ENERGY
EFFICIENCY AND
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OFFICE OF
TRANSPORTATION
TECHNOLOGIES

Just the Basics: Fuel Cells

Transportation
FOR THE 21ST CENTURY

A fuel cell harnesses the chemical energy of hydrogen and oxygen to generate electricity without combustion or pollution. The only byproducts are pure water and useful heat.

What's all the excitement about?

Fuel cells have the potential to power cars, trucks, and buses without emitting harmful tailpipe emissions. Vehicles powered by fuel cells will be cleaner and more energy efficient than those powered by the internal combustion engine. Fuel cells also may provide energy to factories and homes without creating smokestack pollution. This adds up to energy savings for the consumer, energy security for the country, and a cleaner environment.

How does a fuel cell work?

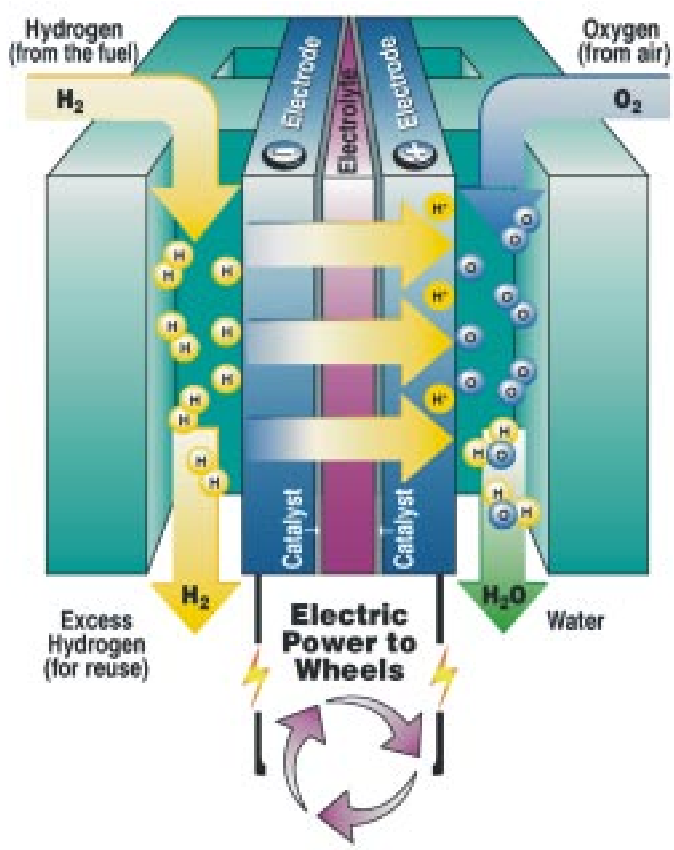
A fuel cell produces electricity directly from the electrochemical reaction between hydrogen from a hydrogen-containing fuel and oxygen from the air. Like an internal combustion engine, it turns fuel into power by doing something to the fuel to make it release energy. The electrochemical reaction is the reverse of what occurs when electricity is used to produce hydrogen and oxygen. In a conventional car engine, what happens is combustion: the fuel burns in tiny explosions that push the pistons up and down. When a fuel burns, it is being "oxidized." That is, the fuel combines with oxygen and, as a result, produces energy. In a regular car (internal combustion) engine, this energy takes the form of heat and kinetic energy (the mechanical motion). In a fuel cell, the fuel is also oxidized, but the resulting energy takes the form of electricity (plus a little heat).

A fuel cell power system has many components, but its heart is the fuel cell "stack." This stack is actually made of many thin, flat "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.) Each cell produces electricity, and the output of all the cells is combined to power the vehicle. Each cell contains several layers of different materials. Some layers help start the reactions that produce electricity; these are called catalysts. Each cell is supplied with hydrogen (from the fuel) and oxygen (from the outside air). The hydrogen moves through the cell and encounters the first of two catalyst layers. The catalyst causes the hydrogen molecules to release electrons and protons, creating the electrical current that powers the car. The protons migrate through the electrolyte to the second catalyst layer where they react with oxygen to form water. Most of the water is collected and reused within the system, but a small amount is released in the exhaust as water vapor. Other layers of materials called bipolar plates are designed to help draw fuel and air into the cell, and to conduct electrical current through the cell.

How does a fuel cell compare to a combustion engine?

The internal combustion engines in today's cars convert less than 20% of the energy in gasoline into power that moves the car. While automotive engineers have found ingenious ways to make internal combustion engines run more cleanly and efficiently, there's a limit to how good these engines can be.

Individual Fuel Cell



Fuel cells are highly efficient. They can capture 40-60% or more of a fuel's energy to power a car, depending on the fuel. Another big advantage is low or zero emissions. A fuel-cell vehicle running on pure hydrogen produces only water vapor.

Fuel cells can also run on any hydrogen-rich liquid or gas, as long as it is suitably processed. Thus, vehicles could run on a whole range of fossil fuels–gasoline, natural gas, liquid propane, petroleum distillates, etc.–as well as renewable fuels, for example, ethanol and methanol. If one of these fuels is used, the vehicle will produce some carbon dioxide and other trace emissions, but far less than a typical car.*

What problems need to be solved?

Before fuel cells can be commonly used in vehicles, research must overcome some problems. It's important to remember that practical applications for fuel cell technologies are still very new. The internal combustion engine is 120 years old and is still being refined. Government and industry scientists are working on new science and technology that will

- reduce the size and weight of all the components of a fuel cell power system to improve overall fuel efficiency,
- reduce the cost of producing the fuel cell stacks,
- help fuel cells start faster and respond better to rapid changes in power requirements,
- increase durability and reliability in extreme operating conditions, and
- improve the processing systems that convert hydrocarbon fuels (such as gasoline) into hydrogen for the fuel cell.

In addition, researchers are working to bring all the benefits of fuel cell power to other forms of transportation, including heavy vehicles (both on-road trucks and off-road heavy equipment) and locomotives.

For more information on how DOE is helping America remain competitive in the 21st century, please contact:

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