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EDITORIAL

Hydrogen, when used in fuel cells, produces electricity with water as the only by-product, making it an attractive alternative to fossil fuels. However, the challenge has always been to produce, store, and transport hydrogen efficiently and economically. This is where hydrogen-based start-ups come into play. They are leveraging cutting-edge technology and innovative business models to overcome these challenges and unlock the potential of hydrogen energy.

Though to fully realize the potential of hydrogen energy, all stakeholders need to pitch in. Governments need to create a supportive regulatory environment and provide incentives for hydrogen-based start-ups. Investors need to provide the necessary capital and take a long-term view of their investments. Established energy companies need to collaborate with start-ups and share their expertise and resources. Finally, start-ups themselves need to continuously innovate, learn from their experiences, and stay resilient in the face of challenges.

So it is yet to be seen, as to how many of these start-ups will remain standing down the line, due to the (non-)availability of investment and finance, though India's 2024 budget is set to ignite the green hydrogen boom with strategic fiscal incentives, which are expected to substantially lower the production costs of green hydrogen, propelling India towards its ambitious target to establish parity with the current costs of grey hydrogen.

As has been globally acknowledged, India has enormous potential in its green hydrogen journey, but also faces hurdles. An Indian School of Business opinion article highlights legislative measures, industry contributions, and India's goal for a cleaner and greener future amid technological developments and proactive government support.

India is poised to become a global leader in sustainable energy. But the journey to a hydrogen-based economy is not without its challenges. The cost of green hydrogen production is currently estimated at $3-6/kg, primarily due to the high capital cost of electrolysers, which can constitute up to 40% of the total project cost. Additionally, storage and transportation, requiring high-pressure tanks or cryogenic temperatures, pose logistical and safety challenges because of their complexity. Efficient hydrogen storage technologies like metal hydrides and liquid organic hydrogen carriers are still in developmental stages and need substantial investment. Technological challenges, especially in the storage and transportation of hydrogen, add to the complexity.

Fortunately, India's renewable energy potential can support its goals for green hydrogen growth, but needs rapid capacity addition.

However, there's a silver lining in the form of active participation from industry giants like Reliance Industries, Indian Oil, NTPC, Adani Enterprises, and others who have announced plans to set up a cumulative annual green hydrogen manufacturing capacity of 3.5 million metric tons. Their investments and involvement in developing green hydrogen projects are crucial in overcoming these obstacles, indicating a robust industrial momentum that can drive the sector towards maturity.

In the inaugural issue in 2023, we covered the Ministry of New and Renewable Energy's (MNRE) National Green Hydrogen Mission strategic document in detail. We also included viewpoint articles from MNRE, Indian Sugar Mills Association/ACME, ONGC, Resurgent, etc., along with the role of multilateral agencies such as the World Bank in our country's hydrogen sector.

This time, international and national opinion articles from NTPC (on India's first green hydrogen blending project in Gujarat) and the World Economic Forum throw light on the future of this sector in India and globally.

State profiles covered last time included Odisha and Maharashtra. Since Gujarat too is making huge strides in the sector—unveiling its ambitious plans to contribute one million tons of green hydrogen by 2030, its initiatives have been detailed within.

Globally, Brazil too is boosting its green hydrogen sector with more than 40 projects underway, and is being supported by international cooperation from Germany, the Netherlands, World Bank, and the European Union, so it is useful to note and track the opportunities being presented and planned in the country.

The Cogeneration Association of India (Cogen India) will play a key role in helping to set up "integrated sugar complexes", focusing on expanding their by-product and revenue base, and invites stakeholders to join hands in this race to lead India's shift to Green Hydrogen. The launch of this HYDROGEN INDIA newsletter in 2023 is a crucial step in raising more awareness in this sector. We request all stakeholders' feedback and support in order to make it more useful for the industry.

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FORTHCOMING EVENTS

Green Hydrogen India – 29-30 August 2024 – New Delhi

The **3rd Edition** of Green Hydrogen India, an International Exhibition & Conference to be held on **29-30 August 2024 at India International Convention Centre, Dwarka, New Delhi.** The inaugural edition was organised by SDLC and Infinity Expo in September 2022.

The previous edition was supported by **Green Hydrogen Organisation** (GHO, Geneva)**, Indo German Energy Forum** (IGEF)**, Indo German Chamber of Commerce** (IGCC)**, GIZ, Innovation Norway, ET Now** and attracted attendance from players like Niti Aayog, World Bank, ADB, HPCL, HMEL, Reliance, ONGC, BPCL, Avaada, ACME, Jio, L&T, Thermax, Oil India, Petronas, GAIL, Tata Consulting, Grasim, Torrent, EIL, IREDA, IGX, Maruti Suzuki, Ashok Leyland, Grasim, Ceres Power, Hero Future, Linde, Austrade, Sirinor, Aker Horizon, Ion Exchange, etc.

In 2024, a collocated **international exhibition** with over 120+ companies will showcase cutting edge technologies, latest products, services and offerings for the Green Hydrogen sector in India.

Expected Participation:

300+ Delegates | 4000+ Attendees | 70+ Speakers | 120+ Product Display | 20+ Sponsors | B2B meetings and Networking

For more information:
please check: http://www.gh2summit.com/index.html

For participation, sponsorship opportunities, delegate & visitor registration: http://www.gh2summit.com/contact.html

Budget 2024: Igniting Green Hydrogen Boom

India's 2024 budget is set to ignite the green hydrogen boom with strategic fiscal incentives, which are expected to substantially lower the production costs of green hydrogen, propelling India towards its ambitious target to establish parity with the current costs of grey hydrogen.

In what could be a transformative stride for the country's energy landscape, the central government is reportedly poised to implement a series of fiscal incentives aimed at bolstering green hydrogen production and utilization, as the nation prepares for the finalization of Budget 2024.

Industry insiders suggest that the forthcoming budget will lay down the groundwork for an increase in subsidies, particularly for sectors that are best positioned to leverage green hydrogen, such as refining and fertilizer production. The move is designed to amplify domestic demand and foster a robust supply chain for the eco-friendly energy variant.

A key aspect of the government's strategy includes diverting subsidies from carbon-intensive fuels to green hydrogen projects. This realignment of fiscal policy is expected to serve as a dual thrust towards achieving India's energy independence and adhering to its international climate commitments.

Investments are also anticipated in creating comprehensive infrastructure for green hydrogen transportation. The 2024 Budget is likely to outline the development of clusters and pipelines that would not only reduce transportation costs, but also enhance the supply chain's efficiency.

To stimulate innovation and private sector investment, the government may extend tax credits and incentives for research and development in the green hydrogen sector. These measures are intended to match global initiatives and position India at the forefront of renewable energy technology.

Export infrastructure is also expected to see a significant enhancement, with the Budget possibly detailing plans for the development of port facilities and the establishment of international standards for green hydrogen derivatives. Such measures would be critical in transforming India into a key exporter in the global green hydrogen market.

On the domestic front, the Budget may announce direct subsidy schemes and capex support for industries ready to transition to green hydrogen. This support is anticipated to catalyze the adoption across various sectors, boosting in-house demand, and fostering developments in green hydrogen by-products, including the burgeoning green steel industry.

The government's comprehensive fiscal approach signifies a substantial commitment to transforming India into a green hydrogen hub, aligning with global energy transition trends and setting the stage for a sustainable economic growth trajectory.

This potential fiscal framework in the Budget, reflective of the strategic recommendations from the "Green Hydrogen: Enabling Measures Roadmap for Adoption in India" report by the World Economic Forum and Bain & Company, could herald a new era for India's energy sector. It suggests a future where India not only meets its energy requirements sustainably but also asserts itself as a pioneer in the global transition to a low-carbon economy. The report, released in early 2024, has been instrumental in highlighting the potential pathways and strategies for India's transition to a green hydrogen economy, offering a blueprint that the Budget is likely to draw upon.

Sources: Jan 2024 (ET EnergyWorld & World Economic Forum websites)

Hydrogen Start-Ups Powering India's Future

Hydrogen, when used in fuel cells, produces electricity with water as the only by-product, making it an attractive alternative to fossil fuels. However, the challenge has always been to produce, store, and transport hydrogen efficiently and economically. This is where hydrogen-based start-ups come into play. They are leveraging cutting-edge technology and innovative business models to overcome these challenges and unlock the potential of hydrogen energy.

The journey of hydrogen-based or energy start-ups has just started, but the early signs are promising. They are attracting significant investment from venture capitalists, governments, and major corporations. According to a report by the Hydrogen Council, the global hydrogen market could reach $2.5 trillion by 2050, creating 30 million jobs worldwide. This presents a massive opportunity for hydrogen-based start-ups.

However, like any other start-up, they also face numerous challenges. The technology is still in its nascent stage, and there are significant technical and regulatory hurdles to overcome. Moreover, they need to compete with established energy companies and other renewable energy technologies. Therefore, the success of these start-ups will depend on their ability to learn from their experiences, adapt to changing circumstances, and continuously innovate.

India, with its ambitious renewable energy targets and rapidly growing economy, presents a unique opportunity for hydrogen-based start-ups. The country has set a target to install 450 GW of renewable energy capacity by 2030, and hydrogen can play a crucial role in achieving this target, as per government press releases. Moreover, India's vast population and growing energy demand mean that there is a huge market for clean energy solutions.

Hydrogen fuel technology has seen significant advancements in recent years. One of the most promising innovations is the development of solid-state hydrogen storage systems that offer higher energy densities, faster refuelling times, and increased safety compared to traditional compressed or liquid hydrogen storage. Another key development is the use of renewable energy sources, such as solar and wind, to produce hydrogen through electrolysis, resulting in zero-emission fuel. Additionally, advances in fuel cell technology improve efficiency and durability, making hydrogen fuel cells a more viable option for transportation and power generation. Overall, these innovations in hydrogen fuel technology hold great promise for a cleaner and more sustainable energy future. Let's dive into 20 innovative hydrogen fuel technology start-ups furthering these technologies in 2024 and beyond!

20 Hydrogen Fuel Technology Start-ups (2024)

- **Neology** – On-board Ammonia Cracking
- **Hydrogenfuel** – Novel Electrolysis Module
- **Hyfluence Systems** – Hydrogen Fuelling Equipment
- **BiSTEMS** – Biomass Gasification
- **Aatral Hydrogen** – Green Hydrogen Generation & Storage (India)
- **Fast Sense** – Hydrogen Consumption Monitoring
- **Fly-Box** – Clean Maritime Freight Transportation
- **HYGN Energy** – Hydrogen Hybrid Kits
- **LYTE Aviation** – Hybrid VTOL
- **Redeem Solar Technologies** – Solar-Powered Hydrogen Production
- **Titan Hydrogen** – Hydrogen Fuel Cell
- **BTE** – Hydrogen Charging Solutions
- **Kaizen Clean Energy** – Hydrogen as a Service
- **Azolla Hydrogen** – On-site Hydrogen Production
- **Metroligic Lab** – Green Hydrogen Fuel Cells
- **Voyex** – Hydrogen-based Alternative Fuel
- **Fuel Cell Millennium Technologies (FCMT)** – Hydrogen Fuel Cell Stack
- **Oort Energy** – Green Hydrogen
- **Ecogenium** – Hydrogen Mobility Fuel Cells
- **Hytern** – Long-Range Fuel Cell For Drones

The evolution of hydrogen-based companies is reshaping India's energy landscape, aligning with the nation's ambitious sustainability goals. In 2015, a story[1] was covered on Reinwo Labs – a 2014 start-up. Hydgas was a ground-breaking solution that generates hydrogen from readily available tap water, indicating a transformative era in both household and commercial cooking. Further, Hydgas redefined traditional LPG usage, contributing to India's hydrogen production targets. Essentially the invention is a cooktop that produced its own gas, by converting water to fuel. The founder, Riswin M.H., Co-founder and head of operations, professed it to be safer than LPG and that it could also be integrated with solar power.

The USP of the product, which the team was banking on to market, was the zero risk involved. The pollution was practically 0%. The by-product of burning hydrogen is just water. And there was no gas storage, which made it safe. The start-up planned to target restaurants and hotels. "In India, the gas distribution is centralized in the hands of big companies. We are trying to make it as decentralized as possible," Riswin shares. For the first two months of its inception, Reinwo Labs was self-funded. Then it got some initial funding from Kerala State Electricity Board (KSEB) and Startup Village. But today there is no presence of this company. Is this another start-up that failed?

[1] *https://yourstory.com/2015/04/hyd-gas*

Challenges

To fully realize the potential of hydrogen energy, all stakeholders need to pitch in. Governments need to create a supportive regulatory environment and provide incentives for hydrogen-based start-ups. Investors need to provide the necessary capital and take a long-term view of their investments. Established energy companies need to collaborate with start-ups and share their expertise and resources. Finally, start-ups themselves need to continuously innovate, learn from their experiences, and stay resilient in the face of challenges.

These start-ups can not only contribute to India's renewable energy goals but also create jobs, foster innovation, and promote sustainable development. They are also providing learnings for other start-ups and stakeholders in the hydrogen ecosystem. For instance, they are demonstrating that it is possible to build a successful business around hydrogen energy, despite the challenges. They are also paving the way to navigate the regulatory landscape, engage with stakeholders, and leverage technology to create value.

Looking ahead, the future of hydrogen-based start-ups in India and globally looks bright. As the world transitions to a low-carbon economy, the demand for clean energy solutions will only increase. Moreover, advancements in technology and supportive government policies are making hydrogen energy more viable and attractive.

Sources: Legal500, startus-insights.com

India's Journey to Leadership in the Hydrogen Revolution

India has enormous potential in its green hydrogen journey, but also faces hurdles. This opinion highlights legislative measures, industry contributions, and India's goal for a cleaner and greener future amid technological developments and proactive government support. India is also poised to become a global leader in sustainable energy.

Image: Shutterstock (Representative image only)

India is on the brink of an energy transformation, with green hydrogen poised to play a pivotal role in its sustainable future. Green hydrogen, produced by splitting water into hydrogen and oxygen using renewable energy sources like solar and wind, offers a clean, carbon-neutral alternative to conventional fossil fuels. The country's vast renewable energy resources, including an estimated solar potential of around 750 GW and a wind potential of approximately 302 GW, provide a strong foundation for this emerging sector. Rajasthan and Gujarat, with their vast solar potential, are prime locations for building green hydrogen production facilities. Rajasthan's Thar Desert is particularly suitable for large-scale solar installations.

The International Renewable Energy Agency (IRENA) estimates that hydrogen could cover up to 12% of global energy use by 2050, helping to avoid six gigatons of carbon dioxide emissions annually. Thus, this transition aligns with global climate goals and positions India at the forefront of the green energy revolution.

Diverse Applications of Hydrogen

Applications for hydrogen fuel cells can be found in several industries. They are a flexible and environmentally beneficial energy source. Hydrogen-powered trains, buses, and certain passenger cars are becoming increasingly common in transportation. Demonstrating their dedication to greener options, cities like Delhi are leading the way in testing hydrogen-powered buses to reduce urban air pollution. Businesses that require a lot of heat, like those that make steel and cement, consider green hydrogen a cleaner alternative to fossil fuels. Adopting green hydrogen could be a crucial step in reducing the environmental impact of fossil fuel consumption, as the global steel industry alone accounts for 7-9% of direct emissions from this source. Furthermore, there is a sizable potential market for using green hydrogen in the fertilizer production industry, which has historically relied on hydrogen.

The adaptability of hydrogen also extends to electricity production, where it can be burnt in gas turbines or used directly in fuel cells. This adaptability presents utilities looking to decarbonize their energy mix with transformative potential. The largest power provider in India, NTPC Limited, is one example of the increasing interest in sustainable energy options. It is actively investigating green hydrogen technologies for energy storage and grid balancing.

Moreover, the ability of hydrogen to be combined with natural gas is helping to lower carbon emissions from heating systems in homes and businesses. This integration shows how to handle environmental concerns in daily energy usage practically. Hydrogen finds wide-ranging uses in transportation, manufacturing, energy production, and heating systems. It highlights its potential to serve as a driving force behind sustainable solutions in pursuing a more environmentally friendly and cleaner future.

The National Green Hydrogen Mission

Considering the vast potential of green hydrogen, the Government of India has taken a proactive stance with the National Green Hydrogen Mission. This mission, which has earmarked Rs 19,700 crore in the 2023 budget, underlines the government's commitment to reducing carbon emissions and dependence on fossil fuels. The Indian government has set an emission limit of two kg of carbon dioxide for every kg of hydrogen produced to qualify as "green" hydrogen. This move brings clarity and standardization to green hydrogen production in India. The potential of the Indian market is also significant, considering that current global hydrogen consumption is estimated to be around 70 million tons per year, the majority of which is grey hydrogen from fossil fuels

India aims to produce 5 million metric tons of green hydrogen annually by 2030, potentially saving more than

$12 billion in fossil fuel imports and reducing 50 million metric tons of carbon emissions. The government has approved $2.3 billion to develop the green hydrogen sector to support this. This investment will help India add 125 GW of renewable energy capacity by 2030.

In comparison, China, the European Union and the United States are also actively investing in green hydrogen, with the global market expected to grow 20-fold to $80 billion by 2030. The strategy includes supporting the development of efficient hydrogen production technologies, such as advanced electrolysis, and supporting research into hydrogen storage and transport solutions. In addition, the government is promoting a favorable regulatory environment, offering incentives and potentially relaxing policies to attract investment and facilitate growth in the sector

Overcoming Obstacles: Challenges & Industrial Momentum

The journey to a hydrogen-based economy is not without its challenges. The cost of green hydrogen production is currently estimated at $3-6/kg, primarily due to the high capital cost of electrolysers, which can constitute up to 40% of the total project cost. Additionally, storage and transportation, requiring high-pressure tanks or cryogenic temperatures, pose logistical and safety challenges because of their complexity. Efficient hydrogen storage technologies like metal hydrides and liquid organic hydrogen carriers are still in developmental stages and need substantial investment. Technological challenges, especially in the storage and transportation of hydrogen, add to the complexity.

However, there's a silver lining in the form of active participation from industry giants like Reliance Industries, Indian Oil, NTPC, Adani Enterprises, and others who have announced plans to set up a cumulative annual green hydrogen manufacturing capacity of 3.5 million metric tons. Their investments and involvement in developing green hydrogen projects are crucial in overcoming these obstacles, indicating a robust industrial momentum that can drive the sector towards maturity.

Strategic Policy Initiatives

The future of green hydrogen in India depends on a balanced approach that addresses technological and infrastructure challenges while leveraging policy support and industrial innovation or something similar. Creating an enabling ecosystem for research and development (R&D), paired with strategic government support and strong private sector participation, is essential. This approach should focus on developing efficient and cost-effective production methods, establishing a reliable storage and transportation network, and creating a comprehensive policy framework that supports growth and innovation in the green hydrogen sector.

With the help of green hydrogen, India can move towards a sustainable and energy-secure future. However, this will require a comprehensive policy framework considering infrastructure, technology, and regulatory constraints. The following three key policy recommendations will boost India's green hydrogen industry:

First, we would need investment in R&D. To support technological progress in the production of green hydrogen, the government should provide significant funding for R&D projects. Creating research facilities and collaborative platforms with academic institutions and commercial entities can accelerate the development of productive and economical manufacturing techniques. Offering subsidies for innovation and encouraging the business sector to participate in R&D initiatives can stimulate the development of new technology and make India a hub for cutting-edge green hydrogen solutions

Second, infrastructure development for storage and transportation is urgently required. Developing a reliable network for transport and storage is essential for the widespread adoption of green hydrogen. The government's top priority should be infrastructure projects that increase the amount of storage space and improve the efficiency of green hydrogen transportation. This means creating a network of specialized hydrogen pipelines and developing cutting-edge storage technologies. The smooth integration of green hydrogen into India's energy landscape will be facilitated by providing financial incentives and opportunities to partner with private sector companies to build storage and transportation infrastructure

Third, a holistic policy framework and regulatory support are most needed. A broad policy framework is necessary for the green hydrogen industry to have a clear roadmap. The government should try to establish industry standards, and specify requirements for green hydrogen emissions, and simplify regulatory procedures. The sector will continue to flourish if an appropriate business environment is created through tax breaks, financial incentives, and deregulation for investment. A framework for flexible and adaptive regulation is ensured by routine revision of laws to match market dynamics and technological improvements, thereby continuously stimulating innovation.

Conclusion

India's commitment to green hydrogen is a testament to its vision of a sustainable, energy-secure future. If the country takes this path, it has the potential to become a global leader in green hydrogen, inspire other nations, and make a significant contribution to global efforts to combat climate change, which is essential. The road ahead is challenging but promises a cleaner, greener, and more sustainable world. By implementing these measures, India can establish itself as a world leader in green hydrogen production, making a significant contribution to global efforts to mitigate climate change and promote economic development and energy security—the proactive and strategic strategy required to manage the potential and challenges of India's green hydrogen journey.

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Courtesy: Forbes India

Indian Academia & Industry Partnerships

The Union Minister for Power and New & Renewable Energy Shri R.K. Singh chaired a meeting on Green Hydrogen R&D Scheme of the Government in New Delhi on 22 February 2024. Principal Scientific Advisor to the Government of India Shri Ajay Sood; Secretary, Ministry of New & Renewable Energy (MNRE) Shri Bhupinder Singh Bhalla; Joint Secretary, MNRE Shri Ajay Yadav; and government, academia and industry representatives from SECI, NCL, IIT Delhi, IIT Bombay, IISc, NISE, BPCL, IIT Roorkee, IOCL, IIT Indore, IIT Patna, IIT Kharagpur, TERI, IIT Kanpur, Institute of Minerals and Materials Technology, DRDO, IIT Ropar, CSIR, HAI, BHEL, BARC, BPCL and private industry representatives attended the meeting in person and through video conferencing.

The Minister said that research efforts under the Mission should be focussed to identify primary areas of research, give necessary support to research institutions, produce necessary technologies and bring them to fruition.

Underlining the need to identify the priority areas, the Minister said that institutions in different fields of expertise need to come together to collaborate and work on identified priority areas.

Shri Singh said that increasing efficiency of electrolyzers is a key aspect which needs to be looked into, in order to bring down the cost of green hydrogen. We should also explore less costly alternatives for producing and transporting green hydrogen, added the Minister.

The Minister informed the industry and research community that a few companies are already working on Internal Combustion Engine (ICE) modifications to make them run on hydrogen derivatives. It was also stated that sea-water electrolysis to produce green hydrogen is also a promising area of research to bring down cost of production and improve scalability.

The Minister said that consortiums could be formed for carrying out research in various areas of the green hydrogen value chain.

MNRE made a presentation on the initial set of more than 40 problem statements which have been identified for consideration under the Mission, under four heads namely, production; storage & transport; applications; and safety, cross-cutting analysis & integration. The problem statements were shared with the stakeholders present, followed by a discussion on what the priority areas for the first round of R&D projects could be.

It was informed that the R&D projects under National Green Hydrogen Mission comprise Mission Mode projects of 0-5 years horizon, Grand Challenge projects of 0-8 years horizon, and Blue Sky projects of 0-15 years horizon. Centres of Excellence too would be identified and supported under the Mission. However, in the initial phase, the focus would be on Mission Mode projects.

First Innovation Challenge Award

Xynteo's Energy Leap, an end-to-end clean hydrogen technology and business accelerator launched in 2023, presented its first Innovation Challenge award to Suzhiyam Industrial Machines, a promising start-up working on a pathbreaking solution in the clean hydrogen value chain, at the Exchange, presented by Hindalco in collaboration with Xynteo, on 16 February.

For the Innovation Challenge, Energy Leap received 23 applications from innovators with early-stage solutions with technology readiness level (TRL). The focus areas for the challenge spanned across production technologies, utilisation solutions for industry applications, advanced storage and transportation, materials, catalysts, digitisation and monitoring.

Suzhiyam won USD25,000 for its innovation on producing clean hydrogen from agri-waste and municipal solid waste sources, and will collaborate with Energy Leap to further their innovation towards market readiness. Grassroots Energy, Hydrovert Technologies and Prasah are the other finalists, and Energy Leap will extend its support for technology validation and networking with partners across the value chain. These four early-stage start-ups will be part of Energy Leap's portfolio alongside high-potential start-ups, Ossus Bio-renewables and SungreenH2, which have advanced and market-ready solutions for scaling up.

Experts and advisors of Energy Leap comprising Dr. Aravind Kumar Chandiran, Associate Professor, IIT Madras; Manish Panchal, Member – CII Green Hydrogen Task Force; Dr. N. Rajalakshmi, Former Head, CFCT, ARCI; Shyam Kishore Chowdhary, AVP, Head Process & Technology, Technip Energies; and Mridula Bhardwaj, Capacity Building Specialist, International Solar Alliance evaluated the applications based on parameters of technical feasibility, commercial viability and market opportunity.

Xynteo's Energy Leap programme is partnered by SED Fund, Technip Energies, Research and Innovation Circle of Hyderabad, with support from Cambridge Cleantech, Energy Systems Catapult, CIIE.CO and Amazon Web Services.

Vikas Mehta, Executive Director, SED Fund said, "We are excited to collaborate with Energy Leap towards enabling the clean hydrogen innovation ecosystem in collaboration with industries and investors. The Innovation Challenge award is a step towards generating a pipeline of viable commercial solutions in the short to medium term, making hydrogen a mainstream agenda towards net zero."

Vipul Kumar, Senior Partner, Xynteo, said, "We are unyielding towards our commitment to create planet-positive impact, and today Energy Leap's Innovation Challenge is another testament to our resolve to work tirelessly towards good growth. This Challenge highlights the need to enable collaboration across the hydrogen innovation ecosystem and demonstrate proof points for various end use-cases. We congratulate Suzhiyam for the award, and with support of our Energy Leap partners, we hope to empower their growth, and help them unlock the vast potential of clean hydrogen in India and beyond."

All portfolio start-ups will receive active support from Energy Leap across areas of technology validation and commercialisation; industry partnerships; business mentoring and investments. The program will focus on supporting ~50 innovations across the clean hydrogen value chain over the next 4-5 years and invites partners from around the world to join the Energy Leap's journey.

About Energy Leap

Energy Leap, a clean hydrogen technology and business accelerator, focuses on driving innovation and market creation for clean hydrogen in India and globally. It supports the wider ecosystem encompassing energy security, the hydrogen economy and decarbonisation.

The programme aims to facilitate technology commercialization, market creation and unlocking capital for start-ups, and bringing together stakeholders such as industry, investors, technology and think tanks. The program's Growth Accelerator works to catalyze new technologies and start-ups across the hydrogen value chain, and commercialise them through business modelling, operational, technology and investment support, and market access.

State Profile: Gujarat

STATE PROFILE

In a ground-breaking move towards sustainable energy, the Gujarat government unveiled its ambitious plan to contribute one million tons of green hydrogen[1] by 2030, aligning with the Prime Minister's national target of 5 million tons. The announcement was made at the Vibrant Gujarat Summit 2024 (10-12 January).

Speaking at the event, V.K. Saraswat, Member, Niti Aayog, emphasized the critical role of hydrogen in achieving net carbon zero. He acknowledged the challenges associated with the cost of green hydrogen and electrolysers, but highlighted the need to reduce electrolyser costs by 80% and improve efficiency to 76%. Saraswat stressed the importance of delivering power at not more than Rs. 2 per unit to make the mission economically viable.

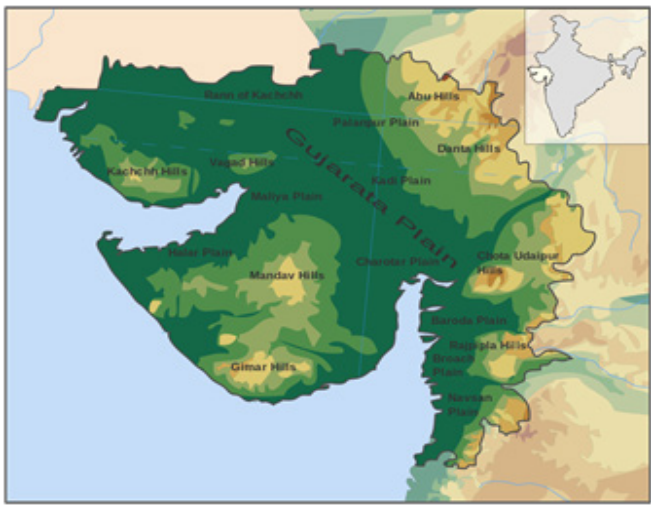


Image: Goran Tek-en, Wikimedia Commons

Saraswat also explored alternative methods for hydrogen production, including the use of nuclear reactors. He suggested that international collaboration, particularly with countries like Norway, could accelerate progress in this direction. Thermochemical and thermoelectric processes were identified as potentially viable solutions.

To achieve India's 5 million-ton green hydrogen mission, Saraswat outlined three key requirements. Firstly, upgrading solar capacity to 211 GW solar power, secondly, identifying suitable areas for setting up photovoltaic (PV) plants spanning 141-190 thousand square hectares, and thirdly, ensuring a water supply of 160 billion liters per year.

[1] Hydrogen produced using renewable energy

The financial aspect of the mission was also addressed, with the current $75 billion allocated to solar energy needing an increase to $243 billion to augment solar capacity. While acknowledging the prevalence of blue hydrogen, Saraswat emphasized the need for a proper transition to green hydrogen for industrialization and fuel production. He called for a shift in nomenclature, advocating the term "clean hydrogen" regardless of its color.

The launch of Gujarat's green hydrogen mission marks a significant step towards a sustainable and carbon-neutral future. The state's commitment to contributing to India's ambitious targets reflects a broader national effort to embrace clean energy solutions and combat climate change.

Gujarat's Renewable Energy Policy 2023 will enable it to source 50% of its energy from renewable sources. The state currently contributes 15% of India's renewable energy capacity and is one of the fastest growing renewable energy-producing regions. Gujarat aims to reach 100 GW in the renewable energy portfolio.

On 2 February 2024, while addressing the Gujarat assembly on the opening day of its budget session, governor Acharya Devvrat said the state could become a global leader in the production of green hydrogen. He added that the Land Policy 2023 announced recently by the state has earmarked 200,000 hectares for allotment to developers to help achieve production capacity of 40 lakh metric tons per annum. The land allotment policy also offers benefits to companies investing in green hydrogen projects, as long as companies achieve 50% of their green hydrogen production capacity within five years of plant commissioning and 100% in eight years.

State delegations have held meetings with leading companies from France, Japan, South Korea, Australia and Singapore, along with companies in India that are engaged in the production of green hydrogen, and discussed opportunities in Gujarat. Companies that have expressed interest in investment cater to sub-sectors such as alternative fuel production, gas/technology-related solutions infrastructure, lithium-ion battery manufacturing, solar PV module manufacturing, decarbonization initiatives, and green hydrogen production.

Global/National Partnerships

Danish maritime companies also expressed interest in procuring green methanol and green ethanol from Gujarat ports. MoUs have been signed with companies such as MeOH Giga Battery (Australia) and Australian Premium Solar Pty Ltd (Australia) to expand Gujarat's renewable energy base.

Gujarat Chief Minister Bhupendra Patel visited Yamanashi Hydrogen Company in Japan to discuss the potential of the green hydrogen energy sector for his state. He learned about the company's demand, sales, and servicing abilities, and invited the Governor of Yamanashi to attend the Vibrant Gujrat Summit.

Indian companies such as Welspun and Kiri Industries signed MoUs with Lili Navitas (Germany) and Sundronix (Germany) to facilitate the export of green hydrogen and green ammonia to Europe, while Shakti Group has signed an MoU to invest Rs. 1,000 crore[2] in the manufacture of green methanol and green ethanol in the state.

Adani Total Gas Limited (ATGL) has already launched a green hydrogen blending project in Ahmedabad to assess its viability as an alternative energy source for compressed gas distribution (CGD) consumers. The pilot project involves blending green hydrogen with natural gas for 4,000 home and commercial petroleum natural gas (PNG) customers. Green hydrogen is produced using renewable energy through electrolysis. The project is expected to be commissioned by FY 2025, gradually increasing the percentage of green hydrogen in the blend. ATGL aims to enhance infrastructure, diversify energy mix, develop hydrogen ecosystem, and reduce carbon dioxide emissions.

Essar Group will develop a 1 GW green hydrogen project in Gujarat with an estimated investment of Rs. 30,000 crore, as per an MoU signed with the state government in December 2023. In February 2024, the Essar Group had formed Essar Energy Transition (EET) with a focus on hydrogen, decarbonization, new energy infrastructure, and biofuels. EET plans to invest a total of $3.6 billion in developing a range of low-carbon energy transition projects over the next five years, of which $2.4 billion will be invested across its site at Stanlow in the UK and $1.2 billion in India – in developing a cost-efficient global supply hub for low-carbon fuels, including green hydrogen and green ammonia. Ammonia will be shipped from India to the UK, Europe, and globally to meet the expanding market demand for green hydrogen.

Green Hydrogen at Ports

Kutch in Gujarat is a crown jewel in the port sector of not just the state, but also the entire country. Deendayal port (DP) in Kandla, a major port under the control of the Centre, and the Adani group's Mundra port have contributed in huge measure to the region's prosperity. The two ports, separated by 75 km, together handled 476 million tons (MT) of cargo — Mundra 339 MT; and DP 137 MT — in 2022-23.

An added boost to the region's economic development is the upcoming green hydrogen hub with massive investment from both ports — nearly Rs. 1.45 lakh crore from DP and $50 billion from the Adani group — over the next ten years, depending on market conditions.

Manufacturing, storage, and bunkering facilities for green hydrogen at Indian ports can attract shipping lines looking to refuel sustainably for the onward journey | Photo Credit: audioundwerbung

At the Global Maritime India Summit 2023, held in Mumbai in October, the Deendayal Port Authority (DPA) entered into 13 MoUs with leading companies engaged in the development of green hydrogen, its derivatives, and associated infrastructure. Some of the prominent names include ReNew E-Fuels; Statkraft India; Welspun New Energy; Sembcorp Green Hydrogen India; Hygenco Green Energies; Torrent Power Ltd; NTPC Green Energy; and Greenko ZeroC.

"DPA has disclosed these developments on its extensive land bank of 26,000 acres, and the land e-auction process for setting up such provision was initiated on October 16. We have got good response from the companies for the tender," SK Mehta, Chairperson, DPA, said.

The DPA has opted for a composite plant to manufacture green hydrogen and green ammonia. "We have identified 300 acres for 1 MT per annum (MTPA) of ammonia and have floated tenders for 12 land parcels of 300 acres each," he said.

[2] 1 crore = 10 million

Mehta attributed the good response from large companies to the fact that DP already has a good ecosystem for liquid cargo handling. It has tank farms of the highest capacity in South Asia at 35 lakh kilo liters. It has as many as seven oil jetties and pipelines, with the eighth nearing completion by the end of this financial year. Three more oil jetties are being planned, he said.

The Adani group, on its part, has set up a wholly owned subsidiary called Adani New Industries Ltd. (ANIL) to invest in backward integration as part of its planned green hydrogen venture. It is developing end-to-end solutions to produce green hydrogen and its associated sustainable derivatives at scale.

The first project for the production of 1 MTPA green hydrogen is being implemented in phases in Gujarat, with production from the initial phase expected by FY 2027. ANIL aims to increase its green hydrogen capacity to 3 MTPA over the next 10 years.

ANIL's green hydrogen generation includes production of downstream derivative products such as green ammonia, green methanol, and sustainable aviation fuel, among others.

Varun Gogia, Assistant Vice President, ICRA Ratings, says the successful execution of the proposals will enable the ports to achieve their net-zero targets while also aiding emission cuts by industries in the hinterland. However, given that green hydrogen and its derivatives cost way higher than conventionally produced grey hydrogen, the progress on the announced projects remains to be seen.

The setting up of green hydrogen manufacturing, storage, and bunkering facilities may enable Indian ports to increase direct port calls as shipping lines may prefer a source of clean fuel for their onward journey, thereby aiding overall reduction in emissions, Mehta said.

Green hydrogen is seen critical for the country's future energy security. Currently India spends over $160 billion on energy imports, which are likely to double in the next 15 years without an alternative solution. With the approval of the Kutch projects, the stage is set for India to become a global champion of green hydrogen production.

[3] NGEL is a wholly-owned subsidiary of NTPC and aims to be the flag bearer of NTPC's renewable energy journey, with an operational capacity of over 3.4 GW, and 26 GW in the pipeline, including 7 GW under implementation.
GSPC is one of the largest gas trading companies of India, engaged in exploration, development and production of oil and natural gas.
GPPL is one of the leading private ports of India promoted by A.P.Møller – Mærsk A/S which currently has the handling capacity of 1.35 million TEUs of containers, 4-5 million tons of dry bulk cargo, 2 million tons of liquid cargo and about 250,000 cars per year.

Though it will be interesting to see who will be the first mover — DP or the Adani Group — in setting up a green hydrogen project.

NTPC's Initiatives

As per a press release in January 2024, NTPC Green Energy Ltd (NGEL)[3] has entered into MoUs with Gujarat State Petroleum Corporation Ltd. (GSPC) and Gujarat Pipavav Port Ltd. (GPPL) during the Vibrant Gujarat Global Summit 2024. The MoU with GPPL aims for the blending of green hydrogen in the gas networks of GSPC, and the promotion of green hydrogen mobility by setting up green hydrogen fueling stations in Gujarat. The MoU was exchanged between CMD, NTPC, Shri Gurdeep Singh and MD, GSPC, Shri Milind Torawane; in the presence of Chief Minister of Gujarat Shri Bhupendrabhai Patel; Minister of Finance, Energy & Petrochemicals, Government of Gujarat, Shri Kanubhai Desai; Member, NITI Aayog, Dr. V.K. Saraswat, and other senior officials and international delegates.

The MoU with GPPL aims to develop a green hydrogen ecosystem including production of green ammonia for export and the domestic market, at the land provided by GPPL. It also aims to explore the development of Pipavav Port as an anchor port by NGEL for exploration, development and operations of offshore wind farms in Gujarat. The MoU was exchanged between GM-Hydrogen, NTPC and MD of APM Terminals, Pipavav.

In another initiative, NTPC Limited has initiated blending of green hydrogen up to 8% (vol/vol) in the PNG network at NTPC Kawas Township, Surat, Gujarat from January 2023.

Energy Transition

By 2030 the plan is to develop green hydrogen production capacity of at least 5 MTPA in India, with an associated renewable energy capacity addition of about 125 GW at an investment of over Rs. 8 lakh crore. This is expected to lead to a cumulative reduction in fossil fuel imports by over Rs. 1 lakh crore and abatement of nearly 50 MT of annual greenhouse gas emissions.

Sources: egov.eletsonline.com, Times of India, The Hindu

Green Hydrogen: Enabling Measures Roadmap for Adoption in India

This INSIGHT REPORT, published in January 2024 as a collaborative effort between the World Economic Forum (WEF) and Bain & Company, is based on extensive interactions with stakeholders and experts, who provided on-the-ground insights into the current status of India's burgeoning green hydrogen economy.

India is currently the third-largest economy in the world in terms of energy needs, and the country's demand for energy is set to surge – demand is estimated to grow 35% by 2030[1]. In 2022, India's energy import bill was $185 billion[2], a figure that is sure to rise if the country continues to supply its growing energy demand through traditional methods.

At the same time, India set a commitment to achieve net zero by 2070 at the United Nations Climate Change Conference in Glasgow (COP26), held in 2021. At the Glasgow summit, India's prime minister, Narendra Modi, said: "Today the whole world believes that India is the only big economy which has delivered both in letter and spirit on the Paris commitment. We are making every effort with determination[3]."

Key provisions in the National Green Hydrogen Mission

Overview of National Green Hydrogen Mission

- Clearly articulated targets for production of 5 MMTPA of green hydrogen by 2030
- $2.3 billion planned outlay as part of National Green Hydrogen Mission, of which $2.1 billion is committed to SIGHT programme for incentivizing green hydrogen production

SIGHT programme ($2.1 billion)		Other initiatives ($0.2 billion)
Direct green hydrogen incentive ($1.6 billion) Direct production incentive up to **$0.5/kg** hydrogen for three-year period Scheme deployment period: **financial years 2026–2030**	Electrolyser production-linked incentive ($0.5 billion) Base incentive at **$54/kW** in Year 1 to taper to $18/kW by Year 5 Scheme deployment: **financial years 2026–2030**	**$0.15 billion** outlay on pilot projects **$0.05 billion** committed for R&D
Enabling measures		
Cost reduction **25-year waiver** on renewable energy interstate transmission charges	Export infrastructure Port authorities to provide land for **storage bunker** set-up	Other incentives Renewable energy consumed for green hydrogen production included in **RPO compliance** of consumer

Note: Strategic interventions for Green Hydrogen Transition (SIGHT) programme under the National Green Hydrogen Mission; RPO: renewable purchase obligation (RPO) is the requirement mandated by central/state regulatory commission
Source: NITI Aayog; RMI analysis; Bain & Company analysis; Indian government websites (e.g. Government of India, Ministry of Petroleum and Natural Gas – MoPNG); literature search

[1] IEA, India Energy Outlook 2021, February 2021: https://www.iea.org/reports/india-energy-outlook-2021

[2] Government of India, Ministry of Statistics and Programme Implementation, Energy Statistics India – 2023, March 2023: https://www.mospi.gov.in/sites/default/files/publication_reports/Energy_Statistics_2023/EnergyStatisticsIndia2023.pdf

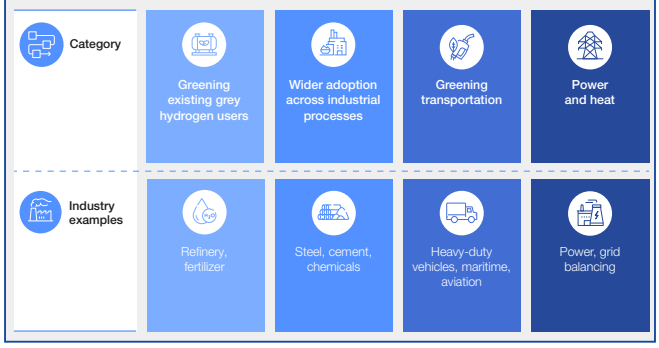
[3] Government of India, Ministry of External Affairs, "National Statement by Prime Minister Shri Narendra Modi at COP26 Summit in Glasgow", 2 November 2021: https://www.mea.gov.in/Speeches-Statements.htm?dtl/34466/National+Statement+by+Prime+Minister+Shri+Narendra+Modi+at+COP26+Summit+in+Glasgow.

[4] India.gov.uk, Ministry of New and Renewable Energy, "National Green Hydrogen Mission": https://mnre.gov.in/nationalgreen-hydrogen-mission/.

Green hydrogen is critical to help meet India's energy security needs while reducing emissions in hard-to-abate sectors on the path to net zero. Recognizing this, the Indian government launched the National Green Hydrogen Mission in early 2022. The aim is to spur green hydrogen production and consumption through roughly $2.3 billion in incentive funding, to be distributed between 2022 and 2030.[4]

Currently, India produces 6.5 million metric tons per annum (MMTPA) of hydrogen, predominantly for use in crude-oil refineries and fertilizer production. Most of the country's current hydrogen supply is grey hydrogen, which is produced using fossil fuels in a process that creates CO_2 gas emissions.

Key sectors driving green hydrogen adoption in India



Source: Bain & Company analysis

The National Green Hydrogen Mission set a target for the production of 5 MMTPA of green hydrogen by 2030 — equivalent to roughly half of India's projected overall hydrogen demand of 11 MMTPA at that time. Green hydrogen production requires an ample supply of renewable energy for the electrolysis process.

Fortunately, India's renewable energy potential can support its goals for green hydrogen growth but needs rapid capacity addition – additional capacity is required to generate green hydrogen as well as to meet the country's electricity needs. The country's solar energy potential alone is estimated at 748 gigawatts (GW) at full capacity[5]. Currently, total installed solar capacity in India sits at 70 GW, or 9% of its total potential.

However, there is limited on-the-ground traction for green hydrogen in the country, and interviews with important players indicate that most are in a "wait-and-watch" phase. Many expect sizeable production of green hydrogen to take effect beginning in 2027 and after.[6]

Important constraints for the expansion of green hydrogen in India include, on the supply side, the cost

Global green hydrogen derivatives import opportunities and key demand drivers

Territory	2023 GH_2 cost ($/kg)	2030 Target (MMTPA)[3]	2030 Imports (MMTPA)	Demand drivers
EU	6.8[1]	20	~10	A minimum of 42% of hydrogen for industries, to be sourced from renewable energy by 2030. "We want to make Germany and Europe a lead market for green hydrogen. We are therefore launching a first auction procedure for the import of green hydrogen worth €900 million." European Commission, 2022
Japan	8.0	0.4	*N/A*	Japan and South Korea importing green ammonia for co-firing power plants. Hydrogen mobility to rise, long with that of fuel-cell vehicles and refuelling stations. "We have positioned hydrogen as one of the priority areas in the Green Growth Strategy." Ministry of Economy, Trade and Industry, Japan, 2021
Singapore	6.6[2]	*N/A*	1–1.5	To be used as a low-carbon fuel across maritime, aviation and road transport. Green ammonia to be imported for blending with fossils to achieve net-zero target. "Singapore believes that low-carbon hydrogen has the potential to be the next frontier of our efforts to reduce our emissions." Deputy Prime Minister, Singapore, 2022

Notes: 1. Prices include subsidies; 2. price for low-carbon hydrogen; 3. targets for low-carbon hydrogen consumption.
Source: Bain & Company analysis; secondary research

Disparity among renewable standards affects demand for green hydrogen (voluntary market mechanisms with published technical criteria [IRENA])

Country	Production method	Year issued	Carbon threshold (kg CO_2e/kg H_2) to qualify as clean or green hydrogen
India	Renewable electricity (electrolysis and conversion of biomass)	2023	2.0
China	Renewable electricity; low-carbon electricity	2023	4.9 (threshold for "low-carbon" hydrogen is different)
International (Voluntary standard by Green Hydrogen Organisation)	Renewable electricity	2022	1

Note: Emissions threshold refers to the maximum permissible emissions limits for various standards to qualify as low-carbon and/or green hydrogen.

Source: Renewable Energy Institute, *Revised Basic Hydrogen Strategy Offers: No Clear Path to Carbon Neutrality*; IEA, Ministry of New and Renewable Energy, "Green Hydrogen Standard for India"

[5] Government of India, Ministry of New and Renewable Energy, "Solar Overview": https://mnre.gov.in/solar-overview/.
[6] Inputs from primary interviews; for this report: 1 INR = ~$0.012, as of 24 November 2023.

Key goals and recommendations to accelerate a green hydrogen ecosystem in India

Supply

Landed cost of green hydrogen needs to be less than or equal to $2/kg (parity with grey hydrogen)

1 Landed cost of round-the-clock (RTC) renewable energy (RE) to be lower than INR 2 (~$0.02)/kWh; support rapid decrease in electrolyser costs

Minimize cost of landed RTC RE

Cost of storage: Reduce through monetary incentives

Banking accessibility: Make available across the country and clarify norms/processes

Transmission and distribution charges: Reduce intrastate/ wheeling charges across all states (only for select few currently)

Rapidly bring down electrolyser cost

Subsidies: Increase quantum for early adopters ($50/KW insufficient)

Capex IRR: Increase duration of incentives, beyond five years for the much longer capex cycle of electrolysers

Tech discovery: Encourage R&D for electrolyser tech suitable for India (e.g. AEM, SOEC)

2 Eliminate or reduce the cost of conversion/ reconversion, transportation and storage

Optimize conversion costs

R&D: Create incentives to develop R&D/pilots for local tech

Reduce transportation costs

Pipelines: Finance creation of hydrogen pipelines in the long term

Reduce storage costs

R&D: Create incentives to develop R&D/pilots for local tech (e.g. type 3 and 4 cylinders)

Clusters: Encourage collaboration between peers so that production and offtake takes place in clusters; this minimizes the need for enabling infrastructure

Allow/encourage companies to form clusters and bid for PLIs/other incentive schemes Benefits such as quick clearances for clusters

Share success stories through a national platform

Demand

Demand to be enabled by supporting industries in the short term and disincentivizing carbon-intensive alternatives in the long term

3 Enable domestic demand through a staggered approach of supporting end-user industries

1. Greening existing hydrogen users (refining, fertilizer)
   - Increase direct subsidy ($0.50/kg is insufficient for early adopters)
   - Institute strategic demand-side mandates (balance the volume of green hydrogen while factoring in economic considerations)
2. Adoption across industrials (steel, cement)
   - Provide CapEx support (e.g. faster depreciation, discounted land) Launch standards for green hydrogen by-products (e.g. green steel) Support in energy tech migration
3. Greening transportation (HDVs, maritime, aviation)
   - Launch standards (e.g. for fuel cell) Support R&D and pilots
4. Energy (power, cement)
   - Support R&D and pilots for blending with existing energy

4 Capitalize on India's export potential

Standards: Work with other countries/ global organizations to develop harmonized global standards (and/or the ability to certify green hydrogen made in India according to importers' norms)

Export infrastructure: Develop conversion and storage facilities at ports

Export economy: Convene MoUs/ bilateral agreements with potential importers to enable export from India

5 Capitalize on India's export potential

Divert subsidies for carbon- intensive fuels to support green hydrogen

Enable carbon tax/ carbon credits mechanism and use the collections to fund energy transition pathways

Source: 20+ interviews with industry players and Indian government agencies; Bain & Company analysis

Enabling measures roadmap

Goal		Enabling measure	Near term CY24–26	Medium term CY27–30	Long term CY31–50
Reduce the cost to produce green hydrogen to less than $2/kg		Cost of energy storage system needs to reduce rapidly	←	—	→
		Consistency can be established across state transport/distribution charges	←	—	→
		Subsidies can be awarded to early adopters	←		
		Long-term policy views can reduce the risks of capital investment	←		
		R&D can support electrolyser technologies that are attuned to India's needs		←	→
Reduce or eliminate costs related to green hydrogen conversion, storage and transportation		Scaling of transportation and conversion/reconversion infrastructure is needed		←	→
		Build technology and infrastructure for green hydrogen storage		←	→
Support industries that are most likely to adopt green hydrogen	**Category 1:** Greening existing grey hydrogen users	Reduce the cost of green hydrogen for existing grey hydrogen users	←	—	
	Category 2: Wider adoption across industrial processes	Investment risk could be reduced for industrial players who make capital commitments for new plants		←	→
		Green hydrogen by-products standards can be set	←	—	
	Category 3: Greening transportation	Facilitate support for R&D/pilots		←	→
		Establish hydrogen mobility technology standards		←	
Capitalize on India's export potential		Greater participation in multilateral initiatives with potential importers	←	—	→
		Development of port infrastructure for green hydrogen derivative exports	←		
		Harmonized global standards and certification mechanisms	←		
Disincentivize carbon-intensive alternatives		Penalties on usage of carbon-intensive alternatives can be enacted, with plans to use collected funds to finance the green hydrogen economy and other transition pathways		←	→

Source: Expert interviews and Bain & Company analysis

contd on pg 18

NTPC's Initiative: India's 1st Green Hydrogen Blending Project in Gujarat

Lakshmanan D, Senior Manager, (NTPC RE Hydrogen Energy)

Introduction

To minimize climate change effects and reduce the usage of natural gas, hydrogen blending is being investigated as a potential solution across the globe.

With the continued focus on clean environment, NTPC has taken up India's first green hydrogen blending project in the piped natural gas (PNG) network of NTPC Kawas. The NTPC Kawas township cluster consists of 200 households with a natural gas requirement of 100 scmd.

Earlier the customers were using liquified petroleum gas (LPG) connections for their domestic cooking applications. Then new PNG pipelines were laid in the township for this project and connected to the main trunk line between the Hazira-Surat CGD network of Gujarat Gas Limited (GGL).

Project Description

The hydrogen blending project includes an electrolyser, blending skid, and hydrogen storage *(refer Fig 1)*. Green hydrogen is produced using electricity during sunshine hours from the existing 1 MW floating solar project of NTPC Kawas. Hydrogen is stored in a cylinder cascade for providing continuous supply of hydrogen for its blending. The hydrogen blending skid ensures blending of hydrogen gas at a pre-determined blending ratio, irrespective of variation in the PNG consumption rate.

Major components of the project are:

- Hydrogen generation system of 1 scm/hr (6.5 kW) output PEM electrolyser.
- Storage capacity (13 scm) of 16 hours of hydrogen supply at 30 bar.
- Hydrogen blending skid for blending hydrogen into PNG at different levels (5-20%).
- Control and power system for stable and safe operation.

Special features of this project are the **import substitution of LNG** and **decentralized decarbonization** of gas-based end-use application.

Project Status

The Hon'ble Prime Minister of India laid down the foundation stone for this project in July 2022. On 2 Jan 2023, the first molecule of green hydrogen from the project was set in motion with 5% v/v of hydrogen blending with PNG with statutory approval from Petroleum and Natural Gas Regulatory Board (PNGRB).

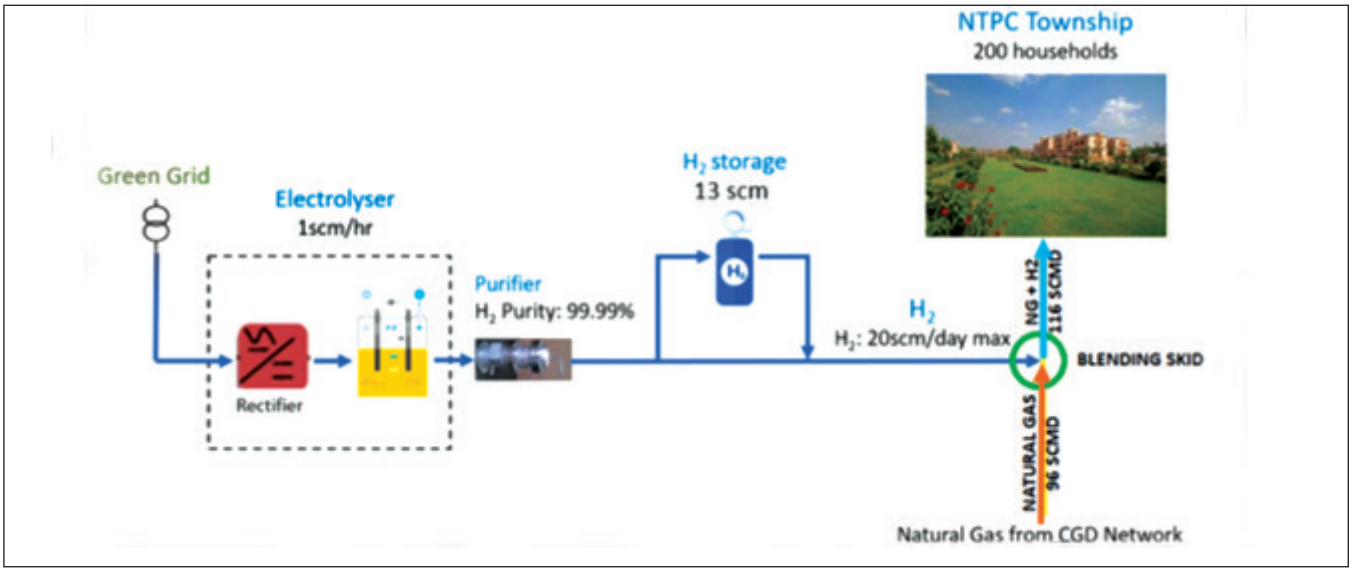


Figure 1: Scheme of hydrogen blending with PNG

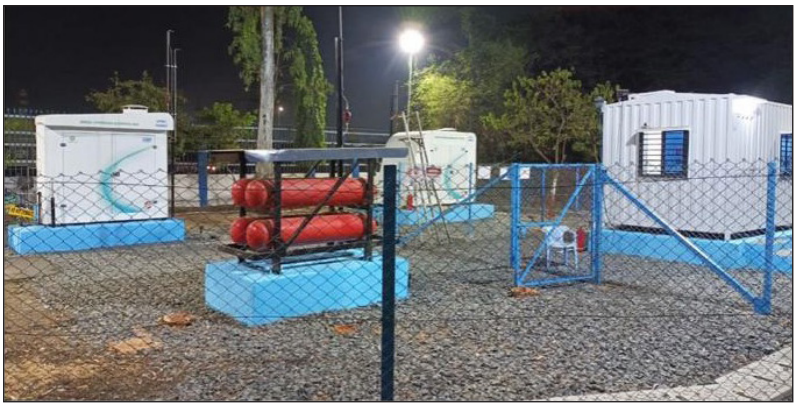


Figure 2: Project view at NTPC Kawas

While this unit is in continuous operation, NTPC has assigned the third-party consultancy and research firm M/s GERMI to carry out the gas homogeneity test to preclude the separation of hydrogen with natural gas, and conduct gas path material properties assessment on the blended gas network. This is to understand the performance of hydrogen blending and impact on the gas network components.

M/s GERMI is also providing periodic training to all users to educate them in all aspects of safety in domestic applications and to conduct consumer perception surveys at periodic intervals.

With rigorous assessments, testing and surveys for a period of 10 months, the outcome of the studies confirmed there was no degradation in the pipelines, sealing materials, or burners. There was no separation of hydrogen in the blended gas and this is ensured in the vertical pipeline at stagnated condition for 48 hours. During the continuous operation, gas homogeneity measurement is being the carried out at two most susceptible locations i.e., farthest point from the blending skid, and the highest point of the gas network with reference to the source of blended gas at the skid.

As a safety practice, mercaptan gas as odouriser is usually added to PNG and LPG to give it a distinctive smell. When hydrogen is added, there may be a possibility that concentration of mercaptan gas may come down below the detectable limit of human sensory capability. The concentration of the odourant gas was measured at the blending unit and at the burner outlet also, to confirm that no dilution effect in the odourant gas exists in the blended gas.

In this exercise, various training programs and surveys are being conducted to educate the users and to obtain their feedback on the hydrogen blending.

PNGRB is being appraised continuously on the performance of the hydrogen blending system. The experienced gained from this project was shared with all stakeholders through PNGRB.

With the satisfactory performance at 5% v/v level and the robustness of engineering design, PNGRB has granted an approval for the increase in hydrogen blending to 8% v/v on 3 Nov 2023. The system has already completed three months of operation with the enhanced blending level.

This testing schedule as elaborated above was also carried out for this increased blending level and will be carried out for pilot operation of three years.

Highlights

Typically, in domestic usage, there will be huge variations and spikes in the natural gas consumption during cooking in the morning, afternoon and evening hours. To ensure the safe, reliable blending of hydrogen into the PNG network during the peak and off-peak periods in the same proportion, the best practices in the industry have been incorporated in the system. These are:

1. Actively monitor pressure regulators.
2. Ultra-low flow, high accurate control valve with PID controller.
3. Static inline mixer for complete mixture of hydrogen.
4. Hydrogen analysers and indigenous gas leak detectors.

Discussion

With the positive results obtained so far, it is expected NTPC will be able to demonstrate safe and functional operation at higher levels of blending also, with approval of the regulator. Considering the natural gas consumption of 100 scmd at NTPC Kawas with 20% v/v hydrogen blending, the reduction in natural gas consumptions is targeted by 8 scmd and the carbon mitigation is of 6 TPA.

At present, there is a restriction of 2% v/v hydrogen content in natural gas in the CNG network. Considering the present natural gas consumption of India in the CGD[1] network of 35 MMSCMD, the reduction in natural gas consumptions with 2% v/v hydrogen blending is

Figure 3: Kawas HoP P Ram Prasad starting the green hydrogen injection into PNG network of NTPC Kawas Township

0.25 MMSCMD and the carbon mitigation potential is 0.2 MMTPA. Also, the cost increases marginally to the tune of merely 1.5% of existing costs.

With the sound engineering configuration developed for this NTPC Kawas project, the same can be readily adopted by other gas operators with minimal changes to have quicker adoption across the country.

This project has the unique distinction of being India's highest level – 8% v/v – hydrogen blending into the natural gas network. Globally, a few countries like the UK, Germany, USA, and Australia have tried blending at various levels of blending ratios. In Australia, the HyPSA-Hydrogen project is currently in operation with 5% v/v of hydrogen blending. In the UK, HyDeploy projects at Keele University and Winlaton have carried out hydrogen blending at 20% v/v and found no impact in the gas networks. In Germany, the Erftstadt Hydrogen project has demonstrated hydrogen blending upto 20% v/v and found no technical problems with residential gas appliances.

In India, GAIL has initiated blending, and a few companies like OIL, Adani and Torrent have announced their intentions to do so shortly.

In India, when this is adapted in mass scale, significant import substitution is possible with minimal cost implication to the consumers. This successful hydrogen blending project at NTPC Kawas is a torch bearer in the domain.

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[1]CGD refers to City Gas Distribution, which is a combination of PNG and CNG. PNG is for domestic and industrial heating uses while CNG is for transportation use. In India more than 42% users are in the PNG category.

contd from pg 15... Green Hydrogen

of production and delivery, and, on the demand side, Indian players' readiness to consume green hydrogen in traditional industrial processes.

Supported by in-depth analysis of cost and demand drivers of green hydrogen, as well as interviews with industry players and government agencies, this report proposes five goals that, if met, can accelerate the offtake of green hydrogen in India. These goals can provide impetus to the green hydrogen demand-and-supply ecosystem by aiming to achieve the following:

– On the supply side, a cost of $2/kg of hydrogen to reach cost-parity with grey hydrogen

– On the demand side, enabling end industries to offtake green hydrogen by creating incentives for its use

Disclaimer: Information included in this report is current as of October 2023 and may not reflect developments that occurred after that time. Photographs have been sourced from this report.

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National Green Hydrogen Mission Initiatives: An Update

The Ministry of New and Renewable Energy (MNRE) has issued guidelines for setting up green hydrogen hubs under the NGHM. The mission envisages to identify and develop regions capable of supporting large-scale production and/or utilization of hydrogen with CFA for developing the core infrastructure.

A scheme implementing agency nominated by MNRE will invite proposals for the projects. The projects will be evaluated based on the planned production capacity (weightage 50%), technology, applications and end use (weightage 20%), and financial commitment (weightage 30%). Evaluation of proposals on this assessment criteria will be given a weightage of 80% with the balance 20% on the basis of the presentation made before the evaluation committee. The letter of award will be issued to the executing agency upon administrative sanction from MNRE.

The CFA will be disbursed to the winning projects as follows: 20% on the date of issue of administrative approval, 70% based on milestones achieved, and 10% on the completion of construction and commissioning.

Green Hydrogen Hubs in India

Under the National Green Hydrogen Mission (NGHM), at least two green hydrogen hubs will be set up by FY 2025-26 with central financial assistance (CFA) of Rs 200 crore for creating the core infrastructure. Each of the hubs will have a production capacity of at least 100,000 mtpa.

An Acme green hydrogen plant in Bikaner, Rajasthan (Source Image: Acme Group)

The objective of the NGHM is to identify and develop regions capable of supporting large-scale production and/or utilization of hydrogen; develop green hydrogen projects in the hubs in an integrated manner to allow pooling of resources and achievement of scale; enhance the cost-competitiveness of green hydrogen and its derivatives; encourage large-scale utilization and export of green hydrogen and its derivatives; and enhance the viability of green hydrogen assets across the value chain.

The core infrastructure to

be supported includes storage and transportation facilities for green hydrogen and its derivatives, pipeline infrastructure, green hydrogen-powered vehicle re-fuelling facilities, hydrogen compression and liquefaction technologies, hydrogen storage systems, water treatment and storage facilities, bunkering facilities in case of ports, infrastructure upgradation for shipping, power transmission infrastructure to the nearest existing grid substation, land re-development, energy storage to manage renewable energy intermittency, effluent treatment plants, etc.

Skill Development Scheme

The government is set to roll out a training program aimed at bridging the skills gap in the emerging green hydrogen sector, as per the directives issued by MNRE. The scheme will involve comprehensive skill gap analysis, the creation of a registry of required skills, and the development of curricula for schools, industrial training institutes (ITI), polytechnics, and higher education institutions (HEIs).

The ministry emphasizes learner-centric training programs to be developed in consultation with the Ministry of Skill Development and Entrepreneurship (MSDE).

Key objectives include the facilitation of one or more model Centres of Excellence (CoEs) for higher-level skilling, and support content creation on the green hydrogen ecosystem. The program will deploy training that includes placement tracking, targeting diverse educational institutions, and encouraging private sector participation, especially for On-the-Job Training (OJT).

According to the ministry, the implementing agency for this scheme will be notified by MNRE in consultation with MSDE. The green light for the program comes with the approval of the Minister of Power and New and Renewable Energy Shri R.K. Singh.

R&D Scheme

MNRE also issued a notice on March 15, 2024, in respect of the Implementation of the Research & Development (R&D) Scheme under the NGHM, as sanctioned by the President of India.

The objectives of the scheme are multi-faceted, aiming to increase the affordability of green hydrogen production, storage, transportation, and utilization while enhancing the efficiency, safety, and reliability of relevant systems and processes. Moreover, the scheme seeks to foster industry-academia-government partnerships to establish an innovation ecosystem for green hydrogen technologies and facilitate scaling up and commercialization of technological advancements with the provision of requisite policy and regulatory support. The scheme will be implemented according to detailed guidelines provided on MNRE's website, ensuring a structured approach towards achieving its objectives.

Funding for the scheme will be met from the budget provisions allocated under the NGHM Head, underscoring the government's commitment to investing in sustainable and eco-friendly energy solutions.

This decision comes in the wake of increasing global efforts towards transitioning to clean energy sources and reducing carbon emissions. The implementation of the R&D scheme signifies India's proactive stance towards embracing green hydrogen technology and driving innovation in the field of renewable energy.

MNRE has also announced the Scheme Guidelines for implementation of "Strategic Interventions for Green Hydrogen Transition (SIGHT) Program – Component I: Incentive Scheme for Electrolyser Manufacturing Tranche – II" under the NGHM, in March 2024.

Source: MNRE (https://mnre.gov.in/national-green-hydrogen-mission/)

Country Update: Brazil

COUNTRY PROFILE

Endowed with plentiful sun and wind, with geographic advantages for export to Europe and the United States, as well as considerable domestic demand, Brazil has the opportunity to become one of the world leaders in the production of green hydrogen (GH2). The production of GH2, financed by both Brazilian and international investors, and supported by international cooperation from Germany, the Netherlands, World Bank and the EU, is taking place throughout the country, with more than 40 projects underway. Brazil's largely renewable, and integrated, electricity grid - powered by hydro, wind and solar - is fuelling green hydrogen production. Further, the generation of green hydrogen with sugarcane ethanol provides another big opportunity.

The strong potential for offshore wind generation in Brazil has also captured attention and investment opportunities. At least 88 licence applications are pending for projects across the length of Brazil's coastline, and partnerships with the Netherlands, Denmark, Norway and the United Kingdom are in train. Offshore wind is expected to be a strong contributor to green hydrogen production. Many GH2 operations have already been established in close proximity to future offshore wind farms, particularly in the north-east of Brazil.

The lack of a legal framework and regulations for both green hydrogen and offshore wind power generation is preventing faster progress. However, Bills covering both sectors are currently being considered by Congress and are expected to be passed in 2024. High production costs (despite relatively cheap electricity in Brazil), infrastructure for transportation and storage, and certification of "green" credentials are potential barriers to the success of the green hydrogen sector. However, these are not insurmountable.

Renewable Energy Powerhouse

Brazil is a clean energy powerhouse with an abundance of renewable sources, including hydro, biomass, wind and solar. As such, the country – the third biggest producer of renewable electricity in the world – is well positioned to play a leading role in the global energy transition and to meet increasing demand for GH2. The vast majority of Brazil's electricity is generated from renewable sources (a record of 93% in 2023) and 45% of the country's overall energy is from renewables, making it one of the cleanest grids in the world. While hydro-electric generation is the primary renewable source, wind and solar capacity has been increasing in recent years; of 7 GW installed capacity expansion between January and August 2023, 6.2 came from wind and solar. As an international leader in ethanol production with the potential to become a "green Saudi Arabia" (according to one Brazilian energy commentator), Brazil is also exploring opportunities for generation of green hydrogen from this energy source.

Strong Start

The first molecular hydrogen production facility in Brazil was launched in the north-eastern state of Ceará in January 2023, drawing on electricity from Brazil's integrated grid. An investment of USD8.4 million, the project is the initiative of EDP, one of the country's largest power companies, with support from both the federal and state governments. This pilot project is not unique, with a number of green hydrogen projects being developed in Brazil that could account for investment of more than USD30 billion according to the Brazilian Institute of Clean Energy. A mapping exercise conducted by H2 Brasil, a project funded by Germany that aims to establish a hydrogen economy in Brazil, in 2022 identified 42 green hydrogen production projects of different sizes and stages of development. Most initiatives are in early phases, such as the signing of memoranda of understanding (Ceará alone has signed more than 30 MOUs) and feasibility assessments. However, some are in the implementation stage with pilot and commercial plants under operation.

One of Brazil's most advanced green hydrogen

endeavours is located in Bahia, also in the north-east of the country. The commercial plant, a venture between Unigel (a Brazilian petrochemical company) and Petrobras (Brazil's state-owned oil and gas enterprise), will enter in operation this year (also using electricity from the grid, which is 80-90% renewable in the state of Bahia) and will have the capacity to produce 10 thousand tons of green hydrogen per year initially, with plans to eventually quadruple production. The hydrogen will be stored as green ammonia, with 10 tons of green hydrogen converting to 60 thousand tons of green ammonia - currently considered the most cost-effective way to store and transport green hydrogen. Another Brazilian company White Martins, one of the largest producers of "grey hydrogen" (generated from fossil fuels – in this case, natural gas) in the country, is also investing in the green version. The company started small-scale production – using solar energy – in Pernambuco in December. It expects to produce 156 tons per year. Other green hydrogen initiatives are in train, including one to supply green hydrogen as fuel for electric vehicles.

International companies are also establishing large-scale green hydrogen investments in Brazil. The Australian mining company Fortescue has pledged to invest USD5 billion in a major green hydrogen production facility in the Port of Pecém in Ceará, and recently received approval for its environmental impact assessment (the first of its kind). Production is due to commence in 2027 and the plant will produce 300,000 tons per year, to be converted to green ammonia for export to international markets.

Stakeholders in Brazil are also assessing the feasibility - including costs and carbon footprint - of producing green hydrogen from ethanol. This clean fuel, produced from sugarcane biomass, has been used widely across Brazil for more than 40 years and has a high hydrogen content (six atoms compared to two in water), thus making it a strong candidate for GH2 production. Shell plans to invest USD10 million in GH2 production from ethanol in the next two years, with a pilot fuelling station for electric vehicles at the University of Sao Paulo planned to enter in operation in 2024.

In addition to Bahia, Ceará and Pernambuco in the north-east, the states of Rio de Janeiro and Rio Grande do Sul further south are ramping up their GH2 production capacity. All five states have industrial ports, which offer competitive advantages such as proximity to export infrastructure, and potential customers in industrial zones.

Strong Comparative Advantage & International Support

A study conducted by McKinsey placed Brazil as the second most competitive place in the world to produce green hydrogen (after Chile and ahead of the US and Australia). Brazil's high capacity for renewable energy generation at a comparatively low cost (Brazil has a low levelized cost of energy [LCOE][1] for solar and wind) is a big factor in Brazil's favour, given 70% of hydrogen production costs are energy inputs. Brazil's interconnected electricity system provides an additional advantage as hydrogen plants can make use of the existing grid, reducing the need for capital investment. According to H2 Brasil's mapping project, Brazil's green hydrogen value chain is also well developed, comprising more than 800 companies and institutions in diverse sectors across the country.

In addition to strong supply, Brazil is in a good position in terms of demand, which could generate USD15-20 billion in revenue by 2040 according to McKinsey and USD30 billion by 2050 according to Roland Berger. There is high interest in the production of green hydrogen in Brazil for export, particularly from the EU, which aims to import 10 million tons of GH2 by 2030. However, McKinsey estimates that about two thirds of GH2 revenues will come from the domestic market given potential high demand from energy-intensive industries such as steel, pulp and paper, and chemicals as well as the agricultural and transport sectors. In addition, Brazil is highly import-dependent for fertiliser supply (80% is imported), so green ammonia could provide a potential way out of this dependency.

As well as strong interest from the international private sector, Brazil has support from international partners to develop its green hydrogen sector. Germany and Brazil have had an Energy Partnership since 2008, with an active working group on GH2. Brasilia and Berlin also work together on the German-funded project H2Brasil, a EUR34 million investment that aims to support the legal, institutional, and technological development of the green hydrogen sector, and the GH2 taskforce, which links companies and institutions to share knowledge and experience. Both collaborations have

[1] *Value of the total cost of building and operating a power plant over an assumed lifetime (U.S. Department of Energy, 2018)*

supported a number of initiatives including fact-finding missions and a mapping of the Brazilian green hydrogen sector.

The Netherlands is also active in the sector. In May 2023, during the visit to Brazil of Prime Minister Mark Rutte, the Netherlands signed an agreement with the state of Ceará to create a Green Hydrogen Corridor between the ports of Pecém and Rotterdam as well as a Green Ports Partnership. Further, a Dutch-Brazilian consortium led by the Trans Hydrogen Alliance plans to invest USD2 billion in a hydrogen production project in Pecém. In June 2023, during her visit to Brazil, President of the European Commission Ursula von der Leyen announced that the EU would invest EUR2 billion in green hydrogen in Brazil, with a focus on energy efficiency in the industry.

But challenges remain

The development of green hydrogen in Brazil has the potential to generate jobs, introduce leading-edge technologies, and attract substantial investment, as well as integrate Brazil into global value chains. Brazilian Finance Minister Fernando Haddad has noted that the low-carbon agenda has the capacity to boost Brazil's economy through "reindustrialisation"– the central economic goal of the current administration.

Barriers & Challenges

However, there are various barriers to green hydrogen succeeding in Brazil. The key challenge is the production cost. Despite Brazil's cost-effective LCOE for solar and wind, currently grey hydrogen is cheaper to produce than green hydrogen. For GH2 to be competitive, the price of electricity generated from renewable sources needs to be cheaper than that of electricity produced from fossil fuels. Green hydrogen's low volumetric energy density compared to other energy carriers also poses a challenge for the transportation of the material. Due to its volume, storing and transporting GH2 requires large, specialised tanks to hold the gas under pressure. This will require substantial investment. The Brazilian Solar Energy Association estimates that investment in the development of green hydrogen in Brazil could reach USD200 billion over the next 15 years - most of it directed towards infrastructure.

The certification of hydrogen as "green" may also create future challenges for Brazil. There is currently no specific international criteria for H2 to be considered green; however, potential criteria include production from renewable energy sources, guarantees of origin and actual reduction in emissions levels. Depending on the criteria agreed upon, Brazil may not be able to use its integrated grid (which includes a small percentage of fossil-fuel generated electricity) to produce green hydrogen, losing one of its competitive advantages. Hydrogen produced from ethanol may also not be considered green, given the environmental impacts of the production of this biofuel.

In addition, Brazil still lacks a comprehensive government strategy and legal framework for green hydrogen, in contrast to Chile, Germany and the United States. In 2022, the government published the "Brazilian Programme on Hydrogen" with six key objectives, including the establishment of a legal framework and guidelines for the sector. A Three-Year Action Plan followed, which was updated by the Lula administration in August last year, including the introduction of regulations to govern the sector set as top priority. The Lower House of Congress has approved a bill creating regulations for the production of low carbon hydrogen, which is now awaiting Senate approval. Attempts were made to include tax incentives for the sector in the bill but were ultimately removed by the Senate at the request of the executive, who cited a lack of funds to implement such tax breaks.

International financial institutions are also supporting the sector. Since 2019, the World Bank has assisted Brazil in evaluating its offshore wind power potential through events and studies. At COP28, the World Bank and the Brazilian Development Bank (BNDES) announced an investment partnership in green hydrogen, with the former establishing a credit line of up to USD1 billion to support GH2 projects in Brazil.

Opportunities for cooperation between Brazil and New Zealand in this area include sharing knowledge and experiences about the reuse of gas infrastructure, transportation, and storage for green hydrogen, as well as new techniques regarding its use and production. Companies with expertise in the fossil-fuel industry, transferable to this sector, such as pipeline-coating solutions and valves, seals, and pump developers, are in a good position to break into the market, as are infrastructure companies and shipyards.

Prepared by the New Zealand Embassy in Brasilia
www.mfat.govt.nz/market-rep

ABOUT COGEN INDIA

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

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

Key Action Areas

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

Activities

- Inaugural launch of National Cogeneration Awards-2022, followed by National Cogeneration Awards-2023, and announcement of the 2024 Awards (www.cogenawards.com)
- Successful organization of webinars, training programs/business meets/field visits in sugar, rice, distillery, paper, food processing, bio-power, waste to energy sectors, etc.
- Quarterly (English) newsletter "Industrial Cogeneration India" - A unique forum for distribution of technical and sectoral information in India/Abroad
- Marathi Bi-monthly newsletter "Nisarg Urja"- Appropriate to the aims and objectives of the association

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

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

Hydrogen Association of India (hai.org.in)

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

HAI aims to:

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