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Fuel Cells Are Coming

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Is There a Fuel Cell in Your Future?

Fuel cells hold promise for Forest Service use, especially in areas where commercial electric power is not available. Although solar, microhydro, and wind power are also environmentally attractive energy sources, their use is not practical everywhere. Fuel cells could provide a clean, quiet alternative supply of power where it is impractical to use renewable energy sources. Possible future applications of fuel cells in the Forest Service include providing power for lights, showers, cooking, and computers at remote fire camps, providing battery-type power for portable field equipment, powering water pumps at recreation sites, and even providing electric power for remote ranger stations. The Forest Service Technology and Development Program, along with other agencies and private industry groups, has begun a fuel cell demonstration installation at the remote Big Goose Ranger Station near Sheridan, WY. This Tech Tip is the first of several that will explain how the Forest Service can use fuel cells.

In 1839, Sir William Grove successfully combined hydrogen and oxygen to produce electricity, inventing the first fuel cell. However, with abundant fossil fuel and the invention of the steam engine, fuel cell technology languished until the 1960s, when the U.S. National Aeronautics and Space Administration (NASA) began using the technology. In space, fuel cells were a desirable alternative to dangerous nuclear power, bulky solar collectors, and heavy batteries—and they produced drinking water. Use of fuel cells by the space program caused industry and government to recognize the potential of fuel cells as a clean energy source.

Fuel cells can power a laptop computer or a clock battery, and large units can be combined to produce many megawatts, potentially serving entire cities. A midsize unit (figure 1) could provide electric power and hot water for your home in the not-too-distant future.

Fuel Cell Basics

Fuel cells are similar to large batteries with constant fuel input. They are energy conversion devices that transform

Figure 1—Moderate-size fuel cells can provide continuous or emergency power for homes or businesses.

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energy stored by hydrogen into electricity, heat, and water. Unless fuel cells use pure hydrogen for fuel, they also produce small amounts of carbon dioxide. The fuel cells have no moving parts. Because they do not burn their fuel, fuel cells produce virtually no pollution. Fuel cells convert 30 percent of the energy in their fuel to electricity, compared to just 20 percent for a typical power plant. The heat produced by fuel cells can be used to provide domestic hot water and to heat or cool buildings, raising the total potential efficiency of fuel cells above 80 percent.

Interestingly, in Europe, where most building heat is provided by hot water radiators, stationary fuel cells are viewed as water heaters that produce electricity as a bonus. Here in America, fuel cells are seen as electric power sources that produce heat as a bonus.

A fuel cell is two electrodes sandwiched around an electrolyte (figure 2). Hydrogen fuel is fed to the anode (positive electrode) of the fuel cell. Encouraged by a catalyst, each hydrogen atom splits into a proton and an electron, which take different paths to the cathode (negative electrode). The proton passes through the electrolyte. The electrons create an electric current (generate electric power) as they return to the cathode. Oxygen enters the fuel cell through the cathode, where the electrons are reunited with the protons and combine with oxygen to form water. Most fuel cells use a reformer to extract hydrogen from propane, natural gas, methane, or other fossil fuels.

Different types of fuel cells operate at different temperatures and use different fuels and different electrolytes to produce electricity. Each type of fuel cell has its strengths, limitations, and potential.

Alkaline fuel cells use an alkaline electrolyte, such as potassium hydroxide. These small fuel cells with very quick cathode reactions were originally used by NASA on space missions. They are becoming less costly and are now being used in hydrogen-powered vehicles.

Phosphoric acid fuel cells use a silicon-carbide matrix to contain a phosphoric acid electrolyte. These relatively large, heavy fuel cells are available commercially in limited quantities and are being used in hotels, hospitals, office buildings, and large vehicles, such as buses.

Proton exchange membrane fuel cells use a thin plastic membrane as the electrolyte. These relatively low-temperature cells can vary their output quickly to meet shifts in power demand. They are being developed for light-duty vehicles, buildings, and perhaps as battery replacements in other applications.

Molten carbonate salts are another electrolyte used in fuel cells. Molten carbonate fuel cells operate at very high temperatures and can use a variety of fuels. They are intended for major electric utility applications and may eventually power heavy machinery.

Solid oxide fuel cells, now in the final stages of precommercial development, use a hard ceramic material instead of a liquid electrolyte. These potentially long-lived, durable, stationary fuel cells show promise for use in industrial applications and electricity generating stations, as well as in small-scale commercial and residential settings.

Protonic ceramic fuel cells share many characteristics with solid oxide fuel cells, but the ceramic electrolyte

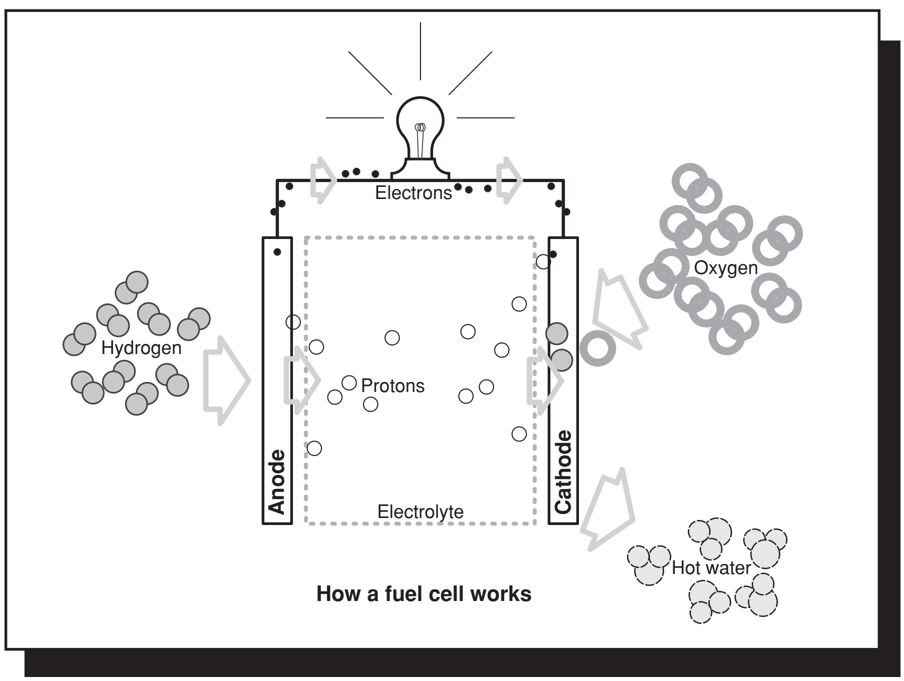

Figure 2—This schematic drawing shows how fuel cells produce electricity.

material oxidizes fossil fuels directly to the anode, eliminating the reforming process that extracts hydrogen from fossil fuels. This new type of fuel cell has potential for large- and small-scale stationary electric power generation stations and for powering vehicles.

Direct methanol fuel cells are similar to proton exchange membrane fuel cells, but they don't need a reformer because a catalyst in the anode draws the hydrogen directly from liquid methanol. The biggest potential for these relatively low-temperature fuel cells may be in powering tiny to midsize electronic appliances, such as clocks, cell phones, and laptop computers.

Regenerative fuel cells use a solar-powered electrolyzer to separate water into oxygen and hydrogen, creating electricity, heat, and more water. The water is recirculated into the solar-powered electrolyzer and the process begins again. NASA and several commercial companies are researching this new fuel cell technology because it could be used when fossil fuels are not available.

Zinc-air fuel cells use an air-permeable membrane and zinc to create electricity when oxygen and zinc are mixed in the presence of an electrolyte. When the fuel is used up, the system is connected to the commercial power grid and the process is reversed in about 5 minutes. These lightweight fuel cells can be used to power electric vehicles and electronic devices.

Fuel Cell Development

Portable battery replacement units producing up to 100 watts are available commercially at the high end of the competitive price range (figure 3). These units are much lighter and last longer than battery systems with similar output. Some manufacturers are producing stationary commercial units (figure 4). However, the cost of

Figure 3—The black box (foreground) attached to this commercial video camera is a fuel cell manufactured by Jadoo Power Systems. The fuel cell replaces much heavier batteries and is used whenever a portable power source is needed. *—Photo courtesy of Jadoo Power Systems, Folsom, CA.*

Figure 4—Steam vents from the top of a 200-kilowatt, model PC 25 fuel cell man-ufactured by UTC Fuel Cells. The unit can produce uninterruptible power for critical needs such as hospital life support equipment, computer centers, or emergency services, in addition to providing electrical power for more ordinary uses. *—Photo courtesy of Concurrent Technologies Corp., Johnstown, PA.*

these large systems is substantially higher than for comparable diesel generators. Some vehicle manufacturers are producing limited quantities of fuel-cell-powered vehicles, and other manufacturers have tested fuel-cell-powered vehicles under commercial conditions.

Stationary fuel cells for domestic or light commercial use are currently available in 5-kilowatt models (figure 5). They cost around $100,000 each installed, or about $20,000 per kilowatt. The very large units (100 kilowatts or more) cost about a quarter to half as much per kilowatt. Small fuel cell systems (under 100 watts) cost less than $100 per watt, a cost comparable to a battery system.

Figure 5—This 5-kilowatt fuel cell manufactured by Plug Power is being tested by the U.S. Department of Defense at the Concurrent Technologies Corp. test facility. It is intended for residential use or small commercial installations. *—Photo courtesy of Concurrent Technologies Corp., Johnstown, PA.*

Honda, Toyota, and Ford displayed hydrogen fuel cell concept cars at the 2002 Future Car Congress sponsored by the U.S. Department of Energy and the U.S. Council for Automotive Research. Ford's vehicle relied solely on power from fuel cells, while the Toyota used batteries, and the Honda used a capacitor to assist the fuel cell during brisk acceleration. The Honda and Toyota perform similarly to their conventional counterparts, while the Ford is an early prototype that will be replaced by a hybrid to improve its sluggish acceleration.

Figure 6—This Honda FCX is one of the first commercially available automobiles to be powered by fuel cells in the United States. *—Photo courtesy of American Honda Motor Co., Torrance, CA.*

The Japanese government strongly supports fuel cell technology. Tokyo has two hydrogen fueling stations and five more are being designed or are under construction. In December 2002, Honda delivered the first commercial fuel cell automobiles to the United States for fleet use in Los Angeles (figure 6).

A newly developed safe method for storing and delivering hydrogen fuel uses a chemical hydride slurry to store hydrogen safely in a nonexplosive, nonflammable form. The slurry, which is about the consistency of thick paint, stores hydrogen 10 times more densely than compressed hydrogen and twice as densely as liquid hydrogen, without the need for a pressure tank. When water is added to the slurry, 99.999-percent pure hydrogen is produced. This could change the emphasis within the fuel cell development industry from ordinary fossil fuels to pure hydrogen, possibly allowing fuel cells to become commercially competitive more quickly.

The Future is Getting Closer

For the past 20 years, commercial fuel cell development has always been characterized as “about 5 years away.” It appears that the state of fuel cell development has finally caught up to the promises. Fuel cells will be powering vehicles, clocks, laptop computers, homes, and businesses in the next few years.

Additional Information

The following Web sites have more information about fuel cells. Readers are encouraged to search other Internet sites or publications that may address their specific interests.

The National Fuel Cell Research Center
http://www.nfcrc.uci.edu/

Fuel Cells 2000
http://www.fuelcells.org/

U.S. Fuel Cell Council
http://www.usfcc.com/

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  Web site: *http://www.nfcrc.uci.edu/*

- **Fuel Cells 2000**
  Web site: *http://www.fuelcells.org/*

About the Authors

Kathleen Snodgrass came to MTDC as a project leader in 2001. She graduated from Washington State University in 1974 with a bachelor's degree in architectural studies. Kathleen worked in facilities, land line, landscape architecture, and general engineering before becoming facilities architect for the Nez Perce National Forest, and has worked in highway design and construction for the Idaho Division of Highways.

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Explains the basics of how fuel cells work and how they might be useful for the U.S. Department of Agriculture, Forest Service at remote facilities and in other situations that require a clean, quiet alternative supply of electrical power.

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