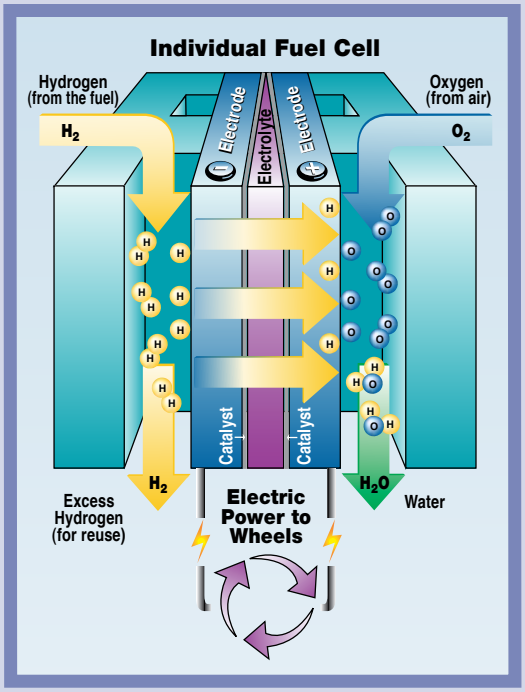
Just the Basics

Argonne NATIONAL LABORATORY

Transportation Technology R&D Center

What are Fuel Cells?

Technically, a fuel cell is an ***electrochemical energy conversion device***. Another familiar electrochemical device, batteries, self-store all the chemicals they need to produce electricity; eventually, though, they "go dead" and need to be recharged or thrown away. A fuel cell, in contrast, never goes dead; as long as chemicals flow into the cell, electricity will flow out of the cell.



Fuel Cell Technology

Take one fuel cell. Add two ingredients: oxygen (O) from the air and any hydrogen (H)-rich fuel, a category that includes fossil fuels (gasoline, natural gas, liquid propane, and petroleum distillates) and renewable fuels (ethanol and methanol). With these two elements, the fuel cell produces both electricity (i.e., potentially useful heat) and — you guessed it! — water. The fuel cell performs this conversion without using combustion or producing pollution, making fuel cells an attractive alternative to fossil-based petroleum fuel power.

As of 2005, some 70 buses and 200 cars powered by fuel cells were navigating cities around the world, and 40 hydrogen refueling stations were 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 55% of this oil — and could be importing as much as 68% by 2025. Furthermore, even if every vehicle on the road were a hybrid car by 2025, we would still need the same amount of oil then as we do right now (Fuel Cells 2000, www.fuelcells.org).

More than $1 billion has been spent to date on government-funded fuel cell research and development, and R&D efforts in the private sector are considerably larger. Another $500 billion could be needed to build and maintain an infrastructure to support successful fuel cell commercialization (which, like our current petroleum infrastructure, will consist of pipelines, truck transport, fueling stations, and hydrogen generation plants). What will make this investment worthwhile?

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 water, the United States could increasingly rely on domestic sources for energy production.
- ***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,"

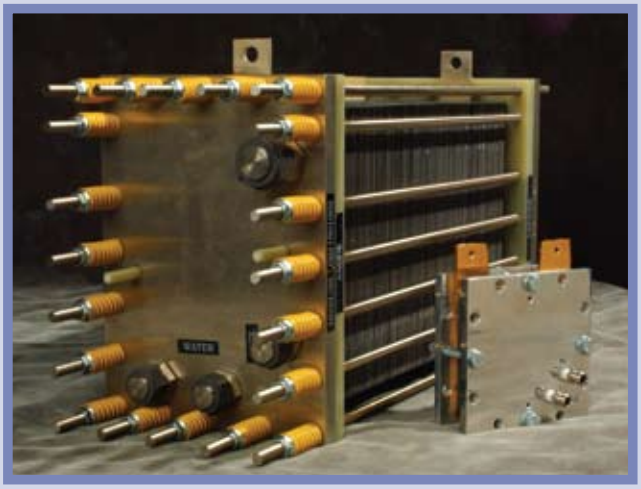
Reasons to Pursue Fuel Cell Technologies *(cont.)*

so even when other types of fuel are used, the vehicle produces some carbon dioxide and other trace emissions but in far smaller amounts than a typical car.

- ***Performance-related advantages.*** The internal combustion engines in today's cars converts less than 20% of the energy in gasoline into power that moves the car — and that's after more than a century's worth of innovations to make them run more cleanly and efficiently! Fuel cells (depending on the fuel used) can capture 40% to 60% or more of a fuel's energy to power a car (60% or higher for stationary applications).

How Do Fuel Cells Work?

The heart of a fuel cell's power system is the fuel cell "stack." This stack is actually made of many thin, flat "cells" layered together that work together: (1) the hydrogen moves through the cell and encounters the first of two catalyst layers; (2) contact with the catalyst causes the H molecules to release electrons and protons, creating the electrical current that powers the car; (3) the protons migrate through an electrolyte layer to the second catalyst layer; there, they react with oxygen (from the air) to form H2O (while most of the water is collected and reused within the system, a small amount is released in the exhaust as water vapor); and (4) other layers of materials called bipolar plates help draw fuel and air into the cell and conduct electrical current through the cell.



The chemical reaction in a single fuel cell produces less than 1.16 volts of electricity, so many separate fuel cells must be combined into fuel cell "stacks," 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.

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Challenges in Implementing 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 fuel cell systems must be reduced to about $35 per kilowatt (kW); current projected costs are $110 per kW. Other challenges involving durability, delivery, infrastructure, on-vehicle storage, and safety need to be resolved.

What Argonne is Doing

Fuel cell research at Argonne National Laboratory focuses on developing the following:

- Catalysts, processes, and reactor designs for fuel processing in integrated fuel cell power systems;
- Improved, lower-cost materials for fuel cells;
- Materials for hydrogen production and storage for polymer electrolyte and solid oxide fuel cell systems; and
- Production of hydrogen from water using a nuclear reactor as a source of heat and electricity.

Argonne is also developing a rugged solid oxide fuel cell, the TuffCell, as well as technology to reform diesel fuel for use in fuel cell applications.

The Fuel Cell Test Facility at Argonne 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 compare performance data and validate the capabilities of competing technologies more effectively.