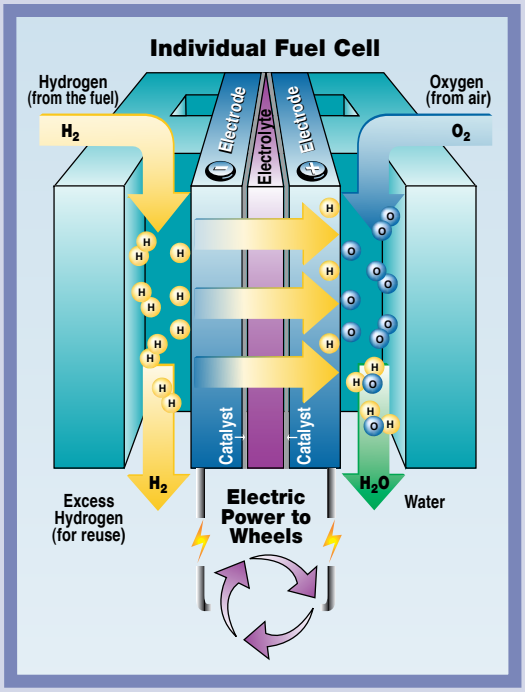
Just the Basics

Argonne NATIONAL LABORATORY

Transportation Technology R&D Center

What are Fuel Cells?

A fuel cell is an **electrochemical energy conversion device** that converts the chemical energy in a fuel to electrical energy. A familiar example of electrochemical devices, batteries, self-store all the chemicals they need to produce electricity; eventually, though, the chemicals are used up and they "go dead" and need to be recharged or replaced. A fuel cell, in contrast, never goes dead; as long as the required chemicals flow into the cell, the cell will continue to generate electricity.



Fuel Cell Technology

Take one fuel cell. Add two ingredients: oxygen, O_2, from the air and hydrogen, H_2 (derived from a fuel such as natural gas, propane, methanol, ethanol, or even electricity). With these two elements, the fuel cell produces electricity, potentially useful heat, and — you guessed it! — water. The fuel cell performs this conversion with high efficiency while producing little or no pollution, making fuel cells an attractive alternative to fossil fuel-based power sources for transportation, residential/commercial, and portable power applications.

As of 2009, more than 200 buses and several hundred cars powered by fuel cells are navigating cities around the world, and more than 100 hydrogen refueling stations are in operation or under construction.

Reasons to Pursue Fuel Cell Technologies

It's a familiar statistic: America's 4.6% of the world's population consumes 25% of all the oil produced in the world. We import two-thirds of this oil.

The following are the primary factors that make fuel cells an attractive alternative to the combustion-based burning of fossil fuels:

- ***Reduced dependence on foreign oil.*** Because hydrogen can be produced from a variety of energy sources, including renewables, fuel cells would permit the use of non-petroleum sources for transportation and other applications.
- ***No emissions.*** Another big advantage is low or zero emissions: a fuel-cell vehicle running on pure hydrogen produces only water vapor. Fuel cells are "fuel flexible," so even when other types of fuels are used for stationary power or other applications, the fuel cell systems produce only trace emissions of regulated pollutants.
- ***Performance-related advantages.*** The internal combustion engines in today's cars convert less than 20% of the energy in gasoline in on-the-road driving — and that's after more than a century's worth of innovations to make them run more cleanly and efficiently! On the other hand, fuel cell cars operating on hydrogen routinely achieve efficiencies of nearly 60%. Similarly, stationary combined heat and power systems have shown electrical efficiencies of 40% or higher, and combined heat and electric efficiencies of higher than 80%.

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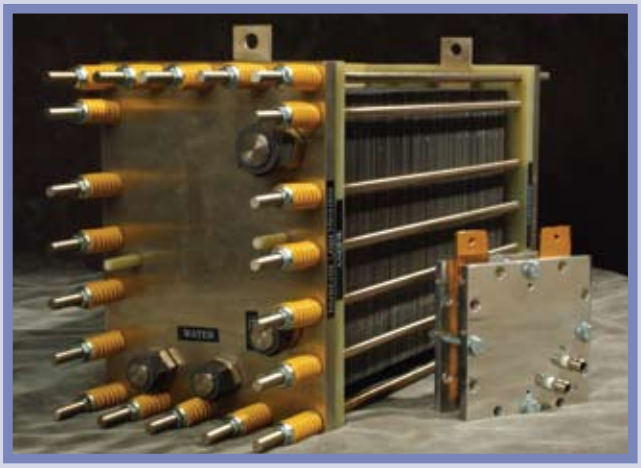
Challenges of Fuel Cell Technology

Scientists are working to sort out some major issues that remain. For example, to compete with gasoline-powered vehicles, the cost of an automotive fuel cell system must be reduced to about $30 per kilowatt (kW); current projected costs are $61 per kW with today's technology being manufactured at high volumes. Other challenges involving fuel cell durability, hydrogen delivery, infrastructure, and on-vehicle storage still need to be resolved.

How Do Fuel Cells Work?

There are several different types of fuel cells. One example is the polymer electrolyte fuel cell (sometimes referred to as the proton exchange membrane or PEM fuel cell), which is being developed for automobiles, residential, distributed power, and portable power applications. At the heart of this fuel cell is a thin polymer membrane electrolyte that is sandwiched between electrode layers on both sides. Hydrogen is fed to one electrode (the anode) and oxygen is fed to the other electrode (the cathode). At the anode, the hydrogen is split into protons and electrons. The protons move through the membrane electrolyte to the cathode, and the electrons flow through an external circuit to the cathode, where they recombine and react with oxygen to produce water.



The chemical reaction in a single operating fuel cell generates an electric potential of less than 1 volt (V), so several cells are connected in electrical series called a fuel cell "stack", as seen here. The potential power generated by a fuel cell stack depends on the number and size of the individual fuel cells that comprise the stack.

What Argonne is Doing

Fuel cell research at Argonne National Laboratory focuses on developing advanced low-cost, high-performance materials and processes for fuel cells, hydrogen production, and hydrogen storage. Specific research activities include:

- Non-platinum and low-platinum electrocatalysts for the low temperature PEM fuel cells;
- Understanding performance limitations and mechanisms of electrocatalyst degradation when used in real operating environments;
- Inexpensive, rugged, and corrosion-resistant bipolar plates for automotive PEM fuel cell stacks;
- Advanced catalysts and processes for hydrogen production at central plants and distributed hydrogen fueling stations using renewable bio-derived fuels;
- Thermochemical processes for producing hydrogen using heat from a solar furnace or a current-technology nuclear reactor;
- Nanoporous polymeric materials for automotive hydrogen storage at ambient temperatures and medium pressures;
- Modeling and analysis of automotive, combined heat, and power fuel cell systems; and
- Modeling and analysis of various hydrogen storage systems and concepts, including the off-board regeneration of these storage materials, if needed.

Argonne's Fuel Cell Test Facility provides fuel cell developers, government agencies, and U.S. automakers with an independent resource for testing and evaluating fuel cell stacks and systems up to 100 kW. Sponsors obtain comparative data on the progress of their fuel cells' performance, operational characteristics, and durability. Argonne's independent testing can help fuel cell developers and automobile companies to effectively compare performance data and validate the capabilities of competing technologies.

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