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EDITORIAL

Hydrogen is a key industrial fuel that has a variety of applications, including the production of ammonia (a key fertilizer), steel, electricity, and in refineries.

The energy industry refers to different 'types' of hydrogen to differentiate how it is produced. The vast majority of industrial hydrogen is currently produced from natural gas through a conventional process known as steam methane reforming (SMR), which produces grey hydrogen and has the major disadvantage of releasing large quantities of CO_2 emissions into the atmosphere. Green Hydrogen is defined as hydrogen produced via electrolysis, the splitting of water into hydrogen and oxygen with electricity generated from renewable energy sources such as solar or wind. This is the most environmentally sustainable way of producing hydrogen.

Green Hydrogen is today one of the fastest growing clean energy sectors and is an important piece of the evolving energy landscape. With its immense potential to help decarbonize hard-to-abate industries as well as the transport and power sectors, all major global economies are jumping on to the Green Hydrogen bandwagon to transition to net zero.

In a big boost to the sector, on 4 January 2023, the Union Cabinet approved the National Green Hydrogen Mission with an outlay of Rs. 19,744 crore[1] from FY 2023-24 to FY 2029-30. The overall objective of the Mission is to make India a global hub for the production, usage and export of Green Hydrogen and its derivatives. The following components have been announced as part of the Mission:

- Facilitating demand creation through exports and domestic utilization;
- Strategic Interventions for Green Hydrogen Transition (SIGHT) program, which includes incentives for manufacturing of electrolysers and production of Green Hydrogen;
- Pilot projects for steel, mobility, shipping, etc.;
- Development of Green Hydrogen Hubs;
- Support for infrastructure development;
- Establishing a robust framework of regulations and standards;
- Research & Development;
- Skill development; and
- Public awareness and outreach.

The detailed Mission document released by MNRE gives an overview of the overall Mission goals, strategies to develop the Green Hydrogen ecosystem on the demand and supply sides, various components under the Mission, governance framework, the implementation roadmap, expected outcomes, and the financial outlay.

India is one of the first countries to announce such an extensive policy roadmap specifically for Green Hydrogen and this has given the industry the much-needed confidence in this nascent sector.

In a press release on 19 August 2023, MNRE has also notified the Green Hydrogen Standard *(refer page 2)* for India.

[1] *1 crore = 10 million*

The notification[2] also specifies that the Bureau of Energy Efficiency (BEE), Ministry of Power will be the Nodal Authority for accreditation of agencies for the monitoring, verification and certification for Green Hydrogen production projects. State governments such as Maharashtra, Odisha, Gujarat, Karnataka, Himachal Pradesh, Haryana and Tamil Nadu have taken the lead in announcing hydrogen policies and pilot projects, and this newsletter will provide updates on their progress.

Sugar industry has already taken the lead in the past, by helping the nation secure ethanol production to meet higher blend requirements and Indian Sugar Mills Association (ISMA) has been at the forefront of leading this process. In the hydrogen space also, to expedite the entire process and to understand the potential of bio-based hydrogen, ISMA has commissioned a project with Indian Institute of Science (IISc.) Bangalore on the production of hydrogen with bagasse as feedstock. ISMA has also commissioned a study with Deloitte to examine this potential and propose methodologies for the computation of carbon and green credits for the entire bio-based value chain.

Sugar factories are now reinventing themselves in the upgraded role of bio-refineries. The subject of diversifying the product slate of a sugar bio-refinery to include derivatives beyond ethanol, like biogas, hydrogen, methanol, SAF, bio-plastics and bio-chemicals, etc. are being investigated as potential options for sugar factories.

The Cogeneration Association of India (Cogen India) will play a key role in helping to set up these "integrated sugar complexes", and invites stakeholders to join hands in this race to lead India's shift to Green Hydrogen. The launch of this inaugural HYDROGEN INDIA newsletter is a crucial step in raising more awareness in this sector. We request all stakeholders' feedback and support in order to make it more useful for the industry.

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Green Hydrogen Standard for India

Under the Indian Government-approved National Green Hydrogen Mission, the definition of Green Hydrogen was issued by the Ministry of New and Renewable Energy (MNRE) on 18 August 2023. For the purpose of the Mission and its ensuing policies and programs, the following have been specified in the memorandum.

Green Hydrogen shall mean hydrogen produced using renewable energy, including, but not limited to, production through electrolysis or conversion of biomass. Renewable energy also includes such electricity generated from renewable sources that are stored in an energy storage system or banked with the grid in accordance with applicable regulations.

Whereas, for Green Hydrogen produced through electrolysis – The non-biogenic greenhouse gas emissions arising from water treatment, electrolysis, gas purification, and drying and compression of hydrogen will not be greater than 2 kg of carbon dioxide equivalent per kg of hydrogen (kg CO_2 eq/ kg H_2), taken as an average over the last 12-month period.

Whereas, for Green Hydrogen produced through conversion of biomass – The non-biogenic greenhouse gas emissions arising from biomass processing, heat/steam generation, conversion of biomass to hydrogen, gas purification, and drying and compression of hydrogen will not be greater than 2 kg of carbon dioxide equivalent per kg of hydrogen (kg CO_2 eq/kg H_2), taken as an average over the last 12-month period.

It further stated that a detailed methodology for measurement, reporting, monitoring, onsite verification, and certification of Green Hydrogen and its derivatives will be specified by MNRE.

The Bureau of Energy Efficiency (BEE) will be the Nodal Authority for accreditation of agencies for the monitoring, verification, and certification of Green Hydrogen production projects in India.

For further details, please contact:
Ministry of New and Renewable Energy (MNRE)
Web: mnre.gov.in

[2] *pib.gov.in/PressReleaseIframePage.aspx?PRID=1950421#:~:text =Green%20 Hydrogen%20Standard%20for%20India,H2%20as%2012-month%20 average&text=In%20a%20significant%20move%20for,Green%20Hydrogen%20 Standard%20for%20India.*

Green Hydrogen – Driver of Decarbonisation in India

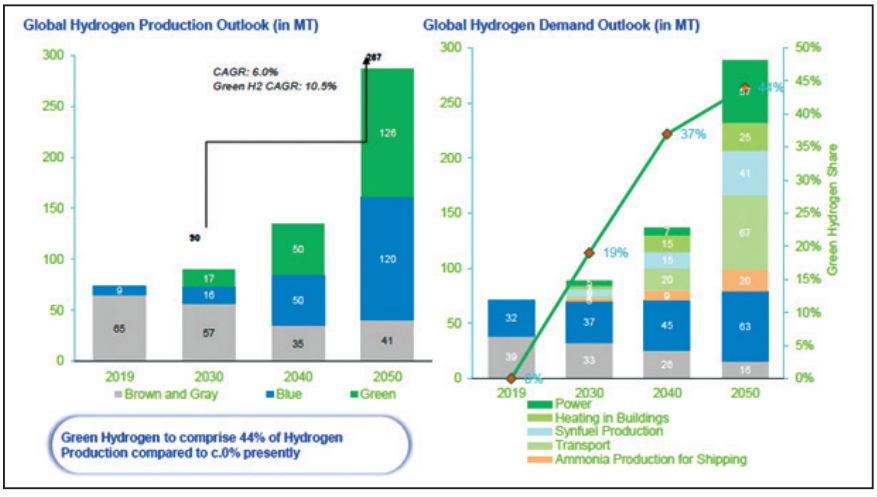
Viewpoint Article by Shri Subhash Kumar, Advisor, ISMA & Director, ACME Solar Holdings

Role of Green Hydrogen in Climate Neutrality

India is, and is expected to remain one of the fastest growing economies of the world. Over the next 25 years or so, Indian energy needs are expected to grow to 225-250% as per various projections. Indian growth will be partly enabled through reduced energy intensity and improved energy efficiency, which means that the energy consumption per unit of GDP growth will come down from the current levels. However, it is critical that the ratio of clean energy consumption also goes up substantially to ensure that while the Indian economy grows 8-10 times over the "Amrit Kal", the carbon footprint of Indian energy consumption comes down drastically in line with emission commitments at various international fora. While India has committed to be net zero by 2070, it already has plans in place to achieve significantly reduced carbon footprint by 2050, a period by which most of the developed world aspires to achieve net zero targets. Unprecedented scale and enormity of the energy transition for a growing economy like India, is both a challenge as well as an opportunity to usher in new business paradigm based on innovation with transition targets at the core of all action plans.

Global GH_2 Production & Demand Outlook

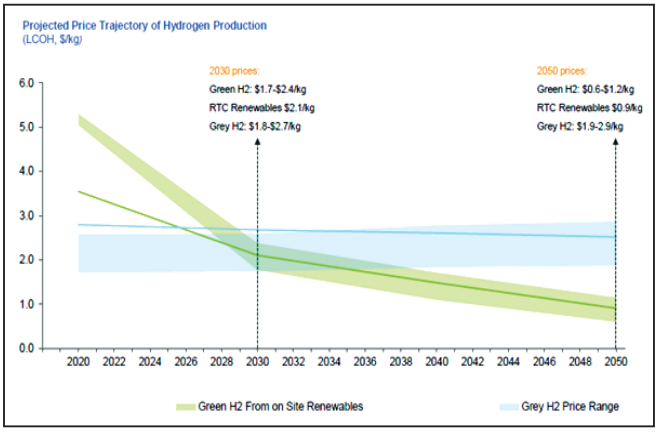
As may be seen from the following graphics, it is anticipated that the global hydrogen offtake will grow rapidly over the coming decades. Hydrogen will constitute a key tool in global armoury to bring down the carbon emissions while still staying on the growth trajectory to more than double global GDP over the next two and half decades. The graphic also indicates that green and blue hydrogen are projected to play a stellar role in the energy transition process.



Source: Report titled Harnessing Green Hydrogen by NITI Aayog and RMI

Price Competitiveness of GH_2 with Grey H_2

The hydrogen scale build up will ride on the expected price decline for both electrolysers and renewables, the constituents of the hydrogen value chain. It is expected that, with advancement in technology, and build-up of scale, the cost of green H_2 in India can fall to approximately $1.7/kg by 2030 and $0.6/kg by 2050.



Source: Report titled Harnessing Green Hydrogen by NITI Aayog and RMI

Hydrogen & Its Derivatives – Outlook for India

In case of India, Green Hydrogen is projected to play a vital role in addressing the energy transition needs and contribute towards addressing the ever-increasing dependence on imports for its energy needs. As per National Hydrogen Mission, Green Hydrogen and Ammonia are envisaged to be the future fuels. Grey Hydrogen sourced through processing fossil fuels was cost effective, but very carbon emission intensive, hence its sustained usage is unsustainable. Production of hydrogen and its derivatives by using power from

renewable energy, termed as Green Hydrogen and Green Ammonia/Green Methanol, etc., are seen as a major prerequisite to ensuring environmental sustainability.

Currently, globally hydrogen is being predominantly consumed in refineries and the fertilizer industries. Steel and cement, included among hard to abate sectors, are other sectors projected to witness significant usage of Green Hydrogen to transition towards net zero carbon footprint over time. Also, some of the newer usages could be to use hydrogen for long-duration storage of renewable energy, replacement of fossil fuels in industry, clean transportation, decentralized power generation, etc. Hydrogen also has promise to play a defining role in mobility through hydrogen fuel cells, and may get to play a role in aviation and marine transport.

There are issues with creating long distance supply chains of hydrogen, so it is expected that initially the hydrogen use case will mostly involve collocated hydrogen production and consumption usage facilities/ industries. Localized hydrogen usage clusters are known to exist globally, however, until the newer solutions for long distance supply of hydrogen through pipelines is established as technologically and economically viable, Green Hydrogen usage could remain localized. Its long-distance value chain or international trade may have to, for quite some time rely on using derivatives like Ammonia/Methanol, which can be shipped over long distances with comparative ease.

Currently, renewables still constitute only a fraction of overall global energy needs. The intermittent nature of energy supply originating from various renewable options will result in far serious intermittency and balancing requirements as the ratio of energy sourced from renewables goes up. Hydrogen could provide a means for storage of variable renewable energy and supplement it when needed. For long duration storage, running into several hours, converting excess available energy into hydrogen and utilizing it for grid support and other applications is seen to be a suitable alternative.

At present, hydrogen produced from natural gas is widely utilized for the production of nitrogenous fertilizers, and petrochemicals. India imports about 85% of the oil it refines, and the imported gas share has also crossed 50%. In the absence of any notable new oil and gas projects in the foreseeable future, import dominance of India's energy value chain could rise alarmingly. India's annual Ammonia consumption for fertilizer production is about 15 million tons (MT), roughly 15 per cent of this demand (over 2 MT per annum) is currently met from imports. Use of hydrogen in steel industry could substitute imported coking coal. During 2018-19, the total demand of coking coal for the steel industry was 58.37 MT and out of that 51.83 MT was met through imports. Substituting energy needs with Green Hydrogen could allow use of renewable energy in these important sectors and reduce import dependence.

Considering the above, it is expected that the Green Hydrogen, produced from cleaner sources i.e., renewable power through electrolysis or by following bio-based routes needs to be explored at scale. Some of Green Hydrogen's inherent green transition supportive attributes are –

a. A suitable substitute for the grey hydrogen, wherever hydrogen usage is taking place currently.
b. Can be an ideal solution for greening value chain and reducing carbon emissions of hard to abate sectors.
c. Can be used directly via fuel cells for varied usages or for electricity generation.
d. Can be used as feedstock to produce more suitable derivatives—such as ammonia, methanol, etc.
e. Can be used as sustainable aviation fuels (SAF)—for specific industrial and transport applications.

Hydrogen – Colours and Production Methodologies

	Production Input	Production Methodology	Carbon Neutrality	Scalability
Green	Renewable (solar, wind, etc), Biomass	Electrolysis	High	High
Pink	Nuclear power	Electrolysis of water	High	Low
White	Natural reserves	Underground extraction	High	Low
Blue	Natural gas	Carbon Capture & Storage (CCS)	Medium (residual emission)	High (in initial stages)
Turquoise	Natural gas	Pyrolysis	Medium (residual methane emission)	Low
Grey	Natural gas	Methane reformation	Low	High
Black/ Brown	Coal	Gasification of coal	Least	-

India Policy Landscape

Central Government Policy Initiatives: National Hydrogen Mission

On January 4, 2022, the National Green Hydrogen Mission was approved. The initial outlay for the

Mission was pegged at Rs. 19,744 crores. This included an outlay of Rs. 17,490 crores for the Strategic Interventions for Green Hydrogen Transition (SIGHT) programme. Other constituents of the program included Rs. 1,466 crores for Pilot Projects, Rs. 400 crores for Research & Development, and Rs. 388 crores towards other Mission components.

In terms of outcomes by 2030, the Mission targets development of Green Hydrogen production capacity of at least 5 MMT (million metric tons) per annum with an associated renewable energy capacity addition of about 125 GW in the country. All the Mission activities were targeted to result in creation of over 600,000 jobs and cumulative reduction in fossil fuel imports of over Rs. 100,000 crores. It was anticipated that the Mission will result in abatement of nearly 50 MMT of annual greenhouse gas emissions. The government has also come out with a clear definition of Green Hydrogen.

State	Governing Policy	Key Incentives/Initiatives
Odisha	**2022 Renewable Energy Policy and Industrial Policy Resolution (IPR)**	• Land cost subsidy • 30% capital subsidy • Stamp duty exemption • Electricity transmission subsidy • Specific environment-friendly infrastructure incentives
Tamil Nadu	**Tamil Nadu Industrial Policy 2021 (TNIP 2021)**	• 33.33% special capital subsidy • Land cost subsidy • Stamp duty exemption • Electricity transmission exemption
Maharashtra	**Approved Green Hydrogen Policy in July 2023**	• Budget sanction of Rs. 8,562 crores • 50% concession on transmission charges • 60% concession on wheeling charges • Rs. 50/kg subsidy for blending GH into gas • 30% Capex subsidy for 1st 20 GH fuelling stations
Gujarat		• Issued policy on land allotment for GH production • To release GH Policy with an outlay of ~Rs. 10 lakh crores
Karnataka		Has signed agreements worth Rs. 2.5 lakh crores with firms manufacturing GH and its derivatives
Himachal Pradesh		Plans to formulate a GH policy, to promote its use and establish the state as a leading hub for its production

GH – Green Hydrogen; 1 lakh = 100,000

Actions by Solar Energy Corporation of India (SECI)

Acting on the above, SECI has already invited bids for the selection of Green Hydrogen producers under the first tranche of the SIGHT program with a combined capacity of Green Hydrogen production of up to 450,000 metric tons per annum (MTPA). The bidding process has recognized the need to promote the bio-based hydrogen pathway as part of the Mission and has allocated a quantity up to 40,000 TPA for biomass-based pathways, within the overall quantum of 450,000 MT.

The minimum capacity allocated under Bucket I, i.e. electrolyser route, has been kept as 10,000 MTPA, while the maximum is 90,000 MTPA. The capacity to be allocated under the bio route has been pegged in the range of minimum 500 MTPA to maximum 4,000 MTPA. The bid process is currently underway, and bids are due to be submitted shortly.

State Level Policy Initiatives

As can be seen from above, there seems to be a healthy competition building up amongst states to attract the hydrogen and hydrogen related businesses to their states.

India Advantage

India, being in the tropical zone, is blessed with high solar irradiance. Its 7,000+ km of shoreline translates into high wind generation potential. India is also blessed with many perennially flowing rivers and its internal river system has high hydropower generation potential. On the electricity front, India has one of the sturdiest grids and unlike elsewhere in the world, has a single grid on single frequency, servicing the entire nation. It has over time demonstrated 99% plus availability and connects practically every nook and corner of the nation. India is richly endowed with water resources, which, if used judiciously, can very easily meet the additional water needed to produce hydrogen at scale within the country. India has pro-growth policies promoting enterprise and has a robust industrial sector, which has responded very positively to the growth-oriented policies, taken risk, and demonstrated enterprise and delivered results year after year. Various Indian companies like ACME, ReNew and Greenko are being globally acknowledged for their initiatives in the hydrogen space. It is necessary that an enabling regime is created for these and several other companies to become global leaders in the hydrogen value chain.

Bio-based Routes

As discussed, while most of the hydrogen production is currently sourced from the steam reforming of fossil fuels (Grey Hydrogen), bio-based routes for Green Hydrogen production are being encouraged and involve utilizing organic feedstocks such as biomass or agricultural waste, to generate hydrogen through processes like gasification, pyrolysis, or biological conversion. This approach aligns well with the objectives of the country's Mission, as can be seen from the advantages listed below:

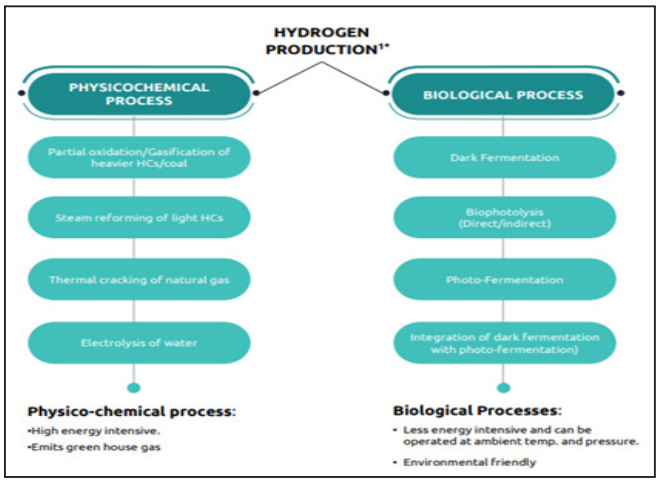
- Carbon Neutrality: Bio-based hydrogen production is considered carbon-neutral because the feedstocks used are derived from organic sources, capturing carbon dioxide during their growth. As a result, the overall carbon footprint is significantly lower compared to Grey Hydrogen production methods.
- Waste Valorisation: Utilizing agricultural residues, such as sugarcane bagasse, for hydrogen production turns waste into a valuable resource. This contributes to waste management and reduces environmental pollution.
- Renewable Feedstock: Biomass feedstocks are renewable resources that can be sustainably cultivated, ensuring a long-term and consistent supply of feedstock for hydrogen production.
- Economic Benefits: Bio-based hydrogen production can stimulate rural economies by providing an additional revenue stream for farmers and agricultural communities. It can also promote local job creation, especially in the context of biomass collection, processing, and conversion.
- Energy Security: Relying on bio-based routes diversifies the energy mix, reducing dependence on fossil fuels and enhancing energy security.

The bio-based routes align with the broader objectives of the Green Hydrogen Policy and the National Green Hydrogen Mission, and could help reduce the cost of Green Hydrogen production, set up disaggregated localized solutions with lower carbon footprint of supply chain, address the need for round-the-clock renewable energy procurement helping to partly address the problem of energy storage and supply at demand, and enhance its competitiveness against Grey Hydrogen. By leveraging the policy support, financial incentives, and enabling measures, India can quickly foster the growth of bio-based Green Hydrogen production.

In conclusion, by embracing bio-based routes for Green Hydrogen production, India can not only achieve its hydrogen-related goals but also contribute to waste reduction, rural development, and environmental preservation.

Bio-Hydrogen - Process Pathways

Green Hydrogen can be produced through different pathways from various renewable resources such as from water through electrolysis and bio-photolysis, and from biomass through biological/thermochemical pathways. Hydrogen produced from biomass



Source: Harnessing the potential of bio-resources to produce low carbon Bio-hydrogen by TERI and Capgemini

through the gasification pathway, and from biomass, carbohydrate-based feed and water through the biological pathway, is termed as 'Bio-hydrogen'.

Key Growth Drivers of Bio-Hydrogen

The Global Bio-Hydrogen Market is projected to grow at a CAGR of 6% in the forecast period of 2021-26. In India, if the current policy push continues, the growth may still be higher, as business, technology providers and supportive policies are creating a regime for the innovation in this space to flourish.

Recommendations

India has tasted huge success in renewables and its approach to create scale and tailwind of economic force to drive this change can serve as a good template to kickstart the hydrogen revolution in the country. SECI has played a pivotal role in creating scale, contract sanctity, making cheaper finance access possible on the back of SECI's long-term contracts, etc., along with several other positives that it has brought to the table resulting in the buildup of domestic renewable energy capacity and fast reduction in tariffs. The same model with some contextual tweaking would be a useful reference or guide to enable the hydrogen ecosystem

Sugar industry has been at the forefront, helping the nation secure ethanol production to meet higher blend requirements and Indian Sugar Mills Association (ISMA) has been at the forefront of leading this process. In the hydrogen space also, as a concrete way forward, to expedite the entire process and to understand the potential of bio-based hydrogen, ISMA has already commissioned a project with Indian Institute of Science (IISc.) Bangalore on production of hydrogen with bagasse as feedstock. About 12 tons of bagasse are under pelletization and transport to IISc, and it is expected that the potential of hydrogen production through this bio-route will be established through this initiative. This pathway will also help generate additional income to the farming community through green credits. ISMA has also commissioned a study with Deloitte to examine this potential and propose methodologies for the computation of carbon and green credits for the entire bio-based value chain.

Sugar factories are now reinventing themselves in the upgraded role of bio-refineries. The subject of diversifying the product slate of a sugar bio-refinery to include derivatives beyond ethanol, like biogas, hydrogen, methanol, SAF, bio-plastics and bio-chemicals, etc. are being investigated as potential options for sugar factories. ISMA is taking the lead in exploring these options in partnership with domain knowledge partners to enable the sugar sector to play a proactive role in building scale in this bio-led energy transition.

to gain scale at speed and for India to become a major export centre for hydrogen derivatives.

Though some specific suggestions for further improvement are as under:

1) Need of a centralized nodal agency to aggregate demand and manage the bidding process in the country. There is need to aggregate the demand of all the major hydrogen users and create scale for the bidders to produce at scale, which will create conditions for the costs to come down and capacity to build up faster.
2) Existing knowledge of aggregation process needs to be suitably modulated to accommodate the specifics of hydrogen usage. Unlike power where India had already a single grid to transmit the power produced in one part of the country to another on that grid, there is no such pre-existing system for the hydrogen ecosystem envisaged to be created. So, an efficient and pragmatic connect between hydrogen production and consuming entities would need to be established, to build a hydrogen system with collocated consuming and producing centres.
3) Use of mandates for a portion of hydrogen usage for the current users could be the starting point for creating scale. Possibility of some sort of aggregation for private sector demand, especially for the sectors likely to face challenges due to Carbon Border Adjustment Mechanism (CBAM), should also be explored with the industry.
4) Like renewable energy contracts the offtake contracts should be long-term and prices discovered in a successful bidding process should be respected over project life.
5) Government should consider a mandated flow of finance to hydrogen and green options such that within the priority sector lending, finance flow to hydrogen and hydrogen derivatives is available at concessional rates, given the early stage of the hydrogen value chain. Mandated lending to the hydrogen value chain will help direct financing to the hydrogen ecosystem, which is currently being perceived as risky by investors.
6) Bio-Hydrogen being a fledgling area, needs special support. Government must provide cheaper finance for all bio-based hydrogen production. Also, where emissions are abated through the bio route, bio-based hydrogen projects should be entitled to higher green and carbon credits.
7) Given the current state and the need for urgency to create scale in the sector, Government must create a knowledge base and set up institutes to support and promote pure and applied research in upstream and downstream of hydrogen and hydrogen derivatives value chain.

Hydrogen value chain requires new skill sets which are not fully known and appraised at this stage. There is a need to map the requirements of skill sets needed to take hydrogen and hydrogen production, and lead the world on the global energy transition challenge, to avoid delays later due to lack of talent. This may also be a pathway for re-deployment in sectors where job growth has stagnated.

Courtesy:
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- Former C&MD and Director - Finance, ONGC
- Member, Energy Transition Advisory Committee

Green Hydrogen: A Promising Tool for Decarbonisation

Viewpoint Article by Shri S. Pillai, Hydrogen Division, Ministry of New and Renewable Energy

Introduction

In the global quest for sustainable and cleaner energy solutions to combat the escalating threat of climate change, Green Hydrogen is expected to play a prominent role given its versatility and potential to provide a clean source of energy for various sectors.

Within this transformative landscape, India stands out as a nation with ambitious energy goals. India has firmly set its sights on attaining energy independence by 2047 and ultimately reaching net zero emissions by 2070. Recognizing the indispensable role that Green Hydrogen will play in these aspirations, the Ministry of New and Renewable Energy (MNRE) released a comprehensive document on the National Green Hydrogen Mission in January 2023.

This Mission represents a comprehensive and forward-looking approach aimed at harnessing the potential of Green Hydrogen to enhance India's energy security and reduce greenhouse gas emissions. The initial outlay for the mission will be Rs. 19,744 crores. The Mission will build capabilities to produce at least 5 million metric tons (MMT) of Green Hydrogen per annum by 2030, with the potential to reach 10 MMT per annum with the growth of export markets. The Mission aims to make India a global hub of Green Hydrogen production, utilization, and export. It also aims to make India a leader in the technology and manufacturing of electrolysers and other enabling technologies (*refer Figure 1*).

Key Developments

The Mission strategy comprises interventions such as firstly, demand creation by making Green Hydrogen produced in India competitive for exports and through domestic consumption. Secondly, addressing supply-side constraints through an incentive framework. Thirdly, the mission will build an enabling ecosystem to support the scaling and development of Green Hydrogen.

MNRE has issued scheme guidelines for the implementation of Strategic Interventions for the Green Hydrogen Transition (SIGHT) program. The framework document comprises two components of the incentive program. While Component I aims at providing electrolyser manufacturing incentives with a total outlay of Rs. 4,440 crores, Component II focuses on Green Hydrogen production with a financial outlay of Rs. 13,050 crores. MNRE has designated Solar Energy Corporation of India Limited (SECI) as the nodal agency for undertaking the effective implementation of the SIGHT program. SECI has also invited bidders to submit bids for both components.

MNRE has also notified the Green Hydrogen Standard in August 2023, which defines what encompasses 'green' in Green Hydrogen. The hydrogen standard requires emissions to stay below 2 kg of carbon dioxide equivalent per kg of hydrogen, and are applicable to both water electrolysis and biomass-based pathways. This will eliminate the ambiguity regarding the criteria for defining Green Hydrogen.

Another key component of the Mission is to establish a conducive research and innovation ecosystem for Green Hydrogen in the country, for which an advisory committee has been set up that has prepared a draft report on the R&D required to support this ecosystem. The committee had conducted in-depth analysis of the current status of technology and ongoing research, benchmarking and gaps, before recommending R&D actions for each part of the Green Hydrogen value chain *(refer Figure 2)*.

The Road Ahead

There is an urgent need to establish a global ecosystem for the production and trade of Green

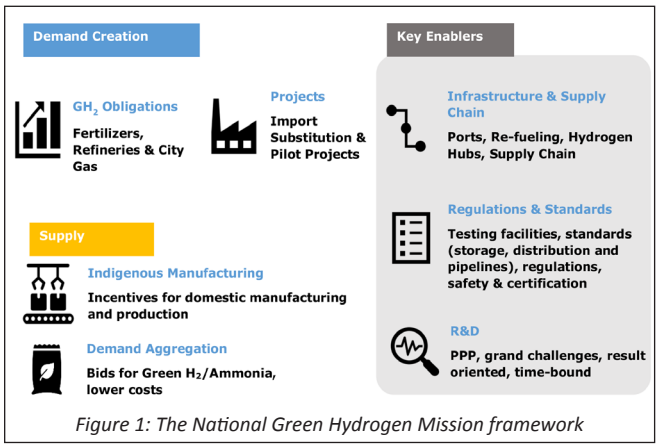

Figure 1: The National Green Hydrogen Mission framework

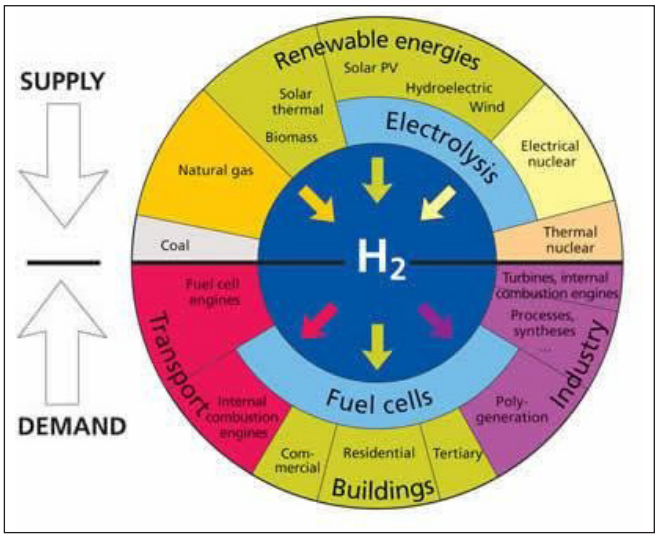

Figure 2. The hydrogen economy.

Source: https://www.researchgate.net/figure/The-hydrogen-economy_fig1_228467579

Hydrogen (including derivatives), and standardization of regulations and certification across the hydrogen value chain. Currently, there is no universally agreed-upon global consensus on hydrogen certification and hydrogen standards.

Developers, oil and gas majors, industries, and manufacturers are all aligning their strategies with the Green Hydrogen revolution, as they recognize its potential as a clean and versatile energy carrier, and for decarbonizing their processes and reducing emissions. Developers are investing in electrolyser capacity and exploring renewable energy integration. Oil and gas majors are diversifying their portfolios to include hydrogen production and distribution.

Challenges & Opportunities

The focus of all the nations on defining the role of hydrogen in their strategies in recent years has helped the industry understand the potential marketplace for hydrogen, and develop plans to incorporate hydrogen into technology and project portfolios. While the prospects are promising, we cannot ignore the challenges that lie ahead.

These technologies are ready to scale, but the hydrogen market is still nascent and its future evolution is uncertain, which is discouraging first movers from reaching final investment decisions (FID). Scaling up Green Hydrogen production to meet India's energy needs will require substantial investments in infrastructure and technology. The high cost of electrolysers, installation of renewable energy plants at an unprecedented pace, and the need for efficient energy storage solutions are challenges that demand innovative solutions. Moreover, ensuring a sustainable supply chain of critical materials is another hurdle to overcome.

Amid these challenges, there are immense opportunities for India. Our vast renewable energy potential can be harnessed to produce Green Hydrogen competitively. The development of a domestic Green Hydrogen industry can create jobs and stimulate economic growth. Moreover, India can position itself as a global hub for Green Hydrogen production and export, strengthening its energy security and international standing.

Conclusion

In conclusion, India's Green Hydrogen journey is a multifaceted endeavour that requires strategic policy support, technological innovation, and collaborative efforts from all stakeholders. As we move forward, it is imperative that we address challenges proactively, leverage opportunities wisely, and remain committed to our vision of a cleaner and more sustainable energy future.

We appreciate the initiative by the Cogeneration Association of India to launch the new 'HYDROGEN INDIA' newsletter, and wish them all the best.

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Shri Sujit Pillai is currently Scientist F in the Hydrogen Division at MNRE. He holds a Bachelor's Degree in Materials and Metallurgical Engineering from IIT Kanpur and an MS in Materials Science and Engineering from the University of California, Berkeley, USA. After having worked in the LED Chip Fabrication and IC Chip Fabrication industries in the US, he returned to India to work on LED Packaging. He developed India's first warm white LED in 2004. After that he worked on Silicon Solar Cell Fabrication and CIGS Solar Cell Fabrication and Characterization. He then joined the government in 2016 to work on advanced Silicon Solar Cells and their characterization, where he set up an ISO Class 8 Clean Room with multiple characterization equipment. He also has a Masters Diploma in Artificial Intelligence.

National Green Hydrogen Mission: Integrated Mission Strategy

In a bold and ambitious move, the Government of India announced the National Green Hydrogen Mission in January 2023. The overarching objective of the Mission is to make India the Global Hub for the production, usage and export of Green Hydrogen and its derivatives. This will contribute to India's aim to become Aatmanirbhar (self-reliant) through clean energy and serve as an inspiration for the global Clean Energy Transition. The Mission will lead to significant decarbonization of the economy, reduced dependence on fossil fuel imports, and enable India to assume technology and market leadership in Green Hydrogen.

To achieve the above objectives, the Mission will build capabilities to produce at least 5 million metric tons (MMT) of Green Hydrogen per annum by 2030, with potential to reach 10 MMT per annum with growth of export markets. The Mission will support replacement of fossil fuels and fossil fuel-based feedstocks with renewable fuels and feedstocks based on Green Hydrogen. This will include replacement of Hydrogen produced from fossil fuel sources with Green Hydrogen in ammonia production and petroleum refining, blending Green Hydrogen in city gas distribution systems, production of steel with Green Hydrogen, and use of Green Hydrogen-derived synthetic fuels (including Green Ammonia, Green Methanol, etc.) to replace fossil fuels in various sectors including mobility, shipping, and aviation. The Mission also aims to make India a leader in technology and manufacturing of electrolysers and other enabling technologies for Green Hydrogen.

Working Together

As part of the Integrated Mission Strategy, all concerned ministries, departments, agencies and institutions of the Central and State Government will undertake focused and coordinated steps to ensure successful achievement of the Mission objectives. Under this directive, the following responsibilities have been demarcated:

1. **Ministry of New and Renewable Energy (MNRE)** will be responsible for overall coordination and implementation of the Mission. The Mission Secretariat, headquartered in MNRE, will formulate schemes and programs for financial incentives to support production, utilization and export of Green Hydrogen and its derivatives. The Ministry will ensure planned deployment of renewable energy and Green Hydrogen capacities, support pilot and R&D projects, undertake capacity building, and promote international cooperation efforts. The Ministry will also ensure holistic development of the Green Hydrogen ecosystem in the country through active coordination with various public and private entities responsible for other aspects of the Mission.
2. **Ministry of Power (MoP)** will implement policies and regulations to ensure delivery of renewable energy for Green Hydrogen production at least possible costs, including through development of the necessary power system infrastructure. MoP will also work with State Governments, distribution companies, regulators and technical institutions to align the electricity ecosystem for large scale Green Hydrogen production.
3. **Ministry of Petroleum and Natural Gas (MoPNG)** will facilitate uptake of Green Hydrogen in refineries and city gas distribution through both public sector entities and private sector. MoPNG will also enable development and facilitation of regulations through the Petroleum and Natural Gas Regulatory Board (PNGRB). New refineries and city gas projects will be planned and designed to be compatible with maximum possible Green Hydrogen deployment, with a goal to progressively replace imported fossil fuels.
4. **Ministry of Chemicals and Fertilizers** will encourage adoption of indigenous green ammonia based fertilizers for progressively replacing imports of fertilizers and fossil fuel based feedstocks (natural gas and ammonia) used to produce fertilizers. This will enable decarbonization of the sector and reduce dependence on imports. The Ministry will enable procurement of green ammonia for its designated entities to create bulk demand.
5. **Ministry of Road Transport and Highways (MoRTH)** will enable adoption of Green Hydrogen in the transport sector through regulations, standards, and codes, primarily for heavy commercial vehicles and long-haul operations. MoRTH will also facilitate technology development for adoption of Green Hydrogen in the transport sector through testing

facilities, pilot projects, and provide support for infrastructure development.

6. **Ministry of Steel** will drive adoption of Green Hydrogen in the steel sector. The Ministry will identify and facilitate pilot projects for use of Green Hydrogen in steel production and undertake policy measures to accelerate commercial production of green steel.
7. **Ministry of Ports, Shipping and Waterways (MoPSW)** will play a crucial role in establishing India's export capabilities for Green Hydrogen and its derivates. MoPSW will facilitate development of the required infrastructure including storage bunkers, port operations equipment, and refuelling facilities. MoPSW will also drive the adoption of hydrogen/derivatives (ammonia/methanol) as propulsion fuel for ships. The Ministry will also work towards making India a Green Hydrogen/derivative refuelling hub.
8. **Ministry of Finance** will explore suitable fiscal and financial frameworks to promote production, utilization and export of Green Hydrogen and its derivatives.
9. **Ministry of Commerce & Industry** will encourage investments, facilitate ease of doing business, and implement specific industrial and trade policy measures for low-cost production and trade of hydrogen and its derivatives. The ministry will undertake dialogue to facilitate global trade of hydrogen and its derivatives. The ministry will also formulate necessary policies and programs for development of an ecosystem for manufacturing of specialized equipment needed in the Green Hydrogen value chain.

Coordinated efforts will be required to establish a robust ecosystem of regulations and standards to enable safe and rapid scaling up of projects for production, delivery, storage and use of hydrogen. MNRE will anchor this activity in partnership with Department for Promotion of Industry and Internal Trade, Bureau of Indian Standards, MoPNG, MoRTH, and associated agencies.

10. **Ministry of Railways** will work on transitioning towards adoption of Green Hydrogen in their operations in view of its ambitious plans to reduce the carbon footprint. Accordingly, Railways is also expected to play an integral role for transporting Green Hydrogen and its derivates. For this, the ministry will put in place the necessary regulations and standards.
11. **Scientific Departments** and agencies, including MNRE, the Office of the Principal Scientific Advisor to the Government of India, Department of Science and Technology, Department of Scientific and Industrial Research, Department of Space, Defence Research & Development Organisation, Ministry of Environment, Forests and Climate Change (MoEFCC), and other public research and innovation institutions will pool resources to build a comprehensive goal-oriented Research and Innovation program in collaboration with the private sector.
12. **Ministry of External Affairs (MEA)** will be instrumental in building bilateral and multilateral partnerships for supporting the Green Hydrogen ecosystem development in India and abroad. MEA will also aid collaborations of Government agencies, institutions and industry with global partners.
13. The **Ministry of Skill Development and Entrepreneurship** will take steps in coordination with MNRE and other ministries for building skillsets ensuring employability in this sector. Suitable courses and programs will be developed for skilling of manpower across the value chain, including manufacturing of equipment, Green Hydrogen project installation, and operations & maintenance.
14. **Ministry of Education** will work towards coverage of hydrogen technologies and latest developments in the pedagogy and curricula at various levels. Practical experience of technologies through guidelines for laboratory set ups in schools and higher education institutions will also be encouraged.
15. **State Governments and State Agencies** will also play an integral role in development of the Green Hydrogen ecosystem. States will have an opportunity to establish themselves as front runners in this sunrise sector through project development, manufacturing, setting up renewable energy capacity, and promoting export of Green Hydrogen derivatives. For this, the States will be requested to put in place fair and rational policies for provision of land and water, suitable tax and duty structures and other measures to facilitate establishment of Green Hydrogen projects.

Source: *MNRE Publication, January 2023*

ONGC Energy Centre: Role in India's Hydrogen Sector

Viewpoint Article by Shri Ravi, Director General, ONGC Energy Centre

ONGC Energy Centre (OEC) has been developing highly efficient clean and green indigenous hydrogen generation technologies using thermochemical water splitting processes *viz.*, the Copper-Chlorine (Cu-Cl), closed and open loop Iodine-Sulphur (I-S) cycle that utilizes high temperatures, which may be obtained from renewables – especially solar and other renewable sources. OEC has been following a collaborative consortium approach in bringing up these technologies on a fast track mode to meet the large hydrogen requirements anticipated in the near future in a techno-economically feasible way. OEC has established the processes at lab engineering scale and is in the process of scaling up at ONGC's premises for process intensification using in-house designs and indigenous fabrications with engineering materials in an effort to move forward for realizing ultimate commercialization goals.

Significant Strides

Despite challenges in indigenous development of such technologies for the first time in India, which are even yet to be commercialized elsewhere in the world, OEC has made significant strides in the development of these processes, including the supporting technology like membranes, catalysts, electrodes, design of corrosion test methods for screening/materials of construction, indigenous sources of fabrication, etc., and earned several national and international patents in countries such as USA, UK, Germany, Japan, South Korea, Canada and China, for the developed products and processes.

The hydrogen campaign of OEC got more thrust with the launch of National Green Hydrogen Mission in January 2022. OEC is joining hands with potential external parties for joint development of the technologies at the earliest with a market approach.

In detail, OEC has developed three cycles for hydrogen, namely:

1. **Cu-Cl thermochemical cycle:** This thermochemical cycle is operational at 550°C with hydrogen generation @25 lph (liters per hour) in a metallic facility. Further scale up at 100 lph is under process.
2. **I-S closed loop thermochemical cycle:** The closed loop I-S thermochemical cycle is operational at 900°C with hydrogen generation @5 lph in a quartz/glass setup. Further scaleup is under process.
3. **I-S open loop thermochemical cycle:** The open loop I-S cycle is operational at 550°C. Proof of concept in the quartz/glass set up has been completed. Further scale up is under process.

CO_2 Valorization

The vision is to integrate the thermochemical cycle for the Green Hydrogen generation system with the CO_2 refinery concept wherein, captured CO_2 from flue gas or any other source can be effectively converted into higher hydrocarbons such as SNG (synthetic natural gas), methanol, dimethyl ether, and other value-added products via CO_2 hydrogenation. A novel combination of bimetallic catalyst has been developed that shows better CO_2 conversion (CH_4 yield 64-84%) and stability (up to 4000 h of reaction time).

OEC's parent company Oil and Natural Gas Corporation (ONGC) plans to invest Rs. 2 trillion ($24.17 billion) on clean energy projects in order to meet its 2038 net-zero carbon emissions goal.

India is aggressively putting efforts to have an electrochemical energy storage system (EC-ESS) by 2030. India is committed to reducing emission intensity up to 33-35% from the 2005 level by 2030 and set the target of 40% non-fossil fuel-based electricity generation in the energy mix. This requires radical measures to scale up India's share of renewable energy, perhaps with new targets by 2030 in the order of 350 to 500 GW.

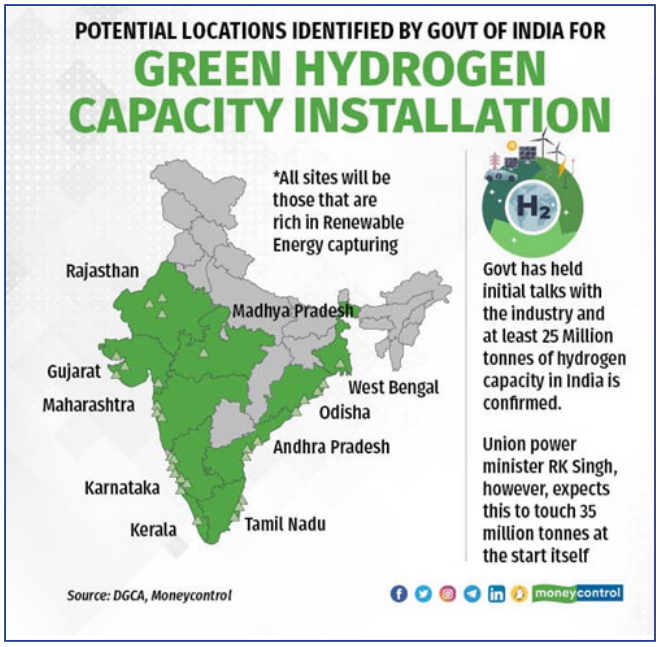
Energy Storage Systems

OEC is also pursuing research, development and demonstration (RD&D) on energy storage systems

contd on pg 14

State Initiatives

The National Green Hydrogen Mission (NGHM) was approved by the Union Cabinet in January 2023 with an outlay of Rs. 19,744 crores from FY 2023-24 to FY 2029-30. To achieve the above objectives, the Mission will build capabilities to produce at least 5 million metric tons (MMT) of Green Hydrogen per annum by 2030, with potential to reach 10 MMT per annum with growth of export markets.



As per the Ministry of New and Renewable Energy (MNRE), in November 2022 the government had identified 10 potential states[1] that could be the key enablers in manufacturing Green Hydrogen in India to kickstart its Mission. These include Karnataka, Odisha, Gujarat, Rajasthan, Maharashtra, Tamil Nadu, Andhra Pradesh, Kerala, Madhya Pradesh and West Bengal. These states are likely to have Green Hydrogen or ammonia manufacturing zones or clusters, and have been identified on the basis of the existing steel and fertilizer industries, refineries and ports located there, along with the operational and potential renewable energy generation capacity in the regions. At some locations, the existing city gas distribution network has also been incorporated, as that is another sector that can offtake green hydrogen.

In each newsletter issue, we will profile updates of some state initiatives in this sector

Odisha

Odisha, the largest manufacturer of steel in the country, has also decided to push for Green Hydrogen and green ammonia manufacturing. Green Hydrogen, obtained from the splitting of water using solar and wind power, offers a cleaner alternative for producing steel. This can also help reduce the sector's dependence on coking coal imports. The state, which has some major ports and is developing new ones, is also projecting itself as a Green Hydrogen export hub to investors.

Maharashtra

Maharashtra became the first state to announce its green hydrogen policy with an outlay of Rs 8,500 crore by way of subsidies and benefits to companies generating the green hydrogen, in a move to promote renewable energy.

The state cabinet approved the state's Green Hydrogen Policy on 4 July 2023. The policy aims to "make Maharashtra a leader in green hydrogen and its derivatives ecosystem in the country". The current hydrogen demand of the state is 0.52 million tons per annum and may reach 1.5 million tons by 2030.

Key Features[1]

- The policy aims to incentivize projects that procure renewable energy through open access, whether

[1] *https://swarajyamag.com/infrastructure/maharashtra-becomes-first-state-to-announce-green-hydrogen-policy-with-an-outlay-of-rs-8500-crore*

from in-state or out-of-state power distribution companies, power exchanges, or for self-consumption.

- According to the policy, there will be a 50 per cent concession in transmission charges and a 60 per cent concession in wheeling charges for the next ten years from the implementation of the project.
- Standalone power plants will receive a 100 per cent concession in power tariff for the next ten years, while hybrid power plants will receive this concession for the next 15 years. Additionally, both types of plants will be exempted from cross subsidy and surcharge.
- Projects related to green hydrogen production will also need to be registered with the Energy Office.
- Land designated for green hydrogen projects will receive complete exemptions from local body tax, non-agricultural tax, and stamp duty.
- A subsidy of Rs 50 per kg will be provided for blending green hydrogen into gas for a period of five years.
- First 20 green hydrogen refueling stations will receive a 30 per cent capital cost subsidy, with a maximum limit of Rs 4.50 crore.
- First 500 green hydrogen-based fuel cell passenger vehicles will be eligible for a capital cost subsidy of up to Rs 60 lakh per vehicle, subject to a 30 per cent subsidy.
- Rs 4 crore per annum for ten years for recruitment of skilled manpower, their training, skill development, single window facility.

contd from pg 12... ONGC Energy

(ESS) in line with various ongoing activities on energy generation for harnessing renewable energy from sources such as solar energy that are location-centric and subject to seasonal variations.

In order to address the expected intermittency issues with solar sources to ensure round-the-clock operations, Redox flow batteries (RFBs) are being investigated as ESS for load levelling and emergency power supply systems. OEC has developed 1 kW/10 kWh Vanadium Redox Flow Battery (VRFB) 24-cell stack powered by solar PV charging (a 2.4 kW solar panel) with a power output of 1.4 kW and energy of 10 kWh for 11 hours of continuous operation. Post demonstration, the battery system is continuously under field trial operation with efficiency of 85-90%.

Courtesy:
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With a B. Tech (Mechanical) from BIT Sindri and MBA in Operation Research from IGNOU, Shri Ravi is leading ONGC Energy Centre (OEC), with a mandate to undertake or assist in Programs/Projects of Fundamental and Applied Research for improving and developing commercially viable energy mediums and sources beyond hydrocarbons, especially in clean and or renewable energy options.

Shri Ravi has been awarded multiple times at the highest level for his significant contribution in ONGC, including the prestigious “Professional of the Year Award” from CMD, ONGC in 2014.

Challenges Ahead: India's Hydrogen Odyssey

Viewpoint Article by Shri Gadia, Managing Director, Resurgent India

Producing hydrogen through natural gas or fossil fuels emits a significant amount of CO_2 into the environment. According to a recent report, the production of such hydrogen is responsible for releasing 830 million tons of CO_2 annually into the atmosphere, which is comparable to the combined emissions of two nations with a population exceeding 300 million people. Green Hydrogen, on the other hand, is seen as a clean way out, replacing production processes that accelerate climate change.

Surging Ahead

After a prolonged period of gradual development, the Green Hydrogen sector in India seems to be surging ahead. The industry is growing with heavy investments from the public as well as the private sector. NITI Aayog, the government's strategic think tank, estimates that India spends more than $160 billion of foreign exchange annually on energy imports, which could double over the next 15 years. Embracing a Green Hydrogen economy would not only significantly bring down these expenses but also offer an opportunity for India to cut down 3.6 giga tons of CO_2 emissions by the year 2050.

On January 4, 2022, the Union Cabinet gave its approval to the National Green Hydrogen Mission, an ambitious initiative that will serve several environmental and economic goals. Chief among these goals is the aspiration to position India as a prominent global producer and supplier of Green Hydrogen and its derivatives, moderating India's reliance on imported fossil fuels and feedstock. The Mission will nurture the growth of domestic manufacturing capabilities, attract substantial investments and open novel avenues for Indian businesses, thus catalysing employment opportunities and boosting the domestic economy. Additionally, the Mission places a strong emphasis on advancing research and development (R&D) in this sector.

Working Together

The Mission outlines the responsibilities of all stakeholders, with the Ministry of New and Renewable Energy (MNRE) assuming the role of Overseer and Coordinator, while the Ministry of Power (MoP) will be tasked with formulating policies and regulations designed to facilitate the cost-effective delivery of renewable energy for Green Hydrogen production, which includes the development of essential power system infrastructure. The Mission also outlines a Strategic Hydrogen Innovation Partnership (SHIP) as a Public-Private Partnership. It combines industry and government funding for research, seeks to nurture international partnerships, and supports breakthrough research to enhance affordability, efficiency, and safety of hydrogen-based systems.

MNRE in India has unveiled a draft R&D roadmap aimed at fostering the growth of the Green Hydrogen ecosystem in the country, by promoting the advancement and integration of alternative energy systems, with a specific focus on the adoption of fuel cell technologies. Projects have already been initiated to establish a Green Hydrogen production capacity of 3.5 million tons. We can also now lay claim to industries that are global leaders in solar and wind energy. With approximately 25,000 MW of solar manufacturing capacity in operation and an additional 40 GW to 50 GW currently underway, India is set to become the largest manufacturer of solar cells and modules outside of China.

Challenges Ahead

The challenge in hydrogen production lies more in its cost and less in its production. Right now, making Green Hydrogen is pricier than the fossil fuel version, setting you back an extra $2 per kilogram. The latter uses renewable resources, like wind and solar, for electrolysis which requires electricity, water, and expensive metals like platinum. Despite significant growth in its renewable energy capacity, we missed our 2022 target by 32%. Meeting the high demand for renewable energy and swapping out "dirty" hydrogen in industries would require almost double the worldwide wind and solar output – a big hurdle in the quest for sustainable Green Hydrogen.

Besides, several domestic factors such as teething troubles in acquiring land for renewable energy projects, and a disconnect between national renewable

energy targets and their enforcement at the state level can easily throw a wrench in India's Green Hydrogen growth plans.

Hydrogen is frequently billed as a zero-emission fuel. When hydrogen is combusted to drive industrial processes, it generates minimal quantities of greenhouse gases (GHG), such as CO_2. However, the release of hydrogen into the atmosphere can lead to indirect warming effects by cranking up the levels of pre-existing GHG like methane or even water vapour, essentially revving up mechanisms that heat up the climate. Even if there's a 10% leakage rate at any stage of Green Hydrogen production, transportation, storage, or utilization, it would completely wipe out the advantages of using it over fossil fuels. To safeguard its climate benefits, we must have effective technology in place to monitor and measure hydrogen leaks.

Global partnerships and strategies should inform India's growth, recognizing the one-of-a-kind challenges and opportunities the sector faces. The United States, which is a major player in Green Hydrogen, has unveiled its National Clean Hydrogen Strategy and Roadmap, outlining ambitious production goals. The plan sets its sights on achieving a production capacity of 10 million metric tons annually by 2030, further scaling up to 20 million metric tons by 2040, and an impressive 50 million metric tons by 2050. The roadmap harmonizes the efforts of both private and public sectors, a joint push towards a greener energy future.

However, producing Green Hydrogen in the US requires rare minerals that are in short supply domestically and are often sourced from Chinese companies. To address this challenge, the US needs to explore economic partnerships with Brazil, India, and South Africa – three BRICS (Brazil, Russia, India, China, South Africa) countries that could have substantial reserves of these rare minerals. These countries already have strong economic ties with the US. Nevertheless, the US and the European Union (EU) will need to be open to dropping their protectionist policies in order to forge meaningful trade agreements with these nations.

China's Role & Plans

China is a major player in both hydrogen production and consumption. However, an extremely tiny fraction, representing less than 0.1% of its hydrogen production, comes from renewable energy sources. China has also laid out a roadmap that includes six objectives–Cost, Infrastructure, Market Demand, Industry Standards and Certification, Technology, and Evolution and Cooperation–which it intends to achieve through a well-orchestrated sequence of actions spanning three distinct phases aimed at accomplishing its key objectives. Phase 1 (2023-24) focuses on favourable policies, demonstration projects, technological breakthroughs, seamless energy integration, and their application in various sectors. Phase 2 (2024-27) emphasizes technical standards, supply network investments, international collaboration, and widespread advancements. Phase 3 (2027-30) centres on price and demand targets, energy infrastructure enhancement, certification mechanisms, innovation networks, and global participation in hydrogen.

China might consider ramping up Green Hydrogen technology for two compelling reasons – first, Green Hydrogen aligns well with its goal of increasing non-fossil energy consumption and serves as a dependable substitute for imported oil and natural gas; second, carbon capture and utilization and storage (CCUS) technology used to produce blue hydrogen is not widely established or promoted in China, except for a few demonstration projects.

China's Green Hydrogen dreams, however, come with a few wrinkles that need smoothing out. The limited development of hydrogen infrastructure in China has been a significant challenge. Under the Chinese regulatory framework, hydrogen is classified as both an energy resource and a potentially hazardous industrial chemical. This dual categorization has added a layer of complexity to the process of establishing the necessary infrastructure. Also, China's dependence on imported materials like catalysts, carbon paper, and high-strength carbon fibre is a big hurdle for its hydrogen cell technology supply chain.

Furthermore, the essential high-pressure hydrogen storage technology, vital for penetrating the long-haul commercial vehicle market, remains a substantial challenge for China's Fuel Cell Vehicles industry. China has put in place a standardization and certification system for its hydrogen industry, but it's not operating as efficiently as desired. The pace of setting these standards has failed to keep up with the rapid growth of the hydrogen industry. Currently, Green Hydrogen is still in its early stages of development in China, as the sector works towards building a new energy system and creating a comprehensive supply chain for hydrogen.

Going green with hydrogen requires a good handle on diverse dynamics, including production capacity, the setting up of a resilient supply chain, governmental push, considerable research and development efforts, and a keen understanding of global dynamics. For India to truly become a global hub for Green Hydrogen production, it must pick out methods to make hydrogen an economically viable and efficient fuel with extensive usage.

We need to bring down the cost of Green Hydrogen production by offering implicit subsidies, extending government support for R&D initiatives, and capitalizing on our unique advantage of cost-effective renewable energy generation. With India holding the G20 presidency, it's in a prime position to really step up and help align global standards and certification systems for Green Hydrogen.

India needs to act swiftly to seize time-sensitive export opportunities. For instance, India is currently in talks with the EU to export 10 million metric tons of renewable hydrogen, and in return, the EU plans to invest in a clean energy project in India. This aligns with the EU's goal, set in 2022, to boost its renewable hydrogen production by an additional 15 million tons by 2030, with an import target of 10 million tons.

Moreover, considering the array of government initiatives aimed at nurturing the Green Hydrogen sector, it's absolutely vital to establish a mandate that obliges industrial sectors like refining and non-urea fertilizers to make a complete switch to 100% Green Hydrogen usage by 2030.

We are on course to produce a minimum of 5 million metric tons of Green Hydrogen annually by 2030 if we stay true to the outlined roadmap. This will result in an addition of around 125 GW of renewable energy capacity in the country, a substantial leap towards reducing CO_2 emissions.

Courtesy:
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Declaration

This article is our original work and the manuscript has not been published, submitted or considered for publication elsewhere.

FORTHCOMING EVENTS

Green Hydrogen in India 2023 Conference
11-12 September 2023
Mumbai, India
https://10times.com/e1rs-p414-9ksg

2nd Edition
GH2 India Conference & Exhibition
13-15 September 2023
Greater Noida, Uttar Pradesh
http://gh2summit.com/

3rd International Climate Summit
14 & 15 September 2023
Vigyan Bhawan, New Delhi
www.ics-hydrogen.com

World Hydrogen Energy Summit
16-17 October 2023
New Delhi, India
http://worldhydrogensummit.in/index.html

10th Hydrogen & Fuel Cell Conference 2023 (IHFC 2023)
3-5 December 2023
Varanasi, Uttar Pradesh, India
https://www.hai.org.in/pdf/10th_international_hydrogen_&_fuel_cell_conference_2023.pdf

2nd Hydrogen India Summit (HIS) 2024
23-24 January 2024
New Delhi, India
http://www.indiahydrogen2022.com/

Sourcing Green Hydrogen

It is estimated that currently around 5 MMT (million metric tons) of hydrogen are consumed annually in India for various industrial purposes like petroleum refining, manufacturing of ammonia for fertilizers, methanol production, treatment and production of metals, etc. Most of this hydrogen is currently sourced from fossil fuels through the process of steam reformation of natural gas, naptha, etc. and is referred to as Grey Hydrogen. The chlor-alkali industry also produces hydrogen gas as a by-product, while some hydrogen is produced by electrolysis of water using grid electricity for specific applications.

India's Interventions

In recent years, pilot projects have been undertaken in India for the production of Green Hydrogen through electrolysis of water using renewable electricity, and from biomass through thermochemical and biochemical routes. India's National Green Hydrogen Mission aims to develop and scale up Green Hydrogen production technology and make it affordable and widely accessible.

The costs of the electrolysers and input renewable energy are the two major components of the Green Hydrogen production cost. The costs of capital, supply and treatment of water, storage and distribution, conversion of hydrogen to suitable derivatives, and enabling infrastructure would also contribute significantly to the final delivered cost of Green Hydrogen for any particular application. The Mission seeks to undertake the necessary steps to enable cost reduction in all of these aspects.

India has substantial experience in renewable energy deployment, contract mechanisms and policy frameworks. As a result, India has achieved some of the lowest long term levelized costs for solar and wind power generation. The downward trend is expected to continue. However, to ensure low cost of delivered renewable energy for electrolyser-based projects, the Mission proposes to extend various facilitative policy provisions for transmission, connectivity, banking, open access, and energy storage for Green Hydrogen production projects.

Another important intervention will be to upscale production and deployment of high-performance electrolysers in sufficient volumes. Currently, the global commercial electrolyser manufacturing capacity is estimated to be only about 2-4 GW/annum. During the past three years, various national governments and industrial organizations have announced deployment goals totalling to over 200 GW electrolyser capacity by 2030. With this, the global electrolyser manufacturing capacity is set to grow rapidly. However, to limit dependency on imports and ensure supply chain resilience in the sector, it is critical to develop a robust domestic electrolyser manufacturing ecosystem in India. The Mission proposes interventions to boost domestic manufacturing to ensure production of electrolysers in India at significantly lower costs. This will also enable competitiveness of Made in India Green Hydrogen in the international markets.

To further enhance cost-competitiveness of Green Hydrogen by reducing the cost of capital required to build projects, mechanisms for dollar-denominated Bids for Green Hydrogen/Ammonia will be explored.

Innovative models to source Green Hydrogen through the use of decentralized renewable energy generation such as rooftop solar and small/micro hydel plants will also be explored. Decentralized Green Hydrogen production will be advantageous to reduce the requirement of its transportation for end-use. This would also allow for optimal utilization of various resources such as land, water, renewable energy potential, etc. Decentralized production would be explored through:

- Biomass-based hydrogen production systems
- Modular electrolysers connected to rooftop solar or other decentralized renewable energy plants like small hydro, etc.
- To optimize water requirements, the use of industrial or municipal wastewater for hydrogen production, wherever feasible, will also be emphasized.

For certain applications such as long-haul mobility, decentralized Green Hydrogen production would be essential. Hydrogen refuelling stations in the cities and along highways could be connected to decentralized renewable energy plants for in-situ production of Green Hydrogen.

It will also be an endeavour to maximize the utilization of the renewable energy potential on various islands in

India. Through appropriate connectivity, the renewable energy generated at islands in proximity to the mainland, could be transmitted and utilized for Green Hydrogen production and other end-uses. For remote islands, renewable energy can be utilized to produce Green Hydrogen in a decentralized mode to meet the local energy requirements. This would save the requirement of land for setting up renewable energy capacities and also help in development of the island regions.

The Mission will also support and facilitate building of required infrastructure for storage and delivery of Green Hydrogen and its derivatives. Port infrastructure required to enable exports of Green Hydrogen derivatives, and pipelines to facilitate bulk transport of Green Hydrogen will also be developed. Further, the producers and consumers of Green Hydrogen and its derivatives will be encouraged to pool resources and develop projects in a coordinated manner in the form of large-scale Hydrogen Hubs.

With these targeted interventions to reduce input and capital costs, it is expected that Green Hydrogen will be competitive with Grey Hydrogen in the next few years.

Production of Green Hydrogen through biomass also holds potential for achieving scale and low costs. Different technological pathways, including biomass gasification and reformation of biogas, etc. are in various stages of development and piloting. Achieving scale and building supply chains for biomass collection are key components for facilitating production of low-cost Green Hydrogen through these routes. These pathways can provide continuous hydrogen output, which would enhance feasibility of hydrogen use for many end-use applications. The Mission, accordingly, aims to initiate focused pilots to arrive at workable models for biomass-based Green Hydrogen production and its use in various applications. The Mission will focus on reducing the costs of biomass collection and delivery, and the capital cost of equipment for conversion of biomass to hydrogen.

Phased Approach

Considering the nascent status of the sector and the rapidly evolving profile of the industry, the Mission is proposed to be implemented in a phased manner, focusing initially on deployment of Green Hydrogen in sectors that are already using hydrogen, and evolving an ecosystem for R&D, regulations and pilot projects. The later phase of the Mission will build on these foundational activities and undertake Green Hydrogen initiatives in new sectors of the economy. The major thrust areas of each phase are identified below.

Phase I (2022-23 to 2025-26)

The focus of Phase I will be on creating demand while enabling adequate supply by increasing the domestic electrolyser manufacturing capacity. In order to ensure Make in India from the inception stage, a bouquet of incentives aimed at indigenization of the value chain and increasing Green Hydrogen production and uptake will be developed. Utilization in the refineries, fertilizers and city gas sectors will also create a sustained demand to support new investments in Green Hydrogen production.

The first phase will also lay the foundation for future energy transitions in other hard-to-abate sectors by creating the required R&D impetus. In this phase, pilot projects will be undertaken for initiating green transition in steel production, long-haul heavy-duty mobility and shipping. Parallelly, work will commence on establishing a framework of regulations and standards to facilitate the growth of the sector and enable harmonisation and engagement with international norms.

The scale up of Green Hydrogen production and use, and the proposed measures under the Mission in the first phase, are expected to drive down costs, allowing for greater and wider Green Hydrogen deployment in the next phase.

Phase II (2026-27 to 2029-30)

Green Hydrogen costs are expected to become competitive with fossil-fuel based alternatives in the refinery and fertilizer sector by the beginning of the second phase, allowing for accelerated growth in production. Depending upon the evolution of costs and market demand, the potential for taking up commercial-scale Green Hydrogen-based projects in the steel, mobility and shipping sectors will be explored. At the same time, it is proposed to undertake pilot projects in other potential sectors like railways, aviation, etc. R&D activities will be scaled up for continuous development of products. The second phase activities would enhance penetration across all potential sectors to drive deep decarbonization of the economy.

Source: *MNRE Publication, January 2023*

World Bank Approves $1.5 Billion to Support India's Low-Carbon Transition

In a press release on 29 June 2023, the World Bank's Board of Executive Directors approved $1.5 billion to accelerate India's development of low-carbon energy. The financing will help India promote low-carbon energy by scaling up renewable energy, developing green hydrogen, and stimulating climate finance for low-carbon energy investments. The $1.44 billion loan is from the International Bank for Reconstruction and Development (IBRD) and is facilitated by a United Kingdom $1 billion backstop aimed at boosting the World Bank's climate change financing to India. A $56.57 million credit from the International Development Association (IDA) is from a recommitment of cancelled IDA credit balances.

India is one of the fastest-growing large economies in the world. While the country's energy consumption per capita is only one-third of the global average, India's energy demand is expected to grow rapidly as the economy expands. This calls for a phasing down of fossil-based energy sources in line with India's goal of achieving net-zero by 2070. The industrial sector is the main driver for future growth of energy demand and emissions, and green hydrogen can play a critical role in initially decarbonizing the hard-to-abate industrial sectors, such as fertilizer and refinery industries, and later heavy industries, including iron and steel.

India has achieved impressive progress in renewable energy installed capacity and a decline in costs. Scaling up the production of renewable energy will accelerate the transition to low-carbon electricity and support the emergence and expansion of the green hydrogen sector.

The Green Hydrogen Initiative

Low-carbon hydrogen is a key enabler in realizing global decarbonization goals and net-zero targets. For low- and middle-income countries, low-carbon hydrogen has the potential to:

- Decarbonize hard-to-abate sectors
- Help the economy grow by attracting investments and creating new green jobs
- Enhance countries' national energy security needs by reducing dependence on imported fossil fuels
- Lower energy costs over time

The First Low-Carbon Energy Programmatic Development Policy Operation – the first in a series of two envisaged operations, will support India in developing green hydrogen. The low-carbon energy is produced by electrolysis of water powered by renewable energy. The financing required to implement India's energy transition is such that public sector funding alone will not be sufficient. Building on recent successes, this operation will help stimulate private financing and other support by addressing viability funding gaps, reducing off-taker risks, boosting grid integration of renewables, and stimulating demand for renewable energy.

"The program will support the successful implementation of the National Green Hydrogen Mission that aims to stimulate $100 billion in private sector investment by 2030," said Auguste Tano Kouame, World Bank Country Director for India. "The World Bank remains committed to supporting India's low-carbon transition by complementing public financing and enabling private sector investments."

The program aims to scale up renewable energy supply, thereby reducing costs and improving grid integration. This will help India reach its committed 500 GW of renewable energy capacity by 2030. The government plans to issue bids for 50 GW of renewable energy each year from FY23-24 to FY27-28, which will avoid carbon emissions of 40 million tons per annum by 2026.

Supporting Policies

A national carbon market is essential to provide a level playing field between low-carbon energy and fossil fuels. This program will support policies for a national carbon credit trading scheme to launch a national carbon market. In January 2023, India issued its first sovereign green bond. The program will support policy actions for the issuance of $6 billion in sovereign green bonds by 2026.

"India can decouple emissions from growth through improved energy efficiency and switching to clean energy," said Xiaodong Wang, Dhruv Sharma, and Surbhi Goyal, Team Leaders for the project. "Through sustained policy reforms India can mobilize private

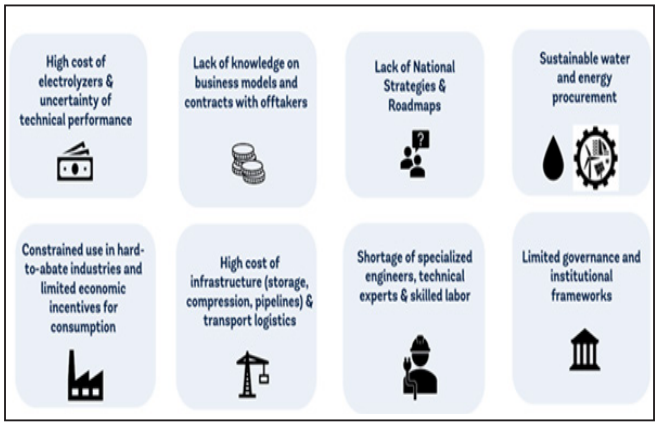
sector investments, create jobs and achieve net-zero targets."

H4D Partnership

This operation is only one piece of the Bank's comprehensive support to energy transition in India. It is aligned with the Government of India's energy security strategy. The operation is also aligned with the Bank's Hydrogen for Development (H4D)[1] Partnership launched at CoP27 in November 2022.

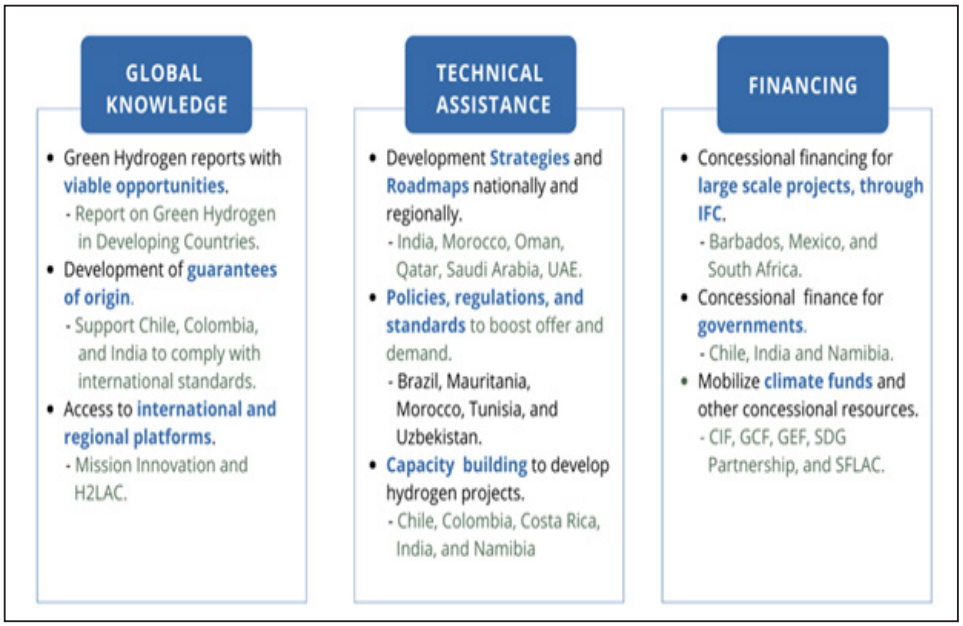
The Challenge: In developing countries, governments and private companies must tackle several obstacles to ignite and scale the low-carbon hydrogen industry.

The Power of Partnership: The World Bank Group and its partners have created the H4D, a new initiative to help catalyze significant financing for hydrogen investments from both public and private sources. By bringing together hydrogen stakeholders and channelizing synergies, the partnership will foster capacity-building and regulatory solutions, business models, and technologies, toward the roll out of low-carbon hydrogen in developing countries.



More specifically, H4D will enable:

- Convening international cooperation to increase the knowledge base in low-carbon hydrogen technologies for developing countries.
- Building capacities by following a global public goods approach.
- Understanding requirements from emerging markets and the private sector for deploying low-carbon hydrogen.
- Creating market opportunities to inform innovation and for new technologies to gain visibility.



- Generating policy dialogue on enabling the deployment of low-carbon hydrogen across countries.

H4D Partners: H4D is open to all hydrogen stakeholders and already counts several industry, academic and research institutions as partners. Partners will meet bi-annually to agree on the H4D work program, assess progress on approved activities, exchange information on partners' activities, and establish organizational arrangements for the delivery of tasks.

The current list of organizations that are H4D partners include: Green Hydrogen Organization, NREL, Rocky Mountain Institute, Australian Hydrogen Council, RISE Research Institute of Sweden, Center for Hydrogen Energy Systems Sweden (CH2ESS), Chile Green Hydrogen Organization, Hydrogen Council, H2LAC, H2 Colombia, H2 Mexico, Agência de Desenvolvimento do Estado do Ceará (Adece), CORFO.

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[1] https://www.esmap.org/Hydrogen_for_Development_Partnership_H4D

Sri Lanka National Hydrogen Roadmap

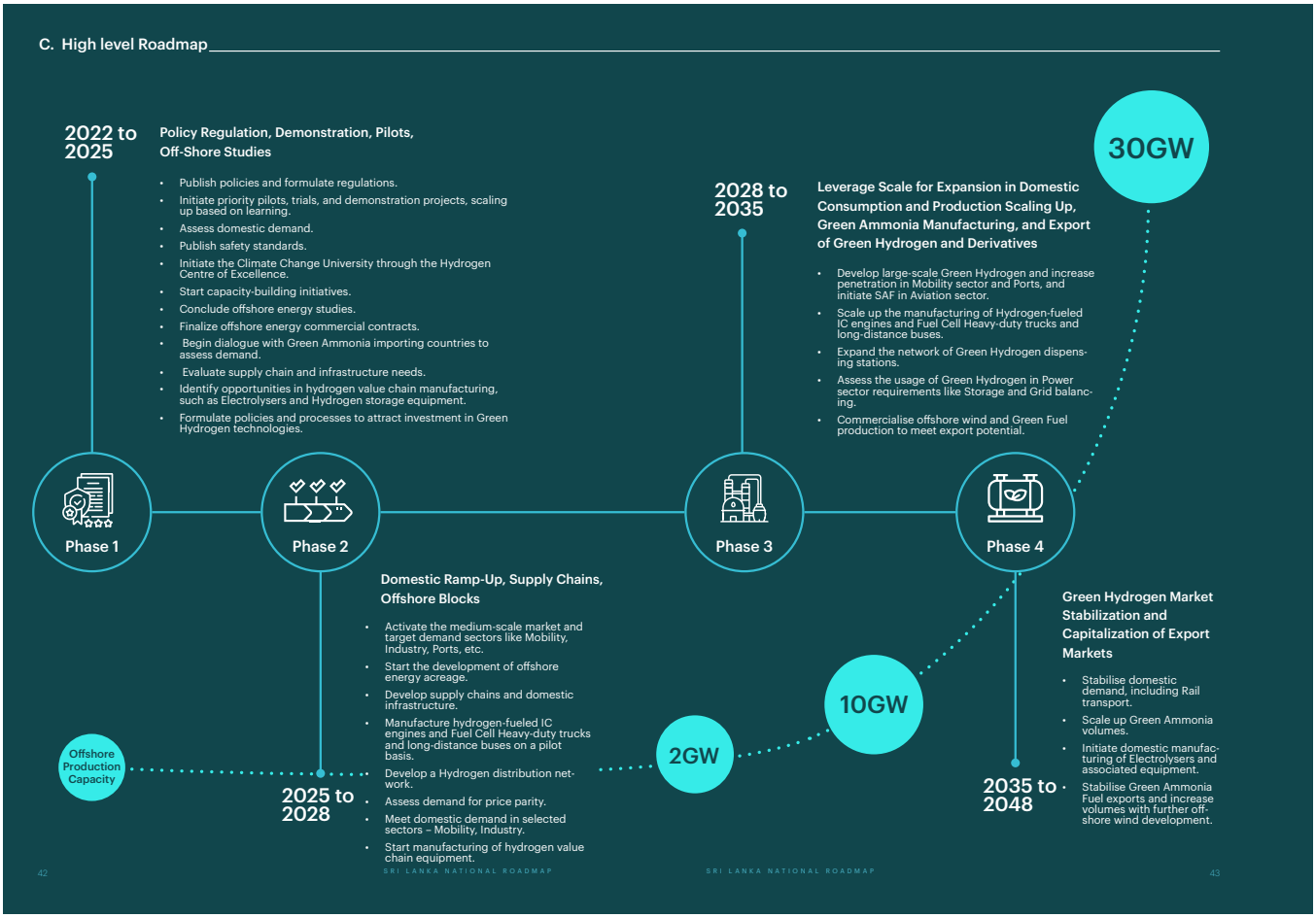
COUNTRY PROFILE

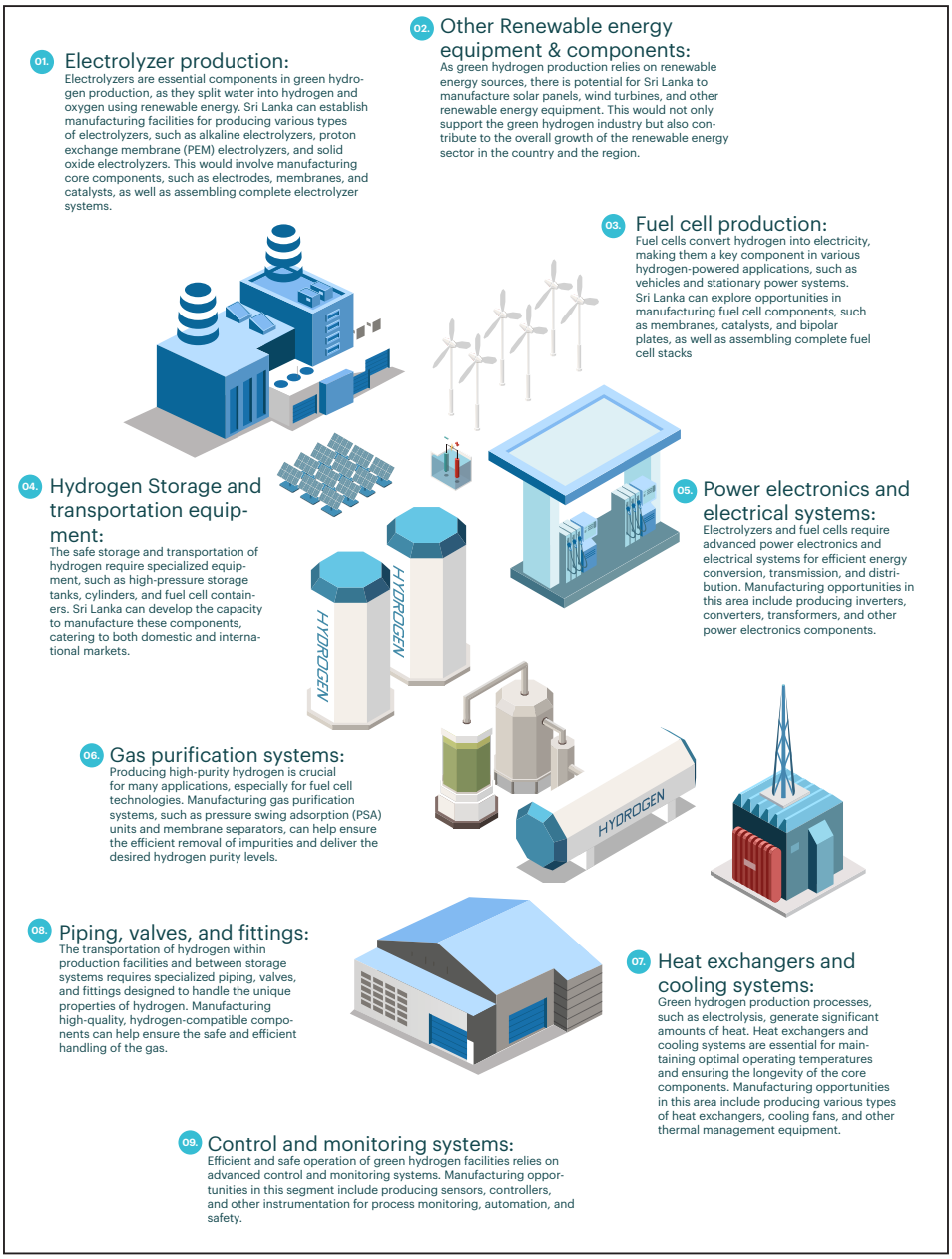
In a ground-breaking move, Sri Lanka has released its Green Hydrogen Roadmap, setting a new benchmark in the nation's pursuit of a sustainable energy paradigm. Greenstat has been at the forefront of this initiative, with its dedicated Sri Lankan team playing a pivotal role in shaping the roadmap.

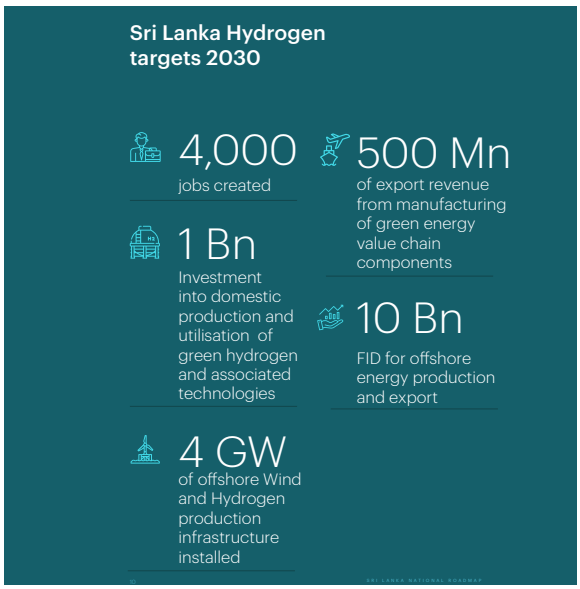
The Government of Sri Lanka has demonstrated visionary leadership by endorsing this robust plan for a sustainable energy transformation. It underscores the collective determination to address the global climate emergency while acknowledging the unique challenges faced by nations in the global South. These countries, although minor contributors to worldwide emissions, endure the brunt of climate change impacts.

"We aim to prioritise modern and sustainable efforts such as renewable energy, green hydrogen, and digitisation. We can draw inspiration from the Andhra region of India, which has excelled in developing these areas. Such modern and sustainable initiatives are vital for the complete transformation of Sri Lanka's economy. Over the next few months, we will make a special invitation to the private sector to submit their own business proposals that align with our vision of modernisation and sustainability. The Sri Lanka Green Hydrogen Roadmap is a step in that direction."

Hon. Kanchana Wijesekera MP, Minister of Power & Energy



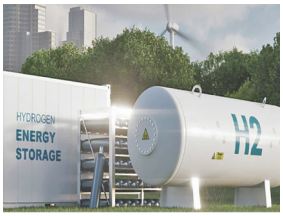




Sri Lanka's bountiful wind and solar energy sources place it in a prime position to champion Green Hydrogen as a cornerstone of its sustainable growth strategy. The country plans to capitalize on excess renewable energy for off-grid exports, propelling the Green Hydrogen sector's swift expansion. Leveraging its strategic geographical location, Sri Lanka aspires to evolve into a global energy nexus, drawing international investments and benefitting its populace.

Partnerships

Greenstat's local presence in Sri Lanka has been instrumental. Their collaboration with domestic stakeholders and energy experts has been central to the roadmap's creation. Their prowess in green energy technologies, fused with their devotion to eco-friendly solutions, has enriched the roadmap's scope and ambition. Emphasizing the power of international cooperation and knowledge sharing, Greenstat, through its Sri Lankan subsidiary, has cultivated robust alliances and engaged deeply with local communities. This ensures the roadmap's relevance and success.



In conclusion, the unveiling of the Green Hydrogen Roadmap is a significant milestone for Sri Lanka, emphasizing Green Hydrogen's integral role in the global shift towards sustainable energy.

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ABOUT COGEN INDIA

The Cogeneration Association of India (Cogen India) strives to promote cogeneration and captive power projects in all applicable industrial and commercial sectors, and lobbies for conducive and sustainable policy and regulatory framework. Along with cogeneration, sugar mills in India have also ventured into the production of Ethanol and Rooftop Solar Power Generation, and hold the potential to venture into many new arenas of renewable energy, gradually transferring into Bio-Energy Complexes instead of remaining only a 'Sugar Industry'.

Cogen India thus has plans to extend its wings and provide advisory services on all aspects related to Bio-Power Projects.

Key Action Areas

- Strategies and measures to promote cogeneration projects in all applicable industrial and bio-power commercial sectors in India
- Capacity building and fuel linkage
- Interacting with Central & State Governments, state electricity boards, regulators, national and international bodies for ensuring sustainable policy framework and tariff rates
- Assisting other sugar-producing countries to set up their cogeneration sectors/projects

Activities

- Inaugural launch of National Cogeneration Awards-2022, followed by announcement of National Cogeneration Awards-2023 (www.cogenawards.com)
- Successful organization of webinars, training programs/business meets/field visits in sugar, rice, distillery, paper, food processing, bio-power, waste to energy sectors, etc.
- Quarterly (English) newsletter "Industrial Cogeneration India" - A unique forum for distribution of technical and sectoral information in India/Abroad
- Marathi Bi-monthly newsletter "Nisarg Urja"- Appropriate to the aims and objectives of the association

- Sugar Cogeneration Handbook - 2021: Unique literature useful for stakeholders in the New and Renewable Energy sectors
- Member of the COGEN World Coalition (CWC), established in 2022 as an international non-profit association. First Country Focus webinar as part of COGEN World Talks webinar series launched, focusing on India, i.e. "India in Focus" on 18 July 2023.

For further information on the above or on membership/subscription/advertisement opportunities, refer www.cogenindia.org

Hydrogen Association of India (hai.org.in)

HAI serves as a common platform for sharing experiences regarding the latest technological trends in generation, usage and safety issues related to the application of hydrogen as automotive fuel and other purposes.

HAI aims to:

- Promote, encourage and develop the growth of hydrogen energy and its applications in the country.
- To disseminate information concerning the developments in hydrogen energy and its applications through publications.
- To establish an active association of all those persons, bodies, institutions (private or public) and industries.
- To render advice (technical or otherwise) to government and commercial bodies on matters pertaining to hydrogen energy and its applications, when needed or requested.