deploy mCHP units in France. CFCL and De Dietrich Remeha are developing a mCHP unit which will produce

up to 2 kW of electric power and provide hot water for use in French households. This agreement to move to the next stage of product development follows the successful completion of the first phase of the partners' product development, delivering a semi-integrated prototype unit to meet performance requirements for the French market.

- In November 2009, CFCL and Japanese appliance manufacturer Paloma (owners of the Rheem brand) extended cooperation and signed an agreement to install BlueGen® as part of Paloma's Sapporo sales office in Japan. Installation is scheduled for May 2010.

- CFCL appointed Neco, a green retailer, to distribute the company's BlueGen® power and heating units in Australia. The non-exclusive agreement gives Neco the right to market, sell, install and service BlueGen® units. The first BlueGen® units will be used for demonstration programs and showcase sites. Installation in residential and commercial buildings will begin from March 2010.

CFCL is also partnering with German utility, EWE, for development of fuel cell CHP units for the German market.

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 as "ultra-clean" under CARB standards.

FuelCell Energy	
Company Type	Public (Symbol:FCEL)
Fuel Cell Type	MCFC
Primary Market Interest	Large stationary power
Employees	Approximately 300
Manufacturing Capability	Not reported
Headquarters	Danbury, Connecticut

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. This is an important step towards achieving profitability. FCE is optimistic about future markets, especially in California, where the Governor signed SB412 which will extend the Self-Generation Incentive Program (SGIP). To date approximately 15 MW of FCE power plants have been installed in California with SGIP assistance, 9 MW of which use renewable biogas as a fuel.

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.

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 is located in Korea. The company's second market focus is wastewater treatment facilities, and the use of biogas. The City of Tulare, California purchased a fourth FCE DFC300 series fuel cell to bring their installation up to 1 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 California. The onion grower and processor is using the nearly 300,000 pounds of onion waste generated every day to produce digester gas to power the two 300 kW fuel cells, saving up to 30,000 tons of CO_2 each year.

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 all their two business units.

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

Hydrogenics Sales (Millions)				
Product or Service	**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**

Hydrogenics is involved in a range of applications, including

- Hydrogen generators for Industrial processes and Fueling stations;
- hydrogen fuel cells for electric vehicles, such as urban transit buses, commercial fleets, utility vehicles and electric lift trucks;
- fuel cell installations for freestanding electrical power plants and UPS systems (uninterruptible power supply); and

- hydrogen storage and power systems for optimizing solar and wind systems during lulls and peaks.

The corporate headquarters are in Mississauga, Canada. Hydrogenics has other corporate and sales offices, and hydrogen installations, operating in countries around the world.

Hydrogenics Corporation is a publicly listed company on the Nasdaq Global Market (stock symbol HYGS) and the TSX (stock symbol HYG).

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, Investec Asset Management, 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	Approximately 90
Manufacturing Capability	Up to 5,000 units
Headquarters	Bend, Oregon

IdaTech offers a family of backup power fuel cell products under the ElectraGen™ series, which can be powered by hydrogen gas, or a methanol water mix unique to the industry. The ElectraGen™ ME series 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 hydrogen as a fuel. The H2 systems are best for applications with short backup duration needs.

The company's goal in 2009 was to focus on achieving profitability in the near term. They worked throughout the year in four areas: seeding the market, new product development, lean production, and focusing on execution. IdaTech increased its distributor network to 35 partners worldwide to help expand target markets.

In 2009, IdaTech added new customers, and completed product certification tests, which has led to an increase in average order size since 2008. Revenues for the year were almost double that of 2008, at $6.6 million dollars, the average order size increased as volume grew but selling price per unit dropped. Overall, in 2009 IdaTech sold 445 systems.

In October 2008, IdaTech signed a supply agreement with ACME Telepower to deliver fuel cell systems for telecommunications deployment in India. That agreement was dissolved at the end of 2009, when IdaTech entered into a distribution contract with ACME Telepower.

IdaTech is also participating in Germany's National Programme for Innovation through its German OEM partner and distributor, b+w Electronic Systems GmbH.

Plug Power

Plug Power focuses on the design, development and manufacture of PEM fuel cell systems in the material handling and stationary power markets. More than 1,000 Plug Power units have been deployed worldwide. 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 (Symbol: PLUG)
Fuel Cell Type	PEM
Primary Market Interest	Materials handling, Stationary Power
Employees	Approximately 212
Manufacturing Capability	10,000 units per year
Headquarters	Latham, New York

The company considers itself to be a development stage enterprise, because nearly all of its resources are devoted to improving fuel cell reliability and durability and to building and expanding markets. However, the company expects to enter the commercial adoption phase in 2010 for the GenDrive and GenSys line of products. In 2008, the company posted a net loss of $22.8 million in the second quarter of 2008. Net loss went down in 2009 to only $40.7 million for the year.

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

Plug Power 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 Wal-Mart, Bridgestone Firestone, Nestle Waters, Central Grocers, and Sysco Foods. The company's GenSys line for backup power offers a low temperature, LPG fueled system designed for continuous power in remote applications, focusing on the telecommunications sector.

Plug Power is also developing a residential GenSys®, which is a high temperature, PEM fuel cell system that reforms natural gas on-site, providing combined heat and power for residential and light commercial applications. The company estimates that it will save consumers 20 – 40 percent off of utility bills and reduce carbon dioxide emissions by 15 – 25 percent compared to incumbent technologies. The residential GenSys is not commercially available at this time.

2009 was a significant year for Plug Power in the materials handling market. Orders increased for their GenDrive product by nearly 60 percent. In September, the GenDrive product line hit a milestone when they installed base exceeded a total combined run time of over one million hours of run time. Plug Power sold 19 GenDrive units to the Department of Defense for a demonstration at Ft. Lewis in Washington. 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.
- Nestle Waters purchased 32 fuel cell systems.
- GENCO purchased 136 GenDrive units with funding from the ARRA.

For primary power generation, Plug Power began a test of residential power units at three homes in New York State. Plug Power and SFO Technologies entered into a manufacturing and supply agreement in October to build GenSys power units in India.

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	Public (Symbol: F3C.DE)
Fuel Cell Type	PEM and SOFC
Primary Market Interest	Portable Power, Remote Power, Mobile Power
Employees	Approximately 95
Manufacturing Capability	Not reported
Headquarters	Southborough, Massachusetts

In 2009 Protonex demonstrated fuel cell power units for military applications across all branches of the U.S. military. These contracts included development of fuel cell systems for unmanned ground vehicle, unmanned aerial vehicles, and soldier portable power. In October Protonex set the unofficial endurance record for unmanned aerial vehicle flight with the Ion Tiger, flying over 23 hours. This flight surpassed the endurance for flight from any technology type. The company also launched the SPM and BPM power managers for military power in 2009. These two products are durable enough to work in a combat setting, and can help soldiers reduce the number and types of batteries carried in their packs.

Protonex is also focusing on the recreational vehicle market, providing mobile power. In 2009 the company entered into a partnership with Cummins Power Generation to promote the M250-B product line for vehicle auxiliary power.

SFC Energy AG

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

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

SFC targets the leisure, industrial, defense, and automotive markets. SFC has deployed nearly 20,000 commercial unites 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 light electric 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 the "EFOY" ("energy for you") brand fuel cell for the leisure 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. At the 47th Annual National RV Trade Show in Louisville, Kentucky, Jayco Inc., a privately held RV manufacturer, and SFC announced a joint research and market development alliance to study the feasibility of fuel cell technology in RVs in North America. To date more than 14,000 EFOY systems have been sold worldwide.

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.

SFC also focuses on the military market. Its lightweight, ultra-compact power sources won numerous awards, including the $1 million dollar U.S. DoD Wearable Power Prize in October 2008[23], and the Wall Street Journal's 2009 Technology Innovation Award. SFC and DuPont received an order from the U.S. Army for the development of the M-25 fuel cell, a portable power supply designed to extend soldier mission times over conventional power sources. The M-25 is part of an integrated body-worn power source that can be carried by the soldier, and is up to 80 percent lighter than conventional power sources. However, both the European and U.S. defense markets were weakened in 2009, leading to the delaying of programs, and subsequently SFC sales. Despite these setbacks, SFC launched two military products in 2009. The JENNY portable power system was launched in February, and is compatible with the company's power manager system. The EMILY was launched in October and acts as a fuel cell generator. The EMILY can also be integrated into vehicles for auxiliary power.

[23] See http://www.sfc.com/en/wpp-man-portable.html

For automotive markets, SFC has shipped already over 500 systems as auxiliary power units (APU`s) for special-purpose vehicles. Furthermore, SFC is developing solutions for combined heat and power generation onboard battery vehicles. Extending the range of battery vehicles, and solving the limitations in cold weather, will significantly improve performance and user acceptance of battery vehicles.

Recently, the company announced a name change: the old "SFC Smart Fuel Cell" was replaced by "SFC Energy" in order to reflect the broadening of the business model, and the positioning as a provider of whole-product solutions for off-grid markets.

UTC Power

UTC Power	
Company Type	Public (Symbol: UTX)
Fuel Cell Type	PAFC, PEM
Primary Market Interest	Large stationary, transportation, aerospace
Employees	Approximately 600
Manufacturing Capability	75 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 and for transportation, defense and space applications. The company has been involved with fuel cell technology since being founded in the 1950s, when it first launched fuel cells to provide electric power, heat, and drinking water on U.S. manned space flights. UTC Power has installed hundreds of stationary fuel cell units at buildings around the globe, and its latest-generation 400 kW system is now providing power for some of the world's most recognizable companies. UTC Power's zero-emission transportation fuel cell system powers buses for several U.S. and international transit programs and sets the industry standard for durability. UTC Power is the only fuel cell company to have worked with all five major fuel cell technologies, and to produce fuel cells for both stationary and transportation applications.

UTC Power manufactured the first commercially available stationary fuel cell to provide on-site building power in 1991. Since that time the company has installed units worldwide that have accumulated more than one billion kWh of experience. The PureCell® Model 400 System is a clean, quiet, efficient and reliable stationary fuel cell powerplant. The standard PureCell solution is a grid-connected unit, operating in parallel with electric utilities; alternative configurations include the ability to operate in a grid-independent mode. 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. Based on phosphoric acid fuel cells (PAFC) technology, the Model 400 has a warranty for a 20-year product life with a 10-year stack life, overall system efficiency of up to 90 percent, and is designed to operate in water-balance – no consumption or discharge of water in normal operations – saving millions of gallons of water when compared to central generation and other fuel cell technologies. Current users of the company's fuel cell products include public safety facilities, schools, supermarkets, bottling facilities and mixed-used developments.

The company's transportation PEM fuel cell product, the PureMotion® Model 120 System, is powering six transit buses in commercial service in the U.S. and in Europe. The Model 120 is ideally sized for transit vehicles, and generates up to 120 kW of power. The modular design is intended to maximize uptime and simplify routine maintenance. The powerplant is particularly well-suited for integration into hybrid vehicle applications. Technology introduced in 2007 currently has demonstrated world-class durability of over 7,500 hours of commercial operation and units fielded in 2010 should improve on that milestone with the introduction of more advanced technology.

Private Companies

Bloom Energy

Bloom Energy	
Company Type	Private
Fuel Cell Type	SOFC
Primary Market Interest	Distributed Power Generation
Employees	300 (estimated)
Manufacturing Capability	Not reported
Headquarters	Sunnyvale, California

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.

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.

ClearEdge Power

ClearEdge Power	
Company Type	Private
Fuel Cell Type	PEM
Primary Market Interest	Residential and small commercial applications
Employees	Approximately 145
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 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 small commercial buildings. 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 either natural gas or propane. 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.

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 instant rebate totaling $12,500 as well as a federal ITC in the $5,000-$15,000 range. In June 2009 ClearEdge entered into an agreement with LS Industrial Systems to sell, distribute, and service over 800 of the CE5 commercial units in the Korean market and has serious discussions underway for distribution in a number of other countries.

Prototype CE5 units have been deployed at a variety of sites, including hotels, fire stations, restaurants, offices, multi-unit apartment buildings, commercial buildings, and private residences. ClearEdge is ramping up its manufacturing facility and expanding its regional customer support, creating jobs in California and Oregon. ClearEdge claims that the CE5 can reduce residential carbon dioxide (CO_2) emissions by more than 33 percent and can reduce utility bills by up to 50 percent.[24]

Horizon Fuel Cell Technologies

Horizon Fuel Cell Technologies was founded in 2003. The company produces a variety of fuel cells (0.5W to 5W micro fuel cells, 10W-10kW 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 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.

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

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

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, 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.

As part of its plan to begin portable fuel cell commercialization - 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 anticipation of entering the vehicle market, in June 2009, Riversimple, located in London, unveiled an "open source" personal hybrid urban vehicle using a 6-kW fuel cell from Horizon, combined with supercapacitors and regenerative breaking systems. The vehicle offers an energy efficiency of 360 mpg, a driving range of 200 miles per hydrogen charge, and is designed for a lease price of 200 GBP/month.

NedStack

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

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 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.

Nuvera Fuel Cells

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

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 one of the first companies in the world to successfully demonstrate a gasoline fuel cell system. In addition, the company has developed a hydrogen generator and hydrogen station that uses steam reformation to produce hydrogen on-site, and unveiled Massachusetts' first hydrogen station, called PowerTap™, located at the Nuvera facility, in August 2008. In November 2008, Nuvera announced that Küsters Zima would be a manufacturing partner for its hydrogen generation product, PowerTap.™

Nuvera is focused on the materials handling industry and has received funding from the DoE. The company sold 14 fuel cell systems and a hydrogen refueling station to H-E-B in San Antonio, Texas to power Class II forklift trucks. Nuvera is also working with East Penn Manufacturing, deploying 20 fuel cell/battery units to the Susquehanna Defense Distribution Depot in New Cumberland, Pennsylvania. The fuel cells have been installed in Yale forklift trucks as part of a two year demonstration project run by the DLA. In April of 2009, Nuvera announced they received a DoE Market Transformation Award to accelerate fuel cell power systems in the materials handling market, funded from the ARRA.

Oorja Protonics

Oorja Protonics	
Company Type	Private
Fuel Cell Type	DMFC
Primary Market Interest	Materials handling
Employees	Not available
Manufacturing Capability	2,000 – 3,000 units per year, 4-6 MW per year
Headquarters	Fremont, California

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.

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 August 2009, Nissan North America replaced 70 battery charging stations with 60 OorjaPacs as its Smyrna, Tennesee manufactering plant, at a net savings of $225,000 dollars per year. These savings come from the fact that the OorjaPac reduces the number of times, and the length of time the batteries

need to be replaced and recharged. Also in August 2009, Super Store Industries ordered additional OorjaPacs only six months after the initial order because the time and monetary savings were so great. Oorja's other customers include Martin-Brower, US Food Service and Unified Grocers.

ReliOn

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	
Company Type	Private
Fuel Cell Type	PEM
Primary Market Interest	Back-up Power
Employees	45
Manufacturing Capability	Scalable as needed through contract manufacturers
Headquarters	Spokane, Washington

ReliOn offers three different commercial products designed around the cartridge architecture. For small scale backup power needs under 175 watts the company debuted its E-200 in 2009. The E-200 is exempt from many air quality standards, even those set by CARB. ReliOn's T-1000 fuel cell system is ascalable product that can provide anywhere from 600 – 1,200 watts. For larger scale power needs, ReliOn offers the T-2000, which can provide 600 – 2,000 watts on a single chassis, or can be combined to provide up to 12 kW of energy.

In 2009 ReliOn received an award from DoEARRA funds totaling $8.6 million dollars. The funding is a cost-share with two customers: AT&T and PG&E (Pacific Gas & Electric). The company plans to install 180 fuel cells with a new refillable 72 plus hour fuel system across the AT&T telecommunications system. ReliOn will also install fuel cells at several PG&E sites to provide emergency and backup power.

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.

In 1997, Daimler, Ford, and Ballard founded the Fuel Cell Alliance to produce fuel cell-powered drivetrains and components for cars, trucks, and buses. In 2008, the Automotive Fuel Cell Cooperation (AFCC) was formed as a private, joint venture among the three companies. Following a successful 10-year Alliance, Ballard then sold its automotive fuel cell assets to Daimler and Ford. These assets are now resident in AFCC, which is responsible for the research and product development of automotive fuel cells. NuCellSys, a subsidiary of Daimler, develops fuel cell system architectures for various platforms. This includes design of the necessary components for supplying the hydrogen and oxygen to the fuel cell stack.

Mercedes-Benz introduced the B-class F-CELL series of vehicles in August, and production commenced at the end of 2009. The first of these vehicles, numbering 200 in total, will be delivered to selected customers in Europe and the USA starting in 2010. In September, Daimler joined many top automotive companies in signing a Letter of Understanding for the development and marketing of fuel cell electric vehicles.

The B-Class F-CELL is the first fuel cell passenger car from Mercedes-Benz to be produced under series conditions. With its 700-bar hydrogen tanks in the sandwich floor unit, it attains a considerable operating range of around 240 miles. Its electric motor develops an output of 136 hp, with a torque of 214 ft-lb.

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. 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. At least 10 of the new buses will be in service in Hamburg, Germany next year.

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, one of the world's largest automakers, traces its roots back to 1908 and 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 development facilities in the U.S. and Europe, which employs more than 400 people GM's fuel cell research is organized as follows:

- Honeoye Falls, New York - fuel cell system development
- Mainz-Kastel, Germany - overall fuel cell propulsion system, including modeling, testing, integration, and on-road testing
- Torrance, California - electric drive development (motor and power electronics)
- Warren, Michigan - basic R&D
- Milford, Michigan - vehicle testing, hydrogen refueling tests
- Pontiac, Michigan - 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. The late 1990s saw debut of the Opel experimental fuel cell vehicle (1997) and introduction of 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 the Sequel, Hy-Wire, AUTOnomy, HydroGen3, HydroGen1, and Precept FCEV. 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. Vehicles were placed with customers in daily, real-world driving conditions. 119 Chevrolet Equinox fuel cell vehicles have been fielded, creating what remains the world's largest fuel cell vehicle fleet. Project Driveway has amassed more than 1.6 million miles, with individual vehicles accumulating more than 40,000 miles. Vehicles were placed with customers in: southern California; New York; Washington D.C.; Michigan; Hawaii; Germany; China; Korea; Japan; and Canada. In 2009 GM introduced their production intent fuel cell concept, which (compared to the Project Driveway propulsion system) is approximately half the size, 220 pounds lighter, eliminates approximately half the parts, and reduces the use of precious metal content from 80 grams (Project Driveway) to 26 grams. The design's sub-systems are highly integrated, allowing the propulsion unit to package into conventional engine compartments, even in low-hood-line cars.

GM is focused on developing the automotive hydrogen fuel cell system for light duty vehicle commercialization and intends to leverage the automotive technology and scale economies for fuel cell applications for other markets including auxiliary power.

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.[26]

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[25]
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"[27] and that their fuel cell vehicles have already proved to be "full function" alternative fuel vehicles.[28] 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. The following year, Honda introduced a hybrid fuel cell/ultra-capacitor vehicle using compressed gaseous hydrogen.

Shortly thereafter, Honda began developing its own proprietary fuel cell technology and built low-volume production lines for fuel cell electric vehicles, systems and stacks. In December 2002, Honda leased five FCX fuel cell vehicles to the city of Los Angeles and delivered another in Japan. It was the first to lease a fuel cell vehicle to an individual retail consumer, the Spallinos in 2005. The company introduced an advanced concept vehicle, the Kiwami, at the 2003 Tokyo Auto Show and developed a fuel cell scooter in 2004. Other concept fuel cell vehicles followed, including the two-seater Puyo in 2007 and the FC Sport in 2008.

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

[25] Employment data solely for fuel cell activities not available.
[26] 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.
[27] http://www.bloomberg.com/apps/news?pid=20601087&sid=afMZ1CSLb2EQ#
[28] "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.

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. Significant advances over Honda's previous generation FCX models include:

- An advanced four-door, four-passenger sedan design;
- a 270 mile (240 EPA certified) driving range, over 30 percent improvement;
- fuel efficiency of 68 miles/kg of hydrogen (60 mpg EPA certified), a 20 percent improvement;
- a 50 percent increase in fuel cell stack power density; and
- a 40 percent smaller and 50 percent lighter lithium-ion battery pack.

The FCX was the first fuel cell car to be certified by CARB and the Environmental Protection Agency (EPA) for everyday use. Both the FCX and the FCX Clarity have been certified by both CARB and EPA as a Zero Emission Vehicle (ZEV) and also by EPA to its Zero Evaporative Emissions standard (ILEV). ZEV and ILEV is the lowest national emission rating. In 2009 the Clarity won World Green Car of the Year by the New York International Auto Show. In September, the Clarity won the Grove Fuel Cell Symposium's Grove Medal.

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 CO2 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, with advancements eliminating the need for a compressor. Both stations are right-sized to produce enough hydrogen fuel for a single car parked at the home.

Toyota

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.

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[29]
Headquarters	Toyota City, Japan

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. In addition to the fuel cell stack and major system components, Toyota manufactures the 10,000 psi carbon fiber hydrogen tanks in-house. The company has announced commercial introduction of a fuel cell vehicle in the 2015 time frame. 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.

Toyota's fuel cell hybrid technology has also been deployed on buses through a joint development effort with Hino Motors. In September 2002, the FCHV-BUS lowfloor bus was certified by Japan's Ministry of Land, Infrastructure and Transport for road use. The latest generation FCHV-BUS is in service at Chubu International Airport, Japan.

In January 2007, Toyota unveiled its hydrogen-powered fuel cell forklift prototype, the FCHV-F. The forklift uses a fuel cell designed and developed by Toyota Industries Corporation.

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.

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

Appendix 2: Examples Fuel Cell Vehicles from Major Auto Manufacturers [30]

Automaker	Vehicle Type	Engine Type	Fuel Cell Size/type	Fuel Cell Mfr.	Range (mi/km)	MPG Equivalent*	Details	Picture
Daimler	A-Class F-Cell	Fuel cell/ battery hybrid	85kW/ PEM	Ballard Mark 900 Series	90mi 145km	56 mpg equiv.	60 fleet vehicles in U.S., Japan, Singapore, and Europe started in 2003 – small fleet in Michigan operated by UPS.	
	B-Class F-Cell	Fuel cell/ battery hybrid	90 kW	N/a	248mi 400km	N/a	Limited production of 200 vehicles began in the end of 2009.	
Ford	Edge FC-PHEV hybrid	Fuel cell/plug-in battery hybrid	N/a	Ballard	305mi 491km	80 mpg	FC is an on-board "generator" to recharge batteries during transit. Charged battery range is 25 mi, FC extends range an additional 280 mi.	
	Advanced Focus FCV	Fuel cell/ battery hybrid	85kW/ PEM	Ballard Mark 900 Series	180mi 290km	~50 mpg equiv.	3-year demo in Vancouver started late 2004. 30 fleet vehicles in Sacramento, Orlando and Detroit.	
GM	Equinox FCEV	Fuel cell/battery hybrid	93kW/ PEM	N/a	200mi 320km	~39 mpg	Leasing started in 2007 – 100 vehicles in California, New York and Washington DC. In Berlin, leased as "HydroGen4" to 9 companies starting in 2008.	
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	Fuel cell/ battery hybrid	100 kW PEM (2007 version)	Kia	N/a	N/a	Demonstrating 33 Hyundai Tucsons and Kia Sportage FCVs in the U.S. between 2004-2009 and in Korea between 2006-2010.	
	Santa Fe SUV	Ambient-pressure fuel cell	75kW/ PEM	UTC Fuel Cells	250mi 402km	N/a	Hyundai's first generation hydrogen vehicle.	
Kia	Borrego/ Mojave FCEV	Fuel cell/ battery hybrid	115kW/ PEM	Kia	426mi 685km	54 mpg	Leasing to Seoul, Korea residents starting in 2009.	
Nissan	X-TRAIL (SUV)	Fuel cell/ battery hybrid	75kW/ PEM	UTC Fuel Cells (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	Leasing, to government agencies and energy companies in Japan, started in late 2008.	

[30] 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[31]				
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

[31] Complied by Fuel Cells 2000, with substantial 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

	HyPX Power Packs	Class 1 Forklift Trucks	PEM / hybrid	8 - 12 kW
	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 – 31kW
	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

Fuel Cell Technologies Web Sites

U.S. Department of Energy Fuel Cell Technologies Program
www.eere.energy.gov/hydrogenandfuelcells/

Fuel Cells 2000
www.fuelcells.org

Fuel Cell Today
www.fuelcelltoday.com

U.S. Fuel Cell Council
www.usfcc.com

National Renewable Energy Laboratory Hydrogen and Fuel Cells Research
www.nrel.gov/hydrogen

Hydrogen Analysis Resource Center
hydrogen.pnl.gov/cocoon/morf/hydrogen

National Hydrogen Association
www.hydrogenassociation.org

California Fuel Cell Partnership
www.fuelcellpartnership.org

International Partnership for Hydrogen and Fuel Cells in the Economy
http://iphe.net/

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On the Cover

Hydrogen and fuel cells can be used in all sectors of the economy, offering a broad range of benefits for the environment, for our energy security, and for our domestic economy. Here, hydrogen and fuel cells provide clean, efficient, reliable backup power to telecommunications equipment.

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Energy Efficiency & Renewable Energy

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