

A clean US hydrogen economy is within reach, but needs a game plan, energy researchers say

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Addressing climate change requires not only a clean electrical grid, but also a clean fuel to reduce emissions from industrial heat, long-haul

heavy transportation, and long-duration energy storage. Hydrogen and its derivatives could be that fuel, argues a Commentary publishing August 11 in the journal *Joule*, but a clean U.S. H₂ economy will require a comprehensive strategy and a 10-year plan. The commentary suggests that careful consideration of future H₂ infrastructure, including production, transport, storage, use, and economic viability, will be critical to the success of efforts aimed at making clean H₂ viable on a societal scale.

"We applaud the U.S. Secretary of Energy, Jennifer Granholm, for launching the ambitious Hydrogen Earthshot program with a technology-agnostic stretch goal of greenhouse gas-free H₂ production at \$1/kg before the end of this decade," write Arun Majumdar, a Jay Precourt Professor and Co-Director of the Precourt Institute for Energy at Stanford University and lead author of the commentary, and colleagues. "Similar R&D programs with techno-economic stretch goals are needed for H₂ storage, use, and transport as well. The Hydrogen Earthshot is necessary to create a hydrogen economy, but it is not sufficient."

About 70 million metric tons of H₂ are produced around the world each year, with the U.S. contributing about one-seventh of the global output. Much of this H₂ is used to produce fertilizer and petrochemicals, and nearly all of it is considered "gray H₂," which costs only about \$1 per kilogram to produce but comes with roughly 10 kilograms of CO₂ baggage per kilogram H₂.

"An H₂ economy already exists, but it involves lots of greenhouse gas emissions," says Majumdar. "Almost all of it is based on H₂ from methane. A clean H₂ economy does not exist today."

Researchers have plenty of colorful visions as to what a clean H₂ economy might look like. "Blue H₂," for example, involves capturing CO₂ and reducing emissions, resulting in H₂ with less greenhouse gas

output. However, it currently costs about 50% more than gray H₂, not including the cost of developing the pipelines and sequestration systems needed to transport and store unwanted CO₂.

"To make blue H₂ a viable option, research and development is needed to reduce CO₂ capture costs and further improve capture completeness," write Majumdar and colleagues.

Another form of clean H₂—dubbed "green H₂"—has also captured scientists' attention. Green H₂ involves the use of electricity and electrolyzers to split water, without any greenhouse gas byproducts. However, it costs \$4 to \$6 per kilogram, a price that Majumdar and colleagues suggest could be reduced to under \$2 per kilogram with a reduction in carbon-free electricity and electrolyzer costs.

"Turquoise H₂," which is achieved through methane pyrolysis, when methane is cracked to generate greenhouse gas-free H₂, is also creating a buzz in the research world. The solid carbon co-product generated in this process could be sold to help offset costs, although Majumdar and colleagues point out that the quantity of solid carbon produced at the necessary scale would exceed current demand, resulting in a need for R&D efforts to develop new markets for its use.

Whether blue, green, or turquoise, greenhouse gas-free (and, in actuality, colorless) H₂ or its derivatives could be used in transportation, the chemical reduction of captured CO₂, long-duration energy storage in a highly renewable energy-dependent grid, and chemical reductants for steel and metallurgy, and as high-temperature industrial heat for glass and cement production. But for these applications to become a reality, H₂ production will have to hit certain cost benchmarks—\$1 per kilogram for the production of ammonia and petrochemicals or for use as a transportation fuel or fuel cells.

The researchers also emphasize that the U.S. will need to consider how H₂ pipelines will be developed and deployed in order to transport it, as well as how to store H₂ cost-effectively at a large scale. "Developing and siting new pipeline infrastructure is generally expensive and involves challenges of social acceptance," write Majumdar and colleagues.

"Hence, it is important to explore alternative approaches for a hydrogen economy that does not require a new H₂ pipeline infrastructure. Instead, it is worth using existing infrastructure to transport the feedstock for H₂—electric grid for transporting electricity for water splitting; natural gas pipelines to transport methane for pyrolysis."

"While there has been some systematic study of geological storage, the United States Geological Survey should be charged with undertaking a national survey to identify the many locations where underground storage of hydrogen is possible while also considering the infrastructure [costs](#) needed to use these caverns," the researchers add.

More information: *Joule*, Majumdar et al.: "A framework for a hydrogen economy"

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