Houston Advanced Research Center

Fuel Cell Industry Assessment Report 2005

The Center for Fuel Cell Research and Applications

4800 Research Forest Drive, The Woodlands, Texas 77381, U.S.A.

Houston Advanced Research Center

Center for Fuel Cell Research and Applications

Houston Advanced Research Center (HARC) is an independent, non-profit organization based in The Woodlands, Texas. We work with industry and government to identify and advance promising environmental technologies into the marketplace.

The Center for Fuel Cell Research and Applications (CFCRA) supports commercialization of fuel cells and hydrogen technologies by providing technical information to early adopters, investors, system integrators, equipment users, and component suppliers. We help industry leaders make strategic decisions regarding technologies and systems of the emerging hydrogen economy.

In 2006, HARC is offering joint industry programs focused on fuel cell and hydrogen technology programs.

CFCRA Core Program

The Core Program provides end-users with information and intelligence on fuel cell products, companies, and emerging technologies and trends.

What you Get:

- ✓ **Monthly Newsletter -** contains noteworthy company news, product information, government activities, general industry trends, USFCC activities, and conference updates
- ✓ **Quick Briefs –** analytical reports on emerging technologies, developing markets, interesting applications, and new products related to fuel cells and to hydrogen production, storage, and distribution technologies
- ✓ **Technical Reports –** detailed reports highlighting commercial or scientific topics of interest providing sponsors detailed information and analysis for in-depth understanding
- ✓ **Fuel Cell Industry Assessment Report –** annual report listing major fuel cell technology developers and system manufacturers in helpful, easy-to-read summaries; also sold separately
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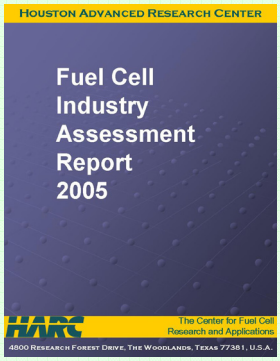

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CFCRA Supplemental Projects

Sponsors of the Core Program have the opportunity to participate in voluntary Supplemental Projects. In 2006, the proposed Supplemental Projects include:

PEM Fuel Cell UPS Test and Evaluation

- Focus on commercial systems targeting telecom applications
- two systems proposed for testing in 2006
- Deliverables include snapshot evaluations and technical reports evaluating key performance attributes and issues

APC InfraStruXure™ (10 kW)

IdaTech ElectraGen™ (5 kW)

Portable Fuel Cell System Test and Evaluation

- Survey and comparison of competing technologies including SOFC, PEM, and DMFC
- Three systems proposed for testing in 2006
- Deliverables include snapshot evaluations and comparative reports evaluating key performance attributes and issues

NanoDynamics Revolution™ 50

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Smart Fuel Cell A50

Distributed Hydrogen Production Equipment Test and Evaluation

- Survey and comparison of competing technologies including reverse PEM, conventional electrolyzer, and NG reformer
- Up to three systems proposed for testing in 2006
- Deliverables include snapshot evaluations and test reports describing performance attributes and issues

Proton Energy Systems HOGEN

Teledyne Energy Systems TITAN HM

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- Work with project sponsors to craft a technology roadmap and other information supporting internal decision-making and program design
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Foreword

The Fuel Cell Industry Assessment Report provides a view of where the fuel cell industry is and where it is headed. This is accomplished by looking at the activities of fuel cell system developers and manufacturers. By examining their activities and directions, accomplishments and setbacks, much can be learned about the state of the technology and the status of commercialization. By taking a large enough sample, a *de facto* view of the current status of the industry can be evaluated. When this snapshot is combined with an analysis of market conditions, trends, and drivers, one can begin to see, not just where the industry is, but where it is going.

The foremost purpose of the report is to identify interesting fuel cell technologies and new fuel cell products that are coming to market. Many of the company overviews discuss the company's technical approach, market strategy, and commercial status of products. The report is based mostly on publicly available information, although observations and insights gained at HARC through our equipment test and evaluation program are also used. Because much of the information comes from company press releases and websites, the company briefs can paint a fairly positive view of company accomplishments and progress. While we are careful to source information and we try to tone down the company's claims, be careful about reading too much into specific performance claims or the success of the company's strategy.

While the report helps to inform about the companies and fuel cell products that are available now or could become available in the future, it is no substitution for actual system testing. In fact, the genesis of the report was the need for HARC's fuel cell testing consortium to generate a short list of equipment that should be considered for further test and evaluation. HARC's testing consortium is undertaking hands-on test and evaluation of fuel cell equipment and is open to those interested in understanding fuel cells at a level deeper than company rhetoric. The report is also a useful single reference source listing major technology developers and system manufacturers, potentially useful for marketing, partnering, or basic competitive analysis. We hope you will find the report meets your information needs.

This 4th edition of the report continues to build on the scope and comprehensiveness of the original report concept. The number of fuel cell developers and manufacturers covered in the report increased from 92 to 110, and more companies receive deeper analysis. The report covers companies working with any technology, any application, located anywhere in the world.

I hope you find the report interesting and useful.

Daniel Bullock
Program Manager

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Glossary

AFC	Alkaline Fuel Cell
APU	Auxiliary Power Unit
BTU	British Thermal Unit
CHP	Combined Heat and Power
DARPA	Defense Advanced Research Projects Agency
DMFC	Direct Methanol Fuel Cell
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
FCV	Fuel Cell Vehicle
HHV	Higher Heating Value
kW	kilowatt
LHV	Lower Heating Value
LPG	Liquefied Petroleum Gas
MCFC	Molten Carbonate Fuel Cell
MEA	Membrane Electrode Assembly
MOU	Memorandum of Understanding
MW	Megawatt
NETL	National Energy Technology Laboratory
NREL	National Renewable Energy Laboratory
PAFC	Phosphoric Acid Fuel Cell
PEM	Proton Exchange Membrane or Polymer Electrolyte Membrane
POX	Partial Oxidation
SECA	Solid State Energy Conversion Alliance
SOFC	Solid Oxide Fuel Cell
UPS	Uninterruptible Power Supply
YSZ	Yttria Stabilized Zirconia
W	Watt

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Fuel Cell Market Context

The year 2005 was a mixed bag for the fuel cell industry. While a few Proton Exchange Membrane (PEM) fuel cell companies had some successes, most companies only muddled through. While little has changed to dramatically alter the industry's prospects in 2006, the year could build nicely on 2005 achievements. As a result, the PEM fuel cell industry should feel pretty good about its future. With some modestly successful product introductions in 2005, renewed interest in power reliability, robust government support, and high fuel prices, PEM companies appear poised for more rapid growth in the coming years. This combination of factors has created burgeoning interest in all types of clean and renewable energy technologies, and this general trend bodes well for the fuel cell industry. We are further encouraged by the performance of a number of the PEM products we've tested and evaluated in the last two years, which look to signal the arrival of real commercial PEM fuel cell products.[1] If the fuel cell industry can parlay these initial successes into greater sales in more applications, we may look back at 2005 as an inflection point in fuel cell commercialization efforts.

PEM Uninterruptible Power Supply (UPS) fuel cell systems are a noteworthy example of progress. The GenCore™ product introduced by Plug Power (tested by HARC in 2004-2005) and those of other fuel cell manufacturers garnered deserved attention. These companies gained market traction in wireless telecom, utility, and general backup power applications. In 2005, Plug Power announced initial and substantial sales of the GenCore, including, for example, the 80 unit order from IST Holdings, a Plug Power distributor headquartered in Pretoria, South Africa. In those applications in particular, HARC sees fuel cells offering a real value proposition relative to traditional battery backups. The UPS application for 5kW fuel cell products in the telecom backup area represents a $2-3B a year market in the United States.[2] Companies like Plug Power, ReliOn, IdaTech, and APC/Hydrogenics all appear eager to exploit the market. Product success for these companies will generate much needed revenues and help build the production volumes that (hopefully) will ultimately drive down manufacturing costs.

Progress in applications like forklifts and industrial trucks (Hydrogenics, Nuvera, and Proton Motor) is placing some of these products on the cusp of market viability. The Nuvera H2e™ system tested at HARC in 2005 was a very reliable performer, and it may meet the technical requirements of that application segment in short order. In Japan, the roll out of small fuel cell CHP systems (Ebara Ballard, Tokyo Gas, and Nippon Oil) could prove the market viability of PEM fuel cells in the important residential market. Successful implementation of residential products in Japan could open new markets for small power systems in Europe and Asia. With engineering solutions addressing the issue of PEM durability somewhat, the industry's prospects will increasingly depend on the ability of manufacturers to reduce system costs from the current average US$3000/kW.

[1] For more on HARC's Center for Fuel Cell Research and Applications, see http://www.harc.edu/fuelcell
[2] Citigroup Global Markets – Switch Signals: Fuel Cells in Distributed Telecom Backup, August 2005

Interesting Transportation Sector Developments

The year 2005 saw some interesting developments in the transportation sector, as sustained high oil prices inspired strategic response from the auto manufacturers. For fuel cells, these events could suggest the potential of large, sustained markets arriving sooner than anticipated. In September 2005, Toyota Motor Co. announced that it will migrate its entire vehicle fleet to hybrid designs. Ford Motor Co. quickly announced ambitious plans to roll out hybrid versions of its Ford, Lincoln, and Mercury models. Other automakers are expected to follow suit. The launch of hybrids by Toyota turned out to be exceptionally well-timed, as increasing gasoline prices provided substantial market pull for hybrids.

What's so noteworthy about hybrid vehicles is that they could be a new and interesting pathway for fuel cell commercialization in vehicles. While the conventional wisdom is that hybrids are competitive to fuel cells, a new type of hybrid, the so-called "Plug-In Hybrid" vehicle, offers the capability of recharging on-board batteries from the electrical grid. This alters the conventional dynamics in two ways. First, because Plug-In hybrids reduce the amount of energy that must be carried on-board the vehicle, they help address the hydrogen storage issues. Second, because the fuel cell would only recharge the batteries and not be the sole motive power, the complexity (and cost) of the fuel cell would be reduced.

While no major car manufacturer has announced immediate plans to introduce a Plug-In Hybrid model, the technology seems to be a logical next step in the overall process of vehicle electrification. Today, electrical energy is far cheaper than gasoline, and electrification allows efficiency technologies like regenerative braking. Widespread penetration of hybrids looks promising in the next five years. The question that remains is whether a role exists for fuel cells in our hybrid future.

While external factors, such as high fuel costs, environment concerns, and government support, favorably impacted the industry in 2005, the overall industry saw mixed performance in 2005. Larger stationary systems using molten carbonate or phosphoric acid technology made relatively little commercial progress in 2005. FuelCell Energy reported flat sales in 2005[3] and initial excitement over UTC's PureCell™ product faded. Late in 2005, FuelCell Energy was sued by Zoot Enterprises because its Direct FuelCell™ system failed to operate independently of the electrical grid, a main selling point for FuelCell Energy and distributed generation generally. One bright spot in this area was the start up of HydroGen, LLC, which successfully rose $13.5M to pursue development and commercialization of the air-cooled phosphoric acid technology developed originally by Westinghouse.

Solid oxide fuel cell

[3] FuelCell Energy received orders for 6 MW in fiscal year 2005, compared to 7.5 MW in fiscal year 2004.

developers also had a mixed year in 2005. SECA partners continued technology development programs and reported progress at the 2005 Fuel Cell Seminar. For example, General Electric was the first amongst the six SECA industrial teams to demonstrate a complete 5 kW prototypes SOFC system. Other companies like Delphi and Cummins also showed positive results and met SECA program goals. The SECA program was largely seen as successful, thus far, though the teams have announced only limited progress toward achieving the $400/kW cost target by 2010.

Today, we are not aware of any companies offering commercial SOFC products. Acumentrics, which had offered "commercial" systems for sale in 2004, ran into financial and technical difficulties that pushed back their commercialization timeline. Similarly, Siemens has twice redesigned the size and shape and their tubes and is now focusing their efforts to develop a core power module resized to 5 kW. Sulzer Hexis, which planned to rollout their 1 kW Galileo SOFC system across Europe in March 2005, failed to raise additional funding and spun out their fuel cell program into a new company called Hexis AG. While technical progress was evident at the 2005 Fuel Cell Seminar, our feeling is that no SOFC company appears to be ready to field a commercial product within a 5-year time horizon.

Portable products, including soldier power, battery chargers, recreational power supplies, wheel chair power, and a host of other niche market products, continue to receive attention. A number of products (Intelligent Energy, Voller Energy, Nanodynamics, Parker Hannifin) were showcased at the 2005 Fuel Cell Seminar. While these companies and products target small, niche markets, fuel cells may serve up a real value proposition in some of these applications and we continue to expect that a number of suppliers will begin to advance in the marketplace. Small victories here may become leverage for the cost reductions and performance enhancements that drive broader deployment.

Finding solutions for technical issues continues to attract attention and funding. Issues like limited stack durability, which affects the commercial viability of all technologies, require significant scientific and engineering breakthroughs. This is driving substantial and increasing interest in fuel cell research at the university level, and much activity in the fuel cell industry is occurring outside of the companies listed in this report. Attendance at the 2005 Fuel Cell Seminar, which attracted over 2300 participants from over 36 different countries, shows that interest and activity in fuel cells remains strong.

Fuel Cell Installations

In the stationary fuel cells market, historically the primary interest for the HARC fuel cell consortium, fuel cell installations are a useful indication of commercial progress. In 2005, Fuel Cells 2000,[4] a project of the Breakthrough Technologies Institute, published on the Internet a searchable database of stationary fuel cell

[4] http://www.fuelcells.org

installations.[5] The database lists key information for stationary fuel cell projects around the world, and initial analysis yields some interesting results about recent stationary fuel cell. Each installation or project may be based on one or more individual fuel cell machines, so further research would be necessary to characterize total kWh or project costs. The results of the analysis are presented in Table 1 below. Some of the key findings include:

- In 2005, 113 projects were reported, continuing a 4-year trend of about 100 projects per year.
- About half the installations in 2005 were in the 1-5 kW power range and one-third were in the 5-250 kW range. This distribution is close to that seen in 2003 and can largely be attributed to a significant reduction in the number of individual projects undertaken by Plug Power (22 in 2005 compared to 44 in 2004).
- Slightly more companies had five or more projects in 2005 than in 2004, and there were more companies with multiple projects in 2005 than in previous years. Approximately two-thirds of the projects in 2005 involved equipment from six different companies. In 2003 and 2004, installers of 5 or more projects accounted for about 80% of installations.

Table 1. Fuel Cell Installation by Total Project Power

Total Power	2003	2004	2005
< 1 kW	2	1	7
1 - 5 kW	53	76	53
5 - 250 kW	39	22	36
250 - 1000 kW	7	10	6
> 1000 kW	1	0	1
Not reported	3	12	10
Total	105	121	113

Price Waterhouse Coopers Fuel Cell Survey

PricewaterhouseCoopers[6] (PWC) also concluded that 2005 was a difficult year for the industry. In their annual Fuel Cell Industry Survey, PWC surveyed 20 publicly traded companies (up from 18 in 2004), including companies based outside the U.S.[7] The survey covers aggregate financial activities for 2004.

[5] http://www.fuelcells.org/info/databasefront.html
[6] http://www.pwc.com/extweb/pwcpublications.nsf/docid/25582836BD5E736A852570CA00178BC7
[7] The companies are: Ballard Power Systems, FuelCell Energy, Quantum Fuel Systems; Distributed Energy Systems, Dynetek Energy Systems, Hydrogenics, Plug Power, Stuart Energy Systems, QuestAir Technologies, Fuel Cell Technologies, Ceramic Fuel Cells, Millennium Cell, Manhattan Scientifics, Pacific Fuel Cell, Palcan Power Systems, Astris Energy, Medis Technologies, Alternate Energy, Ceres Power Holdings, and ITM Power.

Compared to PWC's 2004 report, which clearly indicated the onset of some financial stability among fuel cell companies, this year's report is equally clear that industry growth has not yet resumed. By all measures (revenues, employees, market capitalization), the industry treaded water in 2005.

Key findings in the 2005 PWC report include:

- Revenues for the surveyed companies decreased by 4% between 2003 and 2004, from $244M to $234M. Two companies (Ballard Power Systems and FuelCell Energy) accounted for nearly half of revenues in 2004.
- Market capitalization declined in 2004, from $3.6B in 2003 to $3.2B in 2004. All surveyed companies continued to operate at a loss in 2004, with net loss for the surveyed companies increasing by 20% from $387M in 2003 to $465M in 2003.
- The survey leader, Ballard Power Systems, saw a 32% decrease in revenues in 2004, with approximately two-thirds of the decline coming in engineering and other revenues and one-third of the decline in product revenues. The good news was that with Ballard's declines removed from the data, the rest of the survey companies showed a 22% increase in revenues, with Quantum Fuel Systems, Distributed Energy Systems, and Stuart Energy Systems noticeable leaders.
- Research and development expenditures increased by 2% to $221M, but most companies decreased their R&D investments. Significant increases by FuelCell Energy, Medis Technologies, and Hydrogenics drove the overall increase.
- The number of employees at surveyed firms decreased by 2% to 2,789 in 2004. As with revenues, employment was concentrated in a few larger companies. Ballard Power Systems, FuelCell Energy, and Plug Power retain some 1,600 employees between them.
- Government purchases, utilities, and large automotive original equipment manufacturers continue as the dominant market for fuel cell products.
- A trend toward consolidation in the fuel cell industry, first noted in 2003, continued in 2004. Several strategic alliances, acquisitions and sales were marked in 2004. A number of companies in the survey have extended their product and/or market reach in an effort to strengthen sales and revenues. For example, companies have entered the compressed natural gas field, the broader UPS sector, or related hydrogen technologies (such as metal hydrides for storage). Several companies are pursuing collaborations with customers or distributors in order to gain vertical or regional market strength.

The PWC survey results draw attention to a few key realities associated with fuel cell commercialization and markets. We offer a few discernable trends that continue to control the commercialization process:

- Commercialization processes for new energy technologies are particularly susceptible to general energy market influences like fuel prices, government-sponsored R&D efforts, and perceptions of commercial suitability. Many of these forces, like the impact on new technology funding resulting from the ratification of the Kyoto Protocols, have disparate impacts according to the policy posture of the particular state.
- Internationally-based funds are showing strong interest in supporting initial public offerings for clean energy technology equity. The key drivers for this trend are fairly durable and include the Kyoto Protocols, air pollution associated with fossil fuels, and the increasingly appreciated inherent advantages of distributed energy systems. However, these drivers carry a considerable political risk component.
- Emergent technology companies are often caught in an ebb and flow of specialization and diversification as markets emerge, expand, settle and contract. When opportunities wane in fuel cell UPS markets, for example, a company might leverage experience in power control interfaces to reach into markets for conventional UPS systems. While this offers robustness in terms of revenue generation, it can distract a company from core commercialization objectives.
- Energy market fundamentals, including natural gas prices, the status of customer choice markets, interconnection requirements, and public research funding, all exert powerful impacts on technologies moving from the demonstration stage to early commercial sales. Add to these the need for development of hydrogen infrastructure, which has a strong "public goods" character, and the market context for fuel cell commercialization is by nature challenging. Volatility, regulatory uncertainty and changing public policy agendas add further risk and often delay execution of business plans.
- Emerging technology companies themselves undergo profound change as they move into the early commercialization stage. The shift from technology focus to commercialization focus entails shifts in management structure, in marketing strategies, and in research agendas. These changes can be highly disruptive, often requiring considerable reexamination of overall business strategy.
- The PWC report also highlights the importance of external market factors in driving market acceptance. Federal and State governments are sure to play key roles in 2005, as will a number of other external drivers that are

outside of the control of the fuel cell industry. At the present time, the fuel cell industry benefits from a number of these factors.

Market Drivers

In 2006, key market drivers impacting the prospects of the fuel cell industry include private investment trends, the U.S. government's level of commitment to the hydrogen and fuel cell program, the potency of provisions in the Energy Policy Act (EPACT) intended to stimulate fuel cell implementation, proactive state government involvement in fuel cell demonstrations and commercialization, high energy prices, and environmental considerations. Additional detail on these important trends is provided below.

- *Private Investment Trends*

  The year 2005 started on a positive note for investment in the fuel cell space. New Energy Finance[8] reported on trends building into the year. Venture capital investment coming into 2005 had grown significantly in 2004, compared to recent years. Overall investments in new and renewable energy technologies grew at a dollar growth rate of 130%, significantly besting the growth rate for overall venture investments (67%).[9] Fuel cells benefited from this trend. Over the period 2001-2004, cumulative venture investment in fuel cells totaled $359 million (55 rounds), representing the third largest grouping in the New Energy Finance summary.[10] In fact, the fuel cells and hydrogen technology sector entered 2005 with an annualized volume growth of 39% over the period of the previous four years.[11]

  The pool of active venture capital firms in the space also seems to have diversified over the period 2001-2004. While some 50% of the transaction volume during the period was handled by some 54 investors who made three or more investments, the balance of activity was conducted by more than 200 investors who did just one or two deals in the clean energy space.[12]

  By the end of 2005, New Energy Finance estimated that venture capital investment in the clean energy sector had grown from $958 million in 2004 to $1.7 billion.[13] The overwhelming majority of the venture capital

[8] http://www.newenergyfinance.com/index.html
[9] Liebreich, M., "New and renewable energy technology – trends in venture capital investment," (Feb. 2005), http://www.newenergyfinance.com/NEF/HTML/Press/Venture-Capital-Trends.pdf, at 1.
[10] Id., at 2.
[11] Id., at 3.
[12] Id., at 4.
[13] Liebreich, M., "Clean Energy Finance: Overview & Trends," (Dec. 2005), http://www.newenergyfinance.com/NEF/HTML/Press/Investment_Overview_8_Dec_2005.pdf, at 3.

and private equity investment was in North America in 2005 (73%).[14] Total worldwide annual investment in clean energy is now estimated to have reached $42.2 billion.[15]

Overall IPO and secondary offering financing is estimated at $4.2 billion in 2005.[16] Over 10% of that financing was in the fuel cell sector, representing $496 million in nearly 30 deals.[17] An interesting global distribution emerged in 2005, as the overwhelming majority of equity raised by initial public offerings came from non-US markets.[18]

New Energy Finance's Global Energy Innovation Index,[19] which tracks 50 publicly-quoted pure-play clean energy companies, eight of which are fuel cell and hydrogen companies,[20] saw performance that consistently bested the NASDAQ in 2005, and was up nearly 30% by November 2005 against the start of the year.[21] Two-thirds of the growth in the Index came from the markets located in countries that joined in ratifying the Kyoto Protocols to the Framework Convention on Climate Change.[22]

- *US DOE Hydrogen Program*

  The US Department of Energy claimed considerable success in meeting its hydrogen and fuel cell programs objectives in its annual FY 2005 Progress Report.[23] Work continued on PEM fuel cells through Energy Efficiency and Renewable Energy (EERE) and with SOFC in the Office of Fossil Energy. The fiscal year 2006 budget appropriated about $136 million to hydrogen and fuel cell related projects through the Energy Supply and Energy Conservation programs.[24] As a result, funding for Bush Administration Hydrogen Initiative was down $10 million against 2005. Additional funding in the Fossil Energy and Nuclear energy budgets raised the total somewhat for hydrogen research, but details were not available as this report went to publication.

[14] Id., at 3.
[15] Id., at 2.
[16] Id., at 4.
[17] Id., at 5.
[18] Id., at 6.
[19] See http://www.newenergyfinance.com/NEF/HTML/Index.html.
[20] These companies are Ballard Power Systems, Plug Power, FuelCell Energy, Medis Technologies, Hydrogenics, Hoku Scientific, Quantum Fuel Systems Technologies, and Ceres Power.
[21] "Overview and Trends," at 7.
[22] Id., at 8.
[23] US Department of Energy, Hydrogen Program 2005 Progress Report; http://www.hydrogen.energy.gov/annual_progress05.html.
[24] American Association for the Advancement of Science, AAAS R&D Funding Update on R&D in FY 2006 DOE Final Appropriations; http://www.aaas.org/spp/rd/doe06f.htm.

Congress set a new record in earmarking DOE R&D programs, with more than one in five dollars marked for specific projects overall, and in the case of hydrogen and fuel cell funding, nearly two in five dollars was earmarked to specific projects. The consistently adverse impact of earmarks, which generally overwhelm any budget increase and often cut deeply into core R&D programs, remains a continuous problem for DOE. Earmarks indicate both a degree of politicization of the subject matter and a lack of Congressional confidence in agency program administration and execution.

Given the earmarks and the overall reductions in federal funding, the states will again be a key target for public funding for commercialization support. Importantly, the US DOE has also kept faith with its commitments to carefully monitor research and development progress, to report to the public, and to adjust program activities based on actual results. This may bear fruit over the long term, as public confidence in the administration of US federal research programs can reduce pressure for the earmarking that today consumes a significant fraction of the program budget.[25]

In its annual program review for 2005, the Department called special attention to the passage of the Energy Policy Act of 2005, discussed below. Other notable accomplishments included:

- Agreement by the 16-member International Partnership for the Hydrogen Economy (IPHE)[26] to cooperate on ten projects relating to fuel cells and hydrogen technology.
- The launch of a planning effort relating to manufacturing research and development, with a goal of publishing a roadmap early in 2006.
- The selection of more than $64M in basic energy sciences research relating to novel materials for hydrogen storage, membranes, nanoscale catalyst design, solar hydrogen production, and bio-inspired materials and processes.
- The award of 32 “clean coal” research projects, including two relating to hydrogen handling and storage and hydrogen production from coal.

[25] For an excellent summary of the US hydrogen and fuel cell research and development targets, see “US Hydrogen and Fuel Cell R&D Targets and 2005 Funding,” Kerry-Ann Adamson, Fuel Cell Today, 2005, http://www.fuelcelltoday.com/FuelCellToday/FCTFiles/FCTArticleFiles/Article_934_US%20R&D%20Targets%20and%20Funding.pdf

[26] http://www.iphe.net/

- The award of three projects relating to production of hydrogen through high-temperature under the Department's Nuclear Hydrogen Research program.
- The launch of the Department's "National Hydrogen Learning Demonstrations" for technology validation and assessment.
- Launch of two new hydrogen and fuel cell websites at http://www.hydrogen.energy.gov/ and http://www.hydrogen.gov.
- A near doubling of the number of patent applications filed by and patents granted to US DOE hydrogen program participants compared to 2004.

In all, the DOE programs have struggled to keep up with the ambitious rhetoric of the Bush Administration's Hydrogen Initiative. Core R&D agendas have been severely impacted by earmarks. Most of the significant accomplishments related to planning, the creation of roadmaps and the reworking of information resources, and the execution of paper agreements. Commercial technology developers will have some opportunities to work with DOE and secure supporting funding, but the real impacts will be felt over the next five to ten years as the flow of research and development results in the pipeline dry up. State funding cannot fill a critical R&D gap efficiently, though it can support demonstration programs more effectively than the federal government in many cases. Research and development will depend in the future on private commercial success with strategic reinvestment of revenues into R&D, as well as private sector funding for the venture capital community – at least in the United States.

- *EPACT 2005*

In the U.S., one major event in energy development was the passage and signing into law of the Energy Policy Act of 2005 (EPACT 2005, or the "Act"). This legislation was significant for the fuel cell industry in particular because of the impact that stability in policy has on long- and mid-term research and development agendas, as well as on the level of effort devoted to development of particular market segments. Because public energy research and development funding in the United States is an annual affair, the presence or absence of clearly articulated overarching program policy has a profound effect on the context in which commercialization must occur. The United States had not enacted major energy legislation in nearly two decades. The EPACT 2005 not only set a broad energy agenda for the United States, but also included a new version of overarching hydrogen legislation. The Act provides a basis for stability in US DOE programs for at least the next five years.

Most hydrogen related provisions of EPACT 2005 were contained in Title VIII, sections 801-11.[27] In the parlance of lawmaking in the US Congress, the Act was primarily authorizing legislation—meaning it authorizes Congress to make appropriations in particular areas. Whether the many authorizations are ultimately funded is a function of annual appropriations bills that require separate passage by Congress and signing into law by the President. Still, the bill charts a course of research and development support for hydrogen and fuel cell technologies that is significant, and includes potentially important requirements for reports and studies.

- Overall, the Act authorizes the appropriation of about $3.7B in federal funding over a 5-year period. The Act emphasizes partnership with industry enabling and promoting the development of technologies, with an ultimate goal of establishing a mature "hydrogen economy" in the transportation sector, as well as in demonstrating and commercializing the use of hydrogen in all major sectors. The Act's specific focus on the transportation sector is reflected in the legislative goal of reducing oil imports and in a goal of enabling US auto manufacturers to offer safe, affordable hydrogen fuel cell vehicles in the mass consumer market by no later than 2015.[28] A few of the key hydrogen and fuel cell-related provisions of the Act include:
- Requirement that the Secretary of Energy develop a coordinated 5-year plan for hydrogen and fuel cell programs.[29]
- Competitive merit-based processes to award assistance and contracts.[30]
- Approximately $2 billion in authorized funding for research and development.[31]
- Creation of an interagency task force to plan for infrastructure and implementation issues.[32]
- Creation of a Hydrogen Technical and Fuel Cell Advisory Committee to advise the Secretary of Energy.[33]

[27] Title VIII is also known as the Spark M. Matsunaga Act of 2005. Text of the EPACT 2005 can be found at http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=109_cong_bills&docid=f:h6enr.txt.pdf
[28] Sec. 805.
[29] Sec. 804.
[30] Sec. 805.
[31] Sec. 805.
[32] Sec. 806.
[33] Sec. 807.

- Approximately $1.3 billion in authorized funding for demonstration projects[34].
- Authorization of $138 million for development of codes and standards.[35]
- Requirement that the Secretary of Energy submit reports on progress under the programs.[36]
- Support for development of solar and wind technologies for production of hydrogen.[37]

A number of additional provisions scattered throughout the bill also provide support for hydrogen and fuel cell technology development and commercialization. Most notably, the Act provides for tax credits for individuals and businesses that install qualified fuel cells. The tax credit provision, which is set to expire in 2007, includes a tax credit of up to $500 per half-kilowatt of capacity installed.[38] Other provisions authorize funding for government purchases of fuel cells, research in a wide range of hydrogen production technologies, and fundamental research.

On a related note, the US Congress announced in 2005 the formation of a House Caucus to complement an already extant Senate Caucus on Hydrogen and Fuel Cells. The members of the Caucus join in supporting the promotion of hydrogen as a fuel alternative to petroleum-based fuels. The formation of such caucuses is often a reliable indicator of the perception among members of Congress that an issue has gained significant political traction. That certainly seems to be case in the US Congress for fuel cells and other hydrogen energy technologies.

- *State Governments*

In our opinion, state (and to an increasing extent city) governments will continue to be a source of critical funding for the fuel cell industry. States like Connecticut and Ohio have been eager attract and support fuel cell developers and integrators, and to promote fuel cell demonstrations and deployments. For example, the Connecticut Clean Energy Fund is investing over $30 million in clean energy technologies, including fuel cells, in the 2005 fiscal year. Funding for the program comes from a non-bypassable public benefits fund collected from electricity ratepayers. With the federal government budget beset by earmarks, we anticipate that state governments will continue to provide needed support for the fuel cell

[34] Sec. 808.
[35] Sec. 809.
[36] Sec. 811.
[37] Sec. 812.
[38] Title XIII, secs. 1335-1336.

industry. In addition, New York and other cities could become more fertile ground for projects, as more and more metropolitan areas look to themselves to come up with solutions to deal with problems like traffic congestion, air quality, grid reliability, and decreasing quality of life. However, state funding cannot fill a critical R&D gap efficiently, so state and local funding is unlikely to help in this area.

- *High Energy Prices*

  As we indicated in last year's report, rising prices for oil and natural gas are increasing interest in alternative fuels due to both cost and supply risks. While the long-term prospects for fuel cells will likely benefit from this trend, in the short-term, high fossil fuel prices, and in particular natural gas prices, will be a mixed blessing, as fuel cell vehicles and stationary power systems rely on natural gas as a primary source of hydrogen. Furthermore, with regard to stationary power, the rationale for combined heat and power (CHP) for distributed generation, an excellent potential market for fuel cells, is diminished when spark spreads are low (as they are now in the U.S.), even when the high efficiency of fuel cell systems is considered. On the flip side, developers of large stationary equipment have made some impressive progress using "free" biogas at wastewater treatment facilities and "excess" gas available at chemical and petroleum processing industries. High natural gas prices could enhance the competitiveness of such installations. In the short-term though, high oil and gas prices seem to stack the cards against most fuel cells due to their current reliance on fossil fuels as a source of hydrogen.

- *Environmental Concerns*

  The lack of progress achieved at the UN Climate Conference late last year signals that the Kyoto treaty will likely have minimal impact on the global warming threat. Very few countries are expected to meet the targets of reducing emissions 5% below 1990 levels by 2012. While actions such as the Northeast Regional Greenhouse Gas Initiative to mitigate carbon dioxide emissions are still moving forward voluntarily, the lack of a regulatory framework (Kyoto or other) means that actions in the future will continue on a voluntary basis. While fuel cells, due to their high electrical efficiency, will likely offer a global warming benefit, the pace of technology and policy adoption is unlikely to produce immediate gains to the fuel cell industry.

Final Thoughts

As we mentioned in the report last year, fuel cells may well turn out to be a disruptive technology, but due to unresolved performance and cost hurdles, 2005 has closed with that revolutionary value proposition unfulfilled. By all accounts,

2005 was an uneventful year for the fuel cell industry and most evidence points this out. We do take heart in the success achieved by PEM fuel cell manufacturers with UPS systems and likely with forklifts. Combined with favorable market drivers, this momentum could in retrospect make the events of 2005 much more significant. High energy prices, ongoing air quality and climate change debates, and burgeoning interest in all types of clean and renewable energy bode well for continued progress. A key issue for 2006 is seeing whether the fuel cell industry will be successful in leveraging the potential for success into real market share. We believe that for PEM fuel cell companies to achieve this success, they will have to drive down system costs dramatically. By keeping focus on revenue generating products that provide real value, and with help from DOD, DOE, and state governments, we expect the industry will continue making progress on costs. However, without an unforeseen breakthrough that brings rapid improvement, we carry forward the notion that the commercialization process over the next few years will be a slow and methodical expansion of niche markets.

No finish line exists to identify successful commercialization – it is an ongoing process with no real end. We won't one day wake up to declare the technology commercial. How will we know how well the process of commercialization is progressing? While it's tempting to look at financials like top line revenue growth, this is often masked by public spending and early adopter enthusiasm. Broad public acceptance isn't easily extracted from financial statements. To identify real progress in the adoption, we must look at the products in which fuel cells are a part. When fuel cells themselves are no longer talked about, and discussion turns to the products in which they are integrated, fuel cells will "disappear" through integration. Fuel cells will be fully commercial when they are bought with the same level of attention today's customers give to automobile engine power, blender motor wattage, or computer processor speed. We are a long way from this level of integration. It will require considerably more focus by fuel cell manufacturers on integration of their technologies into larger energy systems, specialized equipment, and appliances. These efforts are underway and will likely characterize progress in the industry in the years to come.

Overview of Companies Included in the Report

This report reviews the activities, products, and technical approaches of 110 private sector companies that are focused on fuel cell technology development and systems integration. These companies cover a very broad cross-section of the fuel cell developer community, ranging from several person start-up companies to divisions in the largest Fortune 500 corporations. The list includes companies that are solely focused on fuel cell technologies, and others that are more broadly focused. Some companies may be engaged in early-stage technology development, while others may be systems integrators looking to field

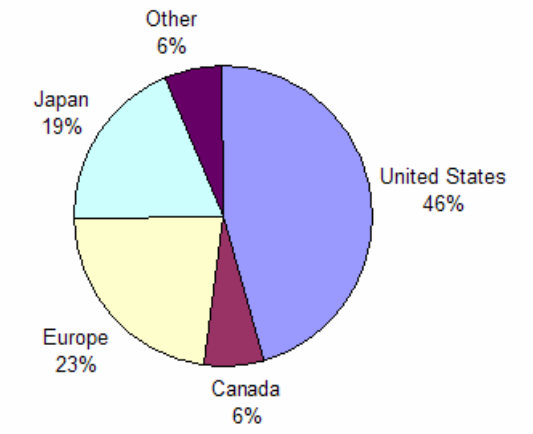
commercial products. The key unifying element of all the organizations included in the report is fuel cell commercialization, so we are looking intently for companies that can deliver technology or products that provide a commercial value proposition.

By looking comprehensively at fuel cell developers, we desire to better understand the current state of fuel cell commercialization, and its prospects. This year's report, which covers a total of 110 companies, increases the number of companies in the report by eighteen. This increase reflects our continuing efforts to increase the comprehensiveness of the report and, to some extent, the limited growth in the industry. Companies included were not selected by technology preference or market application. Our interest is simply to discuss those companies that are active technology or system developers. The report does not evaluate fuel cell groups located at universities, government research labs, and non-profit institutions, or private companies not actively publicizing their efforts.

Even with 110 companies included in the report, it by no means provides a comprehensive list of the fuel cell industry. However, we believe the 110 companies discussed provide a solid overview of the core activity occurring in fuel cell industry. We are sure to have omitted some excellent companies developing very interesting technologies. For that we apologize, as no attempt was made to limit the report's scope, and we are interested in enhancing the comprehensiveness of the report by adding more companies in the future.

This year's report features significant enhancements over last year's. While we continue to use both long and short reviews, the number of companies receiving in-depth analysis is almost double the number in last year's report. The decision to use long versus short descriptions was based first and foremost on information availability. Companies with more thorough descriptions are most likely to be those companies that are pure-play fuel cell developers or companies where information was more readily available. The length of a company's review in no way connotes or implies anything about the quality, relevance, or prospects of a company.

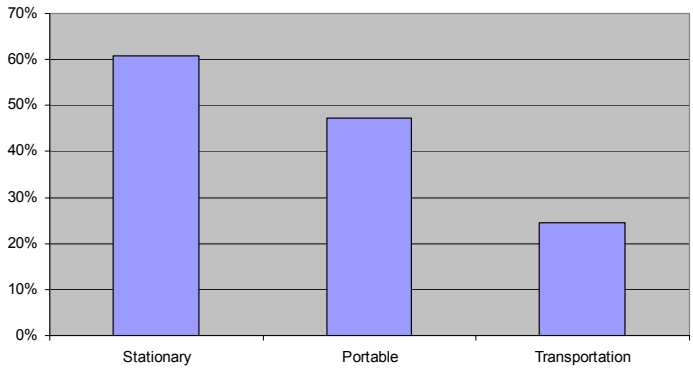
New additions to the report this year include the following eighteen companies: Cellex Power Products, CMR Fuel Cells, Cosmo Oil, Direct Methanol Fuel Cell Corp., Entwicklungs und Vertriebsgesellschaft Brennstoffzelle mbH, European Fuel Cell, H2 ECOnomy, Hydra Fuel Cell, Infinity Fuel Cell, ITM Power, Max Power, MES dea sa, Mesoscopic Devices, MTU CFC Solutions, NTT

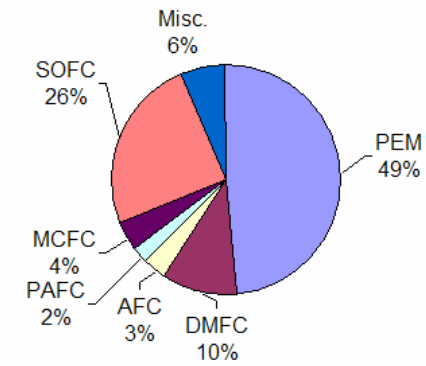


DoCoMo, SiGEN, Technofil, and Ultracell Corp. Companies omitted from the report this year include Energy Vision, which changed its name to Lions Petroleum to focus on oil and gas exploration, while Rogers Corporation reported not working on fuel cell development at this time.

As depicted in the pie chart, the United States remains the leader in fuel cell development efforts with 46% of fuel cell companies located here. As a result of our greater focus to include European activities in the report, we've added a number of additional companies located in EU countries. As a result, nearly one quarter of the companies covered by this year's report are located in Europe, while the United States now hosts somewhat less than 50%. While one might be tempted to conclude that European fuel cell industry growth is outpacing that in the U.S., that conclusion cannot be drawn for this report.

The application focus of companies is an important indicator of where the industry sees its best commercialization prospects. The figure below shows the breakdown between stationary, portable, and transportation applications. As with last year, about 61% of the companies report working on technologies and products intended for stationary applications. About 47% of companies report working on portable applications, up slightly from the 43% involved in portable last year. Due to the high barriers to entering vehicles markets, only 25% of companies report working in transport. Due to the modularity and cross-functionality of fuel cells, some companies pursue a strategy to develop multiple products across a wide range of applications. For example, General Motors is deploying fuel cells in stationary applications, as an interim step prior to the commercialization of fuel cell vehicles. In 2005, about 17% of companies report developing fuel cell technology for two or more applications, down from about 23% in 2004.





The figure at left shows that PEM fuel cells continue to be of most interest to fuel cell developers. Around 59% of the companies are working on both PEM and DMFC technologies, which are closely related technologies. With approximately 26% of the companies reporting that they are working on SOFC, this technology is second

to PEM. Fifteen percent of companies report developing other technologies (MCFC, PAFC, AFC) or novel concepts that are not easily categorized. This breakdown is essentially unchanged from last year.

The number of companies offering products for sale is the most important metric regarding fuel cell commercialization. In 2005, 38 companies out of 110 included in the report indicate that they expect to offer products (pre-commercial or commercial) in 2006. In last year's report, a total of 30 companies expected to have commercial products ready in 2005, but a number of those companies delayed their product launch timelines into 2006, due to either performance issues related to the fuel cell or non technical issues like codes and standards. Many of these companies remain positive regarding product availability in 2006. However, five companies (Asia Pacific Fuel Cell Technologies, Casio, Kyocera, NEC, and Toshiba International Fuel Cells) expecting product launches in 2005 delayed product introductions by several years. Our experience is that most companies overstate their readiness for product launch and few actually deliver products. We expect this to hold true again this year.

A list of companies included in the report is presented below.

About HARC and the CFCRA

Founded in 1982, the Houston Advanced Research Center (HARC) is a non-profit 501(c)(3) organization based in The Woodlands, Texas. The organization is dedicated to moving knowledge into action to promote technologies and policies that improve human well-being and protect the environment. HARC promotes the development of a more sustainable economy by identifying and enhancing the market acceptance of environmentally promising technologies through an integrated approach incorporating science-based research, product testing and evaluation, demonstrations, education, outreach, and public policy. HARC is concerned with technology and policy solutions addressing ecosystems, water, air, energy, and health.

The Center for Fuel Cell Research and Applications (CFCRA) is a HARC program. Through funding from corporate and foundation sponsors, the Center has been testing fuel cell systems since 2001. To date, the Center has completed testing or is in the process of testing equipment from Acumentrics, Ballard, Enable Fuel Cell, Nuvera, Plug Power, and ReliOn. In 2006, the Center plans to evaluate additional equipment including commercial systems from APC/Hydrogenics, IdaTech, and UTC. More information regarding the Center's fuel cell test and evaluation program can be found at http://www.harc.edu/fuelcell.

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List of Companies Included in the Report

	Company Name	Fuel Cell Technologies	Region	Commercial Products in 2006?
1	Acumentrics	SO	US	No
2	Adaptive Materials	SO	US	No
3	Agni	PEM	Asia	No
4	Altergy Systems	PEM	US	Yes
5	Angstrom Power	PEM	Canada	No
6	Ansaldo Fuel Cell	MC	Europe	No
7	Anuvu	PEM	US	Yes
8	Apollo Energy Systems	A	US	No
9	Arcotronics Fuel Cells	PEM	Europe	Yes
10	Asia Pacific Fuel Cell Technologies	PEM	Asia	No
11	Astris Energi	A	Canada	Yes
12	Axane Fuel Cell Systems	PEM	Europe	Yes
13	Ball Aerospace and Technologies	PEM/DM	US	No
14	Ballard Power Systems Inc.	PEM	Canada	Yes
15	Ballard-Ebara	PEM	Japan	Yes
16	BCS Fuel Cells	PEM	US	Yes
17	Casio	PEM	Japan	No
18	Cellex Power Products	PEM	Canada	No
19	Ceramic Fuel Cells	SO	Australia	No
20	Ceres Power	SO	Europe	No
21	ClearEdge Power	Misc.	US	Yes
22	CMR Fuel Cells	DM	Europe	No
23	Cosmo Oil	PEM	Japan	No
24	Creare	DM	US	No
25	Delphi Technologies	SO	US	No
26	Direct Methanol Fuel Cell Corporation	DM	US	No
27	EnerFuel	PEM	US	No
28	Entwicklungs-und Vertriebsgesellschaft Brennstoffzelle mbH (EBZ)	SO	Europe	No
29	European Fuel Cell GmbH	PEM	Europe	No
30	Franklin Fuel Cells	SO	US	No
31	Freedom Fuel Cells	PEM	US	No
32	Fuel Cell Technologies	SO	Canada	No
33	FuelCell Energy	MC	US	Yes
34	Fujitsu Laboratories	DM	Japan	No
35	GenCell Corporation	PEM/MC/SO	US	No
36	General Electric Company	SO	US	No
37	General Motors Corporation	PEM	US	No
38	Giner Electrochemical Systems	PEM/DM	US	No
39	H2 ECOnomy	PEM	Asia	Yes
40	Heliocentris Energy Systems	PEM	Europe	No

41	Helion Fuel Cells	PEM/SO	Europe	No
42	Hitachi	PEM/DM/SO	Japan	Yes
43	Honda Motor Corporation	PEM	Japan	No
44	Hydra Fuel Cell Corporation	Misc.	US	No
45	HydroGen	PA	US	No
46	Hydrogenics Corporation	PEM	Canada	Yes
47	IdaTech	PEM	US	Yes
48	Independent Power Technologies	A/DM	Europe	No
49	Industrial Research Limited	A	Australia	No
50	Infinity Fuel Cell and Hydrogen	Misc.	US	No
51	Intelligent Energy	PEM	Europe	Yes
52	ITM Power	PEM	Europe	No
53	ITN Energy Systems	SO	US	No
54	Jadoo Power Systems	PEM	US	Yes
55	Jülich Research Center	DM/SO	Europe	No
56	Kawasaki Heavy Industries	PEM/MC	Japan	No
57	Kyocera	PEM/SO	Japan	No
58	Lilliputian Systems	SO	US	No
59	Lynntech	PEM/DM	US	No
60	Manhattan Scientifics	PEM/DM	US	No
61	Masterflex AG	PEM	Europe	No
62	Materials & Electrochemical Research Corp	PEM	US	No
63	Materials & Systems Research, Inc.	SO	US	No
64	Matsushita Electric Industrial	PEM	Japan	No
65	Max Power	DM	Europe	Yes
66	Medis Technologies	Misc.	Asia	Yes
67	MES dea sa	PEM	Europe	No
68	Mesoscopic Devices	DM/SO	US	No
69	Microcell	PEM	US	No
70	Mitsubishi Heavy Industries	PEM/SO	Japan	No
71	Mitsubishi Materials Corp.	SO	Japan	No
72	Motorola	PEM/DM	US	No
73	MTI Micro Fuel Cells	DM	US	Yes
74	MTU CFC Solutions	PEM/MC	Europe	No
75	NanoDynamics	SO	US	Yes
76	Neah Power	Misc.	US	Yes
77	NEC	DM	Japan	No
78	Nippon Oil	PEM	Japan	Yes
79	NTT DoCoMo	DM	Japan	No
80	Nuvera Fuel Cells	PEM	US	Yes
81	Osaka Gas	PEM	Japan	Yes
82	Ovonic Fuel Cell	Misc.	US	No
83	Pacific Fuel Cell Corp.	PEM	US	No
84	Palcan Power Systems	PEM	Canada	Yes
85	Plug Power	PEM	US	Yes
86	PowerZyme	Misc.	US	No

87	Proton Motor	PEM	Europe	Yes
88	Protonex	PEM/DM	US	No
89	ReliOn	PEM	US	Yes
90	Rolls-Royce Group	SO	Europe	No
91	Samsung Adv. Inst. of Technology	PEM/DM	Asia	Yes
92	Sanyo Electric	PEM/DM/SO	Japan	Yes
93	Siemens Westinghouse	SO	US	No
94	siGEN	PEM/DM/SO	Europe	Yes
95	Smart Fuel Cells	DM	Europe	Yes
96	SOFCO-EFS Holdings	SO	US	No
97	Sony	DM	Japan	No
98	Sulzer Hexis	SO	Europe	No
99	Technofil	Misc.	Europe	No
100	Teledyne Energy Systems	PEM	US	Yes
101	Tokyo Gas	PA/SO	Japan	Yes
102	Toshiba	PEM/DM	Japan	Yes
103	Toshiba International Fuel Cells	PEM	Japan	No
104	Toyota	PEM	Japan	No
105	Ultracell Corp	PEM	US	Yes
106	UTC Fuel Cells	PA	US	Yes
107	Versa Power Systems	SO	US	No
108	Voller Energy	PEM	Europe	Yes
109	Wärtsilä	SO	Europe	No
110	ZTEK	SO	US	No

PEM – Polymer Electrolyte Membrane Fuel Cell
DM – Direct Methanol Fuel Cell
A – Alkaline Fuel Cell
PA – Phosphoric Acid Fuel Cell
MC – Molten Carbonate Fuel Cell
SO – Solid Oxide Fuel Cell
Misc. – Miscellaneous

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Acumentrics

Headquarters:

20 Southwest Park
Westwood, Massachusetts 02090
Phone: 781-461-8251
Website: http://www.acumentrics.com

Ownership Structure:

Acumentrics is privately held. Major investors and distribution partners include Northeast Utilities, ChevronTexaco, Connecticut Clean Energy Fund, NiSource, Sumitomo, General Dynamics, Morgan Stanley, and Massachusetts Technology Collaborative.

Management:

- Mr. Gary D. Simon – President and Chief Executive Officer
- Mr. John C. Cerulli – Chief Financial Officer
- Dr. Thomas W. Philbin – Senior Vice President
- Dr. Norm Bessette – Senior Vice President of Operations and Engineering
- Robert Tomasetti – Director of Sales

Brief Company Description:

Acumentrics is a technology developer and manufacturer of fuel cell systems based on the company's proprietary tubular solid oxide technology, as well as a manufacturer of ruggedized AC and DC uninterruptible power supplies for military, industrial and commercial applications. The company, which is an active participant in the Department of Energy's SECA initiative, claims its proprietary small diameter tube technology enhances its competitive position. In 2004, there was a major change in the company's top management including chief executive officer and chief financial officer. This was followed by appointment of a new director of sales in July 2005. Acumentrics has approximately 65 employees.

Alliances/Partners:

- Sumitomo Corporation – Acumentrics and Sumitomo formed a joint venture – Acumentrics Japan Co. in September 2003 which was later joined by Nippon Steel Corp. The purpose of this joint venture was to market and sell Acumentrics' proprietary tubular solid oxide fuel cell (SOFC) power systems throughout Japan. Under this agreement, Acumentrics shipped their 5 kW SOFC unit to Sumitomo for testing at Nippon Steel Corp in January

2005. The joint venture is targeting the 2-10 kW Japanese commercial market, and plans to expand later to the 20 – 100 kW range. The joint venture received a Japanese multi year grant of US $10M in June 2004 to further the market penetration of Acumentrics SOFC technology in Japan.

- Department of Energy – In April 2003, Acumentrics was chosen for a SECA grant. The goal of the 9 year program is to develop SOFC power systems by 2012 that meet the $400 per kilowatt SECA cost mandate and provide startup times of 10 minutes or less. In March 2004, the Department of Energy SECA program approved Acumentrics for a fully funded second budget period six months early and highlighted its excellent progress. The department also awarded $1.7M in December 2004 to NiSource with Acumentrics as a prime sub-contractor to develop a SOFC system with CO_2 sequestration module – enabling near zero emissions.
- Merloni Termosanitari S.p.A. (MTS) – In August 2005, Acumentrics and MTS signed a joint development agreement to develop at least two commercial micro CHP units for European HVAC markets. Acumentrics will supply its tubular SOFC stack for integration with MTS heating appliance.
- General Dynamics – General Dynamics has collaborated with Acumentrics for over 5 years. The program goal is to deploy 5,000 highly ruggedized power systems to U.S. Army and U.S. Marine Corps. As a first step, in November 2002, General Dynamics integrated the 5 kW Acumentrics SOFC unit for APU and delivered to SunLine Transit Agency for installation in a Class 8 truck. The main features for the APU system included elimination of noise, vibration, and environmentally hazardous emissions. General Dynamics' APU product line is slated to expand to include field-deployable systems ranging in capacity from 3 to 60 kW and will include portable, vehicle-mounted and towed variants. No updates have been made available on any development under this collaboration.
- NiSource Energy Technologies Inc. – In January 2002, the NiSource Inc. subsidiary entered into a purchase and distribution agreement with Acumentrics to buy up to $10 million worth of fuel cell products and has exclusive distribution rights primarily in the Mid-Atlantic and Midwest markets. No progress has been reported in this regard.

Products:

Acumentrics does not offer any commercial products at this time. However, several products are under development and are available for demonstration under limited terms and conditions.

- Residential fuel cell power plants (5 kW and 10 kW systems). Co-generation option available with 10 kW systems.

- Commercial fuel cell power plants (5 kW and 10 kW systems)
- Uninterruptible Power Supply (UPS - 2 kW system)
- Communications fuel cell systems (2 kW, 5 kW, and 10 kW)

Technology Overview:

Acumentrics is developing an anode-supported, tubular SOFC system based on the company's electrolytic tubes which it manufactures from standard YSZ ceramic powders. While still maintaining its focus on small diameter tubes, the company is in the process of migrating from a very small tube diameter (0.375" OD) to a somewhat larger diameter tube (0.75" OD). This change in diameter is expected to further alleviate thermal stresses, thereby increasing the mechanical strength of the tubes and increasing their output power. Even with the migration to larger tubes, the company remains committed to its small tube design, which it believes is a key advantage of the technology, as smaller tubes reduce temperature induced problems, minimize sealing issues, and allow more rapid start up. In 2005, the company seems to be working on improving the anode conductivity through introduction of higher conductivity of internal layers. During the 2005 Fuel Cell Seminar, the company reported that their cells have achieved over one year of continuous operation with less than 2% performance degradation per 1000 hours. The reported power density for these cells is around 115 mW/cm^2. The company is currently working on a "multiple take-off" tube design that allows longer length tubes to be used without affecting the power densities. The new tube design reportedly produced 50 W per cell or nearly 300 mW/cm^2 – more than double the existing performance.

Acumentrics is also working on reducing the cost of their generator to meet the DOE SECA cost targets. The company stated that they have developed metal injection molded manifolds that have allowed them to reduce the cost by around $2000 per kW. The company is also working on optimizing the recuperator design for cost reduction.

The Acumentrics system can be fueled with a variety of fuels including natural gas, methane, propane, ethanol, methanol, or hydrogen. The company claims that the technology is self-reforming for pure methane, but requires a pre-reformer module to avoid the coking experienced when using heavier fuels such as LPG and even with natural gas, which contains some amount of higher hydrocarbons. The company has pre-reformers using both partial oxidation and steam reforming, although the steam reformation technology is being phased out. The system delivered to NREL in October, 2004 will be the last one to incorporate the steam pre-reformer.

Status of Commercialization:

In 2005, Acumentrics experienced financial and technical setbacks. New management was brought in to refocus the company's technical directions and

strategic goals. While the company works to raise additional capital, its focus on 5 and 10 kW fuel cell products appears to be unchanged. Although their long-term goal is to offer a system competitive for mainstream distributed generation for residential and small commercial customers, their initial products will be marketed into military, transportable clean power units, truck stop power, and other higher margin markets. In October 2004, the company shipped a 5 kW unit to NREL for investigations on biogas derived fuels. The company also shipped five additional 5 kW units – one each to Idaho National Laboratory, Exit Glacier National Park (Alaska), and Cuyahoga Valley National Park (Massachusetts); and two to Big Goose Ranger Station (Wyoming).

While Acumentrics has deployed around 20 alpha and beta prototype units primarily with ChevronTexaco, General Dynamics, and Sumitomo, the product is still evolving. At this time, the company is in the process of upgrading the product to incorporate larger diameter tubes and to standardize on the POX pre-reformer. The company is shelving its SOFC UPS product line in favor of systems compatible with standard residential and commercial needs.

The company claims to have achieved efficiency ratings exceeding 50% from hydrocarbon-based fuels. The company has also stated that their systems, which are capable of internally reforming natural gas and propane, achieve over 40% efficiency gas to AC output, at less than 0.5% degradation per 1,000 hours (as reported in a company press release on September 2, 2003).

Acumentrics has developed an inverter technology with overall conversion efficiency exceeding 94% and priced at $100-150 per kilowatt. At the 2005 Fuel Cell Seminar, the company claimed the start-up time for their 2 kW unit to be 35 minutes. The company reports that the 5 kW units, which require further optimization of the burner size and use of the POX pre-reformer, have an efficiency of 31%. The start-up time on this unit is around 45 minutes. The company believes that the addition a steam reformer and their new inverter technology will increase efficiency to the 42-46% range.

Acumentrics is a participant in DOE's Solid State Energy Conversion Alliance (SECA) program, which will provide $40 million to Acumentrics over the next nine years on an 80% cost recovery basis. The company will match DOE's contribution amount with another $33 million. DOE recently recognized the company for their rapid development and cost reductions including:

- Demonstration of a stable cell performance over 6,000 hours with average degradation rates below 0.25% per 500 hours, nearly achieving the 2010 Phase III SECA goal of 0.1% per 500 hours.
- Development of a tube sealing process that has the potential to reduce the connection cost from greater than $1,300 per kW to less that $1 per kW.

- Reduction in the stack cost by demonstrating an increase in 20% volumetric power density of stack and a decrease in manifold count by 17% for the same number of cells.
- Developed and verified inverter efficiencies of over 96% including the transformer.
- Improved anode conductivity by incorporating an additional high nickel contact layer. This resulted is an increased power output of 10%.
- Reduction of the operating temperature to 650-700 ^{o}C to allow use of stainless steel materials instead of high-temperature alloys.

Adaptive Materials

Headquarters:

4403 Concourse, Suite C
Ann Arbor, Michigan 48108
Phone: 734-302-7632
Website: http://www.adaptivematerials.com

Ownership Structure:

Public (TSX: BLD, NASDAQ: BLDP)

Management:

- Dr. Aaron Crumm – President
- Ms. Michelle Crumm – Chief Financial Officer
- Dr. John Halloran – Chief Technical Officer

Brief Company Description:

Adaptive Materials is a developer of portable solid oxide fuel cell systems in the 20 – 150 W power range targeted for portable power and soldier power markets. The company utilizes its expertise in powder processing of materials to develop thin tubular solid oxide fuel cells. The company has approximately 20 employees.

Alliances/Partners: Products:

- Universal Technology Corporation – Under an agreement signed in March 2004, Adaptive Materials will provide fuel cells for soldier power and unmanned aerial vehicles to the Air Force for evaluation beginning in 2005.

- DARPA – Adaptive Materials has been awarded two rounds of funding from Defense Advanced Research Projects Agency (DARPA) Palm Power program, totaling $4.6 M for development of lightweight, powerful and rugged solid oxide fuel cell soldier power.

Products:

The company does not have any commercial products at this time.

Technology Overview:

Adaptive Materials has developed low cost mass manufacturing proprietary technology for solid oxide fuel cells. The company believes that its core technology of powder forming has enabled them to develop SOFC components and system that have lower cost, simpler (less balance of plant components), fuel flexibility, and are compact. The company claims its microtubule technology has superior power cycling capability and rapid start-up capabilities due to lower thermal mass. The company's SOFC are fuel flexible.

Status of Commercialization:

In March 2004, the company demonstrated a 20 W portable solid oxide fuel cell system developed under the DARPA Palm Power program. The company claims that their prototype is fuel flexible and that it can run on hydrogen, propane, and butane. The company has not published a schedule for commercialization of their products.

Agni

Location: Shah Alam Selangor, Malaysia

Website: http://www.agni-inc.com

Technology: PEM

- Agni Inc. is a developer and integrator of PEM fuel cell systems for grid-connected distributed on-site generation, automotive, backup power, military, cellular and consumer electronics markets. In February 2005, the company reported receiving an order for 1 MW integrated fuel cell engine power plant with CO_2 sequestration from a regional Oil & Gas Company. Later in March 2005, the company demonstrated their first prototype fuel cell powered car REAL (Renewable Energy Automobile) in Malaysia. The car which is reported to have an efficiency of 50% still needs further optimization in terms of temperature and weather performance as per the company press release. Agni claims to have over 50 orders for their fuel

cell vehicles from Europe, US and Asia. The company is also opening a new manufacturing facility in Europe. In January 2006, the company announced that it will be invest 65 million Euros in the new plant in Europe which will primarily focus of production of clean energy technology equipment including fuel cells and fuel reformers.

Altergy Systems

Headquarters:

2330 Gold Meadow Way
Gold River, California 95670
Phone: 916-853-0328
Website: http://www.altergysystems.com

Ownership Structure:

The company is privately owned.

Management:

- Mr. Eric S. Mettler – President and Chief Executive Officer
- Dr. Jerrold E. Franklin – Chief Technology Officer
- Dr. Jeffrey A. Phipps – Vice President, Product Engineering
- Mr. Al Stevens – Vice President, Supply Chain Management and Manufacturing Operations
- Mr. James "Mickey" Oros – Vice President, Government Relations

Brief Company Description:

Altergy Systems is a developer for polymer electrolyte fuel cell systems for stationary and portable power applications. Founded in 2001, the company is developing proprietary high-volume and low-cost manufacturing techniques for fuel cells using stainless steel bipolar plates.

Alliances/Partners:

No alliance/partner information is available for the company.

Products:

Altergy products are focused on stationary and portable applications.

- Freedom Power Systems™ - 1000 (FPS 1000) – 1 kW PEM fuel cell system capable of providing 12-48 VDC and/or 120/240 VAC. The system size is 9" × 10" × 15" and weighs 30 pounds. The system is intended for UPS application for the telecom and utility markets.
- Freedom Power Systems™ - 5000 (FPS 5000) – 5 kW PEM fuel cell system capable of providing 12-96 VDC and/or 120/240 VAC. The system size is 36" × 30" × 24" and weighs 210 pounds. The system is intended for UPS application for the telecom and utility markets, business and residential markets, and premium power applications.

- Portable –
  - Freedom Power Pack™ - 75 (FPP-75) – 75 W PEM fuel cell system capable of providing 12-14 VDC. The system size is 4.5" × 4.5" × 5.5" and weighs 5.5 pounds. The system is packaged to replace batteries for professional video and broadcast markets.
  - Freedom Power Pack™ - 500 (FPP-500) – 500 W PEM fuel cell system capable of providing 12 VDC. The system size is 3.5" × 6.0" × 7.7" and weighs 18 pounds. The system is packaged to replace batteries in campers, motor homes, outdoor camping, boats and other off road vehicles.
  - Freedom Power Pack™ - 1000 (FPP-1000) – 1000 W PEM fuel cell system capable of providing 12 VDC/120 VAC. The system size is 9" × 10" × 15" and weighs 30 pounds. The system is packaged to replace small generators and batteries in campers, motor homes, outdoor camping, boats and other off road vehicles and in agricultural and ranching operations as well as on construction sites.

Technology Overview:

Altergy Systems technology employs metal bipolar plates for their stacks. The company believes that their proprietary technology enables them to develop high-volume, low-cost manufacturing process. The company also claims to have developed a new design that integrates the bipolar separator plates and the membrane electrode assemblies, thereby allowing automating in the manufacturing process. The design architecture enables modularity in sealing, cell to cell contact, reactant management and cooling.

The company's portable fuel cell systems uses hydrogen stored in low pressure metal hydride fuel cartridges. These cartridges can be used for over 100,000 cycles and are available in several sizes – depending on application. Furthermore, Altergy's fuel cell permits hot swapping of these cartridges, which allows for continuous operation of the unit.

Status of Commercialization:

The company is currently marketing its products in less than 1 kW power range with 1 year parts/90 day labor warranty. The company's strategy is to utilize their current Freedom Power Pack platform to package systems in 50 W – 10 kW power range. The company states that they have nine new product introductions planned through 2008. To support their product expansion activities, the companies in October 2005 announced moving to a bigger facility in Folsom, CA. The company believes that their fuel infrastructure and market entry price will determine the roll out of new products. In April 2005, the company announced delivery of their Freedom Power System to State of California Department of Transportation for backup power to stationary and mobile applications. The company also plans to provide fuel cells to the U.S. Air Force for soldier power and unmanned aerial vehicles.

Angstrom Power

Headquarters:

106 - 980 West 1st Street
North Vancouver, British Columbia
Canada, V7P 3N4
Phone: 604-980-9936
Website: http://www.angstrompower.com

Ownership Structure:

Angstrom Power is privately held. Key investors include: Aretê Corporation, GrowthWorks, Ventures West, Chrysalix, and Ontario Power Generation.

Management:

- Dr. Ake Almgren – Chief Executive Officer
- Dr. Gerard McLean – Founder and Chief Technology Officer
- Mr. Godfrey Forssman – Director of Finance
- Mr. Olen Vanderleeden – Director of Business Development
- Mr. Duhane Lam – Director of Product Development

Brief Company Description:

Angstrom Power is a developer of polymer electrolyte membrane (PEM) fuel cells in the 20 W and less range. The company is targeting portable power and

battery replacement applications. Angstrom was formed in late 2001 to commercialize the technology developed at the University of Victoria by Dr. Gerard McLean. The technology involves applying micro fabrication techniques to create "micro-structured" fuel cell system. The company's intellectual property portfolio includes two issued and 40 pending patents. The company announced a new Chief Executive Officer in March 2005 to help the company move from technology development to product commercialization stage.

Alliances/Partners:

The company is working with several organizations including Defense Research and Development Canada, Natural Resources Canada, and National Research Council Canada to test and demonstrate their technology. The company is also collaborating with major universities in the area. In June 2005, the company announced that they have received funding from Sustainable Development Technology Canada (SDTC) for test and demonstration of fuel cells powered portable electronic devices in the Vancouver area.

Products:

The company does not offer any commercial products at this time.

Technology Overview:

Angstrom Power technology utilizes the micro-fabrication techniques to develop "micro-structured" fuel cell. Using proprietary micro-structured topology, large surface area is packed into a smaller volume. This allows the company to accommodate fuel cells in thin layer orthogonal to the planes in which reactants flow. The company's fuel cells operate at ambient conditions without the need of pumps and fans typically required by conventional fuel cell systems. This allows the company to reduce the balance of plant components resulting in a compact and efficient system.

Angstrom Power is pursuing two different designs for their core power module. The first one is V50 cylindrical design which measures 2.6 cm (diameter) × 2 cm (long) and produces 1 watt at 5 volts. The second is V60 prismatic design which measures 5 mm × 27 mm × 19 mm and produces 0.38 watts at 5 volts.

The current generation of company's product incorporates the use of metal hydride for hydrogen storage, although the company is also actively researching on other options like compressed hydrogen and chemical hydrogen storage. The company claims that their proprietary metal hydride technology is tightly integrated with the fuel cell and exhibit an energy density of 700 Whr/l (170 Whr/kg) at 50% net efficiency.

Status of Commercialization:

The company is moving from technology development to commercialization stage. Earlier in 2005, the company demonstrated a prototype fuel cell that powered a 15-cm flashlight. The company claims that the prototype will last 4-10 times longer than the standard battery powered flashlight. Angstrom Power expects that the cost of their mass-produced product to be just 20-30% more than the cost of standard battery powered flashlight. The company expects this product to be available commercially in the next 2-5 years.

Ansaldo Fuel Cell

Location: Genova, Italy

Website: http://www.ansaldofuelcells.com

Technology: MCFC

- Ansaldo Fuel Cells SpA (AFCo) is an Italian corporation formed in 2001 after Ansaldo Ricerche spun out their fuel cell group, which pursued molten carbonate development for over ten years. The company is targeting fuel cell generators in the 500 kW to 5 MW size. The company's main product is the Series 500 MCFC plant, which is capable of providing up to 500 kW. The company has already demonstrated a 100 kW proof of concept and is now working towards development of a 500 kW prototype (Series 2TW). The company states that this "first-of-a-kind" system will include a modular integrated reformer (which allows for fuel flexibility) and two electrochemical stack modules. The company hasn't provided any timeline for commercialization of its products.

Anuvu

Headquarters:

3980 Research Drive
Sacramento, California 95838
Phone: 916-921-7040
Website: http://www.anuvu.com

Ownership Structure: Anuvu in privately held.

Management:

- Mr. Lyn Cowgill – Co-founder and Chief Operating Officer

Brief Company Description:

Anuvu is a designer and manufacturer of PEM fuel cell stacks, systems, and engines. The company is developing these products for small stationary backup power, marine applications, APUs, and transportation applications. Based on its proprietary PEM technology, the company claims their fuel cell products exceed DOE weight and volume goals for mobile applications. In January 2006, the company announced its operations were scaled back due to financial difficulties. The company reported that it has stopped development of products, and instead focusing on providing engineering services to other companies. Founded in 1994, the company had around 20 employees, but this was reduced to 3 after the scale-back.

Alliances/Partners:

The company has worked with several companies for development, and demonstration of their products. Key partners include: W.L. Gore & Associates, Air Products & Chemicals, P.A.-Hilton, Zap, and Mitsui.

Products:

The company had stopped development of products and is focused on providing engineering services to other companies. Products in development included:

- Power-X™ Fuel Cells – fuel cell modules available in 1.5, 3, 6, and 12 kW power range. These modules could be combined to provide a total of 24 kW.
- Fuel Cell System and Engines – these contained two of more Power-X™ fuel cell module integrated with a battery (to supply peak power).

Technology Overview:

Anuvu's fuel cell products were based on polymer electrolyte membrane fuel cell technology. The fuel cell incorporated the use of carbon-based ductile bipolar plates for chemical compatibility with other components, as well provided ruggedness to the stack. The company's patent pending technology allowed the use of lower tooling and production costs. Each cell in the stack contained an elective heat transfer separator that allowed for thermal optimization of the stack. The company's stacks utilize liquid cooling for proper thermal management and are designed to operate over a wide range of humidity levels, thereby increasing system reliability.

Status of Commercialization:

The company demonstrated several products including back-up power, marine applications, and zero emission cars. The company successfully integrated and

demonstrated a 6 kW fuel cell hybrid system into Duffy-Herreshoff 32' electric boat in 2003. In 2004, the company integrated its fuel cell into a Nissan pick up truck that it intended to sell for around $100 K, but the company could not get enough traction from the buyers to continue further development. In 2005, the company reported working with ZAP to provide mobile power for work tools and emergency power on its community vehicle. Under the agreement, Anuvu expected to receive orders for 100 fuel cells in 2005, totaling to around $11 million, but actually received orders for only one prototype system.

Apollo Energy Systems

Headquarters:

2301 N.W. 33rd Court, Bldg. 115
Pompano Beach, Florida 33069
Phone: 954-969-7755
Website: http://www.electricauto.com

Ownership Structure:

Apollo Energy Systems in privately held.

Management:

- Mr. Robert R. Aronsson – Chairman and Chief Executive Officer
- Mr. Raymond Douglas – President and Director
- Mr. Sonny Spoden – Chief Financial Officer and Director
- Mr. Kim Kawasaki – Vice President and Director
- Dr. Barry Iseard – Vice President and Director
- Dr. Karl Kordesch – Vice President and Director
- Dr. T. Nejat Veziroglu – Vice President Hydrogen Development

Brief Company Description:

Apollo Energy Systems was founded as the Electric Auto Corporation in 1994. The company develops storage batteries and fuel cells for stationary, automotive, marine, and space applications. The company's product revolves around combinations of alkaline fuel cells and lead cobalt batteries, commonly combined with an ammonia reformer.

Alliances/Partners:

The company is working with University of Technology Graz, Austria for development and demonstration of their alkaline fuel cells fueled with hydrogen generated from ammonia. The company is also working with ZAP Incorporated for integration of AFC/battery hybrid propulsion system in the cars.

Products:

The company's products are in the demonstration and development phase. These include:

- Propulsion systems for electric vehicles including battery, fuel cell, solar cell, electric motor, motor controller and charger – this product is meant for OEMs and fleet owners.
- Apollo power plant for on-site power (Model 101-B): This includes 11.5 kW Apollo fuel cell, 48 kWh lead cobalt battery, solar cell, DC to AC inverter, and controls.

Technology Overview:

The company's AFC technology involves a circulating liquid electrolyte, which serves as thermal and water management system. The fuel cell is operated at atmospheric pressure and fueled with hydrogen. In recent years, the company has also developed an ammonia cracker to efficiently generate hydrogen for its AFC. The company believes ammonia to be an efficient hydrogen carrier.

Status of Commercialization:

The company continues to develop new energy systems based on its AFC and lead cobalt battery hybrid technology for a vast host of applications. Some of these include: water vehicles (ships, submarines, etc.), aircrafts, automobiles (cars, buses, trucks, etc.), and space vehicles. The company also plans to install their electric propulsion system into cars and test them of the proposal Florida Hydrogen Expressway from Pensacola to Key West. The company hasn't provided a timeline for product commercialization.

Arcotronics Fuel Cells

Location: Sasso Marconi, Italy

Website: http://www.arcotronicsfuelcells.com

Technology: PEM

- Arcotronics Fuel Cells is part of the Arcotronics Nissei Group, one of Europe's leading producers of capacitors that employs 2500 people in sites throughout Europe, US, and Asia. The company recently acquired Roen Est S.r.l., and now employs around 15 people. Arcotronics Fuel Cells develops and markets polymer electrolyte membrane fuel cell systems for industrial, transportation, civil, and aerospace applications. Additionally, the company has developed a patented MEGA (Membrane Electrode Gasket Assembly) technology, which it claims will result in substantial cost savings and a reduction in production times. The company is developing a 5 kW natural gas fueled CHP system for domestic applications. Two prototypes units (1 kW and 5 kW) were unveiled in 2003. The Penta H2™ is a 5 kW PEM system which is commercially available. The company believes products based upon its fuel cell stack can be sized from 500 W to 50 kW.

Asia Pacific Fuel Cell Technologies

Headquarters:

3812 E. La Palma Ave.
Anaheim, CA 92807
Phone: 714-630-9669

4F, No. 22, Ke-Dung 3 Road
Chunan, Miaoli 350,
Taiwan, ROC.
Phone: 886-37-584-019
Website: http://www.apfct.com

Ownership Structure:

Asia Pacific Fuel Cell Technologies is privately owned.

Management:

- Dr. Jefferson YS Yang - Founder

Brief Company Description:

Asia Pacific Fuel Cell Technologies was founded in March 2000 by Dr. Jefferson YS Yang. The company develops PEM fuel cells for light vehicles, such as scooters and wheel chairs, and for portable power systems. The company also sells their PEM stacks and systems in 100 W to 12 kW power

range. The company is also working on metal hydride based hydrogen storage and distribution systems.

Alliances/Partners:

APFCT continues to build strategic partner relationships for early commercialization of its fuel cell products. The company works with a number of materials suppliers and systems integrators including DuPont Fuel Cell, Kurimoto Corporation, Japan Steel Works, Chinese Petroleum Corporation, Taigene Electric Machinery, and Taiwan ITRI.

Products:

APFCT serves three product lines and has developed several products under these categories:

- PEM fuel cell stack, humidifier and systems
    - 40 cm^2 air cooled fuel cell stack (100 – 800 W)
    - 50 cm^2 configurable fuel cell stack (100 – 250 W)
    - 150 cm^2 water cooled fuel cell stack (1 – 12 kW)
    - External humidifier for 100 W – 12 kW stack and providing 90-100% RH at temperature which is 5-10 ^oC lower than the stack.
    - Mobile power generator – 700 W (1 kW max), 110 V AC (60 Hz); 70 kgs; dimensions: 533 mm × 381 mm × 406 mm; DC configuration also available.
    - Fuel cell/Ni-MH battery hybrid wheelchair – developed by APFCT for its strategic partner Kurimoto Ltd. Two generation of these have been developed.
- Metal hydride hydrogen storage system
    - HSC-500 – metal hydride (AB5 alloy) hydrogen storage canister; discharge rate of 0-16 slpm; total weight 4.5 kgs.
- Fuel Cell R&D test station systems
    - FCED-P2000 – multi-functional fuel cell R&D and testing platform. The unit is designed for education demonstration and as a classroom and laboratory teaching tool. The unit has capabilities for fuel cell system development.
    - FCED-DMFCTS100

Technology Overview:

APFCT has developed a broad product base including components and systems. The company believes their technologies are well suited for low-cost, volume

manufacturing and the company has reported using an automated manufacturing process. The company has submitted or been awarded a total of 61 patents in Asia, U.S. and Europe.

Status of Commercialization:

The company has developed several demonstration prototypes for their products over the last 5 years. Recently APFCT announced the approval by Taiwan Ministry of Economic Affairs of a scooter fleet demonstration proposal. Under this project, APFCT will lead a cross-industry team to demonstrate readiness of the hybrid fuel cell scooter and metal hydride based hydrogen infrastructure technologies for commercialization. The demonstration is scheduled for completion in early 2007. The main objective of the scooter fleet demonstration program will be to validate hybrid fuel cell technology, hydrogen supply, evaluate user feedback and verify cost management. In an October 2005 press release, the company stated that they are on schedule to commercialize fuel cell scooters in 2007. The company is also working on hydrogen storage canisters for several applications including scooters. In a 2004 Fuel Cell Seminar paper, the company reported on the optimization work of their hydrogen storage canisters, but believes that codes and standards must be developed for proper usage. The company believes to roll-out commercial products after the fleet demonstration project, but no specific timeline has been given be the company.

Astris Energi

Headquarters:

2175-6 Dunwin Drive
Mississauga, Ontario L5L 1X2
Canada
Phone: 905-608-2000
Website: http://www.astris.ca

Ownership Structure:

Public (NASDAQ: OTCBB; OTC: ASRNF)

Management:

- Mr. Jiri K. Nor – President and Chief Operating Officer
- Mr. H. David Ramm – Director
- Mr. Peter K. Nor – Vice President Marketing and Corporate Development

Brief Company Description:

Astris Energy develops alkaline fuel cell technology for niche markets in stationary, portable, and transportation market segments. Founded in 1983, the company reported opening a pilot production plant at its Czech Republic subsidiary location in 2005.

Alliances/Partners:

- Tropical S.A. – Under the agreement signed between Astris and Tropical in November 2005, Tropical will act as a reseller of Astris AFC generator products, fuel cells and test equipments.
- Czech Republic Ministry of Industry – In August 2005, Astris s.r.o, the wholly owned European subsidiary of Astris Energy received a grant from Ministry of Industry and Trade of Czech Republic to subsidize Astris fuel cell development efforts in Europe.
- Plasma Environmental Technologies – Under the joint agreement signed in February 2005, Astris will jointly work with Plasma Environmental to develop a real-world installation utilizing PET's hydrogen-producing waste processing system and Astris AFC technology.

Products:

The company produces a number of fuel cell stacks, fuel cell systems, and scientific and test equipment.

Fuel Cell Stacks

- POWERSTACK™ MC250: can be sized between 300 – 2400 W. The company claims that stack exceeds efficiency of 57%.
- LABCELL 200: medium size AFC for laboratory experiments and small power applications.
- LABCELL 50: small AFC for laboratory experiments and demonstration purposes.

Fuel Cell Systems

- Model E8 Portable Generator: The system is rated at 2.4 kW, and provides 48 VDC at 50 amps. The generator contains two POWERSTACK™ MC250-1200 W stacks. The generator is fueled with compressed hydrogen (6-200 bar). The company states that the electrical efficiency of this generator is over 50%.

Test Equipment

- Model TL5 Test Load, Testmaster™, Quickcell™ QC200, and Model TLIF Interface Module.

Technology Overview:

The company has been working on the development of alkaline fuel cell technology for over 20 years. The company's AFC stack technology employs the use of lower cost materials and provides capabilities to operate in a broad range of operating conditions. The company states that their fuel cells do not use precious metals (like platinum) and are made from carbon and plastics. The company reports that the stack can be operated in a wide temperature range between -40 to 50 ^{o}C.

Status of Commercialization:

The company unveiled its Model E8 2.4 kW portable generator in December 2003 and from then has reported to receive several orders from its customers. In November 2004, Alternate Energy Corporation placed an order for six units. In 2005, the company received at least 3 more orders for the portable generators – two from Mobile Attic and one from Electronic Machining. In 2005, the company opened its pilot production plant at its Czech Republic subsidiary location. In January 2005, the company unveiled its second generator AFC powered Golf Car during the Vancouver Investment Conference. The Golf Car utilized company 1.8 kW Model E7 alkaline fuel cell generator.

Axane Fuel Cell Systems

Headquarters:
2, rue de Clémencière - BP 15
Sassenage 38360
France
Phone: +33 (0)4 76 43 60 47
Website: http://www.axane.fr

Ownership Structure: Axane Fuel Cell is a wholly owned subsidiary of Air Liquide.

Management:

- Patrick Sanglan – President and Chief Executive Officer

Brief Company Description:

Axane is a developer of PEM fuel cell systems for portable, stationary, and mobile applications. Founded in May 2001, the company is leveraging several years of hydrogen and fuel cell R&D at Air Liquide to develop products

intended for use in remote locations, emergency situations, and in small hybrid vehicles. Axane has around 25 employees.

Alliances/Partners:

- Bouygues Télécom – Under this agreement signed in November 2004, Axane and Air Liquide will supply a 2 kW RollerPac™ fuel cell and hydrogen to Bouygues for operation at Bouygues Télécom pylon located at a remote location (Toulouse).
- STMicroelectronics – In 2003, Axane delivered their Roller Pac fuel cell system to STMicroelectronics for demonstration. In May 2004, the company reported that their unit had operated for over 1800 hours. This project was partially financed by the European Union.

Products:

The company is developing a line of packaged hydrogen fuel cell systems built around a modular concept ranging from 500 W to 10 kW. These include -

- Roller Pac™ - a 2 kW – 230 VAC electric generator.
- Back Pac™ - 500 W – 230 VAC/12 VDC/24 VDC electric generator.
- Polar Pac™ - 150-300 W (200 W nominal) – 24 VDC; weight – 50 kg; dimensions – 112.5 cm × 36 cm × 35 cm. This fuel cell system was operated at North Pole.
- Mobixane™ - stand alone portable power generator.
- Comm Pac™ - stationary fuel cell generator for base load or UPS applications.
- Auxipac™ - can be used as auxiliary power unit or for vehicle propulsion.

Status of Commercialization:

Axane's strategy is to target systems to various niche markets where no satisfactory alternative energy solution exists, such as remote sites, small portable energy power generators, industrial UPS applications, and small utility vehicles. The company demonstrated their POLAR PAC™ fuel cell product near the North Pole, and presented their ROLLER PAC™ product (2.0 kW, 230 V AC generator) and a prototype 2.5 kW fuel cell system based on its EVOPAC™ modular concept at Hannover Fair. In November 2004, the company announced delivery of their 2 kW ROLLER PAC™ to Bouygues Télécom for demonstration. The company claims that first industrial application of their portable power generation products will start in 2006.

Ball Aerospace & Technologies

Location: Boulder, Colorado

Website: http://www.ball.com/aerospace

Technology: PEM/DMFC

- Ball Aerospace & Technologies Corp. provides advanced imaging, communications, and information solutions to government and commercial aerospace markets, including the military services, NASA, other U.S. government agencies, and numerous aerospace industry allies. The company is developing lightweight, rugged PEM fuel cells in 30 W, 50 W and 100 W sizes. These products incorporate the stack technology from a number of stack manufacturers, including Ballard. The 100 W product (PPS-100) has dimensions of 4.3 inch × 8 inch × 10 inch and weighs around 8.3 lbs., while the 50 W product (PPS-50) has dimensions of 4.3 inch × 7.7 inch × 8 inch and weighs around 6.5 pounds. In 2004, the company reported that their 50 W systems had been tested by Army Research Laboratory for system performance and hydrogen safety. The products can be employed to power sensors, scanners, video equipment, radio receivers, transmitters, or other electrical devices with power needs from 15 to 1000 W at varying voltages. The company has also developed low pressure hydrogen-on-demand sources for these products.

  Ball Aerospace & Technologies is also developing 20-500 W DMFC power systems. The 20 W DMFC is being developed for the DARPA Palm Power Program. In 2004, they demonstrated a complete 60 W self-sustained DMFC power system that has dimensions of 20 cm × 20 cm × 19 cm and weighs 6.8 kg. Both 20 W and 60 W systems uses stack technology from Los Alamos National Laboratory. The company is also working with Motorola to improve the fuel conversion efficiency for low-power DMFC units for portable electronic applications.

Ballard Power Systems

Headquarters:

4343 North Fraser Way
Burnaby, British Columbia V5J 5J9
Canada
Phone: 604-454-0900
Website: http://www.ballard.com

Ownership Structure:

Public (TSX: BLD, NASDAQ: BLDP)

Management:

- John W. Sheridan – Chairman, President, and Chief Executive Officer
- Mr. Lee Craft – Vice President, Operations
- Dr. Christopher Guzy – Vice President and Chief Technology Officer
- Mr. Noordin Nanji – Vice President, Marketing and Business Development
- Mr. David Smith – Chief Financial Officer
- Dr. Charles Stone – Vice President, Research and Development

Brief Company Description:

Ballard Power Systems develops, manufactures, and markets PEM fuel cells for transportation, portable, and stationary power applications. The company is also involved in commercializing electric drives for fuel cells and other electric vehicles, power conversion products, and supplies carbon fiber products to automotive and fuel cell industries.

Alliances/Partners:

Ballard is partnered with DaimlerChrysler and Ford Motor Company to develop vehicular fuel cell products, and the company has delivered its fuel cell engines to most major car manufacturers for testing. The alliance started with a four year agreement between Daimler-Benz AG (later became DaimlerChrysler) and Ballard in 1993. Ford Motor Company joined the alliance in late 1997. The alliance continued with funding from DaimlerChrysler and Ford. In July 2004, Ballard signed a MOU with DaimlerChrysler and Ford under which DaimlerChrysler and Ford acquired Ballard's 50% interest in Ballard Power Systems AG (BPSAG) (formerly XCELLSIS), thereby allowing Ballard to focus on fuel cell research and development. DaimlerChrysler and Ford provided Ballard with up to $55 million in equity investment and $58 million in funding of engineering services for the next two generation of vehicular cells and next generation electric drive systems. Later in June 2005, Ballard announced selling its stake in BPSAG to DaimlerChrysler and Ford.

Regarding stationary and portable fuel cell products, Ballard's initial stationary power alliance with First Energy (formerly GPU) created Ballard Generation Systems (BGS). Later ALSTOM and EBARA joined the alliance and today BGS is wholly-owned subsidiary of Ballard Power Systems. Currently, FirstEnergy is a non-exclusive distributor of Ballard's stationary generators in the Northeast and North Central U.S. The jointly owned EBARA Ballard, has

exclusive rights to manufacture and distribute Ballard stationary generators in Japan and likewise, ALSTOM Ballard GmbH has exclusive rights for Europe.

MGE UPS Systems (MGE) is a worldwide (excluding Japan) distributor and authorized service provider for Ballard's AirGen™ fuel cell generator. In March 2004, Ballard and Sanmina SCI Corporation allied together to commercialize and sell fuel cell based backup power systems for the telecommunication sector using Ballard's Nexa® RM fuel cell modules and Sanmina-SCI manufactured outdoor enclosure, In May 2004, Ballard also allied with Alpha Technologies to develop fuel cell backup power systems for Canadian cable television market.

Products:

- Transportation –
    - Mark 902 Fuel Cell Module (4th generation transport platform) – scalable from 10 kW to 300 kW.
    - Mark9 SSL™ Stack Series (4th generation) – configurable for motive and stationary power, increments from 4 to 21 kW.
    - Mark 1030 – designed to be used with reformate gas in residential co-generation systems.
    - Fuel Cell Engine for light duty vehicles: XCELLSIS™ HY-80.
- Power Generation –
    - AirGen™ Fuel Cell Generator (used as portable power and emergency backup power system).
    - Nexa® Power Module (1.2 kW – DC power).
    - Nexa® RM series (1 kW rack mounted UPS) intended applications – extended run backup power, UPS, and use in telecommunications and energy utilities industries.

Technology Overview:

Ballard Power Systems is a leading developer of PEM fuel cells, primarily for transportation, but also for backup, stationary, and portable power. Ballard's transportation fuel cell product is the Mark 902 fuel cell platform, which is specifically designed to provide high power density and to survive in rugged operating conditions (vibrations, extreme temperatures, etc.). The noteworthy advancement in Mark 902 design is use of flexible graphite separator plates, which provide excellent electrical and thermal conductivity at low cost (up to 10-fold reduction in cost). The company's stationary products that are hydrogen fueled are based on its Nexa® power module. The residential cogeneration products are based on Mark 1030 fuel cell platform.

The company appears to be actively pursuing basic materials research to drive dramatic product improvements. During the 2004 Fuel Cell Seminar, the company discussed their accelerated screening tests to evaluate a wide range of new materials and processes. In February 2005, the company announced significant advancements in fuel cell stack technologies. The company reported development of a stack that can start repeatedly from -20 ^{o}C and operated for more than 2,000 hours at substantially reduced cost with no performance tradeoff. In March 2005, the company released its five year technology roadmap plan, where it stated to have commercially viable fuel cell stack technology by 2010 meeting DOE targets for durability, cost, freeze start, and volumetric power density. Later during the 2005 Fuel Cell Seminar, the company presented four papers addressing fundamental issues in the fuel cells and fuel cell stacks.

Status of Commercialization:

Transportation:

Ballard's main focus is commercialization of fuel cell powered vehicles. However, widespread adoption of fuel cell vehicles remains distant. The company is pursuing other business segments like power generation and carbon fiber products, which it believes could provide more immediate commercial prospects.

For the first nine months of 2005, 65% of Ballard's revenue came from transportation business. The company also recorded a much narrower loss in the first three quarters of 2005 compared to same period in 2004. This was partially due to the sale of its German subsidiary to DaimlerChrysler and Ford. The company is now focused on providing a commercially viable automotive fuel cell stack technology by 2010. The complete fuel cell systems development approach appears to have been shelved by the company.

The current expectations point toward a commercial launch of fuel cell vehicles in the 2010 to 2015 time frame. To date, Ballard has supplied fuel cells to DaimlerChrysler, Ford, Daewoo, General Motors, Honda, Hyundai, Mazda, Mitsubishi, Nissan, Volkswagen, and Volvo to support ongoing demonstration programs. Ballard's two alliance partners are taking a major lead in introducing fuel cell vehicles. As of June 2005, DaimlerChrysler has over 60 vehicles in customer hands around the world. Ballard expects to deliver a commercial launch of fuel cell stack meeting requirements of automotive customers by 2010, and is currently focusing on increasing the reliability and durability, as well as lowering costs. Although the company has enhanced stack performance through the introduction of advanced separator plates, customers like Honda and Nissan are working on a parallel development program incorporate their own stack technologies.

The company's products also received attention from materials handling industry. In August 2005, the company stated to deliver 27 Mark 902 4.8 kW

fuel cell stack to Cellex for integration into its power units for electric lift truck applications. Later in September 2004, the company announced a second supply agreement of 100 Mark9 SSL™ stacks (ranging in power from 4.8 to 21.1 kW) to General Hydrogen. General Hydrogen will integrate them into power units for early commercial sales in the lift truck market.

Power Generation:

Ballard's power generation business accounts for only 11% of the company's revenues. Over the last 3-4 years, Ballard's efforts focused developing complete fuel cell systems, working with system integrators to support development of products incorporating its Nexa® power module, and on the commercialization in Japan of residential systems produced by EBARA BALLARD. In 2005 the company appears to have focused on fuel stack production, shelving its efforts to produce complete Ballard branded fuel cell systems.

The Nexa® module is found in the company's Nexa® RM series of back up and UPS systems and in the AirGen® portable generator. Additionally, the Nexa® module is also used by MGE in their Pulsar EX RT UPS system and in IdaTech's FCS 1200 system. In July 2004, BC Hydro in alliance with Ballard Power Systems developed a hydrogen fuel cell based emergency backup system for utility applications. Using the Nexa® RM modules, BC Hydro is looking to replace battery-based backup systems in as many as 500 applications within BC Hydro's operations and thousands of applications in utilities around the world. Ballard commissioned 8 Nexa® RM units in 2004 and a much reduced number in 2005. The company admits that they had higher expectations for Nexa® RM installations.

Through the joint venture Ballard-Ebara, Ballard is involved in the development of advanced pre-commercial 1 kW CHP products for the Japanese residential market. The joint venture has also developed in April 2004 a unique kerosene-fueled 1 kW CHP generator that combined Ballard fuel cell technology with Nippon Oil Corporation (NOC) reformer technology, and EBARA pumps, blowers and production technology. To date over 60 generators powered with Ballard stack have been demonstrated in Japan. In December 2005, NOC announced that it will install 100 residential fuel cell cogeneration systems from EBARA-BALLARD in Japan. Earlier in the year in September 2005, the company committed to develop next generation of fuel cell stack for cogeneration system. Ballard claimed that they will focus on reducing cost and increasing durability of the stack. The targeted lifetime of the stack is 40,000 hours with a market launch in 2008.

Ballard – Ebara

Location: Tokyo, Japan

Website: http://www.ebara.co.jp/en/

Technology: PEM

- Ballard-Ebara is a joint venture between Ballard (see Ballard Power Systems) and Ebara Corporation, which is one of the world's principal manufacturers of fluid transfer machinery, with particularly strong positions in pumps, compressors, fans, and chillers. By combining Ballard stack technology and Ebara systems integration, the company is developing advanced 1 kW fuel cell generators for the Japanese residential market. In 2005, the company sited a 1 kW combined heat and power fuel cell generator at the official residence of the Prime Minister of Japan. The company is also working with Tokyo Gas and Nippon Oil Corporation to integrate natural gas and kerosene reformer technologies. To date, around 85 generators powered with Ballard fuel cells have been demonstrated and tested in Japan, primarily with Tokyo Gas, Osaka Gas, Nippon Oil Corporation, and Toho Gas. The company reports that a number of the systems currently in the field are approaching 10,000 operating hours with minimal maintenance required. In December 2005, the company announced that it will provide 100 units (incorporating Ballard's Mark 1030 fuel cell stack) to Nippon Oil Corporation (NOC) in 2006 – 2007 for integration with their fuel processor. These residential cogeneration systems will be fueled with kerosene fuel and will be installed in Japan by NOC. The company claims that their units have AC electrical efficiency of 35% (LHV), while heat recovery can result in total system efficiency of up to 81% (LHV).

BCS Fuel Cells

Headquarters:

2812 Finfeather Road
Bryan, TX 77801, USA
Phone: 979-823-7138
Website: http://www.bcsfuelcells.com

Ownership Structure:

BCS Fuel Cells is privately owned.

Management:

- Dr. Hari P. Dhar – President

Brief Company Description:

BCS Fuel Cells is a developer of polymer electrolyte membrane (PEM) fuel cell stacks and systems for academic research, education, and public demonstrations of clean energy, portable power generation, uninterrupted power supplies, and backup power generators. The company uses its propriety self-humidified stack technology and believes that their technology results in lightweight and lower cost stacks/systems. Founded by Dr. Hari P. Dhar in 1989, the company has 3 employees.

Alliances/Partners:

The company is working in collaboration with several universities in Texas to provide customized products and/or contract R&D services.

Products:

The company develops a wide range of products, including stacks, MEAs, and control boxes for stacks.

- Convection (air-breathing) fuel cell stacks – Available in 3-150 W power range. These stacks have dead-ended hydrogen side, have load following capabilities, and provides instantaneous power.
- Forced-flow fuel cell stacks – Available in 150 W - 3 kW power range. These stacks have dead-ended hydrogen with periodic release, and provides instantaneous power. The company also sells stacks operating on pure oxygen.
- Control boxes for the stacks.
- Membrane electrode assemblies for standard and self-humidified fuel cells (available in custom sizes for both PEMFC and DMFC).

Technology Overview:

The company's stacks are based on proprietary self-humidification technology. The company believes that self-humidification allows them to eliminate the humidification module in the system design which provides greater simplicity to the system design. In a paper published in the Journal of Power Sources in 2005, the company showed that their forced and convection stacks operate well without any external humidification. The company's technology allows them to operate under maximum hydrogen utilization. Furthermore, since external humidification is not required, parasitic losses associated with humidification unit and water purification are avoided.

Status of Commercialization:

The company's fuel cell stacks and systems are designed to be operated as standalone units. The company markets its products for many applications including: recreational, electronics, backpacks, home and industries, and electric vehicles. Products are available commercially. The company also performs contract R&D work for DOE and NASA.

Casio

Location: Tokyo, Japan

Website: http://www.casio.com

Technology: PEM

- Casio Computer Co., Ltd. is one of the leading consumer electronics companies in the world. The company started the development of portable fuel cell technology in 1998, and is working towards integration of fuel cells with its numerous electronic products. Casio's fuel cells utilize polymer electrolyte membrane (PEM) fuel cell technology, which is fueled by hydrogen generated from a methanol reformer. Earlier in 2002, the company revealed one of their first prototypes that could power a Casio handheld computer for over 20 hours (four times that of Li-ion battery) by using a proprietary miniaturized methanol reformer technology (postage stamp size). The reformer is a micro-reactor formed on a silicon wafer that reforms methanol to high purity hydrogen gas in presence of catalyst at a reforming rate of more than 98%. In 2005, a market survey conducted by Fuel Cell Today stated that Casio has developed an ultra-compact methanol reformer using glass instead of the previously used silicon. The company claims that using glass in the production allows for greater cost-reduction. In May 2004, the company demonstrated a prototype fuel cell for laptops which it claims to be the world's smallest fuel cell. The prototype can easily be fitted in the laptop and can provide power for 8-16 hours. Casio's schedule for the launch of fuel cell products has been delayed to 2007.

Cellex Power Products

Location: Richmond, British Columbia, Canada

Website: http://www.cellexpower.com

Technology: PEM

- Cellex Power is developing PEM fuel cell systems for the material handling industry. The company believes that its proprietary components and unique system integration capability allows them to deliver products with rapid payback for fork-lift applications. The company products include core fuel cell stack technology from DuPont. Cellex has completed several field trials with its systems, while several others are in progress. In 2005, Cellex Power successfully completed fuel cell product field trials of four alpha units at a Wal-Mart food distribution center in Missouri. These fuel cell integrated electric lift trucks were operated for two weeks and were used for materials handling in the distribution center. The units reportedly ran for two weeks and were refueled with compressed hydrogen in one minute. After successful trials of these units, Wal-Mart reported that it will lead the material handling industry and agreed to support Cellex's Beta field trials and commercialization process for electric lift trucks. Cellex Power believes that the fork-lift market is sizeable and the numerous value propositions for customers include increased productivity, reduced operational time, and better working environment. The May 2004 issue of Fuel Cell Industry Report newsletter reports that the company is working with the largest electric forklift OEM in North America for the past several years on distributing its products to customers and on product development for forklift compatibility. The company is also working to provide a Total Power Solution (which includes fuel cell power unit, fuel supply and infrastructure; and product service and support) for industrial vehicles.

Ceramic Fuel Cells

Headquarters:

170 Browns Road
Noble Park, Victoria 3174
Australia
Phone: 61 3 9554 2300
Website: http://www.cfcl.com.au

Ownership Structure:

Ceramic Fuel Cells, Ltd. made its debut as a publicly listed company on the Australian Stock Exchange on July 5, 2004. (ASX: CFU). Major shareholders include Metasource, Energex, and Csiro.

Management:

- Mr. Brendan Dow – Chief Executive Officer
- Mr. Brendan Bilton – Chief Executive Office (Europe subsidiary)
- Mr. Tony Sherburn – Chief Financial Officer
- Dr. Karl Föger – Chief Technology Officer
- Mr. John Rajoo – Chief Operations Officer

Brief Company Description:

Ceramic Fuel Cells Ltd. (CFCL) is developing planar solid oxide fuel cell technology for distributed generation and domestic heating markets. In 2004, the company opened a new European subsidiary to better address emerging demand for residential CHP units in Europe and to take advantage of solid government support. The company is targeting medium to large scale stationary power scale applications (up to 200 kW) such as supermarkets, hotels, office buildings, and apartment blocks. The company believes its all-ceramic modular stack technology, which is designed for ease of manufacture and modularity, has the potential to lower manufacturing costs. The company's market strategy is to commercialize its technology via partnerships for the manufacture of fuel cell stacks and via separate partnerships for the production of a range of end-user systems applications. The company intellectual portfolio includes 28 worldwide patents. Founded in 1992, the company has approximately 100 employees.

Alliances/Partners:

The company is moving towards field trials of their micro-CHP units and have partnered with several companies for demonstration of their product.

- Powerco – Under this agreement signed in November 2004, CFCL will supply its micro CHP units for field trials to Powerco – a major energy distribution company in New Zealand. At least two systems are schedules for field trials in first half of 2005.
- Central Gippsland Institute of TAFE (GippsTAFE) – Under the agreement signed in April 2005, GippsTAFE will conduct first field trials of CFCL micro-CHP prototype in Australia. GippsTAFE has expertise with electrical, gas, energy, water and telecommunications industries.

- EWE – The agreement signed in June 2005 between CFCL and German utility company, EWE, allows for field trial of two CFCL micro-CHP units by EWE in Germany. According to CFCL, Germany is a target market for future volume production and sales for micro-CHP units.
- Szencorp – According to the agreement signed in July 2005, szencorp will install CFCL micro-CHP unit in a commercial office building in Australia.

Products:

The company showcased their first product NetGen™ fuel cell CHP system in October 2005 during the Ninth Grove Fuel Cell Symposium in London. Field trials of this system are expected in 2006.

Technology Overview:

Ceramic Fuel Cells planar SOFC is an all-ceramic technology. The key to CFCL stack technology is a modular 28-cell monolithic sub-stack of about 4 cm high and 13 cm diameter. Each sub-stack produces around 150 W DC power. These sub-stacks are further arranged to form larger stacks. The company claims that up to 14 sub-stacks can be combined in a single stack to provide 1-2 kW power. In an April 2005 report, the company reported improving the production yield of their stacks by a factor of seven in last 2 years. In January 2005, CFC reported a production yield of around 75% and expects to achieve around 95% by July 2006. Furthermore, the company believes that their flat fuel cell design will facilitate low-cost, volume production. In an April 2005, press release the company stated that they have increased the power output per cell from 3 to 5.5 W, which will enable them to reduce the cost of prototype micro-CHP units. These units are designed to operate with methane and produce 1 kW of electric power and provide hot water for residential customers. CFCL has developed a reformer for converting carbon-rich hydrocarbon fuel into methane rich fuel. The company claims that their pre-reformer operates at relatively mild temperatures (500 ^{o}C) and is capable of converting hydrocarbon fuels like LPG and gasoline into methane rich fuel. The company states that their cells have operated for over 4000 hours on reformate from their pre-reformer.

Status of Commercialization:

In the last two years, the company has expanded their product commercialization efforts. CFC is actively pursuing field trials for their micro-CHP units. Two 1 kW technology demonstrators were tested in 2004. These units delivered 1 kW electric power and 1 kW thermal power. The electrical efficiency of these units were 35% electrical and 80% overall. Later in December 2004 and 2005, seven micro-CHP units were installed and field tested at different locations with partner companies. Two of these units were tested in New Zealand by Powerco, one by ETTA in Australia, one by EWE in Germany, and last one by Szencorp in Australia.

CFCL showcased their next generation prototype NetGen™ (1.1 kW CHP systems) during the Ninth Grove Fuel Cell Symposium in London in October 2005. The company expects to put these systems for field trial in 2006.

In September 2004, the company announced a partnership with Ceram Research Ltd. (UK) to advise on location and specifications for a European manufacturing plant. The report was delivered in January 2005. Later in February 2005 as a part of the next step, the company announced its engagement with Sinclair Knight Merz (SKM) to produce architectural plans, plant layout, costings and a project schedule for a volume fuel cell manufacturing plant. The design and costing of commercial European Fuel Cell Manufacturing Plant will conclude in June quarter.

Ceres Power

Headquarters:

Unit 18, Denvale Trade Park
Haslett Avenue East,
Crawley RH10 1SS
United Kingdom
Phone: +44 1293 400 404
Website: http://www.cerespower.com

Ownership Structure:

Ceres Power is a public company listed on the London Stock Exchange Alternative Investment Market (LSE: VLR).

Management:

- Mr. Philip Holbeche - Chairman
- Dr. Peter Bance – Chief Executive Officer
- Dr. Nigel Brandon – Chief Technology Officer
- Mr. Andrew Baker – Head of Product Development

Brief Company Description:

Formed in 2001, Ceres Power is developing metal-supported intermediate temperature (500-600 ^{o}C) SOFC technology. The company is working to build systems in the 1-25 kW power range for a wide range of applications including residential, commercial back-up power, construction, and other off-grid applications. The company is commercializing solid oxide fuel cell technology

developed at Imperial College, which has a 20 year history of work on high temperature (> 800 ^{o}C) SOFC materials with companies like Rolls Royce, Sulzer and Westinghouse. The company has approximately 25 people.

Alliances/Partners:

- BOC – is working with Ceres Power to assess the technology with a range of cylinder gases. The initial contract, which was signed in October 2004 for testing Ceres SOFC technology with LPG fuel has been completed. A follow on contract was signed in September 2005 for pre-commercial testing and development of SOFC technology in particular to specific market applications.
- British Gas – Under an agreement signed in August 2005, British Gas will provide domestic boilers to Ceres Power. The domestic boiler and Ceres Power's SOFC unit will be packaged into a CHP system to provide both electricity and thermal energy (as hot water and central heating).
- Dunlop Aerospace – Under this agreement signed in February 2005, Dunlop will jointly lead the Ceres Power's effort for the development of a highly efficiency integrated CHP system. Dunlop will be responsible for development of application-based systems that allows Ceres Powers' fuel cell to produce heat and electricity using widely available fuels (LPS, natural gas).
- Department of Trade and Industry (DTI) – In February 2005, DTI awarded the company UK£1.9 M contract to improve the gravimetric energy density at lower cost.
- U.K. Carbon Trust – In January 2004, Carbon Trust invested 1 million pounds in return for shares in Ceres Power. Later, in December 2005, the company reported that it has won a 0.5 million contract from Carbon Trust for accelerating its fuel cell commercialization activities.

Products:

The company doesn't offer any commercial products at this time.

Technology Overview:

Ceres Power develops low temperature (550 °C) solid oxide fuel cell products based upon technology originating at Imperial College. Due to the low temperature, the company uses stainless steel components, thin ceramic coatings, and standard sealing technology. As a result, the company claims the low manufacturing cost and robust performance. The company claims its metal-supported technology offers quick start up times and is designed to work with a range of fuels, including LPG, natural gas, methanol, hydrogen and vehicle fuels.

Status of Commercialization:

In September 2005, Ceres Power reported to have successfully designed, built, and tested an integrated fuel cell system comprising stack, fuel processors, and bottled gas supply. Their third generation SOFC prototype reportedly generated continuous power in 250-400 W range for over 3000 hours. The company claims to have achieved these performance targets two years ahead of expectations. The company does appear to be moving from cell testing to stack and product testing. This progress is supported by the company's report in September 2005 of first revenues.

ClearEdge Power

Location: Hillsboro, Oregon

Website: http://www.clearedge.com

Technology: Misc.

- ClearEdge Power, formerly Quantum Leap Technology is developing fuel cells based on silicon architecture for back-up power, auxiliary power units, and small stationary application in the premium power markets. The company's fuel cell technology utilizes silicon wafers processed using lithography techniques. These wafers are assembled into cells and stack using wafer bonding methods. The company believes that utilizing the established Si fabrication technology allows them to accomplish high performance and large volumes at lower costs. The company's Si-based technology is reported to have a performance potential of four-times higher compared to conventional PEM fuel cells. ClearEdge is also developing a fuel processor for reforming propane, natural gas and bio-fuel into hydrogen for their fuel cells. In January 2006, Applied Ventures, a wholly-owned subsidiary of Applied Materials announced that it has invested $2 million in ClearEdge Power for the development of silicon-based fuel cell technology. The company demonstrated a 2 kW prototype fueled with hydrogen in 2003, and continues to refine their technology. ClearEdge anticipates having commercial products ready in 2006.

CMR Fuel Cell

Location: Cambridge, United Kingdom

Website: http://www.cmrfuelcells.com

Technology: DMFC

- CMR Fuel Cell was formed in October 2003 to commercialize technology developed at Generics Group in Cambridge. The company is developing direct methanol fuel cell stack technology for portable power applications. The company utilizes its proprietary Compact Mixed-Reactant (CMR) stack architecture to fabricate fuel cells which are low cost and have low weight and volume. The CMR technology reportedly uses selective electrodes, thereby allowing complete elimination of bipolar separator plates. The company claims that their technology allows for a 5-10 times increase in performance compared to conventional concepts. The company has developed laboratory scale systems and is working towards development of a demonstration prototype. CMR Fuel Cell compact mixed-reactant technology has also been demonstrated for other fuel cell types including PEM and SOFC.

Cosmo Oil

Location: Tokyo, Japan

Website: http://www.cosmo-oil.co.jp/eng/index.html

Technology: PEM

- Cosmo Oil is one of the leading petroleum refining companies in Japan. The company is developing stationary PEM fuel cells for residential applications in the 1 kW power range. The company states that they have interest in developing small fuel cells with a reformer capable of reforming petrol or kerosene fuels. As reported in a March 2005 press release, the company, in collaboration with Toshiba Fuel Cell Power Systems Corporation, has demonstrated a 700 W fuel cell. The fuel cell was run on LPG fuel with 30% electrical and 40% thermal efficiencies values (based on LHV).

Creare

Location: Hanover, New Hampshire

Website: http://www.creare.com/services/fluid/fuelcells.html

Technology: DMFC

- Creare Inc. is an engineering research and development firm with a wide range of activities including biomedical research, fluid dynamics, heat transfer, sensors, and controls. The company is developing fuel cell components and sub-systems for lightweight portable power applications and claims to have produced a prototype stack exhibiting very high power and energy density. The design uses a low-compression seal design, simplified manifold, and passive water management system. The company is also working to develop a 20 W direct liquid compact fuel cell system for military under the Palm Power program. The company has not released any timeline for commercialization of its products.

Delphi

Headquarters:

5725 Delphi Drive
Troy, Michigan 48098
Phone: 248-813-2000
Website: http://www.delphi.com

Ownership Structure:

Delphi is a public corporation (NYSE: DPH).

Management:

- Mr. Robert S. Miller – Chairman of the Board and Chief Executive Officer
- Mr. Rodney O'Neal – President and Chief Operating Officer
- Mr. Robert J. Dellinger – Executive Vice President
- Mr. Guy C. Hachey – President, Delphi Energy & Chassis
- Mr. James A. Bertrand – Vice President, Delphi Corporation; President, Delphi Automotive Holdings Group

Brief Company Description:

Delphi is a leader in mobile electronics and transportation components and systems technology. The company is developing SOFC system and components for automotive, commercial vehicles, residential and military applications.

Alliances/Partners:

- DOE's National Energy Technology Laboratory – Delphi is in the fifth year of a 10 year, $138 million development project to develop and test a SOFC APU design that can be mass produced at low cost. Delphi also has a strong, collaborative partnership with SECA, Department of Energy Office of Fossil Energy, and Pacific Northwest National Laboratory, intended to result in accelerated development of SOFC APUs.
- Delphi is collaborating with BMW to deploy its fuel cell APU in BMW cars. Delphi is also collaborating with PACCAR, the manufacturer of heavy-duty, on- and off-road Class 8 trucks sold around the world under the Kenworth, Peterbilt, DAF and Foden nameplates, to use auxiliary power units in Kenworth trucks. BMW and PACCAR expect to have commercial products by 2007.

Products:

No commercial products are available yet, although the company reports that products will be available by 2010. Initial products are thought to include:

- Auxiliary power unit for military applications, passenger cars, light and heavy trucks, and shipboard power. The company is currently focused on developing systems in 3-5 kW power range.
- Residential SOFC (2 to 5 kW)
- Commercial SOFC (25 kW)

Technology Overview:

Delphi is working in partnership with automakers BMW and Renault to co-develop a high efficiency SOFC auxiliary power unit, delivering up to 5 kW of power. Delphi is now testing their third generation (GEN3) technology, which among other upgrades incorporates Anode Tail Gas Recycle (TGR) for increased system efficiency. In a paper presented at the 2005 Fuel Cell Seminar, the company reported their prototype GEN3 30-cell stack produced 1.8 kW at 21 VDC and 42% fuel utilization. The company claimed that their 5-cell stack has operated continuously for over 2000 hours with less than 10% overall degradation. Delphi views its GEN3 stack as a major step toward product viability. The company is also working on an advanced GEN4 concept and claims it that the system will be ready in 2006-2007. The company is currently

making APUs in range of 3-5 kW, and expects to have pre-commercial units ready in 2-3 years.

The company's SOFC system integrates a fuel reformer that generates hydrogen-rich gas by partial oxidation of gasoline or diesel fuel at 800 °C. Delphi states that the system has a potential electric efficiency of greater that 50%, while waste heat could also be used for the passenger compartment. The company is also developing a flat plate endothermic reformer that has efficiency of greater than 120% (due to utilization of anode tail gas from the stack). During the 2004 Fuel Cell Seminar, the company indicated that current stacks operate at 35% fuel utilization. Delphi has no plans for internal reforming in their SOFC APUs. Delphi also demonstrated the successful operation of its SOFC system with coal gas in September 2003.

When deployed in a vehicle, the APU is anticipated to be independent of engine operation and will supply power to new and existing electrical features, such as lights, windows and mirror motors, fuel pumps, air conditioning, water pumps, power steering, electronic braking systems, and advanced communication and navigation systems. In April 2004, the company was selected by DOE to develop a SOFC APU for long-haul trucks and other commercial vehicles. DOE estimates that the technology can reduce the fuel usage and emissions during idling by as much as 90%.

Status of Commercialization:

Auxiliary Power Units:

Delphi demonstrated the first gasoline-powered SOFC APU in February 2001. Currently it is building and testing its development system A, based on the most recent GEN3 stack technology. The company states that they will demonstration products read in 2006-2007 time frame, while commercial products will be available by 2010.

Stationary:

Delphi activities under the SECA program targets stationary fuel cell applications. The company is focusing its market on residential markets with 2-5 kW grid parallel fuel cell systems with CHP, and on commercial markets with 25 kW grid parallel fuel cell systems. The company reported working on a 3 kW stationary power unit during the 2005 Fuel Cell Seminar. The 3 kW system consists of two 30-cell GEN3 stack, methane CPOx reformer, power electronics, and BOP components. The efficiency of the system is 18%, with future system upgrade allowing up to 35% efficiency. These products are expected to reach commercialization in the second half of this decade.

Direct Methanol Fuel Cell Corporation

Location: Altadena, California

Website: http://www.dmfcc.com

Technology: DMFC

- Direct Methanol Fuel Cell Corporation (DMFCC) was formed in 2002 to commercialize the technology developed at the Caltech Jet Propulsion Laboratory. The company holds all the patent rights related to the DMFC work at Caltech Jet Propulsion. Most recently in January 2006, the company reported that it has exercised an option and signed two license agreements on direct organic fuel cell technology with the Caltech and University of Southern California. Furthermore, DMFCC has developed disposable methanol fuel cartridges for direct methanol fuel cell industry. The company claims that their cartridge can provide 10 hours of runtime for a laptop and cost $2-3 per cartridge. The company is also involved in the development of components (electrodes, MEAs, etc.) and complete systems. The company's business model is to license their technology to fuel cell manufacturers and OEMs under a cartridge supply arrangement instead of license fee. In 2004, the company opened a new office in Japan and is working with a major Japanese portable electronics manufacturer.

EBZ

Location: Dresden, Germany

Website: http://www.ebz-dresden.de

Technology: SOFC

- EBZ (Entwicklungs- und Vertriebsgesellschaft Brennstoffzelle mbH) is developing solid oxide fuel cell system for residential and industrial applications primarily for European countries. The system utilizes planar SOFC concept along with balance of plant components – designed and developed at EBZ. The company is targeting 3-50 kW market. EBZ's modular stack technology allows the stack to be built with repeated units in 1-5 kW power range. In 2004, the company demonstrated two 1.5 kW units fueled with natural gas. Currently, the company is focused on developing CHP units for the European market. The company has not released any timeline for commercialization of its products.

EnerFuel

Location: Fort Lauderdale, Florida

Website: http://www.enerfuel.com

Technology: PEM

- EnerFuel is a technology development company focused on PEM fuel cells. The company has developed an integrated control system, control valve, flow plates, stack, and test fixtures that can be used independently or together to enhance the capabilities and efficiencies of PEM fuel cell systems. The Company's integrated control system was developed to enhance the performance of fuel cells in transportation applications, including the ability to operate efficiently under difficult conditions such as peak acceleration and braking. EnerFuel also has a proprietary method to cold start a fuel cell in sub-freezing temperatures. Its water management controls were designed to prevent over-drying of the fuel cell membrane, which can cause deterioration and lead to potential safety hazards. In addition to transportation applications, the company believes its technologies are suitable for UPS, commercial and residential power, and premium power applications. In March 2004, the company announced that it has raised $14.2 million in private placement. The company is partnering with Florida Hydrogen Initiative, Inc. in HyTech Rest Area project. Under this project the duo will install a 10 kW methanol fueled fuel cell power generator at a Florida Interstate rest stop. In a paper presented at the 2005 Fuel Cell Seminar, the company stated that the methanol fuel used by the system will be derived from organic byproducts of the Florida citrus industry (mainly orange peel). Enerfuel will provide 10 kW methanol fuel cell system for the project. The project is scheduled to be completed in 18 months. In January 2005, the company announced its intentions to acquire the fuel cell division of Giner Electrochemical.

European Fuel Cell

Location: Hamburg, Germany

Website: http://www.europeanfuelcell.de

Technology: PEM

- European Fuel Cell GmbH is a part of the BAXI group that is focused on the development of fuel cell cogeneration units for multi-family residential or small industrial applications. The company's fuel cell unit is rated at 1.5

kW electric and produces around 2.9 kW of thermal heat. The company claims that overall efficiency of the unit is over 80%. Currently, EFC is in process of field-testing their beta units. The company plans to initially install 5-10 units for field-trial followed by another 100 test units.

Franklin Fuel Cells

Headquarters:

83 Great Valley Parkway
Malvern, Pennsylvania 19355
Phone: 610-640-7545
Website: http://www.franklinfuelcells.com

Ownership Structure:

Franklin Fuel Cells is privately held. Key investors include: EnerTech Capital, Hunt Power, The Reinvestment Fund, Gas Technology Institute, and University of Pennsylvania.

Management:

- Mr. John P. Law – Director, President and Chief Executive Officer
- Mr. Wayne E. Gardner – Vice President, Finance and Administration
- Mr. Eduardo Paz – Director, Technical Programs
- Mr. Louis A. Busovsky – Chief Financial Officer

Brief Company Description:

Founded in 2001, Franklin Fuel Cells (FFC) is working to commercialize a copper-based solid oxide fuel cell technology developed at University of Pennsylvania. In addition, Gas Technology Institute has contributed several enabling patents that are supportive and ancillary to the Penn intellectual property. The company's intellectual property portfolio includes 7 U.S. patents, 30 U.S. patent applications, and 13 invention disclosures. The company claims that its technology is superior to other fuel cell technologies developed for mobile markets, because it eliminates the need for a fuel reformer and costly materials. In February 2005, the company announced that it has raised an additional $3M from existing investors, bringing its total to date to $7.4 M. The company moved to a new development and test facility in October 2004 and employs around 15 people.

Alliances/Partners:

- SECA – In October 2005, U.S. Department of Energy Solid State Energy Conversion Alliance awarded $100 K phase 1 award for the development of company's proprietary cathode technology.
- PEDA – In July 2005, Pennsylvania Energy Development Authority (PEDA) awarded $460 K to FFC to further its development of copper-based SOFC for direct use of ethanol and other bio-renewable fuels.
- U.S. Navy – In June 2005, Office of Naval Research awarded FFC a three-year development contract to develop, fabricate and test a fully integrated SOFC system operating directly on diesel and Navy F76 fuels. FFC intends to optimize the prototype system for 10-15 kW application which will be tested at NAVSEA's facilities in Philadelphia. Phase 1 award is around $1 M.
- Sarnoff Corporation – development contractor for Franklin Fuel Cells.

Products:

The company doesn't offer any commercial products at this time.

Technology Overview:

The company's proprietary "Direct Oxidation" technology employs the use of Cu and CeO_2 as a substitute of Ni catalyst in the SOFC anode. The company believes that this combination of materials provides the fuel catalysis and electrical conductivity needed for the cell to operate effectively, while eliminating the propensity for carbon coking reaction. The technology allows the use of dry fuel and eliminated the need of pre-reformer when using higher order hydrocarbon fuels. While the company is still refining its technology for use in stationary and mobile SOFC applications, FFC has shown that its technology works at least as well as SOFC stacks utilizing traditional Ni-based catalysts. In a paper presented at 2004 Fuel Cell Seminar, the company reported the development and operation of 100 cm^2 cell on hydrogen, propane, and butane fuels. An independent theoretical study conducted by TIAX and referenced by FFC indicates system efficiency of a 5 kW system could be as high as 56% (compared to 35% for systems using conventional anodes). The company also reported the development of proprietary cathode technology (for low temperature operation) utilizing the same impregnation technology as they used for the anode.

Status of Commercialization:

The company claims that their unique copper-based technology has the potential to allow effective SOFC operation of propane, butane, and other hydrocarbon fuels like gasoline, diesel without a pre-reformer, thus giving them a unique edge over other SOFC developers. The company continues to refine and

develop its technology by performing cell testing. In March 2005, the company reported successful operation of their SOFC cells for over 100 hours on commercially available gasoline fuel. Later in June 2005, the company reported operating their cells on pure ethanol for over 100 hours, achieving power densities around 400 mW/cm^2 at 0.7 V. The company plans to develop full stacks for modular power systems in range of 3-250 kW, and hopes to have available for demonstration in early 2006. If successful, stack sales to system developers could start by 2007.

Freedom Fuel Cells

Location: Alpharetta, Georgia

Website: http://www.freedomfuelcells.com

Technology: PEM

- Freedom Fuel Cells develops PEM fuel cells for extreme weather and rugged conditions. The company claims that their system can withstand temperatures as low as -80 °F and wind speed up to 80 mph. The company is developing stacks and systems in range of 10 W to 50 kW for remote and stationary power applications. They claim to have better integration of design (flow-field) and components. The company is demonstrating their product in Greenland and Antarctica. In order to expand their product power range, the company is working with the University of Alabama at Tuscaloosa to develop a 3 kW system incorporating super capacitors.

Fuel Cell Technologies Ltd.

Headquarters:

20 Binnington Court
Kingston, Ontario, Canada K7M 8S3
Phone: 613-544-8222
Website: http://www.fct.ca

Ownership Structure:

Public: TSX Venture Exchange (Canada): FCT.

Management:

- Dr. John H. Stannard – President and Chief Executive Officer
- Mr. J. Christopher McFarlane – Chief Financial Officer
- Dr. Wojtek Halliop – Chief Scientist
- Mr. Gary Allen – Director of Sales

Brief Company Description:

Fuel Cell Technologies Ltd. (FCT), a wholly owned subsidiary of Fuel Cell Technologies Corporation, is developing SOFC fuel cell systems in the range of 1-75 kW, using Siemens Westinghouse tubular stack technology. In 2005, the company repositioned itself from a purely research and development company to a production and sales company. The company products are aimed towards remote, commercial, and industrial uses. However, the company states that initial products will be targeting the off-grid power market segment due to fuel cell system costs. The company has a 16-year history of developing aluminum fuel cells, intended primarily for undersea vehicles. In 2005, the company had approximately 28 employees.

Alliances/Partners:

- Siemens Westinghouse Power Corporation (Siemens) – Siemens is a long term development partner of FCT. In November 2000, Siemens and FCT agreed to develop a sub-50 kW size system based upon Siemens tubular SOFC technology. Under the agreement, Siemens will lead SOFC stack development and FCT is responsible for the balance of plant components. In July 2003, the companies expanded their agreement to include development of a "next generation" 5 kW fuel cell unit geared for residential, small commercial, and remote applications. In May 2004, the joint agreement was updated and extended to include supply of the Siemens standard tubular generator component subsystems for the manufacture of FCT's second generation 5 kW product throughout 2004 and into 2005. In June 2004, Siemens purchased two FCT 5 kW power systems incorporating FCT's balance of plant assembly and Siemens' new enhanced generator components and module. These two units are intended to be tested under a broad range of system conditions to enhance testing of Siemens Westinghouse larger 100 kW systems. In November 2004, both companies signed a MOU for global supply, sales and distribution of SOFC systems. In 2005, Siemens purchased BOP components from FCT to test the next generation High Power Density cell stacks.
- U.S. Department of Energy – FCT is a member of the Siemens team that was awarded a $48 million contract under the SECA program to develop a low-cost, portable, solid oxide fuel cell. FCT will receive approximately $1

million per year under the 5-year contract to develop balance-of-plant components.

- TOTO – Under this agreement signed in January 2005, FCT and TOTO will design and build a 2-3 kW SOFC system. The system which is intended for Japanese and European markets will utilize the tubular stack bundle technology from TOTO and balance of plant components from FCT.
- NKK Corporation (now JFE Urban Development Corporation) – is working with FCT to commercialize products in Asia Pacific region.
- Universities – FCT has several programs with Canadian universities including Queen's University, Waterloo University, McMaster University, and Royal Military College of Canada. These programs include materials development, tubular stack modeling, and fuel processing for solid oxide fuel cell systems.

Products:

- 5 kW SOFC – The company's residential cogeneration system provides electricity and heat in a system the size of a home furnace. The company claims a net efficiency of approximately 80%, which the company predicts will result in a 4-year pay back period for a home owner. The product received CSA certification in September 2005.
- Aluminum-Air Power System – customized Aluminum-Air power systems for underwater and remote applications in the 50 W to 5 kW size range.

Technology Overview:

Fuel Cell Technology uses the SOFC stack technology developed by Siemens Westinghouse (for their 5 kW system) combined with the company's balance of plant components including the fuel processing unit, air supply unit, thermal management system, and system controls.

The company is also developing a 2-3 kW residential SOFC for European and Japanese market using the stack technology from TOTO. TOTO has several decades of experience with ceramic processing. In December 2004, TOTO reported that their solid oxide fuel cells have demonstrated over 10,000 hours of continuous operation in single cell tests, and that their cell stacks have reached over 3000 hours of operation with an electrical efficiency of 55% LHV. The company technology reportedly employs low-cost "wet process" technique for mass production of tubular SOFC.

Status of Commercialization:

In 2005, the company focused their strategy towards commercialization from R&D activities – cutting their R&D budget by almost 50% (Q1 2005). The company has delivered around 10 5 kW systems (first and second generation)

for testing and demonstrations to RWE (Germany), Ford Motor, National Research Council (Vancouver, Canada), Siemens Westinghouse, Gas Technology Institute (Tennessee) , Federal University Itajuba (Brazil), JFE Urban Development Corporation (Japan), University of Liege (Belgium) and University of Alaska at Fairbanks. The company's initial prototype that was delivered to University of Alaska at Fairbanks operated in excess of 9700 hours at an average efficiency of 40% LHV. Although the unit was damaged and decommissioned in July 2004, the company believes the University of Alaska unit represents the longest running small scale SOFC in the world. The company tested its second generation SOFC prototype in the second quarter of 2004, but reported that technical challenges have delayed its commercial release and reduced Q2 revenues by over 55% compared to 2003 results. The technical issues related to fuel and air flow distributions in the cell stack were resolved, and in January 2005, the company reported that their second generation unit achieved the target output performance. The company is further exploring how the system can be used in the industrial sector to utilize existing waste streams.

In 2005, the company reported around 16 orders for their 5 kW system – 7 of which have been reported to be delivered to date. Four systems are planned for 2005 delivery to the Hydrogen Village in Toronto. These units will provide electricity and heat (for hot water and area heating) for student residences at the University of Toronto at Mississauga. In a September 2005 press release, the company reported an order for their 5 kW system from BP shipping. The unit is intended to power auxiliary shipboard applications and fueled by LNG. In August 2005, the company reported that one of their systems delivered to Canada Center of Housing Technology has operated in excess of 1600 hours.

FuelCell Energy

Headquarters:

3 Great Pasture Road
Danbury, Connecticut 06813
Phone: 203-825-6000
Website: http://www.fuelcellenergy.com

Ownership Structure: Public (NASDAQ: FCEL).

Management:

- Mr. Jerry D. Leitman – Chairman and Chief Executive Officer
- Mr. R. Daniel Brdar –President and Chief Operating Officer

- Dr. Hansraj C. Maru – Exec. Vice President and Chief Technology Officer
- Mr. Christopher R. Bentley – Executive Vice President
- Mr. Joseph G. Mahler – Senior Vice President

Brief Company Description:

FuelCell Energy, Inc. (FCE) is focused on its proprietary molten carbonate fuel cell technology, which it has developed over the past fifteen years under a $400 million R&D program funded in part through the DOE and DOD. As of today, FCE has the only commercially available molten carbonate fuel cell product on the market, and is the only company in North America with any significant position in molten carbonate fuel cells. The company develops Direct FuelCell/Turbine hybrids based on their molten carbonate fuel cell technology.

FCE has past involvement with the research and development of planar solid oxide fuel cells. In August 2003, FuelCell Energy announced the acquisition of Global Thermoelectric, a developer of SOFC technology. In June 2004, FuelCell Energy sold the thermoelectric generator (TEG) product line of Global Thermoelectric to RockWood equity partners for $22.75M (Canadian), thereby retaining only the Global's SOFC technology development group. The company later merged its SOFC operations with Versa Power Systems. The transaction increased FuelCell Energy's interest in Versa from 16% to 42%. The company has approximately 370 employees, with an additional 90 employees working on SOFC through the acquisition of Global Thermoelectric, Inc.

Alliances/Partners:

- FuelCell Energy has developed commercial distribution alliances for its carbonate Direct FuelCell® products with MTU CFC Solutions in Europe; Marubeni Corporation in Asia; Enbridge Inc. in Canada; and Caterpillar, PPL Energy Plus, Chevron Energy Solutions, Alliance Power and LOGANEnergy in the U.S. FCE has other non-exclusive "market development agreements" with CMS Viron, MWH Corp, Starwood, and Marriott Hotels. FCE also enjoys long-time relationships with Southern Company and the Los Angeles Department of Water and Power. In November 2004, FCE and Marubeni signed an agreement with POSCO to distribute and package systems in Korea.
- In August 2005, Air Products selected FuelCell Energy for the development of a next generation hydrogen energy station based on FCE's Direct Fuel Cell power plant technology and Air Products' advanced gas separation technologies. The project is funded from U.S. Department of Energy. Phase 1 results on this project reported during the 2005 Fuel Cell Seminar, stated that high temperature fuel cells configured to co-produce hydrogen and

electricity can result in significantly lower costs for distributed hydrogen production and generate electricity at commercially attractive rates.

- U.S. Army Engineer Research and Development Center/Construction Engineering Research Laboratory (ERDC/CERL): In August 2004, FuelCell Energy and ERDC/CERL entered into a Cooperative Research and Development Agreement (CRADA) under which the FCE will provide a 250 kW Direct FuelCell® power plant to Department of Defense (DOD) Fuel Cell Test and Evaluation Center (FCTec) for evaluation.
- In April 2003, FuelCell Energy was awarded a SECA grant. The goal of the 9-year contract is to develop a 10 kW solid oxide fuel cell (SOFC) power generation system based on the Versa Power Systems and the University of Utah SOFC technology. They claim the technology can be used to operate at 700 °C, which simplifies sealing methods and reduces thermally-induced stresses. As a result, lower temperature operation is thought to be an important approach in achieving DOE's $400 per kilowatt cost target.

Products:

FCE's commercial product line, which is based on the company's molten carbonate fuel cell platform, is termed the Direct FuelCell® product, due to its ability for internal fuel reforming. The product line consists of the following integrated power plants:

- DFC®300: This unit is currently rated by FCE at 250 kW net AC output capacity. Targeted to the large commercial and institutional market, the DFC®300 is designed as a fully integrated plant on a single skid measuring approximately 28.1' x 9.0' x 10.5'. Major components are a fuel "pre-reformer", desulfurizer, water treatment system, power inverter, and fuel cell module. The unit has a rated electrical efficiency of 45-48% (LHV), and an overall efficiency of 70-80%. Approximately 300,000 BTU/hour of recoverable heat is available in the form of 650 °F exhaust. The unit requires pipeline quality natural gas, municipal-grade water, a sewer connection, and grid interconnection and/or external power source for start-up. FCE does not provide specifications on load following capability. The unit is certified to CARB 2007 ultra clean emission standards.
- DFC®1500: This power plant is rated at 1,000 kW net AC output and is made up of a power module and four separate balance-of-plant skids configured within an area of 1735 sq ft. The power module consists of four 250 kW stacks situated vertically in a cylindrical module. Rated efficiency is 49% LHV and available heat is 1.4 million BTU/hour. The unit is designed for outdoor installation only. Other operating characteristics are similar as those for the DFC®300.

- DFC®3000: The DFC®3000 is billed by FCE as the largest commercially available fuel cell power plant in the world. Rated at 2,000 kW net AC output, it is configured similarly to the DFC®1500, but with two fuel cell modules instead of one.
- DFC® Turbine: This product is still in the development phase. The concept is based on combining the Direct FuelCell® (DFC) and an unfired gas turbine. The hybrid system uses heat exchangers to transfer waste heat from the DFC system to the turbine, which converts a portion of the waste heat to mechanical energy and then electricity – adding 10 to 15 percentage points to the efficiency of the DFC. FuelCell Energy, under a DOE supported Vision21 program, is developing a sub-scale, ultra high-efficiency, 40 MW power plant design.

Technology Overview:

MCFC is a so-called "high temperature" fuel cell technology, operating at atmospheric pressure and a stack temperature of approximately 1250°F. Relative to the other fuel cell technologies, MCFC exhibits high efficiency (approximately 10 percentage points higher than low-temperature fuel cells), but at a lower power density. The key benefits of this high operating temperature are: a) it allows for "internal reforming" that eliminates the need for an external reformer; b) it avoids the use of precious metal catalysts such as platinum; c) it yields a higher power conversion efficiency; and d) it yields a "high-grade" heat that can be applied to a wide range of thermal applications. On the negative side, the major trade-offs include: a) long lead times to "cold start" the unit to operating temperature; b) need for an external heat source to take the unit to operating conditions; and c) potential for thermal expansion leading to electrolyte leakage and/or performance degradation. In 2005, the company reported advances in the power density and thermal management of their systems. By optimizing the electrode pore structure, and reducing the stack temperature gradient (from 120 ^{o}C in 2002 to 75 ^{o}C in 2004), FCE has been able to increase power density by around 20% in their stacks.

Fuel Capabilities:

FCE's Direct FuelCell® plants are fueled with pipeline quality natural gas in the standard configuration. However, the units have been demonstrated on methanol, propane, diesel, biogas, and coal gas in the laboratory. In the last 2-3 years, the company has focused on demonstrating units fueled by both biogas and coal gas.

Certifications:

Both the DFC®300 and DFC®1500 configurations received certification in 2003 under the American National Standards Institute product safety standard

governing fuel cell power plants (ANSI Z21.83). The DFC®300 also received certification under the California Air Resources Board's stringent "ultra clean technology" standards. In September 2004, the DFC 1500 received certification for meeting the California Air Resource Board's (CARB) stringent distributed generation emission standards for 2007. FuelCell Energy's DFC®1500 is the largest fuel cell system to meet 2007 California emissions requirements.

FCE is developing Direct FuelCell/Turbine hybrid for improved efficiency of its DFC® products. In this integrated approach, the fuel cell generates the majority of the power (approximately 80%) and the gas turbine produces power by extracting fuel cell byproduct heat in a Brayton cycle.

Status of Commercialization:

FCE is currently making a concentrated effort to place its Direct FuelCell® units in commercial applications to establish a track record of performance, reliability, and market acceptance. As on November 2005, the company has installed around 10 MW of power plants, the equivalent of forty 250 kW DFC300A power plants. In its 2005 fourth quarterly report, the company reported that they have around 10-13 MW of backlog orders.

FCE is currently conducting what it terms a "Field Follow Program" for the company's DFC300 units. The stated purpose of this program is to monitor fleet performance to build operational history and enhance product design. The program, introduced in 2003, is scheduled to run through the end of 2006. The company stated that their products achieved around 70 million kWh energy generation at 40 different customer sites during 2005.

Product Deliveries:

FCE delivered the first Direct FuelCell® for a commercial field trial in November 1999. Since that time, the company has delivered approximately 40 fuel cell power plants for commercial field trials in Europe, Asia, and the US. The company also commissioned its first 1 MW DFC1500 power plant fueled by natural gas and wastewater anaerobic digester gas at the King County Wastewater Treatment Facility in Washington State. The plant, which began operation in June 2004, has demonstrated better than 90% availability. In October 2004, the company reported sale of the first commercial 1 MW power plant to Alameda County's Santa Rita Correctional Facility.

In July 2004, FCE delivered the first DFC3000 unit for a commercial field trial at Wabash River Energy Ltd., Terre Haute, Indiana. No further details are available regarding the status of the project. In November 2004, FCE and Caterpillar reported the installation of the first fuel cell power plant in North America for utility-scale distributed generation application. The DFC 250 kW unit was installed at a substation in Westerville, Ohio.

The company's DFC product has been delivered and installed world-wide in numerous applications. In December 2005, the company reported delivery of a DFC300A power plant to Japanese ceramics manufacturer – the motive being to reduce the CO2 emissions and lower energy costs. At another installation with a German utility, the FCE DFC power plant was fueled with a mix of natural gas and methanol from organic waste/biomass generated from refuse of the city of Berlin. In November 2005, FCE reported the sale of 1.5 MW of fuel cell stacks (six 250 kW units) to their European partner MTU. With this purchase, MTU has to date purchased a total of 4.25 MW of power plants from FCE. In FY 2005, the company reported total sales of 6 MW of power plant world-wide.

Manufacturing / Cost Reduction:

FCE recognizes cost reduction as the company's most significant challenge. In its 2005 fourth quarter report, the company stated that their DFC300A unit is currently priced at $4,600 per kW, while their DFC1500 unit is at $4,300 per kW. Through better integration of balance of plant components, the company reports that they have reduced the cost of these products by 25-30% over the previous year.

The company has established a state-of-the-art manufacturing facility in Torrington, Connecticut designed to achieve economies of scale at a production volume of 50 MW/year. However, the current order flow indicates that the facility operates at a fraction of the 50 MW/year capacity. The company believes that the cost of their products can be further reduced by 25-30% by increasing production to 50 MW/year. Fuel Cell Energy continues to explore the use of power purchase agreements, rather than equipment sales. The company claims that the technology can provide power in the 5.5-8.5 ¢ per kWh range, when heat, emissions credits, and incentives are considered.

Product Development / R&D:

FuelCell Energy continues to develop its molten carbonate technology, assisted by grants and contracts with the DOE and DOD. A proof of concept fuel cell – gas turbine hybrid system (250 kW DFC stack with a 60 kW Capstone microturbine was tested. During the 2004 Fuel Cell Seminar, the company stated that this plant has operated in excess of 6000 hours in connection with the grid. The company revealed that they are working on two sub-MW DFC/T units. One of these units (alpha) will be tested at Danbury, Connecticut, while the other unit (beta) will be tested at Billings, Montana. During the 2005 Fuel Cell Seminar, FCE reported that fabrication of the alpha unit is complete and will undergo testing at the company's site.

The company is also working with the Navy to develop a shipboard fuel cell system that will run on Diesel fuel and provide non-propulsion power on naval ships. The company is developing a 0.5 MW demonstrators power plant. In

November 2005, the company reported that subsystems testing is underway. The unit is scheduled to be tested at FCE's site before its final delivery to the NAVSEA Philadelphia facility. In addition, through the interests in Versa Power Systems, FCE has interests in solid oxide fuel cell technology. FCE is participating in the SECA program.

Fujitsu Laboratories

Location: Tokyo, Japan

Website: http://www.labs.fujitsu.com/en

Technology: DMFC

- Fujitsu Laboratories is a wholly owned subsidiary of Fujitsu Limited, a leading provider of information technology, electronics, and communications solutions for the global marketplace. The company develops prototype fuel cells for portable devices such as laptops, PDAs, and similar products. The company's approach involves use of an aromatic hydrocarbon solid electrolyte material in its MEA. The new material slows methanol permeation and is covered with high density platinum nano-particle catalyst. Consequently, the Fujitsu claims they can use concentrated methanol. The company developed a prototype micro fuel cell with an output of 5.4 V and 700 mA for their 3G FOMA® handsets. According to a July 2005 press release, the company stated that they have developed a high capacity micro fuel cell prototype in collaboration with NTT DoCoMo. The new prototype utilizes 99% concentrated methanol (filled in a 18 cc methanol fuel cartridge) and provides a recharge time which is three times more than the previous prototype. The company reported that they are working on further improvements in terms of compactness and increasing the operational time of DMFC. The company has not released any timeline for commercialization of its products.

GenCell

Location: Southbury, Connecticut

Website: http://www.gencellcorp.com

Technology: PEM, MCFC, SOFC

- Established in 1997, GenCell develops sheet metal bipolar separator plates, current collectors, and electrodes for use in its fuel cell systems. The company targets the 40 to 100 kW distributed generation market and claims to have working prototypes of both PEM and MCFC. GenCell states that its "manufacturing friendly" designs use patented sheet metal based bipolar plates and its continuous manufacturing methods provide an important cost advantage over other developers. The company has received funding from the Connecticut Conservation and Load Management Fund and Connecticut Clean Energy Fund. In January 2005, the company delivered a 40 kW MCFC power unit to University of Connecticut's Global Fuel Cell Development Center. The unit is connected to the electrical grid. In a paper presented at the 2005 Fuel Cell Seminar, the company stated that they have made significant progress in terms of improving stack and balance of plant components – both in terms of cost and efficiency. Currently, the company is selling bipolar plates to other fuel cell stack OEMs. The company also reported that they are working on developing a second commercial demonstration unit for a customer. In January 2004, GenCell announced a partnership with the MEA-maker Ion Power to jointly develop fuel cells for stationary, portable, and automotive applications.

General Electric

Headquarters:
3135 Easton Turnpike
Fairfield, Connecticut 06431
Phone: 203-373-2211
Website: http://www.ge.com

Ownership Structure: Public (NYSE: GE)

Management:

- Mr. Jeffrey R. Immelt – Chairman and Chief Executive Officer
- Mr. William M. Castell – Vice Chairman
- Mr. John Krenicki – President and Chief Executive Officer, GE Energy
- Dr. Nguyen Minh – Manager – Fuel Cells, GE Power Systems

Brief Company Description:

GE is a diversified industrial corporation whose products include appliances, lighting products, power systems, and plastics. GE Energy Systems is one of the world's leading suppliers of technology to the energy industry with 2004 revenues exceeding $17.3 billion. Within this business unit, GE has a joint venture with Plug Power focused on marketing Plug Power's PEM fuel cell technology. In 2001, GE acquired Honeywell's solid oxide fuel cell program and is now developing a line of fuel cells. This work is being conducted by GE Hybrid Power Generation Systems, also a part of GE Energy Systems. GE acquired Honeywell's contract with SECA and is developing technology through that program. In November 2004, GE Global Research announced it was selected by the DOE to lead an $11M research effort to develop hydrogen production with clean and sustainable technologies.

Alliances/Partners:

- The following five companies have agreed to test and distribute GE's fuel cell systems when commercially available:
  - Flint Energies – Southern Georgia
  - Kubota Corporation – Japan
  - Rahimafrooz Energy Services Ltd. – Bangladesh
  - Soroof Trading Development Company Limited – Saudi Arabia
  - Vaillant – Austria, Germany, Netherlands, and Switzerland
- In September 2001, Honeywell entered into a cooperative agreement with the DOE under the SECA program. Following GE Power Systems acquisition of Honeywell's fuel cell division in January 2002, the SECA contract was transferred to GE in March 2003. The work will progress in three phases, with the ultimate goal of producing a 3-10 kW modular, fuel flexible unit by 2011 at a cost not to exceed $400 per kilowatt.
- General Electric Co. (NYSE: GE), ExxonMobil (NYSE: XON), and Stanford University have formed a partnership - a multi-million dollar collaborative research project to develop alternative energy for the future.

Products:

No products are commercially available at this time. Anticipated products include:

- 3-10 kW SOFC system (under development through SECA initiative)
- MW range SOFC/GT hybrid and multi-MW range IGFC (conceptual stage)
- PEM fuel cell products – see Plug Power profile

Technology Overview:

GE's SOFC technology is an anode supported planar cell design with metallic interconnects operating at 800 ^{o}C. The company is evaluating two systems – an ambient pressure simple cycle SOFC and a pressurized SOFC/gas turbine hybrid. The latter is still in the conceptual phase, but GE claims that their MW power range systems are capable of producing electricity at greater than 65% efficiency.

GE's solid oxide fuel cell technology integrates the fuel cell stack, fuel processing technology, and balance of plant. During the 2005 Fuel Cell Seminar, the company announced the development of a 5 kW thermally self-sustained prototype SOFC system consisting of an Autothermal Fuel Processor and SOFC stack. The prototype system measures around 36" × 15" × 20". The company claimed to have addressed performance degradation in the stack by choosing alternative and/or modified materials for different components for the cathode, anode, and interconnect. The prototype system was operated for over 1700 hours. The electrical efficiency of the unit is 41% and availability of over 90%. The company reported that the degradation rate is around 1.8% per 500 hours of operation.

GE's SOFC/GT hybrid system is still in conceptual phase. However, the company claimed to have made significant progress in this direction. The company reported that they have successfully fabricated cells of up to 40 cm in diameter. Furthermore the company states that for its hybrid system – they have demonstrated pressurized operation of the stack to 4 atm. at 80% fuel utilization. The company is also working on integrated gasification fuel cell (IGFC) plant for multi-MW power plants which involves SOFC/GT concept along with CO_2 sequestration.

Status of Commercialization:

PEM Stationary:

General Electric has a joint venture (GE Fuel Cell Systems) with Plug Power whereby GE will market Plug Power's fuel cell technology. For more information on Plug Power fuel cell technology, see the Plug Power profile.

SOFC Stationary:

GE's solid oxide fuel cell systems are currently in the development stage. The company is using its SECA contract to drive technical improvements and timelines. Through SECA, DOE will provide nearly $74M for the 10-year project, while GE Energy will contribute an additional $59M. The goal of this program is to demonstrate a fuel-flexible, modular 3 to 10 kW SOFC system. The company is working to improve balance of plant components like pre-reformer, system controls, and power electronics. During the 2005 Fuel Cell Seminar, the company reported the development of a 5 kW prototype system.

The estimated cost of the prototype system is around $724 per kW, which is less than the $800 per kW target set for the Phase 1 SECA program. The second phase proposes to develop a solid oxide fuel cell for a cost of $600 per kilowatt, and in the final phase, a prototype will be developed by 2010 for a demonstrated cost of $400 per kilowatt. These prototypes will be applicable to multiple markets utilizing multiple fossil fuels.

General Motors

Research and Development Center:
30500 Mound Road
Warren, Michigan 48090
Website: http://www.gm.com

Fuel Cell Research Activities:
10 Carriage Street
Honeoye Falls, New York 14472
Phone: 585-624-6807

Ownership Structure:

Public (NYSE: GM)

Management:

- Mr. G. Richard Wagoner, Jr. – Chairman and Chief Executive Officer
- Mr. John M. Devine – Vice Chairman
- Mr. Frederick A. Henderson – Vice Chairman and Chief Financial Officer
- Mr. Robert Lutz – Vice Chairman, Global Product Development
- Mr. Larry Burns – Vice President of Research, Development, & Planning

Brief Company Description:

General Motors has a significant fuel cell program administered through their Research and Development Center in Warren, Michigan. The company has established dedicated fuel cell research facilities in United States and Europe. The focus of GM's program is on vehicular applications, with an ultimate goal of placing fuel cell systems in production vehicles by 2010. The company has said that its fuel cell efforts are its single largest R&D program. The company is also pursuing a strategy to deploy fuel cells in stationary applications, as an interim step prior to the commercialization of fuel cell vehicles. The company

intends to invest several billion dollars over the next decade in fuel cell research, product development, engineering, and demonstration.

Alliances/Partners:

- US DOE – In March 2005, GM and DOE to develop hydrogen fuel cell technology. Under the 50-50 cost share agreement, GM will invest $44 M on the development of new demonstration fuel cell cars in Washington, New York, California, and Michigan.
- Quantum Fuel System Technologies Worldwide – In June 2002, GM acquired a 19.9% equity stake and the companies are collaborating on development of advanced hydrogen storage systems to improve the range of GM fuel cell vehicles. The collaboration received certification from a top German safety institute for a 700 bar (10,000 psi) hydrogen storage system that could ultimately allow fuel cell vehicles to achieve a driving range of 300 miles. In April 2005, Quantum reported that it has intentions to transfer its hydrogen storage technology to Japanese fuel cell automakers.
- Giner Electrochemical Systems – In October 2001, GM and Giner agreed to expand their joint fuel cell development activity to include applications beyond the transportation field, including hydrogen generation for refueling systems and regenerative fuel cell units for stationary power. GM holds a 30% share in the company.
- General Hydrogen – In June 2001, General Motors and General Hydrogen announced a 25-year collaboration to accelerate development of hydrogen storage, fuel cell vehicle refueling, energy services, advanced materials, power electronics and electric power production. A key focus is high-pressure, high-power electrolyzers.
- Dow Chemical Company – In May 2003, GM and Dow Chemical signed an agreement to install 35 MW of fuel cells at the Dow Facility in Freeport, Texas. Starting with a single 75 kW module, GM announced the start of Phase 2 in November 2004, which involves construction of a 1 MW pilot plant.
- Shell – In March 2003, GM and Shell Hydrogen announced a collaboration to promote development of hydrogen infrastructure through public policy advocacy, public education, project demonstrations, and knowledge sharing. Through this collaboration, the nation's first hydrogen pump at a Shell retail gas station was unveiled on November 10, 2004 to support a GM vehicle fleet in Washington, D.C. Shell Hydrogen further reported in 2005, that it will support GM's new vehicle demonstration fleets by installing five hydrogen refueling stations in Washington, New York, and in California.
- California Fuel Cell Partnership – GM is a part of the California Fuel Cell Partnership formed in 1999 to commercialize fuel cell vehicles by

addressing issues such as fuel infrastructure, vehicle and fuel safety, market incentives, and consumer acceptance.

- Hydrogenics – This strategic alliance was formed in October 2001 and includes shared intellectual property rights and joint efforts in fuel cell product development, engineering, prototyping, testing, branding and marketing strategies. As part of the agreement, GM purchased 24% ownership in Hydrogenics and warranted to acquire an additional 5% (2.4 million Hydrogenics common shares). In December 2005, Hydrogenics repurchased 2.4 million common share purchase warrants issued to GM in 2001.
- Shanghai Automotive Industry Corp. (SAIC) – This October 2004 agreement involves the development and commercialization of hybrid and fuel cell vehicles in China.
- Other Fuels Research partners – ExxonMobil (hardware, gasoline reforming, and other fuel options); BMW (liquid hydrogen refueling); BPAmoco: (liquid hydrocarbon fuels); ChevronTexaco (gasoline reforming and delivery).
- Other Car Manufacturers – Toyota (agreement in April 1999 to collaborate on development and testing fuel cell technologies); Suzuki (October 2001 agreement to develop small car applications for fuel cells).

Products:

GM does not currently offer commercial products. The company publicized its GM Sequel Fuel Cell concept vehicle in 2005 and displayed the vehicle at the Fuel Cell Seminar in November. The Sequel employs fairly conventional fuel cell architecture with limited "drive-by-wire" technology and likely represents a strategic decision by GM regarding the architecture and technology to be found in early fuel cell models. In the past, the company publicized its Autonomy and Hy-wire vehicles. In addition, the company is testing prototypes intended for stationary power applications.

Technology Overview:

GM is focused exclusively on PEM fuel cell technology. At this time, the company is developing hydrogen fueled systems and following an off-board hydrogen reforming strategy. Prototypes and pre-commercial units are the product of a well-funded development program within GM's R&D division. The company continues to hold information related to the technology and its performance very closely, however, as with PEM technology generally, stack life and durability are thought to be key areas of research for the company. However, the company has indicated in the trade press that stack durability already exceeds an acceptable vehicle durability target of 5000 hours. Additional areas of progress include decreased freeze start-up time (less that 15

seconds at 100% power at -20 ^{o}C) and a ten-fold increase in power density with a proportional decrease in cost in only 2-3 years. In 2005, the company announced development of a novel stack concept that enables a 50% reduction in stack size compared to the stack debuted in the Sequel concept car.

GM has publicly stated that other challenges to broad deployment of fuel cells are achieving cost reductions, developing fueling technology, and creating hydrogen storage and infrastructure. In an effort to reduce fuel cell cost, GM is focusing on process optimization, and catalyst deposition techniques and materials engineering to produce less costly polymer membrane electrode assemblies. At the 2005 Fuel Cell Seminar, the company reported development of *in-situ* techniques for visualizing and quantifying water dynamics in low temperature PEM fuel cells. At the 2004 Fuel Cell Seminar, GM stated that they are focusing on the synthesis of Pt_xCo_{1-x}/C and other Pt-alloy catalysts.

Status of Commercialization:

GM continues to develop its "skateboard" approach with drive-by-wire technology. In parallel to this, the company is pursuing a more conventional approach using traditional vehicles that is providing more immediate demonstration opportunities. At this time, GM has over twelve HydroGen3 fuel cell vehicle cars with several customers around the world. The company states that HydroGen3 is substantial lighter with increased power output, improved range, and increased top speed. Earlier in 2005, the company announced that it will provide 13 FCVs to the New York City in 2006, along with Shell Hydrogen, who will establish the city's first hydrogen service station.

In January 2005, the company unveiled the GM Sequel concept, which incorporates drive-by-wire and wheel hub motors. The company reported that they have doubled the range and halved the 0-60 mph acceleration time in less than 3 years. In April 2005, the company rolled out world's first fuel cell truck. The truck was leased to the U.S. Army for its testing under various climates and terrain. The truck is powered by two hydrogen fuel cell stacks. It has a driving range of 125 miles and a top speed of 93 mph. It reportedly accelerates from 0-60 mph in 19 seconds. Testing is expected to continue through July 2006.

GM believes broad commercialization will require fuel cell systems to be $50 per kilowatt or less and that fuel cell vehicles will ultimately require much improved hydrogen storage systems. The company is working with Quantum, Sandia National Laboratories, and other developers for development of hydrogen storage technologies. In March 2005, the company reported that its partner, HRL Laboratories have developed a new class of metal hydrides that can store large amounts of hydrogen in solid state and has the potential to provide better driving range than the current generation vehicles.

Due to the long time horizon for conditions to be met, GM is also developing products for stationary applications, which could achieve commercialization

before mobile applications. The company is working with Dow to install up to 400 stationary fuel cells, totaling to around 35 MW, at Dow Chemical Plant in Texas. In November 2004, the company announced starting of Phase 2 of the project under which up to 1 MW of fuel cell energy will be provided by GM fuel cells for use in Dow's Texas Operations. Phase 3 of the project is scheduled to start in 2007. The company has also installed its prototype stationary fuel cell unit at its New York fuel cell development facility.

GM's corporate outlook on fuel cell commercialization is that early adopters will likely be in premium power applications at data centers and also at industrial facilities, where opportunity fuels exist. As market acceptance increases and costs are reduced, GM holds out the possibility of placing units in small commercial and even residential applications.

Giner Electrochemical Systems

Location: Newton, Massachusetts

Website: http://www.ginerinc.com

Technology: PEM/DMFC

- Giner Electrochemical Systems is a research and development company focused on a range of electrochemical technologies including fuel cells, electrolyzers, sensors, ozone generators, and capacitors. The company was formed in 2000 by General Motors and Giner Inc. as a part of GM's ambitious plan to develop automotive fuel cell technologies. The company's fuel cell business is developing stacks based on PEM and direct methanol fuel cell technologies. The company has developed a number of prototype products, including:
    - a regenerative fuel cell stack that can operate as an electrolyzer
    - a portable and compact 150 W DMFC for communication devices and battery charging
    - a 5 kW stack (which can operated up to 400 psig) intended for aerospace applications
    - a CO tolerant PEM stack designed for operation on reformate.

  In January 2005, Ener1 announced its intentions to acquire the fuel cell business of Giner Inc.

H2 ECOnomy

Location: Yerevan, Armenia

Website: http://www.h2economy.com

Technology: PEM

- H2 ECOnomy, which spun-off from SolarEn International in 2000, is involved in the development of PEM fuel cell systems and components. The company has developed several products for commercial and educational use including PEM stacks, polymer composite bipolar plates, a fuel cell test station, and DC-DC converters. The company has developed stacks (H2/O2 and H2/air) in the 4-40 W power range and is marketing their products for specific niche markets like portable power applications. The company had a booth at the 2005 Fuel Cell Seminar, where they displayed a number of their products.

Heliocentris Energy Systems

Location: Berlin, Germany

Website: http://www.heliocentris.com

Technology: PEM

- Established in 1995, Heliocentris Energy Systems provides fuel cell and hydrogen technology systems for education, outreach and demonstration. The company has a line of small 20-40 W fuel cells and has a worldwide distribution in over 20 countries. In 2004, the company established a partnership with Ballard Power Systems. Under the partnership agreement, Heliocentris will distribute Nexa™ and AirGen™ fuel cell modules for universities and technical colleges in North America and Europe.

Helion Fuel Cells

Location: Aix-en-Provence, France

Website: http://www.helion-fuelcells.com

Technology: PEM/SOFC

- Helion is a developer and manufacturer of PEM fuel cells power plants ranging from several kW to several hundred kW. The company is developing products for applications such as industrial back-up power units, cogeneration systems, and urban public transport. The company is also developing fuel cell systems for sub-marine applications. The first 2 kW prototype was developed in 2001. In February 2003, the company demonstrated a more advanced fuel cell system including a 5 kW fuel cell unit, electrolyzer (to generate hydrogen and oxygen), and fuel storage system. In a December 2004 press release, the company stated that they have developed a 20 kW fuel cell stack. Later in November 2005, the company reported the development of a 20 kW SYSPAC® fuel cell emergency power system as a part of the European Helps program. The company plans to demonstrate a full power generation system in 2006.

Hitachi

Location: Tokyo, Japan

Website: http://www.hitachi.com

Technology: PEMFC/DMFC/SOFC

- Hitachi is one of the world's largest electronics and electrical companies, with products ranging from information systems and electronics to power generating facilities. The Hitachi Metals subsidiary is developing materials and components for solid oxide fuel cells. The Hitachi Cable subsidiary is developing fluorocarbon resin for membranes and also cladding materials for separators in PEMFC. The company is also developing DMFC for PDAs, laptop computers, and similar electronic products. In December 2005, the company reported on the development of a prototype mobile phone powered with DMFC – Li-ion battery in collaboration with KDDI of Japan. The company plans to begin offering products incorporating DMFCs in the 2006-2007 time frame.

Honda Motor Company

Headquarters:
1919 Torrance Boulevard
Torrance, California 90501
Phone: 310-783-2000
Website: http://www.honda.com

Ownership Structure: Public (NYSE: HMC)

Management:

- Mr. Takeo Fukui – President and Chief Executive Officer
- Mr. Akio Hamada – President of Honda Engineering
- Dr. James Seaba – Chief Engineer, Fundamental Research Laboratories

Brief Company Description:

Honda is focused on the development of low emission vehicles and zero emission fuel cell vehicles. The company has been working on PEM fuel cells since 1989, and has developed a number of fuel cell vehicle prototypes based upon stack technology from both Ballard Power System and Honda. The company's most recent fuel cell vehicle is the 2005 Honda FCX, the second generation fuel cell vehicle to use Honda's fuel cell stack. In June 2005, Honda became the first company to deliver fuel cell car to an individual customer.

Alliances/Partners:

- California Fuel Cell Partnership
- Stanford University – Development of miniature fuel cells to be used as next generation power sources for Honda's portable power products.
- Plug Power, Inc. – Home Energy Station (HES) that generates hydrogen from natural gas for use in FCVs while supplying electricity and hot water to the home.
- Ballard Power Systems – Under this agreement signed in December 2002, Ballard will supply Honda with up to 32 Mark 902 fuel cell modules through 2005.

Products:

No commercial products are available from the company, although vehicle demonstrations of the 2005 Honda FCX fuel cell vehicle which included the Honda stack are ongoing at multiple locations worldwide. Specifications of this latest model are given in the table below. In addition, the company developed a

fuel cell powered scooter using Honda's fuel cell stack technology in August 2004. Announced in August 2004, the company has yet to decide its commercialization strategy for the product.

Technology Overview:

In September 1999, Honda introduced two fuel cell vehicles – the hydrogen fueled FCX-V1 using a stack from Ballard Power Systems; and the methanol fueled FCX-V2 using an on-board reformer developed by Honda. The company's third version, the FCX-V3 introduced in November 2000, also used a stack from Ballard Power Systems. In later versions of FCS-V3, Honda began using their internally designed and built fuel cell stack. Honda continues to develop vehicles using stacks from both companies.

The most noted advantage in the Honda fuel cell stack is its capability to start the FCV at temperature of -20 ^{o}C and at the same time demonstrating high temperature reliability. The stack uses a new fuel cell structure of stamped metal separators and new aromatic membrane material. In a paper presented at the 2005 Fuel Cell Seminar, the company reported that they are using surface impregnated (with electrical conductive metallic inclusions) passive stainless steel allow for the separator plates. The company claims that its stack is 50% thinner and offers easy manufacturability compared to some of the earlier stacks which the company was using. The use of aromatic membrane (with high ionic conductivity at lower temperatures), metal bipolar plates (with increased conductivity), and compact design (with lower thermal capacity) enhances performance of Honda's stacks over a large temperature range.

2005 Honda FCX Specifications:

Complete Car	Maximum Speed	93 mph
	Driving Range	269 miles
	Seating Capacity	4
	Dimensions (L × W × H , mm)	4165 × 1760 × 1645
Motor	Maximum Power Output	107 hp (80 kW)
	Maximum Drive torque	201 lb-ft (272 N-m)
	Type	AC synchronous electric motor (manufactured by Honda)
Fuel Cell Stack	Type	Honda Fuel Cell Stack (PEM)
	Power Output	86 kW
	Secondary Energy Buffer	Ultra capacitor (manufactured by Honda)
Fuel	Type	Compressed hydrogen gas
	Storage	High-pressure hydrogen tank (5000 psi)
	Capacity	156.6 liters

The company reported that their new fuel cell system has achieved an energy efficiency of 55% with an improved fuel efficiency of 22% over their models. The company also claimed that they have achieved improvements in vehicle range in the last 3-4 years. The 2005 Honda FCX has a range of 269 miles, compared to 112 miles for FCX-V3 which was released in 2000.

Status of Commercialization:

Honda has stated that it believes vehicle commercialization will begin in earnest in 2010, primarily in Japan and later in the U.S. and Europe. The company continues to expand its fleet and infrastructure demonstration program. The company is now demonstrating their 2005 FCX vehicles in extreme weather conditions. Apart from the demonstrations that were ongoing in California State, the company delivered two vehicles in New York (where the temperature may be as low as -20 ^{o}C) and two in Las Vegas (where the temperature may be as high as +45 ^{o}C). These vehicles bring the total number of Honda FCVs in the U.S. to fifteen, including (in addition to these) five vehicles in Los Angeles, two in San Francisco, and three vehicles in the Honda demonstration fleet. Honda fuel cell vehicles are the world's first FCVs that have received government certification. The 2005 Honda FCX fuel cell vehicle is certified as Zero Emission Vehicle (ZEV) by both CARB and EPA.

The company is also working on a Home Hydrogen Refueling technology with Plug Power. In November 20005, the company demonstrated the third generation of Home Energy Station in Torrance, CA, which provides heat and electricity for the home and hydrogen for the hydrogen powered FCV. The company reported that the 3rd generation system is much more compact and efficient than their previous two systems.

Hydra Fuel Cell

Location: Beaverton, Oregon

Website: http://www.hydrafuelcell.com

Technology: Misc.

- Hydra Fuel Cell Corporation is a wholly owned subsidiary of American Security Resources Corporation (AmSR). The company's proprietary, silicon-based hydrogen fuel cell technology was developed at EGO Design, which was later acquired by AmSR in October 2005. Hydra is utilizing the printing circuit board technology to develop fuel cell systems in 5-40 kW power range. The company is first focusing on the development of 5 kW hot-swappable unit. In a December 2005 press

release, the company reported that their beta units will be delivered to selected customers for testing and demonstration in early 2006.

HydroGen

Headquarters:
2 Juniper Street
Versailles, PA 15132
Phone: 412-405-1000
Website: http://www.hydrogenllc.net

Ownership Structure:
HydroGen is now a wholly-owned subsidiary of Chiste Corporation (OTCBB: CSTC). In 2005, the company raised around US$13.5 million of gross proceeds through the sale of equity securities.

Management:

- Dr. Leo Blomen – Chief Executive Officer
- Mr. Joshua Tosteson – President
- Mr. Scott Schecter – Chief Financial Officer
- Mr. Scott Wilshire – Chief Operating Officer
- Mr. Gregory Morris – Senior Vice-President

Brief Company Description:

Hydrogen LLC is a fuel cell systems manufacturing company that owns technology, proprietary rights, and manufacturing assets of the 400 kW, air-cooled PAFC modules originally developed by Westinghouse Corporations's Advanced Energy Systems Division through DOE-sponsored R&D programs in the 1980s and early 1990s. In 1993, DOE determined the PAFC technology was commercially-ready and discontinued funding. Westinghouse then sold the technology to a private investor, who subsequently formed FuelCell Corporation of America (FCA) to commercialize the technology. HydroGEN obtained rights to the technology from FCA in 2001 and is now bringing the technology to market.

Alliances/Partners: Ohio Department of Development

Products:

The company doesn't offer any commercial products at this time. Product in development includes a core 2 MW power island, built up from 5 identical 400 kW modules.

Technology Overview:

HydroGen's utilizes unique air-cooled phosphoric acid fuel cell stack technology, originally developed at Westinghouse. The company believes that their technology is much simpler and economical compared to conventional water-cooling PAFC technology. Air-cooled stacks don't need separate channels unlike liquid water cooling in the graphite separator plates and thus can be manufactured economically.

Status of Commercialization:

The company is developing a 2 MW product, but is targeting power plants in 2-30 MW range. Initially, the company is focused on sites where excess or byproduct hydrogen is available, such as chlor-alkali plants. In August 2005, the company received a $1.25 M grant award from the State of Ohio Department of Development. Under this grant, the company will install a 400 kW commercial demonstration fuel cell unit in Ohio.

Hydrogenics

Headquarters:

5985 McLaughlin Road
Mississauga, Ontario
Canada L5R 1B8
Phone: 905-361-3660
Website: http://www.hydrogenics.com

Ownership Structure:

Public (TSX: HYG.TO, NASDAQ: HYGS)

Management:

- Mr. Pierre Rivard – President and Chief Executive Officer
- Mr. Joseph Cargnelli – Chief Technology Officer
- Mr. Salil Munjal – Vice President, Corporate Development

- Mr. Jonathan Lundy –President, Power Systems
- Dr. Mel Ogmen – President, Test Systems
- Dr. Ravi B. Gopal – Vice President, Applications Development
- Mr. Bart Van Ouytsel – President, Onsite Generation

Brief Company Description:

Hydrogenics is a developer and manufacturer of PEM fuel cells, fuel cell test stands, regenerative fuel cells and electrolyzers. The company designs and builds PEM fuel cell systems for power generation and vehicle markets. Hydrogenics launched its fuel cell activities in 1995 with a line of test stations and later expanded its efforts to include fuel cell technology development. The company has since established an extensive product line and important strategic relationships with partners such as General Motors and John Deere. Early in 2003, Hydrogenics announced that it had acquired Greenlight Power Technologies, Inc., its principal competitor in the fuel cell test business, in a transaction valued at approximately $US 19 million. In November 2005, the company re-branded Greenlight Power Technologies to Hydrogenics Test Systems. Hydrogenics is beginning to develop and manufacture hydrogen generation products to complement its fuel cell product development activities, which include PEM electrolyzer stacks, PEM electrolyzer refueling systems, and balance of plant components for reformer-based hydrogen generation systems. In November 2004, the company announced the acquisition of Stuart Energy Systems, the electrolyzer developer. Hydrogenics has operations in Canada, US, Japan, and Germany. The company had approximately 265 employees.

Alliances/Partners:

- Stuart Energy – In November 2004, the companies announced an agreement whereby Hydrogenics would acquire all of the outstanding common stock in Stuart.
- Greenlight Technologies (now called Hydrogenics Test Systems) – The test stand manufacturer is a subsidiary of Hydrogenics.
- General Motors – This strategic alliance was formed in October 2001 and includes shared intellectual property rights and joint efforts in fuel cell product development, engineering, prototyping, testing, branding, and marketing strategies. As part of the agreement, GM purchased a 24% ownership (currently diluted to 21%) in Hydrogenics and warrants to acquire an additional 5%. To date, the alliance has yielded several product demonstrations: fuel cell forklift at GM Canada car assembly, a fuel cell vehicle in China, a regenerative backup power generator in California, and a regenerative vehicular auxiliary power unit on a hybrid-diesel truck. GM also contracts with Hydrogenics to provide engineering services at its fuel

cell development center and to test GM fuel cell stacks. In August 2004, GM awarded a multi-million dollar contract to Greenlight Power Technologies (now Hydrogenics Test Systems) to supply fuel cell test stations to its fuel cell research activities in Honeoye Falls, New York. In March 2005, Greenlight Power Technologies also received an additional order from GM to supply six fuel cell advanced test stations. In December 2005, the company reported additional test station purchases from GM.

- American Power Conversion (APC) – Hydrogenics is supplying its HyPM module to APC for integration into their newly developed fuel cell UPS system, dubbed the InfraStruXure™. Hydrogenics announced in June 2005 that it is supplying 25 fuel cell power modules to APC.
- John Deere – In July 2004, Hydrogenics entered into a five-year agreement with John Deere to enhance their efforts for using hydrogen and fuel cells in commercial vehicles. Under this collaborative agreement which build on the success of earlier joint project between the two companies, Hydrogenics will integrate its HyPM™ fuel cell power module technology intro John Deere off-road vehicles. To date, the company has received nine orders for their HyPM units from John Deere.
- Maxwell Technologies – In February 2004, Hydrogenics and Maxwell Technologies entered into a joint agreement to integrate Maxwell's BOOSTCAP® ultracapacitors into Hydrogenics fuel cell power systems. Under the agreement, Maxwell will provide ultracapacitors to Hydrogenics for a period of four years. The integration is expected to optimize the system performance, cost, and longevity of the combined unit.
- IdaTech – In October 2003, Hydrogenics and IdaTech partnered together to develop a 50 kW fuel cell system that can serve as an independent energy source for large facilities such as hotels, hospitals and office buildings. The partnership is a part of the $9.6 million DOE award to IdaTech to advance fuel cell technology for stationary applications. The 50 kW system will use newly developed component technologies, including Hydrogenics fuel cell power module technology, and IdaTech's fuel processing technology.
- ChevronTexaco Technology Ventures LLC – In May 2004, Hydrogenics and ChevronTexaco entered into a contract for execution of a hydrogen energy station for stationary power generation and transportation fuel applications. Under the agreement, Hydrogenics will provide engineering and product-related services to integrate a fully packaged hydrogen generator and ChevronTexaco will provide its propriety reformer technology.

Products:

Hydrogenics develops a range of fuel cell products intended for systems integrators and end-users. Their major product categories include fuel cell

stacks, hydrogen generators, and refueling systems, fuel cell test stands (through Green Light Technologies), and electrolyzers (through Stuart Energy).

- Fuel Cell Power Systems
  - HyPM™
    - Power output: 8-65 kW
    - H2X™ fuel cell stack
    - High performance and efficiency, with rapid dynamic response
    - Compact lightweight design
    - Modular/scalable design for wide range of applications
    - Available as power module, DC power solution (with regulated DC output) and fuel cell power pack (with integrated hydrogen and energy storage as well as thermal management)
    - Available both for mobile and back-up power applications
- Onsite Hydrogen Generation Systems
  - HySTAT™ - A – includes proprietary inorganic membrane electrolysis technology (IMET).
  - HySTAT™ - P – includes proprietary proton exchange membrane (PEM) electrolysis technology.
- Cell Testing & Control Systems –
  - Hydrogenics Test Systems line of analysis and testing systems (Fuel Cell Automated Test Systems – FCATS™) are suitable for fuel cell systems up to 180 kW.

Technology Overview:

Hydrogenics is focused exclusively on PEM technology and associated systems. The company's product development approach is to provide a robust, modular building block that can be integrated into a wide array of power products. The company's primary product offerings are centered on its HyPM™ fuel cell power modules and HySTAT™ hydrogen generation systems. Hydrogenics has a long standing relationship with Gore for MEA supply.

The fuel cell products are built around the company's proprietary H2X™ Series stack technology. The company states that the power densities of current stacks offer high performance over a power range of 500 W to 65 kW and at an electrical efficiency of over 55% (LHV, for power output greater than 1 kW). The 10 kW module reached a net peak power of 14 kW at 350 A without exhibiting signs for diffusion over potential. The company also claims that the system architecture of HyPM™ module provides performance unaffected by the

start/stop cycling. During the 2005 Fuel Cell Seminar, the company stated that power modules have been tested through 5996 start/stop cycles with no appreciable effect on the durability of the module (580 hour operation, decay rate 36 μV/hr). If true, this level of start-stop performance is exceptional and could represent a significant breakthrough in PEM stack durability. Furthermore, the company claimed to have improved the durability of their stacks by at least a factor of five in last three years. Hydrogenics reported that their current generation HyPM™ 12 module has a low degradation rate of 8 μV/hr (at 350 A) and has operated for over 3300 hours (and was still operating as of November 2005). The company is currently testing their modules under freeze/thaw cycles (-5 ^{o}C, -20 ^{o}C and -40 ^{o}C to +40 ^{o}C). The company also plans to work on improving the durability of their module at higher temperature and lower relative humidity.

Status of Commercialization:

Overview:

Hydrogenics offers commercial test stands and related equipment. Furthermore, the company also sells its HyPM™ power modules with commercial terms and prices. The company is offering HyPM™ modules in 8-17 kW power range. To date the company has shipped around 50 HyPM™ units – several of them to its UPS system partner, American Power Conversion. In December 2005, the company announced that it has secured an $8 million contract to deliver 600 kW capacity of its HyPM™ units to a world leading military OEM for an undisclosed application. Under the contract, Hydrogenics will deliver the modules in 2006 and 2007.

Other products related to hydrogen production and refueling systems are considered to be in development. However, some of these products have advanced into an early commercialization stage with selected clients. The bulk of the company's sales continue to be derived from the sale of testing and monitoring equipment. Hydrogenics' alliance with General Motors appears to be critical to its near-term business and long-term commercialization efforts.

Vehicular:

Hydrogenics' basic strategy is to form premiere alliances with original equipment manufacturers and become an integral part of the overall development of fuel cell vehicles for mass production. The company has developed fuel cell propulsion systems for early-adopting "off road" power applications in this segment since 2001. However, the strategic alliance with GM has positioned the company very favorably in this sector and greatly accelerated the pace of technology development. Likewise, the relationship with John Deere has positioned the company well in the off-road vehicle market. In September 2004, the company won a contract to supply a fuel cell power

module for integration into an aircraft tow tractor. The company has also demonstrated its fuel cell for a forklift application at GM Canada car assembly plant and FedEx Canada.

Stationary:

Hydrogenics is focusing commercialization efforts primarily in the backup power market, particularly for telecommunications. The company has partnered with American Power Company for integration its HyPM™ modules into a fuel cell back up power product, InfraStruXure™. The company also intends to develop strategic partnerships with electric and gas utilities, energy service companies, propane companies, and HVAC dealers to distribute their stationary power products.

Portable:

The company made several sales to the U.S. Army and Air Force, including vehicle-mounted auxiliary power units. In 2004, the company provided 65 kW of fuel cell power module to Department of Defense Fuel Cell Test and Evaluation Center (FCTec) for integration into an Aircraft Tow Tractor by Concurrent Technologies Corporation (CTC). In November 2004, the company reported that NASA Glenn Research Center purchased a 5 kW PEM fuel cell stack for research on regenerative fuel cells.

The company intends to eventually expand market penetration to non-military applications such as scientific and environmental monitoring, remote and extreme weather power generation, control instrumentation at remote sites, and other specialty applications. Hydrogenics plans to establish non-exclusive supplier relationships with large volume major retailers and with existing OEMs who wish to expand into a fuel cell line.

IdaTech

Headquarters:

63065 NE 18th Street
Bend, Oregon 97701
Phone: 541-383-3390
Website: http://www.idatech.com

Ownership Structure:

Owned by IdaCorp (NYSE: IDA).

Management:

- Mr. Claude H. Duss – President and Chief Executive Officer
- Dr. David J. Edlund – Senior Vice President and Chief Technology Officer
- Mr. Michael A. Otterbach – Vice President of Operations
- Mr. Eric L. Simpkins – Vice President of Business Development
- Mr. Bill Shank – Vice President of North American Sales
- Mr. Harol Koyama – Senior Vice President of Sales and Marketing
- Mr. William A. Pledger – Senior Vice President and Chief Engineer

Brief Company Description:

IdaTech's is a developer and systems integrator for PEM fuel cell products in the 100 W – 50 kW power range for military and civilian markets. The company's core competency is in multi-fuel fuel processing, fuel cell stack, and systems integration. The company is developing a variety of products including stand-alone fuel processors and integrated PEM fuel cell systems operating on a multitude of liquid fuels including propane, diesel, and methanol, as well as bio-diesel and ethanol. Additionally, the company produces its own PEM stacks based upon licensed PEM stack technology. Control of PEM stack technology is consistent with the company's strategy to increase vertical integration in its operations. IdaTech is primarily marketing its systems for UPS, auxiliary power, and residential applications. Established in 1996, the company has approximately 80 employees.

Alliances/Partners:

IdaTech has created a Development Partner Program to facilitate partnering for product development. The program is an important part of IdaTech's strategy to let the market determine and fund product and technology development needs. The company's partners are working with IdaTech on technology and system development, fuel reforming enhancements, market, and application development. Key partners include Central Electric Cooperative, Electricite de France, Energy Northwest, EPUD, Fergus Electric Cooperative, Grant County Public Utility District, Idaho Power, Lewis County Public Utility District, Lincoln Electric Cooperative, Methanex, PNGC Power, and Sandia National Laboratories. Apart from the development partner program, the company also has the following partners:

- U.S. Army – In July 2005, the U.S. Army awarded a contract to IdaTech to continue development of 250 W integrated portable fuel cell system. The system, which will contain an on-board fuel processor, will replace non-

rechargeable batteries. The initial development contract was signed in August 2004.

- Rittal – Under this joint agreement signed in March 2005, IdaTech will integrate its fuel cell technology with Rittal's telecommunication and IT systems for back-up power solutions for telecommunications and other critical applications.
- CellCare Technologies – In April 2005, IdaTech signed a sales and marketing agreement with CellCare to promote IdaTech's fuel cell systems for its telecom and standby power customers in UK.
- Volkswagen – In September 2004, IdaTech agreed to design and manufacture an integrated fuel processor system operating on diesel fuel to be used in an auxiliary power unit.
- RWE Fuel Cells and Buderus Heiztechnik – In February 2004, IdaTech and RWE Fuel Cells (Germany) entered into a partnership to jointly develop the technology and markets for multi-dwelling and light commercial applications up to 50 kW. As a part of this agreement, the companies announced the installation of two 5 kW fuel cell systems with CHP operating on natural gas in Berlin, Germany. In July 2004, Buderus Heiztechnik (a company in the Bosch group in Germany) joined the collaboration. Under the agreement, IdaTech will build the fuel cell systems, and RWE Fuel Cells and Buderus Heiztechnik will integrate the fuel cells with heating systems to create a complete CHP system. RWE Fuel Cells and Buderus will also test these systems in the laboratory and in the field as a part of the demonstration program.
- RENCO – In June 2004, IdaTech and RENCO S.p.A., a Italian energy engineering company entered into an agreement for the market development and distribution of IdaTech's fuel cell systems and hydrogen generation products. Under the agreement, RENCO will distribute the IdaTech's fuel cell products into multiple Italian markets including backup power, hydrogen infrastructure development, and CHP.
- Department of Energy – In October 2003, U.S. Department of Energy awarded $9.6 million to IdaTech for the development of a 50 kW PEM fuel cell system to provide grid-independent energy systems for large facilities. The three year cost-shared cooperative agreement will result in the development of a fully integrated PEM fuel cell system combining IdaTech's patented multi-fuel fuel processing technology and Hydrogenics fuel cell power module. Three of these systems are planned to be field tested, one each with Sempra Utilities, Puget Sound Energy and Marriott International. In November 2004, DOE awarded the company a $1.4 million contract to conduct a three-year program for off-road fuel cell vehicle development.

Products:

IdaTech offers a broad range of products in various stages of commercial development.

- Fuel Processors
    - FPM™ Family (20, 40 and 60) – fuel processor modules operating on a broad range of fuels including propane, diesel and methanol; the methanol unit available commercially.
- Backup Power
    - ElectraGen™ 5 System – 5 kW fuel cell system for VRLA battery replacement; available pre-commercially.
    - ElectraGen™ 3 System – 3 kW fuel cell system for VRLA battery replacement; available pre-commercially.
- Remote Power
    - Integrates a 1.2 kW IdaTech FCS 1200™ fuel cell system with a 1 kW solar array and a 48 V battery bank.
- Portable Power
    - iGen™ 250 W system – a suitcase sized 250 W size fuel cell system for portable applications. The system runs on methanol using IdaTech's reformer technology and stack.
- On-site Power
    - EtaGen™ 5 – pre-commercial 5kW residential CHP system incorporating IdaTech's stack technology. The system operates on propane or natural gas.
    - FCS 1200™ – a portable pre-commercial fuel cell system that incorporates the FPM 20™ fuel processing module, Ballard's Nexa™ power module, a fuel tank, complete balance of plant, and an optional pure sine wave inverter. System fueled by dilute methanol mixture.
    - IdaTech 50 kW system – This development stage system will use the IdaTech reformer technology integrated with Hydrogenic's fuel cell power module. The company expects to field test three systems at Marriot International, Sempra Utilities, and Puget Sound Energy.

Technology Overview:

IdaTech's fuel processor module is comprised of an integrated steam reformer and hydrogen purifier. The commercial unit (FPM™ 20, 40, or 60) reforms

methanol/water fuel into greater than 99.9% pure hydrogen and less that 1 ppm CO. This unit is designed on a scalable platform and is capable of powering fuel cell systems ranging from 1 to 6 kW. After vaporization of liquid fuel, the unit is essentially a steam reformer with integral palladium purifier. After an initial start-up period, waste gases are burned to reduce emissions and provide energy for vaporization of the liquid fuel. The company is refining their reformer technology for other fuels like kerosene and diesel.

IdaTech's FCS™ 1200 portable fuel cell system combines the company's fuel processor with a Ballard Nexa stack. Other fuel cell systems incorporate the company's proprietary stack technology. The company has intentions to phase out their FCS™ 1200 system and transit it to a 2-3 kW portable fuel cell system.

Status of Commercialization:

Portable:

IdaTech's methanol reformer technology and FCS1200™ system are both available commercially. The company has been testing other fuels including propane, JP-8, kerosene, and diesel, which it expects to offer as an enhancement to the FCS1200™ product line shortly. In a paper presented at the 2005 Fuel Cell Seminar, the company reported the development of a 250 W portable power system for military and commercial markets. The system incorporates IdaTech's proprietary stack and reformer technology.

IdaTech is continuing development work on their fuel cell products in field tests in North America, Europe, and Japan. These programs are currently being carried out with their partner/alliance companies.

Stationary:

At the 2004 Fuel Cell Seminar, IdaTech unveiled a 5 kW UPS system. This hydrogen fueled, 24 V DC power supply is intended to provide backup power to the telecom industry and others relying on traditional battery backup. IdaTech indicated the base system is for sale for $15,000 with commercial terms and warranty. No further details are available at this time. The company also released a 3 kW UPS product in December 2005.

IdaTech also offers a 4.6 kW fuel cell system for residential CHP. The company is developing this product in collaboration with RWE Fuel Cells and BBT Thermotechnik of Germany. In a 2005 Fuel Cell Seminar paper, the company reported that their system has achieved greater than 5,000 hours. The company claimed that in last 2-3 years, the electrical efficiency of the system has increased from 22 to 30%, and expects to reach 35% during series production.

Independent Power Technologies

Location: Moscow, Russian Federation

Website: http://www.independentpower.biz

Technology: AFC & DMFC

- Formed in 2002, IPT is comprised of the core team of scientists and engineers of the former RPE "KVANT" fuel cell division. The company has developed a 6 kW alkaline fuel cell system (named as Cascade-6) for auxiliary and back up power applications. The first demonstration of this generator was done in September 2003 in Belgium. One of the unique features of the generator is a patented zero-waste regenerative scrubber used for the removal of carbon dioxide from the incoming air. As a result, the company believes the commercial potential of AFC technology is not limited by carbon dioxide contamination in the incoming air. The company is also working on Direct Liquid Fuel Cells (DLFC) – which combines the robustness and reliability of AFC technology with the use of liquid fuels like methanol and ethanol. The company is also working with E-Vision of Arendonk, Belgium to enhance AFC electrode design and manufacturing techniques resulting in enhanced characteristics and lifetime performance.

Industrial Research

Location: Christchurch, New Zealand

Website: http://www.irl.cri.nz

Technology: AFC

- Industrial Research is involved in wide variety of projects covering the physical sciences and biotechnology. The company is working on a number of hydrogen distributed energy generation products including fuel cells, electrolyzers, CO_2 sequestration, and solar. Industrial Research is developing a range of fuel cell generators incorporating alkaline fuel cell stacks in the 5-100 kW range. In 2002, the company installed and demonstrated its first 400 W AFC system. Currently, the company is involved in development of fuel cell systems up to 100 kW. The company built several small alkaline fuel cell systems (up to 5 kW) and is now focused on demonstration projects and commercialization for stationary and early niche markets.

Infinity Fuel Cell and Hydrogen

Location: Suffield, Connecticut

Website: http://www.infinityfuel.com

Technology: Misc.

- Infinity Fuel Cell is developing a regenerative fuel cell that stores solar or wind energy as hydrogen. The company is developing products in the 1 – 5 kW power range. In a poster presented at the Connecticut Fuel Cell Summit in October 2005, the company reported working on an XStorra™ Smart Modular Regenerative Fuel Cell Product Demonstration Project to provide off-grid power at lower cost. The regenerative fuel cell included a 1.3 kW solar power module (for water electrolysis to generate hydrogen) and a 3 kW fuel cell module. The company claims that they will have products ready for demonstration and testing in early 2006, with a goal to provide commercial products by 2007.

Intelligent Energy

Headquarters:

42 Brook Street
Mayfair, London W1K 5DB
England
Phone: 44 (0)20 7958 9033
Website: http://www.intelligent-energy.com

Ownership Structure:

Intelligent Energy is privately owned.

Management:

- Mr. David Blewden – Chairman
- Dr. Harry Bradbury – Chief Executive Officer
- Mrs. Judith Bradbury – Vice President, Marketing and Communications
- Dr. Jon Moore – Director, Intellectual Property Center

Brief Company Description:

Launched in August 2001, Intelligent Energy focuses on developing integrated energy solutions including hydrogen generation, storage, and PEM-fuel cell power generation, primarily for populations of the developing world including Africa, Latin America, and Asia. The company develops and manufactures PEM fuel cells, and desires to market products ranging in size from 10 W to 50 kW. The company is working on both ambient and high-pressure stacks, potentially suited for a wide variety of applications such as those in stationary, portable, automotive, and military markets. The company also claims to be developing a range of complementary and synergistic technologies, including a fuel cell component analyzer, reformer technology, fuel cell systems, and systems design and modeling. In April 2004, the company announced the acquisition of MesoFuel of Albuquerque, New Mexico, a developer of micro reformer technologies. The company states that this acquisition will supplement Intelligent Energy fuel cell system development activities and make them a "complete energy solution business." In 2005, the company announced that it had raised an additional 11.3 million pounds in working capital. The company had approximately 80 employees in Europe and the U.S., with over half working on fuel cells.

Alliances/Partners:

In the last several years, Intelligent Energy has acquired additional technology through acquisitions. In August 2001, the company acquired Advanced Power Sources Ltd (APS), a UK research and development company based at Loughborough University, and all of that company's intellectual property in PEM fuel cell and related technologies. In May 2003, Intelligent Energy also acquired Element One Enterprises LLC, adding fuel processing, hydrogen generation, and hydrogen refueling capabilities. The company then acquired MesoFuel Inc. of Albuquerque, New Mexico in April 2004. Additionally, the company claims ten OEM partners performing early product evaluation including:

- Boeing – to develop a fuel cell-powered aircraft.
- Two U.S. government programs (Defense Foreign Comparative Test Program).
- Japan Steel Works – to develop a fuel cell powered portable DVD-player.
- BOC – the industrial gas company ran trials on a 100 W system.

The company is involved in regional consortia in South Africa and Latin America focused on delivering integrated energy services to local populations, including remote power supply, back-up applications and grid embedded systems.

Products:

The company does not have commercially available products at this time. Products in development include:

- Pressurized PEM fuel cell stacks/systems (1 to 50 kW). The company presented a 50 kW stack at the Hanover Fair in April 2004. 1.3 kW system produces 56 VDC (regulated) and has a system efficiency of 49%.
- Ambient pressure PEM fuel cell stacks/systems – 10 W to 1 kW.
- Fuel Cell powered Motor bike (ENV) – includes 1 kW fuel cell generator; top speed – 50 miles per hour.
- Combined Heat and Power cogeneration system – 12-24 VDC, 80 A, 2 kW electric power; and 2 kW thermal output.

Technology Overview:

Intelligent Energy claims their proprietary PEM fuel cell design and use of specialized materials provide a competitive advantage against other companies. In particular, they site their high volumetric power density, which results from their high cell stacking densities and compact designs, as an example. The company uses thin metallic bipolar plates which they believe will prove to be robust and durable. Additionally, the company sites its expertise in systems integration and growing vertical integration as key to its growth strategy.

At the 2004 Fuel Cell Seminar, Vehicle Project LLC reported that an international consortium is developing a 1.2 MW fuel cell powered railway locomotive for commercial and military railway applications. Intelligent Energy will provide a hydrogen plant for the project using catalytically cracked ammonia, a fuel that offers high energy density and non-flammability.

Status of Commercialization:

Intelligent Energy's fuel cells are undergoing trials at more than a dozen sites, including schools and small hospitals in South Africa. In March 2005, the company launched the world's first fuel cell motorbike, ENV. The bike which uses the Intelligent Energy's CORE fuel cell, hydrogen storage, and battery technology is capable of reaching up to 50 miles per hour. The generator in the bike is a 1 kW fuel cell hybridized with battery to provide up to 6 kW of peaking power. The company expects to start selling these bikes commercially in late 2006 at $6,000 at mass production of around 10,000 units. This invention hit the world news and the company received several awards/recognitions on the product. In 2003, Intelligent Energy delivered a 2 kW fuel cell generator to the U.S. Army. It has also installed 100 W power supplies and 2 kW CHP systems in the UK and South Africa.

ITM Power

Location: Huddersfield, U.K.

Website: http://www.itm-power.com

Technology: PEM

- ITM Power is working on novel materials for polymer electrolyte membranes, and low cost manufacturing of fuel cells and electrolyzers. In 2003, the company reported on the in-situ manufacturing of MEAs in the fuel cell stack. ITM Power claims that their prototype C-MEA have been demonstrated at lab scales. The company believes that their low cost manufacturing technology uses fewer and cheaper components and can be applied to the fabrication of a complete stack. In a November 2005 press release, the company reported that they are currently focused on technology validation through demonstration of prototypes.

ITN Energy Systems

Location: Littleton, Colorado

Website: http://www.itnes.com

Technology: SOFC

- ITN Energy Systems is developing a planar solid oxide fuel cell (SOFC) for portable, residential, and commercial electric power markets. The company is teamed with several strategic partners including the Idaho National Environmental and Engineering Laboratory (INEEL), the Colorado School of Mines (CSM), and the University of Colorado. The company's SOFC technology includes a thin film electrolyte operating at a reduced temperature in the 500-800 ˚C) range. The company reports the use of a direct conversion anode, which allows fuel flexibility without the need of an external reformer. The company reports achieving a power density of 1-2 W/cm^2 at 800 ˚C due to the use of a gas manifold with monolithic fabrication, and advanced sealing; and advanced thermal management system. The company has developed a 20 W portable SOFC system that operates on clean kerosene fuel. This work was performed in collaboration with Mesoscopic Devices under the DARPA Palm Power Program.

Jadoo Power Systems

Headquarters:
181 Blue Ravine Rd.
Folsom, CA 95630
Phone: 916.608.9044
Website: http:www.jadoopower.com

Ownership Structure:

Jadoo Power is a privately held company. Major investors include Sinclair Ventures Inc., Mohr, Davidow Ventures, and Venroc.

Management:

- Larry Bawden – Chief Executive Officer/President
- Jack Peterson – Vice President of Marketing
- Michael C. Downs – Senior Vice President of Sales
- Dan Sanders – Vice President of Manufacturing & Operations
- Andrew P. Wallace – Director of Product Development
- Muralidharan (Lee) Arikara – Vice President of Business Development

Brief Company Description:

Jadoo Power Systems is a developer and seller of portable fuel cell systems targeted towards law enforcement, military, and electronic news. In April 2005, the company announced it had raised $11 M in new Series B funding from MDV-Mohr Davidow Ventures, Venrock Associates, and strategic partner Sinclair Broadcast Group. As a result, the company plans to expand its R&D activities and accelerate product development activities. Last year, the company launched several commercial products designed to power professional video cameras used in the broadcasting industry. The company sells its products through an online ordering system. The company has around 35 employees.

Alliances/Partners:

- MesoFuel – In March 2003, MesoFuel and Jadoo Power signed a collaborative agreement for the development and integration of an on-board hydrogen generator in Jadoo's portable fuel cell product. In April 2004, MesoFuel was acquired by Intelligent Energy.

Products:

Jadoo Power products are available commercially and can be brought online at http://store.jadoopower.com/

- NABII – PEM fuel cell system for professional video camera applications. The system provides 12 – 14.4 V DC power. The unit size is 4.2 in. × 4.5 in. × 7.2 in and weighs 4.7 pounds. The fuel cell system comes with two hydrogen cartridge options: N-Stor™ 8 (275 Whr capacity, 4.1 pounds) and N-Stor™ 4 (130 Whr capacity, 2 pounds). The $NABI^{II}$ package is priced at $3,495 and contains one NAB^{II} fuel cell power unit, two N-Stor™ 4 energy cartridge and one Fillpoint refill stations. The package includes the equipment needed to outfit one professional video camera with a Jadoo NAB^{II} power system.
- JBox – available in 2 platforms: JBox-S (100 Ahr on-board energy) and JBox-L (320 Ahr on-board energy). JBox system consists of SuRe45W fuel cell that is designed to manage peak power demands of up to 60 W for 2 minutes. The JBox-S is available for $6,250 and JBox-L for $9,450.

Technology Overview:

Jadoo Power utilizes its proprietary polymer electrolyte membrane fuel cell technology along with metal hydride energy storage for their fuel cell systems. The company claims that NAB^{II} provides thee times the runtime of a standard brick battery, and that the hydrogen storage canister is hot swappable and can be refilled in less than an hour. Furthermore, the company states that their product doesn't self discharge and provides consistent power throughout its life.

The company's N-Stor™ energy cartridge is an advanced metal hydride compound that stores hydrogen gas at low pressure. In 2004, the company announced that it has received the first exemption from the U.S. Department of Transportation to transport its hydrogen cartridges via air cargo. The company is also working on developing a new refill station and energy storage system. The company claims that their new system will allow users to charge the system to 75% full (100 Whr of run time) in around 20 minutes.

Commercialization:

Jadoo Power's product portfolio targets the $3 B professional video camera market. The company is also seeking other niche market applications like surveillance, and estimates a total of $12 B market for their products. The company is also working with the military to provide custom power products for their applications. Jadoo Power offers commercial fuel cell products through their online purchasing system.

Jülich Research Center

Location: Jülich, Germany

Website: http://www.fz-juelich.de

Technology: SOFC, DMFC

- Jülich is working on advanced SOFCs with planar cells and thin electrolytes for distributed generation, decentralized CHP, and APUs. The organization states that they have operated a 40 cell stack at a record value of 9.2 kW using hydrogen. They are also testing a 13.3 kW system with hydrogen and an 11.9 kW system with methane. In addition, Jülich scientists have developed a fundamentally new architecture for DMFC with the goal of producing a 500 W system to replace batteries in video cameras, laptops, and mobile phones. The group is also involved in developing DMFC systems for mid-power applications (wheel chairs, scooters, golf carts, etc). In a paper presented during the 2005 Fuel Cell Seminar, the company reported on the development and demonstration of a 1 kW DMFC system in a scooter application. The company reports utilizing mass manufacturing methods, including the use of expanded graphite sheets as a bipolar plate material.

Kawasaki Heavy Industries

Location: Tokyo, Japan

Website: http://www.khi.co.jp/index_e.html

Technology: PEM/MCFC

- The company is developing small cogeneration systems powered by fuel cells for on-site power generation. Additionally, in conjunction with FuelCell Energy and Marubeni, the company is a packager of Direct FuelCell® power plants in Japan. Kawasaki is installing a DFC®300A power plant at its Akashi Works near Osaka, Japan, where it will undergo evaluation and testing to create a Kawasaki-branded carbonate fuel cell power plant, which the company anticipates introducing to the Japanese market in 2006. In January 2005, the company reported developing a technology for transporting liquid hydrogen in a special container over a long distance (~ 375 miles).

Kyocera

Location: Kyoto, Japan

Website: http://www.kyocera.com

Technology: PEM/SOFC

- Using their expertise in ceramic powders and materials processing, Kyocera Corporation is developing a 1 kW solid oxide fuel cell for distributed power applications. In late 2003, the company announced achieving 54% electrical efficiency with their technology operating at 780°C. The company claims that their cogeneration system could save over $700 per year in heating and lighting costs for a four-person Japanese family and also reduce CO2 emissions by 40%. The company had plans to commercialize 1 to 10 kW products by 2005, although the company has not launched any commercial products to date. Anticipated cost for a 1 kW system was thought be around $11,100. The company also manufactures bipolar plates for PEM fuel cells.

Lilliputian Systems

Location: Cambridge, Massachusetts

Website: None

Technology: SOFC (micro)

- Lilliputian Systems is developing next generation “fuel cell on a chip” micro SOFC system for portable electronics and wireless applications. The company’s SOFC generator uses a microchip about the size of a dime to convert butane to hydrogen fuel and carbon monoxide. The venture capital backed company hasn’t disclosed many details on the technology. The company claims their silicon-based SOFC chip is the only portable power solution that can deliver a true form factor replacement for Li-ion batteries and 10 times the run-time, thereby solving the energy problem faced by today’s power-hungry wireless devices. The company employs a proprietary MEMS-based technology developed by the founders at MIT and Lawrence Livermore National Lab (under DARPA sponsorship). While no timeline has been made public for prototype demonstration, the company is working toward SOFC generators that will last for only 2-3 years and that can be quickly recharged by butane cartridges. In November 2005, the company reported raising $30 million in venture funding for further development of their SOFC technology.

Lynntech

Location: College Station, Texas

Website: http://www.lynntech.com

Technology: PEM/ DMFC

- Lynntech is a technology development company that builds on a core expertise in electrochemistry. The company is engaged in research and development of hydrogen and methanol fueled PEM fuel cell products. The company has produced high power density stacks for mobile and stationary power generation in the 500 W to 5 kW range. The company is working with Aerovironment under the DARPA program for the development of a fuel cell powered micro air vehicle. The company has no commercial or near-commercial products.

Manhattan Scientifics

Location: Los Alamos, New Mexico

Website: http://www.mhtx.com

Technology: DMFC/PEM

- Manhattan Scientifics is developing a micro direct methanol fuel cell technology for portable power applications including pagers, cellular phones, and similar electronic devices. The company is currently developing direct methanol fuel cell units for replacement of cellular phone battery packs. The company states that their product, once developed, will provide one week of talk time instead of the current 5 hours on Li-ion batteries. The company is also working on a portable product suitable for laptops, cordless appliances, wheelchairs, bicycles, boats, and home energy fuel cell systems. The company in 2004 announced the delivery of a 700 W NovArs prototype fuel cell system to the U.S. Army.

Masterflex

Location: Herten, Germany

Website: http://www.masterflex.de/com/index.html

Technology: PEM

- Masterflex is a R&D company that has been developing customized PEM fuel cells systems in the 100 to 250 W range for portable applications for over four years. The company has carried out extensive R&D on small PEMFCs in co-operation with German Fraunhofer Institut for several years. The company wants to integrate its 50 W prototype into "mobile office units" It is also working with AIRBUS Deutschland to develop a fuel cell system for possible aerospace applications, and with Veloform and Swizzbee in the development of a fuel cell powered bike. Earlier in 2005, the company announced a partnership with Hawk Bikes of Germany. Under this partnership agreement, the duo will develop cargo bikes for transportation of smaller loads.

Materials and Electrochemical Research Corporation

Location: Tucson, Arizona

Website: http://www.mercorp.com

Technology: PEM

- Materials and Electrochemical Research Corporation is a materials R&D company working in a wide variety of advanced composites, coatings, and energy conversion technologies. The company utilizes SBIR programs to develop and commercialize technologies in their areas of interest. In the past, the company had developed fuel cell stacks and systems in 5 W to 13 kW range based on PEM fuel cell technology, and the company highlighted its pilot scale facilities to produce MEAs up to an area of 625 cm^2. In a paper presented at the 2005 Fuel Cell Seminar, the company reported demonstration of their 13 kW PEM UPS system. The system which was grid-connected consisted of two 6.6 kW stacks, and produces a 3-phase 220 V AC electrical output. The reported efficiency of the stack was 40% at full power and 5 psi hydrogen pressure. The company has also developed a closed-cycle electrolyzer that produces hydrogen and oxygen using the grid power when the fuel cell is in idle mode. The company expects to commercialize its fuel cell UPS system in near-future, although no definite timeline has been released.

Materials & Systems Research

Location: Salt Lake City, Utah

Website: http://www.msrihome.com

Technology: SOFC

- MSRI is developing reduced temperature; electrode supported planar SOFC for distributed generation. The company has developed proprietary materials and processes for reduced temperature operation of SOFC. MSRI is working on or anticipates working on 10 - 200 W portable systems and 1 - 5 kW modules. The company claims its technology has produced power densities as high as 1.9 W/cm^2 for single cells and 0.5 W/cm^2 for stacks at 800 °C. The company states that they have demonstrated the internal reformation capability of their cells with liquid fuels (methanol and ethanol). In a presentation made at the 19th Annual ACERC & ICES Conference in 2005, the company showed their results on prototype 40-cell, 1 kW stack with 90 cm^2 active area running on hydrogen. The company is currently working on developing a 5 kW prototype that the capability to internally reform natural gas. No timeline for commercialization is provided for the products. The company is a partner with FuelCell Energy, Gas Technology Institute, the University of Utah, and Electric Power Research Institute in Versa Power systems. The company has got over 25 grants/awards totaling to over $6.5 million from several organizations including Department of Defense (Air Force, DARPA), Department of Energy, NASA, NSF, NIST-ATP etc. Established in 1990, the company now has around 16 employees.

Matsushita Electric Industrial Co.

Location: Osaka, Japan

Website: http://www.panasonic.com

Technology: PEM

- Matsushita Electric Industrial, who owns several well-known brands like Panasonic and JVC, is developing a home-use fuel cell cogeneration system. The company demonstrated the first cogeneration unit in January 2000. The company also tested 1 kW prototype system at its Osaka research facility, and reported operation at 35% electrical efficiency. The company states that the system will meet 40–50% of the power consumption of an ordinary Japanese household and provide hot water.

The company aims to commercialize small stationary fuel cells in Japan through work with the New Energy and Industrial Technology Development Organization (NEDO). Over the last 4-5 years, the company has made significant progress in terms of system efficiency, and compactness. The company plans to begin selling their units commercially in near future for around 1 million yen ($US8500). In November 2005, the company installed their fuel cell unit in a model house in Tokyo as a part of campaign to reduce green house gases.

Max Power

Location: Cannes-Mandelieu, France

Website: http://www.max-power.com

Technology: DMFC

- Max Power has developed a direct methanol fuel cell system to provide power to on-board electrical equipments on boats, sailing yachts, etc. Using the DMFC technology, the company has developed a 12 VDC marine fuel cell product (AHD-100) that is capable of charging batteries (up to 100 amps per day) to power refrigerators, microwaves, and other auxiliary equipments. According to the company, 7 kg product is capable of continuous duty. The company's fuel cell product is available commercially and costs around EUR5000 per unit.

Medis Technologies

Location: Yehud, Israel

Website: http://www.medistechnologies.com

Technology: Misc.

Established in 1992, Medis Technologies is developing power packs for the military and for a variety of portable electronic devices such as cell phones, digital cameras, PDAs, MP3 players, hand-held video games, and other devices with similar power requirements. Central to the fuel cell products is a patented highly-advanced liquid fuel, the basic component of which are borohydride alkaline solutions combined with alcohols. The company claims the device achieves better performance than methanol

fuel cells through a very simple design consisting of an anode, a cathode, a chamber for the liquid electrolyte, and a fuel chamber. The company opened new pilot manufacturing facilities in Israel in 2004. The company demonstrated their product prototype in 2005. According to a fuelcelltoday.com story in February 2005, the company announced the demonstration of its fuel cell Power Pack at the Marriot Hotel in New York City. The company also announced cooperation agreement with General Dynamics and a UK mobile operator for test/demonstration of its products during 2005. The company believes it will start selling units on a limited scale in second half of 2006, followed by a more comprehensive product launch in 2007.

MES DEA

Location: Stabio, Switzerland

Website: http://www.mes-dea.ch

Technology: PEM

- MES-DEA was formed in 1999 by the merger of MES and Zebra technology. The company, which now employs over 100 people, manufactures a wide range of components for electric vehicles, including battery chargers, circulation pumps, fluid heaters, and other components. Some time ago, the company developed and tested a 3 kW PEM prototype stack for automobile applications, but more recently claims to have developed a very compact, simple and economical fuel cell system incorporating microprocessor controlled balance-of-plant with the fuel cell stack.

Mesoscopic Devices

Headquarters:

510 Compton Street, Suite 106
Broomfield, Colorado
Phone: 303-466-6968
Website: http://www.mesoscopic.com

Ownership Structure:

Mesoscopic Devices is privately held.

Management:

- Dr. Jerry L. Martin – President
- Ms. Christine Martin – Vice President
- Mr. William Matvichuk – Director of Business Development

Brief Company Description:

Mesoscopic Fuel Cells develops fuel cells systems and components for portable power applications. The company is working on DMFC and SOFC technologies, and developing systems in 20 W to 2 kW power range for military, remote communication systems and consumer electronics application. The company is transitioning currently from product demonstration and prototyping phase to commercialization phase. The company has around 15 employees.

Alliances/Partners:

Mesoscopic Fuel Cells have received funding from several federal agencies including DOD, DOE, and NASA for the development of their technology. The company is also partnering with Materials and Systems Research and University of Utah to develop a SOFC system operating on low-vapor pressure liquid fuel.

Products:

The company is developing both DMFC and SOFC products. Products in development include:

- MesoPower-20 – 12 VDC, 20 W DMFC unit for portable power electronics, energy density 700 Wh/kg for a 72 hour, 20 W load. The system is a battery-fuel cell hybrid, battery provides the start-up and peaking loads.
- MesoGen-75 – 75 W SOFC unit for battery charging application. The system is a battery-fuel cell hybrid, battery provides the start-up and peaking loads.
- MesoGen-250 – 250 W SOFC unit for battery charging and APU application. The system is a battery-fuel cell hybrid, battery provides the start-up and peaking loads.

Technology Overview:

Mesoscopic Device fuel cell technology incorporates the proprietary precision fabrication techniques of both active (pumps, compressors, etc.) and passive

(heat and mass transfer devices) devices. The company believes that their unique system integration expertise enables them to develop compact systems for military and other applications.

The company's DMFC systems utilize 100% methanol allowing for greater run time. The SOFC systems operate on propane or kerosene and are extremely compact (around size of lunch box). The company reported demonstration of their 75 kW portable SOFC generator at the 2005 Fuel Cell Seminar. The generator consisted for a 90 W stack consisting of 17 planar cells (with 16 cm^2 active area), CPOX reformer, batteries (for peaking power) and BOP components. The company's CPOX reformer is extremely compact, and starts within seconds without external water. The generator has an energy density of 2000 W-hr/kg (based on 6 kg fuel for 10 day mission). The company states that future generation of this product will include alternative stack design and tighter integration to achieve shorter startup time and high power density.

The company has also developed a proprietary Rapid Cycle Desulfurizer™ technology to remove sulfur from liquid fuels such as JP-5, JP-8, kerosene and diesel. The technology utilizes multi-beds for maximizing the sorbent efficiency and minimizing the sorbent mass.

Status of Commercialization:

The company has developed demonstration products under federal grants from DOD, DOE, and NASA. While initially being developed for military applications, the company is also looking to market their systems for industrial application such as auxiliary power for recreational vehicles, and remote/emergency communications.

Microcell

Headquarters:

6003 Chapel Hill Road, Suite 153
Raleigh, North Carolina 27636
Phone: 919-858-8500
Website: http://www.microcellcorp.com

Ownership Structure:

Microcell is privately held. Key investors include Advanced Energy Corporation, Pepco Holdings Inc., and Progress Energy.

Management:

- Mr. Raymond R. Eshraghi – President and Chief Executive Officer
- Mr. Andrew W. Williams – Chief Financial Officer
- Ms. Elizabeth Rehbock – Director of Operations

Brief Company Description:

Microcell Corporation is a developer of tubular polymer electrolyte membrane fuel cell technology for portable, distributed generation, and automotive market segments. In May 2005, the company received the Crystal Flame Innovation award for entrepreneurship. The company intellectual portfolio consists of 11 US patents and 10 US patent applications. Established in 2000, the company has around 20 employees.

Alliances/Partners:

The company's partners include Advanced Energy, Pepco Holdings, Progress Energy, and ECO Technology Solutions. In 2001, NIST - Advanced Technology Program awarded $2 M to Microcell to develop their new fuel cell technology based on a novel microfiber membrane structure. This program was completed in late 2004, but the company continued to progress and refine its technology. In December 2005, the Microcell announced that Progress Energy has invested $1 million for development of its tubular PEM technology for industrial, commercial and consumer markets.

Products:

The company doesn't offer any commercial products. Products under development include:

- Distributed Generation – 1-25 kW units utilizing CHP option.
- Automotive – 25-250 kW units.
- Portable Electronics – up to 100 W, air-breathing stacks.

Technology Overview:

Microcell is developing its tubular PEM fuel cell based on its patented extrusion-based microfiber design. The technology allows all cell components (electrocatalyst of cathode and anode, membrane, and current collectors) to be extruded as one fiber, ranging in size from few hundred to several thousand microns. The company claims that this technology provides them major advantages in areas of size, cost, and power density. Utilizing extrusion-based scalable process allows for cost-reduction at a large scale production, and also allows versatility in size and shape of the tubes. Furthermore, the cell's fibrous geometry provides for the highest achievable MEA surface area to volume ratio,

resulting in very compact fuel cells. Microcell fuel cells' operate on hydrogen or methanol fuel and are scalable in milliwatt to kilowatt power range.

Status of Commercialization:

The company is currently developing 1-25 kW prototypes aimed at the distributed generation market. These units incorporate the capability of capturing the thermal energy for hot water and space heating. The company states that they are currently testing 1 kW beta units. The company has work ongoing to design larger units for automotive applications and smaller units for portable products using liquid methanol.

Mitsubishi Heavy Industries

Location: Tokyo, Japan

Website: http://www.mhi.co.jp/indexe.html

Technology: PEM/SOFC

- Mitsubishi Heavy Industries is developing both PEM and tubular SOFC power generation technologies. In June 2003, the company reported the development of an compact 1 kW PEM fuel cell, measuring only 100 × 60 × 30 cm. The company indicates that it is optimizing this system to reduce costs and prepare for market introduction. The company aims to commercialize small stationary fuel cells in Japan through work with the New Energy Foundation and the Japan Gas Association. The company is also working on the development of an on-board reforming system using di-methyl ether (DME) for vehicular applications. In collaboration with several gas and energy companies in Japan (JGC, Renaissance Energy Research, Osaka Gas, Mitsubishi Gas Chemical, and Japan Oil, Gas and Metals National) the company reported on development of two reformer types – autothermal and external-heating reformer. In a poster presentation at the 2005 Fuel Cell Seminar, the company claimed that DME reforming systems are competitive with compressed hydrogen systems and metal hydride tank systems. The company continues to refine the technology in terms on size and system response.

  In conjunction with Chubu Electric Power Company, Mitsubishi has worked for over 15 years on its MOLB (Mono-block Layer Built) SOFC unit. The company installed a 10 kW SOFC unit in 2003 and claims to have operated the unit for over 3000 hours without any performance degradation. Furthermore, in a paper presented at the 2005 Fuel Cell Seminar, the company reported on the development of several next-

generation 10 kW systems. Two of these systems were demonstrated during the 2005 EXPO Aichi in Japan. The company is implementing the technology into a larger, 200 kW SOFC CHP system. The company reported that this system will have an overall efficiency of 80% and will be available for demonstration in 2007.

Mitsubishi Materials Corp.

Location: Tokyo, Japan

Website: http://www.mmc.co.jp

Technology: SOFC

- In conjunction with Kansai Electric Power Co., Mitsubishi Materials Corp. is developing an intermediate temperature solid oxide fuel cell under the Japanese NEDO program for stationary combined heat and power applications. The company's goal is to develop and commercialize a 10 kW SOFC module. The work, which started in 2001, has resulted in the demonstration of four generations of a 1 kW prototype system. The company's IT-SOFC technology is based on doped lanthanum gallate electrolyte which allows operation at around 750 ^{o}C. In a paper presented at the 2005 Fuel Cell Seminar, the company reported that their 4th generation 1 kW unit has a DC electrical efficiency of 54% (HHV). The company stated that they are working to demonstrate a 10 kW system by spring of 2007.

Motorola

Location: Tempe, Arizona

Website: http://www.motorola.com

Technology: PEMFC/DMFC

- Motorola is working on Direct Methanol and Reformed Methanol fuel cells for application in portable electronic devices. In the past 6 years of activity, the company indicates that it made significant advancements in terms of materials, system components, and integration. Motorola uses a hybrid configuration strategy, such that the battery supplies the peak power while the fuel cell provides base-load power and battery charging.

In 2004, the company reported working on the development of a multi-layer ceramic technology, miniature catalytic fuel processor, and miniature balance of plant components. The company demonstrated a PDA powered by a 2" × 2" fuel cell. During the 2005 Fuel Cell Seminar, the company described its work on Single Wall Carbon Nanotubes based catalysts and electrodes in collaboration with Carbon Nanotechnologies and Johnson Matthey Fuel Cells. In other work reported at the Seminar, the company is developing a 20 W reformed methanol PEM fuel cell system. The system will include a onboard miniature methanol steam reformer (200-230 ^{o}C) integrated with a high temperature PEM fuel cell stack (150-200 ^{o}C, utilizing a PBI based membrane from Celtec).

MTI Micro Fuel Cells

Headquarters:

431 New Karner Road
Albany, New York 12205
Website: http://www.mtimicrofuelcells.com

Ownership Structure:

MTI Micro Fuel Cells is a wholly owned subsidiary of Mechanical Technology Inc. (NASDAQ: MKTY).

Management:

- Dr. William P. Acker – Chief Executive Officer
- Juan Becerra – Vice President of Market and Business Development
- Dr. Shimshon Gottesfeld – Vice President and Chief Technology Officer
- Mr. Russel Marvin – Vice President of Engineering

Brief Company Description:

MTI Micro Fuel Cells is a developer of micro direct methanol fuel cell technology for portable power devices and serves military and consumer markets. The company believes that products based on their Mobion® technology will be competitive in the $8 B portable power consumer market. The company's intellectual property portfolio includes over 70 patents and patent applications. Established in 2001, the company has around 60 employees.

Alliances/Partners:

- U.S. Army – In May 2005, MTI received a sub-contract from U.S. Army for the development of a hybrid system that can substantially increase the army mission duration and at the same time reduce the weight carried by the soldiers.
- The Methanol Institute – MTI is on a team with The Methanol Institute for a three year Department of Energy program. The program focused on development of mass manufacturing techniques for MTI micro DMFC.
- Gillette – Under this joint agreement signed in September 2003, both the companies will jointly develop and commercialize micro fuel cell products for high volume, mass market, portable consumer devices.
- Intermec Technologies Corporation – Under this strategic commercial partnership signed in 2002, the duo will develop MTI Mobion® technology for integration into Intermec's mobile computing equipment. In December 2004, MTI delivered its first micro fuel cell product to Intermec.
- Harris RF Communications Division – Under this agreement signed in 2002, MTI will develop micro fuel cell system prototypes for Harris Falcon® II tactical radios.
- DuPont – Under this agreement signed in 2001, the duo will work on optimize DuPont membrane for use in MTI's direct methanol fuel cells.

Products:

- Mobion® cord-free rechargeable power packs – The Company is packaging its Mobion® technology for different consumer market products including military batteries, portable radio frequency identification reader, PDA/smart phones, among others. The company is demonstrating prototypes with these products. Mobion® fuel cell power system is UL and CSA certified.

Technology Overview:

MTI's Micro Fuel Cell is based on the proprietary direct methanol fuel cell technology called Mobion®, which generated electric power using 100% methanol as fuel, offers a run time of 2-10 times compared to existing battery technologies. The company states that their proprietary technology eliminates the need of a water re-circulation loop or pump by internally transferring water from the cathode to the anode. Also, the company states that their Mobion® technology eliminated micro-plumbing which helps them to make compact products for portable power devices. Furthermore, the technology employs existing, proven and highly available materials – which improves the cost effectiveness of the Mobion® technology.

Status of Commercialization:

MTI Micro Fuel Cell launched its Mobion® product in December 2004. From that time, the company has demonstrated its product in consumer and military products. In September 2005, the company announced the deliver of 5 prototypes for sensor applications to U.S. Special Operations Command. Earlier in March, the company announced that its Mobion® based test and evaluation kits are available for government labs and military device manufacturers. In November 2004, the company integrated its Mobion® power pack technology into Intermec Technologies portable radio frequency identification reader for use in industrial markets. The company states that it is on schedule for delivering products to the government and military markets in 2006. The company expects to roll out products for the consumer market in 2007.

MTU CFC Solutions

Location: Ottobrunn, Germany

Website: http://www.mtu-friedrichshafen.com

Technology: MCFC, PEM

- MTU CFC Solutions is a joint venture of MTU Friedrichshafen and RWE Fuel Cells. The company is working with molten carbonate fuel cells for stationary applications through its partnership with Fuel Cell Energy (FCE) of Danbury, Connecticut and through additional internal design and development efforts. MTU's products integrate the HotModule system design of MTU CFC with the Direct FuelCell technology of FCE. The company has reportedly installed over 35 fuel cell plants (around 8 MW) in collaboration with FCE. The company is also involved in the development of fuel cell power plants in 1-3 MW size range with tri-generation (electricity, heating and chilling) capabilities.

NanoDynamics

Headquarters:

901 Fuhrmann Boulevard
Buffalo, New York 14203
Website: http://www.nanodynamics.com

Ownership Structure:

NanoDynamics is privately owned.

Management:

- Mr. Keith Blakely – Chief Executive Officer
- Mr. Richard Berger – President and Chief Operating Officer
- Mr. Glenn Spacht – Chief Technology Officer
- Dr. Alan Rae – Vice President Market and Business Development
- Mr. Anthony DeSimone – Vice President and Chief Accounting Officer
- Mr. F. Mark Modzelewski – Vice President of Strategic Opportunities

Brief Company Description:

NanoDynamics is a producer of advanced nanomaterials (metal, carbon, and ceramics) and components for the defense, energy, electronics, and engineering industries. The NDEnergy business unit of the company is involved in the development of portable solid oxide fuel cell systems (50 W to 2 kW range) utilizing their proprietary nano technology. The company believes that their SOFC products provide long lasting power in less volume and at a lighter weight than either batteries or other fuel cell approaches. In October 2005, the company announced the opening of a new office in Pittsburgh, PA Established in 2002, the company has around 70 employees.

Alliances/Partners:

- MetaMateria Partners – a joint venture between NanoDynamics, The Ohio State University, the Edison Welding Institute, SOFCo-EFS, the Business Technology Center, and MetaMateria. In October 2003, a $968 K Ohio Third Frontier Action Fund award was given to MetaMateria to advance SOFC components and produce affordable products.

Products:

The company showcased its first product, the ND Revolution™ 50 SOFC, during the 2004 Fuel Cell Seminar. The product is now available commercially.

- ND Revolution™ 50 SOFC – this portable SOFC operates on propane and produces 50 W DC power. The system weighs 9.5 pounds and is 9” (w) × 6” (d) × 12” (h). The efficiency of the system is reportedly in 50-60% range.

Technology Overview:

NanoDynamics products are based on the company's proprietary nano materials and processes that it has developed. The company believes that developing materials and devices at nano and atomic scale allows for precise control of properties. The company utilizes its nano-technology to develop nano materials for electrodes, catalyst, and electrolyte in their SOFC product. The company claims that doing so enables them to achieve high power densities at reduced temperatures (600 ^{o}C). Furthermore, the company states that their product can start in 15 minutes and support a 7 day runtime between refueling.

Status of Commercialization:

The company is selling their 50 W portable SOFC system which was introduced in late 2004. The products can power lighted advertising and vending machines. The current price of the unit is $12,000 (50 W system), although the company expects the prices to fall once their pilot plant comes up in a year. The company believes their scalable nano-technology has the potential to reduce cost to as low as $1000 per unit. The company is also working to increase the fuel flexibility of their systems, and hopes to offer systems that can operate using kerosene, diesel, and JP-8. The company is working on a larger system in the 250 W to 1 kW range.

Neah Power

Headquarters:

22122 20th Ave SE, Suite 161
Bothell, Washington 98021
Phone: 425-424-3324
Website: http://www.neahpower.com

Ownership Structure:

Neah Power is a privately-held company. Key investors include: Frazier Technology Ventures, Alta Partners, Intel Capital, Castile Ventures and WestAM.

Management:

- Mr. David Dorhein – President and Chief Executive Officer
- Dr. Arthur Homa – Vice President of Engineering
- Mr. Leroy Ohlsen – Co-Founder and Chief Technical Officer

- Mr. Steven Tallman – Chief Financial Officer
- Mr. Gregg Makuch – Vice President of Marketing and Administration

Brief Company Description:

Neah Power is a developer of micro fuel cells for portable electronic devices, including notebook PCs and other computer, entertainment, and communication products. The company uses their patented, silicon-based design, which it hopes will provide long-lasting, efficient, and safe power solutions for portable power devices. Founded in 1999, the company has around 40 employees.

Alliances/Partners:

- Department of Defense – $3.5 M in federal funding was included for Neah Power in the house-passed fiscal year 2006 DOD appropriations bill for continuing development of cutting edge fuel cell technology based on novel silicon-based architecture.
- Montecito Group – Under the agreement signed in October 2003, Neah Power and Monetecito Group to jointly pursue research and product development opportunities within DOD and its key suppliers.

Products:

The company does not have commercially available products at this time. The company is developing prototype products for ultra-light notebook PC.

Technology Overview:

Neah Power fuel cell technology utilizes a Direct Methanol Fuel Cell with silicon-based design architecture. The silicon-based design eliminates the need for the polymer electrolyte membrane used in traditional PEM fuel cells. This silicon structure could enable high power in a small form-factor, due to a 3D reaction zone (and consequently much larger reaction surface area) resulting from deep holes in the silicon in which liquid electrolyte flows. The company believes that their technology will have an advantage as it takes utilizes decades of process and materials expertise from the integrated circuit industry. The company continues to refine their technology. In a April 2005 press release, the company claimed that their stacks have exhibited power densities as high as 80 mW/cm^2 at room temperature while reducing the size of the stack by around 70% compared to their first prototype, which was unveiled early 2003.

Status of Commercialization:

The company innovative technology has received several awards including World's Top Young Innovators by Technology Review Magazine, Prestigious Red Herring Top 100 Innovators Award, 2005 Venture All Stars™ Top 25 Emerging Growth Company, and 2004 Start Up Company of the Year. The

company has proven and refined its technology through several prototypes demonstrated over the last 2-3 years. The company focus is on developing micro fuel cell products in 0.5 to 100 W power range, and hopes to sell its products commercially by 2006.

NEC

Location: Tokyo, Japan

Website: http://www.nec.com

Technology: DMFC

- NEC first developed a working DMFC prototype in August 2001, in collaboration with Japan Science and Technology Corp. and the Institute of Research and Innovation. The company employs its carbon "nanohorn" technology – a type of carbon nanotube developed at NEC in 1998. The company believes that their "nanohorn" technology enhances the electrode performance and produces as high as 10 times the energy capacity of standard Li-ion batteries. The company has developed several prototypes over the last 3-4 years. The most recent version was unveiled during the World PC Expo in Tokyo in late 2005, has a power output of 70 mW/cm^2 and can power a notebook PC for 10 hours with a single 250 cm^3 methanol cartridge. This version also incorporates the company's proprietary flat mounting technology to develop compact fuel cell systems allowing easy integration of the laptop with the fuel cell unit. The company's plans to introduce commercial products by 2004 – 2005 have been delayed. The company now claims it intends to sell commercial products by 2007 when regulations will be set for carrying methanol cartridges on airlines.

Nippon Oil

Location: Tokyo, Japan

Website: http://www.eneos.co.jp/english/

Technology: PEM

- Nippon Oil is developing a kerosene fuel cell cogeneration system for residential applications. The company believes that kerosene offers ease of handling for delivery and storage compared to other fuel options sought

for fuel cells. In addition this approach seeks to leverage the infrastructure available for supply of kerosene. The company has developed and demonstrated two products – a 1 kW fuel cell cogeneration system, and a 10 kW fuel cell cogeneration system. The 1-kW system was jointly developed in collaboration with EBARA Ballard. The system utilizes Nippon's proprietary sulfur absorbent and reforming catalyst technology, and Ballard's stack technology. The company expects to sell these units at $4200 per kW. The 10-kW cogeneration system was developed in collaboration with Mitsubishi Heavy Industries. Both of these systems have an electrical efficiency of around 33% and cogeneration efficiency of over 76%. These systems operate in grid parallel/base load mode. The prototypes of these systems were demonstrated in 2004, and the company expects to begin selling these units commercially in 2006.

NTT DoCoMo

Location: Tokyo, Japan

Website: http://www.nttdocomo.com

Technology: DMFC

- NTT DoCoMo is a leading world-wide mobile communication company. In 2004, the company reported that it had developed a DMFC micro fuel cell system for their 3G FOMA mobile phone handsets. The development resulted from collaboration with Fujitsu Laboratories. The company believes that methanol fuel cells can meet the growing demand of energy requirements in portable devices.. In a July 2005 press release, the company reported the development of an advanced prototype system. The new prototype utilizes 90% concentrated methanol and has three times higher energy density compared to the previous version. Work on this prototype is expected to be completed by March 2006.

Nuvera Fuel Cells

Headquarters:

20 Acorn Park
Cambridge, Massachusetts 02140
Phone: 617-245-7500
Website: http://www.nuvera.com

Ownership Structure:

The company is privately held by two main shareholders: Amerada Hess Corporation (53%) and Gruppo De Nora (47%). The French car maker, Renault, acquired a 10% stake in Nuvera in May 2004.

Management:

- Mr. Roberto Cordaro – President and Chief Executive Officer
- Mr. William Mitchell – Vice President, Marketing
- Mr. James Cross – Vice President, Research and Development
- Dr. Srinivasa Prabhu – Vice President, Product Development

Brief Company Description:

Nuvera is developing PEM fuel cell technology for both stationary and mobile applications. Due to a core competency at the company and at the parent companies in chemical reactor design, electrochemistry, catalysis, and fuel processing, Nuvera also develops fuel processors for natural gas, gasoline, diesel, and military fuels.

Nuvera was created in April 2000 by a merger of Epyx Corporation (a wholly owned subsidiary of Arthur D. Little, Inc.) of Cambridge, Massachusetts and De Nora Fuel Cells (a wholly owned subsidiary of Gruppo De Nora) of Milan, Italy. In 1997, the company (still as the Epyx Corporation) developed the world's first gasoline powered fuel cell in cooperation with the U.S. DOE. The company has approximately 190 employees worldwide.

Alliances/Partners:

- Vehicle Projects – Nuvera manages an international consortium of companies interested in integrating a Forza module into a railway locomotive. In September 2005, Vehicle Projects signed a contract with an offshore railway research organization to develop a 150 kW fuel cell power plant prototype for advanced rail vehicle. The prototype will utilize the new Forza power module from Nuvera.
- East Penn Manufacturing – Under an agreement signed in January 2005, East Penn (a manufacturer of lead-acid battery) and Nuvera will jointly develop a hybrid battery/fuel cell electric engine. The engine is intended for industrial vehicles and also for airport ground support equipment.
- Uhdenora – Under this joint agreement signed in February 2005, Nuvera and Uhdenora agreed to engage in the development of modular fuel cell system for electrochemical power plant to reduce the power consumption by around 20%.

- Fiat Group – Nuvera is a test partner for fuel processing systems and fuel cell stacks for the Fiat Group. In April 2005, the company announced that their PEM stack successfully powered a FIAT Seicento Hydrogen prototype vehicle.
- Others – In 2004 and before, Nuvera has partnered with several companies for development/integration/testing of their products. These include: Bekaert Fibre Technologies (development partner developing metal fiber media in new components to improve the functionality of PEM fuel cells); Best Water Technology (development partner of a new polymeric membrane for industrial, high temperature fuel cell applications); FIAMM S.p.A. (development partner of a hybrid battery / fuel cell power pack for industrial materials-handling vehicles); Nissan (test partner for fuel processing systems and fuel cell stacks); TotalFinaElf (development partner for gasoline fuel processors and fuel cell stacks); Takagi Industrial Co. Ltd. (development partner for CHP systems); and RIVOIRA S.p.A. and the SIAD Group (Italian Gas companies), with Praxair Inc. (partners opening a test facility in Osio Sopra, Italy).

Products:

Automotive Products

- Andromeda™ – 85 kW PEM fuel cell with metallic bipolar plates, peak power of 100 kW, and low pressure operation with no external humidification.
- STAR™ – Substrate Transportation Autothermal Reformer (processes 200 kW_{th} of California grade gasoline and volume of approx. 75 liters). In recent testing, the device met all goals for on-board reformers established by U.S. Freedom Car, except for the approx. 10 minutes start up time, which was much greater than DOE norms of 30 seconds.
- PowerFlow™ – The PowerFlow PEM fuel cell system is a hydrogen fueled, DC power system intended for a wide range of applications including forklifts and on-board truck power. While the standard size for the unit is 5 kWe, the system can be sized from 2.5 to 5 kW to meet a wide range of customer needs. PowerFlow is a next generation of H2e™ fuel cell sold by the company and is available pre-commercially.
- PowerTap™ - The PowerTap product is an integrated system consisting of fuel processor, reformate compressor, pressure swing absorption unit, hydrogen compressor, and dispenser. It is being marketed to support early market fuel cell applications (like for material handling industry).
- Forza™ – Forza is a 120 kW PEM fuel cell system. Nuvera states that this system will commercially available in 2006.

Stationary Products:

- Avanti™ – This small-scale CHP system provides 4.6 kWe AC and 6.9 kW_{th} from natural gas fuel. The company claims that this product has a 30% AC electrical efficiency at full power and 25% at half power.

Technology Overview:

Due to their different performance requirements, the company uses two distinct fuel cell platforms for its automotive and stationary markets. While many similarities exist, the company is standardizing on a 340 cm^2 MEA size for automotive stacks and a 500 cm^2 MEA size for stationary stacks. Importantly, both products use metal bipolar plates, which are thin, inexpensive designs, and use the company's proprietary 'direct water injection' technology, which the company claims enhances stack simplicity and reliability while generating higher power density.

In addition to the MEA, Nuvera's stationary systems also differ due to the integrated fuel processing technology. According to Nuvera, its Avanti™ product offers electrical efficiency of 31.5% LHV, but overall efficiency can reach greater than 80% when operated in CHP mode. The system is 31" x 27.5" x 60" and weighs about 950 lbs. Avanti™ is currently in a number of demonstration programs including at the U.S. Coast Guard facility in Bristol, RI.

The large scale Forza™ units are low-pressure, steady state, baseload-designed units that use pure hydrogen fuel and are being developed for industrial ruggedized applications. At 2004 Fuel Cell Seminar, Vehicle Project LLC reported that an international industry-government consortium (including Vehicle Project, AeroVironment, Nuvera, HERA-Hydrogen Storage Systems, and Intelligent Energy) is developing the world's largest FCV – a 109 metric ton locomotive for commercial and military railway applications. Nuvera will provide eight Forza™ power modules or a total of 1.2 MW for the locomotive. The company is also collaborating with Uhdenora to develop an advance energy system for electrochemical industry. Under the agreement signed in February 2005, Nuvera will provide Forza™ stacks which will generate DC power from the excess hydrogen produces at chloro-alkali plants. The generated DC power is intended to be either used in the plant process (thereby increasing the process efficiency) or converted to AC and exported to grid.

Status of Commercialization:

The company offers pre-commercial products at this time for automotive, and stationary markets.

Vehicular:

The company has conducted several demonstrations with its H2e™ fuel cell system for materials handling industry, including one at Houston Advanced

Research Center. The company is currently marketing PowerFlow™ which is a next generation of H2e™ system. In December 2005, the company reported demonstration of their PowerFlow system in an ice resurfacer in North Dakota. The product is available commercially for selected customers. The company's "Total Power Solution" concept – which includes the PowerFlow module and PowerTap™ fuel processor (which reforms natural gas into hydrogen) is currently in development. The company believes to start selling these products commercially for fork lift applications by 2006.

The company is conducting multiple demonstrations of the Andromeda system in conjunction with its automotive partners. The Andromeda system is undergoing additional testing to determine durability and system integration issues, with efforts ongoing to reduce costs. Nuvera's Forza fuel cell system (250 kW PEM) has been selected by Vehicle Projects LLC, which has assembled an international consortium to integrate the unit into a railway locomotive.

With regard to reformer systems, Nuvera continues to work on the STAR™ fuel processors, in spite of the recent DOE "No-go" decision regarding on-board reforming. During the 2004 Fuel Cell Seminar, the company stated that they are working on catalyst development and optimal operating conditions for on-board reforming to yield better hydrogen reformate gas. The STAR™ fuel cell processor system is currently undergoing laboratory trials with automobile manufacturers (mainly Renault). The company states that it will have pre-commercial units ready for demonstration in fuel cell vehicles by 2010.

Stationary:

Nuvera is marketing the Avanti™ fuel cell system as a residential and small-scale industrial micro CHP solution, primarily for European and Asian markets. The company believes the value proposition is best when the system is base loaded on the thermal demand. The company indicates that commercial deployment in Europe could start in 2005-2006, with broader commercial deployment in the 2006-2007 timeframe. The first Avanti CHP system has been delivered to the Japanese Gas Association for testing in the Japanese market.

The company's new testing facility in Osio Sopra, Italy will be used to test H2e units (5.5 to 25 kW), Forza™ units (around 120 kW), and Andromeda™ fuel stack systems. In November 2004, the company delivered an H2e™ module to Toro for evaluation and potential use in off-road applications. The company is also working with Uhdenora to develop an advanced energy system using its Forza™ stack for the chloro-alkali industry to improve the efficiency of that process.

Osaka Gas

Location: Osaka, Japan

Website: http://www.osakagas.co.jp/indexe.htm

Technology: PEM

- Osaka Gas is involved in several hydrogen technology areas including reformers, hydrogen storage, PEM and SOFC fuel cells. In the 1970s, the company operated and evaluated over 55 PAFC systems with a view toward increasing gas sales. In 2003, the company started marketing its proprietary reformer technology to accelerate the commercialization of Japanese residential PEM fuel cell systems. The company has transferred their technology to Ebara Ballard, H Power, and Sanyo Electric. The company is working to increase the durability of the PEM fuel cell stack for use in residential applications. In a paper presented at the 2004 Fuel Cell Seminar, the company indicated that they have achieved 20,000 hour durability under saturated humidified conditions in their single cell tests. The company plans to launch a domestic PEM fuel cell cogeneration system in 2005-06. The company is also developing SOFC technology and has jointly worked with Murata Manufacturing for more than 10 years. In 2004, the company announced that is will provide operation assessments for Kyocera's SOFC cogeneration system in residences starting in 2005. These systems are intended to be commercialized in 2008.

Ovonic Fuel Cell

Headquarters:

2983 Waterview Drive
Rochester Hills, Michigan 48309
Phone: 248-293-0440
Website: http://www.ovonicfuelcell.com

Ownership Structure:

Public (NASDAQ: ENER). Ovonic Fuel Cell is a part of ECD Ovonics.

Management:

- Mr. Stanford Ovshinsky – President & Chief Scientist and Technologist
- Ms. Iris Ovshinsky – Vice President, Special Projects

- Mr. Robert Stempel – Chairman and Chief Executive Officer
- Mr. James Metzger – Executive Vice President and Chief Operating Officer
- Mr. Steve Zumsteg – Vice President and Chief Financial Officer
- Ms. Nancy M. Bacon – Sr. Vice President -- Government & Special Projects

Brief Company Description:

ECD Ovonics is involved in the development of new materials and production technologies. The company's fuel cell division, Ovonic Fuel Cell, is focused on the development and commercialization of Ovonic Metal Hydride Fuel Cell technology. The company believes that their proprietary technology has the potential to address some of the key issues with the traditional fuel cells like start-up time and sub-zero operation. Markets sought include: automotive, military, UPS, and the stationary segment. The company has 12 people working in the fuel cell group.

Alliances/Partners:

- Michigan Public Service Commission – In August 2005, the company was awarded $400,000 by the Michigan Public Service Commission to develop a prototype fuel cell system for UPS and energy power applications based on the company's regenerative fuel cell technology.
- Texaco Ovonic Hydrogen Systems – In 2000, a 50-50 joint venture between ECD Ovonics and Chevron Texaco was established to develop and sell hydrogen storage systems for fuel cell application based on ECD's metal hydride technology.

Products:

The company is in the prototype development phase and is developing cells and stacks in the size range from few watts to 100 watts. The initial prototype cell has an electrode surface area of 60 cm^2.

Technology Overview:

The heart of the company fuel cell technology is based on the company's proprietary metal hydride materials for the anode in the fuel cell. The Ovonic Regenerative fuel cell utilizes this along with oxygen storing material for the cathode. The company states that this approach can work for any kind of fuel cell with an ionic electrolyte, although most of the work at the company has focused on the use of alkaline electrolytes due to better kinetics at the cathode. Furthermore, the use of alkaline electrolyte solutions allows for the facile introduction of metal hydride materials developed for NiMH battery applications. The anode side is charged chemically with the gaseous hydrogen or through electrochemical oxidation of water. The company believes that by

placing hydrogen and oxygen intrinsically in the fuel cell, several key features like regenerative operation, instant start, and excellent low temperature performance can be realized. The company is working to better specific power and power density through improved electrode and current collector design. In a presentation made at the Fuel Cell 2005 Conference & Exhibit on Advancements in Fuel Cell Applications & Technology, the company stated that their current prototypes have power densities of 100 W/kg (vol. 100 W/liter), but claimed that their new engineering prototypes have power densities values which are double of these. The company IP portfolio include over 15 issued U.S. patents and over 25 published U.S. patent applications.

Status of Commercialization:

The company is demonstrating their regenerative fuel cell technology for UPS and automotive market applications. In a paper presented at Hydrogen and Fuel Cells 2004 Conference and Trade Show, the company stated that their low cost technology along with instant start and excellent low temperature start operation will be important attributes for these applications. The company has showcased their technology and working prototypes in 2004 during the conferences and trade exhibits, but to date have not developed any field demonstration units. The company doesn't provide any timeline for commercialization of their products.

Pacific Fuel Cell Corp.

Location: Tustin, California

Website: http://www.pfce.net

Technology: PEM

- Pacific Fuel Cell Corp (OTCBB:PFCE) is a development stage company working with the University of California at Riverside to develop a commercially viable fuel cell prototype using carbon nanotube-based electrodes. The company believes multi-walled carbon nanotubes as a platinum support for PEM fuel cells will reduce the manufacturing cost of fuel cells through a decreased use of platinum. The company is developing its technology for use in small electronic device applications. The company received funding of their work from Department of Energy in 2004 and through University of California's SMART program. The company has also received private funding from investment funds over the last 3 years. Earlier this year, the company acquired intellectual property rights for a new carbon nanotube MEA technology for hydrogen and methanol fuel cells. In a September 2005 press release, the company claimed to have made a prototype of its

proprietary nanostructured Membrane Electrode Assembly. Later in November 2005, the company showcased their nanoMEA technology at the Fuel Cell Seminar.

Palcan Power Systems

Headquarters:

8658 Commerce Court
Burnaby, B.C. V5A 4N6
Canada
Phone: 604-422-8868
Website: http://www.palcan.com

Ownership Structure: Public (TSX: PC)

Management:

- Dr. John Shen – Founder, Chairman and Chief Executive Officer
- Mr. Jeremy J. Tomlinson – Chief Operating Officer (COO)

Brief Company Description:

Palcan Power Systems is developing PEM fuel cell technology in the 100 W to 5 kW power range for low power output applications where batteries and smaller IC engines are typically employed. The company utilizes their proprietary rare earth metal hydride storage technology. Fuel cell products incorporate the company's proprietary MEA technology, which the company believes gives it a significant advantage against competitors using commercial MEAs. The company feels that its core competency is its direct control over its components and subsystems development. The company is also developing products for UPS market segments as well as several custom designed products. Founded in 1998, the company has around 20 employees.

Alliances/Partners:

- CET Technologies – Under an agreement signed in March 2004, CET Technologies will test and evaluate Palcan's Palpac™ fuel cell system and backup power generator for use by the Singapore Armed Forces.
- Mingliang Plastic – A joint venture agreement between Palcan and Mingliang Plastic was signed in December 2003 to establish a commercial manufacturing facility in Shanghai. Later in December 2004, with support from the Government of China, Palcan opened a wholly owned

manufacturing plant for making fuel cell stacks using company's proprietary technology.

- University of Victoria – Under this contract with the Institute of Integrated Energy Systems at University of Victoria, Palcan will provide two scooters – one conventional battery scooter and other fuel cell powered scooter for performance comparison.

Products:

The company provides a range of products including fuel cell stacks, UPS back-up power solutions, and customized product solutions. The company's stacks are available commercially, along with the MEAs and rare earth metal hydride canisters.

- Fuel Cell Stacks
  - PC3 air-cool stack – 500 W
  - PC5 air-cool stack with humidifier – 1 kW
  - PC6 water-cool stack – 2 kW
- PalPac® 500 UPS: Intended for telecommunications, data processing, networks, manufacturing, security, and safety applications.
  - Provides up to 5 hours of back up at 500 W
  - 110-120 V AC or 220 V AC
  - Dimensions: 53 cm (width) × 47 cm (depth) × 50 cm (height)
  - Operating temperature: 5 – 40 ^{o}C
  - Fuel: 1,800 liters of hydrogen stored in 6 canisters.
- Customized Products – These include scooters, electric bikes, wheel chairs, golf carts, marine propulsion units, portable auxiliary power units, portable battery re-chargers, and integrated photovoltaic fuel cell power modules.

Technology Overview:

Palcan Power Systems is focused on the increased power density, while reducing the costs through the development and incorporation of low-cost materials and processes. The company's MEA technology is based on proprietary low-cost materials and processes and provides improved power density requirements. The company's novel low-pressure stack technology eliminates the need of air compressors and water pumps. Furthermore, the Palcan system stores hydrogen safely and at low pressure in rare earth metal hydride canisters.

Status of Commercialization:

The company doesn't offer any complete commercial fuel cell systems at this time. However, MEA's, stacks, and metal hydride hydrogen storage canisters products based on company's proprietary technology are available commercially. The company has demonstrated several of their products including a 300 W fuel cell powered bicycle, a 1.5 kW fuel cell powered wheel-chair, a 2 kW fuel cell powered scooter, and a 2 kW stationary regenerative energy system. Furthermore, the company also plans to deliver a 5 kW stack to China Shipbuilding Industry for integration into a boat. In October 2004, the company reported selling one of its 500 W UPS fuel cell systems to one of the largest oil companies in China for their pipeline security monitoring system. The company is working with Yuang-Qiang Technology of China to develop hydrogen and air fuel subsystem components. In a November 2004 press release, the company stated that they are increasing operations in their China manufacturing plant to position themselves strongly in the growing Asian market.

Plug Power

Headquarters:

968 Albany-Shaker Road
Latham, New York 12110
Phone: 518-782-7700
Website: http://www.plugpower.com

Ownership Structure: Public (NASDAQ: PLUG)

Management:

- Dr. Roger B. Saillant – President and Chief Executive Officer
- Mr. Allen K. Bucknam – VP of Strategy and Business Development
- Mr. Paul J. Burton – Vice President of GenCore and Product Engineering
- Dr. John F. Elter – Chief Technology Officer
- Dr. William D. Ernst – Vice President and Chief Scientist
- Mr. Robert A. Sinuc – Vice President of Engineering
- Mr. Gregory A. Silvestri – Chief Operating Officer
- Mr. Mark A. Sperry – Chief Marketing Officer

Brief Company Description:

Plug Power designs, manufactures, and markets PEM fuel cells for stationary applications. The company is focused on fuel cell systems fueled by natural gas, liquid petroleum gas (LPG), and hydrogen gas for residential, small commercial, and back up power markets. In 2004, the company began marketing a new line of hydrogen generators called GenSite, which is based upon the company's autothermal reforming technology. The company has approximately 350 employees.

Alliances/Partners:

- PEMEAS GmbH (formerly Celanese Ventures) – PEMEAS is working with Plug Power on the development of a high temperature membrane electrode unit for stationary fuel cell system applications.
- DTE Energy Technologies – DTE Energy Technologies has exclusive distribution rights for Plug Power's PEM fuel cells in Michigan, Illinois, Indiana, and Ohio.
- Engelhard – Engelhard is working with Plug Power to develop and supply advanced catalysts that increase overall performance and efficiency of the fuel cell system.
- General Electric – GE Fuel Cell Systems (GEFCS) is a joint venture between GE Power Systems and Plug Power. GEFCS is the exclusive worldwide distributor and service provider for Plug Power PEM fuel cell products (except the four-state area served by DTE Energy).
- Honda R&D Co., Ltd. Of Japan – Honda has signed an agreement with Plug Power to jointly develop home refueling systems for Honda's fuel cell vehicles.
- Vaillant GmbH – Vaillant jointly developed a PEM fuel cell heating appliance for the European market. These appliances provide both heat and electricity for residential and small commercial applications.
- Tyco Electronics – Tyco Electronics and Plug Power have entered into an agreement on marketing, promoting, and selling Plug Power's GenCore systems for telecommunication backup applications (the agreement has been formally announced in September 2004).

Products:

- GenSys™ Prime Power Systems – Stationary on and off-grid power systems for small commercial applications, residential 'home refueling systems' as well as the telecom and industrial mass markets and Combined Heat and Power fuel cell systems (for the European market only).

- GenCore™ Backup Power Systems – Backup power products for telecommunications, cable broadband, and industrial uninterruptible power supply applications; 2 – 12 kW.
- GenSite™ – On-Site H2 Generation Systems, for industrial hydrogen gas applications.
- Home Energy Station™ – A home energy system in support of the fuel cell vehicle infrastructure (in cooperation with Honda). In November 2004, the companies announced successful operation of the unit.

Technology Overview:

Plug Power is focused exclusively on PEM fuel cell technology for the residential and small commercial distributed generation markets. The company has over 250 patents (issued and pending) in United States and abroad. The company is working on a number of fronts to improve their systems including a program to enhance reliability by eliminating unneeded parts. At the 2005 Fuel Cell Seminar, the company reported that its next generation of GenSys system contains fewer parts, more sophisticated embedded software and controls, and other improvements – including water independent, high efficiency low weight and volume, and low cost. The company reported that they have developed over 12 prototypes of next generation GenSys prototype. These prototypes have logged several thousand hours of run-time and are being tested for their reliability and certification tests. Field demonstrations are expected to start in late 2005 to early 2006 time frame.

The company is working with PEMEAS GmbH on the development of high temperature MEAs for PEM fuel cells to address issues related to durability and stability of cell components. The companies are experimenting with PBI-based MEAs for high temperature PEM fuel cell technology. The companies have tested and demonstrated numerous single cells, short stacks, and full sized stacks. During the 2005 Fuel Cell Seminar, the company also reported working on the development of a high temperature fuel processor for integration with its high temperature PEM fuel cell technology to achieve better system efficiency.

The company is addressing durability and stability of cell components by working with PEMEAS on high temperature and novel membrane materials and by developing neutron radiography techniques that allow for *in situ* diagnosis of the PEM to help reduce water management issues and improve design and operating parameters.

Status of Commercialization:

As of December 2005, the company has delivered more than 600 PEM fuel cell systems to several countries including United States, Germany, Japan, France, and United Kingdom. The Plug Power UPS product, GenCore, is available

commercially. The company's stationary residential power product, GenSys, is still evolving, although the company has demonstrated several of these at customers' locations worldwide.

In 2005, the company received 306 GenCore™ orders, compared to 94 in 2004. According to company's January 2006 press release, 116 units have been shipped and the others are scheduled to be shipped in 2006. Tyco Electronics by far remained the largest customer for the company with a total order of 98 units in 2004 and 2005. The company also received 12 orders of GenCore from the Florida Department of Environmental Protection. Plug Power states that the majority of the 2005 orders were from end users in telecommunications and utility market segments.

The company also field tested the next generation of their GenSys stationary residential power systems. The company installed 10 prototypes of their GenSys product at Robins Air Force Base, in Georgia, in September 2005 for a one-year field trial. In a 2005 update press release the company reported that these systems have generated over 52 MWh of electrical energy.

As a result of these sales and large demonstration programs with Long Island Power Authority (LIPA) and the DOD Construction Engineering Research Laboratory (CERL), Plug Power has been able to focus on systematic product enhancements to improve reliability, enhance performance, and decrease cost. Recent equipment testing performed at HARC shows that the company has been successful in all three accounts. The most recent Plug Power systems have significantly reduced cost, size, and weight, while also providing longer stack lifetime and greater operating stability.

With improvements to the GenCore product, the company claims to have reduced the direct material cost by around 29% from 2004 levels. In their 2005 update, the company claims that this reduction in cost have been possible due to several initiatives including design improvements, process simplifications, and supplier negotiations. Plug Power sells the GenCore™ system for $3,000 per kilowatt, a price which appears to provide economic value to the backup power market. By eliminating the reformer and inverter, and by making the system water neutral, the company has been able to reduce costs substantially. Plug Power has recently expanded the GenCore™ product portfolio to include a 24 V and a 48 V systems, and, recently, a 110 V floating ground system intended for utility substation markets.

With the GenSys product, the company has reduced costs by over $15,000 per kW in the last 2-3 year. The price of the system still falls in the $8,000-10,000 per kW range. The company claims to have made improvements in the stack durability with current stack durability values in 8,000 – 10,000 hours range. Although this remains far less than the often cited durability range of 40,000 hours, substantial markets are unlikely to develop without further cost reductions and performance enhancements in the technology. The company in

July 2005 announced that it is not taking any new orders for the GenSys systems. Rather, Plug Power said that they plan to develop a next-generation system that is smaller, lighter, less costly, more efficient, easier to assemble and service, and that has additional performance features.

The company is also working on Home Energy Station (HES) technology with Honda. In 2005, the company announced that they have secured a contract with Honda for Phase 3 of the HES. Later in the year, the company demonstrated the third generation of Home Energy Station in Torrance, CA. The system provides heat and electricity for the home and hydrogen for a hydrogen powered FCV. The company reported that the 3rd generation system is much more compact and efficient than their previous two systems located at Latham, NY and Torrance, CA.

PowerZyme

Headquarters:

7 Deerpark Drive, Suite G
Monmouth Junction, New Jersey 08852
Phone: 732-438-9300
Website: http://www.powerzyme.com

Ownership Structure:

PowerZyme is privately owned. Key investors include Battelle Ventures, Calvert Funds, Commons Capital, Micro-Generation Technology Fund, Rockport Capital Partners, SAM Private Equity, and Zon Capital Partners

Management:

- Mr. Michael Powell – Chief Executive Officer
- Dr. Ross Ritts – Chief Operating Officer
- Dr. Steve Sun – Chief Technologist
- Dr. William Chiang – Chief Scientist

Brief Company Description:

PowerZyme is developing biological fuel cells for portable power. The company believes that their proprietary "active proton transport" technology enables them to compete with portable power applications where Li-ion battery is currently used. The company believes their enzyme-driven fuel cell technology has the ability to yield an intense power source with load following capabilities. The company has 8 employees.

Alliances/Partners:

No alliance/partners information is available.

Products:

The company does not have any products available at this time.

Technology Overview:

PowerZyme's technology is based on nature's active proton transport mechanism that exists in all living systems. The heart of the company's innovation is the Active Transport Membrane™ which dynamically pumps protons across the membrane with a self-regulating control based on load. The traditional fuel cells utilizes a passive process (diffusion based) to move protons across of the membrane. The company believes that active transport of protons across the membranes will yield much greater energy density than the conventional designs. The company's IP portfolio is based on three areas:

- Active Transport Membrane: delivers high power density with cost-effective, bio-degradable components.
- Enzyme-catalyzed chemistries: eliminates the use of previous metal catalysts by realizing higher specific energies.
- Self-regulating microfluid systems: provide orientation independent operation in the biological cell.

PowerZyme is developing this technology for lightweight portable power units like laptops, cell phone, PDA, etc.

Status of Commercialization:

The company is developing a next generation power supply source for portable electronics such as laptop computers. The company has demonstrated several units and claims that its "enzymatic battery" offers run-times as much as ten times greater than the current Li-ion battery technology. The company claims that it is on track to demonstrate a 50 W fuel cell with a 300 mil profile for a laptop battery and that it has a prototype that can power a digital camera. The company is also working on a concept that they call the ZyCube™. The key concept is to shift the locus of power from the appliance to the person by offering a compact, lightweight portable power unit capable of powering the user's complete arsenal of electronic devices: laptop, cell phone, PDA, digital audio and video games.

Proton Motor

Location: Starnberg, Germany

Website: http://www.proton-motor.de/protonenglisch/index2.html

Technology: PEM

- Proton Motor is developing hydrogen-fueled PEM fuel cell systems in the 5 - 150 kW range primarily for vehicle applications. The company's first demonstration was done in 1999, when they equipped a car with a fuel cell engine. Over the last five years, the company has developed complete fuel cell solutions for other vehicles including buses, forklifts, etc. The company is working with Linde AG and Still GmbH to develop an advanced lift truck fuel cell power system that can be easily refueled in minutes compared to hours for recharging the battery. In February 2004, the company stated that their fuel cell system easily fits in the space occupied by conventional batteries and carries the same power density as the batteries. Field demonstration of the fuel cell power lift truck is being carried out at the Munich airport. The company is also developing hybrid propulsion systems in collaboration with its sister company, Magnet Motor. The company announced delivery of a 2 kW system to a customer in Italy for load profile testing. According to the company profile as published on Fuel Cell Today, the company is now engaged in field trials of their fuel cell equipped vehicles.

Protonex

Headquarters:

153 Northboro Road
Southborough, Massachusetts 01772
Phone: 508-490-9960
Website: http://www.protonex.com

Ownership Structure:

Protonex is privately owned. Key investors include Conduit Ventures, SAS Investors, Solstice Capital, Commons Capital, Parker Hannifin, Contango Capital Management, Massachusetts Green Energy Fund, Venture Capital Fund of New England, and Yellowstone Energy Ventures. In June 2005, the company announced that they have increased their second round of institutional funding from $9 million to $11 million.

Management:

- Mr. Scott A. Pearson – Chief Executive Officer
- Dr. Paul Osenar – Chief Technology Officer
- Mr. Greg Cipriano – Vice President of Marketing & Military Development
- Mr. Daniel R. Davis – Chief Financial Officer & Vice President of Business Development
- Dr. Mohammad Enayetullah – Vice President of Advanced Technology
- Mr. Phil Robinson – Vice President of Engineering and Manufacturing

Brief Company Description:

Protonex develops fuel cell systems for portable and remote power applications in 10 W to 1 kW power range. The company is focused on developing systems that have high energy storage, can be operated for extended duration, are compact and durable, have easy refueling capability, and are low in cost. The company products are ruggedized to withstand harsh environments with high thermal and mechanical shocks. Established in 2000, the company has around 15 employees.

Alliances/Partners:

- Northrop Grumman – Under an agreement signed in September 2005, Northrop Grumman and Protonex will develop portable power fuel cell systems for U.S. Air Force. The system is based on the Protonex 30 W fuel cell unit fueled by chemical hydride.
- U.S. Air Force Research Laboratory – In April 2004, the laboratory awarded $2.6 million to Protonex to develop an innovative extended power solution for soldiers. Millennium Cell is a sub-contractor on this project. In March 2005, the company announced that they have delivered to the U.S. Air Force fully-integrated 30 watt portable fuel cell power system (P1) fueled by chemical hydride cartridges.
- Parker Hannifin – Under an agreement signed in October 2004, Parker Hannifin and Protonex will undertake joint product development and manufacturing activities. Protonex will provide its stack technology while Parker Hannifin will provide their expertise in pumps, valves, seals, and manifolds to develop complete fuel cell system. The agreement also calls for joint collaborative sales and marketing of Protonex's NGen™ fuel cell products to military and commercial customers.
- U.S. Army – In July 2004, the U.S. Army awarded $1 million to Protonex to further development of their NGen™ PEM/DMFC stacks for man-portable military applications.

- Millennium Cell – Under this agreement signed in February 2004, Millennium Cell will provide its hydrogen generation and storage technology, Hydrogen on Demand™, and Protonex will provide its fuel cell technology to develop a clean, safe, compact, and durable fuel cell portable power system.

Products:

Protonex has developed and demonstrating several products in 10 – 500 watts range. These products are categorized under three platforms.

- Platform 1: 10 – 100 W Power Units
  - 30 W soldier power unit (two generations P1 and P2)
  - 50 W, 75 W for military and commercial applications
- Platform 2: 100 – 300 W Power Units
  - 150 W power generator for electric wheelchair
  - 150 W military battery charger
- Platform 3: 300 – 500 W Power Units
  - 500 W fuel cell power unit (battery charger/range extender) for Vectrix electric motorcycles

Technology Overview:

Protonex fuel cell integrated systems utilize Protonex fuel cell stack technology along with Millennium Cell hydrogen generation and storage technology. The fuel cell stack technology, called NGen™, is based upon the company's low-cost, simple, and mass-scalable filtration cassette assemble process for manufacturing stacks. The unique molded, adhesive seal approach provides much greater repeatability and robustness at much lower cost. In a paper presented at 2004 Fuel Cell Seminar, the company stated that their injection molding process enables a cost reduction of at least 80% compared to other standard processes. The company has build and tested over 500 fuel cell stacks in 10 – 500 W power range using this approach.

Millennium Cell's Hydrogen on Demand™ hydrogen generation and storage technology utilizes sodium borohydride-based cartridges that allow safe storage of hydrogen. The company utilizes a proprietary blend of sodium borohydride and a stabilizer. Protonex also utilizes compressed hydrogen or metal hydride fueling in cases where hydrogen infrastructure is present. For 100 – 500 W power range, the company utilizes reforming methods to generate hydrogen for their stacks.

Status of Commercialization:

Protonex provides long duration portable and remote power sources primarily for OEMs serving military customers. The company has developed integrated system prototypes under contact from U.S. Air Force and U.S. Army. Earlier this year, the company announced the delivery of a 30 W P1 integrated fuel cell system to the U.S. Army. The company expects to have more field trial units deployed later in 2005-06. The company is also developing next generation of this product, P2, which they claim to be only 33% of the weight of the existing battery solutions. Military field trial of this product is planned for 2006.

The company is also developing products for industrial, commercial and non-military government applications. The company has applied cost-cutting manufacturing routes to deliver durable, compact, and cost-effective products. In a 2004 Fuel Cell Seminar paper, the company claimed that their 50 W system has 300% less weight, 300% less volume, and 500% less cost than their competitors.

ReliOn

Headquarters:

15913 E. Euclid Ave.
Spokane, Washington 99216
Phone: 509-228-6500
Website: http://www.relion-inc.com

Ownership Structure:

ReliOn is privately owned. Key equity partners include Enterprise Partners Venture Capital, Chrysalix Energy LP, Wall Street Technology Partners, Buerk Dale Victor, LLC, and Avista Corporation. In November 2004, the company raised an additional $25 million from Oak Investment.

Management:

- Mr. Gary Flood – President & Chief Executive Officer
- Mr. Jim Baumker – Vice President – Operations & Chief Financial Officer
- Mr. Joe Blanchard - Vice President, Product Line Management
- Mr. William Fuglevand – Vice President, Research & Development
- Mr. Mark Grimes – Vice President, Engineering

- Mr. Bill Stafford – Vice President, Sales
- Mr. Frank Ignazzitto – Vice President, Government Sales

Brief Company Description:

ReliOn (formerly Avista Labs) develops and markets its patented modular, cartridge-based, PEM fuel cell technology. The company believes its modular cartridge technology lowers maintenance costs and enhances system reliability. Cartridge replacement can be carried out in minutes by untrained personnel without tools and without interruption of power. The company has applied the same notion of modularity to control and power electronics in their new generation of the product to improve the ease the maintenance and reliability of their systems. The company is currently marketing its 1 kW backup power system called the Independence™ 1000 to telecommunications, energy, transportation, and government customers.

Alliances/Partners:

- CEA Telecom – Under this agreement signed in September 2005, CEA Telecom was given exclusive distribution rights to sell ReliOn fuel cell products to their wireline and wireless telecommunication customers in Canada.
- havePower, LLC – The agreement between havePower, LLC and ReliOn provides exclusive marketing rights to havePower for specific government communications requirements in 18 states. The agreement calls for havePower to purchase a minimum of 40 kW in 2003, 260 kW in 2004 and 400 kW in 2005; the contract runs through 2006.
- SGS Future – distributor of ReliOn's fuel cell units in Italy.
- ARMS/TPSC - Automated Railroad Maintenance System (ARMS), through its selling agency, Transportation Product Sales Company (TPSC) is a distributor of ReliOn fuel cell products to the railroad industry for backup and remote power applications. The agreement runs through 2006.
- Celestica – Under an agreement signed in 2004, Celestica will provide manufacturing, assembly, and testing of ReliOn's fuel cell products.
- DOD/CERL – The Department of Defense through its fuel cell demonstration program awarded a $363,781 contract to ReliOn for testing of its Independence 1000™ 1 kW fuel cell systems in critical military applications. The project is scheduled for a period of one year starting from June 2004.
- Maxwell Technologies – Maxwell Technologies supplies PowerCache™ ultracapacitors to ReliOn to optimize performance and reduce the cost of its systems.

Products:

- Independence 1000™ PEM Fuel Cell Backup System (with outdoor enclosure). The company is currently selling their latest model, the J64, which is a refinement of their previous J48 model. The 1 kW, 48VDC system is priced at $6500.

Technology Overview:

ReliOn utilizes their patented modular, cartridge-based, PEM fuel cell technology with Maxwell Technologies PowerCache™ ultracapacitors in their Independence 1000™ fuel cell systems. The modular cartridge-based approach allows for cartridges to be swapped out of the system without shutting down, thereby enhancing power reliability. In the latest version of product, ReliOn has implemented modularity in the control and power electronics board, and in the fan pack. The company feels that providing redundancy in the system components will increase reliability, a critical parameter for UPS applications. Ultracapacitors or customer-supplied batteries can be used to deliver power for startup and peak load buffering. ReliOn uses a proprietary method of water management, thereby making the system water neutral. As a result, the system is exceedingly simple to install and operate. ReliOn claims their unit will run on standard industrial grade hydrogen (99.95%). The 1 kW unit is 44.5 cm × 69 cm × 51 cm and weighs 66 kg.

Status of Commercialization:

The Independence 1000™ system is now available with commercial terms and prices. The unit is UL and CE certified. ReliOn has more than 200 systems installed in several regions including the U.S., Europe, South America, and Japan. The company's customers include telecommunications providers, UPS providers, government communication sites, utilities, and railroad suppliers. In a September 2005 press release reprinted by Fuel Cell Today, the company reported it is working with Verizon to test and demonstrate their fuel cells at remote locations, under harsh environmental conditions in States of California, Idaho, and Washington. The company claims that their products have flawlessly operated during hurricanes and other severe weather conditions, providing reliable power for several hours during grid failure. In an article published in the Fuel Cell Catalyst Summer 2005 issue, the company reported that their products have availability of 99.4% and can operate in temperatures as low as -40 ^{o}C.

Rolls-Royce Fuel Cell Systems

Headquarters:

Rolls-Royce Fuel Cell Systems Limited
P.O. Box 31, Derby DE24 8BJ
England
Phone: 44 (0) 1 332 260343
Website: http://www.rolls-royce.com

Ownership Structure:

Rolls-Royce Fuel Cell Systems Ltd. is a joint venture between Rolls-Royce and EnerTek. The Rolls-Royce group, a public company headquartered in the U.K. holds a 75% share while EnerTek holds 25% share in the company.

Management:

- Sir John Rose – Chief Executive Officer of Rolls Royce plc.
- Mr. E. Thomas Curley – President, Energy Business
- Dr. Charles Coltman - Chairman and CEO of Rolls Royce Fuel Cell Systems

Brief Company Description:

Rolls-Royce is a global company providing a wide variety of power and engine products. The company has established leading positions in civil aerospace, defense, marine, and energy markets. Important parts of their energy product portfolio are gas turbine and gas engine packages. Rolls-Royce has experience in the system integration of several different types of fuel cells. It believes that solid oxide fuel cell technology is well suited for stationary power generation applications, and that products can be developed for various transportation, military, and marine applications. Rolls-Royce Fuel Cell Systems was formed in 2003 as a wholly owned subsidiary of Rolls-Royce group to commercialize the SOFC technology under development at Rolls-Royce since 1992. At this time, Rolls-Royce plc, the parent company of Rolls-Royce Fuel Cell Systems Ltd., injected around $100 million in cash and technology into the effort. With joint investment from EnerTek and Rolls-Royce, EnerTek now holds a 25% stake in the company. The company has 50 employees.

Alliances/Partners:

Rolls-Royce has many partners helping with different aspects of their fuel cell program. Some of these were cited in the 2003 Industry Assessment Report. More recent partnerships include:

- BTU International – In June 2005, BTU was chosen by Rolls-Royce to build the world's first automated pilot production line in England.
- EnerTek Singapore – Under this agreement signed in April 2005, Rolls-Royce and EnerTek will invest $100 million to develop a commercial viable SOFC power system. With this investment, EnerTek will hold 25% stake in Rolls-Royce Fuel Cell Systems and will bring technical expertise in ceramics and manufacturing automation.
- University of Genoa – In August 2004, Rolls-Royce Fuel Cell Systems (RRFCS) opened a new University Technology Center (UTC) in collaboration with University of Genoa in Italy to conduct research into fuel cell systems. The Center is working on the technical programs for RRFCS.
- The company is a member of the 'London Hydrogen Partnership' and also a member of the 'High Level Group' established by the European Commission for the development of a comprehensive hydrogen strategy.

Products:

- SOFC/GT Hybrid System (1 – 10 MW) – The company has designed a 1 MW hybrid power plant combining 800 kW of solid oxide fuel cells with 200 kW of gas turbines, which the company anticipates commercializing in 2007. Dimensions of the system are about 40'L × 7'8"W × 8'6"H.
- IP-SOFC (1kW) – In cooperation with University of Genova, the Risoe Center, and Gaz de France, the company claims to have developed a novel 1 kW stack, which it terms an Integrated Planar Solid Oxide Fuel Cell (IP-SOFC). The work was partially funded through the EC 5th framework programme. Rolls-Royce continues to develop a 10 kW product based upon the technology.

Technology Overview:

The 1 MW hybrid power plant is designed to be modular and is comprised of several 250 kW fuel cell and microturbine units. The company claims that their compressed hybrid system is significantly more efficient than any conventional gas turbine or reciprocating engine, and produces fewer emissions. The company's Integrated Planar SOFC is advertised to be simple, durable, and easily maintainable. It is also stated that the system can be configured to use either natural gas or liquid fuels and even coal-gas or biomass fuels.

Status of Commercialization:

Rolls-Royce is focused on developing a solid oxide fuel cell (SOFC) gas turbine hybrid system fueled by natural gas for megawatt-sized stationary power generation applications. The hybrid power plant will be built up to the desired 1 MW system in a step-wise fashion. The company expected to develop a 60 kW

Integrated Tier Demonstration unit in 2005, but to date no information has been publicly released. A 250 kW generator module is planned for 2006. In April 2005 press release, the company stated that their 1 MW SOFC hybrid system will be commercially available before end of 2008. The partnership with Singapore based EnerTek is seen as strategically important decision for the company that will enable the company to easily commercialize their SOFC technology in that region. The company projects costs of about $4,000 per kilowatt in 2006 and declining rapidly to roughly $2,000 per kilowatt around 2007. Rolls-Royce plans to achieve $1,000 per kilowatt costs during 2009. However, the company plans to begin selling demonstration units of the hybrid system in 2005-06 with full commercialization not expected until 2008 or later.

Samsung Advanced Institute of Technology

Location: Giheung, Korea

Website: http://www.sait.samsung.co.kr/eng/main.jsp

Technology: PEM/DMFC

- In collaboration with Sanyo, Samsung is developing residential PEM systems in 1-10 kW power range for household and back-up power applications. The Institute is also advancing fuel cells for portable electronic devices. Through its collaboration with Millennium Cell, the company is developing a hydrogen-on-demand system for portable electronics. The company is also working on the development of DMFC systems and addressing some key challenges like methanol cross-over. In May 2004, the company reported that it had developed a small prototype 20 W DMFC that can power a notebook computer for 10 hours. The company has plans for commercialization of this device in 2005, but this seems to be delayed now. In a 2005 paper published in Korean Journal of Chemical Engineering, the company showed their results on a two-layer cathode structure for reducing the methanol permeation in their DMFCs.

Sanyo Electric

Location: Japan

Website: http://www.sanyo.com/home.cfm

Technology: PEM/DMFC/SOFC

- Sanyo Electric has been working on the development of residential systems for some 7-8 years. Its initial plans to commercialize a 1 kW PEMFC systems were delayed, although the company has demonstrated prototypes. The company is working with Osaka Gas, who provides the reforming technology. The company aims to develop compact 1-10 kW units for household and back-up power applications. In a paper presented during the 2004 Fuel Cell Seminar, the company stated that it was working on new stack design with improved gas flow distribution systems. The company is also collaborating with Hoku-Scientific to jointly develop the MEA for fuel cells. Additionally, Sanyo is working with Samsung to jointly develop PEM technology – although few details are available. Sanyo and Osaka Gas have also jointly focused on the development of 1 kW SOFC residential systems and plan to move to commercialization of the technology in the 2006-2007 timeframe. During the 2004 Fuel Cell Seminar, Sanyo reported working on porous metal supported SOFC to improve the durability of their stack. In November 2004, the company launched a new division in Hungary for production and distribution of fuel cell products. In August 2005, the company, in collaboration with IBM, reported the development of a DMFC hybrid system for laptop computers. No timeline for commercialization has been released by the companies.

Siemens Westinghouse Power Corporation

Headquarters:

1310 Beulah Road
Pittsburgh, Pennsylvania 15235-5098
Phone: 412-256-2022
Website: http://www.pg.siemens.com/en/fuelcells

Ownership Structure:

Public (NYSE: SI); The Stationary Fuel Cell group is a division of Siemens Westinghouse Power Corporation (SWPC), which is a subsidiary of Siemens Power Generation (SPG). SPG, based in Orlando, Florida, is a business unit of the parent company, Siemens AG, which is based in Munich, Germany.

Management:

- Mr. Klaus Voges – Group President, Siemens Power Generation
- Mr. Thomas Flower – President, Stationary Fuel Cells Division
- Mr. Adam Kupec – Business Administration, Stationary Fuel Cells Division

Brief Company Description:

Siemens Westinghouse Power Corporation is a pioneer in the development of tubular solid oxide fuel cell (SOFC) technology for commercial scale distributed generation markets. Created in 1998 by Siemen's acquisition of Westinghouse Power Generation, the fuel cell division of Siemens Westinghouse has its headquarters in Pittsburgh, PA. The company has approximately 150 employees.

Alliances/Partners:

- Fuel Cell Technologies – Development partner to advance the technology in residential and small commercial distributed generation markets and for balance of plant components. In November 2004, both companies signed a MOU for global supply, sales, and distribution of SOFC systems.
- Solid State Energy Conversion Alliance – Siemens Westinghouse is an original member of the SECA program. Team members include Fuel Cell Technologies and Blasch Precision Ceramics. The goal is to develop a SOFC system prototype with net power output of 5-10 kWe for stationary and transportation applications and costing less than $400/kWe.
- Shell Hydrogen – Working together on carbon dioxide capture technology and fuel cell systems.

Products:

Siemens Westinghouse does not offer any commercial products at this time. Products under development include:

- SFC-200: SOFC cogeneration system (configurable in multiple units for 500 kW rating) providing 125 kW electric power and up to 100 kW thermal heat. The system is intended to be fueled with natural gas. Electrical efficiency is expected in 45-47% range at full load while the overall CHP efficiency is expected to be greater than 80%. Commercial products are planned for 2007.
- 250 kW SOFC cogeneration system fueled by natural gas.
- 250 kW pressurized SOFC/gas turbine hybrid system fueled by natural gas.
- CO_2 separating system in conjunction with fuel cell products.

Technology Overview:

The tubular SOFC design was pioneered by Westinghouse Electric Corporation in late 1970s. The current generation of Siemens SOFC is built as layers on the cathode with an axial interconnection that makes the cathode accessible and allows cells to be connected together in series. The current tubular cell in closed at one end with 2.2 cm diameter, 150 cm length, and operated at 1000 ^{o}C to

generate electricity efficiently. At atmospheric pressure, 85% fuel utilization, and 25% air utilization, a single cell generates up to 210 W of DC power. These cells are bundled together (electrically connected) using a nickel felt to generate commercially level of electricity.

Under the SECA program, Siemens is working to develop a low-cost SOFC system through enhancements in cell power. The company is focused on lowering the cathode polarization losses and the ohmic polarization losses in the cell to improve the cell efficiency and decrease the cost. During the 2004 Fuel Cell Seminar, the company reported testing a new composite interlayer (50% doped lanthanum manganite + 50% YSZ) in their cells, which they claim exhibits 40% improved efficiency compared to cerium oxide interlayer (which they previously used) at 0.65 V (900 ^{o}C, 85% fuel utilization). Further, in the 2005 SECA presentation, the company reported the development of new cathode material which helps in increasing the cathode conductivity by 50%. The company is actively seeking new designs for their cells to lower the ohmic resistance in the cell. The reported high power density (HPD) cell design has several advantages over the conventional tubular design, *viz.* (1) maintain seal-less design; (2) reduction in resistance and cost; (3) increase in cell power; and (4) more compact design. The company is testing several variants of HPD cell configurations, including one with 10 channels for the air flow (HPD10 design). During the 2004 Fuel Cell Seminar, the company stated that their HPD5 (with 5 channels) exhibited 30% improved efficiency compared to the tubular cell at 0.65 V (1000 ^{o}C, 85% fuel utilization). At the SECA conference in 2005, the company revealed that they have tested HPD5 and HPD10 cells for over 3000 hours at 1000 ^{o}C and no performance degradation was observed. The company stated that their HPD10 cell design yields a 75% power enhancement over the tubular design at 0.65 volts. During the conference, the company also disclosed a new generation design termed as HPD Delta 9. The company claims that this new design has 40% more surface area and a power density of 600 mW/cc (compared to 200 mW/cc for HPD5 cells).

The company is also integrating its SOFC into a gas turbine hybrid system. The hybrid system uses air pressurized by the turbine compressor and heated in a recuperator before entering the cell stack. The exhaust from the cell stack is a hot pressurized gas flow that drives the turbine generator. The hybrid cycle is believed to result in electrical efficiency of 70% at a total capacity of 2-3 MW.

Status of Commercialization:

Siemens is still in the development, testing, and demonstration stage for its SOFC products. The company has demonstrated several SOFC prototype systems in the last several years. These include the demonstration of a 100 kW cogeneration system for over 20,000 hours in Netherlands and Germany (the system was refurbished and installed at Gas Turbine Technology SpA, Turin, Italy), a 250 kW cogeneration system that is being tested in Toronto, and a 220

kW SOFC/GT system tested in California. Early in 2004, the company announced that a new $122 million fuel cell plant in Munhall, Pennsylvania will be delayed by several years due to the slow economy and because new technology has not advanced as rapidly as anticipated. The company continues its development and commercialization work through SECA. The company is now focused on bringing their 125 kW SOFC cogeneration system to market by 2007. Two more product demonstrations for 125 kW system are scheduled, one each in 2005 and 2006.

SiGEN

Location: Bucksburn, Aberdeen, United Kingdom

Website: http://www.sigen.co.uk

Technology: PEMFC/DMFC/SOFC/Other

- siGEN is a system integrator developing fuel cell systems in 1-10 kW power range. The company is involved in several projects ranging from providing hydrogen solutions to fuel cell product development. The company has deployed over 12 fuel cell systems from leading fuel cell manufacturers including Ballard, ReliOn, US General Fuel Cell and Plug Power. The company promotes the development of hydrogen from renewable sources and is working in collaboration with PURE in Shetland to design and install a hydrogen production facility from wind power. The company is also involved in development of solar fuel cell hybrids for remote applications in power range of 100 W to 2 kW, mobile cogeneration systems in range of 300 W to 600 W, and industrial back-up power systems in 1-10 kVA power rating.

Smart Fuel Cells

Headquarters:
Eugen-Saenger-Ring 4
85649 Brunnthal-Nord
Germany
Phone: +49 89 607 454 60
Website: http://www.smartfuelcell.de

Ownership Structure:

Smart Fuel Cells (SFC) is privately owned. Since the company's founding in 2000, PriCap Venture Partners AG and 3i Group Ltd. have been the main investors.

Management:

- Dr. Manfred Stefener – Managing Director
- Dr. Jens Müller – Chief Technology Officer
- Mr. Pieter Bots – Chief Marketing and Sales Officer

Brief Company Description:

Smart Fuel Cells develops and manufacturers direct methanol fuel cell (DMFC) fuel cell systems in the range of few watts to one kilowatt. The company's DMFC technology is based upon proprietary work performed by Dr. Manfred Stefener – the founder of the company. The company believes that its expertise in miniaturization of stacks along with proprietary water and heat management strategies provides them a unique competency in the DMFC portable power market. The company's IP portfolio includes more than 20 patents worldwide. Founded in 2000, the company has approximately 35 employees.

Alliances/Partners:

Smart Fuel Cells has collaborated with several companies and research institutes worldwide that have helped the company maintain its leading position in DMFC technology area.

- Medion and CONSEL Case Solutions – In March 2003, SFC signed partnership agreements with Medion and CONSEL Case Solutions to develop a notebook docking station and suitcase power.
- Heliocentris – In April 2005, Heliocentris and SFC signed an agreement under which the Heliocentris will distribute the SFC A50 M (50 W DMFC) to universities and educational institutions. The company seeks to build interest in its technology among future engineers and technicians.
- Hymer AG – Under a collaborative agreement signed in July 2005, Hymer will integrate SFC's A50 fuel cell into their Hymermobile S-Class motor home. The SFC fuel cell supplies the vehicle's onboard power needs when parked.
- German Federal Army – Under a cooperative agreement signed in August 2005, SFC will develop next generation highly compact, long lasting portable fuel cells for the German Federal Army.

Products:

SFC products are focused on portable power, recreational vehicles, and off-grid power for telecom and traffic lights.

- SFC A50 – This product is suited for off-grid power systems and recreational vehicles. The system has a charging capacity of 1200 Wh/day and delivers a nominal power of 50 W at 4 Amps. The system is designed to operate in -20 to 40 ^{o}C temperature range. The system has the capacity to generate more than 300 Ah of electricity from a five liter methanol cartridge.
- MFC 100 – This product is designed specifically for blue-water yachting. The Marine Fuel Cell (MFC) is capable of supporting all 12 volt on-board equipment. The system has a continuous output of 4 amps and 12 volts DC and can operate in -20 to 40 ^{o}C temperature range. The system consumes around 1.2 liters of methanol for each 1 kWh of energy production.
- SFC C 20 – This product is being designed for portable power devices and is not available commercially. The system provides 20 watts of continuous power at 11.1 volts nominal voltage. The system weighs about 2 kg and generates more than 440 Wh of energy with one single 500ml fuel cartridge.

Technology Overview:

Smart Fuel Cells utilizes "Active Crossover Control" technology to control methanol crossover in DMFCs. The company uses the methanol crossover to generate water and heat for quick start up operation under extreme environmental conditions. In February 2005, the company announced a new membrane technology that it claims will lead to reduced catalysts loadings and consequent reduction in cost. Furthermore, the company claims to utilize simplified fluid systems, sealing concepts, and electrical connections in their products. This approach has enabled the company to introduce DMFC products that are reliable and efficient, with good transient response. The company claims its product enables storage densities which are 3-5 times higher that those of lithium-ion batteries at comparable volume and reduced weight. Additional advantages of the systems are easy handling and rapid recharge even during operation. The company's power supply solutions can be used independently as external power generators, or they can be integrated into portable devices or recreational vehicles.

Status of Commercialization:

SFC's first product (A25 system) was demonstrated in October 2001 and the system was commercially available in September 2003. The company claims that their DMFC technology provides them a technology edge over other competitors including those from U.S. and Asia. Early in 2005, the company introduced their A50 system (50 watt) for recreational vehicles and other off-

grid applications. The cost of this system is EUR 2,999. The company also announced a methanol fuel distribution network in Europe to ensure the easy availability of methanol cartridges for their A50 customers. The company has also obtained CE, TÜV, and GS certification for their products. The company anticipates selling their portable DMFC products at a price comparable to Li-ion batteries at large production volumes.

SOFCo-EFC Holdings

Headquarters:

1562 Beeson Street
Alliance, Ohio 44601
Phone: 330-860-6797
Website: http://www.sofco-efs.com

Ownership Structure:

SOFCo-EFS Holdings LLC is a wholly owned subsidiary of McDermott International Inc. (NYSE: MDR)

Management:

- Mr. Bruce W. Wilkinson – Chairman and Chief Executive Officer, McDermott International
- Mr. John A. Fees – President and Chief Operating Officer, BWX Technologies (includes McDermott Technology, Inc. and SOFCo-EFS)
- Dr. Rodger W. McKain, President, SOFCo-EFS
- Dr. Eric A. Barringer – Technical Director, SOFCo-EFS

Brief Company Description:

SOFCo-EFS Holdings LLC is headquartered in Alliance, Ohio. The company develops planar solid oxide fuel cell components for stationary and mobile power systems, as well as gaseous and liquid fuel processors that support a broad range of fuel cell applications. SOFCo-EFS has a patented all-ceramic SOFC design that combines state-of-the-art ceramic materials with the manufacturing technology for multi-layer ceramic packages currently used by the microelectronics industry. The company is also developing fuel reformers for a wide range of gaseous to liquid fuels including diesel. SOFCo-EFS's versatile fuel processing technology is being integrated into SOFC systems being developed by the company as well as other industry stakeholders. The company has about 40 employees.

Alliances/Partners:

- U.S. Army – Under this 18 month contract awarded by U.S. Army in June 2005, SOFCo-EFS will develop a desulfurizer unit that will enable utilization of high sulfur logistics fuels in SOFC units.
- Stark State College of Technology – SOFCo is working with the College to build a Fuel Cell Prototyping Center using $5.2 million in federal and state funding. The Center is expected to open in early 2006.
- Cummins Power Generation – SOFCo-EFS and Cummins Power Generation are developing solid oxide fuel cell systems for auxiliary power in recreational vehicles and commercial work trucks, and for emergency power at remote telecommunication sites. U.S. Department of Energy (DOE) is providing development funding of $74 million to support these efforts.
- International Truck and Engine (ITE) – SOFCo-EFS and Cummins Power Generation have teamed with ITE, a leading truck manufacturer, to develop SOFC auxiliary power systems for heavy-duty trucks. The company believes that application of fuel cell technology as truck APUs will sharply reduce engine idling time for America's 458,000 long-haul trucks, thereby shrinking fuel consumption and reducing pollution emissions.
- U.S. Department of Energy (DOE) – The U.S. Department of Energy, through the Solid State Energy Conversion Alliance (SECA) and Office of Energy Efficiency and Renewable Energy (EERE), have strongly supported the company's solid oxide fuel cell (SOFC) development efforts. Key programs include:
    - Truck Auxiliary Power Unit – SOFCo, Cummins, and ITE were awarded a $4.8 million contract from the DOE to develop a solid oxide fuel cell APU for heavy-duty trucks. This two-year program will be completed in August 2006.
    - SOFCs Operating on Coal Derived Syngas – Ohio University and SOFCo-EFS were the recipients of a $3.9 million award from the DOE to prove the viability of solid oxide fuel cells operating on syngas derived from domestically produced coal. Development efforts were initiated in 2003.
    - Solid State Energy Conversion Alliance (SECA) – In 2001, Cummins Power Generation and SOFCo-EFS were selected for a $74 million award from the DOE for development of 3 – 10 kW SOFC power systems for auxiliary power in recreational vehicles and commercial work trucks, and for emergency power at remote telecommunication sites. The goal of this 10-year program is to develop SOFC systems that can be produced for $400 per kilowatt. SOFC systems meeting the SECA cost and performance targets are expected to displace

reciprocating-engine technology. In a paper presented at the 2005 Logistic Fuel Processing Conference in Panama City, FL, the company reported the development of a 5 kWe "waterless" CPOX reformers for natural gas and LPG.

- Affordable Multi-layer Ceramic Manufacturing for Power Systems (AMPS) – In 1999, the DOE awarded a $9 million contract to the company for a program called Affordable Multi-layer Ceramic Manufacturing for Power Systems. The feasibility of the multi-layer interconnect and the all-ceramic stack design was successfully demonstrated in this program.
- 50 kW Multi-fuel Processor – In 1999, the DOE selected the team of SOFCo-EFS, Catalytica Advanced Technologies (CAT), and NexTech Materials, Ltd. to develop a fully integrated 50 kW catalytic multi-fuel processor suitable for automotive applications. The proprietary design incorporated state-of-the-art reforming, liquid-phase desulphurization, and advanced CO clean-up to achieve compact size, simplified controls, and high efficiency. Desulphurization of the gasoline was accomplished in a compact, replaceable canister. Fabrication and testing of the system were successfully completed in 2002.
- Integrated SOFC and Catalytic Partial Oxidation – In June 2005 under a grant from DOE, Idaho National Laboratory (INL) demonstrated the feasibility and operation of an integrated system consisting of a SOFCo catalytic partial oxidation reformer and Acumentrics stack. The system was run of a low-sulfur commercial diesel fuel and synthetic diesel (manufactured by Syntroleum in Okalahoma).

- Ohio Department of Development (ODOD) – The Ohio Department of Development is supporting SOFCo through the following programs:
  - Auxiliary Power Units – SOFCo is partnering with NexTech Materials, Edison Materials Technology Center, and NASA Glenn Research Center to develop SOFC APU's for transportation and aerospace applications. The fuel cell is expected to achieve 5 times the power density of current state-of-art SOFC.
  - Low Manufacturing Cost SOFC – Under this grant, MetaMateria Partners and Ohio State University are developing a compact SOFC for SOFCo-EFS and other fuel cell integrators in the state of Ohio. Ohio State University will use its expertise in nanotechnology to develop this SOFC system.
  - Fuel Cell Prototyping Center – $5.2 million in federal and state funding has been provided for construction of a Fuel Cell Prototyping Center on the Stark State College of Technology campus in Canton, Ohio. The facility will house a production tape caster and other

equipment required for the prototype manufacture of multi-layer ceramic components for fuel cells. Production capacity of 2-5 MW is anticipated. SOFCo-EFS will be the initial tenant in the facility when it opens in early 2006.

- Fuel Cell Demonstration – SOFCo-EFS was the recipient of a $1 million award by the ODOD for demonstration of a 1-2 kW SOFC power system. The unit, which will operate on natural gas, will be housed in the Fuel Cell Prototyping Center when construction of the facility is completed.
- Sulfur Tolerant SOFC Systems Operating on Distillate Fuel – SOFCo-EFS is working with academic, government, and industry collaborators (NASA Glenn Research Center, Case Western Reserve University, and Sud-Chemie Inc.) to conduct fundamental research necessary for the successful development and commercialization of sulfur tolerant SOFCs. The state of Ohio has provided $775,000 for this development effort. In August 2005, the company reported successful demonstration of a 10 kW diesel fuel processor integrated with a SOFC.

- Office of Naval Research – In 1998, SOFCo-EFS teamed with Ballard Power Systems and Gibbs & Cox to develop a PEM fuel cell generator for Navy ship-service power. Phase 1 of the program produced a conceptual design of a 2.5 MW, ship-service fuel cell and demonstrated critical components under military marine conditions. A 20 kW autothermal reformer, in combination with hot-gas desulphurization and shift reactors, was operated on NATO F-76 naval distillate. A follow-on contract was received for design, fabrication, and testing of a 500 kW integrated fuel processing system. The system was constructed at the Idaho National Laboratory (formerly, the Idaho National Engineering and Environmental Laboratory – INEEL) and is currently undergoing testing. In November 2004, the company reported the development of a system to reform dirty diesel fuel into a 30% hydrogen mixture.

Products:

The company does not offer any commercial products at this time. Products in development include solid oxide fuel cells (1-10 kW auxiliary power units) and fuel processing systems.

Technology Overview:

SOFCo has focused on “all-ceramic” planar solid oxide fuel cell technology. The company’s approach combines state of art SOFC materials with the manufacturing technology and infrastructure established for multi-layer ceramic packages for microelectronics industry, which has proven capability to achieve high quality, low-cost manufacturing. The company believes that their ceramic

interconnect fabricated using multiple layers of yttria-stabilized zirconia tape and conductive vias facilitate the uniform distribution of air and fuel gas to the respective electrodes in the cells. Further, in a technical publication on the company's website, the company reported that their multi-layer ceramic approach for interconnects enables close thermal match of the interconnect with the zirconia-based cells. The company continues to develop the technology with support from DOE under the SECA grant. Performance enhancement and cost reductions are the two key goals. The company is looking to lower temperature operation and high volume production techniques as important strategies.

The company is currently focused on the development of Autothermal (ATR) (for PEMs) and Catalytic Partial Oxidation (CPX) (for SOFCs) reformers. The company believes that catalyst screening, long-term catalyst testing, and catalyst development are a key in their reformer product development activities.

Status of Commercialization:

The company continues to develop the technology with support from DOE under the SECA grant. During the 2005 Fuel Cell Seminar, SOFCo presented their results on 1 kW prototype system (C1) and waterless partial oxidation (CPOX) reformer that converts pipeline natural gas to hydrogen-rich reformate stream. The prototype system has been tested for over 600 hours while the reformer for over 3000 hours. In a SECA presentation, the company indicated that their next generation SOFC system (C2) will be developed and tested by end of 2005.

The company has also developed a compact 10 kW diesel fuel processor. The reformer which reportedly was integrated with sulfur tolerant SOFC, operated for over 1600 hours on low-sulfur diesel and diesel reformate. Earlier in 2004, the company reported that they have developed and are testing a 500 kW fuel processor for naval distillate fuel. The company is also looking for integration of their SOFC power modules into CHP systems, and expects to have demonstration prototypes ready by September 2006.

Sony

Location: Tokyo, Japan

Website: http://www.sony.net

Technology: DMFC

- Sony is developing DMFC fuel cell technology for use in electronic devices. The company uses advanced carbon fullerene technology in its MEAs to downsize fuel cells. As reported on Fuel Cell Today website,

Sony's Frontier Science laboratories division has employed fullerenes to develop a credit-card sized fuel cell that can generate 1.2 V without water vapor. Very few details about Sony fuel cell activities and commercialization timelines are available in the public literature.

Sulzer Hexis/Hexis AG

Location: Winterthur, Switzerland

Website: http://www.sulzer.com

Technology: SOFC

- In August 2005, Sulzer Corporation closed their Sulzer Hexis fuel cell business segment due to lack of funding. Later in December 2005, Sulzer spun out their fuel cell program into a new company called Hexis AG. Sulzer Hexis had anticipated commercial launch of its second generation product (Galileo) in Europe in March 2005 and in the U.S. later in the year, but fell on financial difficulties and scrapped those plans. The company, which had about 70 employees, was developing a planar solid oxide fuel cell technology for the residential and small commercial distributed generation market.

Technofil

Location: Cerro Maggiore, Milan, Italy

Website: http://www.technofil.sul-web.com/

Technology: DEFC

- Technofil develops direct ethanol fuel cells for daily use electronic devices including mobile phones, PDAs, GPS devices, and video cameras. The company released a 1.5 W direct ethanol fuel cell product prototype as reported in April/May 2005 issue of Fuel Cell Magazine. The 1.5 W Technofil DEFC-01 system measures about 10 cm × 6 cm × 4 cm and can charge a mobile phone battery for around 10 times. The company uses the proprietary non-precious metal catalysts termed as Platinosintetico – jointly developed in collaboration with ICCOM-CNR Institute. The novel catalyst contains nanometric and sub-nanometric iron, nickel, cobalt particles, arranged on a conductive material. The company believes that

using easily available materials will provide them a leading edge. Technofil also believes that their fuel cell systems are more environmentally responsible because ethanol can be derived from renewable sources. No dates for commercial release of products have been announced by the company.

Teledyne Energy Systems

Headquarters:

Teledyne Energy Systems, Inc.
10707 Gilroy Road
Hunt Valley, Maryland 21031
Phone: 410-771-8600
Website: http://www.teledyneenergysystems.com

Ownership Structure:

Teledyne Energy Systems is a subsidiary of Teledyne Technologies (NYSE: TDY)

Management:

- Dr. Robert Mehrabian – Chairman, President, and Chief Executive Officer, Teledyne Technologies, Inc.
- Mr. Rhett Ross – President
- Mr. Jan Hess – Chief Financial Officer
- Mr. Charles Wolf – Vice President, Engineering
- Mr. Frank Flaherty – Vice President, Operations

Brief Company Description:

Teledyne Energy Systems, Inc. (TESI) is a global provider of on-site gas and power generation systems based on proprietary fuel cell, electrolysis, and thermoelectric technologies. The company's fuel cell business was started in July 2001 with the acquisition of Florida-based Energy Partners, Inc. Since then, the company has added PEM fuel cell stacks and systems, hydrogen and oxygen generation systems, test stands and systems, and fuel cell engineering services to its product offerings. The company fuel cells efforts are targeted at having a modular system with flexible fuel/air combination ranging from hydrogen/oxygen, hydrogen/air, dilute hydrogen/air, and reformate/air. TESI

also offers a full range of design and testing services of fuel cell systems and components for use in space, terrestrial, and submarine applications. They are also an exclusive worldwide distributor (except Japan and Korea) of fuel cell testing equipment and software manufactured by Scribner Associates, Inc.

Alliances/Partners:

- NASA –is a long time fuel cell development partner:
  - August 2005 – the company delivered a 12 kW PEM Fuel Cell Power Plant to NASA's Glenn Research Center.
  - August 11, 2003 – the company was awarded a $4.3 million contract extension to develop and deliver an "engineering model" PEM fuel cell power system NASA's Glenn Research Center. A 12 kW system was delivered to NASA under this contract in August 2005.
  - May 14, 2003 – the company received two contracts under NASA's Radioisotope Power Conversion Technology Program.
  - April 1, 2003 – the company delivered a 5 kW breadboard PEM fuel cell power system to NASA's Glenn Research Center.
  - December 14, 2001 – the company was awarded a $1 million base contract by NASA Glenn Research Center to develop an advanced PEM fuel cell power plant.
- US Department of Energy
  - March 30, 2004 – the company entered into a $3.1 million cost shared Cooperative Agreement with the DOE to conduct research and development in hydrogen production by advanced water electrolysis.
  - June 30, 2003 – the company, together with the Rocketdyne Propulsion & Power business unit of Integrated Defense Systems of The Boeing Company (NYSE:BA), was selected by DOE to develop the Multi-Mission Radioisotope Thermoelectric Generator for use in deep space exploration projects.
- Scribner Associates, Inc.
  - May 13, 2002 – the company is the exclusive distributor (except Japan and Korea) of fuel cell testing equipment and software manufactured by Scribner Associates Inc (SAI).

Products:

Fuel Cells

- Teledyne Perry NG Series™ Fuel Cell Stack (NG1000, 2000, 3000) – These are available in sizes ranging from 2 kW to 50 kW, and require low-

stoichiometric fuel to oxidant ratio, while providing a flexibility in the fuel/oxidant. Modular design supports a variety of active areas, operating voltages, and operating pressures. These units are intended and marketed for laboratory testing, and to provide power for portable, stationary, transportation, and space/aviation applications. The company also makes custom sized stack based on end-user requirements.

- Teledyne FTU™ Series power systems – TESI offers its FTU™ systems for a wide range of stationary and mobile applications. The company has tested these systems in actual end-user applications including power systems for tractors, utility vehicles, automobiles, submarines, natural gas fueled generators, space power, and direct hydrogen portable generators.

Gas Generators

- Teledyne TITAN™ – Teledyne TITAN™ (HP, EC, HM series) hydrogen/oxygen gas generators utilize the principle of electrolysis of water to generate high purity (99.9998%) hydrogen and oxygen gases at usable pressure. The TITAN™ product line is available in various ranges from 50 to 2500 SLPM of hydrogen.
- H_2Oasis™ – Teledyne H_2Oasis™ Hydrogen Gas Station integrates a complete hydrogen production and storage system into a convenient, easy to install and commission portable weather-tight building. The system provides ultra high hydrogen gas in the capacity range from 2.8 to 42 Nm^3/hr at pressure to over 5,000 psig. The product can be used for virtually any numerous applications including semiconductor fabrication, argon purification, metals processing, and hydrogen fueling.

Fuel Cell Test Stations

- Teledyne MEDUSA™ (RD and LS series) – The Company also offers a line of fuel cell test stations and is a leading supplier of fuel cell test stations worldwide. The RD series can test single or multi-cell stacks of up to 3 kW while the LS series can test stacks up to 10 kW. These test stations are currently in operation worldwide for different applications including: fuel cell design verification, fuel cell component R&D, fuel cell endurance testing, quality testing, benchmark testing, and single or multi-stack testing.

Technology Overview:

The basic platform for the company's PEM fuel cell technology was acquired from Energy Partners, Inc. Energy Partners made several industry breakthroughs including the first PEM fuel cell in the United States to produce electricity from natural gas for residential applications. Their intellectual property portfolio included proprietary technologies related to the fabrication of composite graphite fuel cell collector plates and self-humidifying fuel cells. At

the time of acquisition, Energy Partners had produced over 550 fuel cell stacks and accumulated over 100,000 hours of stack and system testing.

TESI's fuel cell activities are squarely focused on research and development, with special expertise in systems using pure oxygen and pure hydrogen. In August 2005, TESI announced that it has delivered a 12 kW PEM Fuel Cell Power Plant to NASA. The company claims that this "engineering model" has better water management, high fuel efficiency, and low start-up time capabilities. Prior to this delivery, the company had also delivered a 5 kW breadboard PEM fuel cell in April 2003. This unit demonstrated the ability to deliver peak power beyond its nominal 5 kW rating. The unit met or exceeded all the program design requirements including weight, volume, power output, and efficiency.

The company continues to work on performance enhancements. During the 2004 Fuel Cell Seminar, the company reported on long-term MEA durability research and development including their efforts to identify the most durable MEAs and correlate the failure mechanism to fuel cell design, components, and operating conditions. Accelerated MEA failure tests indicated that holes and tears formed either mechanically (creep) or chemically (contaminant precipitation) are the primary failure modes.

Status of Commercialization:

TESI has several ongoing R&D contracts with NASA and DOE and have delivered products to these organizations designed against specific requirements. While the company offers several fuel cell products prototypes suitable for laboratory testing, portable power, stationary power, transportation power, and space/aviation power; no plans or timetable have been announced for the introduction of standard commercial products. Industry observers have commented that TESI appears less interested in stationary fuel cell market than Energy Partners.

Tokyo Gas

Headquarters:

1-16-25 Shibaura
Minato-ku, Tokyo 105-0025
Japan
Phone: +81 3 5484 4531
Website: http://www.tokyo-gas.co.jp/index_e.html

Ownership Structure:

Publicly traded corporation.

Management:

- Mr. Kunio Anzao - Chairman
- Mr. Hideharu Uehara – Vice Chairman
- Mr. Norio Ichi – President

Brief Company Description:

Tokyo Gas is the biggest distributor of natural gas in Japan. The company has a history of advancing phosphoric acid fuel cell technology, working primarily with UTC for more than 30 years, but also with Fuji Electric. The company is active in the development of desulfurizer and fuel processor technology and has successfully demonstrated products that can reform natural gas and LPG to be used as a fuel for PEM fuel cells. In 2005, the company began marketing the world's first residential PEM fuel cell cogeneration system, in collaboration with Ebara Ballard and Matsushita Electric. The system utilizes Tokyo Gas' proprietary fuel processing technology. In collaboration with it partners—Kyocera, Rinnai, and Gaster—Tokyo Gas is also developing SOFC units in the range of 5 – 10 kW for industrial systems.

Alliances/Partners:

- Ebara Ballard and Matsushita Electric Industrial – The Company announced in July 2003 its intention to develop PEMFC cogeneration system in collaboration with Ebara Ballard and Matsushita Electric Industrial.
- Kyocera, Rinnai, and Gaster – Under this joint development agreement, Kyocera, Rinnai, Gaster, and Tokyo Gas will construct a 5 kW SOFC system for industrial use.
- Osaka Gas – Under this partnership, Tokyo Gas and Osaka Gas performed the verification test of the 25 kW SOFC system developed by Siemens Westinghouse.
- Sulzer Hexis – Under this partnership, Tokyo Gas tested a 1 kW SOFC system module from Sulzer Hexis. Tokyo Gas also tested some of their SOFC cells operating at 1000 ^{o}C in Sulzer Hexis 1 kW system.

Products:

1 kW Residential PEMFC Cogeneration System – The system developed in joint collaboration with EBARA Ballard and Matsushita Electric Industrial was

first introduced in the market on a limited scale in February 2005. The 1 kW residential systems has the following specifications:

- Dimensions (Matsushita type)
    - Width: 310 – 345 cm; Length: 126 – 128 cm; Height: 255–260 cm
- Dimensions (Ebara – Ballard type)
    - Width: 283 cm; Length: 155 cm; and Height: 255 – 260 cm
- Fuel: 13 A city gas
- Electric power
    - Rated power 1 kW, Direct current 3 lines, AC 100/200C, 50 Hz, Power range 1 – 3 kW.
- Power generating efficiency: More than 31% HHV (100% Output)
- Heat recovery efficiency: More than 40% HHV (100% Output)
- Hot water tank capacity: 200 liters
- Back up boiler: Type 24

Technology Overview:

Tokyo Gas has developed the 1 kW residential PEMFC cogeneration system around its core technology of desulfurizing and fuel processing. The technology developed by the company is reported to work well with natural gas and LPG. The technology was licensed to Ebara Ballard in 2002 for development of 1 kW residential PEMFC cogeneration system. Tokyo Gas continues to develop its fuel processing technology to further reduce the cost and improve the durability of the fuel processors in order to promote the commercialization of its systems. The company also appears to be working on alternate reformer designs for it fuel processing technology. In 2004, the company reported developing a membrane reformer system that produces hydrogen from hydrocarbon fuel by selective permeation of hydrogen into modules placed in the catalyst bed where the steam reforming reaction occurs. The company claims the newly developed membrane reformer operates at much lower temperature of 500 ^{o}C, compared to conventional reformers, which results in higher hydrogen production efficiency in a simple, compact design.

Tokyo Gas SOFC technology is a result of the work performed under the NEDO (New Energy and Industrial Technology Development Organization) project. Under this program the company is developing membrane-supported SOFC cells which can operate at a reduced temperature of 750 ^{o}C. The company reported using metal separators and heat stress resistance materials to enable rapid change in temperature at a rate as high as 200 ^{o}C per hour. Tokyo

Gas is also advancing the flat-tube cell stacks originally developed by Kyocera. The company also seems reportedly working on anode-supported SOFC for reduced temperature operations. In a paper presented at the 2004 Fuel Cell Seminar, the company reported the development of anode-supported SOFC with metallic interconnects at reduced temperature (800 ^{o}C) with lower ohmic resistance.

Status of Commercialization:

Tokyo Gas strategy is to use its PEMFC technology for residential cogeneration system (1 kW), and SOFC technology for industrial cogeneration system in the range of 5-10 kW and later expanding to 50-100 kW range. The company's first 1 kW PEMFC residential cogeneration system was introduced in February 2005. In a press statement released in December 2004, the company announced that it would install 200 units (110 Ebara-Ballard, and 90 Matsushita Electric Industrial) at preferred locations in Japan by the end of the 2005 fiscal year (March 2006). In order to ease the market penetration, the company also announced reduced gas rates for residential fuel cell cogeneration systems. As of early December 2005, the company had already installed 100 systems and except to install another 100 by March 2006. The company expects to reach full-scale commercialization of their units by 2008.

On the SOFC front, Tokyo Gas is working with Kyocera (which has also developed a 1 kW SOFC unit for domestic application), Rinnai, and Gaster to jointly develop a 5 kW SOFC system for industrial use. The company expects to develop this product for market entry in 2008 for industrial applications like restaurants and stores. Expected efficiency of the system is around 45 % (AC electric, HHV basis).

Toshiba

Location: Tokyo, Japan

Website: http://www.toshiba.co.jp/index.htm

Technology: DMFC/ PEM

- Toshiba is developing highly compact micro fuel cells for electronic devices such as laptops, cameras, mobile phones, and other handheld devices. The company is making prototype products and has demonstrated products in the 100 mW to 20 W range. In March 2003, the company announced the first DMFC for portable PCs. In October 2003, Toshiba unveiled a 1 W DMFC, which the company claims can provide energy for up to 20 hours with just one 25 cc fuel cartridge. In June 2004, the

company unveiled a tiny 5.6 × 2.2 × 0.5-0.9 cm power pack with no moving parts for MP3 players. In February 2005, the company's 100 mW prototype micro fuel cell was certified as World's smallest by Guinness World Records. In March 2005, the company also unveiled a 20 W DMFC that can power a notebook computer for 10 hours. Toshiba believes that their optimized electrode structure allows for reduced methanol cross-over thereby enabling the use of highly concentrated methanol solution and consequently a more compact and more efficient fuel cell. The company anticipates offering products incorporating their technology in 2006-07.

Toshiba Fuel Cell Power Systems

Headquarters:

1-1, Shibaura 1-chome
Minato-ku
Tokyo, Japan 105-8001
Website: http://www.toshiba.co.jp/product/fc/fce/index.htm

Ownership Structure:

Toshiba Fuel Cell Power Systems is a wholly owned subsidiary of Toshiba Corporation

Management:

- Yoshiyuki Kimura – President

Brief Company Description:

Toshiba Fuel Cell Power Systems (formerly Toshiba International Fuel Cells) was formed as a result of the rearrangement in November 2004 between UTC Fuel Cells and Toshiba International Fuel Cells (TIFC). TIFC was initially formed in March 2001 as a result of a joint venture between Toshiba and UTC Fuel Cells to develop PEM fuel cells for residential and small sized commercial applications, and 200 kW phosphoric acid fuel cells for industrial and commercial application in the Japanese and Asian markets. The rearrangement was due to differing market foci for UTC fuel cells and TIFC. Established in December 2004, Toshiba Fuel Cell Power Systems has around 65 employees.

Alliances/Partners:

- UTC Fuel Cells – Toshiba Fuel Cell Power Systems was formed initially as a result of joint venture between UTC Fuel Cells and Toshiba Corporation.

The venture was discontinued in November 2004 due to differences in market focus for both the companies. In a press statement released in November 2004, UTC stated their intention to focus on fuel cells to power cars and buses. Toshiba, on the other hands, aims to focus on bringing their 1 kW PEM fuel cells to residential markets in the next 3-4 years.

- Osaka Gas – In 2003, Osaka Gas and Toshiba Fuel Cell Power Systems signed an agreement to jointly develop residential CHP systems. Under this agreement Osaka Gas will provide its expertise in the fuel reforming towards the development of a PEM fuel cell residential cogeneration system.
- Cosmo Oil – Under this collaboration, Cosmo Oil and Toshiba Fuel Cell Power Systems will develop fuel cells that will extract hydrogen from LPG.

Products:

No commercial products are available at this time.

Technology Overview:

Toshiba Fuel Cell Power Systems has developed cell stack technology internally. The company claims that their stacks have operated for over 9,000 hours and are within their target values for degradation rates. Few details of the Toshiba PEM fuel cell technology were found in the literature. However, the PEMFC 1 kW residential cogeneration system has the following specifications (2004 target):

Capacity	700 W (AC-net)
Output Voltage	200 V/ 50 & 60 Hz
Electrical Efficiency	> 35% (LHV)
Thermal Efficiency	> 45% (LHV)
Waste Heat Grade	> 60 °C
Fuel	Natural Gas / LPG
Operation node	GC / Idle
Noise	< 45 dB
Volume	< 210 liters
Weight	< 120 kW
Package Size	830 (W) × 300 (D) × 840 (H)
Start-up Time	< 45 min

Status of Commercialization:

Toshiba Fuel Cell Power Systems has developed a 1 kW PEM fuel cell cogeneration system for residential application. The company has already delivered more than 40 – 1 kW systems to government, utility companies and housing companies in Japan for field testing. The company claims that their system has successfully achieved over 6,000 operating hours (70,000 cumulative hours) with 38% electrical efficiency (based on LHV). The company has plans to install and demonstrate several hundred of their 1 kW systems with support from Japan's Ministry of Economy, Trade and Industry. The company expects full commercialization of their systems by 2008.

Earlier in 1999, the company also demonstrated a 1 kW PEMFC system (fueled with LPG) for vending machines. The current 1 kW system is build upon the experience captured from this prototype unit. The company also reported having a 5 kW PEM fuel cell system that it planned to begin selling in 2004 for commercial use in Japan. This system was to use the reformer technology developed by HydrogenSource, a joint-venture of UTC and Shell Hydrogen that was later dissolved. No further information is available about this system.

Toyota Motor Company

Headquarters:

Higashifuji Technical Center
1200 Mishuku
Susono, Shizuoka, 410-11 Japan

19001 S. Western Ave. #A403
Torrance, California 90501
Phone: 310-468-4000
Website: http://www.toyota.com

Ownership Structure:

Public (NYSE: TM).

Management:

- Mr. Hiroshi Okuda – Chairman
- Mr. Katsuaki Wantanabe – President

Brief Company Description:

Toyota is developing fuel cell vehicles based upon the company's proprietary PEM fuel cell technology. The company expects to sell their environmentally friendly fuel cell cars at a commercially viable price by target date of 2015. Toyota started leasing their fuel cell vehicles in 2002 and to date has leased some 16 vehicles, mainly in Japan and the U.S. The company plans to lease some 20-30 fuel cell vehicles per year over next few years as a part of its demonstration program. Toyota is also developing a 1 kW residential natural gas fueled fuel cell (CHP) with commercial production set to start in 2008. The company believes that selling residential fuel cells will lower the fuel cell production cost and also help commercialize fuel cell vehicles.

Alliances/Partners:

- California Fuel Cell Partnership
- ExxonMobil – The companies will jointly develop the science and technology required for next generation automotive systems through an integrated hardware and fuel combinations approach.
- General Motors – General Motors and Toyota explored forming a joint venture for fuel cell vehicle development. This move was stalled in July 2005 and later on dismissed in August 2005 due to issues relating to the sharing of intellectual property rights by both the companies.

Products:

The company does not offer any fuel cell products at this time, but is developing the following:

- Toyota FCHV-5 (fuel cell vehicle car) (previous models: FCHV-4, FCHV-3).
- Toyota FCHV-BUS2 (fuel cell hybrid bus).
- Toyota MOVE FCV-K-2 (jointly developed by Totota and Daihatsu, this fuel cell hybrid mini-car is the first car to get approval from Japan's Ministry of Land, Infrastructure and Transport for use on public roads).
- Toyota residential 1 kW fuel cell cogeneration system fueled by natural gas.

Technology Overview:

The company's new FCHV-5 model uses Toyota's on-board CHF (clean hydrocarbon fuel) reformer to generate hydrogen from gasoline. The FCHV-5 improves on the predecessor FCHV-4 with the capability of reforming, enabling marketing and operation in regions where hydrogen supply infrastructure is not available. The FCHV-5 CHF reformer technology has the capability of producing clean fuel from crude oil, natural gas or low-sulfur coal. The company is currently working to reduce the start-up time required by the reformer. During the 2004 Fuel Cell Seminar, the company reported that they are working to address the limited cruising range of current generation of fuel cell vehicles by both developing new hydrogen storage materials and by examining several methods to allow the use of on-board reforming. The company revealed that they are looking at carbon-based materials to enhance the amount of on-board hydrogen storage. In a press statement released in May 2005, the company revealed that they have developed a 70 MPa high-pressure hydrogen tank certified by High Pressure Gas Safety Institute of Japan that provides the same cruising range as gasoline tank. Few details of the Toyota fuel cell technology were found in the publicly available literature. However, the Toyota FCHV-4 vehicle has the following specifications:

Complete Car	Maximum Speed	96 mph (155 km/h)
	Vehicle (curb) Weight	4,092 lbs (1,860 kg)
	Driving Range	180 miles (290 km)
	Seating Capacity	5 adults
Motor	Maximum Power Output	109-hp (80 kW)
	Maximum Drive Torque	194 lb-ft (260 N-m)
	Motor Type	Permanent magnet
Fuel Cell Stack	Stack Type	Toyota FC Stack (Polymer electrolyte fuel cell)
	Power Output	90 kW
	Secondary Battery	Nickel-metal hydride battery
Fuel	Fuel Type	Pure Hydrogen Gas
	Storage Method	High-pressure Hydrogen Storage Tanks
	Max Storage Pressure	5,000 psi (35 MPa)

Toyota is working to develop a new PEM membrane material to allow practical use of methanol fuel. The company believes that methanol-based fuel cell vehicles have great potential to foster commercialization due to ease of methanol reforming and widespread availability of the relatively inexpensive fuel. The company is also developing intermediate temperature fuel cells that allow the use of liquid fuel and an on-board reformer. One approach has been the development of an ultra-thin proton conductor electrolyte (Y-doped $BaCeO_3$) supported on a solid metal (Pd), hydrogen-permeable membrane, referred to as the Hydrogen Membrane Fuel Cell (HMFC). According to a poster at the 2004 Fuel Cell Seminar, the device exhibits performance equivalent to high temperature SOFCs, even though it is operated at intermediate temperatures.

The company is also developing a 1 kW fuel cell/micro gas turbine cogeneration system for residential application using natural gas as a fuel. The system uses the reformer to extract hydrogen from natural gas and generate electricity. The exhaust gases are used to generate more power in the micro gas turbine. The company claims that their product has the capability to generate electricity at an electrical efficiency of 55%. The waste heat from the cogeneration system is also captured for residential applications. The company believes that introduction of 1 kW residential system will enable cost reduction and understanding of market barriers, facilitating commercialization of the fuel cells for their cars.

Status of Commercialization:

The company expects full-scale commercialization of fuel cell vehicles to begin by 2015. In a news article published by Fuel Cell Today, the company is planning to reduce the cost of their fuel cell vehicles to around US$50,000 from a current value of over US $1,000,000. As of June 2005, Toyota had 16 fuel cell hybrid vehicles on the road in Japan and the U.S., mainly with government agencies, private companies, and universities. In June 2001, Toyota delivered a fuel cell hybrid bus for public transport in Tokyo. The FCHV-BUS2 is a standard low floor city bus that can hold 60 passengers. Additionally, the company anticipates market introduction of its 1 kW residential fuel cell cogeneration system by 2008.

UltraCell

Headquarters:

230-A South Vasco Road
Livermore, CA 94551
Phone: 925-455-9400
Website: http://www.ultracellpower.com

Ownership Structure:

UltraCell is privately held organization. Key investors include: Sevin Rosen Funds, Onpoint Technologies, Star Ventures, and BankInvest Group.

Management:

- Dr. James L. Kaschmitter – Chairman and Chief Executive Officer
- Mr. Norm Allen – Chief Operating Officer
- Mr. Mark Saliman – Chief Financial Officer
- Mr. William D. Hill – Vice President

Brief Company Description:

UltraCell is a developer and manufacturer of micro fuel cells for portable devices. The company was founded in 2002 to commercialize the micro fuel reforming technology originally developed at Lawrence Livermore National Laboratories. The company is developing complete power solutions for mobile, military, professional, and industrial applications based on their reformed methanol fuel cell technology.

Alliances/Partners:

- U.S. Army - CERDEC – Under this agreement signed in September 2005, UltraCell and U.S. Army's Communication-Electronics, Research, Development and Engineering Center will jointly develop a lightweight, energy-dense, pouch-pocket sized fuel cell power systems. The device will assist soldiers on extended missions.

Products:

- UltraCell 25 – Fueled with methanol and delivers 25 W of continuous power, Energy density = 340 W-h/kg and weight = 1.6 kg for a 24 hour operation.
- UltraCell XX90 – Fueled with methanol and delivers 45 W of continuous power, Energy density = 550 W-h/kg and weight = 2.6 kg for a 72 hour operation.

Technology Overview:

UltraCell's "Reformed Methanol Fuel Cell (RMFC)" technology utilizes the advantages of high energy density of methanol fuel and the high efficiency of hydrogen fuel cell. The company believes that their compact micro-scale fuel processing technology, along with their high efficiency hydrogen stack technology enables them to eliminate bulky water management systems. In a paper presented at 2003 Fuel Cell Seminar, the company claimed that their stacks can produce over 0.6 volts at 300 mA/cm^2. Due to the use of hydrogen fuel instead of methanol in the stack, the company is able to make products that are about half the size of direct methanol fuel cell (DMFC) stacks, while running twice as efficiently as DMFCs. The company's fuel cell stack uses the high temperature membrane from PEMEAS Fuel Cell Technologies, resulting in high tolerance to CO and impurities.

Status of Commercialization:

The company delivers customized fuel cell products to OEM customers in mobile, computing, military, and ruggedized portable applications. In September 2005, the company announced the development of a prototype 25 W fuel cell system (named the "XX25") for the U.S. Army. This 25 W system utilizes the same technology as the originally developed 45 W system but is more compact. The company plans on making this product available in 2006 for commercial use under the name UltraCell25™ for mobile, professional, and industrial applications.

UTC Fuel Cells

Headquarters:

195 Governor's Highway
South Windsor, Connecticut 06074
Phone: 866-383-5235 / 866-900-7693
Website: http://www.utcfuelcells.com

Ownership Structure:

UTC Fuel Cells is part of UTC Power, a unit of United Technologies Corp. (NYSE: UTX).

Management:

The UTC Fuel Cells and UTC Power organizations share a common management team.

- Mr. Jan van Dokkum – President
- Mr. Klaus Thieme – Vice President, Sales and Marketing
- Dr. Francis R. Preli, Jr. – Vice President, Engineering

Brief Company Description:

The company's experience with fuel cells dates to the 1960s with development of fuel cell technology for the manned space program. The company still provides alkaline fuel cells to NASA for the space shuttle fleet. Beginning in 1991, the company began producing its 200 kW "PC-25™" (now called PureCell™ 200 power system) phosphoric acid fuel cell for commercial applications. Since that time, more than 278 units have been delivered to locations around the world and have logged more than seven million operating hours producing over one billion kWh of energy. UTC is now developing PEM fuel cells for transportation (through its collaboration with Nissan, Hyundai, and BMW). The company's effort to develop a small stationary fuel cell for residential applications, through its collaboration with Carrier and Toshiba, appears to have been shelved. The company has around 550 employees.

Alliances/Partners:

- Toshiba and Carrier – the companies are working to develop a 5 kW PEM fuel cell to be commercialized by European heating equipment manufacturer Buderus Heiztechnik. In November 2004, UTC rearranged its partnership with Toshiba to allow joint efforts on key initiatives and emerging technologies like SOFC. UTC also announced it would sell its 49% interest in Toshiba International Fuel Cell to Toshiba.

- Nissan/Renault – Under an agreement reached in early 2002, UTC Fuel Cells is to provide fuel cell power plants to Nissan for evaluation, based on UTC's proprietary ambient-pressure PEM technology.
- Hyundai – UTC Fuel Cells have collaborated with Hyundai for over 5 years on development of fuel cell vehicles. In 2003, both the companies signed an agreement to jointly develop a fuel cell power plant for Hyundai FCV that is capable of operating in sub-zero conditions.
- ChevronTexaco and Hyundai – In April 2004, DOE selected the companies to engage in a five year demonstration and validation project to showcase practical applications of hydrogen technology. The companies are to develop safe, convenient, and reliable hydrogen-based distributed power generation and fuel cell vehicle fueling infrastructure.
- BMW – UTC Fuel Cells developed and delivered a PEM fuel cell auxiliary power unit (APU) for a BMW 7 series car. The 5 kW fuel cell APU runs on pure hydrogen and provides energy for all the car's on-board electrical needs, including climate control.
- Thor Industries and Irisbus – UTC Fuel Cells is working with Thor Industries and Irisbus to develop and demonstrate its proprietary fuel cell technology in buses and fleet vehicles.
- Shell Hydrogen – In 2004, the UTC Fuel Cell/Shell joint venture operating as HydrogenSource, LLC was dissolved. The venture was developing a prototype onboard gasoline reformer for use in vehicular fuel cells.

Products:

The company offers the PureCell™ 200 Power System for commercial/industrial customers.

- PureCell™ 200 Power System (formerly PC25™) – This unit produces 200 kW of AC power (at 480 V) and heat (900,000 BTU/hr) suitable for cogeneration applications. The unit, which operates on natural gas at a rated efficiency of 37% LHV, has an approximate (uninstalled) cost of $900,000.
- UTC Fuel Cells continues to develop PEM fuel cells for primary and auxiliary power for automobiles and vehicles. The company integrated its Series 300 fuel cell into a Hyundai SUV for primary power, and developed a 5 kW PEM auxiliary power unit for its automobile partner BMW, for use in a BMW 7 series car. The company has developed a 75 kW ambient pressure fuel cell, and a 100 kW methanol fuel cell as a part of their transportation product development activities. A number of demonstrations are ongoing (see "Status of Commercialization," below), although no commercial products are available at this time.

Technology Overview:

Stationary:

In 2004, the company refocused its efforts on the PC25™ product, re-launching the product as the PureCell™ 200. In addition, the company has significantly scaled back its efforts to develop a PEM fuel cell product (of any size) for stationary applications.

Transportation:

UTC's transportation products are based upon its proprietary ambient-pressure fuel cell design, which the company claims results in a simpler, lower cost system. UTC claims to be the only fuel cell company developing ambient pressure fuel cell technology, a source of competitive advantage due to quieter operation, enhanced fuel efficiency, improved water management, and easier installation. Major technical challenges are cost reduction and fuel processing.

The company is working in collaboration with University of Connecticut, Northeastern University and Virginia Tech to develop high temperature membranes and improved cathode catalysts for automotive PEM fuel cells. In the 2005 DOE hydrogen program review, the company reported that Pt-alloy (PtCo, PtIrCo) catalysts resulted in higher activity and durability than conventional Pt catalysts. The company also reported working on composites membrane based on Nafion, and sulfonated biphenyl sulfones membranes for high temperature operation – reduced RH operation.

Status of Commercialization:

Stationary:

For the past eleven years, UTC Fuel Cells has been the undisputed leader in stationary fuel cell commercialization, with more than 278 of its PureCell™ 200 power systems (formerly PC25™) installed in facilities around the world. After some thought about discontinuing the product, UTC decided in 2004 to continue the PC-25™ product line, re-launching it as the PureCell™ 200. In May 2005, the company stated that the UTC Purecell™ 200 products have cumulatively produced 1 billion kWh of energy with consistent durability of five years. The company is now gearing toward doubling the durability of their system to ten years (80,000 hours), along with reduction in the costs. These systems are expected to be commercially available in 2007. In addition, the company has significantly scaled back its efforts to develop a PEM fuel cell product (of any size) for stationary applications. No products are anticipated.

Transportation:

As with vehicular fuel cells in general, UTC Fuel Cells has a time horizon on the order of 7-10 years for introduction of fuel cell vehicles to the broad marketplace. In late 2002, the company demonstrated a 75 kW PEM fuel cell

power plant in a 30-foot ThunderPower (joint venture between Thor Industries and ISE Research) bus operated by SunLine Transit Agency in California. In February 2005, the company demonstrated an 80 kW, all-weather fuel cell stack in a Hyundai Tuscon fuel cell vehicle at ChevronTexaco hydrogen fueling station as a part of the U.S. DOE hydrogen research initiative. Later in July 2005, the company reported that their fuel cell stack had achieved over 25,000 "trouble-free" kilometers powering a 2003 Nissan X-Trail FCV under real-world driving conditions.

Versa Power Systems

Headquarters:

900 18th Street, Suite 130
Golden, Colorado 80401
Phone: 303-384-2488
Website: http://www.versa-power.com

Ownership Structure:

Versa Power Systems is a joint venture of the FuelCell Energy, Gas Technology Institute (GTI), Electric Power Research Institute (EPRI), University of Utah, and Materials and Systems Research Inc (MSRI). FuelCell Energy currently owns 42% of the Versa stock.

Management:

- Dr. Robert Stokes – Chief Executive Officer
- Mr. William Barker – Director, Program Development
- Mr. Brian Borglum – Vice President and Chief Technology Officer

Brief Company Description:

Versa Power Systems is a joint venture founded in September 2001 by GTI, University of Utah, EPRI, MSRI, and FuelCell Energy. The company's products are based upon work originally performed at University of Utah and MSRI on cell materials and design development and further developed by GTI. The company is developing a planar SOFC technology for commercial and residential CHP, telecommunications, remote, and automotive APU applications. The company believes its reduced temperature of operation will allow use of stainless-steel based components in the systems instead of expensive ceramic materials typically needed to withstand higher temperatures.

The company is focused on "natural gas" fueled systems, to take advantage of the technology's ability to reform fuel internally. The company is currently focused on introducing pre-commercial SOFC systems with 3-10 kW prototype systems for field demonstrations. In October 2004, FuelCell Energy merged their Canadian SOFC operations (previously acquired from Global Thermoelectric in November 2003) with Versa Power Systems. The company has about 35 employees.

Alliances/Partners:

- FuelCell Energy – FCE is one of the founding companies of Versa Power Systems. The company joined Versa to pursue the Department of Energy SECA Program in 2002. FCE was selected as prime contractor for the cost-shared SECA program, with Versa as a sub-contractor in April 2003. Recently in October 2004, FCE combined their Canadian SOFC operations (which FCE acquired from Global Thermoelectric in November 2003) with Versa. FCE believes this will enhance their ability to advance in latter phases of the SECA program and also utilize much from Versa core competency in the SOFC technology. In this transaction, FCE increased their Versa share from 16 to 42%.

Products:

Versa Power Systems has no commercially available products at this time. The company anticipates introducing products over the next few years, although no specific timeline has been given.

Technology Overview:

Versa Power Systems is developing anode-supported planar SOFC technology that operates at reduced temperatures. Their technology, which reportedly operates in the range of 650-800 ^{o}C, uses a proprietary microstructure in thin-cell components that enables low temperature operation with increased power density. The company has reported improvements in cell manufacturing processes over the last few years to achieve lower cost and better yield. The company is developing the technology in conjunction with the following partners:

- Pacific Northwest National Laboratory – Modeling
- Dana – Low cost manufacturing
- FuelCell Energy – Internal reforming, metal interconnects, stack manufacturing, power plant development
- University of Utah – Cell technology
- MSRI – High power density stacks, advanced materials

- GTI – System design, fuel processing
- EPRI – Power electronics

Versa's proprietary intellectual property (19 patents and pending patent applications) is derived from early work undertaken by University of Utah, MSRI, GTI, and EPRI, but enhanced by the company. The company believes that stainless steel materials can be used at reduced temperatures, thereby avoiding the use of exotic high cost ceramic materials. The company's proprietary system design allows for increased power density. The company claims to have developed a proprietary high-temperature compressive seal that allows their stack to be thermally cycled without inducing any cracks.

The recent merger of FuelCell Energy's Canadian SOFC operation will enhance Versa Power's development efforts, as the company will gain the proprietary fuel cell system developments of Global Thermoelectric (such as the fuel cell system prototypes called RP2 and Aurora, including 26 patents and pending applications) and knowledge of pilot manufacturing processes and methods. This merger will enable Versa Power Systems to transfer from a purely research-based company to a manufacturing company.

Status of Commercialization:

Under the 9-year, 3-phase SECA program, Versa Power Systems successfully demonstrated the use of its patented planar, reduced temperature SOFC and thermally integrated power systems (TIPS) design. The company has demonstrated the use of uncoated ferritic stainless-steel interconnects in single cell endurance test for over 26,000 hours with a degradation rate of 1.3% per 1000 hour. Over the last few years, the company has upsized their stack platform from 16 cell stacks (81 cm^2 active area) to 112 cell stacks (121 cm^2 active area). Thus far, these technologies have been incorporated in 2 kW (84 cells) and 3 kW (112 cells) stacks operating at between 700 – 750 ^oC. The 2 kW ("Aurora") and 3 kW ("3-1") systems have DC electrical efficiency of 41% and 47%, respectively. The company is currently developing 2-3 kW prototype units for grid-parallel operation, and plans to introduce products in range of 3-10 kW for application up to 100 kW. The company anticipates having a 10 kW pre-commercial unit with a net efficiency of over 40% for field demonstration by 2008-2009, and anticipates that its SOFC systems will be priced under $1000 per kilowatt.

Voller Energy

Headquarters:

Rawdon House, Bond Close
Kingsland Business Park, Basingstoke
Hampshire RG24 8PZ
United Kingdom
Phone: +44 (0) 1256 813900
Website: http://www.voller-energy.com

Ownership Structure:

Voller Energy was listed on the London Stock Exchange Alternative Investment Market (LSE: VLR) in February 2005.

Management:

- Mr. Stephen Voller – Chief Executive Officer
- Mr. Mike Clarke – Chief Operating Officer

Brief Company Description:

Voller Energy was found in 2002 to produce battery chargers and mobile power generators. The company products incorporate Voller's system integration expertise and stack technology from Protonex. The company has to date focused on hydrogen fuel for fuel cells, although, the acquisition of low-cost fuel reforming technology from KAT- Chem GmbH in February 2005 might open new doors for use of reformate gas from liquid fuels like propane, diesel and JP-8.

Alliances/Partners:

- Palcan Fuel Cells – In June 2003, Voller Energy selected Palcan fuel Cells to supply the PC-150 stacks for their VE100 portable fuel cell system. The company reported that Palcan stacks are superior in terms of wear and tear – and important requirement for portable power products.
- Speedy Hire – In February 2005, Speedy Hire signed a three year exclusive deal with Voller Energy for the UK market. Under the agreement, Voller Energy will develop 1.2 kW portable fuel cell systems costing around £1000 by January 2006 for use in the rental industry.

Products:

- VE100 Portable Fuel Cell System – The Company started shipping its latest version of the system v3 from May 2005. The VE100 v3 weighs 9 kg and is fueled with hydrogen stored in metal hydride storage canister.

The system is capable of producing both 110V/60 Hz and 230V/50 Hz AC power, and 12V DC power.

Technology Overview:

The company's first product was released in September 2003. From that time, the product has evolved three generations. The current VE100 v3 product incorporates the proprietary Voller controller board technology – which the company claims allows for easy operation and configuration. The product is suitable for directly recharging car type batteries, which are often used in remote locations to power a wide variety of measuring and monitoring equipment. The company uses the stacks supplied from Protonex, although it appears that the company has tested stacks from Palcan Fuel Cells in their recent generation of the VE100 product. With the acquisition of the KAT-Chem GmbH – a hydrogen reformer technology developer, Voller intends to power their portable power fuel cell systems with commonly available fuels like LPG, camping gas, etc. The company is currently developing a 600 W reformer based fuel cell system running on LPG fuel and plans to introduce by end of 2006. The company also has plans to develop 1200 W reformer based unit running on diesel and aviation fuel.

Status of Commercialization:

Voller Energy is offering commercial products at this time. Voller has introduced its third generation of V100 portable power system and is being marketed under the trade name of Portapack™. This fully integrated system is currently priced at $7200 (including a canister), although the company expects this cost will be greatly reduced with volume production. The company claims to have markets in Germany, U.S., and China, and the U.K. Currently, the company has a production capability of around 100 systems per month. In a press release reported on Fuel Cell Today website the company stated its intentions to scale up the production because of their exclusive deal with Speedy Hire (U.K.), potentially a large market for its portable product. The company has already received the CE certification on their product in June 2005. In November 2004, the company also announced that their portable fuel cell system can use the DOT exempted metal hydride canisters – thereby enabling the portability and transportation of their systems by end-users. The company is partnering with various companies to develop customized fuel cell products.

Wärtsilä Corporation

Location: Helsinki, Finland

Website: http://www.wartsila.com

Technology: SOFC (planar)

- Wärtsilä supplies power plants for sea transportation and decentralized power generation to customers worldwide. The company produces 1-300 MW power plants used for base load, peaking, combined heat and power (CHP), standby, mechanical drive systems, and renewable energy applications. In 2000, Wärtsilä started a R&D program to develop and commercialize Solid Oxide Fuel Cell based CHP units for distributed power generation and marine APU markets. Later in 2002, the company collaborated with Danish technology company Haldor Topsøe (now Topsoe Fuel Cell (TOFC)) to provide highly efficient stack and fuel processing technologies. Wärtsilä will utilize its system integration and application know-how along with TOFC expertise in stack and fuel processing to develop SOFC products with power outputs above 200 kW, primarily for distributed power generation and marine applications. The company is currently testing a 1-5 kW SOFC system and developing a 20 kW prototype system. First field demonstrations are targeted for 2007, followed by production of pre-commercial units. Commercial production is anticipated by 2010.

ZTEK Corporation

Headquarters:

300 West Cummings Park
Woburn, Massachusetts 01801
Phone: 781-933-8339
Website: http://www.ztekcorp.com

Ownership Structure:

Privately held Massachusetts corporation.

Management:

- Dr. Michael S.S. Hsu – President and Chief Executive Officer

Brief Company Description:

ZTEK Corporation is developing turnkey SOFC system solutions for the stationary market segment. The company's primary focus is to develop fuel cell/gas turbine hybrid systems with capacity of 200 kW to 1 MW for base loaded distributed generation applications. The company is also working to integrate absorption chillers with its fuel cell systems (SOFC-HVAC) in cogeneration mode. Although the main aim is development of planar-SOFC fuel cell systems and hybrids only, the company has started to separately market its reformer technology. That technology is aimed at the transportation market segment and was initially developed to be used with SOFC systems. Founded in 1983, the company uses technology developed at the Massachusetts Institute of Technology (MIT) Lincoln Labs.

Alliances/Partners:

- Beacon Energy, LLC – (formerly The Renewable Resources Group, LLC) this firm is a partner with ZTEK in the Dinosaur State Park project.
- Connecticut Clean Energy Fund – provided funding for a demonstration of ZTEK's 25 kW SOFC system with an absorption chiller at Dinosaur State Park in Rocky Hill, CT.
- California Fuel Cell Partnership – ZTEK is collaborating with Pacific Gas and Electric (PG&E) to construct and operate a 600 standard cubic foot per hour hydrogen refueling station at PG&E's Service Center in San Carlos, CA.
- Maw-Chong Corporation– ZTEK's distributor in Japan and Taiwan; this firm has committed to receive two hydrogen reformer units for operational training and two commercial-size hydrogen reformers for delivery in 2003-2004. According to the company's website these deliveries are now re-scheduled for 2005.

Products:

The company does not have commercial products at this time. Several ZTEK products are now being demonstrated.

Reformers

ZTEK reformers will convert gasoline, natural gas or methanol to hydrogen at 85% efficiency and are targeted to support hydrogen refueling infrastructure for fuel cell vehicles. Individual models will fit in a 10'× 10' × 10' space, which will allow easy integration into existing gasoline fueling stations. The company is primarily demonstrating its 600H High Temperature Steam Reformer, which produces 99.99% hydrogen for fuel cell applications. The product integrates desulphurization, water purification, low NO_x burner, steam generator, catalyst assembly, water-gas shift reactor, and pressure swing absorption units. The

company is also working on integrating carbon dioxide sequestration technology with its reformers to enable zero-emissions operation. The company's reformer products include:

- ZES 600H – reformer that produces 600 standard cubic feet of hydrogen per hour.
- CTU 300H/12 E – emerging ZTEK product (mentioned in the 2004 Fuel Cell Seminar paper) that produces 300 standard cubic feet of hydrogen per hour plus 12 kW of electricity for distributed power generation applications.
- ZES 2000H/75E – fuel cell-reformer hybrid that produces 2000 standard cubic feet of hydrogen per hour plus 75 kW of electricity for distributed power generation applications.
- ZES 4000H – reformer that produces 4000 standard cubic feet of hydrogen per hour.

Solid Oxide Fuel Cell Hybrid Systems

ZTEK is also developing SOFC systems for the distributed generation marketplace including:

- DG 200E – SOFC - gas turbine hybrid.
- DG 150E/50 AC – SOFC coupled with an absorption chiller.
- ZES 2000H/75E – SOFC coupled with the company's steam reformer for co-production of hydrogen.

Technology Overview:

ZTEK is developing large, commercial-scale SOFC and reformer technologies, and aims to provide these turnkey systems for the distributed generation and automotive market segments. The company claims to have over 200 patents protecting a variety of its planar solid oxide technologies and its high-temperature steam reformer. The company claims that their core SOFC technology is unique and allows for radiant thermal integration, which results in effective heat recovery and high efficiency. Also, the company claims that their SOFC integrates well with gas turbines to achieve highly efficient hybrid systems. The SOFC units are modular, allowing for easy installation and scaling.

Status of Commercialization:

ZTEK is focusing on the distributed generation market with 200 kW SOFC and SOFC-hybrid modules. In 1995, with funding from the Electric Power Research Institute, the company operated a 1 kW fuel cell stack for over 16,000 hours to prove their SOFC design concept. Since that time, the company has continued developing its concept and is now demonstrating both its fuel cell and reformer

systems. Beginning in 1998, a 25 kW HECP (hydrogen and electricity co-production) system was demonstrated at Huntsville, AL and later moved to Woburn, MA. As reported during the 2004 Fuel Cell Seminar in San Antonio, this particular installation has logged more than 30,000 hours of operation, and helped in the refinement of the balance of plant component technology. The company is currently demonstrating a 25 kW SOFC system with an absorption chiller at Dinosaur State Park in Rocky Hill, CT, while their 200 kW SOFC/GT hybrid system is under construction. A definitive timeline for commercialization of either system is not known, however, the company claims their fuel cell systems will hit the marketplace in the "next couple of years" at a cost of $1,600 per kilowatt and an efficiency approaching 60%. The company states that their 25 kW SOFC systems are currently available for field demonstration for around $650,000.

The company is also working with Pacific Gas and Electric to construct and operate a 600 standard cubic foot hydrogen refueling station. The company also delivered one of their high performance steam reformers to PG&E in 2004 to support hydrogen refueling infrastructure; one more unit is scheduled to be delivered later in 2005.