The Renewable and Nonrenewable Resource

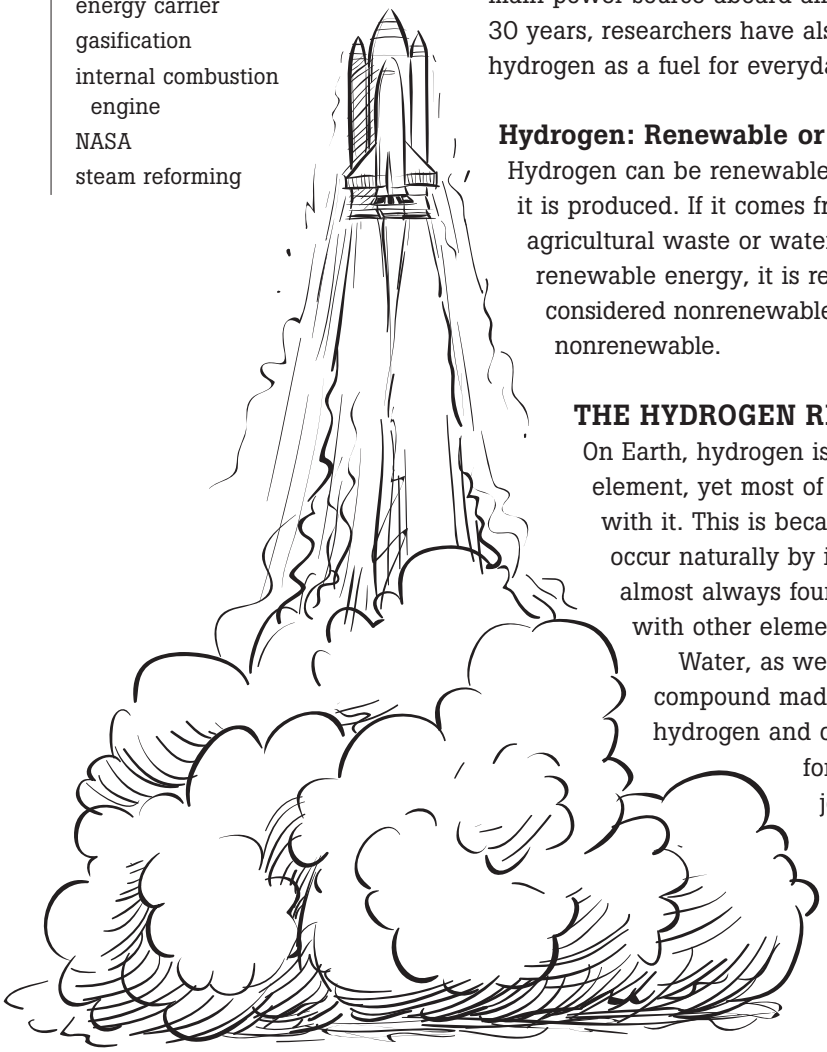
The Renewable and Nonrenewable Resource: HYDROGEN

TERMS IN GLOSSARY

anaerobic digestion
anode
cathode
compound
electrochemical
electrode
electrolysis
electrolyte
element
energy carrier
gasification
internal combustion engine
NASA
steam reforming

HYDROGEN IS ONE OF THE MOST ABUNDANT elements on Earth. Yet it wasn't until the 1700s that scientists first proved its existence, and it was later still that they recognized its value. Finally, by the mid–1800s, people were using hydrogen in "town gas," providing light and heat in cities across the United States and Europe. More recently, it has become useful in the production of ammonia, fertilizers, glass, refined metals, vitamins, cosmetics, cleaners, computers, and much more.

Hydrogen has launched many U.S. rockets into outer space. And hydrogen fuel cells, first used successfully in the 1960s, have been the main power source aboard all of NASA's space shuttles. Over the last 30 years, researchers have also been looking at other ways to use hydrogen as a fuel for everyday life.

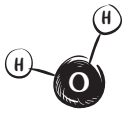


Hydrogen: Renewable or Nonrenewable?

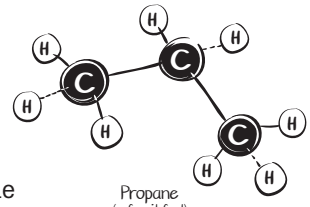
Hydrogen can be renewable or nonrenewable, depending on how it is produced. If it comes from a renewable resource (such as agricultural waste or water) and is produced using electricity from renewable energy, it is renewable. Otherwise, the hydrogen is considered nonrenewable. Most hydrogen produced today is nonrenewable.

THE HYDROGEN RESOURCE

On Earth, hydrogen is the third most common element, yet most of us aren't very familiar with it. This is because hydrogen doesn't occur naturally by itself. Instead, it is almost always found in combination with other elements.



Water



Propane
(a fossil fuel)

Water, as we know, is a compound made of the elements hydrogen and oxygen — hence the formula H_2O. Hydrogen joins with carbon to make fossil fuels such as natural gas, coal, and petroleum. It is a main building block of life. Hydrogen is found in the molecules of all living things.

Hydrogen: An Energy Carrier

In its natural state — in compounds with other elements — hydrogen's energy cannot be readily used. But hydrogen can *carry* the energy from those compounds to be used or stored, much as electricity carries energy from its source to its user. Hydrogen (like electricity) is therefore called an energy carrier.

Hydrogen Unbound

In order to use hydrogen we must separate it from the compounds in which it is bound. Hydrogen, once freed, is a colorless, combustible, carbon-free gas that carries a great deal of energy. Scientists have developed several different ways to produce hydrogen.

Producing *Renewable* Hydrogen

By Electrolysis. Electrolysis was first closely studied in the 1830s by English scientist Michael Faraday. In the electrolysis process, electricity is passed through water. The electrical charge causes the hydrogen and oxygen in the water molecule to split apart and turn into gases. An electrolyte, which may be a chemical or solid material, is often added to the water to help conduct electrons through it.

Water used in electrolysis is, of course, a renewable resource, but for the resulting hydrogen to be considered renewable, the electricity for this process must also have come from a renewable source. Any renewable method of generating electricity could be used.

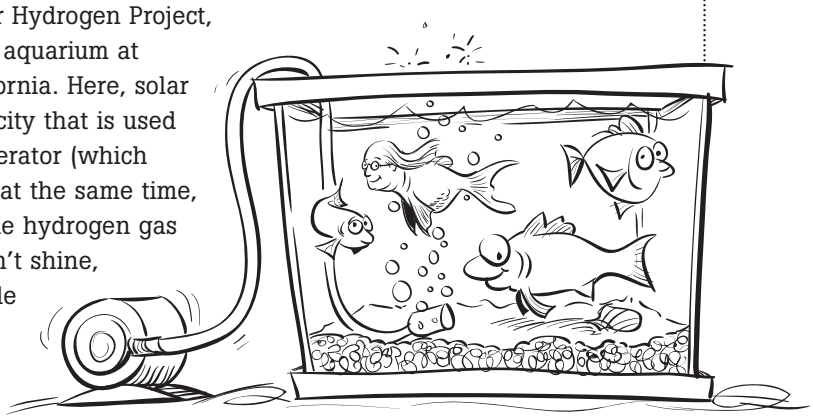
HYDROGEN TO GO

One day our cars may operate using hydrogen gas. Some major car manufacturers have designed engines that burn hydrogen instead of gasoline. The engines of these cars are similar to those in the vehicles we drive today.

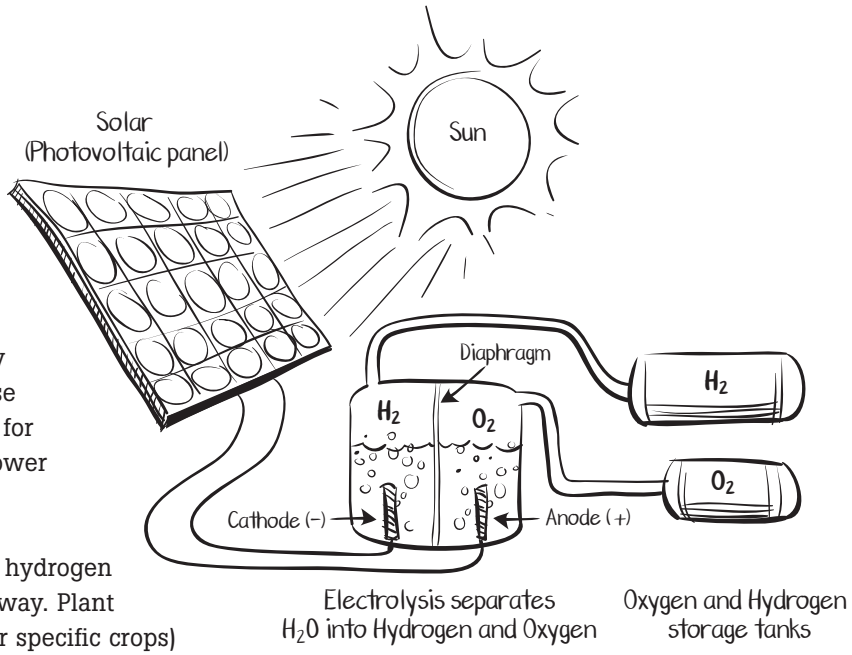
People like the idea of using these engines because burning hydrogen produces few polluting emissions. Researchers are now working on ways to store hydrogen aboard a vehicle, along with ways to make hydrogen "filling stations" widely available. Some companies are developing vehicles that use hydrogen without combustion. (See "Fuel Cells," page 110.)

POWER SKETCH: Hydrogen Fuel Cells Keep Aquarium Bubbling

A unique energy system, the Schatz Solar Hydrogen Project, helps keep fish alive in the marine lab aquarium at Humboldt State University in northern California. Here, solar panels mounted on the roof produce electricity that is used for two purposes: to drive the aquarium's aerator (which adds oxygen to the water for the fish) and, at the same time, to produce hydrogen gas by electrolysis. The hydrogen gas is stored and then, whenever the sun doesn't shine, the hydrogen is used in a fuel cell to provide electricity for the aquarium's aerator. This remarkable renewable energy system has been running day and night since 1994.



In the future, electrolysis systems might be installed at renewable energy power plants. Some or all of the electricity could be used for electrolysis, producing hydrogen gas that could be transported and used for other purposes. Electricity could be produced for customer use when needed, then shifted to use for hydrogen production at times of lower electricity demand.



Producing renewable hydrogen using electrolysis

Using Biomass. Biomass gives off hydrogen gas when it's heated in a certain way. Plant material (such as tree trimmings or specific crops) or organic waste can be used in this process, called gasification. Gasification is a thermal process that converts organic material into hydrogen, carbon monoxide, carbon dioxide, and small amounts of other gases. This mixture is frequently called synthesis gas, or syngas, because it can also be used to produce other chemicals.

Using Landfill Gas. When organic material begins to break down in our landfills, it gives off gases such as methane. Hydrogen can be produced from this methane gas and then used to generate electricity with a fuel cell. Hydrogen production from methane gas does give off carbon dioxide (as is also true with producing hydrogen from fossil fuels). However, since methane is a more potent greenhouse gas than carbon dioxide, using it to produce hydrogen is still considered preferable to allowing it into the atmosphere.

Using Biological Organisms. Some micro-organisms produce methane and other gases when they are caused to digest under special conditions; this process is called *anaerobic digestion*. Hydrogen can be extracted from the resulting methane gas. (See "Munching Microbes," page 40.) Anaerobic digesters can be used for a variety of purposes, including cleaning waste water and converting industrial waste.

Producing *Nonrenewable* Hydrogen

By Electrolysis. Hydrogen can be produced by electrolysis (described on page 108) using electricity from either renewable or nonrenewable resources. If the electricity comes from a fossil fuel or nuclear plant, then the resulting hydrogen is nonrenewable.

By "Steam Reforming." Another method of producing hydrogen involves using a fossil fuel, such as natural gas, and steam to produce hydrogen and by-products, in a process called *steam reforming*.* This method involves boiling equal amounts of natural gas and water to produce hydrogen and byproducts. The high-temperature steam separates hydrogen from the carbon atoms in the fossil fuel. Steam reforming is the process most commonly used today to produce hydrogen.

By Gasification. Gasification is described on pages 40 and 109 as a means of producing gas from biomass. A similar process can be used with a fossil fuel to produce hydrogen.

GENERATING ELECTRICITY FROM HYDROGEN

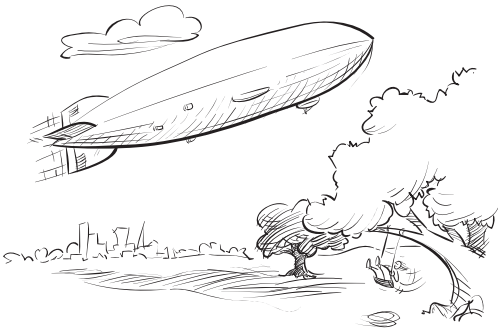
Fuel Cells

Fuel cells were once thought to be a "far out" technology suitable only for use aboard space shuttles. However, fuel cell technology is advancing rapidly. Fuel cells are already popping up in many aspects of everyday life, including generating electricity, powering vehicles, and operating small electrical devices. Even fuel-cell powered toys are now available.

Most of us associate the word "fuel" with burning something for its energy. However, in spite of the name, nothing is burned in fuel cells. Instead, fuel cells produce electricity using a method that is actually the reverse of electrolysis. Hydrogen (the "fuel") and oxygen are combined (rather than separated) through an electrochemical process that produces electricity, heat, and water.

Some types of fuel cells can use liquid or gas hydrocarbons directly, although most can use them only if the hydrocarbons are first converted into hydrogen.

**The steam reforming method can also be accomplished using certain geothermal resources. When geothermal steam is used, the resulting hydrogen is renewable.*



DISPELLING A MYTH

On May 6, 1937, a flash fire engulfed *The Hindenburg*, a luxury zeppelin aircraft filled with hydrogen gas. Dozens of people were killed. As the flaming airship plunged to the ground, newsreel cameras captured the disaster. The film footage caught the world's attention, and for decades hydrogen gas took the rap for causing the fire. Recently, hydrogen expert (and former NASA researcher) Addison Bain proved conclusively that hydrogen was not to blame. Rather, the fire was caused by the design and highly flammable fabric covering the craft, working in deadly combination with electric sparks from a developing thunderstorm. Bain's findings were confirmed by eye-witnesses who described the fire as a bright, fireworks-like display of color. Hydrogen would have burned with a colorless flame.

Fuel cells produce no polluting emissions. And, if the hydrogen used is produced with renewable methods, then the fuel cell is also considered renewable.

Because fuel cells are so clean, some states already provide financial incentives, or even exemption from permitting requirements, for fuel cell projects. Fuel cells range from very small units to those that produce more than one megawatt. Because they are modular, extra units can be added when more power is needed.

REMINDER

W = watt
kW = kilowatt = 1,000 watts
MW = megawatt = 1,000 kilowatts

1 megawatt can serve about 1,000 homes in the United States.

Hydrogen as a Combustible Fuel

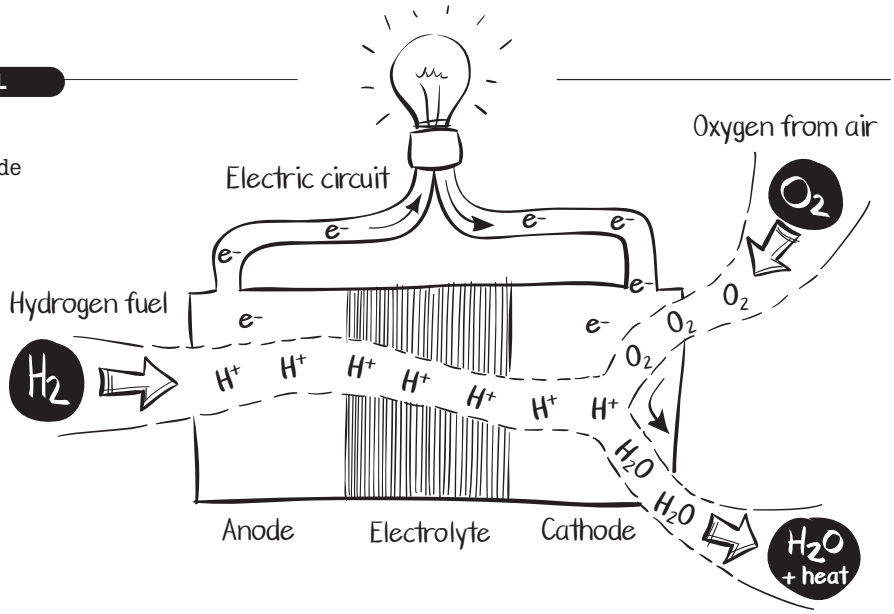
Hydrogen can also be used as a combustible fuel, in either a liquid or gaseous state. Hydrogen burns completely with very few pollutants and has a high energy content.

Sometimes hydrogen is added to natural gas at traditional power plants, making them work more efficiently and helping to reduce pollutants. It is possible that these power plants could be remodeled to run solely on hydrogen gas. If the hydrogen gas came from a renewable source, then these updated power plants would both supply renewable power and be easy on the environment.

Most of the current attention paid to combustible hydrogen fuel is for use with turbines, which would be used in a smart grid. (See "Smart Grids," page 147.)

INSIDE A FUEL CELL

In a fuel cell, hydrogen is introduced into the anode side and oxygen into the cathode side. Electrons are stripped from the hydrogen atoms and flow as an electric current. At the cathode end of the fuel cell the hydrogen joins with the oxygen, resulting in water and heat.



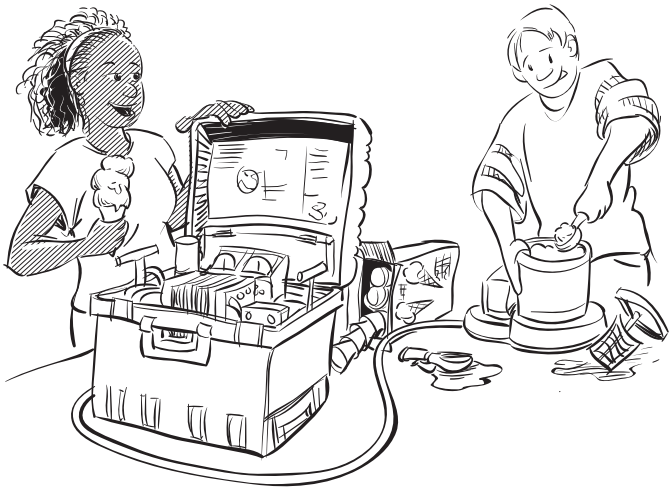
Hydrogen at Work in the U.S.

Around the country, many cities, utilities, hospitals, and industrial facilities are exploring the potential for fuel cells in electricity generation. Fuel cell power projects have already been installed in almost every state and new applications are being tried out. One example is a fuel cell that runs on hydrogen converted from methane, which was installed in a coal mine in Ohio. This fuel cell reduces dangerous coal mine methane emissions, while it provides electricity for miners. In Texas, a chemical manufacturer is using the hydrogen it produces onsite — which was once considered a waste — in a fuel cell that provides power for the factory. Below are some other examples of cool projects happening around the U.S.

A large fuel cell installation is providing power for a training school in Connecticut. At a wastewater treatment facility in Portland, Oregon, fuel cells using hydrogen produced from waste gas provide back-up power for plant operations. In New York, the Central Park Police Station runs on fuel cell power. The U.S. Department of Defense has already installed several stationary fuel cell power stations at a number of military bases.

Some major grocery chains are now using fuel cell forklifts, and telephone companies are using fuel cells to supply back-up power for cell phone towers and switching stations. A microwave relay station mounted atop a fire watchtower in Redwood National Park in northern California runs on both solar PV and fuel cell systems. A school in Santa Cruz, California, has a portable fuel cell unit that fits in a small suitcase. A renewable-energy teaching tool for the students, this system can run an ice cream maker, a blender, or even a computer.

The California Fuel Cell Partnership, founded over 10 years ago, links dozens of private and government groups to test fuel cell cars and to encourage building of hydrogen fueling stations. Hundreds of fuel cell cars have operated on California highways since 1999.



Portable fuel cell unit providing electricity to an ice cream maker

Image adapted with permission of the Schatz Energy Research Center

Hydrogen at Work Around the World

Iceland, already a leader in the use of hydropower and geothermal energy, is promoting the use of hydrogen to displace the 30 percent of its energy that comes from imported oil. Doing so would make Iceland completely energy self-sufficient. India is using fuel cells to meet exploding demand for cell phones. Korea has plans to be a huge supplier of fuel cells and hopes to create over half a million jobs in this industry. Many European countries, along with India, Japan, Korea, China, Australia, and others, are also pursuing the use of hydrogen fuel cells.

CONSIDERATIONS

- Hydrogen is a transportable fuel. This is important because many renewable energy resources are not transportable. In remote and unpopulated areas, far from transmission lines, local geothermal, ocean, solar, and wind resources can be used to produce electricity. Then the electricity can be used on-site to make renewable hydrogen that can be stored to provide electricity when power is not available and/or transported for use elsewhere as a combustible fuel or in fuel cells.
- If hydrogen escapes from its container, it rapidly disperses into the air rather than puddling on the ground the way heavier-than-air fuels, such as gasoline, tend to do. However, hydrogen burns easily and invisibly, so care needs to be taken when handling it, especially if it escapes and collects in a contained space. (Hydrogen is explosive if exposed to oxygen.) With proper precautions, hydrogen is thought by some to be just as safe as gasoline. Currently, engineers are perfecting systems to contain and transport hydrogen safely and economically because it is considered an important fuel for our future.
- Hydrogen burns cleanly, though it does produce some emissions when burned. Used in a fuel cell, the only by-products are heat and water.
- Hydrogen has about three times the energy of gasoline by weight, yet only one third as much energy by volume. Hydrogen storage is therefore an issue that could limit future applications. Scientists are working hard on new storage options.

(continued)

CONSIDERATIONS (continued

- Currently, much of our hydrogen gas comes from processes that use fossil fuels. If we continue producing hydrogen in these ways, we will probably have the same concerns about hydrogen production that we now have about fossil fuel use — i.e., energy insecurity, depletion, and pollution. (See pages 122–123, "Considerations," and all of Chapter 4, "Energy, Health, and the Environment.")
- The production of hydrogen, especially with renewable methods such as electrolysis, is still quite expensive. It is hoped that costs will come down as the technology for producing renewable hydrogen is perfected through research and experience.
- Some people think that hydrogen will replace fossil fuels as our primary source of energy. Conversion to a "hydrogen economy" will require new technology and distribution networks that will take years to develop. In the U.S. enthusiasm for hydrogen as a power option has diminished over the last decade. However, according to industry experts, Europe, Asia and the Middle East, still view hydrogen as a strong competitor as a fuel option and also as a storage medium for renewable energy.
- Within the fuel cell industry, some consider hydrogen to be renewable if it is produced from a renewable resource, even if by a process using nonrenewable electricity.