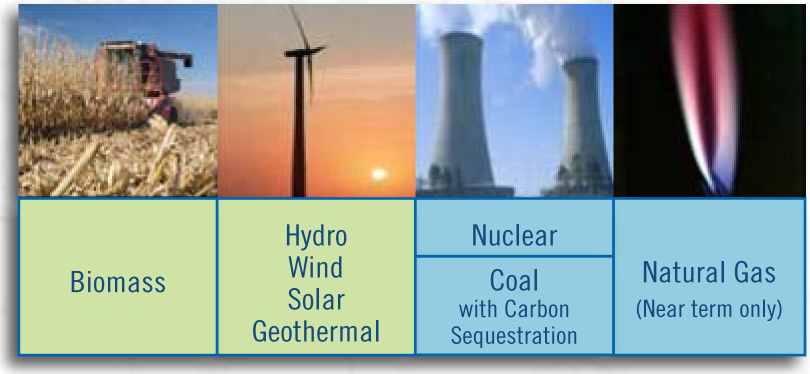
Hydrogen Production

DOE Hydrogen Program

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. 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.



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.

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.

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 (CO_2) 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 CO_2 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.

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.

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Hydrogen Production Quick Facts

- The U.S. currently produces over 9 million tons of hydrogen annually, mostly for use in petroleum refining and fertilizer production. That's enough to fuel more than 34 million cars.
- Natural gas is an important resource for near-term hydrogen production — it has a high hydrogen-to-carbon ratio (it emits less CO_2 compared to other hydrocarbons) and an existing pipeline delivery infrastructure. But there is a limited supply of natural gas so large-scale production of hydrogen from natural gas is not considered a long-term option.
- It takes energy to produce hydrogen — but producing any fuel, even gasoline, requires energy. On a "well-to-wheels" basis, however, accounting for the full fuel cycle from energy source to production to end-use, fuel cell vehicles running on hydrogen produced from natural gas would use less energy and emit less carbon than both gasoline hybrid electric vehicles and conventional internal combustion engine vehicles. *Source: A.D. Little, Inc. Guidance for Transportation Technologies, pp. 59 and 61*
- It is estimated that using natural gas to produce hydrogen in the near term would increase overall U.S. natural gas consumption by less than three percent.
- The United States has more proven coal reserves than any other country in the world. FutureGen is a 10-year, $1-billion initiative to demonstrate the world's first coal-based, near-zero atmospheric emissions powerplant to produce electricity and hydrogen.
  See www.fossil.energy.gov/futuregen
- DOE's Nuclear Hydrogen Initiative conducts research and development focused on hydrogen production technologies that can be coupled to next generation nuclear reactors.
  See www.ne.doe.gov/hydrogen/hydrogenOV.html
- Today, the United States has more than 6,300 megawatts (MW) of wind generating capacity and 80,000 MW of hydropower generating capacity, which can contribute to creating electricity for hydrogen production.
  Source: www.eere.energy.gov/windandhydro
- Biomass — which includes agriculture crop residues, forest residues, special crops that can be grown specifically for energy use, and organic municipal solid waste — supplies approximately four percent of the total energy produced in the United States.
  Source: www.eere.energy.gov/biomass/biomass_today.html

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October 2006