VIEW POINT

THE PROMISE OF HYDROGEN: FUEL OF THE FUTURE

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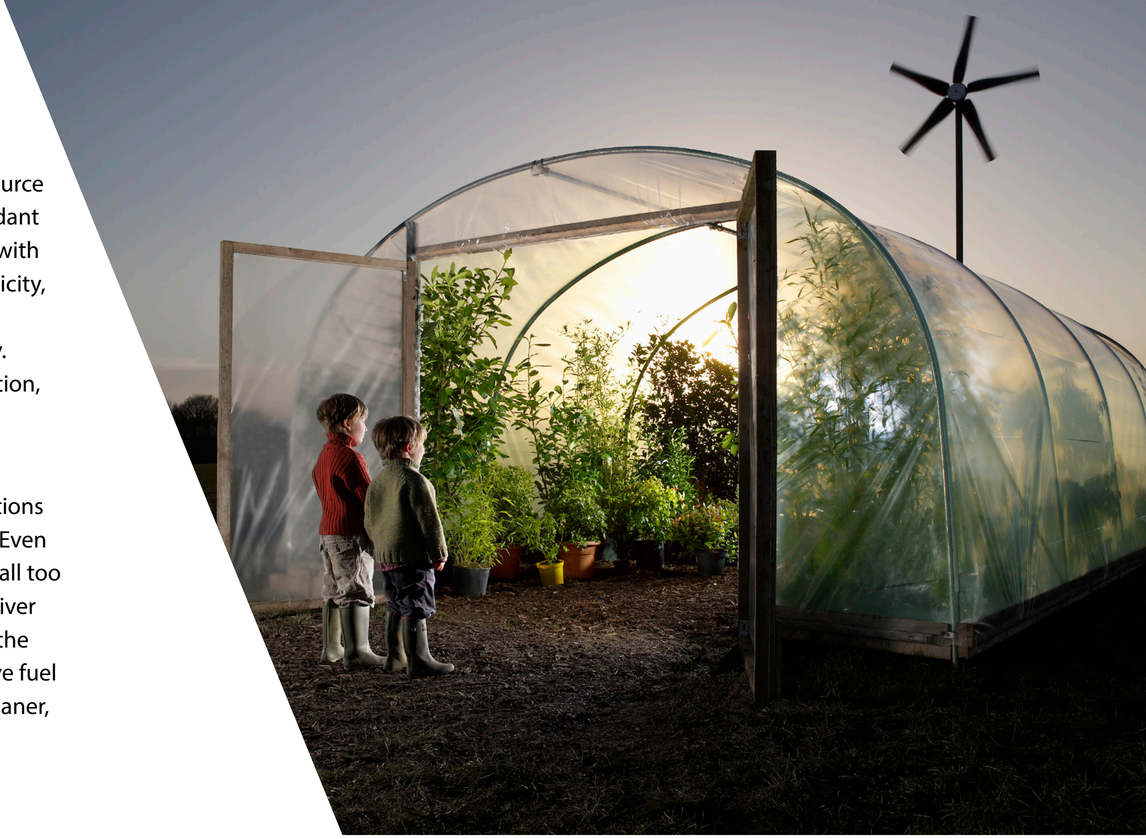
Abstract

Hydrogen is touted as the next big source of fuel for energy. It is the most abundant element in the universe. It combines with oxygen in fuel cells to generate electricity, emitting only water as a by-product. This makes it a source of clean energy. Hydrogen can be used for transportation, refining oil, manufacturing steel, and producing fertilizers.

Globally, countries and large corporations are racing to join the 'hydrogen rush.' Even so, there are several questions: Is this all too good to be true? Will it last? Will it deliver on its promise? This article examines the potential of hydrogen as an alternative fuel across industries in our quest for a cleaner, greener future.



Introduction

As the world confronts the challenge of mitigating the harsh impact of climate change, transitioning to sustainable clean-energy systems is becoming increasingly critical. With activity around hydrogen witnessing unprecedented momentum in the energy sector today, organizations worldwide expect it to be a big part of a net zero carbon future. The World Economic Forum's Accelerating Clean Hydrogen Initiative[1] aims for low-carbon hydrogen to meet approximately 12% of global energy demand by 2050.

Hydrogen for a Net Zero Carbon World

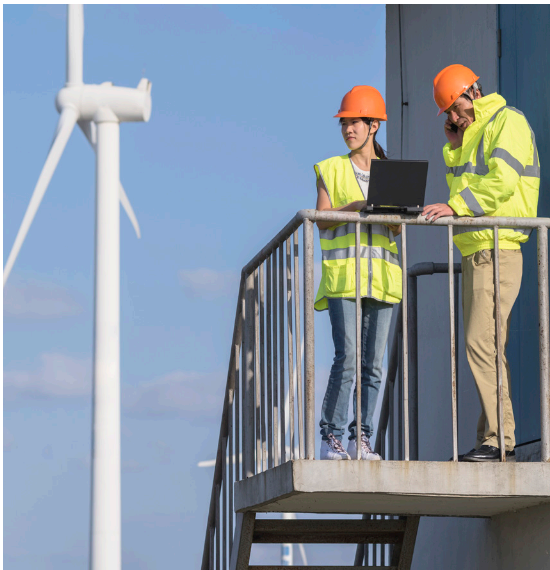
Hydrogen is produced by separating it from other chemical elements in a compound, such as through electrolysis of water (H2O). Hydrogen is, therefore, a carrier or a secondary source of energy. Clean or green hydrogen, generated from renewable sources, can be stored and transported to produce heat and electricity. Hydrogen storage systems can be integrated with existing grid infrastructure.

Hydrogen can help cut carbon emissions by acting as a feedstock for industries that depend on fossil fuels for operations, such as transportation, chemical manufacturing, oil and gas, cement, steel, and utilities. Refineries, fertilizer units, and other enterprises use large quantities of hydrogen in their manufacturing processes. Such enterprises can replace hydrocarbon-based hydrogen with green hydrogen for near-net zero operations.

Hydrogen as a Viable Alternative to Fossil Fuels

Emerging technologies are enabling the transformation of hydrogen into clean fuels such as synthetic methane, 'green' ammonia, and methanol. Having high energy density, large amounts of hydrogen are stored in smaller volumes for ease of transportation. Potential use cases for hydrogen range from lighting and heating homes and commercial buildings to cement and ceramics manufacturing, as well as heavy engineering and multimodal transportation.

The International Energy Agency (IEA) expects the share of fossil fuels in total energy supplies to reduce from about four-fifths to almost one-fifth by 2050[2]. Several hydrogen projects across industries worldwide are already operational or in progress. A pilot project to produce carbon-free steel using low-carbon hydrogen is underway in Sweden, expecting to go into commercial production by 2026[3]. Renewables-based hydrogen is being used for ammonia production in Spain, with the intention of decarbonizing its overall production by 2027. In the United States, the HyGrid Project[4] in New York proposes to decarbonize energy networks by blending green hydrogen into the existing grid distribution system to heat homes and fuel municipal vehicles.



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Color-coding Hydrogen's Environmental Footprint

Hydrogen is a colorless gas. However, hydrogen is color-coded to indicate its production process and carbon footprint.

Green hydrogen, produced by water electrolysis, is powered by renewable energy sources, such as biogas, geothermal or solar power, and wind. Gray hydrogen is produced from fossil fuels like natural gas, and is associated with high carbon emissions. Brown hydrogen is generated from coal. Supporting gray and brown hydrogen production through sequestration processes or with carbon capture and storage (CCS) systems in deep saline aquifers and depleted gas reservoirs results in blue hydrogen. Therefore, although blue hydrogen is also produced from fossil fuels, it records lower emissions. Advancements in CCS technology can further transform blue hydrogen into green hydrogen.

At the end of 2021, almost 47% of the global hydrogen production was from natural gas, 27% from coal, and only around 4% came from electrolysis. Calculating the global average renewable share of electricity, only about 1% of global hydrogen output is actually produced with renewable energy[5, 6]

The Practicality of Emission-free Hydrogen

Several factors determine the cost-efficiency of hydrogen, including electricity costs, energy conversion efficiency, electrolyzer capacity, CCS investment, transportation, and on-site storage. Green hydrogen produced via electrolysis is relatively more expensive due to the high cost of electrolyzers and renewable energy requirements. However, with an increase in the capacity of electrolyzers, renewable energy farms, and CCS infrastructure, green hydrogen has the potential to become an economically feasible alternative fuel.

Hydrogen as a fuel for transportation

Hydrogen can be a viable approach to eliminate carbon emissions from transportation fuel. It is a lightweight fuel with potential use in rail, road, air, and marine transportation. Hydrogen-powered fuel cell vehicles are more efficient than gasoline-based internal combustion engines, without tailpipe emissions. Hydrogen can also power buses, heavy-duty trucks, and specialty vehicles such as tractors and forklifts. For instance, DHL Express has introduced hydrogen-fueled trucks into its fleet for long-haul logistics operations.

Hydrogen as an aviation fuel

Several shipping and aviation companies have undertaken pilot projects using hydrogen and hydrogen-based fuels. In a world first, Rolls-Royce recently converted a conventional aircraft engine to use green hydrogen generated from wind and tidal energy. Also, Airbus announced its plans for 'ZEROe,' a series of zero-emission commercial concept aircraft with hydrogen-fueled propulsion systems. However, decarbonizing air travel with green hydrogen poses several challenges. Besides adapting aircraft design to accommodate fuel cells and carry liquefied hydrogen, airports must also prepare their infrastructure to accommodate the requirements of the alternative fuel.

Overcoming the barriers to commercialization

The success of the hydrogen economy depends on the safety of the transportation and storage infrastructure. Hydrogen, stored in gaseous or liquid forms, risks leakage and fire hazards. Liquid hydrogen requires cryogenic tanks, while gas needs high-pressure tanks. As its molecules are smaller, lighter, and more inflammable than natural gas, hydrogen requires robust and secure transmission networks for transportation from the production site to the industrial zones. Existing pipeline networks for natural gas can be repurposed after rigorous assessment, extensive testing, and required upgrade.

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Conclusion

Hydrogen is a versatile energy carrier crucial to a global clean-energy system, but its widespread adoption requires significant investments in production, distribution, and infrastructure. Several countries in the European Union as well as the US, Japan, China, India, and South Korea have launched hydrogen strategies. Global enterprises are working to develop hydrogen as a sustainable energy ecosystem built on renewable resources.

Although green hydrogen is currently expensive, it has the potential to become a cost-effective alternative fuel that can help us transition to a low-carbon economy. Innovations in technology can offset the high production cost of clean hydrogen and ensure its parity with fossil fuels. Energy specialists must focus on improving the performance of fuel cells, durability of materials, efficiency of electrolyzers, capacity of CCS systems, as well as the availability of surplus renewable energy to transform hydrogen into the fuel of the future.

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