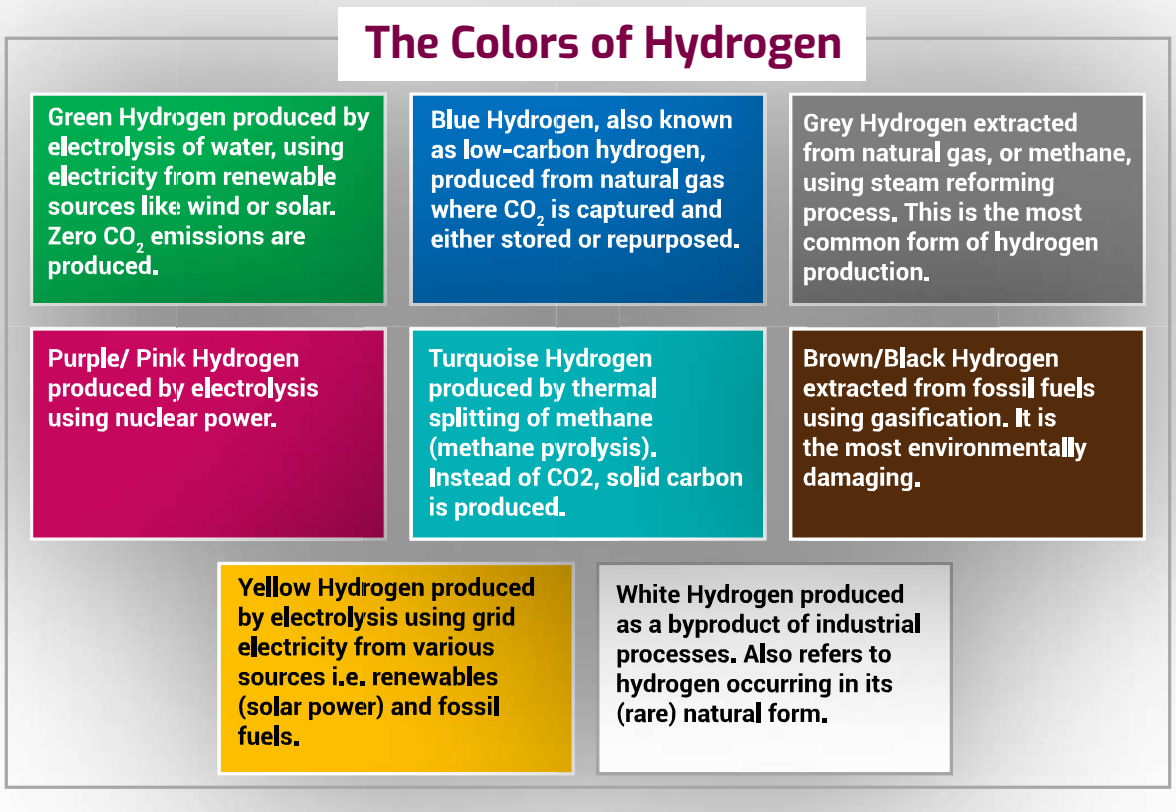
Green Hydrogen: An Invisible Molecule for the Sustainable Energy Future

Madhulika Bhati
Principal Scientist, CSIR-NIScPR, New-Delhi, India
Email: madhulikabhati@niscpr.res.in



Across the globe, the way energy is created, processed, stored and used in its different forms is changing dramatically. The mass awareness regarding the need to transition to a society where energy production and consumption should not result in climate change or pollution is increasing globally. Green hydrogen, i.e., hydrogen generated from renewable power, connects renewable energy to several end-use applications. In future, green hydrogen — due to its involvement with solar and wind energy — has a considerably larger potential than fossil fuels. As far as decarbonisation is concerned, green hydrogen is the sole zero-carbon option for hydrogen production. Green hydrogen can be transformed into various energy carriers such as ammonia, methanol, methane, and liquid hydrocarbons once it is produced at scale and at a low cost.[1] The energy stored in hydrogen can be converted into electricity by fuel cells, which have a wide range of transportation applications, as seen in Fuel Cell Electric Vehicles (FCEVs), including heavy-duty transport vehicles such as trucks, buses and ships.[2] Green hydrogen can also minimise greenhouse gas (GHG) emissions in industries that currently use hydrogen generated from fossil fuels.



Green hydrogen, like other forms of energy production, has its own set of difficulties. These include the current higher expenses involved in its production across the entire value chain, from electrolysis to transportation and fuel cells; the lack of existing infrastructure for transportation and storage; and higher energy losses which demand higher wind/solar deployment rates.[3]

India is one of the countries with the optimal weather conditions for green hydrogen production and hence, the potential to produce cheaper green hydrogen as compared to blue hydrogen by 2025.[4] It creates the possibility of trading globally low-cost green hydrogen from the best renewable resources to regions with limited land or renewable potential in the long run.

Current Status of Green Hydrogen in India

Self-reliant India (*AatmaNirbhar Bharat*), is the motto with which our country has progressed in the past two years, since the outbreak of the Coronavirus pandemic, proving that it is more than just a phrase for display, but an attitude and sentiment that flows throughout the country. On 15 August 2021, Indian Prime Minister announced the launch of the National Hydrogen Mission (NHM) intending to cut down carbon emissions and increase the use of renewable sources of energy. Moreover, at the COP 26 session in Glasgow last year, he pledged to make India a net-zero country by 2070. Recently, while addressing a webinar on 'Energy for Sustainable Growth', he stated, "Ample availability of renewable energy power gives India an inherent advantage, it can be a global hub of green hydrogen."

Amitabh Kant, the CEO of NITI Aayog, on 26 April 2022 at the Raisina Dialogue remarked that India has brought down the cost of renewable energy and can be the cheapest producer of the green hydrogen in the world. In the renewable sector, from 2014 to 2018, India has spent 42 billion USD in driving down the costs by employing renewable technologies at scale.[5]

In India, hydrogen is already widely employed, mostly as an industrial feedstock for the production of ammonia-based fertilisers. The majority of hydrogen is produced via Steam Methane Reforming (SMR), which results in more CO_2 emissions. Though Carbon Capture and Storage (CCS) technology can seize these emissions significantly, it is at an incipient stage in India. Electrolysis, in which water splitting is achieved through electricity, is an alternate method of hydrogen production. The Nangal Facility in India boasts of one of the first large-scale alkaline electrolyser plants in the world, producing hydrogen from electricity way back in 1962.[5]

On 17 February 2022, the Ministry of New and Renewable Energy (MNRE) released a framed Green Hydrogen Policy in response to the raised concerns over the requirement to reduce emissions "especially in the hard to abate sectors."

Some of the frameworks outlined by the Government of India (GoI) are as follows:

- From the projects commissioned before 30 June 2025, a waiver of inter-state transmission charges will be granted for 25 years to the producer of green hydrogen.
- Open access for sourcing of renewable energy will be granted to the green hydrogen plants within 15 days of receipt of application complete in all respects. The charges will be laid down as per GoI rules.
- Land in renewable energy parks can be allotted for the manufacture of green hydrogen.
- Green hydrogen plants can be set up in any "Manufacturing Zones" as proposed by the GoI.
- Green hydrogen manufacturers will be allowed to set up bunkers near Ports for storage for export/ use by shipping. The land will be provided by the port authorities at applicable charges.
- MNRE will set up a single portal for all statutory clearances and permissions required for the manufacture, transportation, storage and distribution of green hydrogen. The concerned agencies/ authorities will be requested to provide the clearances and permissions, preferably within 30 days from the date of application.

These policies will boost and strengthen the steps taken in the direction of green hydrogen production. In recent years, transportation has emerged as the fastest-growing end-use industry, and India is poised to invest heavily in transportation infrastructure, including motorways, railways, metro lines, as well as airports and ports. At the CSIR-National Chemical Laboratory in Pune, the Council of Scientific and Industrial

Research (CSIR) and KPIT successfully tested India's first hydrogen fuel cell (HFC) prototype car, powered by an indigenously produced fuel cell stack. On 30 March 2022, Mr Nitin Gadkari – Union Minister for Road Transport and Highways, in an attempt to raise awareness about FCEVs and green hydrogen, arrived at the parliament in a green hydrogen-based electric car. This new sector has the potential to produce millions of high-quality, green employment in addition to helping to decarbonise transportation and energy since a total of 11% of CO_2 emissions in the country come from the transportation sector.[6]

Moreover, the power ministry has recently announced to manufacture 5 million tonnes of green hydrogen per annum by 2030, aiming to make India a production and export hub for the fuel.

According to The Energy and Resources Institute (TERI)[7], the annual production of hydrogen is roughly 6.7 million tonnes, and the annual demand is expected to rise by 23 million tonnes in 2050, with the majority of consumption from fertiliser factories and refineries. If the net-zero carbon target is to be met, its production must increase to 28 million tonnes by 2050 and 40 million tonnes by 2060. Hydrogen has the potential to save 162 billion USD worth of imports for India – 112 billion USD in crude imports, 9.6 billion USD in natural gas/LNG imports, 23.6 billion USD in coal imports, 16.2 billion USD in petroleum products imports, and 775 million USD in ammonia imports.[8] The current price of hydrogen in India is 4.5 to 5.3 USD per kg. The cost uniformity can be achieved only when green hydrogen is produced at 2 USD per kg.[9] The GoI further announced that with effect from 2023-24, 10% of refinery hydrogen demand (increasing to 25% in the following five years) and 5% of hydrogen demand for fertiliser production (increasing to 20% in the following five years), should be met with renewable hydrogen.

India, thus, has the opportunity to lead the shift by providing the necessary funds, a good policy framework and technology-driven breakthroughs for green hydrogen generation.

Ensuring the Development of the International Hydrogen Market and Ways to Enhance Cooperation with other Countries

At the Dubai Expo 2020, India as a step toward exploring areas of collaboration invited the GCC (Gulf Cooperation Council) member countries for investing in the hydrogen energy sector. India is expecting to direct foreign investments of up to 120-160 billion USD annually, and with already established India-GCC relations, opportunities like these need to be capitalised on. The GoI has allotted, in the Union Budget 2021-22, INR 25 crores for the hydrogen energy development. On the same track, the GCC countries have also heavily invested in hydrogen energy development and seek to become the largest exporter of green hydrogen to European and East Asian markets.

A major concern for GCC countries in manufacturing hydrogen is the incompatibility of electrolysers with saline water. The seawater must be desalinated before electrolysis. India and GCC countries have the opportunity to enhance their cooperation in this domain. Several Indian research groups are focusing on producing hydrogen from seawater. For example, the CSIR-Central Electrochemical Research Institute (CECRI) is working on the design of electrodes and electrolytes for seawater hydrogen generation, and the Centre for Fuel Cell Technology at the International Advanced Research Centre for Powder Metallurgy and New Materials (ARCI) in Chennai is working on seawater electrolysis.

The Indian government has further progressed in developing indigenous transition fuel: hydrogen compressed natural Gas (H-CNG/Hythane). The Indian Oil Corporation Limited (IOCL) has initiated an H-CNG project in order to diversify the energy mix of the country.

Similarly, GCC countries have an abundance of solid waste due to their rising consumption patterns that can be employed to make hydrogen. The Indian Institute of Science (IISc), Bangalore, the National Institute of Technology (NIT), Rourkela, the Indian Institute of Chemical Technology (IICT), Hyderabad, and the National Institute of Technology (NIT), Raipur are conducting research on the production of Bio Hydrogen from solid waste, paving the way for collaboration between India and GCC countries, especially the UAE, which produces the world's highest daily per capita municipal solid waste. The GCC countries, particularly Saudi Arabia and the UAE, have invested in improving CCUS, and there is an opportunity for Indian institutes working on the subject to interact in terms of information/ technology transfer. Likewise, these countries have made significant expenditures on FCEV, and the linkages can help Indian research groups.

Challenges and Solutions to Advance Green Hydrogen Technology in India

Green hydrogen is supposed to hugely benefit India's energy industry considering its progress in the renewable energy sector. But it is marred with critical challenges which India needs to overcome for unstoppable growth in this sector.

Firstly, the hydrogen energy budget of our country is inadequate in terms of setting up initial infrastructure. Moreover, the cost-related aspects of electrolysers and research in this direction need stimulus in view of the fact that it is a vital facility for converting renewable energy into green hydrogen. While scale-up is imperative to reduce costs, technological innovation is crucial to increase the technology's performance (i.e., its efficiency and lifetime). It can be accomplished by the use of new catalysts and configurations, design standardisation and equipment mass production.[10]

Additionally, to promote, encourage and develop the growth of hydrogen energy and its applications in the country, strengthening societies like the Hydrogen Association of India (HAI) and Indian Association for Hydrogen Energy and Advanced Materials (IAHEAM) is necessary.

Zero-carbon hydrogen energy technologies would have been widely embraced in the last two decades, if investor enthusiasm alone could foresee the future of hydrogen power. Many technological and financial roadblocks that impeded early hydrogen attempts are now being used to inform new methods for launching the new energy economy. From government policies and incentives to technological and infrastructure advances, enabling a cost-effective shift to hydrogen energy is at the heart of India's decarbonisation efforts.

However, there is a prerequisite for a safety framework, and the Petroleum and Explosive Regulatory Board is expected to formulate a comprehensive Hydrogen Safety Management Plan soon. An all-inclusive study of the water footprint of hydrogen production, leakage and related ozone depletion assessment and use of noble metals need to be done.

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