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

2008 FUEL CELL TECHNOLOGIES MARKET REPORT

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Authors

This report was written primarily by Bill Vincent of the Breakthrough Technologies Institute in Washington, DC, with significant assistance from Jennifer Gangi, Sandra Curtin, and Elizabeth Delmont.

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List of Acronyms

APU auxiliary power unit

BTU British thermal unit

CARB California Air Resources Board

CHP combined heat and power

CNG compressed natural gas

CO_2 carbon dioxide

DMFC direct methanol fuel cell

EPA U.S. Environmental Protection Agency

FCEV fuel cell electric vehicle

FCV fuel cell vehicle

HCNG hydrogen/natural gas blend

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

mpg miles per gallon

MW megawatt

NGO non-governmental organization

OEM original equipment manufacturer

PAFC phosphoric acid fuel cell

PE private equity

PEM proton exchange membrane fuel cell

PIPE private investment in public equities

PV photovoltaic

R&D research and development

RD&D	research, development and demonstration
SOFC	solid oxide fuel cell
UAV	unmanned aerial vehicle
VC	venture capital
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. Moreover, 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.

Global concerns about climate change, energy security, and air pollution are driving demand for fuel cell technology. More than 630 companies and laboratories in the United States are investing $1 billion a year in fuel cells or fuel cell component technologies.[1]

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. Within these categories, and sometimes defying categorization, are an exceptional number of fuel cell applications being developed or demonstrated worldwide.

This report provides an overview of trends in the fuel cell industry and markets, including product shipments, market development, and corporate performance. It also provides snapshots of select fuel cell companies, including general business strategy and market focus, as well as, financial information for select publicly-traded companies. It is important to note that the performance of these companies may not reflect the performance of the industry as a whole. Many fuel cell companies are privately-held, with limited financial data publicly available. Similarly, other companies are business units or subsidiaries within much larger companies, such as United Technologies Corporation, Honda, Toyota, and General Motors. In such cases, financial and other information regarding the fuel cell business unit typically is not available.

Notable Stationary Power Applications

- A Pepperidge Farm bakery in Connecticut is using two fuel cells to meet 70 percent of its electricity needs.
- Fuel cells provide 1.4 MW of electricity and 6.3 million BTUs of heat for a Verizon call-routing center in New York, reducing carbon dioxide emissions by 8,000 metric tons annually and saving more than $600,000 in utility bills during the first year.
- 1.2 MW of fuel cells (four units), along with a 1.4 MW solar array, provide the majority of the electricity requirements for a Sierra Nevada brewery and capture waste methane gas, substantially reducing the brewery's greenhouse gas emissions.
- A Whole Foods Market in Dedham, Massachusetts derives nearly 100 percent of its electricity and hot water from a 400 kW fuel cell.
- Gills Onions' processing facility captures waste biogas to generate 600 kW of power through a fuel cell.
- In Japan, more than 3,000 residential combined heat and power fuel cell units are in use, reducing household carbon dioxide emissions by more than 30 percent.

[1] Source: Fuel Cells 2000

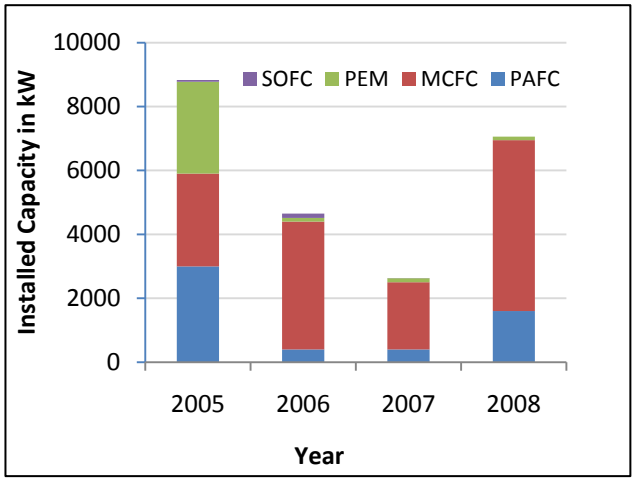
Trends and Developments in 2008

There were significant positive developments in the fuel cell industry in 2008. A number of companies received large orders for fuel cells and related equipment, as segments of the industry continue to transition from a demonstration-phase to commercialization. Among publicly-traded companies, some grew revenues and improved net income, although most continue to experience significant operating losses. In October 2008, the United States' investment tax credit for fuel cells was extended for eight years, enabling business owners to claim a tax credit of 30 percent of the cost of the fuel cell, up to $3,000/kilowatt (kW), increased from the previous provision of up to $1,000/kW. Homeowners can also claim a tax credit of 30 percent of the cost of the fuel cell, up to $1,000/kW.

The stationary market experienced significant growth for both primary and backup power. FuelCell Energy, a Connecticut-based producer of stationary power fuel cells, reported a 2008 order backlog of 32.5 megawatts (MWs), more than double the backlog from 2007, as well as a substantial increase in its production rate, to 30 MW annually. In 2008, FuelCell Energy also booked its single largest order in company history – a $70 million sale of 26.5 MW of fuel cell power to POSCO Power, a South Korean company.

Fuel cell companies also appear to be making significant inroads in the telecommunications industry. For example, IdaTech, with its primary facilities based in Oregon, signed a contract in 2008 to deliver up to 30,000 units to provide back-up power for wireless communications towers in India.

Figure 1: Estimated Annual U.S. Stationary Fuel Cell Installations



Source: Fuel Cells 2000

In the U.S., the annual installed generating capacity appears to be increasing. As shown in Figure 1, the generating capacity of new stationary fuel cells installed in the U.S. in 2008 was significantly higher than in 2007 and 2006. Although the installed capacity in 2005 was greater than in 2008, many of the 2005 installations were associated with a Department of Defense Residential Demonstration Project for proton exchange membrane (PEM) fuel cells. The final installations under this program occurred in 2006. Molten carbonate fuel cells (MCFC) appear prominent in Figure 1, because MCFC installations were large-scale, thus representing a high percentage of the total installed generating capacity.

The transportation and motive power sector also appears to be growing. Daimler AG and Honda operate production lines for fuel cell vehicles, and most major automakers plan to introduce fuel cell cars by 2015. Fuel cell buses continue to operate in cities around the world, including five fuel cell buses in California (AC Transit) and Connecticut (CTTransit) that logged nearly 72,000 miles and more than 7,500 hours of service between August 2007 and August 2008.[2] The AC Transit fuel cell buses achieved fuel economy 84 percent greater than diesel buses and the CTTransit fuel cell buses achieved a fuel economy 131 percent greater than compressed natural gas (CNG) buses, operating on the same route. Finally, a number of fuel cell companies are targeting the materials handling industry, offering fuel cells as a replacement for batteries in lift trucks. Plug Power, one of the main fuel cell suppliers for forklifts, sold at least 367 units in 2008, according to company filings with the Securities Exchange Commission.

There were roughly 9,000 shipments worldwide of portable fuel cells in 2008, a slight increase over 2007.[3] The portable fuel cell market continues to be limited largely to toys, battery chargers, and educational units, although a significant number of shipments were made in 2008 for military applications.[4] Many of these military applications were for soldier power systems and other light applications, such as unmanned aerial vehicles.

There also were a small number of units produced in 2008 for the consumer electronics market, mainly for cell phones, cameras, and laptops. In some cases, such as mobile phones, the fuel cells are designed as battery replacements. In other cases, like laptops, the trend appears toward the fuel cell acting as a battery charger. The consumer electronic units were pre-commercial, shipped for testing purposes. However, it appears that a number of advances have been made in miniaturization, power density, and durability, suggesting that commercial shipments could begin within a few years.[5] Device makers such as Toshiba have announced commercialization schedules.

It appears that 2009 will be another positive year for fuel cells. A number of major orders have been received for fuel cells in the telecommunications and materials handling industries.

Notable Transportation Developments in 2008

- Honda commissioned the world's first dedicated fuel cell production facility for the Clarity and began leasing a limited number of FCX Claritys in California.
- General Motors launched "Project Driveway", the first real world road test of its fuel cell-powered Equinox by volunteers across the United States.
- Toyota's fuel cell Highlander achieved over 300 miles on a single tank of compressed hydrogen in a real world road test.
- AC Transit in Oakland, California ordered eight hybrid fuel cell buses for revenue service, the largest fuel cell bus order to date in the United States.
- Fuel cell buses in California achieved fuel economy 84 percent greater than diesel buses and 131 percent greater than CNG buses.
- BC Transit in British Columbia, Canada ordered 20 fuel cell buses.
- Twenty fuel cars were used in the Beijing Olympics to provide shuttle services.
- Nine major automakers drove a fleet of fuel cell cars from Portland, Maine to Los Angeles, California.

[2] *Fuel Cell Buses in US Transit Fleets: Current Status 2008*, National Renewable Energy Laboratory (available at http://www.nrel.gov/hydrogen/pdfs/tp44133.pdf)
[3] *Portable Fuel Cell Survey 2009*, Fuel Cell Today (available at http://www.fuelcelltoday.com/online)
[4] Ibid.
[5] *Portable Fuel Cell Survey 2009*, Fuel Cell Today (available at http://www.fuelcelltoday.com/online)

Similarly, several major companies have ordered stationary units for combined heat and power applications. The U.S. stimulus package (American Recovery and Reinvestment Act) also allocated more than $40 million specifically for fuel cell projects.

Revenues

Fuel cell companies generally derive revenue from the sale and support of fuel cells and related equipment, such as hydrogen generators, and from contract research and development. As shown in Table 1, major publicly traded fuel cell companies have experienced revenue growth over the last four years. SFC Smart Fuel Cells (SFC) leads the group on a percentage basis, increasing revenues more than five-fold. FuelCell Energy more than tripled gross revenues during the same period. As discussed above, a significant portion of this growth appears to be from the sale and installation of new units.

Table 1: Gross Revenues for Select Public Fuel Cell Companies (Thousand USD)

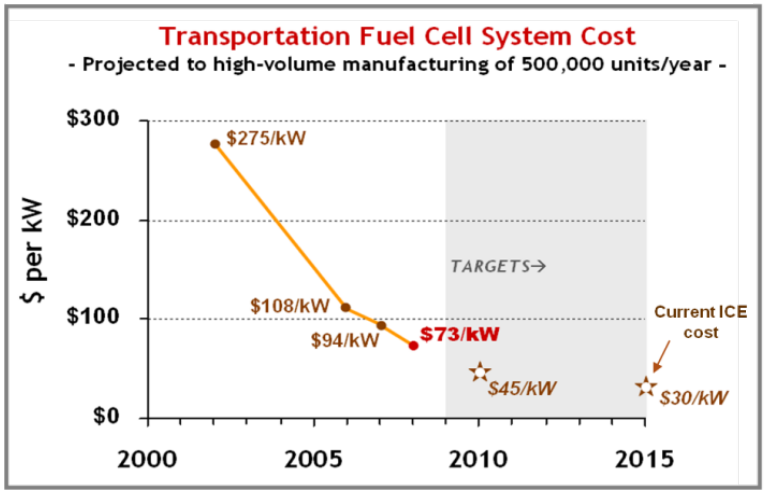
Company	2008	2007	2006	2005
FuelCell Energy	100,735	48,234	33,288	30,370
Ballard Power Systems	59,580	65,532	49,832	42,248
Plug Power	17,901	16,271	7,836	13,487
SFC Smart Fuel Cells AG	21,394	19,661	8,025	4,031
Hydrogenics Corp.	39,340	37,990	30,059	37,191
TOTALS	**238,950**	**187,688**	**129,040**	**127,327**

These companies were selected because their primary product is fuel cells and because they are publicly owned and traded on major stock exchanges.
Source: Fuel Cells 2000

Costs

There have been significant reductions in the cost of fuel cell systems. Figure 2 shows the estimated cost of a transportation fuel cell system (2008 technology) for high volume manufacturing (500,000 units per year) is $73/kW.[6] This is a reduction of more than $200/kW, or 75 percent, since 2002 and close to the target of $30/kW established for 2015. Research and development efforts appear to be on track to achieve cost-competitiveness with internal combustion engines within the next few years.

Figure 2: Declining Transportation Fuel Cell System Costs



Source: U.S. Department of Energy

Net Income, Total Assets, and R&D Expenses

Most fuel cell companies remain development stage companies, focused on product improvement, reducing product cost, and market development. As a result, most companies operate at a loss, and these losses have been growing in recent years. For example, despite significant revenue growth, FuelCell Energy has seen losses climb from $68.2 million in 2005 to $93.4 million in 2008, and Plug Power losses

[6] *Fuel Cell System Costs for Transportation – 2008 Cost Estimate*, US Department of Energy (May 2009) (available at: http://hydrogendoedev.nrel.gov/pdfs/45457.pdf)

grew from $51.7 million in 2005 to $121.7 million in 2008.[7] Many fuel cell companies therefore have placed a significant focus on cost reduction.

There are a few companies showing improvement. Ballard Power Systems has gone from a loss of $87 million in 2005 to positive net income of $43.9 million in 2008. Hydrogenics has trimmed its losses from $37.3 million in 2005 to $14.3 million in 2008.

Some fuel cell companies also have experienced reductions in total assets between 2005 and 2008 (see Table 2). A notable exception is SFC, which grew net assets substantially during the period. As discussed in the Select Company Profiles section of this report, SFC is experiencing significant growth in the leisure (recreational vehicles, yachts, and cabins) and military markets. Moreover, some of the reductions in net assets likely are the result of cost reduction activities, such as the sale by Ballard Power Systems of some of its automotive fuel cell assets.

Table 2: Total Assets for Select Public Fuel Cell Companies (Thousand USD)

Company	2008	2007	2006	2005
FuelCell Energy	185,476	253,188	206,652	265,520
Ballard Power Systems	208,443	298,691	350,038	524,874
Plug Power	209,112	268,392	307,920	139,784
SFC Smart Fuel Cells AG	80,613	82,124	16,714	2,929
Hydrogenics Corp.	47,579	67,940	97,173	214,657
TOTALS	**731,223**	**970,335**	**978,497**	**1,147,764**

Source: Fuel Cells 2000

Table 3: R&D Expenditures for Select Public Fuel Cell Companies (Thousand USD)

Company	2008	2007	2006	2005
FuelCell Energy	16,059	13,438	24,714	21,840
Ballard Power Systems	37,172	58,478	52,274	64,891
Plug Power	34,987	39,218	41,577	36,319
SFC Smart Fuel Cells AG	1,143	865	501	3,336
Hydrogenics Corp.	7,296	9,690	9,379	7,745
TOTALS	**96,657**	**121,689**	**128,445**	**134,131**

Source: Fuel Cells 2000

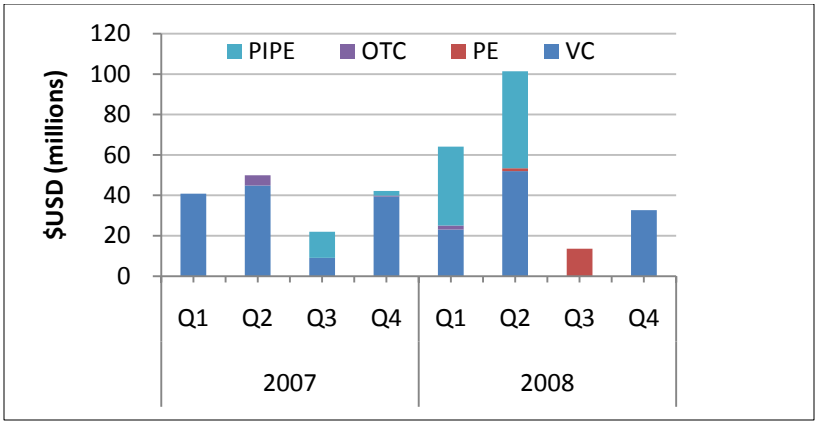
Finally, as shown in Table 3, R&D expenditures appear to have either been trimmed or remain flat in several fuel cell companies. In many cases, this is a reflection of a transition to increased manufacturing and commercialization. In other cases, this may be related to the sale of research-related assets, such as Ballard, which cut its R&D expenses nearly in half between 2005 and 2008.

[7] Source: Information compiled by Fuel Cells 2000

Venture Capital and Private Equity

Cumulative global investment in fuel cell companies totaled roughly $367 million in 2007 and 2008 (see Figure 3). Roughly 66 percent of this amount was venture capital (VC) and 28 percent was private investment in public equities (PIPE).

Figure 3: Global Investment in Fuel Cell Companies (2007-2008)



Worldwide Venture Capital (VC), Private Equity (PE), Over-the-Counter (OTC), and Private Investment in Public Equities (PIPE) Investments in Fuel Cell Companies (2007 – 2008)
Source: New Energy Finance

Total investments increased by nearly 37 percent between 2007 and 2008, rising from roughly $155 million to nearly $212 million. As shown in Figure 3, most of the increase is attributable to an increase in PIPE financing. 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. PIPE transactions were popular during the credit crisis of 2008, with a record $123 billion raised through PIPES in 2008.[8]

Table 4 shows that U.S. investors have made the greatest cumulative investment in fuel cells since 2000, totaling $760.9 million, followed by United Kingdom investors, at $232 million. U.S. and UK companies collectively comprise six of the top ten largest fuel cell investors during the same period.

Table 4: Top Ten Venture Capital and Private Equity Investors, By Company and By Country (1/1/2000 – 12/31/2008)

Company and Headquarters Country	Amount (million USD)	Country	Total All VC and PE Investment (million USD)
Kleiner Perkins Caufield & Byers (US)	$63.8	US	$760.9
World Gold Council (UK)	$60.0	UK	$232.4
GreenShift Corp (US)	$58.1	Canada	$152.7
Investec (South Africa)	$57.1	Germany	$101.4
Mobius Venture Capital (U.S.)	$51.5	South Africa	$57.1
EnerTek Singapore Ptd Ltd (Singapore)	$50.0	Singapore	$50.0
Rolls Royce Plc (UK)	$50.0	Australia	$46.5
Jolimont Ventures (AUS)	$45.5	Denmark	$29.3
Chrysalix Energy LP (CAN)	$44.6	Switzerland	$27.8
Conduit Ventures Ltd (UK)	$28.1	Netherlands	$23.3
TOTAL	**$508.7**	**TOTAL**	**$1,481.4**

Source: New Energy Finance

[8] See PrivateRaise Announces Record PIPE Investment; Releases 2008 League Tables (January 14, 2009), available at http://www.businesswire.com/portal/site/home/permalink/?ndmViewId=news_view&newsId=20090114005670&newsLang=en

Shipments

As shown in Figure 4, the total volume of fuel cell shipments continued to increase in 2008, reflecting an ongoing trend toward commercialization. Between 2006 and 2008, total global fuel cell shipments nearly tripled, with the largest percentage increase in the transport sector. This increase appears due largely to increased shipments of APUs, such as SFC's battery charger product for recreational vehicles (see Figure 5), as well as battery-replacement fuel cells for materials handling equipment, such as forklifts. The portable power sector also showed significant growth, driven largely by educational toys, battery chargers, and military applications, like unmanned aerial vehicles.

In North America, total shipments more than doubled between 2006 and 2008, with the largest increase in the small stationary sector (see Figure 6). This increase appears driven largely by increases in shipments of fuel cells for back-up power, primarily in telecommunications applications. There is a similar trend globally, where the total number of small stationary fuel cell shipments has increased roughly seven-fold since 2004, again driven largely by the telecommunications market (see Figure 7).

Finally, the power output of shipped large stationary units continues to increase. Since 1996, roughly 600 large stationary units have been shipped and installed, with a total capacity of 183 MW (see Figure 8).

Between 2006 and 2008, however, installed capacity per year increased sharply while the number of installed units per year remained roughly constant, suggesting that the capacity of each unit is increasing.

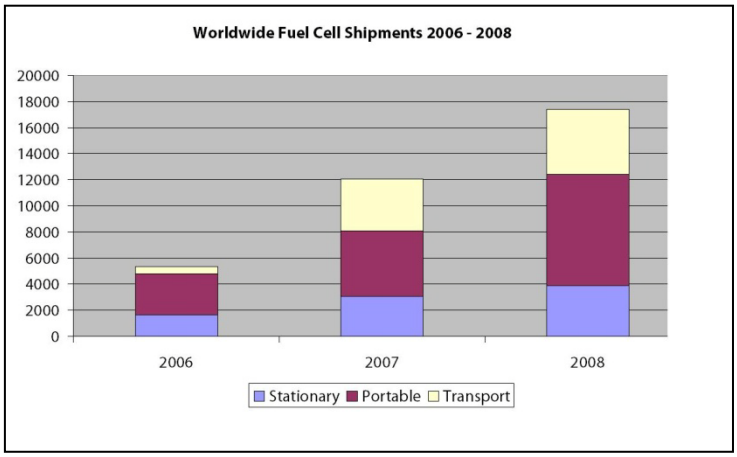


Figure 4: Global Fuel Cell Shipments by Application (2006-2008)
Source: Fuel Cell Today (Copyright 2009)

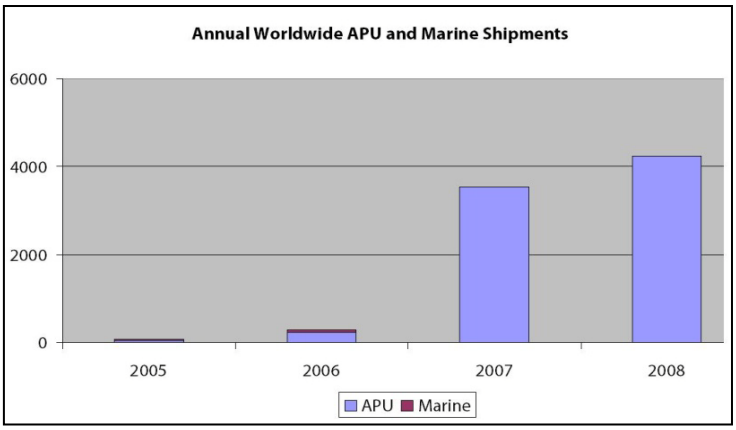


Figure 5: Annual APU and Marine Shipments (2005-2008)
Source: Fuel Cell Today (Copyright 2009)

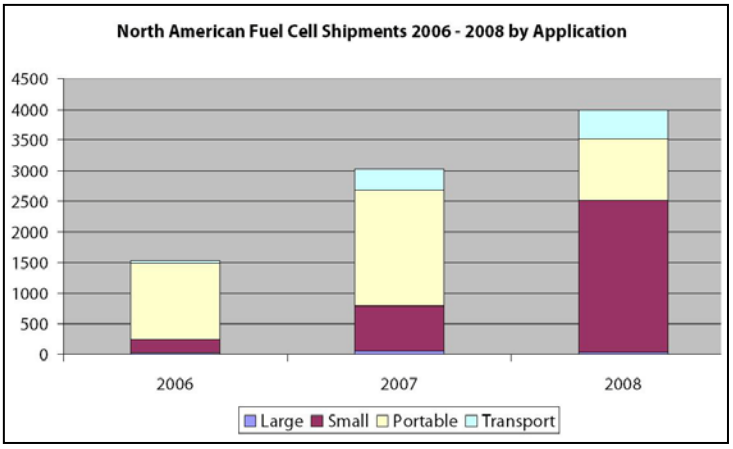


Figure 6: North American Shipments by Application (2006-2008)
Source: Fuel Cell Today (Copyright 2009)

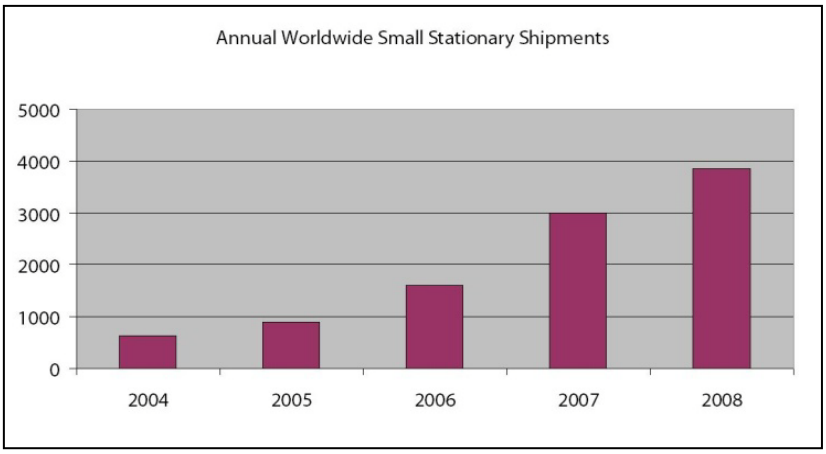


Figure 7: Worldwide Small Stationary Fuel Cell Shipments (2004-2008)
Source: Fuel Cell Today (Copyright 2009)

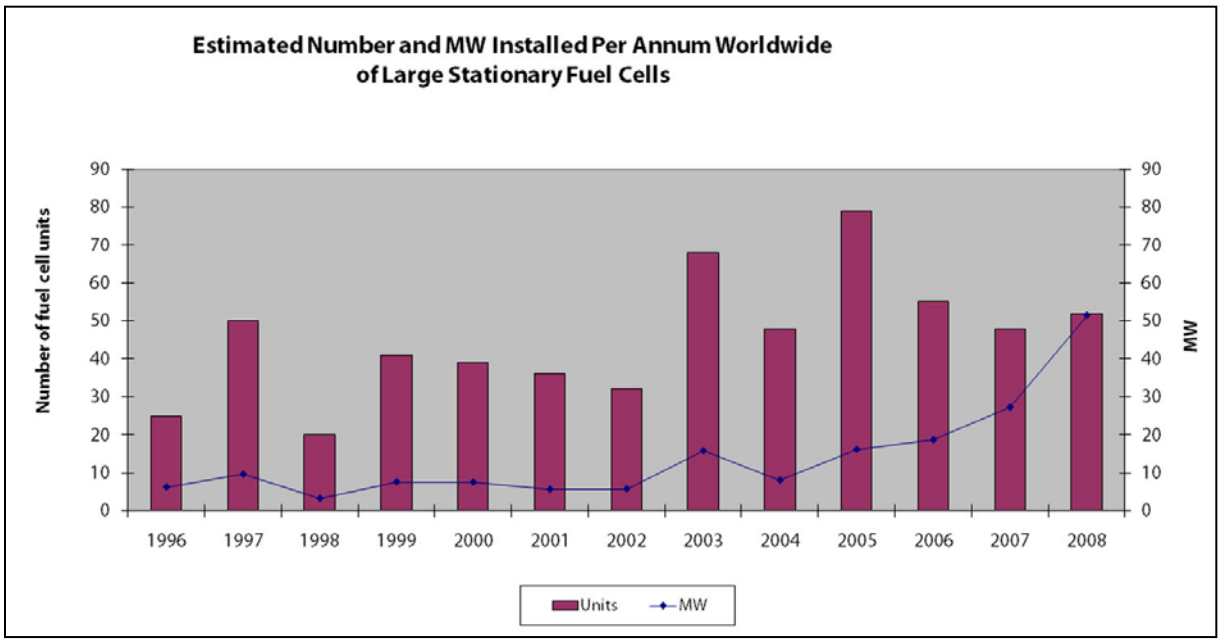


Figure 8: Large Stationary Installations Per Annum, by Number and MW (1996-2008). Number of units is represented by bars (left scale) and number of megawatts represented by the line (right scale).
Source: Fuel Cell Today (Copyright 2009)

Government Policy

The federal and state governments have been important partners in the development of the fuel cell industry. In 2008, the U.S. federal government's Investment Tax Credit (ITC) for fuel cell technology was extended for eight years, until 2016. The ITC entitles the taxpayer to subtract the amount of the credit (dollar-for-dollar) from total federal tax liability. For businesses, the credit was increased to 30 percent of the cost of the fuel cell, up to $3,000/kW, compared to 10 percent or $1,000/kW prior to the revised legislation. The business credit is available for a variety of applications, including forklifts and other industrial equipment. For residences, the credit also is 30 percent of the cost of the fuel cell, but up to $1,000/kW.[9]

Federal government agencies also released significant studies related to fuel cells in 2008. A study funded by the U.S. Department of Energy estimates that up to 677,000 jobs could be created by 2035 in the fuel cell and hydrogen sector.[10] The Oak Ridge National Laboratory issued a report finding, among other things, that fuel cell vehicle market share could grow to 50 percent by 2030 and 90 percent by 2050, if appropriate policies are put in place between 2012 and 2025 to encourage the development of hydrogen infrastructure to support these vehicles.[11]

Nearly half of U.S. states and the District of Columbia specifically referenced fuel cells in their renewable portfolio standards, net metering rules, and/or interconnection standards. Several states encouraged fuel cell deployment through incentive funding. For example, the California Public Utility Commission's Self-Generation Incentive Program (SGIP) is one of the largest distributed generation incentive programs in the United States. As of January 1, 2008, qualifying technologies included only wind turbines and fuel cells.

According to the California Stationary Fuel Cell Collaborative, 50 percent of U.S. installed fuel cell capacity is in California. This includes fuel cells at the City of Tulare Wastewater Treatment Plant, the Santa Rita Jail, four power plants in the San Diego area, the University of California, Irvine, the Turlock Regional Water Quality Control Facility, and Gills Onions, to name a few.

Table 5: States Referencing Fuel Cells and Hydrogen in Energy Standards

Standard or Rule	Number (including DC)	List of States
Renewable Portfolio Standard	26	AZ, CA, CO, CT, DC, DE, HI, KS, ME, MD, MA, MN, MO, MT, NH, NJ, NM, NY, NC, ND, OH, OR, PA, RI, WV, WI
Net Metering	28	AR, CA, CO, CT, DC, DE, FL, GA, HI, ID, IL, KS, LA, ME, MA, MI, MO, NJ, NM, OH, OR, PA, RI, SD, UT, VT, WA, WV
Interconnection Standard	26	AZ, AR, CA, CO, CT, DC, GA, HI, ID, KS, LA, ME, MA, MI, MN, MO, NJ, NM, NY, OH, OR, PA, TX, UT, WA, WI

Source: Fuel Cells 2000

[9] The 2009 American Recovery and Reinvestment Act (ARRA) provided additional incentives for fuel cells and related infrastructure, including increasing the dollar cap of the 30% hydrogen fueling infrastructure tax credit from $30,000 to $200,000. The ARRA will be discussed in greater detail in the 2009 edition of this report.

[10] *Effects of a Transition to a Hydrogen Economy on Employment in the United States*, US Department of Energy (July 2008, available at http://hydrogen.energy.gov/pdfs/epact1820_employment_study.pdf)

[11] *Analysis of the Transition to Hydrogen Fuel Cell Vehicles and the Potential Energy Infrastructure Requirements*, Oak Ridge National Laboratory (March 2008, available at http://cta.ornl.gov/cta/Publications/Reports/ORNL_TM_2008_30.pdf)

Foreign governments also are taking an active interest in hydrogen and fuel cells. According to the U.S. Fuel Cell Council, major international initiatives in 2008 include:

- A measure approved in 2008 by India's Standing Committee on Emission Regulation for the addition of up to 20 percent hydrogen to compressed natural gas (HCNG) for use in motor vehicles, making India the first country to approve this mixture for widespread use.
- A $15 billion plan by the Abu Dhabi city government (United Arab Emirates) to develop clean energy technologies that will include construction of the world's largest hydrogen power plant (500 MW) by 2014.
- Investment of about $500 million by China's government for hydrogen production, storage and delivery and fuel cell research. The Chinese government also offers roughly $37,000 per vehicle for purchase of fuel cell vehicles in 13 cities. China's 11th Five Year Plan on Energy Development lists hydrogen and fuel cells as a "key frontier technology."
- A subsidy by the government of Japan of nearly half of the cost of purchasing a fuel cell for residential use.
- An 80 percent subsidy by the government of South Korea to offset a portion of the cost of purchasing and installing residential fuel cells, gradually diminishing to a 30 percent subsidy in 2020.
- Significant fuel cell bus deployments in Europe, Asia, and Canada, including 20 fuel cell buses for the 2010 Winter Olympics in Vancouver.

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.

Public Companies

Ballard Power Systems

Ballard Power Systems, Inc. operates in three segments: Stationary Power, Motive Power and Material Products. The Stationary Power segment offers fuel cell products and solutions for backup power, supplemental power and distributed generation. The Motive Power segment offers fuel cell products for material handling and heavy-duty applications. The Material Products division of the business offers carbon fiber products, primarily for automotive transmissions, and gas diffusion layers, for fuel cells.

Table 6: 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 390
Headquarters	Burnaby, Canada

Source: Fuel Cells 2000

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 has been decreasing its participation in the automotive fuel cell markets. In early 2008, Ballard sold its automotive fuel cell research and development assets to Daimler AG and Ford Motor Company, forming AFCC, a joint venture among the three companies (see section on Daimler for more details).

Table 7: Ballard Power Systems Sales

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

Source: Fuel Cells 2000

Previously, Ballard had been involved in systems development for the residential cogeneration market through a joint venture with the EBARA Corporation of Japan. Although this joint venture has since ended, opportunities continue to exist in Japan and elsewhere for fuel cell stack sales into residential cogeneration markets.

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 California Air Resources Board standards.

Table 8: FuelCell Energy

Company Type	Public (Symbol:FCEL)
Fuel Cell Type	MCFC
Primary Market Interest	Large stationary power
Employees	Approximately 500
Headquarters	Danbury, Connecticut

Source: Fuel Cells 2000

FCE was founded as the Energy Research Corporation in 1969, initially focusing upon fuel cells but later expanding into batteries. In 1992, ERC demonstrated a 120 kW high temperature carbonate fuel cell system. In 1996, a two MW power plant went online in Santa Clara, California. In 1999, ERC split the advanced battery component into a new company, and renamed what was left FuelCell Energy.

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% electrical efficiency. FCE has operations for a wide variety of applications, including grid-support, wastewater treatment plants, food and beverage processing, manufacturing, hospitals and prisons, hospitality, colleges and universities. FCE currently has more than 55 installations globally.

FCE also conducts contract research and development that has targeted biofuels, carbon sequestration, logistic fuels, hybrid power systems, hydrogen co-production, and solid oxide fuel cells (SOFCs). The company has contracts with several U.S. government organizations, including the U.S. Navy for marine applications of DFC technology, the Department of Defense, and the Department of Energy.

FCE has developed various distribution partners, including large companies like Enbridge Inc. and POSCO Power.

Hydrogenics

Hydrogenics designs, manufactures, and installs industrial and commercial fuel cell and hydrogen systems. The company has more than 1,700 installations in more than 100 countries.

Table 9: Hydrogenics

Company Type	Public (Symbol: HYGS)
Fuel Cell Type	PEM
Primary Market Interest	Renewable energy storage, transportation, back-up power, hydrogen generation
Employees	Approximately 125
Headquarters	Mississauga, Canada

Source: Fuel Cells 2000

Hydrogenics focuses on three markets: fuel cell power systems, renewable energy systems, and hydrogen generation. Key products include hydrogen generators, fuel cells for electric vehicles, stationary and backup power supplies, and fuel cell systems designed to optimize solar and wind power systems.

Table 10: Hydrogenics Sales (Millions)

Product or Service	2008	2007	2006
Hydrogen Generation	$31.2	$19.6	$12
Power Systems	$5.6	$6.1	$7
Fuel Cell Test Equipment	$2.5	$12.3	$11.1
TOTAL SALES	**$39.3**	**$38**	**$30.1**

Source: Fuel Cells 2000

Hydrogenics works with early technology adopters and original equipment manufacturers such as Andrew/CommScope, American Power Conversion, EVAmerica, Proterra, Crown, NACCO Material Handling Group, Vision Industries, Toro, John Deere. Customers include Shell Hydrogen, Chevron Hydrogen, Linde, Air Liquide, Air Products, and Powertech.

Hydrogenics' fuel cell systems are currently powering over ten fuel cell hybrid MidiBuses operating in Europe. Hydogenics also has contracts to provide fuel cell power modules to other bus manufacturers for hydrogen hybrid transit buses around the U.S. and Europe, including Proterra, EVAmerica, and MAN.

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.

Table 11: IdaTech

Company Type	Public (Symbol:IDA London Stock)
Fuel Cell Type	PEM
Primary Market Interest	Backup power for telecommunications
Employees	Approximately 90
Headquarters	Bend, Oregon

Source: Fuel Cells 2000

IdaTech's main telecom backup power fuel cell product is the ElectraGen™, which is available in both 3 kW and 5 kW outputs. There are three different products within the ElectraGen™ Product Family – The ElectraGen™ which is fueled by hydrogen, and the ElectraGen™ XTR Skid System and ElectraGen™ XTi System, both include a proprietary fuel reformer that converts methanol and water liquid fuel into hydrogen gas to power the system. By generating its own hydrogen, the need for delivery and storage of bottled hydrogen is eliminated.

IdaTech also manufactures a 250 watt iGen™ System designed to be integrated with photovoltaic (PV), wind, and grid power to recharge batteries in industrial applications including traffic signaling and portable traffic signage. The iGen™ System includes IdaTech's proprietary fuel reformer that converts methanol and water liquid fuel into hydrogen gas to power the system.

In October 2008, IdaTech signed a large-volume supply agreement with ACME Telepower to deliver fuel cell systems for telecommunications deployment in India with the initial 310 system order scheduled for delivery in 2009 and further deployment in 2010. Ballard Power Systems is supplying the fuel cell stacks to IdaTech for this project.
IdaTech is also participating in Germany's National Programme for Innovation through its German original equipment manufacturer (OEM) partner and distributor, b+w Electronic Systems GmbH. IdaTech received an order for 30 ElectraGen™ systems from b+w for delivery in 2009 and early 2010. This order is in addition to a 30 systems order received from b+w at the end of 2008.

IdaTech sells fuel cell systems worldwide and has participated in notable projects, including partnerships with the Oregon State Police, the Department of Homeland Security, and the Pennsylvania Turnpike

Commission to provide backup power. According to IdaTech's 2008 annual report, the company experienced significant growth between 2007 and 2008, including:

- A 16.8 percent increase in sales, to $5.9 million;
- A 250 percent increase in product revenue, to $2.4 million;
- A 24.7 percent increase in R&D investment, to $12 million.

Plug Power

Plug Power focuses on the design, development and manufacture of PEM fuel cell systems in the material handling, remote prime power, residential combined heat and power, and telecommunications 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.

Table 12: Plug Power

Company Type	Public (Symbol: PLUG)
Fuel Cell Type	PEM
Primary Market Interest	Materials handling, telecommunications, residential
Employees	Approximately 200
Headquarters	Latham, New York

Source: Fuel Cells 2000

Table 13: Plug Power Shipments and Orders

Product	2008	2007
GenDrive		
Shipments	132	77
Orders	358	94
GenCore		
Shipments	146	180
Orders	109	106
TOTAL		
Shipments	**278**	**257**
Orders	**467**	**200**

Source: Fuel Cells 2000

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. The company posted a net loss of $22.8 million in the second quarter of 2008. In June 2008, Plug Power adopted a restructuring plan to become a market and sales driven organization, focusing on its GenDrive™, 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 offers a low temperature, liquid petroleum gas (LPG)-fueled system designed for continuous power in remote applications, focusing on the telecommunications sector. In 2008, this product successfully completed a field trial on a cell phone tower in India operated by Tata Teleservices Limited.

Plug Power is also developing the residential GenSys®, 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 fifteen to 15-25 percent over incumbent technologies. The residential GenSys is not commercially available at this time.

SFC Smart Fuel Cell AG

SFC Smart Fuel Cell (SFC) manufactures low temperature fuel cells that use direct methanol fuel cell (DMFC) technology. Founded in 2000, the company is based in Germany and listed in the Prime Standard on the German stock exchange (WKN 756857).

Table 14: SFC Smart Fuel Cell AG

Company Type	Public (Symbol: F3C.DE)
Fuel Cell Type	DMFC
Primary Market Interest	Portable, small stationary, APUs
Employees	Approximately 95
Headquarters	Brunnthal, Germany

Source: Fuel Cells 2000

SFC targets the leisure, industrial and defense markets and has fuel cells deployed 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.

SFC markets its fuel cells for the leisure markets under the "EFOY" ("energy for you") brand and offers four models, the EFOY 600, 900, 1200 and 1600, with charging capacities ranging from 600 to 1600 watt hours/day. EFOY fuel cells provide electrical current to appliances on mobile homes, trailers, sailboats, and in holiday cabins. The EFOY fuel cell is offered as standard or optional equipment by 37 international motor home manufacturers.

SFC also offers the EFOY Pro Series, which is designed to meet the needs of professional and government users. The EFOY Pro series consists of three models: the EFOY Pro 600, 1200 and 1600 (600 to 1600 watt hours charging capacity/day). If more power is needed, several EFOY Pro fuel cells can be combined. 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. 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. The M-25 program was awarded $1 million through the U.S. Department of Defense Wearable Power Prize in October 2008.[12]

UTC Power

UTC Power, a unit of United Technologies Corp., is a Connecticut-based developer and producer of fuel cells that generate energy for buildings and for transportation, defense and space applications. Formerly known as International Fuel Cells, the company has been in business for more than 50 years.

Table 15: UTC Power

Company Type	Public (Symbol: UTX)
Fuel Cell Type	PAFC, PEM
Primary Market Interest	Large stationary, transportation, aerospace
Employees	Approximately 600
Headquarters	South Windsor, Connecticut

Source: Fuel Cells 2000

UTC Power manufactured the first commercially available stationary fuel cell to provide on-site building power in 1991. Since that time it has installed units worldwide that have

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

accumulated more than one billion kilowatt-hours (kWh) of experience. The company's presently markets phosphoric acid fuel cell (PAFC) and PEM units, but its work over the years has focused on five of the major fuel cell technologies.

UTC Power's stationary fuel cells have operated more than nine million operating hours, with more than 260 units deployed in 19 countries. Current users of the company's fuel cell products include public safety facilities, schools, hospitals, banks, supermarkets, and telecommunications companies, including high profile units for Whole Foods, Hilton Hotels, and Verizon. UTC Power's PAFC stationary fuel cell product, the Pure Cell®, is available in both a 200 and a 400-kW version suitable for providing combined cooling, heating and power. Both products are designed to meet or exceed the most stringent air emission standards in the United States as established by the California Air Resources Board in 2007.

The company's transportation PEM fuel cell product, the PureMotion® Model 120 fuel cell power plant, is powering six transit buses in commercial service in the U.S. and in Europe. The company has also worked with Hyundai-Kia Motor Company, Chevron Technology Ventures, Nissan, BMW and the U.S. Department of Energy to develop fuel cell power plants and fuel cell technology for automotive applications.

UTC has provided fuel cell-generated electrical power and drinking water for all manned space flights since 1966. The company also works on defense applications, with a focus on marine undersea and shipboard applications.

Private Companies

ClearEdge Power

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.

Table 16: ClearEdge Power

Company Type	Private
Fuel Cell Type	PEM
Primary Market Interest	Residential and small commercial applications
Employees	Approximately 145
Headquarters	Hillsboro, Oregon

Source: Fuel Cells 2000

ClearEdge Power manufactures and markets the ClearEdge5 (CE5) a compact, 5 kW combined heat and power PEM fuel cell energy system for use in residential and small commercial buildings. The CE5 operates at up to 90 percent efficiency, generating 3,650 kWh per month and 20,000 BTUs per hour. It can be installed in less than 35 square feet in most applications.

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 $50,000 - $56,000 range, 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 initially 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.

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.[13]

Horizon Fuel Cell Technologies

Horizon Fuel Cell Technologies was founded in 2003. The company produces compact and lightweight PEM fuel cells as well as hydrogen storage and generation systems.

Horizon's strategy was to start with small and simple products, such as fuel cell educational kits, then expand into larger applications. 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 to over 60 countries and in the hundreds of thousands of units.

In 2007, the company announced that an 5 kilogram (kg) unmanned aerial vehicle (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.

Table 17: Horizon Fuel Cells

Company Type	Private
Fuel Cell Type	PEM
Primary Market Interest	Educational, portable, small stationary, transportation, aerospace
Employees	Approximately 110
Headquarters	Singapore

Source: Fuel Cells 2000

In 2008, Horizon unveiled a first version of its Hydropak, a portable fuel cell power system capable of producing 60 W using ultra-light 200 watt-hour (Wh) cartridges, as well as the first version of a small 3 W micro-fuel cell power extender for consumer devices called MiniPAK. In the same year, the company announced a fuel cell electric bicycle capable of 25 kilometers per hour and a range of 300 kilometers before requiring a hydrogen refill.

NedStack

NedStack fuel cell technology BV is a privately-owned company that produces both PEM fuel cells and systems. NedStack was founded in 1998 to continue the fuel cell activities of AKZO Nobel, a multi-national corporation dealing in healthcare products, coatings and chemicals. Employees and founders own 55 percent of NedStack's shares. NedStack holds more than 20 patents and patent-pending applications, and describes itself as the "the biggest producer of PEM fuel cells in Europe."

Table 18: NedStack

Company Type	Private
Fuel Cell Type	PEM
Primary Market Interest	Small stationary, large stationary, back up, heavy duty transport
Employees	Approximately 50
Headquarters	Arnhem, Netherlands

Source: Fuel Cells 2000

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

NedStack targets the large and small stationary and automotive markets, with its PEM fuel cell stacks ranging from one kW up to a MW or more. Applications include on-site power generation and back-up power, auxiliary power units, material handling and large automotive. The company claims that its largest stationary unit, the 100 kW PS100, has an endurance of 20,000 hours. NedStack also is targeting the transportation market, including buses, trains, and ships.

The company's strategy is to focus on improving durability and performance and achieving cost reduction. To accomplish this, NedStack is developing partnerships with a wide range of customers, suppliers, co-developers, governments, non-governmental organizations (NGOs), and universities. Through these partnerships, NedStack has completed a number of contracts through the European Community fifth framework program and with the government of the Netherlands, including research and development regarding:

- An autonomous energy supply system with reversible fuel cell as long-term storage system for PV stand-alone systems and uninterruptible power supplies;
- A PEM fuel cell for automotive applications;
- A PEM fuel cell system for public transport;
- A PEM fuel cell based power plant with direct connection to a chlor-alkali plant; and on-site hydrogen storage.

Nuvera Fuel Cells

Nuvera Fuel Cells was formed in April 2000 through the merger of Epyx Corporation and De Nora Fuel Cells. Hess Corporation is the majority shareholder of Nuvera.

Table 19: 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
Headquarters	Billerica, Massachusetts

Source: Fuel Cells 2000

Nuvera focuses on the development of multi-fuel processing and fuel cell technology for the industrial utility vehicle market and stationary power applications. The company also develops natural gas fuel cell power systems for cogeneration applications, and onboard gasoline fuel processors and fuel cell stacks for automotive applications.

Nuvera was the first company 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's 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 Department of Energy. 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 twenty 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 Defense Logistics Agency.

Automotive Companies

Daimler AG

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

Table 20: 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

Source: Fuel Cells 2000

Daimler has been developing fuel cell vehicles since the early 1990s. More than 20 concept vehicles and prototypes have been produced, including cars, vans and buses. There are more than 100 Daimler fuel cell vehicles in use worldwide and these vehicles have been driven more than 2.7 million miles and have attained a fleet operating time of more than 200,000 hours. The company anticipates commercialization of its fuel cell vehicle by 2015.

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. AFCC conducts research and product development for automotive fuel cells. NuCellSys is a separate company that is part of AFCC. NuCellSys develops the components necessary for supplying the fuel cell stacks with hydrogen and oxygen as well as other hardware, creating the fuel cell system architectures for use in various vehicle platforms.

Daimler continues to actively develop fuel cell buses and has already deployed 36 Mercedes-Benz Citaro buses in 12 cities in Europe, Australia, and China. These buses traveled more than 1.25 million miles during 135,000 operating hours, serving more than eight million passengers. Since 2000, the company has invested approximately $111 million in their fuel cell bus program.

General Motors

General Motors Corp. (GM) was founded in 1908 and sells and services vehicles in 140 countries, with the largest national markets in the United States, China, Brazil, the United Kingdom, Canada, Russia and Germany. GM has extensive fuel cell research and development facilities in the U.S. and Europe and employed more than 600 people during 2008 to work solely on the development of fuel cell vehicles.[14] GM's fuel cell research is organized as follows:

Table 21: General Motors Co.

Type	Public (Symbol: GM)
Product (s)	Fuel cell vehicles
Primary Market Interest	Passenger cars with commercialization by 2015
Employees	Approximately 600
Headquarters	Detroit, Michigan

Source: Fuel Cells 2000

- Warren, Michigan - basic R&D

[14] gmeurope.tv, http://www.metacafe.com/watch/1093266/dr_lars_peter_thiesen_hydrogen_fuel_cell_deployment_4/

- Honeoye Falls, New York - fuel cell development
- Torrance, California - electric drive development (motor and power electronics)
- Mainz-Kastel, Germany - overall fuel cell propulsion system, including modeling, testing, integration, and on-road testing.

GM also has a fuel cell R&D facility in Tokyo that focuses on the Asian market.

GM produced the industry's first operational fuel cell-powered passenger vehicle in 1968. The 1990s saw initiation of the Giner Stack Development Program (1995), 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.

GM launched Project Driveway in 2008, the first large-scale market test of fuel cell vehicles with customers in daily, real-world driving conditions. More than 100 Chevrolet Equinox fuel cell vehicles have been placed with customers in southern California, the New York City area, and Washington DC.

GM also has ventured into the stationary and auxiliary power markets. In 2001, GM and Hydrogenics unveiled a prototype fuel cell unit to provide back-up power to cell towers during power outages. That same year, GM showcased a fuel cell stationary power unit capable of supplying electricity to homes and businesses. The company has also developed a fuel cell auxiliary power unit for a diesel military hybrid pickup truck.

GM has collaborated with many fuel cell RD&D partners over the years. In 1991, GM and the U.S. Department of Energy co-founded the Los Alamos–General Motors Joint Development Center to conduct fuel cell R&D. The company formed relationships with ExxonMobil to conduct collaborative research on hardware and fuel options for advanced vehicles (1997) and with Toyota (1998) to develop advanced vehicle technologies, including fuel cells. In 2000, GM created Giner Electrochemical Systems (GES) with Giner, Inc. to perform fuel cell research and development. In 2001, GM formed additional partnerships, including collaborations with Suzuki Motor Corporation on fuel cells for small cars; ChevronTexaco to advance fuel cells using gasoline fuel; and General Hydrogen to accelerate hydrogen infrastructure and vehicle deployment in North America, Europe, Asia and emerging markets. The same year, GM also announced a substantial minority ownership position in QUANTUM Technologies to develop hydrogen handling and electronic control technologies for fuel cell applications. In 2003, GM formed a joint program with Federal Express to conduct a commercial fuel cell vehicle test in Japan, partnered with Shell Hydrogen on fuel cell vehicle testing and infrastructure in Washington, DC and agreed to work with the BMW Group to jointly develop refueling devices for liquid hydrogen vehicles. GM also partnered with Sandia National Lab (2005) to design and test an advanced method for storing hydrogen.

GM is developing its next generation fuel cell system that will reportedly be half the size, 220 pounds lighter, and use less than half the precious metal of the current system found in the Chevrolet Equinox. The goal is to develop a fuel cell power-train that will fit in about the same space as a four-cylinder engine. GM is targeting commercialization of fuel cell vehicles by 2015 and cost-competitiveness by 2022.

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.[16]

Table 22: 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[15]
Headquarters	Minato, Japan

Source: Fuel Cells 2000

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"[17] and that their FCVs have already proved to be "full function" alternative fuel vehicles.[18] Honda has announced plans to begin mass production of fuel cell vehicles in 2018 and anticipates that the retail price will be comparable to gas-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 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 dedicated fuel cell vehicle production facility for the Clarity, and 200 Claritys 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.

[15] Employment data solely for fuel cell activities not available.
[16] 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.
[17] http://www.bloomberg.com/apps/news?pid=20601087&sid=afMZ1CSLb2EQ#
[18] "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.

The Clarity is the first fuel cell car to be certified by the California Air Resources Board (CARB) and the Environmental Protection Agency (EPA) for everyday use. The FCX has 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 + ILEV is the lowest national emission rating.

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

Table 23: 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[19]
Headquarters	Toyota City, Japan

Source: Fuel Cells 2000

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.

Toyota's fuel cell hybrid technology has also been deployed on buses through a joint development effort with Hino Motors. In September 2002, four FCHV-BUS2 vehicles were certified by Japan's Ministry of Land, Infrastructure and Transport for road use and these are currently deployed in Japan.

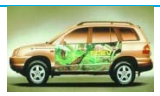
In January 2007, Toyota unveiled its hydrogen-powered fuel cell forklift prototype, the FCHV-F. The forklift uses a fuel cell designed and developed by Toyota Industries Corporation (TICO).

Toyota also is pursuing the stationary fuel cell market, focusing on development of PEM and solid oxide fuel cell 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.

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

Appendix 1: Examples of Pre-Production Fuel Cell Vehicles from Major Auto Manufacturers

Automaker	Vehicle Type	Engine Type	Fuel Cell Size/type	Fuel Cell Mfr.	Range (mi/km)	MPG Equivalent*	Details
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.
	NECAR 5.2 (A-class)	Fuel cell/ battery hybrid	85kW/ PEM	Ballard Mark 900 Series	300mi 482km	N/A	 Awarded a road permit for Japanese roads. Completed drive from California to Washington, DC.
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.
	Explorer FCV	Fuel cell/ battery hybrid	60kW/ PEM	Ballard	350mi 563km	35 mpg	 Powered by a FC system. Uses a hybrid system with a secondary battery to augment power from the FC.
	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.

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 2: Examples of Commercially Available Fuel Cell Products

Manufacturer	Product Name	Application	Type	Output
Ballard	Mark 902	Transportation	PEM	85 kW
	Mark 9 SSL	Materials Handling / Light Mobility	PEM	4.4 - 19.3 kW
	Mark 1030	Cogeneration	PEM	1.3 kW
	Mark 1020 ACS	Back-up power / Light Mobility	PEM	300 - 5000 W
	HD6	Transportation / Bus	PEM	65 or 130 kW net
FuelCell Energy	DFC 300MA	Stationary	MCFC	300 kW
	DFC 1500MA	Stationary	MCFC	1200 kW
	DFC 3000	Stationary	MCFC	2400 kW
	HyPM XR Power Modules	Stationary	PEM	4, 8, 12 kW
Hydrogenics	HyPM XR (DC) Backup Power Systems	Stationary	PEM	4, 8, 16 kW
	FCXR Cabinet	Stationary	PEM	10, 20, 30 kW
	FCXR System	Stationary	PEM	150 kW
	HyPM HD Power Modules	Mobility	PEM	4, 8, 12, 16 kW
	HyPX Power Packs	Class 1 Forklift Trucks	PEM / hybrid	8 - 12 kW
	HySTAT Hydrogen Generator	Hydrogen Refueling	Alkaline Electrolysis	4 - 60 Nm3/hr
	ElectraGen™ 3XTR	Backup	PEM - Liquid Fuel	3 kW
	ElectraGen™ 5XTR	Backup	PEM - Liquid Fuel	5 kW
IdaTech	ElectraGen™ 3 XTi	Backup	PEM - Liquid Fuel	3 kW
	ElectraGen™ 5 XTi	Backup	PEM - Liquid Fuel	5 kW
	iGen™	Portable	PEM	250 W
	ElectraGen ™ 3	Backup	PEM - Hydrogen	3 kW
	ElectraGen ™ 5	Backup	PEM - Hydrogen	5 kW
Medis	Medis Power Pack	Portable	Direct Borohydride	1 W
MTI MicroFuel Cells	Mobion30M	Micro / Portable	DMFC	30 W
	Mobion 1M	Micro / Portable	DMFC	1 W
Nuvera	PowerFlow PFV-5	Industrial Vehicles	PEM	5 kW
	Andromeda Fuel Cell Stack	Transportation	PEM	100 kW
	Forza Industrial Power	Large Industrial / Stationary	PEM	250 kW
	HDL-82 Power Module	Transportation	PEM	82 kW
	GenDrive GD1—3000 Series	Class I Lift Trucks	PEM	9 - 11 kW
	GenDrive GD1—5000 Series	Class I Lift Trucks	PEM	9 - 14 kW
Plug Power	GenDrive GD1—8000 Series	Class I Lift Trucks	PEM	14 kW
	GenDrive GD2—Series	Class II NA Lift Trucks	PEM	9 - 11 kW
	GenDrive GD3—Series	Class IIII Pallet Trucks	PEM	3 kW

	GenDrive GD6—Series	Class VI Tow Tractors	PEM	3 - 11 kW
	GenDrive GD—AGV Series	Automated Guided Vehicles	PEM	3 - 14 kW
	GenCore® 5T Series	Backup -Telecom	PEM	5 kW
	GenCore® 5U Series	Backup -Utilities	PEM	5 kW
ReliOn	GenCore® 5B Series	Backup - UPS	PEM	5 kW
	T-1000	Backup	PEM	600 - 1200 W
	T-2000	Backup	PEM	600 W - 2kW
	I-1000	Backup	PEM	1 kW
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

Compiled by the U.S. Fuel Cell Council. For a more details see http://www.usfcc.com/resources/outreachproducts.html

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

Key Report Contacts

For more information on this report, please contact:

Sunita Satyapal, Fuel Cell Technologies Program
202-586-2336; Sunita.Satyapal@ee.doe.gov

Bill Vincent, Breakthrough Technologies Institute
202-785-4222, ext. 30; bill@fuelcells.org

On the Cover

Fuel cells offer significant benefits for a wide range of applications such as forklifts, distributed power systems, backup power, automobiles, buses, auxiliary power units, and portable electronics. This shows fuel cell-powered lift trucks at Sysco of Houston, which are funded through one of DOE's American Reinvestment and Recovery Act projects.

Photo Credit: Sysco of Houston

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