FACTS ABOUT FUEL CELLS—THE FUTURE OF ENERGY?

from Ameren Corporation, Your Energy Advisor

The question of where Americans will get their future energy supply is a major concern. Traditional generation sources are expensive to build, and some plants emit greenhouse gases that are associated with climate change. Americans are looking for an electric generating resource that is environmentally friendly, reliable and inexpensive. In this publication, Ameren offers some answers about this much-talked-about energy source—fuel cells—that provide a solution.

A fuel cell is a device that generates electricity by a chemical reaction. Every fuel cell has two electrodes, one positive and one negative, called, respectively, the anode and cathode. The reactions that produce electricity take place at the electrodes.

Why Are Fuel Cells Valuable?

If fuel cells become more commercially viable, consumers could generate their own electricity at their homes and businesses—leading to savings on energy bills. Unlike conventional fossil fuel power plants, electrolytes used in these cells produce little of the greenhouse gas—carbon dioxide.

The future looks bright for this emerging generating option. Over 5,000 fuel cells are providing heat and energy for Japanese homes. In the United States, tests are being conducted on a range of cell types. Major manufacturers—General Electric, Delphi, Mitsubishi and Honda—are investing heavily in fuel cell technology research and development.

However, the technology needs to be developed more fully before fuel cells will be readily available and affordable for the average consumer.

Are Fuel Cells New? How Do They Work?

Fuel cell technology has been around for more than 100 years.

The purpose of a fuel cell is to produce an electrical current that can be directed outside the cell to do work, such as powering an electric motor or illuminating a light bulb or a city. The chemical reactions that produce this current are the key to how a fuel cell works.

There are several kinds of fuel cells, and each operates a bit differently. But in general terms, hydrogen atoms enter a fuel cell at the anode where a chemical reaction strips them of their electrons. The hydrogen atoms are now "ionized," and carry a positive electrical charge. The negatively charged electrons provide the current through wires.

As long as a fuel cell is supplied with hydrogen and oxygen, it will generate electricity.

What is the Difference Between a Fuel Cell and a Battery?

Fuel cells and batteries are similar because they use a chemical reaction to provide electricity. A battery stores the chemical reactants, usually metal compounds like lithium, zinc or manganese. Once used up, you must recharge or throw away the battery. A fuel cell actually creates electricity through reactants (hydrogen and oxygen) stored externally. The fuel cell will produce electricity as long as it has a fuel supply.

How Are Fuel Cells Being Used?

Fuel cells are currently being developed for residential, commercial and industrial power generation and heating; automobiles; laptops; cell phones; and military/governmental applications.

What Types of Fuel Cells Exist? How Are They Being Used?

There are six general types of fuels cells:

Alkaline Fuel Cells (AFCs) were one of the first fuel cell technologies developed, and they were the first type widely used in the U.S. space program to produce electrical energy and water on spacecrafts. These fuel cells use a solution of potassium hydroxide mixed with water as the electrolyte and can use a variety of non-precious metals as catalysts.

AFCs' high performance is due to the rate at which chemical reactions take place in the cell. In space applications, they have also demonstrated efficiencies that approach 60%. The disadvantage of this fuel cell type is that it is easily poisoned by carbon dioxide.

Proton Exchange Membrane Fuel Cells (PEMFC)—or Polymer electrolyte membrane (PEM) fuel cells use a solid polymer as an electrolyte and porous carbon electrodes containing a platinum catalyst. They need only hydrogen, oxygen from the air, and water to operate and do not require corrosive fluids, like some fuel cells. They are typically fueled with pure hydrogen.

PEM fuel cells are used primarily for transportation applications and some stationary applications. Due to their fast startup time, low sensitivity to orientation, and favorable power-to-weight ratio, PEM fuel cells are particularly suitable for use in passenger vehicles, such as cars and buses.

Phosphoric Acid Fuel Cells (PAFC) use liquid phosphoric acid as an electrolyte and porous carbon electrodes containing a platinum catalyst. The phosphoric acid fuel cell (PAFC) is considered the "first generation" of modern fuel cells. It is one of the most mature cell types and the first to be used commercially.

This type of fuel cell is typically used for stationary power generation, but some PAFCs have been used to power large vehicles, such as city buses.

PAFCs are more tolerant of impurities in fossil fuels that have been reformed into hydrogen than are PEM cells, which are easily "poisoned" by carbon monoxide because carbon monoxide binds to the platinum catalyst, decreasing the fuel cell's efficiency.

Molten Carbonate Fuel Cells (MCFC) are currently being developed for natural gas and coal-based power plants for electrical utility, industrial, and military applications. MCFCs are high-temperature fuel cells that use an electrolyte composed of a molten carbonate salt mixture suspended in a porous, chemically inert ceramic lithium aluminum oxide matrix.

Because they operate at extremely high temperatures, non-precious metals can be used as catalysts at the anode and cathode, reducing costs. Improved efficiency is another reason MCFCs offer significant cost reductions over phosphoric acid fuel cells.

Molten carbonate fuel cells are not prone to carbon monoxide or carbon dioxide "poisoning"—they can even use carbon oxides as fuel—making them more attractive for fueling with gases made from coal. The primary disadvantage of current MCFC technology is durability.

Solid Oxide Fuel Cells (SOFC) use a hard, non-porous ceramic compound as the electrolyte. Because the electrolyte is a solid, the cells do not have to be constructed in the plate-like configuration typical of other fuel cell types.

SOFCs are targeted for use in stationary energy sources, transportation and military applications.

SOFCs are expected to be around 50%–60% more efficient at converting fuel to electricity. In applications designed to capture and use the system's waste heat (co-generation), overall fuel use efficiencies could reach 90%. Solid oxide fuel cells operate at very high temperatures—around 1,830°F. High-temperature operation removes the need for precious-metal catalyst, thereby reducing cost. It also allows SOFCs to reform fuels internally, which enables the use of a variety of fuels.

In fact, SOFC technology dominates competing fuel cell technologies because of the ability of SOFCs to use currently available fossil fuels, thus reducing operating costs. Other fuel cell technologies (e.g., molten carbonate, polymer electrolyte, phosphoric acid and alkali) require hydrogen as their fuel.

Direct Carbon Fuel Cells (DCFC) use a carbon-rich material as a fuel. The cell produces energy by combining carbon and oxygen in an electrochemical process. The carbon may be supplied by coal, coke, biomass or any non-fossilized source of carbon. The carbon is gasified without water into carbon monoxide by the re-circulating carbon dioxide.

DCFC could be used primarily for power applications, including emergency backup power for business and residential facilities, primary power for remote locations, and for transportation applications and to power military vehicles.

Generating electricity from coal electro-chemically may significantly reduce carbon dioxide (greenhouse gas) emissions compared to traditional combustion technology. DCFCs are expected to be up to 70% more efficient, thus reducing the emissions and ash for each megawatt generated.

Direct Carbon Fuel Cells are currently in the research phase. Cost for cell materials, operating characteristics, and durability are unknown at this time.

What Are the Barriers to Using Fuel Cells to Generate Electricity to Consumers?

Cost and durability are the major challenges to fuel cell commercialization. Size, weight, and thermal and water management are also barriers to the commercialization of fuel cell technology.

The key challenges include:

Cost. The cost of fuel cell power systems must be reduced before they can be competitive with conventional technologies. For stationary systems, the acceptable price point is considerably higher —up to $14,000 per kilowatt (kW).

Durability and Reliability. The durability of fuel cell systems has not been established. For stationary applications, more than 40,000 hours of reliable operation will be required for market acceptance.

Air, Thermal, and Water Management. Air, thermal and water management for fuel cells are issues because the small difference between the operating and ambient temperatures necessitates large heat exchangers.

Improved Heat Recovery Systems. Technologies need to be developed that will allow for higher operating temperatures and/or more-effective heat recovery systems and improved system designs that will enable higher efficiencies. Technologies that allow cooling to be provided from the low heat rejected from stationary fuel cell systems also need to be evaluated.

What Companies Are Selling Fuel Cells?

- PEMFC – In California, ClearEdge Power is selling 5 kW combined heat and power (CHP) units for $70,000 installed; the initial cost is offset partially by state and federal tax credits of $27,500, bringing the net cost to the consumer to $42,500. ClearEdge states that in homes that are 5,000 square feet or larger, the payback period is less than five years when waste heat is utilized for pool heating. They are also marketing to small commercial end-users.
- Toshiba, partnering with the Japanese government, installed approximately 3,000, 1 kW CHP units in 2005. Each unit's cost is $35,000, with government subsidies of $15,000. The unit is paired with a 50-gallon water tank and achieves an efficiency of approximately 70%. Longevity and durability of the fuel stack have been questioned.
- The most recent advances in fuel cell technology are coming from SOFCs. Honda, Siemens, Ceramics Fuel Cell Limited, BloomEnergy, Ceres Power, Kyocera and many Japanese companies are currently developing SOFCs.

What About Bloom Energy—Aren't Their Fuel Cells Available?

Bloom Energy has achieved relative success with their SOFC prototypes, and the company is expected to further commercialize operations.

In 2009, Bloom announced the availability of the Bloom Energy Server™, a patented SOFC technology that the company touted as a cleaner, more reliable, and more affordable alternative to both today's electric grid as well as traditional renewable energy sources.

The Bloom Energy Server

To get a view of the cost and benefits, eBay installed five of the boxes in 2009 at their headquarters and cited savings of $100,000 on energy in the first nine months. However, at the maximum cost—$4 million—the investment on a Bloom Box would appear to take 30 years to recoup. The company says it hopes to bring those costs down.

What Does the Future Hold for Fuel Cells?

Fuel cells could provide an alternative energy supply resource for consumers—offering affordable power, increased reliability and lower emissions than conventional coal-fired power plants.

Ameren and the entire electric utility industry are investing in fuel cell research with the expectation that, if and when, fuel cells become competitive with other supply technologies, the utility industry can partner with customers to use this alternative energy source.

For more on energy and what Ameren is doing to help customers save energy and improve the environment, go to **Ameren.com**.

About Ameren:

With assets of approximately $24 billion, Ameren serves approximately 2.4 million electric customers and almost one million natural gas customers in a 64,000-square-mile area of Missouri and Illinois. Ameren owns a diverse mix of electric generating plants strategically located in its Midwest market with a generating capacity of 16,900 megawatts.