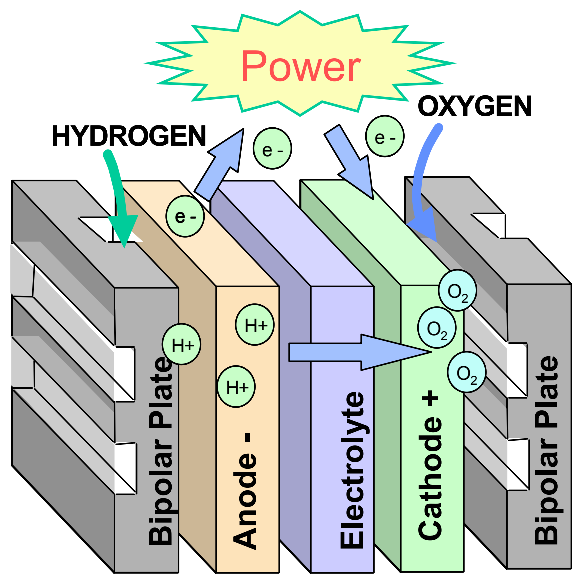
Fuel Cell Overview

Fuel cells use the chemical energy of hydrogen to generate electricity. When pure hydrogen is used, the only by-products are pure water and useful heat. Fuel cells are unique in terms of the variety of their potential applications; they can provide energy for systems as large as a utility power station, as small as a laptop computer, and just about everything in between, including light cars and trucks.

A single fuel cell consists of an electrolyte and two catalyst-coated electrodes (a porous anode and cathode). Several different types of fuel cells are currently under development, each classified primarily by the kind of electrolyte it uses. The electrolyte determines the kind of chemical reactions that take place in the cell, the temperature range in which the cell operates, and other factors, which, in turn, affect the applications for which the fuel cell is most suitable, as well as its advantages and limitations.

The DOE Hydrogen Program, which is focused on transportation, supports research and development (R&D) of polymer electrolyte membrane (PEM) fuel cells, which are currently used primarily for light-duty vehicles. Research to advance other types of fuel cells, including Molten Carbonate and Solid Oxide fuel cells, is also underway within DOE, although not directly under the Hydrogen Fuel Initiative since these technologies have a stronger tie to stationary usage than transportation. For more information, please visit www.hydrogen.energy.gov.



To view an animation of how a PEM fuel cell works, please visit www.eere.energy.gov/hydrogenandfuelcells.

How does a PEM Fuel Cell work?

A fuel cell power system has many components, but its heart is a fuel cell "stack." The stack is actually made of many thin, flat fuel cells layered together. (The term "fuel cell" is often used to refer to the entire stack, but strictly speaking, it refers only to the individual cells.) A single cell produces a small amount of electricity, but many cells stacked together can provide enough to power a vehicle.

→ When hydrogen is fed to a PEM fuel cell and encounters the first catalyst-coated electrode, called the anode, the hydrogen molecules release electrons and protons.
→ The protons migrate through the electrolyte membrane to the second catalyst-coated electrode, called the cathode, where they react with oxygen to form water.
→ The electrons, however, can't pass through the electrolyte membrane to the cathode. Instead they must travel around it – this movement of electrons is an electrical current.

PEM fuel cells operate at relatively low temperatures, around 80°C (176°F). Low temperature operation allows them to start quickly (less warm-up time) and results in less wear on system components, resulting in better durability. However, it requires that a noble-metal catalyst (typically platinum) be used to separate the hydrogen's electrons and protons, adding to system cost.

Challenges to fuel cell commercialization

Although hydrogen fuel cell vehicles often make today's newspaper headlines, they are many years away from reaching the mass commercial market. Through partnerships with the private sector, DOE seeks to develop the technologies needed to make it practical and cost-effective for large numbers of Americans to choose to use hydrogen fuel cell vehicles by 2020. DOE supports high-risk research required to overcome the technical challenges to fuel cell technology commercialization, including –

- *Cost:* Fuel cell power systems must be reduced in cost before they can be competitive with gasoline internal combustion engines (ICEs). The cost for automotive ICE power plants is currently about $25-35/kW; a fuel cell system needs to cost less than $50/kW for the technology to be competitive.
- *Durability:* The durability of fuel cell systems has not been established. Fuel cell power systems will be required to be as durable and reliable as current automotive engines, i.e., 5,000 hour lifespan (150,000 miles equivalent) and able to function over the full range of vehicle operating conditions (-40° to +40° C).
- *Air management:* Air management for fuel cell systems is a challenge because today's compressor technologies are not suitable for automotive fuel cell applications.
- *Thermal and water management:* Fuel cell operation at lower temperatures creates a small difference between the operating and ambient temperatures necessitating large heat exchangers and humidifiers. These components use part of the power that is produced, reducing overall system efficiency.
- *Size and weight:* The size and weight of current fuel cell systems must be further reduced to meet the packaging requirements for automobiles. Size and weight reduction applies not only to the fuel cell stack (catalysts, membranes, gas diffusion media, bipolar plates), but also to the ancillary components (e.g., compressor/expander, heat exchangers, humidifiers, and sensors) making up the balance of plant.

Other critical challenges related to hydrogen technology must also be solved before hydrogen fuel cell vehicles will be widely available to consumers. Specifically –

- *Hydrogen storage:* On-board hydrogen storage systems must enable a driving range of greater than 300 miles while meeting vehicular cost and performance requirements without intruding into vehicle cargo or passenger space.
- *Hydrogen production:* With current production technologies, hydrogen is still currently three to four times as expensive as gasoline. The cost of hydrogen must be cost-competitive, on an energy content basis, with existing transportation fuels.
- *Hydrogen delivery:* A cost-effective and energy-efficient hydrogen delivery infrastructure is needed. The cost of hydrogen delivery from the point of production to the point of use must be reduced.

Activities to address all of these technical challenges are described in detail in the Hydrogen, Fuel Cells, and Infrastructure Technologies Multi-Year Program Plan, which is available at http://www.eere.energy.gov/hydrogenandfuelcells/mypp/.