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WHAT WORKS

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Expanding the Role of Natural Gas

With global population now at 7 billion and climbing, demand for efficient, environmentally aware energy is going nowhere but up. According to the Energy Information Agency (EIA), the U.S. alone will see an expected 223 GW of new generating capacity demand between 2010 and 2035.

The trouble is, this increased demand can no longer be met solely by the construction of large, central generation power plants. More complex permitting for centralized plants, particularly clean air permitting, high project costs and limitations in the transmission infrastructure all point to a solution comprised of smaller power plants at locations right where the power is consumed. However, there is real opportunity for utilities, independent power producers and large industrial power users to capitalize on the natural-gas infrastructure to meet this demand by using distributed generation fuel cell power plants.

Natural gas is a low-carbon fuel source compared to other conventional fuels used in power generation. The average carbon dioxide emission from natural gas is approximately 119 lb/MMBtu, while that for coal ranges from 205-227 lb/MMBtu^[1]. Abundant gas supplies in North America, a well-established distribution infrastructure and low natural gas costs provide an attractive long-term outlook for natural gas powered base-load distributed generation, as long as that power can be clean, quiet and efficient. To that end, fuel cells stand out as the most efficient means available to produce electricity from natural gas for their size class; low emissions and quiet operation make them particularly well-suited to distributed generation applications.

What is a fuel cell?

A fuel cell is a device that converts the energy present in a fuel to electricity using an electro-chemical process.



Fuel cell with heat recovery used for hot water heating at a university.
Photo courtesy FuelCell Energy.

It is similar to a battery in some ways; a battery converts stored chemical energy to electrical energy. However, a fuel cell does not store energy in the form of internally contained reactants; instead, fuel and oxidant reactions are continuously fed to a fuel cell, which converts the energy in the fuel to electricity through an electrochemical reaction between the fuel and oxygen. Like a battery, a fuel cell consists of two electrodes – an anode (which is supplied with fuel) and a cathode (which is supplied with oxygen, typically ambient air). An electrolyte separates the electrodes and conducts ions between the anode and the cathode, which then drives an external electrical load, as shown in the figure.

Fuel cells require hydrogen as the fuel source. However, due to the absence of a well-established hydrogen infrastructure, commercial fuel cell manufacturers make provisions in their equipment for producing hydrogen from a readily available fuel source such as natural gas,

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TABLE 1 BASELOAD DISTRIBUTED GENERATION

	Low Temperature		High Temperature	
Packaged system	PEM	Phosphoric Acid (PAFC)	Carbonate (MCFC)	Solid Oxide (SOFC)
size range	~<10 kW	400 kW	300 kW to 2.8 MW	200 kW
Advantages	Load following, low temperature	CHP with low grade waste heat	High efficiency, CHP with high grade waste heat, fuel flexible	High efficiency
Electrical efficiency	25%-35%	40%-42%	43%-47% and higher using turbine or organic rankine cycle	50%-57%
Typical application	Transportation, residential	baseload distributed generation	large and small scale baseload distributed generation, natural gas or biogas	baseload distributed generation

or renewable biogas. In low temperature fuel cells, the hydrogen conversion system is external to the fuel cell. In high temperature fuel cells, the hydrogen conversion system is integral to the fuel cell, resulting in higher efficiencies.

Types of Stationary Fuel Cells

There are four types of commercially available stationary fuel cells, and they are named after the type of material used in the electrolyte. The figure shows the different type of fuel cells and their associated chemical reactions.

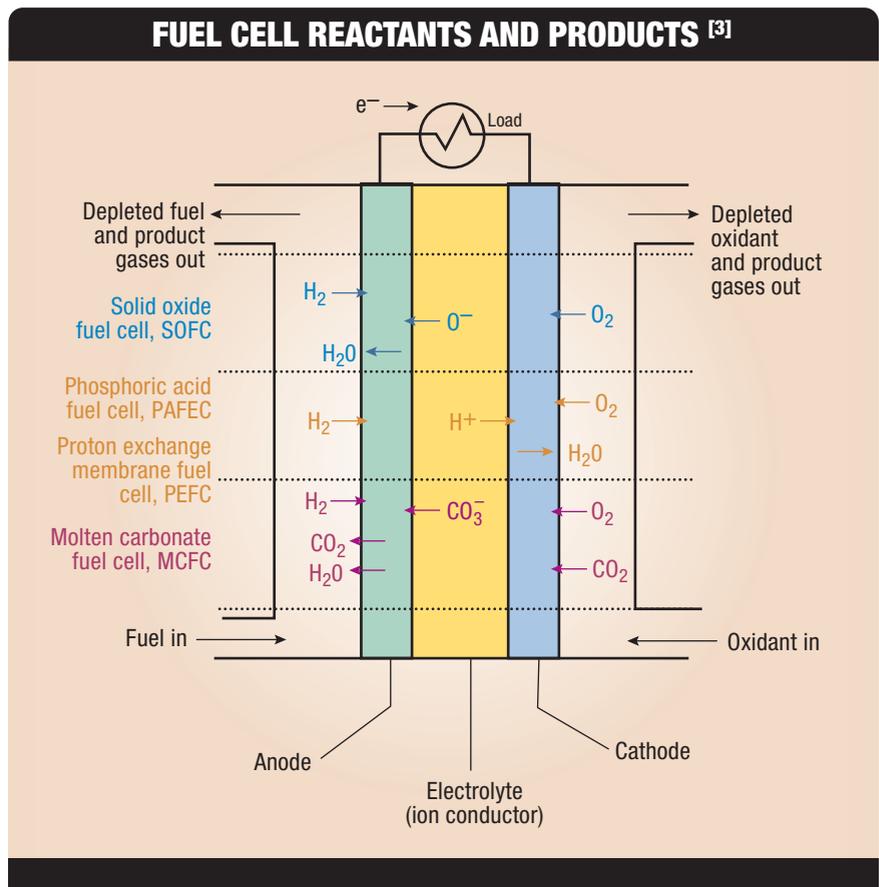
Table 1 summarizes the attributes of commercially available fuel cells. Fuel cells commercially deployed in large stationary power applications typically include phosphoric acid, molten carbonate and solid oxide types, and range in power output from 100 kW to an 11.2 MW fuel cell park, the world's largest as of the date of this article.

Fuel Cells are Clean and Efficient

Unlike conventional powerplants, fuel cells extract electricity from the fuel without going through a combustion process. This results in a clean emission signature, without any of the pollutants associated with combustion such as nitrogen oxides (NOx) or particulate matter. Table 2 compares the typical pollutants generated by fuel cells with those generated by conventional methods, illustrating how fuel cells virtually eliminate pollutants from the power generation process and significantly reduce greenhouse gas emissions versus the average U.S.

fossil fuel power plant.

Due to the direct conversion to electricity, fuel cells are also more electrically efficient than conventional combustion, especially in the distributed generation size range. In fact, fuel cells yield more power per a given unit of fuel than virtually all other methods of power production. They typically range from 40 to 60 percent electrical efficiency, and can achieve up to 90 percent total efficiency in Combined Heat and Power (CHP) applications.



Combined Heat and Power from Fuel Cells

One of the more advantageous byproducts of the fuel cell reaction is heat, which can then be used in a CHP setting to increase the total efficiency of the system. High temperature fuel cells, such as molten carbonate (MCFCs) lend themselves particularly well for heat recovery due to the high temperature (>700 F) of the exhaust gas. Users can put this high temperature exhaust to use for a variety of value-add applications such as hot water heating, steam generation or absorption cooling.

Economics

Stationary fuel cell power plants fueled by natural gas are easy to site in urban locations due to their favorable emission profile, relatively modest space requirements, and quiet operation. Costs continue to decline as manufacturing

TABLE 2 EMISSIONS FROM A FUEL CELL [2]

	NOx, lb/MWh	SOx, lb/MWh	PM-10, lb/MWh	CO2, lb/MWh
Average U.S. Grid, baseload	1.9366	5.2589	0.19	1,314
Average U.S. fossil fuel plant	5.06	11.6	0.27	2,031
Microturbine	0.44	0.008	0.09	1,596
Small gas turbine	1.15	0.008	0.08	1,494
Gas engine (uncontrolled, lean burn)	2.2	0.006	0.03	1,108
Gas engine (low NOx)	0.5	0.007	0.03	1,376
DFC Powerplant, 47% efficiency	0.01	0.0001	0.00002	940

that is more than combustion-based generation equipment at present. However, in certain high cost regions such as California and Connecticut, carbonate fuel cell plants are close to being competitive with the grid, even before incentives. Fuel cell manufacturers have a clear path for achieving pricing below the grid as higher manufacturing volumes will further drive costs down.

Recent advances in fuel cell technology, increases in production volume and competition among manufacturers of stationary fuel cell systems continue to lower the gross system costs. Various states in the U.S. have attractive programs for the deployment of fuel cells. For example, the State of California renewed the Self Generation Incentive Program (SGIP) in November 2011, which offers a capital cost incentive of up to \$2,250 per kW for natural gas and \$4,250 per kW for biogas fueled fuel cells. California also recently enacted a feed-in tariff for CHP applications. Connecticut has a similar capital cost incentive program for fuel cells, as well as an attractive feed-in-tariff scheme. In addition to several state incentives, the Federal Investment Tax Credit (ITC) provides a tax credit of 30 percent of the project costs, up to \$3,000/kW for fuel cell plants, and the Energy Policy Act of 2005 still provides for accelerated depreciation of fuel cell assets for tax purposes.

In the international arena, South Korea includes fuel cells operating on either natural gas or renewable biogas in its Renewable Portfolio Standards (RPS) and has an attractive feed-in-tariff program for fuel cells. The high efficiency of fuel cells is especially attractive to South Korea, as it imports about 95 percent of the natural gas used for power production. European countries also provide an array of capital cost and operating incentives for combined heat and power applications, with favorable treatment for fuel cell generation in some countries.



A 11.2 MW fuel cell installation in South Korea with thermal energy sold to a neighboring wastewater treatment facility

volumes increase, although comparing current direct cost per kWh without accounting for attributes such as the virtual lack of pollutants does put fuel cells at a price point

Conclusions

The long-term abundance and low cost of natural gas

provides real, long-term opportunity for power producers and large-scale consumers, especially as fuel cell technology continues to come into its own. Public opinion and policymakers are embracing efficiency and environmentally friendly power production while moving away from combustion-based processes and nuclear power. Today, there are several manufacturers of fuel cells for industrial-grade, stationary power applications, ranging in size from 100 kW to several megawatts. Fuel cells are characterized by high efficiency, low emissions, low-noise and can be easily sited in urban areas due to these attributes. Some even provide the advantage of heat recovery, further enhancing the technology's economic and environmental value for distributed, stationary base-load generation. **pe**

References

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