LPRO: Legislative Policy and Research Office

HYDROGEN ENERGY

BACKGROUND BRIEF

Hydrogen is the most abundant element in the universe, but on earth it rarely occurs naturally in its pure state. Instead, hydrogen is usually combined with other elements such as oxygen or carbon. According to the United States Department of Energy, hydrogen can be used to store and transport energy, but it is not itself a source of energy. When produced from wind or other renewable resources, hydrogen can store carbon-free energy that can later be used to generate electricity or power vehicles (Figure 1).

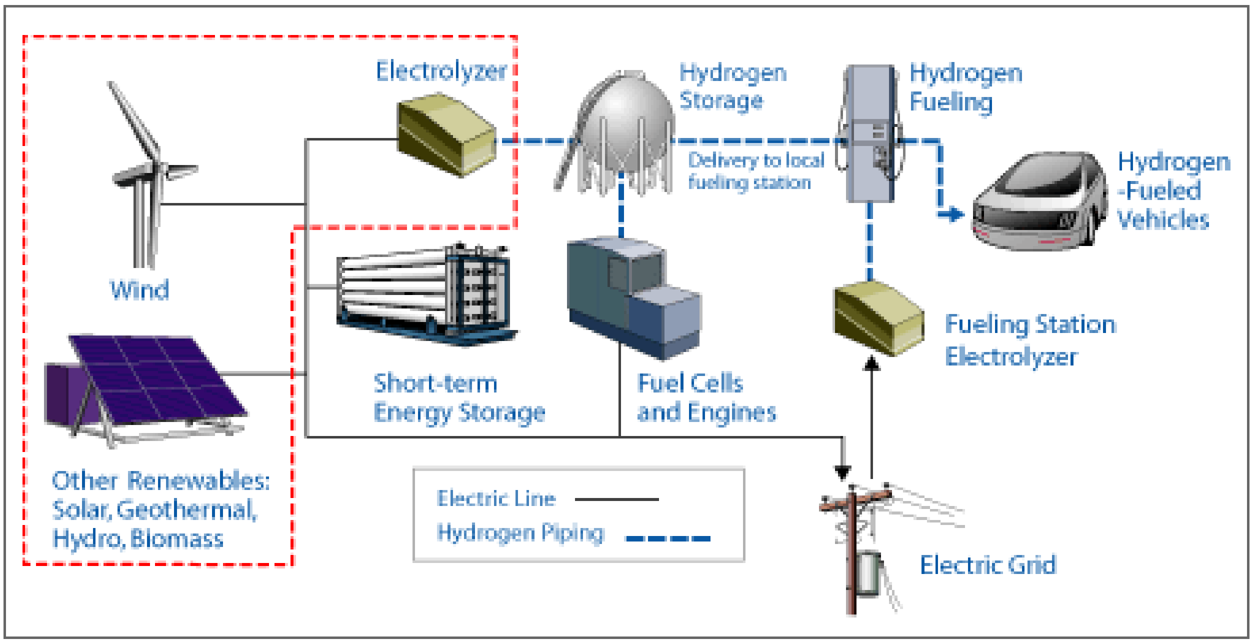

Figure 1: Hydrogen Grid and Storage Integration (NREL)

According to the U.S. Department of Energy, the major challenge to hydrogen production is cost. To compete as a transportation fuel, hydrogen must be comparable to conventional fuels and technologies on a per-mile basis. For fuel cell electric vehicles to be competitive, the total untaxed, delivered, and dispensed cost of hydrogen needs to be less than $4/gge. A gge, or gasoline gallon equivalent, is the amount of fuel that has the same amount of energy as a gallon of gasoline. One kilogram of hydrogen is equivalent to one gallon of gasoline on an energy basis.

PRODUCING HYDROGEN

Pure hydrogen can be produced using a variety of sources, including fossil fuels such as coal and natural gas, or renewable sources such as biomass, wind, solar, geothermal, and water. Currently, about 95 percent of hydrogen in the United States is made from natural gas for use in petroleum processing and fertilizer production.

Each year, about 10-11 million metric tons of hydrogen are produced in the United States, enough to power 20-30 million cars or five to eight million homes. The majority of this production takes place in California, Louisiana, and Texas.

All technologies to produce pure hydrogen involve breaking the chemical bonds between hydrogen and its companion elements. In the United States, the most common way hydrogen is produced is large-scale ***natural gas reforming***. Natural gas reforming is an advanced and mature production process that builds upon the existing natural gas pipeline delivery infrastructure. Today, about 95 percent of the hydrogen produced in the United States is made by natural gas reforming in large central plants.

Electrolysis, another relatively common technology, produces hydrogen using electricity to split water into hydrogen and oxygen atoms. This method in and of itself does not generate emissions, but it does require a substantial amount of electricity and, depending on how the electricity is generated, can have a high greenhouse gas input. While new technologies are being developed to reduce costs and improve efficiency, electrolysis is currently an expensive process. Similar technologies are in development to use microbes or semiconductors to harness light energy instead of electricity to split water molecules. In addition, multiple other technologies are in the development phase seeking to produce hydrogen more efficiently and with a lower carbon footprint.

HYDROGEN STORAGE

Hydrogen storage for large-scale use has been a challenge due to hydrogen's low-energy content per volume. Hydrogen can be stored as a *compressed hydrogen gas* in high-pressure tanks, as *cryogenic liquid hydrogen* in insulated tanks, as a compound within other materials, or on the surface of other materials. Liquid hydrogen has a higher energy density per volume than hydrogen gas but is costly to produce due to the energy needed for cooling. According to USDOE, "hydrogen storage in materials offers great promise, but additional research is required to better understand the mechanism of hydrogen storage in materials under practical operating conditions and to overcome critical challenges related to capacity, the uptake and release of hydrogen, management of heat during refueling, cost, and life cycle impacts."

One storage concept discussed in Oregon is the hydrogen hub. A hydrogen hub would use hydroelectric or wind power to synthesize ammonia, a hydrogen-rich compound, to take advantage of excess energy that would otherwise be lost (for instance, during spring run-off when energy demand is low, but hydroelectric generation is high). During peak power demand, the ammonia would be burned to produce electricity with water vapor and nitrogen gas as byproducts. A hydrogen hub has not been built.

FUEL CELLS

A fuel cell uses oxygen and hydrogen to create electricity through a chemical process instead of combustion. The fuel input may be pure hydrogen or a hydrogen-rich compound such as methanol, ethanol, or other hydrocarbons. Fuel cells that use pure hydrogen as the fuel emit only heat and water as byproducts. Fuel cells are adaptable to scale and can be used in a variety of applications, including utility-sized power plants, back-up generators, powering portable battery-powered devices (e.g., laptop computer), and vehicles. Cost and durability are the primary challenges for fuel cell adoption, although other technical challenges exist based on the type of technology and its intended application.

DISTRIBUTING HYDROGEN

Hydrogen is currently transported by pipeline, in high-pressure tube trailers, or as liquefied hydrogen. Currently, hydrogen is primarily produced near the location where it is used, as a large scale infrastructure for delivery does not exist. Due to gaseous hydrogen's low-energy density per volume, transport using tube trailers is typically cost effective over distances less than 200 miles from the point of production. Hydrogen can also be transported in chemical carriers, such as ethanol, for easier transport to be converted at the site of use.