PERP Program – New Report Alert

November 2003

Nexant's ChemSystems Process Evaluation/Research Planning program has published a new report, ***Stationary Fuel Cells (02/03S6)***.

Background

Fuel cells (FC) have received a tremendous amount of attention in the press, government and academic R&D programs, government policy formation, and among investors. Billions of dollars annually are being expended worldwide on FCs and related developments among thousands of organizations. FCs are a revolutionary and potentially widely applicable technology that is also somewhat misunderstood and perhaps over-expected by investors and the public at large.

The recent severe blackout in the northeastern United States and in Canada that affected 50 million people has spurred increased interest and boosted stock prices of FC industry players, given the fact that the lights stayed on at hospitals, businesses and other locations with on-site generation (to which some FCs are targeted). Indeed, some in the New York City area and in Canada were already using FCs. Overall, interest in FCs for central and distributed power generation is being driven by deregulation of the electric power industry in the U.S., Europe and elsewhere, along with the problems this has partially wrought with aging power transmission systems and the demand for natural gas. The "9/11" tragedy has also widened interest in power security, which distributed power generation using FCs can help address.

Beyond some recent advances in several aspects of the basic, ancillary and enabling technologies, fuel cells will require much more research and development and a several-fold decrease in price before they are widely adopted for the variety of applications that are proposed for them. The engineering development and price reduction challenges fall into several key categories that should be of interest to PERP subscribers:

- Materials – polymer and ceramic membrane materials; catalysts for fuel processors (reforming, water gas shift, etc.), flue gas conversion and guarding against sulfur, CO and other FC poisons; seal systems; polymer, composite and metallic structures

- Manufacturing systems – many are similar to those used in the semiconductor, consumer electronics or ceramics industries, as well as the automotive assembly sector and its components supply chain

- System integration – largely chemical and electronic engineering issue to be solved

The several competing types of FCs each have strong proponents in industry, government and academia. The public discourse about FCs is colored by the priorities and agendas of these champions, and their positioning for the purposes of commercial advantage (product sales and stock price), public image or sharing in public funding of R&D. There is also great confusion over FCs for vehicle applications contrasted with stationary applications, and over-association of both with the very tenuous development of a postulated "hydrogen economy".

In the 1960s, NASA adopted alkaline-type fuel cells for its space program. Since their initial use in space, fuel cells have been improved and are becoming commercially available in products such as: residential and small business power generators; commercial and industrial power-and-heat cogenerators operating on purchased fuels and waste gases; and larger-scale stationary power generators. They are expected to be available in the future in automobiles, computers and cell phones. Fuel cells also have potential as independent or distributed power providers for credit card processing centers, jails, cellular phone towers, mining equipment, communication centers, navigation equipment, road signs, defense installations, urban transit buses, in truck cabs and even portable household appliances.

Operating Principles

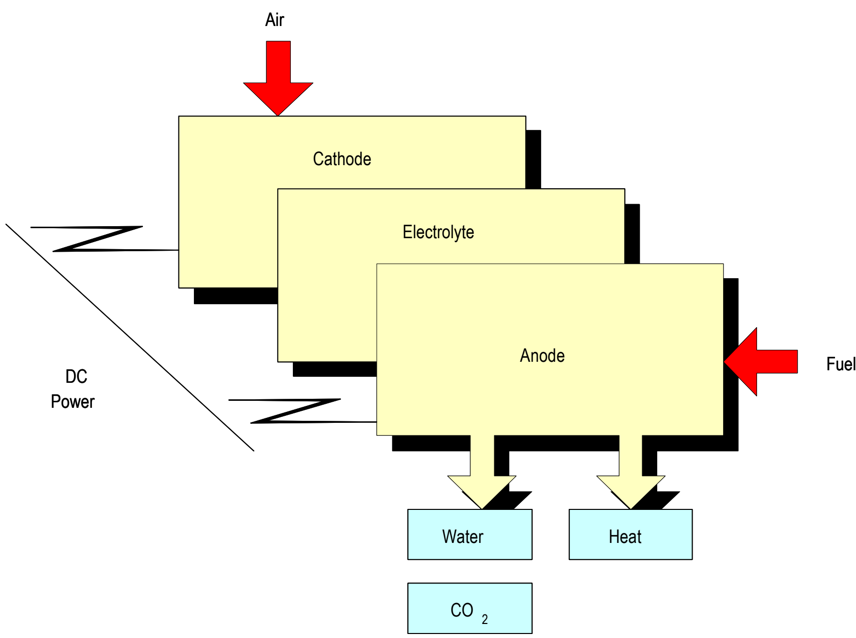
Generically, a fuel cell uses an electrochemical process to generate electrical power through catalytic oxidation of a fuel.

Figure 1, below, illustrates a generic fuel cell operation.

In its simplest chemical form, the fuel cell catalytically oxidizes hydrogen using the following steps:

- Hydrogen molecules adsorb on the surface of the anode catalyst
- The hydrogen molecule is split, with the two resulting atoms being ionized to H^+ ions (protons) with the residual electrons being conducted away through an electrical circuit
- Protons desorb from the anode catalyst and diffuse through an electrolyte layer to the cathode, driven by potential and diffusion gradients
- At the cathode, oxygen molecules are adsorbed and split into individual atoms
- The oxygen atoms accept free electrons from the electrical circuit to form O^{2-} ions
- Finally, two protons combine with the O^{2-} ions to form water, which desorbs from the cathode – nitrogen in the air is vented from the cathode area and carries off waste heat

Figure 1
Fuel Cell Operation



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A voltage potential develops across the cell, due to the concentrations of hydrogen ions at the anode and oxygen ions at the cathode. This, combined with the free electrons that are available to travel through the external circuit result in the fuel cell providing useful power, derived from the energy available in the oxidation process. Individual cell voltages are generally too low for larger scale practical applications. To get higher voltages and more power, many cells are ganged together in a stack.

Fuel Cell Types

There are four major types of fuel cells currently under development with mass market potential today:

- Two low temperature types
  - Proton exchange membrane (PEMFC)
  - Phosphoric acid (PAFC)

- Two high temperature types
  - Solid oxide (SOFC)

– Molten carbonate (MCFC)

The PEMFC and SOFC types use solid-state ionic exchange membranes, while the PAFC and MCFC types are based on liquid ionic exchange media. Two versions of SOFC are being developed, planar and tubular, each having distinct potential advantages in manufacturing and operating characteristics.

This report focuses on SOFCs for stationary applications, and presents technical, commercial, and practical evidence for this choice. Patterns emerging in the multi-faceted, complex, entrepreneurial, and politically-charged field of fuel cell development that support this view are detailed.

The drivers for stationary FCs are primarily:

- Higher fuel conversion efficiencies for electricity generation, in general, than heat engine generator sets (e.g., for natural gas, 40-60 percent versus 25-45 percent)

- Modular designs afford the same high efficiencies at low capacities as high capacities for distributed generation (DG)

- Lower emissions, quieter, more compact than heat engine generator sets

- No moving parts, potentially allowing more feasible untended startup on demand and lower maintenance costs

- DC electricity generation can yield improved power quality

- Potential for combined heat and power generation (CHP)

The relevance and degree of each of these drivers varies with the application, fuel, and type of FC. For example, DC power quality and untended startup are not as important features in central power plants as they may be at remote sites, while high fuel efficiency and low emissions are key for large utility and industrial applications. In contrast to both of these cases, small CHP/DG systems are generally targeted at residential, commercial and industrial sites, and are not relevant to power plants or remote emergency power systems.

Stationary FCs will continue to compete, for R&D resources and commercially, with rapidly-developing wind and solar energy, especially combined with advanced batteries and other energy storage media for remote and emergency power and DG, and with fully commercial microturbines for CHP/DG.

All the types of fuel cells continue to have many technical challenges to overcome. In particular, ceramic membrane-based solid oxide fuel cells (SOFCs), in both tubular and planar membrane configurations, face challenges of durability and cost. However, they are also capable of mass production and have other excellent characteristics for stationary power applications.

At a typical price of $4,500/kW in 2003, fuel cell technology is not ready to compete in the market, as seen in Table 1.

Table 1
Fuel Cells Compared to Other Stationary Energy Technologies

Generation Technology	Typical Installed Capital Cost (US$ per kilowatt)	CHP Capability	Air Emissions
Gas Turbine	700 to 900	Yes	Small
Microturbine	450 to 1000	Yes	Small
Steam Turbine	800 to 1000	Yes	Moderate
Wind Turbine	800 to 1300	No	None
Natural Gas IC Engine	200 to 350	Yes	Moderate
Fuel Cell	3700 to 5000	Yes	Negligible
Solar Photovoltaic (PV)	over 5000	No	None

Source: Northeast Regional Biomass Program, Xenergy report, 2002

This report also discusses:

- Characteristics/issues of fuel cell types
- Environmental drivers and issues
- Auxiliary requirements (fuel generation, fuel/effluent treating, power conditioning, heat recuperation, etc.)
- Profiles of developers of SOFC (and other types)
- Chemical manufacturer opportunities in SOFC materials
- Market assessment and competing technologies for SOFC in DG/CHP applications.

Figure 2 illustrates the applicability of the various fuel cell types to segments of the distributed generation market.

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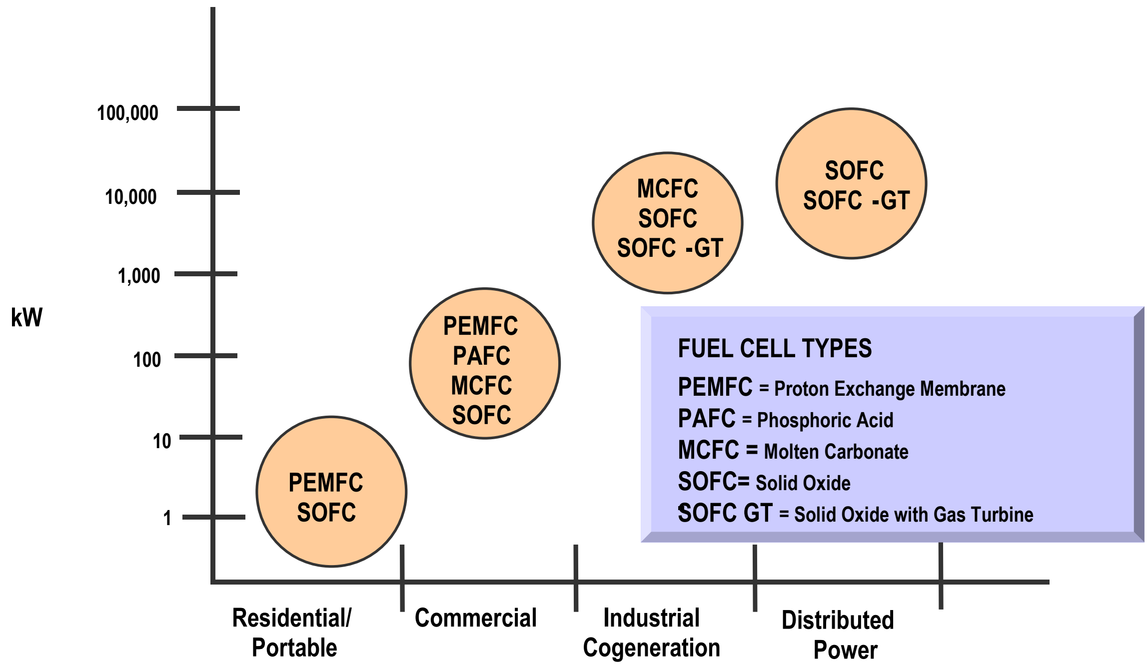
Figure 2
Fuel Cell Distributed Generation Market Sectors



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