HYDROGEN FACT SHEET

Hydrogen Production Overview

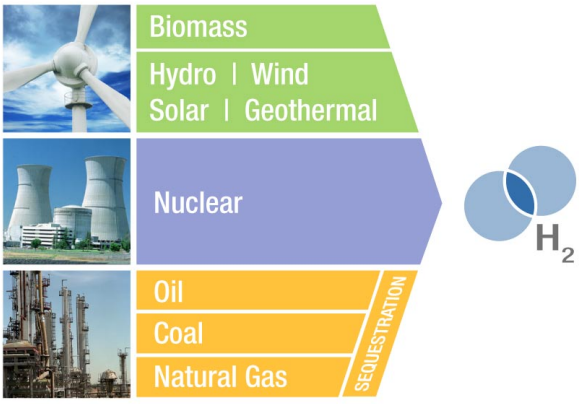
Introduction

The future hydrogen economy will feature hydrogen as an energy carrier in a reliable and sustainable energy supply system. In today's energy supply system, electricity serves as the energy carrier. Electricity made by the conversion of primary energy sources (see sidebar) is easily transported and delivered in a usable form to end-users. Hydrogen produced from hydrogen-containing feedstocks using primary energy sources is the first and most crucial step in the path toward a future hydrogen energy economy. The U.S. Department of Energy and its industry and university partners are conducting extensive research and development to advance hydrogen production technologies.

Sources of Hydrogen

Hydrogen does not exist alone in nature but must be "made" typically by isolating hydrogen from a hydrogen-containing substance or feedstock. Water (H_20), an abundant natural resource, contains hydrogen as do natural gas (CH_4), biomass (cellulose), and "hydro" carbons like fossil fuels. One benefit of hydrogen as an energy carrier is that it can be produced from a very diverse base of naturally occurring feedstocks via processes powered by any of the available primary energy sources. This allows hydrogen to be produced almost anywhere in the world using the resources and processes that are most economical or consciously preferred by the various countries, states, regions, or locales.

Figure 1. Sources of Hydrogen



Primary Energy Sources

Primary energy sources are found or stored in nature. These include biomass, coal, oil, natural gas, sunlight, wind, water, nuclear power from radioactive substances, thermal power stored in the earth's interior and oceans, and potential energy from the earth's gravity.

Secondary Energy Sources

Secondary sources of energy are produced from primary energy sources using technology. These secondary energy sources include, for example, the production of electricity by burning coal, or using photovoltaic cells to harness solar energy, or the production of alcohol or methanol from corn and other crops. Secondary energy sources are also energy carriers.

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Hydrogen Production

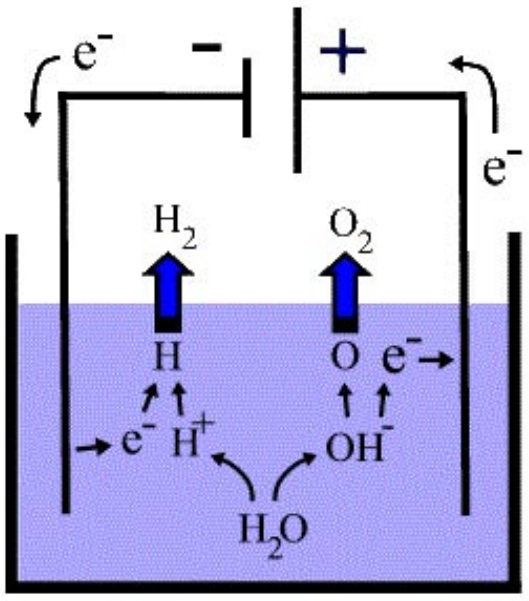
With the diversity of feedstocks and primary energy sources available there is a corresponding variety of technologies to produce hydrogen. All of the hydrogen production processes are based on the separation of hydrogen from hydrogen-containing feedstocks. There are three primary methods to achieve separation: thermal, chemical, and biological. The hydrogen feedstock dictates the selection of separation method.

The hydrogen produced today for the industrial sector, roughly 9 million tons, is largely by thermal processes with natural gas as the hydrogen feedstock. The steam methane reformation of natural gas consists of two steps: (1) reformation of methane with high temperature steam supplied by burning natural gas to obtain a synthesis gas, and (2) a water gas shift reaction to form hydrogen and carbon dioxide from the carbon monoxide produced in the first step. To a lesser degree, hydrogen is produced electrochemically from water when higher purity hydrogen is needed. The process by which hydrogen is produced from water is called electrolysis, where electricity is passed through water in an ionic transfer device to separate water into its hydrogen and oxygen parts. These two processes are well understood and time-tested, but are currently too expensive to produce hydrogen in the quantities necessary to serve the energy sector. Technical challenges in performance and cost must be overcome before these production technologies can contribute to large-scale use of hydrogen as an energy carrier.

Carbon Sequestration

Carbon sequestration is the process of utilizing natural and man-made processes to store carbon, on a long-term basis, in an effort to reduce or slow the buildup of carbon dioxide (the principal greenhouse gas) in the atmosphere. Carbon is naturally sequestered in the earth's terrestrial biosphere, and geologic and oceanic reservoirs. In theory, it will be possible to expand on natural sequestration and capture, separate, store and/or otherwise utilize carbon in a manner that will benefit society. Carbon sequestration also encompasses the reuse of carbon for other value-added applications.

Figure 2. Electrolysis: Using Electricity to Split Water



energy (electricity) + 2 H_2O = O_2 + 2 H_2

Research and development efforts supported by the U.S. Department of Energy (DOE) focus on near-term production of hydrogen from natural gas and coal with advanced, cleaner gasification technologies. In the long-term, the DOE plans for commercially available, high-efficiency, low-cost hydrogen production technologies making use of a diverse blend of primary energy sources, including fossil fuels with carbon sequestration, nuclear, and renewable resources.

Production Infrastructure

The development of a national hydrogen production infrastructure to support a hydrogen economy could evolve along one or more pathways: distributed production infrastructure located at the point of use or centralized production infrastructure at large industrial production sites. Distributed hydrogen production presents the advantages of smaller capital investments and minimal transport and delivery infrastructures, yet fails to achieve the economies of scale of centralized production. Power Parks, where hydrogen would be centrally produced for industrial use or to generate electricity via fuel cells, would offer another production pathway for providing transportation fuel.

Distributed Production

Located at point of use. Often produces small quantities of hydrogen.

Centralized Production

Central production station featuring pipelines or other transport infrastructures to deliver the hydrogen to points of use. Usually produces hydrogen on a large scale.

Role in the Transition to a Hydrogen Economy

Hydrogen production represents a vital foundation for a hydrogen economy. Research, development, and demonstration, however, must continue in order to bring down the cost, increase the efficiency, and address the emissions issues associated with hydrogen production technologies. The transition to a hydrogen economy will feature a variety of processes from a diverse resource base, beginning with fossil fuels and nuclear fuel in the near- and mid-term and eventually featuring renewables in the long-term. The U.S. DOE, in its National Hydrogen Vision, foresees hydrogen as a flexible, safe, affordable, domestic energy resource that will become “America’s ‘clean energy choice,’ joining electricity as a primary energy carrier and providing the foundation for a globally sustainable energy system.”

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HYDROGEN PRODUCTION OVERVIEW

Interested in Learning More?

U.S. Department of Energy
www.eere.energy.gov/hydrogenandfuelcells

National Hydrogen Association
www.hydrogenassociation.org

U.S. Fuel Cell Council
www.usfcc.com

International Partnership for the Hydrogen Economy (IPHE)
www.iphe.net

Major Hydrogen Production Processes

Primary Method	Process	Feedstock	Energy	Other
Thermal	Steam Reforming	Natural Gas	Heat, possibly from nuclear power plants	70% efficient. Will require carbon sequestration
	Thermochemical Water Splitting	Water	High temperature heat from advanced gas-cooled nuclear reactors	No emissions
	Gasification	Coal, Biomass	Steam and oxygen at high temperature and pressure	Some emissions. Will require carbon sequestration
	Pyrolysis	Biomass	Moderately high temperatures steam	Some emissions. Will require carbon sequestration
Electrochemical	Electrolysis	Water	Renewables, including wind and solar, and electricity	Some emissions depending on source of electricity
	Photoelectrochemical	Water	Direct sunlight	Minor emissions
Biological	Photobiological	Water and algae strains	Direct sunlight	No emissions
	Anaerobic Digestion	Biomass	High temperature steam	New, undeveloped technology
	Fermentative Micro-Organisms	Biomass	High temperature steam	New, undeveloped technology

Descriptions of various hydrogen production processes can be found at www.eere.energy.gov/hydrogenandfuelcells

Sources:

- U.S. Department of Energy. *Multi-Year Research, Development and Demonstration Plan*. June 2003.
- U.S. Department of Energy. *A National Vision of America's Transition in a Hydrogen Economy - In 2030 and Beyond*. February 2002. U.S. Department of Energy.
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- National Academy of Science. *The Hydrogen Economy: Opportunities, Costs, Barriers, and R&D Needs*. 2004.

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