

Hydrogen Production

Hydrogen is an energy carrier, not an energy source — it stores and delivers energy in a usable form, but it must be produced from compounds that contain it.

Hydrogen can be produced using diverse, domestic resources including fossil fuels, such as coal (with carbon sequestration) and natural gas; nuclear; and biomass and other renewable energy technologies, such as wind, solar, geothermal, and hydroelectric power. This great potential for diversity of supply is an important reason why hydrogen is such a promising energy carrier.

Hydrogen can be produced at large central plants as far as several hundred miles from the point of end-use; semi-centrally, 25 to 100 miles from the point of end-use; or in small distributed units located at or very near the point of end-use, such as at refueling stations or stationary power sites.

How Is Hydrogen Produced?

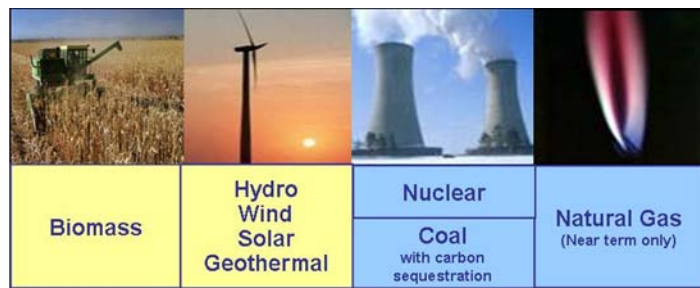
Researchers are developing a wide range of technologies to produce hydrogen economically from a variety of resources in environmentally friendly ways.

Natural Gas Reforming

Hydrogen can be produced from methane in natural gas using high-temperature steam. This process, called steam methane reforming, accounts for about 95 percent of the hydrogen used today in the United States. Another method, called partial oxidation, produces hydrogen by burning methane in air. Both steam reforming and partial oxidation produce a “synthesis gas,” which is reacted with water to produce more hydrogen.

Renewable Electrolysis

Electrolysis uses an electric current to split water into hydrogen and oxygen. The electricity required can be generated using renewable energy technologies, such as wind, solar, geothermal, and hydroelectric power.



Hydrogen can be produced using a variety of resources. This diversity of sources makes hydrogen a promising energy carrier and enables hydrogen production almost anywhere in the world.

Gasification

Gasification is a process in which coal or biomass is converted into gaseous components by applying heat under pressure and in the presence of steam. A subsequent series of chemical reactions produces a synthesis gas, which is reacted with steam to produce more hydrogen that then can be separated and purified.

- ▶ Producing hydrogen directly from coal by gasification and reforming processes is much more efficient than burning coal to make electricity that is then used to make hydrogen. Researchers are developing carbon capture and sequestration technologies to separate and store the carbon dioxide (CO₂) produced in this process. With carbon capture and sequestration, hydrogen can be produced directly from coal with near-zero greenhouse gas emissions.
- ▶ Like coal, biomass can be gasified using high temperatures and steam to produce hydrogen. Because biomass resources consume CO₂ in the atmosphere as part of their natural growth process, producing hydrogen through biomass gasification releases near-zero net greenhouse gases.

Renewable Liquid Reforming

Biomass can also be processed to make renewable liquid fuels, such as ethanol or bio-oil, that are relatively convenient to transport and can be reacted with high-temperature steam to produce hydrogen at or near the point of end-use.

Hydrogen Production

Nuclear High-Temperature Electrolysis

Heat from a nuclear reactor can be used to improve the efficiency of water electrolysis to produce hydrogen. By increasing the temperature of the water, less electricity is required to split it into hydrogen and oxygen, which reduces the total energy required.

High-Temperature Thermochemical Water-Splitting

Another water-splitting method uses high temperatures generated by solar concentrators (special lenses that focus and intensify sunlight) or nuclear reactors to drive a series of chemical reactions that split water. All of the chemicals used are recycled within the process.

Photobiological and Photoelectrochemical

When certain microbes, such as green algae and cyanobacteria, consume water in the presence of sunlight, they produce hydrogen as a byproduct of their natural metabolic processes. Similarly, photoelectrochemical systems produce hydrogen from water using special semiconductors and energy from sunlight.

What Are the Challenges?

The greatest technical challenge to hydrogen production is cost reduction. For transportation, a key driver for energy independence, hydrogen must be cost-competitive with conventional fuels and technologies on a per-mile basis. This means that the cost of hydrogen — regardless of the production technology, and including the cost of delivery — must be in the range of \$2.00 to \$3.00 per gallon gasoline equivalent (untaxed). Note: Transportation fuels are often compared based on their equivalency to gasoline. The amount of fuel with the energy content of one gallon of gasoline is referred to as a gallon gasoline equivalent (gge).

Research Directions

Hydrogen production technologies are in various stages of development. Some technologies, such as steam methane reforming, are becoming well-developed and can be used in the near term. Others, such as high-temperature thermochemical water-splitting, photobiological, and photoelectrochemical, are in the very early stages of laboratory development and considered potential pathways for the long-term.

In general, research is focused on reducing capital equipment, operations, and maintenance costs, as well as improving the efficiency of hydrogen production technologies. Related research includes developing carbon sequestration technology to ensure that coal-based hydrogen production releases almost no greenhouse gas emissions and improving agricultural handling practices and breeding efforts to reduce the cost of biomass resources used in hydrogen production.

For print copies of this fact sheet, please call the DOE Energy Efficiency and Renewable Energy Information Center at 877-EERE-INF(O)/877-337-3463.

Did you know...

Hydrogen is an energy carrier, not an energy source, meaning that it stores and delivers energy in a usable form.

Hydrogen can be produced using abundant and diverse domestic energy resources, including fossil fuels, such as natural gas and coal; renewable energy resources, such as solar, wind, and biomass; and nuclear energy.

Using hydrogen as a form of energy can not only reduce our dependence on imported oil, but also benefit the environment by reducing emissions of greenhouse gases and criteria pollutants that affect our air quality.

The DOE Hydrogen Program supports research and development of fuel cell and hydrogen production, storage, and delivery infrastructure technologies needed to support hydrogen fuel cells for use in transportation and electricity generation.

The DOE Hydrogen Program works with industry, academia, national laboratories, and other federal and international agencies to overcome critical technology barriers, facilitate the development of model codes and standards, validate hydrogen fuel cell technologies in real world conditions, and educate key stakeholders who can facilitate the use of hydrogen and fuel cell technologies.

Increase Your H2IQ! Visit
www.hydrogen.energy.gov

November 2008