Opportunities with Fuel Cells

by Marvin I. Singer and Charles E. Pax[1]

Introduction

The concept for fuel cells was discovered in the nineteenth century. Today, units incorporating this technology are becoming commercially available for cogeneration applications.

Fuel cells provide a way of generating electricity without combustion and without air and water pollution. They are electrochemical devices much like batteries that convert the chemical energy in a fuel, such as methane or methanol, directly into electricity. They have some features similar to batteries: both have positive and negative electrodes, and an electrolyte. However, unlike a battery, which can provide power for only a limited time before requiring recharging or replacement, the fuel cell can operate continuously, producing electricity as long as a fuel and air are supplied.

Fuel cells are efficient. In units commercially available today, over 40 percent of the energy in the fuel is converted directly to electricity. When used in cogeneration applications, over 80 percent of the energy in the fuel is available as useful heat and electricity. Fuel cells can produce greater value from the natural gas consumed than any other type of power generation system. Future fuel cell systems are projected with electric generation effectiveness of 50 to 60 percent.

Products that will be competing with fuel cells in the power generation market include gas turbines and, for large units, gas turbine combined cycle systems. Efficiencies over 50 percent have also been projected for these technologies. Market share among the competing products is expected to depend heavily on overall costs and ability to meet future emission requirements. Of particular importance in cogeneration uses, will be the ability to meet specific site requirements such as the need for quiet operation and availability of units in the site range of several hundred kilowatts to several megawatts.

The Department of Energy has sponsored the development of fuel cell technologies in cooperation with gas and electric utilities and other private sector interests. The Department is assisting this newly emerging industry to accelerate providing the benefits of these technologies to the Nation and, through export sales, to the world.

Why Fuel Cells Interest the Natural Gas Industry

Fuel cells can provide new business opportunities to gas utilities—early products are available now and additional ones are coming. Costs will be decreasing and uses of these power plants will be increasing.

Natural gas is the fuel of choice for bringing fuel cells to market due to considerations of cost, availability, cleanliness and the minimum amount of fuel pretreatment required. Other compressed gas or liquid fuels can provide backup or emergency operating capabilities.

Benefits for Gas Suppliers

Fuel cell power plants provide a new way to increase the value of natural gas to both suppliers and customers. Fuel cells provide a clean, convenient, and efficient means for generation of electricity and cogeneration of heat. However, the early units that are now on the market are still quite expensive at the current low production rate.

Gas utilities can realize increased gas sales by applying fuel cells for distributed power generation and cogeneration. New business opportunities also exist involving energy services, equipment lease, distribution and sales of equipment, and export markets. Increased gas sales and overall profitability improvements are also available through leveling of seasonal loads, with fuel cells providing electricity as well as satisfying heating and cooling demands.

[1]Marvin Singer is the Deputy Assistant Secretary for Advanced Research and Special Technologies and Charles Pax is Program Manager for the Fuel Cell Systems, both with the Office of Fossil Energy, Department of Energy.

In areas that are environmentally constrained or that incur high costs for increased electricity transmission, fuel cells provide an attractive means not only to preserve the market, but to greatly expand the market for gas. In some cases marketable emission credits can also be realized.

Benefits for Gas Customers

Gas customers can benefit through lower costs and the presence of emergency or backup capabilities for electricity, heating, and cooling. The ability to locate fuel cells near or at the point of power use also reduces electricity transmission requirements and losses, thus reducing costs which would otherwise be passed on to the user. Customers also will receive significant environmental benefits from these clean power plants that will greatly simplify siting and permitting. Emission levels of fuel cell power plants currently operating at customer sites are less than one-tenth of the most stringent emission standards projected by the year 2000. Blanket exemptions for most siting permits have been granted by the California South Coast Air Quality Management District for the fuel cell units installed in their district.

Present Uses

The gas industry has been a very active participant in the development and field testing of fuel cell power plants. Gas utilities and the Gas Research Institute (GRI) have played major roles in the marketing of the early commercial units.

Table FE1. Sales of Commercial Fuel Cell Units Manufactured in the United States (Two Hundred-Kilowatt Units)

Country	User / City	Units Ordered
United States	Atlanta Gas Light / Atlanta	1
United States	Brooklyn Union Gas / Brooklyn	1
United States	Consolidated Natural Gas / Pittsburgh	1
United States	Equitable Gas / Pittsburgh	2
United States	National Fuel Gas / New York	2
United States	People's Gas, Light & Coke / Chicago	1
United States	Rochester Gas & Electric / Rochester	1
United States	Sacramento Municipal / Sacramento	1
United States	Southern California Gas / Los Angeles area	10
Austria	Austrian Ferngas / Vienna	1
Canada	Ontario Hydro / Toronto	1
Denmark	Jutland Gas / Toftland	1
Finland	Imatran Voima / Vanaja	1
Germany	Ruhrgas / Dorsten	1
Germany	HEAG / Darmstadt	1
Germany	Thyssengas / Duisburg	1
Italy	Milan Municipal / Bologna	1
Japan	Tokyo Gas / Tokoyo	10
Japan	Toho Gas / Nagoya	1
Japan	Osaka Gas / Osaka	10
Korea	Korea Gas / Amsan	1
Sweden	Sydkraft / Bara	1
Switzerland	Geneva Gas (SIG) / Geneva	1

Source: ONSI Corporation.

The initial commercial units being sold in the United States are rated at 200 kilowatts electrical output and up to 220 kilowatts co-product thermal output (760,000 Btu/hour) at temperatures above 74 ˚C (165 ˚F). These units are being manufactured by the ONSI Corporation of South Windsor, Connecticut, a subsidiary of International Fuel Cells Corporation, also of South Windsor. Over 50 units have been delivered to approximately 25 utilities in the United States and other countries. Some of these are shown in Table FE1. The Southern California Gas Company is installing 10 units in a range of applications in their service area including office buildings, hospitals, hotels, and other industry and commercial applications. One unit (shown in Figure FE1) is installed at the headquarters building of the South Coast Air Quality Management District — an excellent place to demonstrate the environmental advantages of this new type of power plant. The units are truck transportable and fully enclosed for outdoor installation. Forty of the 200-kilowatt units were installed and operating by January 1, 1994, and had logged a total of over 250,000 operating hours. Operating availability has been approximately 95 percent. Demonstrated emission levels are on the order of 1 percent (or less) of California standards for combustion engines. Operation of the units is reported to be proceeding smoothly for a newly introduced product.[2]

Demonstrations of Future Uses

The 200-kilowatt units use a cell electrolyte composed of phosphoric acid. In addition to establishing a growing market presence, the 200- kilowatt units are expected to pave the way for improved phosphoric acid fuel cell products as well as fuel cells utilizing carbonate electrolytes and solid oxide electrolytes. These more advanced products are expected to provide simple systems having performance and operational advantages that will enable substantial expansion of the market for fuel cell products. Developers are preparing to demonstrate advanced natural gas-fueled units in 1994 and 1995 at several sites in California.

A cogeneration unit with a 250-kilowatt electric output is to be installed in San Diego with participation of San Diego Gas and Electric Company. The design of this field test unit is the result of a team effort by M-C Power Corporation of Burr Ridge, Illinois, the Institute of Gas Technology, the Bechtel Group, and Stewart and Stevenson Services, Incorporated.[3]

A second field test will involve a 2-megawatt power plant to be installed at Santa Clara, California, with the participation of a consortium that includes several utilities and municipalities. This unit has been designed by Fuel Cell Engineering Corporation, a wholly owned subsidiary of Energy Research Corporation of Danbury, Connecticut, together with Flour Daniel Corporation. Both of these units are based on fuel cells using a carbonate electrolyte in the cells and operating at temperatures which will permit co-product heat at temperatures approaching 550 ˚C (1,000 ˚F). The layout at a proposed site of the 250-kilowatt cogeneration field test demonstration is shown in Figure FE2. The fuel cell unit would be located beside other on-site hospital equipment and provide approximately 10 percent of the electricity and heat demand of the hospital complex shown. Figure FE3 shows one of the 16 fuel cell stacks that will be installed in the 2-megawatt power plant at Santa Clara. Power produced by the plant will be utilized on the utility grid.[4]

Westinghouse Electric Company is planning the demonstration of a 20-kilowatt unit with Southern California Edison Company in 1994 and a 100-kilowatt unit with Southern California Gas Company in 1995. These demonstrations are based on fuel cells using a solid oxide electrolyte operating at temperatures that will permit co-product heat at temperatures approaching 1,000 ˚C (1,800 ˚F). An earlier 20-kilowatt test unit built by Westinghouse is shown in Figure FE4. This unit is a complete generator which produces regulated AC power output and accepts pipeline natural gas input.[5]

A recent study estimated a world market for fuel cells in the year 2,000 ranging from approximately 1,150 to 2,850 megawatts per year. The North American market was estimated to be between 500 and 1,000 megawatts per year. The degree of success in these markets will be very dependent on how much progress is made in reducing capital costs.[6]

[2]ONSI Corporation.

[3]Alliance to Commercialize Carbonate Technology & M-C Power Corporation.

[4]Fuel Cell Commercialization Group and Energy Research Corporation.

[5]Westinghouse Electric Company.

[6]"The Role of Fuel Cell Technology in the International Power Equipment Market - Policy/Strategy Issues," Arthur D. Little, Inc. (September 1993).

Costs and What Is Being Done About Them

The current market-entry units have been produced in small volume and consequently have had a high cost. Existing production facilities have been operating at approximately 10 percent of capacity. The lack of sustained, high-capacity production has prevented the "learning curve" cost reductions typically experienced in manufacturing a new product. Installed cost of the 200-kilowatt units have varied depending on the particular installation, but values at or above $3,000/kilowatt have been reported. A recent study estimated that a significant market for these cogeneration units will require installed costs in the $2,000- to $1,500-/kilowatt range.[6] DOE and developer cost goals for advanced fuel cell units for power generation are below $1,000/kilowatt.[7] Little long-term operating data exists on fuel and operating costs, however with the high fuel efficiencies demonstrated and the low maintenance and high availability expected, these costs should be quite favorable.

Industry and Government Cooperation —DOE Activities

Costs are expected to decrease substantially as sales volume increases and improvements are made in the product and in manufacturing methods. The U.S. Department of Energy (DOE), the GRI, and the Electric Power Research Institute (EPRI) have been working with the gas industry and electric utilities to enable the manufacturers to produce products that meet user needs at competitive prices. Currently, a major area of emphasis in the development effort is improved integration and packaging for simple, trouble-free use and rapid installation. Further cost reductions are also expected through improvements to individual components, increased use of existing high-volume components, and gains in the manufacturing processes.[7] In fiscal years 1993 and 1994 the U.S. Congress also provided funding to the Department of Defense for purchase of commercially available fuel cell power plants.[8]

A commercial manufacturing capacity of approximately 200 of the 200-kilowatt phosphoric acid units per year exists at present. Two pilot manufacturing facilities exist for the carbonate fuel cell units with capacities of 2 to 4 megawatts per year each, and these capacities can be increased with modest modifications to the manufacturing facilities. Pre-pilot manufacturing capacity of less than a megawatt per year exists for the solid oxide technology. Increased manufacturing capacity and additional field testing of improved products are part of the manufacturers' commercialization plans.[9]

While substantial progress has been made in the development of carbonate fuel cells, further advances will be necessary to achieve the cost and performance required for commercial viability. These advances are expected to involve not only the fuel cell stack itself but also simplification of the "balance-of-plant" equipment. Improvements are also expected in system integration and in packaging the final product. Therefore, in June of 1993, DOE issued a procurement to develop a complete, lower cost carbonate fuel cell power plant package. It is anticipated that this new, $150-million "product improvement and cost reduction" effort will lead to the manufacturing of high-performance, commercially competitive 500-2,000-kilowatt natural gas-fueled carbonate fuel cell power plant modules. This new effort is expected to begin in calendar year 1994.

The DOE is continuing to support development and scale-up of tubular solid oxide fuel cells at Westinghouse Electric Company with much of this effort also focused on reducing overall system costs to meet market requirements. Alternative concepts continue to be evaluated by DOE to ensure that opportunities are not missed, and research efforts on specific areas contributing to high costs are also being pursued.

The current Administration supports federal programs that go beyond research and development, where appropriate, to promote the broad application of new technology and expertise. The DOE has been an active participant in cost-shared funding of industry research and development of fuel cell power plants. New programs are being proposed to stimulate the growth of this emerging United States manufacturing industry by providing market incentives to help overcome the hurdle of higher first costs associated with the market-entry units.

[7]DOE Office of Fossil Energy, Fuel Cell Program Plan, 1993.
[8]FY 1993 and FY 1994 Defense Appropriation Acts.
[9]Source: Fuel Cell Manufactures.

Making Opportunities

Opportunities exist to participate in the early market applications of these entirely new types of power plants. The market for power generated by fuel cells is large and is expected to expand because of their high efficiency and low emission levels. Some gas utilities in California, such as Southern California Gas and San Diego Gas and Electric, are among the leaders in realizing these opportunities. The environmental awareness which has hastened introduction of these power plants in California is increasingly extending to other States as well.

The developers and potential users of these new technologies agree that additional field test demonstrations are needed. These demonstrations would provide customers and financial backers with the confidence required for rapid commercialization of these more advanced power plants. Manufacturers are currently discussing future field tests with gas utilities and other interested groups.

Two consortia have formed to assist in commercialization of fuel cell technologies (and to be early participants in realizing benefits from commercialization). One consortium is the Fuel Cell Commercialization Group (FCCG), a buyer's consortium cooperating with Energy Research Corporation and composed of approximately 40 members representing public and private gas and electric utilities and independent power producers in 18 States and Canada. The second consortium, Alliance to Commercialize Carbonate Technology (ACCT), is cooperating with M-C Power Corporation and consists of approximately 68 members from utilities and other prospective users of these power plants. These consortia were established by the private sector to stimulate end-user input and to create a strong partnership between customer and developer. Both consortia as well as other utilities have been active in providing awareness of user needs and in planning field tests. The consortia also provide an effective means to keep informed of progress in developing and using these technologies.

Summary

The first commercial fuel cell products operating on natural gas are now available. The user evaluation, product improvement, and cost reduction processes are well underway. Significant opportunities exist for new business by gas utilities with these market-entry fuel cell products. Additional opportunities are developing that involve advanced fuel cell products, and some consortia have been forming to take advantage of these opportunities.

FOR MORE INFORMATION:

Addresses of some of the organizations mentioned in this article:

Fuel Cell Commercialization Group,
1101 Connecticut Ave., NW,
Washington, DC 20036-4303
(202)296-3471

Alliance to Commercialize
Carbonate Technology,
8040 South Madison St.,
Burr Ridge, IL 60521-5808
(708)986-8040 ext.107

Gas Research Institute,
Cogen and Prime Mover Research,
8600 West Bryn Mawr Ave.,
Chicago, IL 60631
(312)399-8178

Electric Power Research Institute,
Fuel Cell Program,
3412 Hillview Ave., PO Box 10412
Palo Alto, CA 94303
(415)855-2292

Department of Energy,
Fuel Cell Program, FE 73,
Washington, DC 20585
(301)903-2832

RELATED READING:

"Overview, Fuel Cells," EIA *Natural Gas Monthly* (June 1992).

"The Gas Powercel National Market Report, Characterization of the Onsite Fuel Cell Market," GRI-85/0308, (December 1985).

J.B. O'Sullivan, "Advances in Fuel Cell Technology," Proceedings of the Electric Utility Congress '93, Association of Energy Engineers, June 1993.

"The Vision of Distributed Generation," *EPRI Journal* (April/May) 1993.

Fuel Cell Systems Program Plan, Fiscal Year 1993, Report No. DOE/FE-0280, U.S. Department of Energy.

Fuel Cells, Technology Status Report, Report No. DOE/METC-92/0276, (July 1992).

Fuel Cells A Handbook, Report No. DOE/METC-88/6096, U.S. Department of Energy.

T.A. Damberger, "Fuel Cells for Energy Generation at Medical Centers," 1993 World Energy Congress.

"The Pole of Fuel Cell Technology in the International Power Equipment Market-Policy/Strategy," Arthur D. Little, Proposed for the World's Fuel Cell Council, January, 1993.

Note: DOE reports are available from the National Technical Information Service (NTIS), U.S. Deptartment of Commerce, 5285 Port Royal Rd., Springfield, VA 22161.