Powering the Future:
Fuel Cells Promise Clean, Reliable Power

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Fuel cells, which use hydrogen and oxygen to produce electricity through electrochemical reactions, form the heart of fuel cell power generation systems. They have the potential to create much more reliable power, with lower levels of undesirable emissions and noise and higher overall efficiency than more traditional power generation systems. With existing and projected applications ranging from spacecraft to private automobiles, large stationary power generation systems to small electronic devices, fuel cells are poised to play an increasingly critical role in meeting the world's growing demand for clean, reliable power.

[For a more detailed discussion of fuel cell systems and how they work, click here.]

Connecticut is currently home to a number of companies and research centers on the cutting edge of fuel cell research and development. These include United Technologies Corporation's UTC Fuel Cells (formerly International Fuel Cells) in South Windsor, which has supplied NASA with fuel cells for manned space flight since the early Apollo missions and has long been considered a world leader in fuel cell technology; Fuel Cell Energy in Danbury and Torrington, the largest manufacturer of molten carbonate fuel cells in the world; and Proton Energy Systems in Wallingford, a leader in the field of medium-sized hydrogen generating systems. New, but important, players in the state's fuel cell industry are Southbury-based GenCell, rapidly becoming known for innovative approaches to fuel cell design, manufacture and system reliability; and the Connecticut Global Fuel Cell Center, a center for research and development established at the University of Connecticut's Storrs campus in 2001. The Center's mandate includes advancing research and development of advanced fuel cell technologies and associated technologies, educating "students of all ages," commercializing fuel cell technology, and serving as the "principal center" for demonstrating innovative and critical applications of fuel cell technology.

The presence of some of the world's largest fuel cell manufacturers, along with a number of smaller companies engaged in innovative research and development and a world-class center of excellence, makes Connecticut a leader in the field of fuel cell technology.

In April 2002, the Connecticut Academy of Science and Engineering was asked to conduct a study of the fuel cell industry, to include a description of the most current fuel cell technology, a description of current applications for fuel cells, an examination and summary of potential future applications for fuel cells, and an assessment of the leading fuel cell technologies and their development status and application time frames, with particular focus on Connecticut fuel cell producers. That study, requested by the Connecticut Department of Economic and Community Development (DECD) and the Connecticut Economic Resource Center (CERC) was released in December of 2002.

Entitled "A Study of Fuel Cell Systems," the study identifies five different kinds of fuel cell technologies that have been developed for varying applications. These are

1. **Alkaline Fuel Cells**, which can be very small, and have been used in NASA's space shuttle and in other applications where pure gases can be used as fuel;

2. **Molten Carbonate Fuel Cells** (MCFC), designed for large, stationary systems;

Application	**Fuel Cell Type**				
.	AFC	MCFC	PAFC	PEMFC	SPFC
Small electronic devices	.	.	.	x	.
Portable power/APU	..	..	..	x	x
Transportation-automotive	.	.	.	x	.
Transportation - bus and truck	.	.	.	x	.
Military and space applications	x	.	.	x	.

Residential power and heat	.	.	.	x	x
Off-grid	.	.	.	x	x
Commercial building power and heat	.	x	x	x	x
Assured power	.	x	x	x	x
Distributed stationary power	.	x	.	x	x
Central station power	.	.	.	.	.
Hydrogen generation	.	.	.	x	.

3. **Phosphoric Acid Fuel Cells** (PAFC), the only kind of fuel cells that are currently in widespread use in commercial or relatively large stationary applications;

4. **Polymer Electrolyte Membrane Fuel Cells** (PEMFC), expected to be the system of choice for vehicular power applications, but also being developed for stationary power applications; and

5. **Solid Oxide Fuel Cells** (SOFC), a prime candidate for relatively large, stationary systems.

The most important advantages (cited for all fuel cell technologies) are “very low levels of unwanted emissions” and “low noise,” according to the study, while the most significant challenges to the development of fuel cell power systems include cost (system and life cycle), lack of demonstrated reliability for most types, lack of infrastructure for some types, and the need to identify and develop markets.

The report notes that Connecticut is already considered a world leader in the application of fuel cell systems for stationary power applications (for instance, UTC Fuel Cells already has over 250 PAFC-based units installed worldwide) and is the only state that can claim “substantial system experience in any fuel cell power application.” However, the authors also note that other states, including Michigan, Ohio, California, and Texas, are actively engaged in developing fuel-cell-based industries which could pose “significant challenges” to Connecticut’s existing lead in the field of stationary power applications as well as its efforts to enter the market for transportation applications (automobiles and buses).

The study identifies a wide range of uses, or applications, for fuel cells — from commercial building heat and power to military applications to small electronic devices — and time frames for achieving market penetration that range, depending upon the application, from one to seven years.

Summary of Fuel Cell Commercialization

Use/Application	Power Levels (kW)	CT Companies	Estimated Year for Commercial Volume
Small electronic devices	0.001- 0.01	Proton Energy, GE	.
Portable power and auxiliary power units	0.5 to 10	Proton Energy	Current
Transportation-automotive	550 to 1000	UTC Fuel Cell	2012
Transportation - bus and truck	100 to 200	UTC Fuel Cell	2009
Military and space	Wide range	UTC Fuel Cell, Fuel Cell Energy	.
Residential power and heat	1-5	.	2007
Off-grid power	Wide range	.	.
Commercial building power and heat	100 and up	UTC Fuel Cell, Fuel Cell Energy	2003
Assured power	100 and up	UTC Fuel Cell, Fuel Cell Energy, Sure Power	2003
Distributed stationary power	100 and up	UTC Fuel Cell, Fuel Cell Energy	2003

“Large capacity stationary power” — defined as a system with an output power capability exceeding 100kW — is likely to be the “first significant commercial market,” according to the Academy report. This market should see immediate growth (in 2003-2004) due to significant price level breakthroughs which were recently announced. This market includes Stationary Reliable Power (applications in which reliability is vital, such as rapid response financial systems, on-line commerce, hospitals, etc.); Commercial Building Power (small, commercial buildings or strip malls, where the heat generated by the system often is also used, resulting in a combined usage called “Combined heat and power” or CHP); and Distributed Power (applications that serve several customers or a small substation, usually as part of the overall power grid). Two Connecticut companies, UTC Fuel

Hydrogen generation	Produces hydrogen gas	Proton Energy	Current

Cells and Fuel Cell Energy, are nationally competitive in this market, with even greater market penetration anticipated as production volume increases and prices drop.

Transportation markets, which include transit buses, other fleet-type commercial vehicles, and automobiles, will be more difficult to penetrate, according to the study, because of the relatively low cost of existing piston-engine power plants. Although the potential market is large, costs must be reduced sufficiently to make fuel cells an economically competitive alternative.

Very low power (~1-5 kW) fuel cells for electronic applications offer a promising market, and one which no Connecticut company is currently targeting, according to the study.

Finally, the use of fuel-cell-like devices to make pressurized hydrogen gas is expected to be a small but growing “niche” market, competing with the pressurized bottled gas industry.

The study concludes that, while there are still major obstacles to large-scale fuel cell commercialization, including cost and reliability issues, there are also many opportunities for “rewarding investments” aimed at lowering the manufacturing costs, improving long-term reliability, and increasing market penetration. — ***Martha Sherman, Connecticut Academy of Science and Engineering***

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