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EDITORIAL

The three-day International Conference on Green Hydrogen (ICGH-2024), held from September 11-13, 2024, highlighted the strides the sector is making towards our country's ambitious targets. Inaugurated by Shri Pralhad Joshi, Union Minister of New & Renewable Energy; Consumer Affairs, Food & Public Distribution, the event attracted over 8,500 delegates, including 3,000 plus youth and students. It also featured an exhibition showcasing innovations and technological advancements in the Green Hydrogen sector, with a hydrogen-powered bus and hydrogen internal combustion engine (H2ICE)-powered truck receiving much attention.

Addressing the valedictory session, Minister of State, Ministry of New and Renewable Energy (MNRE), Shri Shripad Y. Naik underlined that India has ushered into a new era of energy transition driven by a shared commitment to advancing the Hydrogen Agenda. Prof. Ajay K. Sood, Principal Scientific Adviser to the Government of India, said, "Our commitment to Green Hydrogen is not just about meeting emission targets, which of course is important. It is about seizing a historic opportunity to redefine our energy systems, create new jobs, and secure a cleaner, healthier planet for future generations", he said.

During his address, Secretary, MNRE, Shri Bhupinder S. Bhalla reiterated, "Green Hydrogen is not just a new energy source, it is a pathway towards a future where clean energy is the norm, and industries are decarbonized. Over the past three days, we've seen how collaboration among policymakers, scientists, and industry leaders can drive innovation and push the Green Hydrogen agenda forward. The discussions and breakthroughs will play a critical role in making India a global hub for Green Hydrogen production, usage, and export. The journey ahead will be challenging, but our collective ambition is strong, and the opportunities are vast."

Shri Pankaj Jain, Secretary of the Ministry of Petroleum and Natural Gas (MoPNG), Government of India stressed on the importance of international cooperation and innovative technologies in advancing the Green Hydrogen economy.

Along with other senior government officials, Mr. Ajay Yadav, Joint Secretary, MNRE highlighted that as many as 13 states have policy provisions for supporting the Green Hydrogen ecosystem. He pointed out the Mission would lead to the creation of 600,000 lakh green jobs, and also stressed on the importance of skilling, safety, pilot projects, research & development, and innovation.

The plenary sessions held during the conference highlighted the initiatives and advancements from the US, European Union, Australia, the Netherlands, and Germany, along with the global perspective as presented by International Renewable Energy Agency (IRENA). These sessions underscored the importance of international collaboration and knowledge exchange in accelerating the Green Hydrogen economy.

The 22 breakout sessions delved into the

contd on pg 10

CONTENTS

Sugar Industry and Green Hydrogen: Opportunities and Challenges

Green Hydrogen Companies in India

Financing Green Hydrogen Projects

Enhancing the Viability & Cost-Effectiveness of Green Hydrogen for Refineries

DST's Hydrogen & Fuel Cell Program in India

National Green Hydrogen Mission Initiatives: An Update

Powering the Future: Energy Leap's Trailblazers in Clean Hydrogen Innovation

Strategic Pathways for Green Hydrogen Project Developers: Navigating Export/ Domestic Markets & Building Competitive Capabilities

Green Hydrogen: Leading the Charge on Future Renewable Fuels

Clean Hydrogen Alternative for Phasing Out Diesel Generators

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'.

In line with the pragmatic changes by way of the Solar & Biofuel Policy, Cogen India too has added Solar Power with other Bio-Energy & Green Energy resources in the list of responsibilities, to share knowledge and experience, and pursue active interaction with all stakeholders.

Key Action Areas

- Providing advisory services on all aspects related to Bio-Power Projects
- Providing consultancy services for Rooftop Solar Power Projects at Sugar Complexes (Solar Symposium 2024 organized)
- 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 projects

Activities

- Inaugural launch of National Cogeneration Awards-2022, followed by National Cogeneration Awards-2023 and 2024 (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 (75 issues have been published till date)

- 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
- New Hydrogen India newsletter, launched in Sept 2023

For further information, refer www.cogenindia.org

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Heartiest Congratulations!

'Lifetime Achievement Award' to Shri Jaiprakash Dandegaonkar, Hon. Vice Chairman, Cogen India

We are delighted to extend our heartiest congratulations to Shri Jaiprakash Dandegaonkar, Former Minister; Hon. Vice Chairman, Cogeneration Association of India; and Hon. Chairman of Purna SSK Ltd., for being the distinguished recipient of the 'Lifetime Achievement Award' for his significant achievements in the Sugar Industry. The award was presented at the prestigious Sugar Technologists Association of India's 82nd Annual Convention & International Expo 2024 held at Jaipur on 30 July 2024.

Shri Dandegaonkar has also completed his tenure as Chairman, National Federation of Cooperative Sugar Factories Ltd. New Delhi as well as Chairman, Maharashtra State Co-operative Sugar Factories Federation Ltd. Mumbai.

The Board of Governors of Cogen India expresses their deepest gratitude to Shri Jaiprakash Dandegaonkar, for his continuing vision, guidance, and motivation, which has been instrumental in conceptualizing the idea of National Cogeneration Awards.

Sugar Industry and Green Hydrogen: Opportunities and Challenges

India aims to revolutionize its energy landscape by producing 5 million tons of green hydrogen annually from 2030 onwards. This ambitious pursuit aligns with India's domestic consumption figures, with a further aspiration to scale production to an impressive 10 million tons, as per the objectives of India's National Green Hydrogen Mission.

With the emergence of the Global Biofuel Alliance and commitment of the country for net zero carbon emissions by 2070, manifestation and commercialization of clean hydrogen fuel is being considered important in achieving the goal. In this article the authors have elaborated the various forms of hydrogen, probable technologies for production of green hydrogen, salient features of each, and utilization in various sectors. Various opportunities and challenges with respect to technologies available, cost and safety issues have also been discussed. Work carried out on a pilot plant scale for producing green hydrogen through methane pyrolysis indicates that sugar industry can also contribute significantly in providing green hydrogen.

Introduction

India has taken the lead by restricting the use of fossil fuels and opting for clean, green fuels and renewables. In this direction, significant capacity building for biomass, solar and wind power generation has taken place during the last decade or so. Indian sugar industry has also remained at the forefront in developing green energy by contributing bagasse-based electricity; juice, molasses and grain-based ethanol for India's Ethanol Blending Program (EBP); and compressed biogas or bio-methane produced from filter cake and spent wash.

Various countries have set targets to achieve net zero emissions by 2045 to 2070 (Table 1), wherein apart from various other biofuels, green hydrogen is also being considered with significant potential.

Table 1: Targeted years for achieving net zero emissions

Country	Target Year
Australia	2050
Canada	2050
China	2060
France	2050
Germany	2045
India	2070
Netherlands	2050
Russia	2060
UK	2050
USA	2050

Types of Hydrogen

Hydrogen is defined as of many types indicated in shades, mainly depending upon the feedstock and environmental impact/carbon footprints *(refer Fig. 1)*. However, it may be mentioned that green hydrogen refers to hydrogen that is produced using renewable energy sources, such as wind or solar power. It has a much lower environmental impact as it doesn't produce greenhouse gas (GHG) emissions during the hydrogen generation process.

The Ministry of New and Renewable Energy (MNRE) has recently defined "Green hydrogen as having a well to gate emission of not more than 2 kg CO_2 equivalent per kg H_2".

Production of Green Hydrogen: Technological Options

Green hydrogen has the potential to serve as a clean and sustainable energy carrier in various sectors. The cost of producing green hydrogen can vary and depends on several factors, including the technology used, the source of renewable energy, and the local market conditions. As reported, on commercial scale, it can be produced by following two techniques:

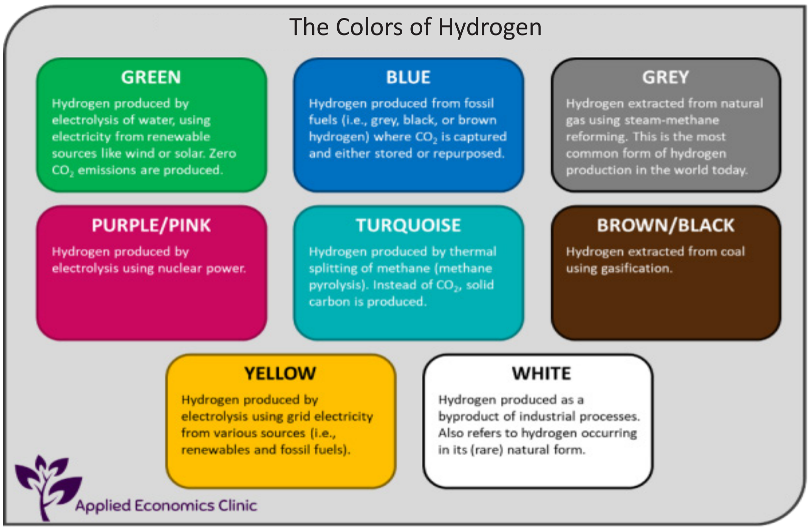

Fig. 1: Types of hydrogen

- **Electrolysis** (Fig. 2), where water (H_2O) is split into hydrogen (H_2) and oxygen (O_2) using electricity, typically generated from renewable sources like wind or solar power.
- **Methane pyrolysis** is another technique to produce green hydrogen, wherein, thermal energy is applied to

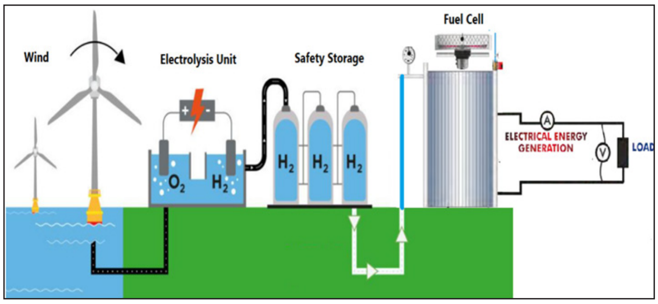

Fig. 2: Production of green hydrogen through electrolysis

methane (CH_4) to break the chemical bond between carbon and hydrogen, generating hydrogen gas and a solid carbon product with no CO_2 emissions (Fig. 3). Only a small portion of methane may remain unreacted depending on the reactor's efficiency.

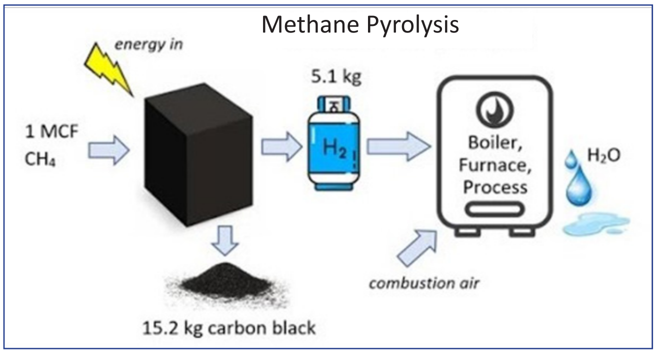

Fig. 3: Production of green hydrogen by methane pyrolysis

Production of Green Hydrogen in Sugar Industry

Since sugar industry produces biomass-based renewable energy (bio-electricity) and also compressed biogas from filter cake (press mud) and spent wash, both the routes for production of green hydrogen may be considered (Fig. 4). The bio-electricity may either be used for electrolysis (Option-1) or in catalytic conversion of biogas (methane pyrolysis) produced from filter cake and spent wash to green hydrogen and carbon black.

Encouraging results were achieved during initial pilot plant scale trials for producing green hydrogen from compressed biogas, by M/s Pagnism Innovations Pvt. Ltd. at National Sugar Institute, Kanpur, wherein green hydrogen and carbon black was successfully produced through pyrolysis of compressed bio-methane from filter cake.

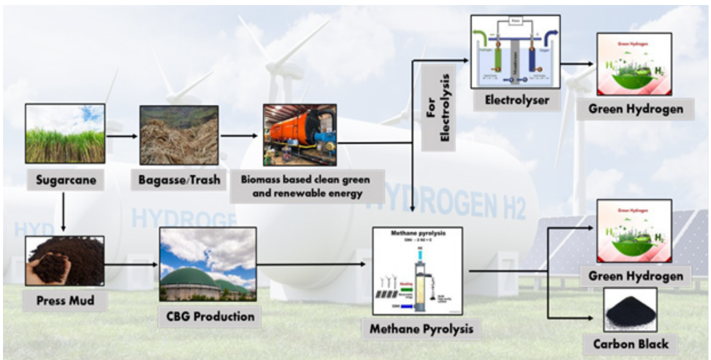

Fig. 4: Possible routes for production of green hydrogen in sugar industry

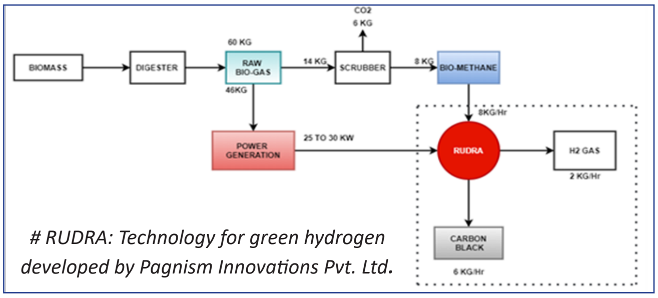

Fig. 5: Schematic diagram of green hydrogen production through methane pyrolysis

Generation of green hydrogen takes place as per the following chemical reaction:

CH_4 = C (Carbon Black, Solid) + $2H_2$ (Green Hydrogen, Gas)

In this process, 4 kg of methane yields: 1 kg Hydrogen and 3 kg Carbon Black. The other salient features of the system and process parameters are as under:

Reactor: Parallel Tube Type

Catalyst: Initial Catalyst is Carbon Black then shifts to Auto-Catalysis

Heating: Electrical Furnace

Operational Temperature: 1080 ^{0}C to 1125 ^{0}C

Efficiency: 93% to 96% (Conversion rate)

Throughput: Carbon Black and H_2 (approx. 75% and 25% respectively)

Operation: Automated

The "RUDRA" technology, besides producing green hydrogen, also results in production of carbon black which is a value-added product for many industries (Fig. 6).

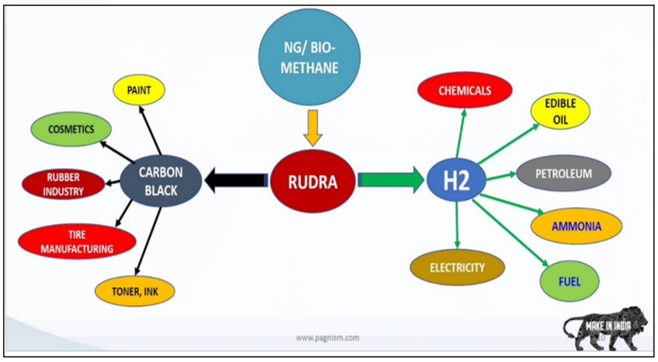

Fig. 6: Uses of green hydrogen and carbon black

The merits and demerits of each above technique for producing green hydrogen are discussed below:

Through Electrolysis

- *Cost:* Adoption of this technology requires higher initial capital costs and limited economies of scale.
- *Energy storage*: Hydrogen can serve as an energy storage medium, but faces competition from batteries, which have higher round-trip efficiency and are better suited for short-term energy storage and grid stability than green hydrogen.

- *Infrastructure development*: The existing hydrogen infrastructure is primarily built around grey hydrogen (produced from natural gas by steam methane reforming or SMR technology), and transitioning to green hydrogen or setting up new facilities for green hydrogen would require significant investment in infrastructure development.
- *Carbon footprint of electrolysis:* While green hydrogen production is considered clean, the environmental impact of the electrolysis process, including the manufacturing of electrolysers and the materials involved, i.e. carbon footprints of the entire system, are to be addressed.
- *Transportation and storage:* Hydrogen is challenging to transport and store. It has low energy density by volume, making it less efficient for long-distance transportation.
- *Safety issues*: Hydrogen is highly flammable, thus, ensuring its safe handling and storage is always a significant challenge. Stringent safety measures are necessary to avoid any mishaps.
- *Water availability and treatment cost:* The production of green hydrogen depends upon the availability of good quality water. Hence treatment costs for ensuring water quality may add to overall cost.
- *Innovations and technological development:* The adoption of green hydrogen on a wider scale is dependent upon advancements in technology to improve the efficiency and reduce the costs of production, storage and transportation, etc.
- *Competition from other clean energy sources:* Green hydrogen faces competition from other clean energy solutions, such as batteries, which have made significant advancements in recent years.

Through Methane Pyrolysis

Some of the main challenges in green hydrogen production through methane pyrolysis include:

- *Energy requirement:* Methane pyrolysis requires a substantial amount of energy to break the strong chemical bonds in methane. Ensuring a clean and sustainable energy source is a challenge. However, the sequestering of carbon in the form of generated carbon black counters the use of regular electricity in the preview of CO_2 emission limit.
- *Carbon emissions:* Although methane pyrolysis can potentially be a low-carbon process, it can still produce carbon emissions if the feedstock itself contains impurities.
- *Scale-up:* Commercializing methane pyrolysis and scaling it up to meet the demand for green hydrogen is a significant challenge. Developing cost-effective, large-scale reactors and infrastructure is considered essential.
- *Development of catalysts*: Efficient catalysts are crucial for methane pyrolysis. Finding and developing catalysts that are durable, cost-effective, and selective for the desired reactions is considered challenging. Carbon black generated in the process is a suitable catalyst.
- *Sourcing of methane:* Renewable sources of methane, such as biogas or synthetic methane produced from captured CO_2, are potential solutions. However, their continuous availability needs to be ensured.
- *Economics:* The cost of producing green hydrogen through methane pyrolysis needs to be competitive with other hydrogen production methods. Reducing capital and operational costs along with utilization of byproducts, e.g. carbon black, is important to make the process viable.
- *Regulatory and safety concerns:* Meeting safety standards and regulatory requirements, especially for handling and storing hydrogen can be complex.
- *Integration with existing infrastructure:* Integrating green hydrogen produced through methane pyrolysis into existing hydrogen infrastructure and end-use applications is also considered a challenge.
- *Technological innovation*: Continuous research and development are required to improve the efficiency and reliability of the methane pyrolysis process, making it more feasible and competitive with other processes of green hydrogen production.

Uses of Green Hydrogen

The utilization of green hydrogen is mainly aimed at serving hard-to-abate sectors and electrification as shown in Fig. 7.

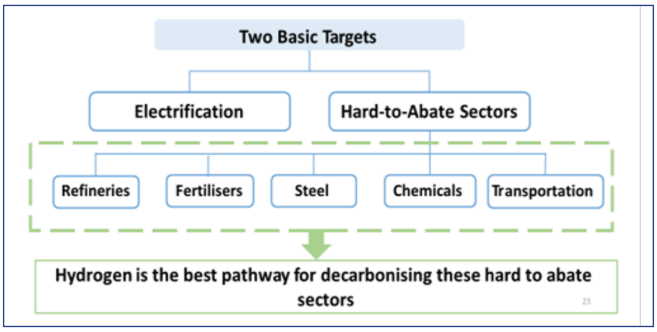

Fig. 7: Green hydrogen utilization

Green hydrogen is a key feedstock for various industrial processes. Industries like chemicals, refineries, and steel production can use green hydrogen as a cleaner alternative to hydrogen produced from fossil fuels. It can also be used as a fuel for fuel cell vehicles, providing a clean alternative to traditional internal combustion engines. It can be particularly useful for heavy-duty transport, such as buses, trucks, and trains.

As regards heat and power generation, green hydrogen can be burned directly or used in fuel cells to generate heat for residential, commercial, or industrial heating applications. This can be an alternative to natural gas, with the advantage of being a cleaner-burning fuel. Further it can be used as a fuel in gas turbines to generate electricity. This can provide a cleaner alternative to conventional power generation methods, especially in areas where renewable energy sources might not be consistently available. Besides these,

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Green Hydrogen Companies in India

With an ambitious target to produce five million tons of green hydrogen by 2030, the Indian government had announced the National Green Hydrogen Mission with an initial investment of $2.3 billion. The breakdown includes $2.1 billion for the SIGHT (Strategic Interventions for Green Hydrogen Transition) Program, $176 million for pilot projects, and $48 million for R&D.

The mission will empower green hydrogen producers in India to produce green hydrogen and green ammonia without incurring transmission costs for 25 years straight. Indian public sector oil and gas companies plan to build a combined capacity of 38,000 tons of green hydrogen per annum by the next financial year. The prominent private sector conglomerates, including Reliance Industries and Adani Group, have already expressed interest in investing heavily in green hydrogen production and green hydrogen energy storage.

The Top Seven Companies

As per Blackridge Research, as on 24 July 2024, there were seven large green hydrogen producing companies in India:

1. Adani Green Energy Ltd. (AGEL)
2. Reliance Industries Ltd. (RIL)
3. Indian Oil Corporation Ltd. (IOC)
4. Oil & Natural Gas Corporation Ltd. (ONGC)
5. GAIL India Ltd. (GAIL)
6. Bharat Petroleum Corporation Ltd. (BPCL)
7. National Thermal Power Corporation Ltd. (NTPC)

We will profile these in each issue of HYDROGEN INDIA, along with updates on their respective projects and initiatives.

Adani Green Energy Ltd. (AGEL)

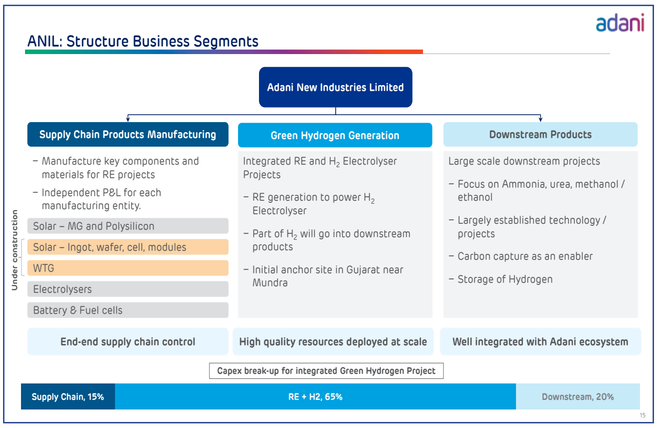
This, by far, is the top green hydrogen manufacturing company in India, and it has made heavy investments in green energy and other renewable energy sources. Adani New Industries Ltd. (ANIL), a subsidiary of Adani Group, announced on June 14, 2022, that it had entered into a partnership with French energy giant Total Energies SE to invest $50 billion in India over the next decade to produce green hydrogen and create "the world's largest green hydrogen ecosystem" around it. The joint venture (JV) is expected to focus on developing infrastructure for green hydrogen production, storage, transportation, and distribution across India.

The slides below are based on an ANIL PowerPoint compilation on Green Hydrogen Ecosystem in June 2024.

Earlier in 2024, AGEL announced the completion of the JV with Total Energies, including a $300 million investment by the latter for a 50% stake in a portfolio of more than 1 GW of solar and wind projects. The new JV's portfolio already includes 300 MW in operation and 500 MW under construction, as well as 250 MW of under-development assets. The launch of the JV forms the latest in a series of partnerships and transactions between the companies, including the acquisition by Total Energies of a 20% stake in AGEL in 2021, and an initial JV established in 2020 for the operation of 3 GW of solar power.

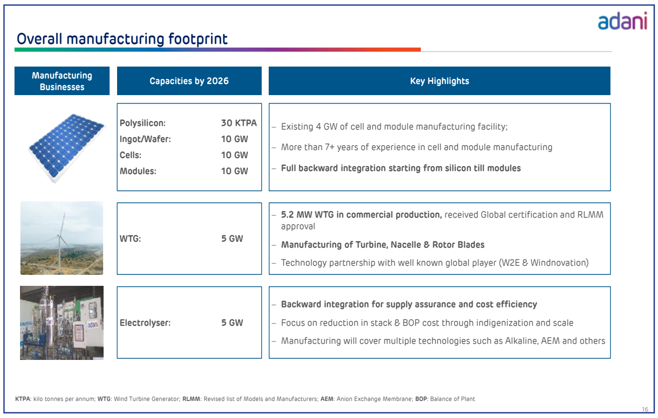
ANIL has set an initial target of producing 1 million tons per annum of green hydrogen by 2030, which will contribute significantly to the country's renewable energy goals.

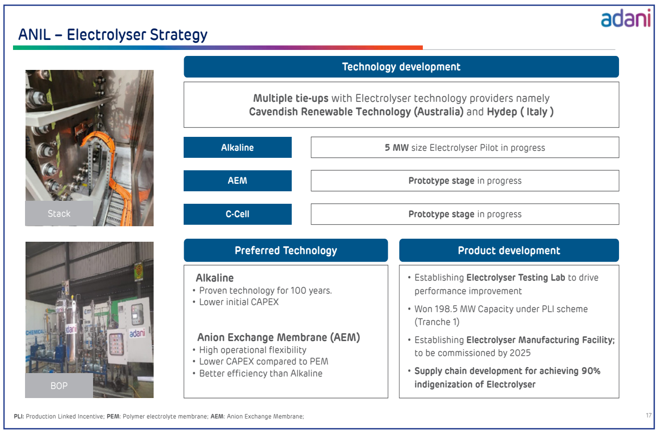
ANIL's partnership with Total Energies SE and its collaboration with Cavendish Renewable Technology Pty. Ltd. (CRT) highlights the company's commitment to invest in green hydrogen production and infrastructure, and also create employment opportunities and boost economic growth. ANIL's efforts to develop green hydrogen technologies could also drive innovation and reduce the cost of production, making it more accessible and affordable for businesses and consumers.



Expertise in giga-scale renewable energy project development – Largest renewable energy developer in India
Expertise in setting up long-distance transmission lines – Largest transmission system developer in India
Expertise in developing and handling large ports and associated infrastructure – Largest port operator in India

Maire Tecnimont Group and Adani Enterprises Ltd. (AEL) also signed an MoU in 2024 to develop a green hydrogen plant in India, and other projects for the production of chemicals, ammonia, and hydrogen from renewable feedstock. The agreement was signed through Maire Tecnimont's subsidiaries NextChem, Stamicarbon, and MET Development (MET DEV). AEL and Maire Tecnimont Group's subsidiaries will mutually



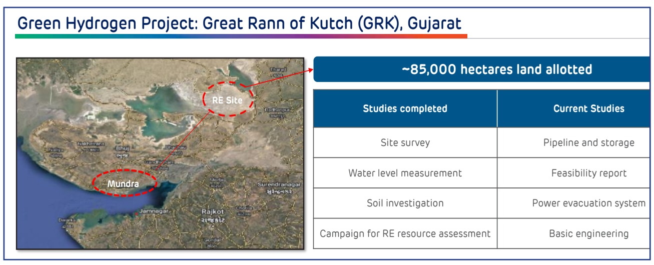


explore the integrated opportunities for the valorization of the renewable feedstock by exploiting Next Chem's and Stamicarbon's technologies for chemicals, ammonia, and green hydrogen applied to the chemicals value chain.

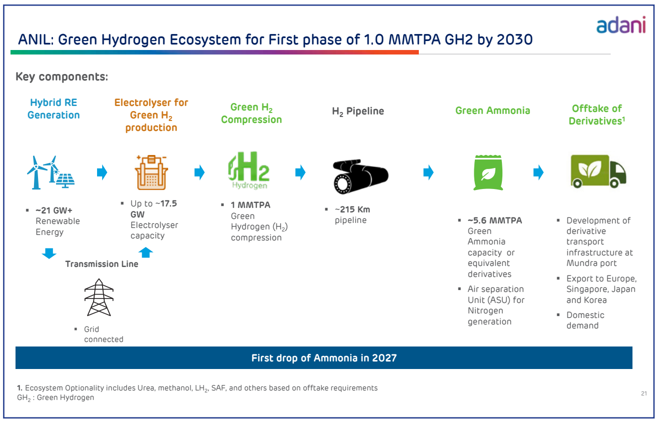
Pierroberto Folgiero, Maire Tecnimont Group, and Next Chem CEO said, "India is playing an increasingly strategic role in the green acceleration roadmap, which Maire Tecnimont Group has been implementing so far. Today we take another crucial step in the green economy arena partnering with a prominent and innovative player such as AEL. We firmly see green chemistry as the future chemistry, and we are perfectly equipped to be its technology-driven enabler worldwide, also thanks to the synergies within the group."

Jayant Parima, Advisor to Chairman, Adani Group stated, "Adani Group is at the forefront of India's energy transition, and green hydrogen is a natural extension of our globally leading renewable portfolio. Scaling up of the green hydrogen economy will require multiple use-cases, including green ammonia and green chemicals."

Adani Group has secured $2.6 billion to develop several green hydrogen and infrastructure projects in India, as part of their initiative in achieving 25 GW of renewable power generation by 2025.



In Gujarat, Adani Group is expanding green supply chains, including solar panels, green ammonia, hydrogen electrolyzers, and wind turbines, including the world's largest green energy plant, in the Khavda district of Kutch. Adani Group plans to invest $9 billion towards manufacturing and transportation infrastructure at its green hydrogen plant in Kutch, Gujarat. The move will help the project aim at a capacity of one million tons per annum of green hydrogen in its initial phase, produced through the electrolysis of water using renewable power sources.



Initially, the project will utilize alkaline electrolysers, with future plans to manufacture electrolysers based on anion exchange membrane technology. This initiative is expected to generate between 7,500 to 10,000 work opportunities and will be pivotal to Adani Group's strategic growth agenda. The plan includes deployment of specialised ships to export hydrogen to Europe and Asia.

Simultaneously, Adani Green Energy revealed plans to invest Rs 1.5 lakh crore to scale up capacity to 30 GW at the Khavda renewable energy project site over the next five years. Currently, operations have commenced for 2 GW of the planned 30 GW capacity, within a year of project initiation.

The conglomerate is committed to energy transition projects, with plans exceeding $100 billion (approx. Rs 835 crore) for manufacturing essential components for green energy generation. This includes establishing solar parks and wind farms for electricity production, alongside facilities for manufacturing electrolysers, wind power turbines, and solar panels.

Source: ETN News, Projects Today, Adani Website

Financing Green Hydrogen Projects

Financing green hydrogen and renewable energy projects requires a multi-pronged approach. Traditional methods remain important, but innovative solutions and supportive policies are crucial to unlock the full potential of clean energy investments. Along with the financing options of debt and equity, green financing facilities like Green Bonds and Sovereign Loans can be explored. Collaboration between public and private sectors is key to bridging the financing gaps and accelerating the transition to a sustainable future

Financing green hydrogen projects often requires innovative approaches due to their initial capital-intensive nature. This article examines various financing options, including public-private partnerships (PPPs), green bonds, and innovative financial instruments designed to bridge the investment gap and accelerate the growth of the green hydrogen sector.

PPPs

Establishing PPPs can mobilize private sector capital and expertise to finance green hydrogen projects. Governments can provide incentives such as tax breaks, subsidies, and regulatory support to attract private investment in green hydrogen infrastructure development.

Government Subsidies & Grants

Direct financial support from government agencies can significantly reduce the upfront costs of green hydrogen projects, making them more attractive to investors. Subsidies, grants, and incentives for research and development (R&D), pilot projects, and commercial-scale deployments can spur innovation and drive down production costs.

Low-cost Financing from Multilateral Agencies

Partnering with multilateral development banks such as the World Bank, Asian Development Bank (ADB), and the Green Climate Fund (GCF) can provide access to concessional loans and grants for green hydrogen initiatives.

Carbon Financing & Carbon Credit

Monetizing carbon credits generated from emissions reductions can provide an additional revenue stream for green hydrogen projects. Participating in carbon markets or implementing carbon pricing mechanisms can incentivize investments in low-carbon technologies, including green hydrogen production.

Special Purpose Vehicles (SPVs) & Green Bonds

Establishing Special Purpose Vehicles (SPVs) or issuing Green Bonds dedicated to financing green hydrogen projects can attract capital from institutional investors interested in sustainable investments. Green Bonds offer investors an opportunity to support environment-friendly projects while generating financial returns.

Export Credit Agencies (ECAs)

ECAs can provide financing and insurance solutions to support export of green hydrogen technologies and equipment. By mitigating political and commercial risks associated with international transactions, ECAs can facilitate cross-border investments in green hydrogen projects.

Venture Capital & Private Equity investments

Venture capital firms and private equity investors can provide early-stage funding for startups and innovative companies developing breakthrough technologies in the green hydrogen sector. These investments can catalyze innovation, scale up production, and drive down costs.

Innovative Financing Mechanisms

Exploring innovative financing mechanisms such as carbon finance, crowdfunding, and impact investments can broaden the investor base and attract capital from diverse sources. These mechanisms can align financial returns with environmental and social objectives, fostering sustainable development.

Role of the Banking Sector & Private Companies

Mobilizing green finance requires an extensive assessment of current capabilities and assets. This includes factors like available capital, the level of participation from both public and private sectors, and the evolving outlook of financial institutions. The contributions in the financial sector from the public and private institutions in shaping a broader green financing landscape are briefed below:

Banking Sector: The Reserve Bank of India (RBI) has issued Green Bonds to promote green finance within the country along the lines of countries like the United States and China. These bonds are issued and regulated by the Securities and Exchange Board of India (SEBI) specifically for sustainable projects and assets.

In recognition of the booming green energy sector, India's banking sector has strategically positioned itself to capitalize on this growth. They have devised various "green financing" schemes to attract investors. These initiatives have resulted in the rise of loans and credits to support the purchase of green energy products.

Banking institutions act as the lifeline of the green energy ecosystem, channeling financial resources between green energy companies, investors, and consumers. Their involvement is essential for a flourishing green energy market, as they act as the critical bridge that connects all stakeholders.

Private Sector Companies: The private sector is positioned as a game-changer for unlocking a sustainable economy, generating undeniable excitement about the future. However, while renewable energy resources are abundant, their full potential remains hampered by limitations in infrastructure and technology. Recognizing the enormous potential of the green energy sector, investors are directing their resources into green industries.

Latest Developments in Financing

Investors have acknowledged the potential of the green energy sector and are investing in green industries.

Government: The central government has announced plans to collect INR 20,000 crore through the issuance of 'Sovereign Green Bonds' in the second half of the financial year 2024-25, as per a Sept 2024 press release.

World Bank: In June 2024, the World Bank's Board of Executive Directors approved $1.5 billion in financing for a second operation to help India accelerate the development of low-carbon energy. The operation will seek to promote the development of a vibrant market for green hydrogen, continue to scale up renewable energy, and stimulate finance for low-carbon energy investments.

> India is the fastest-growing large economy in the world, and the economy is expected to continue to expand at a rapid pace. Decoupling economic growth from emissions growth will require scaling up renewable energy, especially in hard-to-abate industrial sectors. This, in turn, will require an expansion of green hydrogen production and consumption as well as a faster development of climate finance to boost the mobilization of finance for low-carbon investments.

The **Second Low-Carbon Energy Programmatic Development Policy Operation** – the second in a series of two operations similar in size – will support reforms to boost the production of green hydrogen and electrolyzers, critical technology needed for green hydrogen production. The operation also supports reforms to boost renewable energy penetration, for instance, by incentivizing battery energy storage solutions and amending the Indian Electricity Grid Code to improve renewable energy integration into the grid.

In June 2023, the World Bank approved the $1.5 billion First Low-Carbon Energy Programmatic Development Policy Operation, which supported the waiver of transmission charges for renewable energy in green hydrogen projects, the issuance of a clear path to launch 50 GW of renewable energy tenders annually, and creating a legal framework for a national carbon credit market.

"The World Bank is pleased to continue supporting India's low-carbon development strategy, which will help achieve the country's net-zero target while creating clean energy jobs in the private sector," said **Auguste Tano Kouame, World Bank Country Director for India**. "*Indeed, both the first and second operations have a strong focus on boosting private investment in green hydrogen and renewable energy."*

The reforms supported by the operation are expected to result in the production of at least 450,000 metric tons of green hydrogen and 1,500 MW of electrolyzers per year from FY25/26 onwards. In addition, it will also significantly help to increase renewable energy capacity and support reductions in emissions by 50 million tons per year. The operation will also support steps to further develop a national carbon credit market.

"India has taken bold action to develop a domestic market for green hydrogen, underpinned by rapidly expanding renewable energy capacity. The first tenders under the National Green Hydrogen Mission's incentive scheme have demonstrated significant private sector interest," **said Aurélien Kruse, Xiaodong Wang, and Surbhi Goyal, Team Leaders for the operation**. "*The operation is helping in scaling up investments in green hydrogen and in renewable energy infrastructure. This will contribute towards India's journey for achieving its Nationally Determined Contributions targets."*

This operation is aligned with the Government of India's energy security plans, and with the World Bank's Hydrogen for Development (H4D) Partnership.

The financing for the operation includes a $1.46 billion loan from the International Bank for Reconstruction and Development (IBRD) and a $31.5 million credit from the International Development Association (IDA).

IREDA: Indian Renewable Energy Development Agency Ltd. (IREDA) signed a Memorandum of Understanding (MoU)[1] with Indian Overseas Bank (IOB) at IREDA's Business Centre in New Delhi in January 2024, with a view to collaborate towards co-lending and loan syndication for multiple continuums of renewable energy projects across the nation. The partnership aims to rationalize loan syndication and underwriting processes, management of Trust and Retention Account (TRA) for IREDA borrowers, and work towards offering stable interest rates over a 3-4-year period.

IREDA and Punjab National Bank (PNB) also signed an MoU[2] in February 2024 to provide joint support for co-lending and loan consortiums for the development of renewable energy projects.

Asian Development Bank (ADB): ADB approved a $250 million policy-based loan[3] in November 2023 for India to modernize its power grid and scale up renewable energy projects.

ReNew: ReNew Energy Global Plc (ReNew) (Nasdaq: RNW, RNWWW), India's leading renewable energy company and a preferred decarbonization partner, signed an MoU[4] with ADB to collaborate on climate change mitigation and adaptation projects. The MoU covers projects with an investment value of more than $5.3 billion between 2023 and 2028.

The MoU was signed at COP28, Dubai in December 2023 by ReNew's Founder, Chairman & CEO, Sumant Sinha and Suzanne Gaboury, Director General, Private Sector Operations Department, ADB. The MoU identified potential investments in renewable energy projects, manufacturing, carbon offset projects, and green hydrogen, with the aim of jointly supporting sustainable energy transition.

[1] https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1997167
[2] https://pib.gov.in/PressReleasePage.aspx?PRID=2007058
[3] https://www.adb.org/news/adb-support-power-sector-reforms-india
[4] https://www.thehindubusinessline.com/companies/renew-signs-mou-with-asian-development-bank-for-53-billion/article67604346.ece#:~:text=The%20MoU%20covers%20projects%20with,the%20NASDAQ-listed%20company%20said.

The MoU, a first of its kind in the Indian renewable energy sector, is expected to draw interest from additional international investors to participate in financing long-term debt for significant renewable energy infrastructure projects. In addition, it will help ADB achieve its funding ambition of $100 billion in green energy projects by 2030.

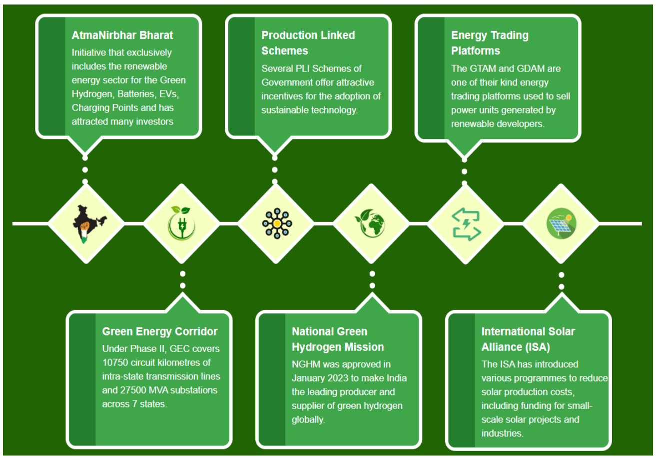
Sumant Sinha, ReNew, said: "Today's agreement marks an exciting time for ReNew. Significant financing is needed to reach global climate targets and this agreement helps secure the capital needed. We look forward to collaborating with ADB over the coming years to meet India's target of achieving 500 GW of renewable capacity by 2030."

Suzanne Gaboury, ADB, said: "This collaboration between ADB and ReNew envisages the continued cooperation of both organizations over the next five years, by providing a framework for working together towards shared goals and to deliver on the results envisioned in combating climate change."

With a portfolio of almost 14 GW of clean energy capacity, ReNew is among the top 10 clean energy companies globally, excluding China. The company has already invested around $8 billion in the clean energy space and the MoU will enable ReNew to raise further funding for renewable energy projects.

Others:

- REC Limited under the Ministry of Power, along with a leading Non-Banking Financial Company (NBFC), has signed an MoU to formulate funding solutions for renewable energy projects with the National Investment and Infrastructure Fund Limited (NIIFL) in January 2024.



- ACME struck a $7 billion deal with the Karnataka government to develop an integrated Solar-to-Green Hydrogen-to-Green Ammonia facility.
- TotalEnergies has partnered with Adani New Industries, pledging a staggering $50 billion investment for the next decade to produce green hydrogen.

Conclusion

Green hydrogen/derivatives projects are capital intensive projects, and to fulfil the capital requirements of these projects, an economical and competitive financing package will help the industry in competing with the rest of the world.

Source:

Report on India's Green Hydrogen Revolution – An Ambitious Approach, May 2024 by Ernst & Young LLP (EY) and Ministry of New and Renewable Energy (MNRE), Government of India

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Editorial... contd from pg 1

An innovative GH2THON Hackathon, thought-provoking quiz, poster competition, and an engaging youth session were other interesting elements of the event, with Nandlal Gupta from IIT Bombay proclaimed as the Hackathon winner.

Another key feature was "The Hydrogen Challenge: Test Your Elemental Knowledge," an engaging quiz moderated by Deepak Taneja, Deputy General Manager at Indian Oil; Nandlal Gupta and Chandramani Rai from IIT Bombay emerged as winners.

Winners of the poster competition, showcasing outstanding research in the Green Hydrogen field, included Kapil Kedar Tirpude and Trashna Thakur from IIT Bombay.

technical, financial, and policy aspects of Green Hydrogen – optimization and indigenization of electrolysis processes, storage and transportation solutions, applications in the defence sector, and the integration of biomass pathways.

They also discussed the future of hydrogen-based fuels for the transport sector, the seamless integration for shipping and aviation, and the viability of Green Hydrogen for steel production and oil refineries.

MNRE and the Office of the Principal Scientific Adviser to the Government of India, in association with the MoPNG, the Department of Science and Technology (DST), and the Department of Scientific and Industrial Research (DSIR), organised the 2nd International Conference of Green Hydrogen 2024 (ICGH2024). The Solar Energy Corporation of India (SECI) and EY were the implementation and knowledge partners, respectively. FICCI was the industry partner. The US was the official partner country in this second edition of ICGH.

As we at Cogeneration Association of India continue to bring you updates in the Green Hydrogen space, we look forward to your feedback to make this newsletter more useful to our readers, and hope all stakeholders will join us as members to take this "Green Revolution" forward.

Enhancing the Viability & Cost-Effectiveness of Green Hydrogen for Refineries

The transition to a low-carbon economy necessitates the adoption of sustainable energy sources. Green hydrogen, produced using renewable energy, offers a promising alternative to fossil fuels. However, the high cost of green hydrogen production and the unique requirements of refineries present significant challenges. The global green hydrogen market is projected to reach $89.18 billion by 2030, growing at a CAGR of 54.7% from 2021 to 2030" (Allied Market Research, 2021). As major consumers of hydrogen, refineries play a crucial role in this transition. However, refineries have specific requirements regarding hydrogen purity, supply reliability, and integration with existing infrastructure. This article explores strategies to enhance the viability and cost-effectiveness of green hydrogen procurement/production by the refining industry.

Issues Faced by Refineries

Land acquisition for green hydrogen plants can be a significant challenge. Refineries often face limitations in terms of available land within their existing premises to accommodate large-scale projects. Obtaining land and right-of-way (RoW) approvals can be a time-consuming process involving multiple government agencies and stakeholders.

The cost of acquiring land and negotiating RoW agreements can be substantial, especially in urban or industrial areas. Additionally, land acquisition and development can raise environmental concerns, such as impacts on biodiversity and local communities. Addressing land constraints for green hydrogen plants requires innovative solutions.

Refineries can strategically acquire land in advance or explore joint ventures with land developers. Off-site development in industrial parks or green hydrogen hubs can provide access to land and infrastructure. Innovative land-use strategies, such as vertical integration and floating solar plants, can maximize available space. Streamlining regulatory processes, including single-window clearance and simplified procedures, can expedite land and RoW approvals. Engaging with local communities through transparent communication and sustainable development practices is essential. Government incentives, such as land subsidies, tax benefits, and public-private partnerships, can further support green hydrogen development and mitigate risks associated with land acquisition.

Renewable Energy Power Infrastructure

Green hydrogen producers can either have their own renewable energy power plant, or should be able to buy renewable energy power under a power purchase agreement (PPA) to meet the power requirement for a green hydrogen plant, or use a mix of both options. Renewable energy power infrastructure, including the Indian power grid, plays a key role in the green hydrogen transition. India's power grid is among the largest in the world. The interconnection of its five regional grids into a unified national network ensures a smooth flow of electricity across the country. As of August 2024, India's renewable energy capacity was 199.52 GW. India's ambitious goal is to increase this to 500 GW by 2030 and potentially 1 TW by 2035.

Table 1: India's current renewable energy capacity

Renewable Energy Source	Current Capacity (GW)
Solar	89.43
Wind	47.19
Hydro	51.98
Bioenergy	10.92
Total	**199.52**

The role of Central Transmission Units (CTU) and State Transmission Units (STUs) is crucial for integrating green hydrogen generation into the power grid. These entities face several challenges, including upgrading grid infrastructure to accommodate increased power flows, ensuring grid voltage stability, and addressing the intermittent nature of renewable energy sources. They must also guarantee that the power quality delivered to green hydrogen plants meets their specific requirements.

To facilitate a smooth transition to a hydrogen-based energy future, CTUs and STUs should prioritize investments in expanding and upgrading grid infrastructure. This includes building new transmission lines, substations, and implementing advanced grid control systems. Additionally, deploying energy storage systems and implementing advanced grid management tools can enhance grid flexibility and efficiency.

The green hydrogen policy provides incentives for green hydrogen projects completed by December 31, 2030, such

as waiving Interstate Transmission System (ISTS) tariffs for up to 25 years. It also accelerates the process of granting open access to renewable energy sources and allows for the banking of unused renewable energy for 30 days.

Water Availability

Producing 1 kg of green hydrogen requires approximately 9 liters of de-ionized water. To achieve 5 million tons of green hydrogen, we need 50 billion liters of deionized water or roughly 100 billion liters of fresh water. This strains already limited water resources, especially in water-scarce regions. Water quality impacts electrolysis efficiency and hydrogen purity. Contaminated water requires additional treatment, increasing costs.

Water shortages can be addressed by using advanced treatment and recycling methods, exploring alternative sources like salty or used water, managing water resources wisely, collaborating with other regions for water sharing, and creating clear water protection and sustainable use regulations. While desalination might help with water scarcity, It uses a lot of energy, which could hurt the environment if the energy comes from fossil fuels, can harm the environment with salty water waste, high energy use, land use, and cost. Besides cost, desalination plants require land to set up.

Table 2: Water consumption intensities by hydrogen production technology

Technology	Water Consumption (liter/kg hydrogen)
PEM Electrolysis	17.5
Alkaline Electrolysis	22.3
SMR-CCUS	32.2

Source: IRENA and Bluerisk (2023), *Water for hydrogen production report*

However, as per International Renewable Energy Agency (IRENA), green hydrogen is the most water-efficient of all clean hydrogen types. It is found that on average, proton exchange membrane (PEM) electrolysis has the lowest water consumption intensity at about 17.5 liters per kg of hydrogen (l/kg). Alkaline electrolysis follows PEM electrolysis, with a water consumption intensity of 22.3 l/kg. These may be compared with steam methane reforming–carbon capture, utilization and storage (SMR-CCUS), at 32.2 l/kg. Electrolysis efficiency directly impacts water consumption in green hydrogen production. For every 1% increase in efficiency, water withdrawal and consumption decrease by approximately 2%.

Electrolysers Manufacturing

Electrolysers are a crucial component of green hydrogen plants, making up 30-35% of their total cost. The Production-Linked Incentive (PLI) scheme offers incentives to electrolyser manufacturers in India, and aims to make electrolysers more efficient, using local materials. It has a total budget of Rs 4,440 crore for five years of incentives. With combined annual sales of up to 3 GW during the scheme period of five years, India can have an electrolyser installed capacity of 15 GW by 2030, which can cumulatively produce up to 2.62 MMTPA of green hydrogen by 2030, 52% of the national target of 5 MMTPA.

Operational Understanding

Green hydrogen can help address the problem of variable nature of solar power. Daytime hydrogen production can stabilize the grid and reduce costs. Combining high-capacity electrolysers with daytime operation can significantly reduce the cost of green hydrogen. This could eliminate the need for expensive storage solutions. To meet increased daytime demand, suppliers may need larger electrolysers, leading to economies of scale. Refineries need a consistent hydrogen supply. Traditionally, refineries managed their hydrogen generation unit O&M. If an external O&M agency is unavailable, ensuring safety and operational efficiency will require skilled personnel.

Agreement Period

To encourage companies to invest in green hydrogen, clear and consistent regulations are essential to instill confidence and mitigate risks. The Levelized Cost of Hydrogen (LCOH), a financial metric that evaluates the long-term economic viability of hydrogen production projects, is a key consideration. Long-term agreements, spanning up to 25 years, can help reduce LCOH by providing stable revenue streams and mitigating uncertainties related to energy prices, regulations, and market demand. Such agreements can create a favorable investment climate, attracting domestic and foreign investors, and potentially leading to increased competition and lower LCOH. While long-term agreements offer stability, they may also limit flexibility in adapting to changing market conditions or technological advancements. To address this, a balanced approach is necessary, combining long-term agreements with mechanisms like price adjustment clauses or renegotiation options to maintain adaptability.

Research & Development (R&D)

Technological advancements in green hydrogen are crucial for improving cost-effectiveness. Investing in R&D to improve the efficiency of electrolysers can significantly reduce energy consumption and lower the production cost of green hydrogen. There is a need to pursue the development of solid oxide electrolyser cell (SOEC) and anion exchange membrane (AEM) technologies, which stand out as the cutting-edge technologies of the future for green hydrogen production. Optimizing the integration of green hydrogen production with renewable energy sources like solar and wind power can further leverage their cost-effectiveness and reduce reliance on non-renewable resources. Developing advanced hydrogen storage solutions is essential to address the intermittent nature of renewable energy generation and ensure a reliable supply of green hydrogen for refineries.

Carbon Pricing & Green Hydrogen

Carbon credits, a market-based mechanism that rewards emissions reductions, can significantly boost the viability of green hydrogen for refineries. By offering financial incentives for refineries to adopt cleaner technologies like green hydrogen, carbon credits can help offset the initial investment costs. This makes green hydrogen a more attractive alternative to traditional fossil fuels. The Bureau of Energy Efficiency (BEE) is actively developing the Indian Carbon Credit Trading Scheme (CCTS). This scheme aims to reduce greenhouse gas emissions (GHG) in India by creating a market for carbon credits. The BEE has published the Detailed Procedure for Compliance Mechanism under the CCTS and the Accreditation Procedure and Eligibility Criteria for Accredited Carbon Verification Agencies. The Compliance Mechanism mandates obligated entities (refineries) to meet GHG emission intensity targets. This can accelerate the transition to a low-carbon economy and contribute to achieving ambitious climate goals.

International Policies

The Carbon Border Adjustment Mechanism (CBAM) and the Carbon Offset and Reduction Scheme for International Aviation (CORSIA) can indirectly influence the adoption of green hydrogen in the refinery sector. CBAM's carbon tax on imports, including aviation fuel, can incentivize airlines to seek more sustainable alternatives like green hydrogen-powered aircraft or green hydrogen-derived fuels. This growing demand for sustainable aviation fuels (SAF) can create a new market for green hydrogen. Additionally, CORSIA, which allows airlines to offset carbon emissions through carbon credits, can indirectly support green hydrogen projects if these credits are used to fund such initiatives. While CBAM and CORSIA primarily target aviation, their ripple effects can significantly impact the refining sector by creating new markets for green hydrogen and fostering a more sustainable fuel landscape.

Building a Robust Market for Green Hydrogen

Establishing a robust market for green hydrogen is crucial for its long-term viability. Facilitating demand aggregation among multiple refineries can create a larger market, enabling refineries to negotiate better terms with suppliers. Developing a market for green hydrogen derivatives, such as green ammonia or green fuels, can expand its applications and increase demand. Exploring the potential for refineries to earn carbon credits by using green hydrogen can provide an additional revenue stream and incentivize its adoption.

Conclusion

In conclusion, the successful integration of green hydrogen into refineries hinges on addressing several key challenges. By implementing strategies such as optimizing electrolyser technology, leveraging renewable energy sources, addressing land constraints, enhancing grid infrastructure, and ensuring water availability for producers, refineries can significantly improve the viability and cost-effectiveness of green hydrogen procurement. Additionally, government policies, international cooperation, and market development initiatives are crucial for creating a favorable environment for the adoption of green hydrogen. By addressing these challenges, refineries can play a pivotal role in accelerating the transition to a low-carbon economy and securing a sustainable energy future.

Disclaimer: The views expressed here are personal and do not represent the authors' official position or the views of CHT or MoPNG. For the references, please contact the authors.

Authors:

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R.C. Agarwal, Executive Director at CHT (MoPNG), is a seasoned professional with 35+ years in the oil and gas sector. He holds a unique blend of technical expertise (B.E. in Mechanical Engineering) and financial acumen (M.S. in Financial Management), and has a proven track record of leading major projects and is a strong proponent of energy transition initiatives within the oil and gas industry.

DST's Hydrogen & Fuel Cell Program in India

HFC-18

The Department of Science and Technology (DST), Ministry of Science and Technology, Government of India, initiated the development of a hydrogen and fuel cell (HFC) technology program in 2018, focusing on creating volumes and infrastructure, demonstrating niche applications, facilitating policy support, and establishing symbiotic international linkages. This has advanced HFC technologies through R&D and validation, aiming to make these technologies competitive in terms of cost and performance, while also reducing institutional and market barriers to commercialization – directly supporting Ministry of New and Renewable Energy's (MNRE) National Green Hydrogen Mission.

A total of 30 proposals under the Research and Technology Stream were approved for funding, with an approximate cost of Rs. 31 crore. These proposals focused on the development of new electrode materials, exchange membranes, and catalysts for hydrogen storage and fuel cell applications.

AHFC

Under HFC-18, DST also supported 11 projects with the cost of Rs. 28 crore under the Advanced HFC Program (AHFC) – the list will appear in the next issue. The objective of this program is to promote and support activities related to the indigenous development of new and existing materials in large quantities, including catalysts, membranes, components for fuel cells, electrolyzers, hydrogen storage materials, materials for Type IV cylinders, and prototypes for the implementation of various HFC applications in the country, which aligns with the R&D roadmap requirements of the National Green Hydrogen Mission and the Make in India initiative.

Indo-Danish Initiative

Under HFC-18, DST recently supported four projects under the Indo-Danish Research and Innovation Cooperation in the area of "Green Fuels, Including Green Hydrogen." These projects focus on green fuels for transport and industry, as well as solutions to convert electricity from renewable energy into products that can reduce emissions in sectors where cost-effective alternatives to fossil energy are not available. The target of the India-Denmark joint program is to enhance value creation through research and innovation for the development of new technologies, solutions, services, and business models.

Project Title	PI Details	Specific Area	Duration	Total Cost (in Rs.)
ZDHYDRO Development of an Integrated Zero Discharge Model for Sewage Sludge to Enhanced Hydrogen Production DST/INT-ETC/IGDF-2022/08	**Prof. M.M. Ghangrekar** Indian Institute of Technology Kharagpur	Hydrogen Production	3 years	9,656,702
PyroGreen – Pyrolysis for Green Fuels and Enabling Future Green Hydrogen DST/INT-ETC/IGDF-2022/09	**Mr. Suhas Dixit** APCHEMI Pvt. Ltd. Navi Mumbai **Dr. Mrutyunjay Suar** CEO, KIIT-Technology Business Incubator (KIIT-TBI), Odisha	Hydrogen Production	3 years	7,437,619
Towards Decarbonization of Cement Industry Model-based Optimization of a Pyrolysis Technology for Flexible Use of Waste Fuels DST/INT-ETC/IGDF-2022/12	**Dr. Varunkumar S.** Indian Institute of Technology Madras	Hydrogen Utilization	3 years	9,387,446
Efficient Cost-saving Grid-friendly (ECoGrif) Power-to-X (PtX) Converter DST/INT-ETC/IGDF-2022/18	**Prof. Krishna Vasudevan** IIT Madras	Hydrogen Production	3 years	15,345,172

Virtual Centers

Under HFC-18, a theme-based initiative was launched to support R&D across the entire spectrum of energy conservation and storage technologies, from early-stage research to technological breakthroughs in materials, systems, and scalable technologies, with the aim of maximizing resource use efficiency. The purpose of this initiative is to support recognized centers of energy materials research, encourage them to collaborate with new research groups working in complementary areas, and link these centers into a coordinated national network. This initiative aims to create a strengthened energy materials research community that covers the full breadth of energy research areas and is strongly linked both nationally and internationally. Under this initiative, two Energy Storage Platforms on Hydrogen are supported by DST, with a total cost of Rs. 18 crore.

DST-IIT Bombay Energy Storage Platform on Hydrogen[1]: DST has

[1] https://www.ese.iitb.ac.in/esphy/

supported the center with a total cost of Rs. 9.83 crore for five years. This platform has been established to conduct research on materials and systems, demonstrate prototypes, develop technology, incubate innovative ideas, facilitate industrial interactions, and promote collaborations, manpower development, and information dissemination in the field of hydrogen. The lead organization is IIT Bombay, with four partnering institutions: IIT Guwahati, IIT Kanpur, IIT Tirupati, and NIT Rourkela. The center aims to become a source of information and a nodal point where individuals and organizations in India working in the area of hydrogen can receive mentorship, materials, or other necessary support.

DST-NFTDC Energy Storage Platform on Hydrogen[2]: DST has supported a total cost of Rs. 8.56 crore to this center, which will be established at the Nonferrous Materials Technology Development Centre, Hyderabad, with a core theme of hydrogen-based materials for energy devices. The focus of this center will be on specific hydrogen-related systems. The network of researchers engaged in this center includes scientists from IISc Bangalore, IIT Madras, IIT Bhubaneswar, and Sri Chitra Thirunal College of Engineering, Thiruvananthapuram.

Some Technologies Developed & Commercialized under DST's HFC-18

PI name	Project	Description	Commercialization
Dr. Somenath Garai Banaras Hindu University, Varanasi	Cutting-Edge Quantum-Technology-Backed Green Hydrogen Production	Developed by: Benares Hindu University (BHU) Quantum-powered green hydrogen production technology with a photocatalyst system for efficient energy generation achieving a production rate of over 1 liter/min per 10 g of quantum photocatalysts.	Technology transfer: Aaparth Engineers Pvt. Ltd. Approved for implementation by Indian Navy Headquarters Foreign technology transfer: Quazer Investment Company, UAE
Prof. P. Muthukumar IIT Guwahati	Metal Hydride-Based Multi-Stage Hydrogen Purification System	Developed by: IIT Guwahati A system with a purification capacity of 6,000 to 10,000 liters per batch, delivering 99.999% purity using low grade thermal inputs in the range of 30-50°C.	Technology transfer: NTPC Financial grant: Rs. 20 lakh
Prof. P. Muthukumar IIT Guwahati	Metal Hydride-Based Multi-Stage Hydrogen Compression System	Developed by: IIT Guwahati & IIT Tirupati A pre-industrial-scale prototype for compressing hydrogen from 1-2 bar to 400-450 bar utilizing a temperature range of 20-95°C.	Technology transfer: NTPC Financial grant: Rs. 38 lakh
Dr. Pratibha Sharma (Lead PI & Institute) IIT Bombay	Metal Hydride-Based Hydrogen Storage System for Two-Wheelers	Developed by: IIT Bombay Developed a hydrogen storage system integrated with a PEM fuel cell, retrofitted on a two-wheeler for a 60-km test drive. Joint project recommended with BPCL and Godrej & Boyce for commercialization.	Technology transfer: Centre for High Technology, MoPNG Financial grant: Rs. 1.92 crore

HFC-2023

HFC-2023 was then launched under DST's Climate, Energy and Sustainable Technology (CEST), Division to identify leading solutions for sustainable hydrogen production, storage, and transportation, and to upgrade them to higher Technology Readiness Levels (TRLs) suitable for industrial-scale implementation and commercialization. The submission deadline was 30 January 2024.

The primary focus is on prioritizing the upgrade of lab-scale technologies, which are at TRL 3-4, to reach prototypes (TRL 5) and pilot plants (TRL 6) at the earliest possible timescale. The startups with appropriate technologies at the pre-commercialization stage were also eligible to apply for this call.

Identified Areas

The following areas were identified and project proposals invited for:

- Developing completely indigenous technologies pertinent to hydrogen production from water splitting, including but not limited to electrolysis, photo-electrochemical cells, and solar thermochemical systems at the scale mentioned below.
- Cost-effective green hydrogen production technologies belonging to TRL ≥ 4 for wide range adoption and utilization in India to enable resiliency of the power generation while aligning to the existing requirement of domestic industries and transportation sectors. Medium to large capacity electrolyzer (PEM water electrolyzer, alkaline water electrolyzer, solid oxide electrolyzer cell, and other versions of electrolyzers) prototypes capable of producing molecular hydrogen (H_2) at a rate of at least 5.0 liters per minute (5.0 LPM) or 300.0 liters per hour (300.0 LPH). The full balance of plant (BoP), including the components and the electrolyzer, should be indigenously developed.
- Active indigenous prototype models of photochemical units capable of producing H_2 at a rate of at least 22.50 g-H_2/m^2/day under 1.0 sun equivalent of irradiance (1.0 kW/m^2).
- Active indigenous prototype models of photo-electrochemical units capable of producing molecular

[2] https://dst.gov.in/sites/default/files/DST%20-%20NFTDC%20MECSP%20Centre%20Brochure%20v6%2811Feb2019%29%20%281%29.pdf; https://www.nftdc.res.in/mecsp/

hydrogen (H_2) at a rate of at least 5.0 LPM or 300.0 LPH (under 1.0 kW/m^2).

- Industrially viable hydrogen generation approaches from biomass. Showcasing the design of variable converters that can deploy the major variants of biomass available in India. The final prototype models should be capable of processing at least 50.0 kg/h of biomass and producing H_2 at a rate of at least 750 LPM.
- Designing new prototypes of methanol reformers capable of producing H_2 at a rate of at least 5.0 LPM or 300.0 LPH operating at ≥ 60% efficiency. This prototype should also contain appropriate CO_2 capture units to minimize the carbon footprint of the reformer unit.

Hydrogen Storage

Hydrogen storage is critical for enabling the hydrogen value chain. These are the focus areas required for proposals:

- Hydrogen storage system development, including compressed tanks (Type III and Type IV tanks with a capacity of 5 kg of hydrogen storage capacity at 350 or 700 bar resp.). All the development should be indigenous and should include variable components, such as temperature and pressure sensors, and safety vent arrangements.
- Materials-based indigenous hydrogen storage tanks developed to store 5.0 kg of hydrogen at 30.0-35.0 bar with materials synthesized indigenously and using raw materials available in the country. The cost of metal hydrides or material medium used should be Rs. 3000-5000/kg and all developments should be indigenous.
- Prototypes or pilots for material-based hydrogen storage tanks for hydrogen purification, thermal energy storage, heating or cooling applications for mobility applications.
- Conversion of hydrogen to liquid organic hydrogen carrier (LOHC) molecules and the subsequent conversion of LOHC to hydrogen should be established. Energy-efficient and cost-effective hydrogen to appropriate hydrogen-rich organics transformation technology. The LOHC solutions should showcase long-term storage potential along with the possibility of long-distance transportation using the established transport logistics. Here, the new technologies should be capable of converting (i) 300.0 liters of hydrogen per hour to the appropriate organic chemicals, (ii) < 11 kWh/kg-H_2 energy requirement for dehydrogenation from LOHC, and (iii) cyclability of LOHC > 1500 cycles with < 5% loss of H_2 storage capacity.

Other Requirements

Involvement of industries: It is envisaged that the end product of development will be transferred to industries for commercial production. Hence, it is desirable that the industry be associated with the project right from the beginning with defined participation in technical terms.

As far as possible the proposed prototype/device should have sufficient users in the country and there should be adequate demand for the product.

Project duration: The projects should be time-bound normally for the duration of 2-3 years depending upon the prototype/device to be developed.

Funding available: Rs. 5 crore maximum

Status

A total of 196 proposals were received, with 95 evaluated for final selection and recommendation by a DST-constituted Expert Panel Committee (EPC). The EPC-recommended proposals (around 10-15) are currently under consideration and will be announced by October 2024.

HVICs

DST's latest endeavor is the establishment of Hydrogen Valley Innovation Clusters (HVIC), a unique initiative in the country designed to showcase a seamless integration of hydrogen technology across the value chain. Each cluster will be located at distinctive geographical locations of the country and aim to produce up to 2 tons per day, or 500 tons per annum, of green hydrogen, with DST financial assistance of up to Rs. 50 crore per cluster over five years and each cluster will be required to have a post DST financial support sustenance plan. The produced green hydrogen will be utilized in the transport (marine, road), steel, fine chemical sectors, etc. Funding for four upcoming green hydrogen valley projects in India has been approved (*refer Vol 1 Issue 3 of this newsletter for details*).

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National Green Hydrogen Mission Initiatives: An Update

The Government of India organized an International Conference on Green Hydrogen (ICGH-2024) on 11-13 September 2024 at Bharat Mandapam, New Delhi, to discuss the recent advances and upcoming technologies across the entire Green Hydrogen value chain. Apart from domain-specific interaction on hydrogen production, storage, distribution and downstream applications, the conference also discussed green financing options, human resource upskilling, and start-up initiatives in this area.

https://icgh.in/

Green Hydrogen Certification Scheme of India

The Ministry of New and Renewable Energy (MNRE), through OM No. 353/35/2022-NT dated 18 August 2023, defined Green Hydrogen standards, establishing specific criteria for its production. The definition incorporated a threshold for greenhouse gas (GHG) emissions (non-biogenic) at 2 kg CO_2eq/kg H_2 for system boundaries as defined. The threshold will be measured as an average over the previous 12 months.

The Ministry also envisaged to develop detailed methodology for the measurement, monitoring, reporting, onsite verification, and certification of Green Hydrogen and its derivatives. It has designated the Bureau of Energy Efficiency (BEE) as the nodal authority responsible for accrediting agencies for the monitoring, verification, and certification of Green Hydrogen projects. For this, MNRE has specified a certification scheme[1] under the National Green Hydrogen Mission (NGHM), called Green Hydrogen Certification Scheme of India (GHCI). One of the main objectives is to outline the governance structure of the certification scheme, and further define roles and responsibilities for various stakeholders involved in the certification process.

The draft scheme for Stakeholder Consultation was issued on 4 September 2024 with comments invited until 27 September 2024.

Testing Facilities

On 4 July 2024, the President of India sanctioned the scheme[2] on "Funding of testing facilities, infrastructure, and institutional support for development of standards and regulatory framework" under NGHM, for implementation during the period 2024-26 at a total cost of Rs. 200 crores.

The main objectives being:

i. To identify the gaps in the existing testing facilities for components, technologies and processes being used in the value chain of Green Hydrogen and its derivatives.

ii. To create new testing facilities/infrastructure to test, validate and certify technologies and processes in the value chain of Green Hydrogen and its derivatives.

iii. To upgrade existing testing facilities available with different testing agencies.

iv. To ensure safe and secure operations of equipment/ instruments used in the Green Hydrogen value chain.

v. To encourage participation from private as well as government entities for establishment of world-class testing facilities in India.

The scheme guidelines emphasize a robust quality and testing ecosystem, commensurate with the specified standards/guidelines in the Green Hydrogen sector. The National Institute of Solar Energy (NISE) will be the Scheme Implementation Agency (SIA).

For further details, refer MNRE's portal (www.nghm.mnre.gov.in)

[1] https://cdnbbsr.s3waas.gov.in/s3716e1b8c6cd17b771da77391355749f3/uploads/2024/09/20240906752526163.pdf
[2] https://cdnbbsr.s3waas.gov.in/s3716e1b8c6cd17b771da77391355749f3/uploads/2024/07/202407042082639305.pdf

Sugar Industry and Green Hydrogen... contd from pg 5

decarbonization of hard-to-abate sectors such as aviation and certain industrial processes, could potentially benefit from green hydrogen as a clean energy source.

Conclusion

Development of techno-economic processes for production of green hydrogen is part of global efforts for reduction of GHG emissions, thus, addressing issues related to global warming and climate change facilitating transition towards a more sustainable and low-carbon energy system. Challenges in production of green hydrogen, particularly with respect to production techniques, cost and competitiveness need to be addressed to maximize its potential and ensuring its role in a sustainable and low-carbon future. Sugar industry has a role to play in producing this future fuel at an affordable cost, with the production of clean and renewable power and biogas.

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Powering the Future: Energy Leap's Trailblazers in Clean Hydrogen Innovation

Energy Leap is proud to introduce three more ground-breaking start-ups from our inaugural cohort. These companies are pushing the boundaries of clean hydrogen technology, offering innovative solutions across various sectors of the hydrogen value chain.

Ossus Bio-Renewables: Transforming Industrial Effluent Waste into Clean Hydrogen

Based in Bengaluru, Karnataka, Ossus Bio-Renewables is revolutionizing the way we think about clean hydrogen production. Founded by Dr. Suruchi Rao and her team, this innovative start-up has developed a technology to extract clean hydrogen from industrial effluents.

The Energy Leap team with Ossus co-founder Kamar Suhail

Ossus offers a sustainable, on-site clean hydrogen generation solution for heavy industries such as metals, petroleum, and chemical/fertilizer production. This approach not only addresses the growing demand for clean hydrogen, but also helps industries manage their waste more effectively.

The company has already made significant strides, executing several clean hydrogen production pilot projects with large steel makers and oil companies. With plans to scale up its clean hydrogen production capacities, Ossus is poised to make a substantial impact on the industrial sector's transition to cleaner energy sources.

www.ossusbio.com

Grassroots Energy: Pioneering Bioenergy Solutions

Headquartered in Bengaluru as well, Grassroots Energy is a bioenergy start-up co-founded by Mateen Abdul, Firas Ahmad, and Dr. Shyamali Sarma. The company offers reliable and cost-effective clean fuels, including biogas, biomethane, bio-hydrogen, and carbon capture solutions.

Grassroots Energy, in partnership with IIT-Hyderabad, is developing a disruptive, modular clean hydrogen generation system that uses fermentation from diverse organic residues. Their bi-phasic hydrogen generation solution consumes 70% less energy and water compared to conventional methods,

Grassroots-IITH team with Energy Leap team

making it a highly efficient and sustainable option.

With an ambitious goal to produce hydrogen at US$1/kg by 2028, Grassroots Energy is working towards making clean hydrogen economically viable on a large scale. Their circular economy hydrogen model generates zero residue from operations, offering applications in thermal processes, mobility, gas grids, and distributed power.

www.grassrootsenergy.com

Hycell Engage: Global Expertise in Fuel Cell Technology

Hycell Engage, founded by Venu Varma and based in Hyderabad, brings global fuel cell expertise to the Indian market. Incorporated in India after six years of global R&D and significant investments, Hycell Engage has developed a fully functional Proton Exchange Membrane (PEM) fuel cell suitable for various heavy and long distance mobility and stationary applications.

The company's standard high capacity fuel cells have been successfully tested by several European companies and institutions, including Volkswagen Group, the Government of Barcelona, and universities in Chemnitz and Dresden. Hycell Engage's unique selling proposition lies in its ability to significantly reduce fuel cell costs – by up to 10 times, representing a major disruption in the industry.

Hycell Engage boasts not only cost reduction, but also

Hycell team

contd on pg 23

Strategic Pathways for Green Hydrogen Project Developers: Navigating Export/Domestic Markets & Building Competitive Capabilities

As green hydrogen emerges as a critical lever for decarbonization of hard-to-abate sectors, project developers must assess markets, develop strategic capabilities, and evaluate project economics before investing in such projects.

Export markets: Key geographies

Green hydrogen is gaining prominence as an energy carrier that can be transported in liquefied form, creating new export opportunities. The European Union (EU) and Japan, with their substantial import needs and aggressive production targets, represent attractive markets for hydrogen exporters. The US also offers significant opportunities, largely because of substantial domestic subsidies provided under the Inflation Reduction Act.

Japan, although a smaller market compared to the EU and the US, presents a promising opportunity, supplemented by US$20 billion incentives.

Successfully navigating these markets will require project developers to identify target geographies and sectors, and develop supply capabilities leveraging strategic advantages to effectively address competitive pressures and capitalize on export opportunities.

Country/ Region	Total demand for hydrogen (MTPA) (2023)	Low-carbon hydrogen production goals (MTPA) (2030)	Operational & planning stage projects[1] (MTPA)	Subsidy ($/kg)	Export opportunity	Remarks
EU	8.4	20[2]	1.3 / 36	0.5[4]	Green	• 10 MTPA import target • Competition from North America, MENA & South American producers - potential export opportunities from other geographies
US	12.5	10.0	0.9 / 14.8	3.0[3]	Red	• Significant low-carbon hydrogen production subsidy
Japan	2.1	3.0	0.0003 / 0.1	$20Bn (CfD)	Yellow	• Production and import subsidies, competition from other regional suppliers
India (For comparison)	6.9	5.0	0.002 / 7.2	0.4		

Operational/FID projects; Planned project

Source: BNEF| S&P | Oxford Energy | Government websites| IEA database |Xynteo analysis | ushydrogenstudy.org
1.As of Dec 31, 2023 (IEA database- includes green hydrogen blue hydrogen, hydrogen derivatives)| 2. EU targets 10MT domestic and 10MT import opportunities |3. The Inflation Reduction Act (IRA) includes a Clean Hydrogen Production Tax Credit that provides up to $3.00 per kilogram of hydrogen produced, depending on the carbon intensity of the production process. This credit is available for 10 years|4. Data from $772m hydrogen bank auction where subsidies up to $0.5/kg were determined | MENA- Middle East North Africa| CfD-contracts for difference | FID- Financial Investment Decision | MTPA: Million Tonne per Annuum

For example, the EU aims to produce 20 million tons per annum (MTPA) and import 10 MTPA of low-carbon hydrogen by 2030, presenting a significant opportunity for project developers.

Although the US market is promising, it is highly competitive

India markets: Focus sectors

In India, the primary focus for green hydrogen producers should be on high-demand sectors such as fertilizers and refineries, which currently constitute bulk of the hydrogen demand.

Large scale hydrogen end-use sectors	Total hydrogen demand 2023 & 2030 (MT) (2023 / 2030)	Likely mode of procurement	Green H2 market serviceability	Remarks
Fertiliser	3.3 / 4.2	Public Tender	Green	• Heavily subsidised sector- could **absorb green premiums** • **Long-term off-take contracts** for green ammonia from SECI under bidding
Refinery	3.0 / 4.9	BOO/Owned (Co-located)	Yellow	• Some of the refiners are building **in-house green hydrogen generation** capabilities • **Limited ability to absorb green premium** due to competitive end-product markets
Steel	0.4 / 0.7	BOO/Owned (Co-located)	Yellow	• Major steel companies have **affiliate firms developing green hydrogen generation** capabilities

Source: Niti Aayog, Xynteo Analysis| GH2- green hydrogen | SECI: Solar Energy Corporation of India Ltd.|
1. Operators could choose to deploy hydrogen generation plant on Build-own-operate transfer mode, providing project developers business opportunities with these

The fertilizer sector, which consumes 3.3 MMTPA of hydrogen, is particularly promising due to substantial government subsidies, and the ability to absorb green premiums associated with green ammonia. It is notable that Solar Energy Corporation of India Limited (SECI) is aggregating demand from various fertilizer companies to procure over 700,000 tons of green ammonia.

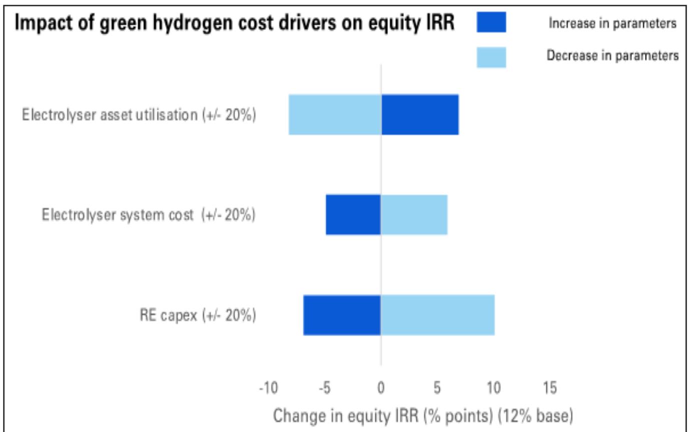
Refineries are also a viable market where green hydrogen production could be integrated through third-party ownership or direct investments by the refineries themselves. In the steel industry, leading companies are developing green hydrogen capabilities in-house or through affiliated firms, potentially limiting opportunities for external green hydrogen project developers.

Nevertheless, third-party project developers can explore opportunities through Build-Own-Operate (BOO) models to establish green hydrogen projects with customers from fertilizer, oil refining, and steel sectors.

Developing capabilities for green hydrogen production & supply

Economic viability of green hydrogen production depends on several key factors, such as the cost of renewable power and electrolyser systems, and asset utilization rates. To produce green hydrogen at competitive prices, project developers need to build capabilities that optimize these elements. This can be achieved by deploying renewable power assets in regions with high solar and wind potential, utilizing hydropower assets, adopting innovative electrolyser technologies with long life and high efficiency, leveraging available incentives and subsidies, and securing low-cost capital.

We found in our detailed techno-commercial studies that the following parameters influence the economic viability of green hydrogen projects the developer deploys a captive renewable power asset:



Base case assumptions: Electrolyser system cost $800/kW; Electrolyser capacity: 100 MW, Electrolyser efficiency: 67%; Asset utilization: 60%; Renewable energy capex: $2.5Mn/MW; Leverage: 80%; Interest rate: 9%; Base IRR – 12% (equity)

- **Renewable energy capex reduction:** Reducing the capital expenditure for renewable energy infrastructure has the most significant impact on financial performance. For example, a 20% reduction in renewable energy capex could result in a substantial increase of 10 percentage points in the project's internal rate of return (IRR), making the investment far more attractive.
- **Electrolyser asset utilization:** Improving the utilization rate of electrolyser assets also notably enhances returns. A 20% increase in utilization can raise the equity IRR by approximately 7 percentage points, highlighting the importance of maximizing asset use to achieve better financial outcomes.
- **Electrolyser system cost reduction:** Decreasing the cost of electrolyser systems directly affects profitability. A 20% reduction in electrolyser system costs can increase the equity IRR by around 6 percentage points, demonstrating that cost efficiency in electrolyser technology is a critical factor for improving overall project viability.
- **Operational capability development:** Further, strategic partnerships could enhance a project developer's capability to operate green hydrogen projects. To expand green hydrogen offerings, project developers could evaluate partnerships with industrial gas suppliers. These suppliers serve industries such as glass, chemicals, pharmaceuticals, etc., which use hydrogen in smaller quantities, through centralized hydrogen production plants, and distribute hydrogen via established supply networks. Collaborating with these suppliers could help green hydrogen project developers to leverage existing gas suppliers' distribution channels, and develop gas handling capabilities.

Moving forward

In conclusion, to thrive in the growing green hydrogen market, project developers should strategically target high-potential export markets like the EU and Japan, while focusing domestically on sectors such as fertilizers and refineries. Success will depend on optimizing input costs, maximizing asset utilization, and forming strategic partnerships to enhance market reach and capabilities. By leveraging these strategies, developers can capitalize on both export and domestic opportunities, and drive progress in the green hydrogen sector.

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For more information about Energy Leap, visit: www.xynteo.com/our-universes/energy-leap

Green Hydrogen: Leading the Charge on Future Renewable Fuels

Hydrogen has emerged as a potential key player in the energy transition, garnering increased attention in recent months. While the primary goal is to rapidly reduce greenhouse gas emissions, it is now clear that the transition away from fossil fuels is more complex than envisaged.

However, renewable energy growth over the past couple of decades, particularly in India, has enabled more aggressive actions towards sustainability. India ranks 4th and 5th globally in wind and solar capacity, respectively, with new policies supporting further expansion. The economic viability of these sources has significantly reduced electricity production costs, and this affordability opens up opportunities to leverage renewable energy in innovative ways, including the production of hydrogen through electrolysis. Hydrogen's potential applications are vast, particularly in hard-to-abate and hard-to-electrify sectors, offering promising solutions for decarbonization efforts.

The Global 'Mission Innovation'

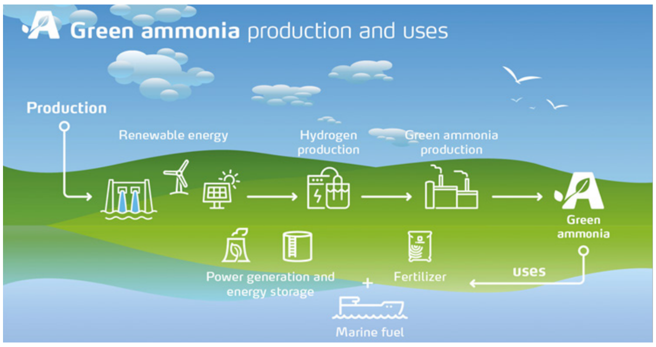
Countries worldwide are developing 'hydrogen ladders' to identify optimal applications and assess hydrogen's viability across sectors. Mission Innovation[1], a global initiative comprising 23 countries, aims to make clean energy accessible and advance the Paris Agreement's goals. Its Clean Hydrogen Mission targets reducing hydrogen costs to USD2/kg by 2030 through advancements in production, handling, transportation, and storage. India's National Hydrogen Mission aspires to make the country a global hub for green hydrogen production, usage, and export. As India pursues its goal through this mission, addressing storage and transportation challenges without compromising economic feasibility is crucial. Research at the Energy Consortium by IIT Madras (IITM) is exploring these aspects to support the mission's broader objectives.

Win-win Benefits

Hydrogen boasts the highest calorific value among fuels, but suffers from poor volumetric energy density due to its gaseous nature. Liquefaction, requiring high pressures (>13.1 atm) and low temperatures (<33 K), is necessary to improve this density. However, storage and transportation under these conditions are challenging and expensive.

Hydrogen carriers offer an alternative. Promising options include methane (25 wt% H_2), ammonia (17.6 wt% H_2),

[1] https://mission-innovation.net/



Source: https://www.weforum.org/agenda/2021/01/green-ammonia-stop-fossil-fuels/

and metal hydrides (<12.5 wt% H_2). Green ammonia, produced through electrochemical nitrogen reduction, is particularly promising due to its high hydrogen content, ease of liquefaction (240 K at atmospheric pressure), and existing global infrastructure.

Our research faculty at IIT Madras (IITM) are contributing to the national green hydrogen mission in multiple ways. We have ambitions to set up a Hydrogen Resource Hub at our Discovery campus. These efforts are already underway and will see us establishing the capability to evaluate a typical hydrogen application by mimicking the entire value chain on a pilot scale. We are planning to study green hydrogen production with transportation as one sector in mind, and are collaborating with Hyundai for this initiative. There are other numerous active research activities exploring the use of sea water electrolysis, solid oxide electrolyzer cells as well as hydrogen as a fuel, at IITM.

Susstains Engineering, an IITM-incubated startup, recently won ArcelorMittal's XCarb®[2] challenge for their unique approach that proposes biochar as an alternate to coal used in blast furnaces for steel making. XCarb® is designed to bring together all of ArcelorMittal's reduced, low and zero-carbon products and steelmaking activities, as well as wider initiatives and green innovation projects, into a single effort focused on achieving demonstrable progress towards carbon neutral steel. Alongside the new XCarb® brand, ArcelorMittal has launched three XCarb® initiatives: the XCarb® innovation fund, XCarb® green steel certificates, and XCarb® recycled and renewably produced, for products made via the Electric Arc Furnace route using scrap.

[2] https://corporate.arcelormittal.com/climate-action/xcarb

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Clean Hydrogen Alternative for Phasing Out Diesel Generators

Today, India faces the challenge of balancing its growing energy demand with the transition towards sustainability, especially with reference to its commitments towards decarbonization and increasing the use of renewable sources.

India's evolving energy landscape: Push towards Net Zero

India's energy landscape is complex and constantly evolving, marked by a strong push towards sustainability while managing the needs of a growing economy. India also faces challenges related to energy security, given its dependence on imported fossil fuels. The country is working to diversify its energy supply and increase domestic production, but despite progress, access to energy remains a challenge. Addressing India's energy needs involves ensuring a reliable, affordable, and sustainable energy supply while balancing environmental concerns with economic growth.

Hydrogen is the answer to India's growing hunger for clean energy

We believe that hydrogen is one of the most promising technologies that will help the country chart a path towards decarbonization, besides potentially generating economic opportunities. According to NITI Aayog, the hydrogen industry in India could generate over US$150 billion in revenue and create approximately 1.5 million jobs by 2050. The report also suggests that hydrogen could meet a significant portion of India's total energy needs by 2050, reducing the country's dependence on imported fossil fuels.

However, one of the challenges with renewable energy sources such as solar and wind, is their intermittent nature. During periods of excess renewable energy generation, clean hydrogen can be produced and stored for later use. This stored clean hydrogen can then be converted back to electricity using hydrogen fuel cell electricity generators, providing a reliable backup power source and enhancing grid stability. The Ministry of New and Renewable Energy (MNRE) in India also highlights the importance of hydrogen storage to help manage the variability of renewable energy.

According to India's National Clean Air Programme, 18% of city pollution is contributed by diesel generators (DGs). In fact, the Commission for Air Quality Management has banned the use of DGs for the industrial and commercial sectors in the National Capital Region.

Hydrovert's hydrogen fuel cell electricity generators

Hydrovert is addressing the need for hydrogen-based stationary power generators. Its generators are being developed to ensure reliable energy supply, especially in regions with limited electrical infrastructure or where grid supply is unreliable.

Stationary fuel cell generators ensure:

1. **Zero carbon emissions:** Water vapor is the only by-product, assuming the hydrogen production method is clean (electrolysis, bio-hydrogen, etc.).
2. **Zero-noise:** No noise is generated, enabling indoor installations.
3. **Ease of use:** It is a plug-and-play solution, enabling easy integration into existing infrastructure.
4. **Low maintenance cost:** Since the generator does not have complex moving parts, maintenance costs are low.
5. **Scalability:** The system can be sized based on the energy and power requirement of the application. The power is determined by the size of the fuel cell, which can range from few kilowatts (kW) to few megawatts (MW). The energy stored is determined by the size of the cylinder. Both can be scaled independently. Therefore the increase in size only increases the cost marginally, unlike a battery energy storage system which has limited scalability.

Economic viability: Comparison with diesel and natural gas generators

For any type of power generation systems [diesel, natural gas (NG) or hydrogen fuel cell], operational costs or fuel expenses are the biggest contributor by far over the lifetime of the system. The cost of fuel and efficiency of the system affect the operational cost predominantly.

	Diesel	Natural gas	Hydrogen fuel cell
Fuel cost	INR92/liter	INR79/kg	INR300/kg
Fuel efficiency	20%	25%	50%
Fuel consumption per kWh produced	0.4 liter/ kWh	0.26 kg/ kWh	0.0625 kg/ kWh
Operating cost (INR/ kWh) of electricity produced	36.8	20.5	18.8

Table 1: Comparison of cost of electricity with alternatives

Though the capex of hydrogen systems is relatively higher compared to natural gas gensets and DGs, increased demand and the emergence of disruptive technologies, both in components and manufacturing processes, are

expected to lead to the reduction in the cost of fuel cell generators. Currently, for applications that require the use of a generator for over 8 hours, hydrogen generators are far more cost effective compared to other alternatives.

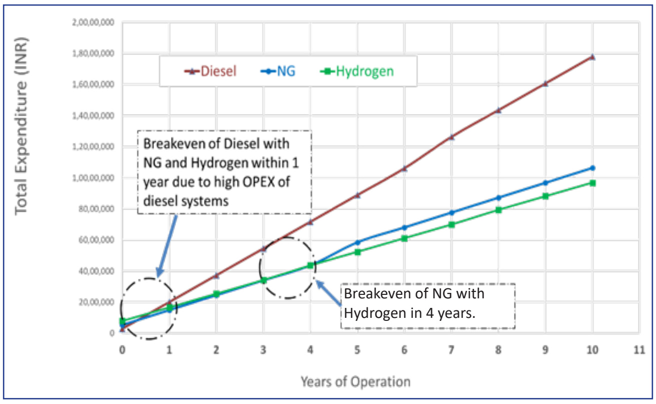

Figure 1: TCO comparison of Hydrogen FC generators with alternatives (Diesel and CNG) (200 kVA system)

Industries and commercial establishments in many of India's states today are facing the reality that their power needs cannot be reliably fulfilled by the electricity grid. It is clear that DGs must be phased out due to their high localized emissions and noise pollution. This offers significant opportunity for hydrogen fuel cell-based generators to replace diesel and natural gas gensets in India.

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Contact us to learn more about our solutions (www.hydrovert.in)

Powering the Future.. contd from pg 18

decreased delivery times and the highest durability in the market. The company is competing with global giants like Toyota, Bosch, Ballard, and Proton to optimize the fuel cell production process, positioning itself as a formidable player in the global hydrogen technology race.

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The Path Forward

As Energy Leap continues to nurture these innovative start-ups, we remain committed to our vision of accelerating the transition to clean hydrogen. By bringing together visionary companies, established industry leaders, and forward-thinking investors, Energy Leap is fostering an environment of collaboration and innovation. Together, we are working towards a future where clean hydrogen plays a central role in decarbonizing industries, transforming mobility, and creating a more sustainable world.

We look forward to sharing more updates on the progress of our cohort and the exciting developments in the clean hydrogen sector. Stay tuned for future showcases as we continue to highlight the brilliant minds shaping the future of energy.

For more information about Energy Leap and our initiatives, visit www.xynteo.com/our-universes/energy-leap

IITM Initiatives.. contd from pg 21

Compared to liquid hydrogen and metal hydrides, electrochemically produced ammonia can be synthesized, stored, and transported in near-ambient conditions. It can be directly combusted with zero carbon emissions or cracked into hydrogen when needed. This process is more eco-friendly than steam methane reformation, which releases tons of carbin dioxideinto the atmosphere.

Green ammonia production uses renewable energy, supporting green hydrogen initiatives. It can be produced centrally using nitrogen and water, then shipped to where hydrogen is needed. Ammonia cracking can be done chemically at 673-873 K, with research ongoing for ambient electrochemical cracking.

The versatility of hydrogen across various applications such as power generation and chemical processes can further help bring down these sectors' carbon footprint. These factors make ammonia a viable candidate for large-scale hydrogen storage and transport in a decarbonized energy system.

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Energy Leap, a platform by Xynteo, aims to accelerate the production and consumption of clean hydrogen in India through technology innovation, commercialisation and deployment.

- Are you a leading renewable energy project developer, heavy industrial company, or automotive company looking for technological solutions to produce, transport, utilise clean hydrogen or deploy pilot projects?
- Are you a venture capital or private equity investor or project financier, looking for opportunities to invest in clean hydrogen technologies and projects?
- Are you a clean hydrogen technology company looking to accelerate your growth through market access and fund raise?

Join us at Energy Leap to accelerate the adoption of clean hydrogen.
Let's connect and explore how we can work together!

WHAT WE DO

- Project Conceptualisation
- Technology Incubation & Acceleration
- Technology Discovery

HOW WE DO IT

- Strategic Partnerships
- Catalytic Funding
- Innovation Challenge

We have discovered 15 clean hydrogen technology companies and are working with several corporates, foundations, investors and eco-system enablers to commercialise these technologies to drive clean hydrogen production and consumption in India.

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