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HYDROGEN FACT SHEET: PRODUCTION OF LOW-CARBON HYDROGEN

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MAY 2021

To reach net-zero emissions by 2050 to limit global temperature rise to 1.5 degrees Celsius (°C), low-carbon hydrogen can play an important role both as a carbon-free fuel and as a feedstock for fuels and products. Hydrogen use can be versatile: a substitute fuel for industrial heat or chemistry, a feedstock to make synthetic fuels (e.g., ammonia or methanol), and an efficient power technology when converted into electricity with a fuel cell.[1]

Hydrogen is abundant in water, biomass, and hydrocarbons. It is easily ignited and burns at about 2,200°C[2] in air, yielding water, with zero direct greenhouse gas emissions. Generating hydrogen can be carbon intensive, however, and the process of compressing, cooling, and liquifying it is energy-intensive. For hydrogen use in different applications to be carbon free, it must be produced through a low-carbon process.

Hydrogen Production

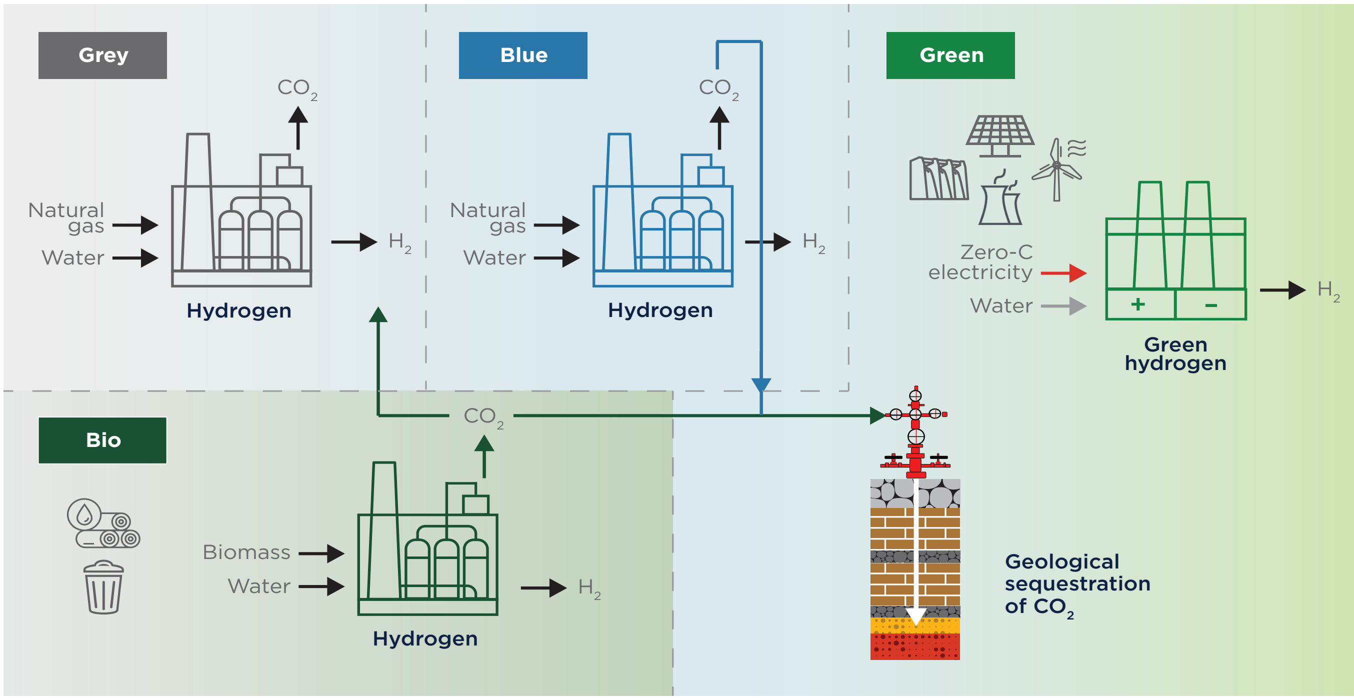
The global demand for hydrogen was about 70 million metric tons (Mt)[3] per year in 2019. Half was used to make ammonia and fertilizers; half in petrochemical refineries or production. There are 169 hydrogen projects currently operational across 162 countries.

Today, 98 percent of hydrogen is made from fossil fuels with no CO_2 emissions control and is responsible for 830 Mt of CO_2 each year. In the United States, 95 percent of hydrogen is produced by a reaction between a methane source, such as natural gas, and high-temperature steam (700°C–1,100°C), referred to as steam methane reforming (SMR).[4] About 4 percent is produced through coal gasification, a process that involves reacting coal with oxygen and steam under high pressures and temperatures, and 1 percent is produced from electrolysis. Globally, 76 percent of hydrogen is produced from natural gas by SMR, with 22 percent produced through coal gasification and 2 percent from electrolysis. Hydrogen produced from uncontrolled fossil fuels is referred to as **"grey" hydrogen**.

To qualify as low-carbon hydrogen, conventional production must be coupled with carbon capture and utilization or storage (CCUS), referred to as **"blue" hydrogen**. Adding CCUS increases the cost of hydrogen production by 20 to 80 percent—that increase varies by the production method of the hydrogen. There are currently seven blue hydrogen facilities in operation, four in the US and three in Canada, producing over 350,000 tons[5] of "low-carbon" hydrogen, with more than 20 planned developments in the next decade.

Hydrogen can be produced through electrolysis of water, splitting water (H_2O) into hydrogen and oxygen, using an electrolyzer. Electrolysis generates no direct greenhouse gas emissions, and if the input electricity has no associated greenhouse gas emissions in its generation process (e.g., from solar, wind, hydropower, or nuclear), this type of zero-carbon hydrogen is referred to as **"green" hydrogen**. Two types of electrolyzers are commercially available: polymer electrolyte membrane (PEM), which uses a solid specialty plastic material as its electrolyte, and alkaline electrolyzers, which use a liquid alkaline solution of sodium or potassium hydroxide as the electrolyte. The largest green hydrogen plant, with planned production of 650 tons per day by 2025, is being developed by Air Products[6] and ACWA Power in Saudi Arabia. The Asian Renewable Hub (AREH)[7] green hydrogen plant in Australia (1.75 Mtpa) is expected to surpass Air Products production when it comes on stream before 2028. Both projects will convert hydrogen into ammonia.

Figure 1: Green hydrogen production process



Production Costs Today and Projections for 2030

The cost of producing hydrogen varies in different geographies as a function of gas price, electricity costs, renewable resources, and infrastructure. Today "grey" hydrogen costs between $0.90 and $1.78 per kilogram, "blue" hydrogen ranges from $1.20 to $2.60 per kilogram, and "green" hydrogen costs range from $3.00 to $8.00 per kilogram. An analysis by the International Energy Agency forecasts a 30 percent decline in green hydrogen prices[8] by 2030 as a result of declining cost of reliable renewable electricity and scaled hydrogen production, although others disagree.[9] The price difference between grey and blue hydrogen is predicted to narrow with cheaper natural gas prices and a decline in the cost of CCUS.[10]

Table 1: Cost of hydrogen production in the US

Hydrogen production method	Cost low ($/kg)	Cost high ($/kg)	Cost mean ($/kg)
SMR without CCS	$1.05	$1.50	$1.29
SMR with CCS (89% capture)	$1.71	$2.15	$1.93
Wind energy	$6.02	$7.25	$6.64
Solar energy	$6.70	$8.30	$7.50
Hydropower	$4.80	$6.34	$5.57

Source: J. Friedmann, Z. Fan, and K. Tang, "Low-Carbon Heat Solutions for Heavy Industry Report," Center on Global Energy Policy, Columbia University, October 2019, https://www.energypolicy.columbia.edu/research/report/low-carbon-heat-solutions-heavy-industry-sources-options-and-costs-today.

Challenges to Production

Increased production of low-carbon hydrogen faces substantial challenges: technical concerns, cost and economics, infrastructure needs, and absence of manufacturing capability for key equipment and sufficient market-aligning policies. Producing green hydrogen in geographies with cheaper renewable energy at less than $30/MWh, with a 90 percent capacity factor, can lead to significant cost reduction, as will investment in producing more efficient and cheaper electrolyzers. Countries such as the United Kingdom are currently investing in hydrogen production hubs to reduce storage, ports, and electricity grid infrastructure needs. Additional financial policy support[11] to attract private financing and investment is required to develop large hydrogen projects.

Notes

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