FEATURE STORY

HYDROGEN-Potential Fuel of the Future

By Deepika Lal

Hydrogen has lately become the favourite subject of clean energy advocates in global energy conferences. The fuel is enjoying unprecedented political and business attention, with a number of dedicated policies and projects world over, driven by the target to increase its share in the country's clean energy transition.

But don't think that it's role in energy is something new. Infact, the fuel has a long history – powering the first internal combustion engines over 200 years ago to becoming an integral part of the modern refining industry today. What is driving the attention to it currently is its potential to act as a clean energy fuel and becoming a major contributor in our primary energy mix instead of just being a tiny component. Of course, to reach there, it needs to be adopted by many more important sectors where it is almost completely absent today, such as transport, buildings and power generation.

In this issue, NGS attempts to give you a brief synopsis on hydrogen as a fuel. We will talk about why it is in vogue; the ways in which hydrogen can help to achieve a clean, secure and affordable energy future; where things stand now,

both globally and in India; what are the various challenges towards achieving hydrogen goals and, how we can go about realising its potential.

What makes hydrogen in demand?

First things first, what makes hydrogen in demand? You would know that a fuel is a chemical that can be 'burnt' to provide useful energy. Burning normally means that chemical bonds between the elements in the fuel are broken and the elements chemically combine with oxygen (often from the air).

For centuries, we've burnt fossil fuels such as oil, coal and natural gas to heat our homes and businesses, and for power stations to generate electricity. In the UK, 85% of homes and 40% of the country's electricity currently relies on natural gas; in the US, 47% of households rely on natural

gas and 36% on electricity.

We continue to use these fossil fuels since they are readily available resources and are cost effective. Natural gas is also a much cleaner alternative to coal and oil and therefore, its use world over has increased over last many years. But even natural gas, when burnt, produces carbon dioxide, which when released into the atmosphere contributes to climate change.

Here comes the use of hydrogen. Hydrogen is a clean alternative to these fossil fuels. Burning hydrogen has the benefit that it does not release this carbon dioxide at all if produced from renewable sources. And therefore, countries around the world are realising that hydrogen could make a huge difference to their carbon emissions.

The need has been necessitated by an increase in global temperature of 1.1°C, over the pre-industrial levels, all thanks to these carbon emissions. At the current point of time, there is a broad understanding globally that net zero by 2050 is imperative to increase the chances of keeping this temperature increase to within 1.5°C. And therefore, by April 2022, 131 countries covering 88% of global greenhouse gas emissions had announced their net zero targets. This renewed focus means that these countries will have to make clean energy transitions to mitigate the impact of energy production on the climate. While energy efficiency, electrification and renewables provide a solution to achieving a large part of these goals, hydrogen too can help where other options are less mature or more costly.

How is hydrogen produced?

Blue hydrogen vs Green hydrogen

Hydrogen can be produced from a variety of resources. It can be extracted from fossil fuels such as natural gas, nuclear power, biogas and renewable sources like solar and wind.

Most of the hydrogen manufactured now is either grey hydrogen (produced from natural gas) or the so-called 'black or brown' hydrogen (produced from coal). These processes use two primary methods. Steam methane reformation is the most common method for producing bulk hydrogen and accounts for most of the world's production. This method uses a reformer, which reacts steam at a high temperature and pressure with methane and a nickel catalyst to form hydrogen and carbon monoxide. Alternatively, autothermal reforming uses oxygen and carbon dioxide or steam to react with methane to form hydrogen. The downside of

Selected Colour-code Typology of Hydrogen Production

	GREY HYDROGEN	BLUE HYDROGEN	GREEN HYDROGEN
Process	Reforming or gasification	Reforming or gasification with carbon capture	Electrolysis
Energy source	Fossil fuels	Fossil fuels	Renewable electricity
Estimated emissions from the production process[a]	Reforming: 9-11[b] Gasification: 18-20	0.4-4.5[c]	0

Note: a) $CO_{2\text{-}eq}$ /kg = carbon dioxide equivalent per kilogramme: b) For grey hydrogen, 2 kg $C_{02\text{-}eq}$/kg assumed for methane leakage from the stream methane reforming process. c) Emissions for blue hydrogen assume a range of 98% and 68% carbon capture rate and 0.2% and 1.5% of methane leakage.

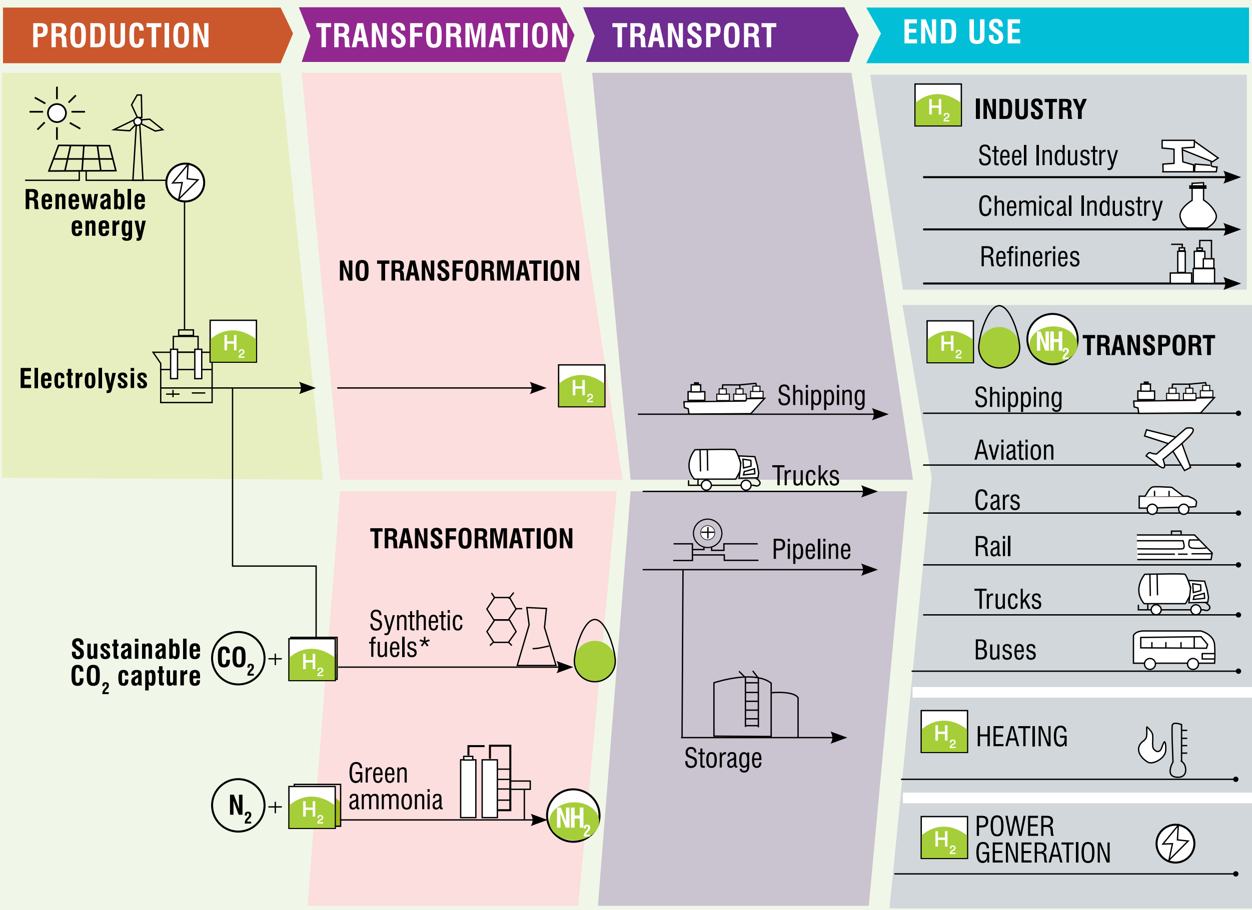
both these methods is that they produce carbon as a by-product. When the ensuring carbon emitted is captured via carbon-capture and storage (CCS) processes in above cases, it is referred to as blue hydrogen.

However, what is desired is the production of 'green hydrogen', which currently accounts for a miniscule part of the global hydrogen production. Green hydrogen is when hydrogen is produced via electrolysis, the splitting of water into hydrogen and oxygen with electricity generated from renewable energy sources such as solar or wind. This according to experts, is the most environmentally sustainable way of producing hydrogen since it does not release any harmful by-products back in the atmosphere during its production. An added benefit is that, because this method uses electricity, it also offers the potential to divert any excess electricity – which is hard to store (like surplus wind power) – to electrolysis, using it to create hydrogen gas that can be stored for future energy needs.

What are the uses of hydrogen?

Hydrogen is versatile. Hydrogen, with the help of technologies existing today, can be produced, stored and moved. It can be transported as a gas by pipelines or in liquid form by ships, much like LNG. It can be transformed into electricity and methane to power homes and feed industry, and into fuels for cars, trucks, ships and planes. It offers ways to decarbonise a range of sectors – including long-haul transport, chemicals, and iron and steel – where it is proving difficult to meaningfully reduce emissions. It can also help improve air quality and

Green Hydrogen Production, Conversion and End Uses Across the Energy System



Source: IRENA

** The term synthetic fuels fefers here to a range of hydrogen-based fuels produced through chemical processes with a carbon source (CO and CO_2 captured from emission streams, biogenic sources or directly from the air). They include methanol, jet fuels, methane and other hydrocarbons. The main advantage of these fuels is that they can be used to replace their fossil fuel-based counterparts and in many cases be used as direct replacements - that is, as drop-in fuels. Synthetic fuels produce carbon emissions when combusted, but if their production process consumes the same amount of CO_2, in principle it allows them to have net-zero carbon emissions.*

strengthen energy security.

However, its use today is primarily restricted to few industrial sectors including oil refining, ammonia production, methanol production and steel production. For decades, liquid hydrogen has also served as a powerful rocket fuel, and more recently, aerospace applications of hydrogen have expanded to include both fuel cells and combustion fuel. This is because of it being light with the lowest molecular weight burning with extreme intensity. Could hydrogen power be the future for both aviation and space flight, is yet to be seen. Let us tell you about some of its other potential uses.

Transport

The competitiveness of hydrogen fuel cell cars depends on fuel cell costs and refuelling stations while for trucks the priority is to reduce the delivered price of hydrogen. Shipping and aviation have limited low-carbon fuel options available and represent an opportunity for hydrogen-based fuels.

Buildings

Hydrogen could be blended into existing natural gas networks, with the highest potential in multifamily and commercial buildings, particularly in dense cities while longer-term prospects could include the direct use of hydrogen in hydrogen boilers or fuel cells.

Power generation

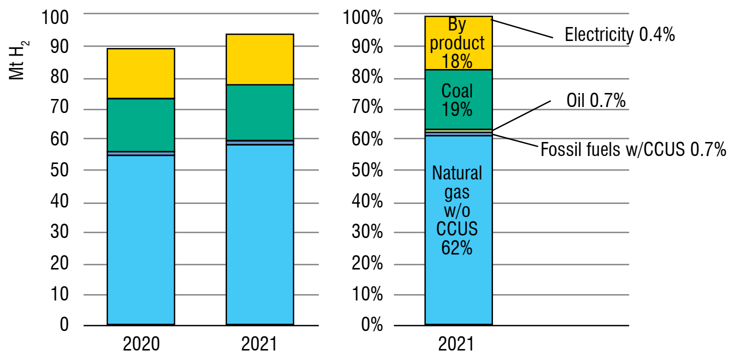
Hydrogen and ammonia can be used in gas turbines to increase power system flexibility. Hydrogen has the potential to help with variable output from renewables, like solar photovoltaics (PV) and wind, whose availability is not always well matched with demand. It can store energy from renewables and could develop to be a promising lowest-cost option for storing electricity over days, weeks or even months. Hydrogen and hydrogen-based fuels can transport energy from renewables over long distances – from regions with abundant solar and wind resources, such as Australia or Latin America, to energy-hungry cities thousands of kilometres away.

Worldwide status of hydrogen

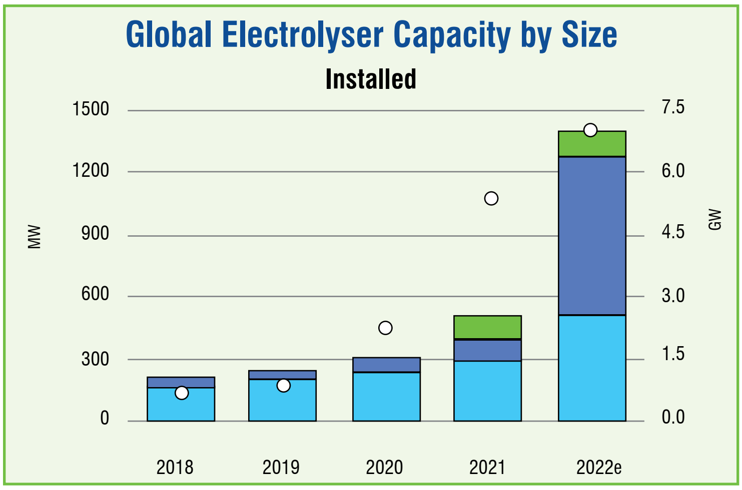
Production mix: Global hydrogen demand reached 94 million tonnes in 2021, a 5% increase on demand in 2020, driven mainly by the recovery of activity in the chemical sector and refining. Natural gas without CCUS is the main route and accounted for 62% of hydrogen production in 2021. Hydrogen is also produced as a by-product of naphtha reforming at refineries (18%) and then used for other refinery processes (e.g. hydrocracking, desulphurisation). Hydrogen production from coal accounted for 19% of total production in 2021, mainly based in China. Limited amounts of oil (less than 1%) were also used to produce hydrogen.

However, low-emission hydrogen production

Hydrogen production mix, 2020 and 2021



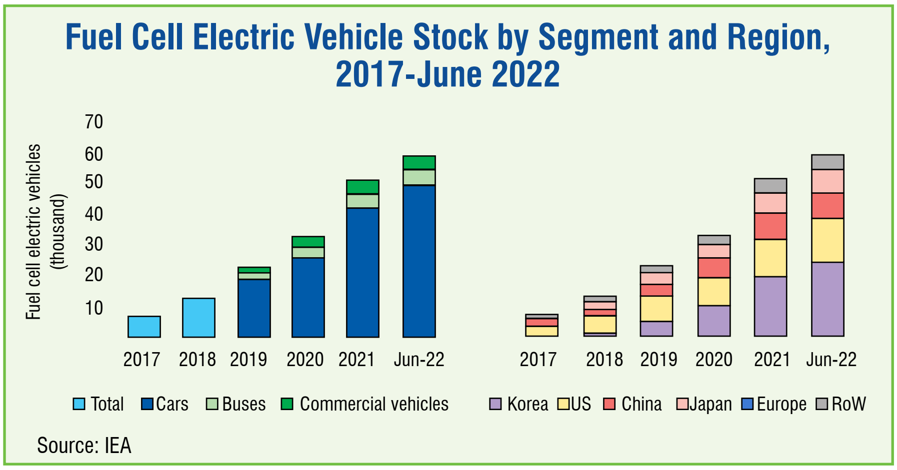
Note: CCUS = carbon capture, utilisation and storage. Source: IEA



was less than 1 million tonne (0.7%) in 2021, almost all from fossil fuels with CCUS, with only 35 kt H2 from electricity via water electrolysis (around 0.1% of global hydrogen production). The amount of hydrogen produced via water electrolysis, while very small, increased by almost 20% compared to 2020.

The installed capacity of electrolysers is also expanding quickly and reached 510 MW by end-2021, an increase of 210 MW, or 70% relative to 2020. The 2022 estimated figure for global electrolyser capacity is 1.4 GW, almost tripling the 2021 level, with almost 40% of this capacity developed in China and around a third in Europe. Based on the current project pipeline, according to IEA, global electrolyser capacity could reach 134 GW in 2030.

Sector-wise consumption: Sector-wise, hydrogen demand remains concentrated in traditional applications in the refining and chemical sectors, with very limited penetration (less than 0.1%) in new applications such as transport, high-temperature heat in industry, hydrogen-based DRI, power and buildings. Most of this new demand is concentrated in road transport, which observed a significant increase as a result of the accelerated deployment of Fuel Cell Electric Vehicles (FCEVs), particularly fuel cell heavy-duty trucks in China. By end-June 2022, the global stock of FCEVs was more than 59,000, with almost 90% of those in four countries: Korea, the US, China and Japan. The number of hydrogen refuelling stations around the world reached 975 by the end of June 2022. Of course, it doesn't need to be told here that this translates into a very small fraction of the global vehicle fleet and refuelling infrastructure currently.

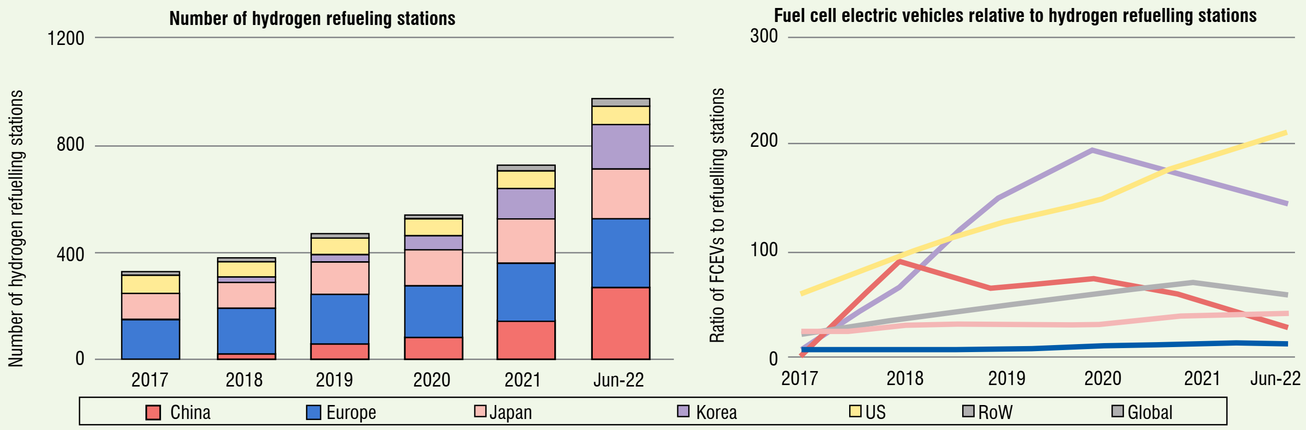


Source: IEA

Apart from road transport, few key developments for hydrogen application in transport sector are worth a mention here. The first fleet of hydrogen fuel cell trains have started operating in Germany. There are also more than 100 pilot and demonstration projects for using hydrogen and its derivatives in shipping, and major companies are already signing strategic partnerships to secure the supply of these fuels.

In the power sector, the use of hydrogen and ammonia is attracting more attention; announced projects stack up to almost 3.5 GW of potential capacity by 2030. Several demonstrations of hydrogen's potential end uses such as

Hydrogen Refuelling Stations by Region and Ratio of fuel Cell Electric Vehicles to Refuelling



Note: FCEV = Fuel Cell Electric Vehicle; US = United States; RoW = Rest of World

Source: IEA

in chemicals production (Iberdrola-Fertiberia Project in Spain), iron and steel (Hybrit project in Sweden) and power generation (JERA project in Japan) have been well received. But bringing these technologies to commercialisation is a huge challenge and critical for hydrogen to make a big difference in energy mix.

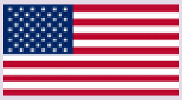
Policy support: The number of countries with polices that directly support investment in hydrogen technologies is also increasing, along with the number of sectors they target. There are around 50 targets, mandates and policy incentives in place today that directly support hydrogen, with the majority focused on transport. Over 2021-22 alone, 9 governments adopted a hydrogen strategy. Few developing countries are targeting their resources to advance their low-carbon hydrogen plans. For example, Chile, abundant in solar and wind resources, is aiming to produce the world's cheapest low-carbon hydrogen by 2030, positioning itself among the top three exporters by 2040. Morocco is working to develop large low-carbon hydrogen projects that will attract private investors, while Brazil aims for the State of Ceará to become a major hydrogen fuelling hub.

Public funding for hydrogen R&D observed its largest annual increase in 2021, with a 35% increase compared with 2020. Hydrogen technologies received around 5% of the total R&D budget for clean energy technologies. European countries were the main contributors to this increase, nearly doubling their expenditure.

Some international agreements between governments have also been signed, most of them focused on the development of international hydrogen trade. Also, private sector companies have joined forces to develop first-of-a-kind technologies and international supply chains. In this direction, the Breakthrough Agenda was launched at COP26 in November 2021, with a commitment from 44 countries to work together to make clean technologies affordable and accessible globally before 2030; hydrogen is one of the breakthroughs adopted. In May 2022, the G7 launched a Hydrogen Action Pact to accelerate the ramp-up of low-emission hydrogen, technology development, the shaping of regulatory frameworks and standards, and financial commitments.

Countries which are ahead in their hydrogen goals

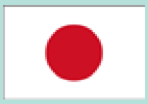
CHINA: China's five-year economic plan recognises hydrogen as one of the six industries of the future. Accordingly, it consumes and produces more hydrogen than any other country in the world – its current annual usage is around 28 million tonnes. The country issued its first hydrogen roadmap in 2016, leading to it having the world's third-largest FCEV fleet and becoming a pioneer in developing fuel cell trucks and buses. However, most of the country's production is currently "grey" hydrogen produced from fossil fuels like coal. But China is also working towards creating green hydrogen - more than 30 projects involving "green" hydrogen form renewable energy have been set up since 2019. Though the country has no national strategy in place, hydrogen features in atleast 16 of its provincial and city energy strategies.



UNITED STATES: Accounting for 13% of global hydrogen demand, the US is the world's second-biggest producer and consumer of hydrogen after China. US states such as California supported the country's FCEV market growth for more than a decade with initiatives like the Clean Vehicle Rebate Programme. The US led the world in this field until 2020. When the government passed into law the Infrastructure Investment and Jobs Act of 2021, it contained a $9.5 billion budget to boost clean hydrogen development. This was followed by the launch of the government's Hydrogen Earthshot programme, with its so-called "111 goal" to cut the cost of clean hydrogen to $1 per 1 kilogramme in 1 decade. In the US, one of the first and largest clean hydrogen projects – The HyGrid Project, located on Long Island – was launched in 2021. By blending green hydrogen into the existing distribution system, it will help to decarbonise the existing gas networks and is expected to heat approximately 800 homes.

THE EUROPEAN UNION: EU, the fourth largest consumer of hydrogen, released its national hydrogen strategy in 2020 towards achieving policy goals such as the European Green Deal. The bloc's strategy is heavily focused on emissions-free green hydrogen, with a target to install 40 GW of renewable hydrogen electrolyzer capacity by 2030.

The European Clean Hydrogen Alliance was launched to support investment and large-scale deployment of clean hydrogen projects, as the EU aims to become the industrial leader in clean hydrogen. Within the bloc, different member states look set to become large-scale hydrogen importers, exporters or transit hubs.



JAPAN: In 2017, Japan became the first country to formulate a national hydrogen strategy as part of its ambition to become the world's first "hydrogen society" by adopting the fuel across all sectors. However, since the country itself lacks renewable sources to be able to produce green hydrogen, it is developing long term supply agreements to import hydrogen. Alongside government investment in hydrogen and fuel cell technologies – totalling $670 million in 2020 – policymakers have set mobility targets of 800,000 FCEVs and 900 hydrogen refuelling stations by 2030.

SOUTH KOREA: South Korea announced its hydrogen roadmap in 2019 in which clean hydrogen was regarded as a key driver of economic growth and job creation. The nation has its sights set on becoming a global leader in producing and deploying FCEVs and large-scale stationary fuel cells for hydrogen power generation. Its Green New Deal contains an ambitious target of deploying 200,000 FCEVs by 2025 – about 20 times more than in 2020. And last year, South Korea passed the Economic Promotion and Safety Control of Hydrogen Act, the world's first law aimed at promoting hydrogen vehicles, charging stations and fuel cells.

Plans are in place for hydrogen to provide 10% of the energy needs of its cities, counties and towns by 2030, with its share rising to 30% by 2040 before it becomes the country's largest single energy carrier by mid-century.

India's Hydrogen Story

Like in other countries, hydrogen has picked up momentum in India too. India's government approved a ₹19,744 crore National Green Hydrogen mission in January 2023. The primary underlying feature of the policy is to become a hydrogen export hub to the Middle East, Southeast Asia, and Africa, backed by its advantageous geographic location and the presence of an abundance of natural resources. With low-cost renewable power and rapidly decreasing electrolyser prices, green hydrogen production can be made cost-effective in India by adding the necessary capacity for renewable power generation, storage and transmission. Let us tell you about what our government plans to achieve with the hydrogen mission:

National Green Hydrogen Mission

Targets

- Develop green hydrogen production capacity of at least 5 MMT per annum (approximately eight to 10 times the amount at 60-100 GW of electrolyser capacity in India) by 2030. This will entail the decarbonisation of the industrial, mobility and energy sectors; reducing dependence on imported fossil fuels and feedstock; developing indigenous manufacturing capabilities; creating employment opportunities; and developing new technologies such as efficient fuel cells.
- Oil refineries must replace 30 per cent of fuel usage with green hydrogen by 2035, beginning from 3 per cent in 2025. Fertiliser production should include 70 per cent green hydrogen by 2035, starting from 15 per cent in 2025. By 2035, urban gas distribution networks should replace 15 per cent of their fuel volume with green hydrogen, starting from 5 per cent in 2025.

Mission programmes and incentives

Two umbrella sub-missions have been planned. The first is the Strategic Interventions for Green Hydrogen Transition Programme (SIGHT), that will fund the domestic manufacturing of electrolysers and produce green hydrogen. The second is to support pilot projects in emerging end-use sectors and production pathways. States and regions capable of supporting large scale production and/or utilisation of hydrogen will be identified and developed as Green Hydrogen Hubs. Following main incentives will be provided under the policy:

- Manufacturers can purchase renewable power from outside or set up renewable capacity themselves.
- A manufacturer of green hydrogen has the option to store any excess renewable energy for a maximum of 30 days with the distribution company, and then retrieve it as needed.
- To avoid any delays in the process, the producers of green hydrogen and the renewable energy plant will be granted priority access to the grid.
- Renewable Purchase Obligation (RPO) incentive will be granted to hydrogen manufacturers.
- A single platform for promptly completing all tasks (including statutory approvals) would be established by the Ministry of New and Renewable Energy to ensure ease of doing business.
- Inter-state transmission charges will be waived for 25 years.

Investments & Environment benefits

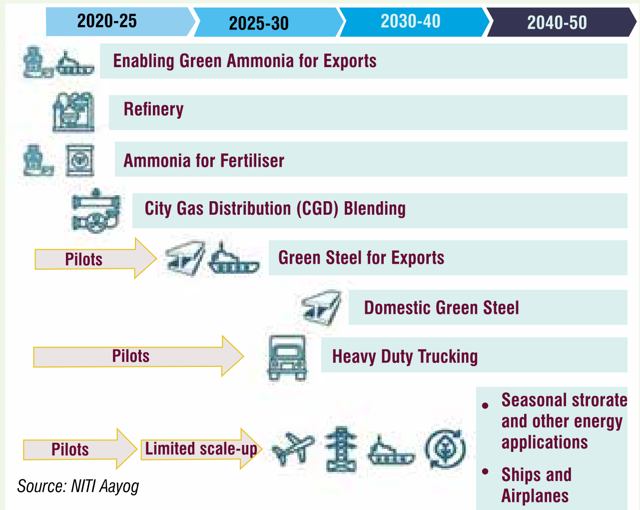
- According to estimates, ₹17,490 crore would be for the SIGHT programme, ₹1,466 crore for pilot projects and hydrogen hubs, ₹400 crore for research and development and ₹388 crore for other parts of the mission. In all, along with investments in supporting sectors, the mission will bring in investments worth ₹8 trillion and create over six lakh jobs by 2030.
- Being the third-largest emitter of CO2 globally, India has taken multiple initiatives to lower its carbon footprint and attain net zero emissions by 2070. As per its Nationally Determined Contribution (NDC) to meeting the goals of the Paris Agreement, India has committed to reduce emissions intensity of its GDP by 45% by 2030, from 2005 levels. With the implementation of the mission, about 50 MMT per annum of CO2 emissions are expected to be averted by 2030.

Other recent developments in India to support hydrogen

Several big government companies and industrial houses have announced plans to facilitate India's adoption of green hydrogen. However, most of these plans are for hydrogen blending and in transport sector. Few notable developments in past year are hereunder:

- **Hydrogen blending with gas:** Petroleum and Natural Gas Regulatory Board approved 5 per cent of blending green hydrogen with PNG initially while adding the

Potential Roadmap for Green Hydrogen Adoption in India



Source: NITI Aayog

blending level maybe be scaled phase-wise to reach 20 per cent. In January this year, National Thermal Power Corporation commissioned India's first green hydrogen blending project with Gujarat Gas Limited (GGL) in Surat, aimed at reducing the amount of natural gas consumed.

- **Hydrogen Fuel Trains:** The Indian Railways Organization for Alternate Fuels (IROAF) has called for proposals to develop a hydrogen fuel cell-based hybrid power train to convert the 700 HP diesel-hydraulic locomotives operating on the Kalka-Shimla narrow-gauge stretch in Himachal Pradesh.
- **Green Hydrogen Mobility Project:** In July 2022, Prime Minister Mr. Narendra Modi laid the foundation stone for the Green Hydrogen Mobility Project in Leh, a test project in which five fuel cell-infused buses will ply around Leh. NTPC has issued a global request for expressions of interest (EoI) to supply 10 hydrogen fuel cell-based electric buses and 10 hydrogen fuel cell-based electric vehicles in Leh and Delhi.
- **Green Ports:** The shipping ministry recently announced its plans to develop some of the ports – Paradip Port in Odisha, Deendayal Port in Gujarat and V.O Chidambaranar Port in Tamil Nadu - as hydrogen hubs under its Green Shipping initiative as part of the Maritime India Vision 2030.

However, all the above plans are premised on India being able to access a reliable stream of components, upgrading the manufacturing and skill levels of its small and medium manufacturing enterprises and developing a transmission network that can supply the hydrogen produced from supply-spots to industrial centres across the country.

Way to Growth

Solar and wind power were prohibitively expensive a decade ago, but are now among the cheapest forms of energy and supplying almost a quarter of the world's electricity needs. That same spirit of global innovation and cooperation can steer the transition to low-carbon hydrogen. Some of the growth strategies that IEA recommends are as follows:

Establish a role for hydrogen in long-term energy strategies. National, regional and city governments can guide future expectations. Policies that create sustainable markets for clean hydrogen, especially to reduce emissions from fossil fuel-based hydrogen, are needed to underpin investments by suppliers, distributors and users. By scaling up supply chains, these investments can drive cost reductions, whether from low carbon electricity or fossil fuels with carbon capture, utilisation and storage. Targeted and time-limited loans, guarantees and other tools can help the private sector to invest, learn and share risks and rewards. R&D is crucial to lower costs and improve performance, including for fuel cells, hydrogen-based fuels and electrolysers. Enhanced international co operation is needed across the board but especially on standards, sharing of good practices and cross-border infrastructure.

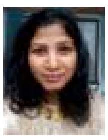
Make industrial ports the nerve centres for scaling up the use of clean hydrogen. Today, much of the refining and chemicals production that uses hydrogen based on fossil fuels is already concentrated in coastal industrial zones around the world, such as the North Sea in Europe, the Gulf Coast in North America and southeastern China. Encouraging these plants to shift to cleaner hydrogen production would drive down overall costs. These large sources of hydrogen supply can also fuel ships and trucks serving the ports and power other nearby industrial facilities like steel plants.

Build on existing infrastructure, such as millions of kilometres of natural gas pipelines. Repurposing natural gas pipelines for the transmission of hydrogen can cut investment costs 50-80%, relative to the development of new pipelines. There are projects under development to repurpose thousands of kilometres of natural gas pipes to 100% hydrogen. However, practical experience is limited and significant reconfiguration and adaptation will be necessary.

Expand hydrogen in transport through fleets, freight and corridors. Powering high-mileage cars, trucks and buses to carry passengers and goods along popular routes can make fuel-cell vehicles more competitive. Launch the hydrogen trade's first international shipping routes. International hydrogen trade needs to start soon if it is to make an impact on the global energy system.

Challenges to Achieving the Hydrogen Dream

- **Hydrogen is almost entirely supplied from natural gas and coal today.** This threatens the climate the same way as the fossil fuels. Both the capture of CO2 from hydrogen production from fossil fuels and greater supplies of hydrogen from clean electricity are required to make it a bigger source of energy in future.
- **Producing hydrogen from low-carbon energy is costly at the moment.** According to estimates, a kilogram of black hydrogen costs $0.9-1.5 to produce while grey hydrogen costs $1.7-2.3 and blue hydrogen can cost anywhere from $1.3-3.6. However, green hydrogen costs $3.5-5.5 per kg, according to a 2020 analysis by the Council for Energy, Environment and Water. However, with declining costs of renewable electricity, increasing electrolytic hydrogen capacities, it is expected that the green hydrogen costs could reach $1.3 per kg by 2030. Down the years, building electrolysers at locations with excellent renewable resource conditions could become a low-cost supply option for hydrogen, even after taking into account the transmission and distribution costs of transporting hydrogen from (often remote) renewables locations to the end-users.
- **There is no hydrogen market and very little hydrogen infrastructure currently.** The development of hydrogen infrastructure is very slow and holding back its widespread adoption. Globally, there are only about 4,500 km of hydrogen pipelines. Also, hydrogen is not a traded commodity today, which means there is no price index. This translates into higher costs paid by consumers since there is low price transparency and competition. Using renewable resources from remote locations would require additional investment in the transport infrastructure, from pipelines to conversion and liquefaction units, as well as storage, which increases the initial investment needed. The increase in infrastructure such as pipelines, refuelling stations and their usage would also bring down the hydrogen prices for consumers.
- **There is no established way to differentiate green hydrogen from fossil-based hydrogen.** That is, there is no way for consumers to know the origin and environmental impact of the hydrogen produced. However, there are multiple ongoing efforts on hydrogen certification that could breach this gap.
- **There is still a lack of policies to create demand for hydrogen, particularly in key applications.** Most of the policy efforts (primarily through purchase subsidies), have so far focused on road transport, particularly for FCEVs and refuelling stations. A very small number of policies target industrial applications, despite accounting for the majority of current hydrogen demand and representing the best short-term opportunity to create demand for low-emission hydrogen. Applications, such as power generation, are well behind in terms of policy action, with only a few examples available.
- **Apart from individual national efforts, international cooperation is crucial** to align objectives, increase market size and promote knowledge-sharing and the development of best practices.
- **A key technical challenge is also the development of a safe hydrogen system.** Hydrogen used in the fuel cells is a very flammable gas and can cause fires and explosions if it is not handled properly. These challenges are not solely faced by facilities handling hydrogen processes but also by suppliers of equipment to be used in a safe hydrogen system.



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