HYDROGEN INDIA

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Editorial

India is making headway under the National Green Hydrogen Mission. Some updates have been provided in this issue, along with a detailed description of the role of Solar Energy Corporation of India Limited (SECI) under the mission.

To maximize the role of biomass in green hydrogen production, India needs an integrated approach. Incentives for biomass-based hydrogen should be established, similar to those for electrolysis-based hydrogen. Infrastructure development is necessary, with decentralized biohydrogen hubs in agricultural regions minimizing transport costs and carbon emissions. Public-private partnerships (PPP) can encourage investment from energy companies and start-ups to develop commercially viable biomass-based hydrogen projects. R&D funding for technologies can accelerate innovations in catalytic gasification and advanced fermentation techniques.

Biomass supply chains can play a pivotal role in India's green hydrogen ecosystem by providing an alternative feedstock that complements renewable energy-driven electrolysis. With the right policy interventions, infrastructure investments, and technological advancements, biohydrogen can emerge as a key pillar in India's clean energy transition. By leveraging its vast biomass resources, India can move closer to its energy security and net-zero emissions goals while creating sustainable livelihoods in rural areas. PRESPL has extensive experience in the biomass sector, and is poised to take this forward and maximise India's biomass potential, as per its article within.

The Xynteo Energy Leap's Clean Hydrogen Innovators continue to "shape the future". Three innovators have been introduced this time, along with two special viewpoints on the "Challenges (and Solutions) in Financing Decarbonization Projects in India", and on the natural hydrogen potential (also known as geological, native, white, or gold hydrogen), which stands out as a promising yet relatively unexplored avenue.

Another viewpoint article on "Solid Hydrogen Logistics: The Missing Piece in the Clean Energy Ecosystem" by the co-founder of Galaxy FCT in Malaysia throws light on the roadblocks and applications of solid hydrogen. In contrast, INOXCVA discusses the potential and future of liquid hydrogen.

As per the Guidelines for Hydrogen Valley Innovation Clusters (HVICs) by the Indian Government's Department of Science and Technology (DST), a hydrogen valley is a defined geographical area where hydrogen serves more than one end sector or application in mobility, industry, and energy. A study was conducted on the 'Development of a Roadmap for a Green Hydrogen Cluster in Ramagundam' under the International Hydrogen Ramp-up Programme (H2Uppp) of the German Federal Ministry for Economic Affairs and Climate Action (BMWK) to promote projects and market development for green hydrogen in selected developing and emerging countries. This study was authored by Deloitte, and published by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH in September 2024, in partnership with Indo-German Energy Forum (IGEF) and the Government of Telangana.

The industrial cluster of Ramagundam in the state of Telangana has been identified as suitable for developing a hydrogen valley. This region has potential for renewable generation, availability of land and water, and some key industries which use hydrogen already, such as fertilizers, refineries, etc. as well as few industries such as coal mines and glass industry, which have future potential of hydrogen use. This set-up minimizes hydrogen transportation and hence negates safety concerns and fugitive energy losses. A brief overview has been provided this time on the current status of this initiative.

Sembcorp Green Hydrogen Pte. Ltd., a wholly-owned subsidiary of Singapore-based energy

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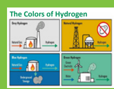


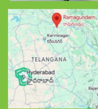

Japan to Finance Energy Projects in India

The Japan Bank for International Cooperation's (JBIC) Governor, Hayashi Nobumitsu, signed on 15 January 2025, a General Agreement to set up a credit line totalling up to JPY120 billion, of which the JBIC portion is JPY72 billion, with Power Finance Corporation Limited (PFC), a government financial institution in India[1].

The credit line is intended to finance, through PFC, the necessary funds for energy projects in India, such as renewable and next-generation energy supply as well as energy-saving power generation and heat supply, as part of Global action for Reconciling Economic growth and ENvironmental preservation (GREEN) operations. Under the GREEN initiative, JBIC has financed projects aimed at preserving the global environment—such as projects that significantly reduce greenhouse gas (GHG) emissions—while propagating advanced Japanese environmental technologies around the world.

PFC is a company owned by the government of India, specializing in offering financial support to the power and infrastructure sector and is an important institution for realizing the government's electricity policy. Through the credit line, JBIC supports efforts made by the government of India and PFC to preserve the global environment.

As Japan's policy-based financial institution, JBIC will continue to financially support initiatives for global environmental preservation by drawing on its various financial facilities and schemes and by performing its risk-assuming function.

In India, the economic growth rate is high, and the demand for electric power is expected to grow. At the same time, however, the country, which is the world's third largest emitter of carbon dioxide, has an urgent need to address climate change. The government of India pledged on the country's Independence Day in August 2021 that India will become "energy independent" by 2047, and at COP26 in November 2021, it committed to realizing carbon neutrality by 2070. It also aspires to achieve 50% cumulative electric power generation from non-fossil-fuel-based energy resources by 2030 as its Nationally Determined Contribution (NDC), an action plan to address climate change under the Paris Agreement. Under these circumstances, the government is introducing renewable energy and promoting countermeasures against climate change, such as the enhancement of green hydrogen production capacity and the dissemination of energy efficiency technologies. In addition, with the launch of the Clean India Mission, the government is focusing on waste-to-energy throughout India.

Courtesy:
https://www.jbic.go.jp/en/information/press/press-2024/press_00122.html

[1]This is the second credit line to PFC, following the first one set up in July 2022.

Shri Sharad Pawar
President
Cogen India

Shri Jaiprakash Dandegaonkar
Vice President
Cogen India

Shri Sanjay Khatal
Director General
Cogen India

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and urban development company Sembcorp Industries (Sembcorp), together with Kyushu Electric Power Co. Inc and Sojitz Corporation, announced Nippon Yusen Kabushiki Kaisha (NYK)1 as a shipping partner for the export of green ammonia to Japan (the Proposed Project). Under the agreement, the partners aim to focus on the supply chain side, and produce "highly competitive" green ammonia in India.

Without financing, these projects cannot move forward. Therefore, it is heartening to note the Japan Bank for International Cooperation (JBIC) signed on 15 January 2025, a General Agreement to set up a credit line totalling up to JPY120 billion, of which the JBIC portion is JPY72 billion, with Power Finance Corporation Limited (PFC), a government financial institution in India. The credit line is intended to finance, through PFC, the necessary funds for energy projects in India, such as renewable and next-generation energy supply as well as energy-saving power generation and heat supply, as part of Global action for Reconciling Economic growth and ENvironmental preservation (GREEN) operations. Under the GREEN initiative, JBIC has financed projects aimed at preserving the global environment—such as projects that significantly reduce greenhouse gas (GHG) emissions.

As we at Cogeneration Association of India continue to bring you exciting 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.

Courtesy:
Cogeneration Association of India

Solid Hydrogen Logistics: The Missing Piece in the Clean Energy Ecosystem

Viewpoint Article by James Khong (Co-founder, Galaxy FCT)

The sirens of the climate crisis are no longer distant alarms—they are blaring in real time. Record-shattering heatwaves, collapsing polar ice, and extreme weather patterns have transitioned from grim forecasts to front-page headlines. While humanity's strides in clean energy innovation—solar, wind, and battery storage—are laudable, two persistent "pain points" continue to hinder progress:

(1) the struggle to decarbonize where infrastructure is impractical or non-existent; and

(2) the absence of scalable, long-term energy storage solutions without hydrocarbons.

Enter 'Solid Hydrogen Logistics', an emerging ecosystem which could potentially address these "pain-points" and transform the way we store, move, and deploy hydrogen – in the form of a stable, storable "green molecule", which can seamlessly complement "green electrons" delivered through the grid/battery ecosystem.

Solid Hydrogen Logistics

At its core, Solid Hydrogen Logistics is deceptively simple. Instead of grappling with the complex physics of hydrogen gas, all storage and logistical activities are conducted using a solid feedstock—specifically, Sodium Borohydride ($NaBH_4$). Clean energy is converted into hydrogen at the point of production and then "packaged" into $NaBH_4$, an energy-dense compound that is non-flammable, non-explosive, and can be handled at ambient temperatures without pressure.

> Galaxy FCT (www.galaxyfct.com) owns issued patents (including in USA, Japan, Korea, China, India, Saudi Arabia, Africa, Indonesia, Australia and Brazil) pertaining to a process which enables rapid and efficient release of hydrogen gas "on demand" from solid feedstock.

When needed, hydrogen gas is released through an exothermic hydrolysis reaction (which does not require external energy input) at the user's location. This approach simplifies storage and logistics across the entire supply chain, making it safe, cost-efficient, and infrastructure-light. By eliminating the need for extensive storage and logistical infrastructure, hydrogen can be made available "on demand" anywhere in the world.

Sodium Borohydride ($NaBH_4$): as Hydrogen Carrier – the "Green Molecule"

$NaBH_4$ stands out for its logistical efficiency and high energy density. Each cubic meter of $NaBH_4$ enables the release of **126 kg of hydrogen gas**, compared to just **71 kg per cubic meter of liquid hydrogen**, which requires cryogenic storage at -253°C. Moreover, $NaBH_4$ is cheap to store, easy to move, safe to handle, and infrastructure light logistically. Once produced, it can be shipped globally in standard containers, bypassing the need for pipelines, compressors, or specialized vessels.

These attributes make $NaBH_4$ the perfect complement to the grid/battery ecosystem. While grids and batteries excel in areas with strong infrastructure, Solid Hydrogen Logistics thrives in regions where infrastructure deployment is challenging/impractical and where long-duration energy storage is required. Together, they form a robust framework for achieving global decarbonization.

Global Decarbonization: The Role of Green Hydrogen

To meet net-zero emissions by mid-century, the world will require vast quantities of green hydrogen. According to McKinsey, annual hydrogen demand could reach **660 million metric tons by 2050**, with green hydrogen accounting for over 60% of total production by 2035. However, the lowest-cost locations for producing green hydrogen—typically remote deserts with abundant renewable resources—are often far from load centers.

This geographic mismatch necessitates innovative solutions for transporting and storing hydrogen. Traditional logistic modalities, such as pipelines or liquefied hydrogen, are expensive and infrastructure intensive. The Solid Hydrogen Logistics ecosystem, in contrast, can potentially offer a scalable, low-cost alternative that can effectively bridge both the distance gap and the duration gap. Cheap, safe and simple long-duration storage coupled with infrastructure-light distribution, means that green hydrogen (in the form $NaBH_4$) can now be pragmatically deployed globally, wherever and whenever it is needed.

Remaining Major Roadblock: Production Costs

The major sticking point that stands in the way of Solid Hydrogen Logistics is the high cost of $NaBH_4$ production. The good news is that none of the base raw material components are expensive. Sodium comes from NaCl (salt), hydrogen comes from water, and boron can be recycled from the by-product after hydrogen gas is released. This means the primary cost drivers are energy and process costs, coupled with the oligopolistic market structure given that it's a specialty chemical today.

As renewable energy prices globally continue to plummet—desert solar power purchase agreements (PPAs) have already reached a record low of USD1.04 cents/kWh—the largest cost component of $NaBH_4$ production will continue to diminish with every passing year in the most productive locations ("Prime Sites"). By commoditizing $NaBH_4$ production at unprecedented scale, costs can be brought down rapidly and substantially, unlocking its full potential. There is no need to wait for new technology breakthroughs, although production processes must be highly integrated and reconfigured differently at a scale never seen before.

Hyperscaling: The Key to Cost Reduction

One of the most exciting aspects of Solid Hydrogen Logistics is the potential for hyperscaling $NaBH_4$ production. Hyperscaling involves integrating renewable energy generation with $NaBH_4$ production in resource-rich "Prime Sites"—typically harsh, windy deserts near the sea. These locations are ideal for large-scale renewable energy projects but are often far from transmission infrastructure or load centers.

Once produced in its solid form, $NaBH_4$ is easily stored and can be shipped globally in standard shipping containers. This opens up vast swathes of previously unused land for immediate large-scale production of "green molecules", allowing productive renewable sites closer to transmission lines and load centres to be freed up to supply green electrons directly to the grid.

Next-Level Hyperscaling: Leveraging Symbiotic Clusters

Integrating symbiotic clusters—such as desalination, agrivoltaics, green steel, and green aluminium production—can bring hyperscaled production to the next level. Consider the following:

- **Desalination:** Freshwater produced from seawater can address water scarcity while providing raw materials (H_2O) for $NaBH_4$ production. Brine valorisation can also be incorporated to recover valuable minerals like Magnesium, NaCl, Lithium and Potassium.
- **Agrivoltaics:** Planting crops under solar panels improves land use, enhances food security, and increases energy generation efficiency of solar panels. It will also improve the capacity of desert lands to sequester much more carbon over time.
- **Green Steel and Aluminum:** Apart from symbiotically benefitting from lowest cost renewable energy and green hydrogen by co-locating in the same complex, the massive quantities of waste heat from these industries can be recycled for $NaBH_4$ production processes (which can use even low-level heat for drying and distillation), creating a mutually beneficial ecosystem.

By fully leveraging these, Solid Hydrogen Logistics can achieve even greater economies of scale and operational efficiency, to crush the production cost of $NaBH_4$ and provide the world with massive quantities of cost effective green molecules to fight the climate crisis.

Solid Hydrogen Applications: Moving from Niche to Mainstream

"The adoption of solid hydrogen will unfold in stages, driven by changes in production costs over time"

1. **Early-Stage Applications:** In its nascent phase, Solid Hydrogen Logistics is well-suited for critical, high-value applications that prioritize safety, availability, and resilience. Examples include emergency backup power for remote healthcare facilities, vaccine storage, strategic communications, and military operations.
2. **Intermediate-Stage Applications:** As production costs decrease, Solid Hydrogen Logistics can expand to include mainstream applications that require significant energy – e.g., being used as the logistical backbone for hydrogen refilling stations to support Hydrogen Mobility. Its flexibility and resilience make it ideal for complementing other clean energy carriers in areas where deploying extensive infrastructure networks is unfeasible or where long duration energy storage is required.
3. **Maturity-Stage Applications:** At maturity, when production costs go down substantially, the following use-cases would also come into the sweet spot — Mining trucks and excavators; Clean shipping; Peak power and grid stability; and Long-duration strategic energy reserves.

Conceptually, once the ecosystem has "matured" and production costs have been brought down to reasonable levels at scale, we can think of solid hydrogen as "green diesel" of the future. The use cases and how it would complement the grid/battery ecosystem will be very similar to how diesel/petrol complements the electricity grid today. The deserts of the world can be turned into gigantic sunlight refineries to produce these green molecules that will be distributed across the world – an interesting transition pathway that national/global oil and gas companies are probably best positioned to be first movers.

Some Unique India Perspectives …

India is uniquely positioned to accelerate this exciting ecosystem. With sun-baked deserts ripe for solar farms, a thriving tech sector, and a population hungry for energy access, India could become the global hub for solid hydrogen production. The deserts in Rajasthan, for instance, receive extremely high levels solar irradiation and are very attractive sites for hyperscaled production.

India's strong capabilities in desalination, green steel/aluminum also puts it in a uniquely strong position to further leverage these symbiotically integrating production.

The economic ripple effects would be profound: massively increased demand within the country for all supply chain items required for hyperscaled production (solar panels, electrolysers, fuel cells, inverters, stationary batteries, etc.) will support rapid scale-up of the entire renewable supply chain, create jobs in renewable manufacturing, reduce reliance on imported fossil fuels, and enable energy access for millions in rural areas.

Moreover, India's infrastructure challenges—patchy grids, unreliable power in remote regions—become strengths in this context. Solid hydrogen sidesteps the need for costly transmission lines, delivering clean energy directly to villages, factories, and hospitals via trucks, trains, or barges, seamlessly complementing the existing infrastructure.

Optimizing Energy Usage

Infrastructure-intensive ecosystems often encourage low-value applications in areas with strong infrastructure, leaving other regions underserved. By distributing clean energy efficiently across various locations and time, Solid Hydrogen Logistics enables more high-value applications to be met while discouraging low value usage.

Choosing the Climate Battleground

Solid Hydrogen Logistics also provides mankind the ability to move a substantial portion of the climate battle from fighting an infrastructure battle all over the world into a "production battle" within a manufacturing-like environment where learning curves (Wright's Law) apply. This allows us to judiciously deploy infrastructure only where it really counts (i.e., where ideal conditions for infrastructure exist) and take the road less travelled in other areas with Solid hydrogen Logistics and distributed systems—recognizing the stark reality that in many parts of the planet, the infrastructure battle is a lost cause even before we begin.

Two Persistent Forecasting Biases/Errors – The Tipping Point is Much Closer Than We Realize

When evaluating the potential of Solid Hydrogen Logistics, it is crucial to acknowledge two systematic and deeply ingrained biases in forecasting that often skew our perception:

1. **Underestimating Learning Curves at Scale:** We consistently underestimate the power of learning curves (Wright's Law) in controlled manufacturing-like environments. Technologies such as semiconductors, solar PV, wind turbines, and batteries have all followed steep cost-reduction trajectories due to Wright's Law, which predicts that costs decrease by a fixed percentage for every doubling of cumulative production. Yet, despite ample evidence, forecasts repeatedly fail to account for how quickly costs can fall at scale.
2. **Overestimating Infrastructure Deployment Capability:** We persistently overestimate our ability to deploy large-scale infrastructure projects on-spec, on-time, and on-budget. Transmission lines, pipelines, and sprawling cross-border infrastructure face numerous real-world challenges, from regulatory hurdles to geopolitical tensions and environmental concerns.

If we truly adjusted for these systematic biases, we would undoubtedly realize that the **tipping point for Solid Hydrogen Logistics** is already much closer than we initially thought.

Pragmatic Platform for Global Climate Collaboration

Solid Hydrogen Logistics can also contribute immensely towards fostering international climate cooperation. Renewable-rich but capital-poor nations could host production facilities, funded by wealthier countries in exchange for carbon credits or a share of output. By encouraging global collaboration and jointly investing in hyper-scaled production under a multilateral "umbrella" (e.g., the United Nations), we can unlock the full potential of renewable energy and trackle climate change.

As the world grapples with geopolitical tensions and economic uncertainties, Solid Hydrogen Logistics provides a framework for meaningful cooperation. Nations can pool resources, share risks, and jointly develop Prime Sites, ensuring equitable access to clean energy for all. More importantly, this can be carried out without being hamstrung by the need for building expensive and interdependent logistical infrastructure networks all over the world – which cost too much, takes too long, and is geographically and geopolitically too complex.

The Future of Hydrogen is SOLID

The latest United Nations Environment Programme (UNEP) Production Gap report notes that governments, in aggregate, still plan to produce more than double the amount of fossil fuels in 2030 than would be consistent with limiting warming to 1.5 deg C. Every government talks about reducing emissions, but the scene at the oil-fields is business as usual. The latest report notes that top fossil fuel producers plan even more extraction despite climate promises. This is a major problem. Short of kinetic means, it is difficult to envisage how these much-needed reductions could ever be enforced.

Perhaps we could all consider working together to fast track the evolution of the Solid Hydrogen Logistics Ecosystem so that the world would have lots of green molecules at a price point where market forces will do the job of keeping the excess hydrocarbons in the ground.

Solid hydrogen can't solve every climate challenge, but it can be the bridge between today's fossil dependency and tomorrow's renewable future. The climate emergency cannot wait for the perfect solutions. It's time to build that bridge … and let's make it SOLID.

Email: jameskhong@galaxyfct.com / jpw.gfct@gmail.com

The Liquid Hydrogen Handbook

Viewpoint Article by Savir Julka, Global Head – Industrial Gases (IG)

In the race to combat climate change and transition to sustainable energy systems, HYDROGEN has emerged as a promising contender. This versatile, high-energy density carrier stands at the forefront of the clean energy revolution, offering both exciting possibilities and formidable challenges in its transportation and logistics.

As nations and industries worldwide accelerate their shift towards carbon-neutral solutions, the demand for efficient, large-scale hydrogen distribution has skyrocketed. The vision of a 'Hydrogen Economy' – an energy infrastructure centred on this elemental fuel – is rapidly materializing from concept to reality.

Hydrogen serves various purposes, primarily for power generation, industrial processes and transportation. The same gas, when cooled at -252.88°C boiling point, becomes more efficient when liquified, and can therefore be used for more energy-efficient purposes, like fuel-cells for vehicles, power generation, energy storage, rocket propulsion, and even for fusion experiments and material sciences. The industry has witnessed the recent traction for hydrogen as a fuel in commercial sectors such as public transportation, exemplified by South Korea's establishment of hydrogen plants to fuel electric vehicles (EVs) used in public transport.

Benefits of Liquid Hydrogen

The benefits of liquid hydrogen (LH2) extend beyond those already stated. LH2 boasts a higher energy density than compressed gaseous hydrogen, allowing it to store more energy in a smaller volume, making it particularly suitable for mobility applications and offering longer range. LH2 storage tanks also require less maintenance compared to high-pressure cylinders used for gaseous hydrogen, reducing the risk of leaks and related failures. Additionally, LH2 has a lower flammability range and can be stored at lower pressures, making it relatively safer than compressed gaseous hydrogen.

The uses of LH2 are diverse and significant. Beyond its role as a rocket fuel, LH2 is employed in industrial processes, internal combustion engines, and fuel cells, where it produces only water as a by-product, while producing electricity only through a chemical reaction between hydrogen and oxygen. It also offers a clean alternative to traditional fossil fuels in heating and marine transport.

Transportation of LH2

However, the journey from production facilities to end-users involves a complex web of technological, safety, and economic considerations. Hydrogen is commonly transported and delivered in its liquid state. Several transportation methods are employed, including pipelines and cryogenic tanker trucks, along with options like rail and marine transport.

For longer distances, hydrogen is transported as a liquid in super-insulated, cryogenic tanker trucks. After liquefaction, the liquid hydrogen is dispensed to delivery trucks and transported to distribution sites where it is vaporized to a high-pressure gaseous product for dispensing. Long-haul trucking of liquid hydrogen is more economical than trucking gaseous hydrogen because a liquid tanker truck can hold a much larger mass of hydrogen than a gaseous tube trailer can.

Challenges with liquid transportation include the potential for boil-off during delivery due to sloshing and flashing. Sloshing is due to movement of the liquid while being transported. This generates kinetic energy which is transferred to thermal energy to the liquid in the tank. Flashing is caused by the introduction of hydrogen from a higher-pressure tank into one at a lower pressure. This injection of liquid hydrogen into the body of the liquid in the receiving tank generates thermal energy and again promotes boil-off. Even transferring liquid from one container to another can create a lot of boil-off.

Marine transport is emerging as a crucial method for international hydrogen trade. Purpose-built ships, similar to liquefied natural gas (LNG) carriers but with more advanced insulation, are being developed to transport liquid hydrogen across oceans.

Storage of LH2

Storing LH2 demands advanced cryogenic technologies. Specialized double-walled or multi-layered tanks, utilize vacuum insulation and multiple radiation shields to minimize heat transfer. These tanks cater to various needs and applications, in the form of Dewars[1], cryogenic tanks, insulated tanks, etc., in both portable, as well as stationary conditions. Despite these measures, some heat ingress is inevitable, causing gradual boil-off. Boil-off management systems either vent the evaporated hydrogen or re-liquefy it, depending on the storage duration and economic considerations. For longer-term storage, large spherical tanks with capacities up to 5,000 m^3 are employed, featuring

[1] A container that stores and transports liquid hydrogen at low pressure. Dewars are designed to minimize heat leaks and can be made from stainless steel.

sophisticated insulation systems that can limit boil-off to less than 0.1% per day.

It's important to note that even with advanced insulation, the hydrogen molecule will gradually leak away, typically at a rate of 1% per day. An effective insulation system in LH2 tanks reduces this boil-off rate, increasing operational efficiencies and improving safety. Due to hydrogen's expansion ratio of 848:1, a tank full of liquid hydrogen at 1 bar pressure would experience a pressure rise to 1,720 bar if it were to convert back to gas. Therefore, hydrogen can only be stored in self-regulating systems fitted with pressure relief valves or bursting discs.

Safety and LH2

The dangers of liquid hydrogen fall into three categories: physical, which can occur due to embrittlement or storage tank failure; physiological, which can cause cold burns, hypothermia, asphyxiation and respiratory issues; and chemical, which can lead to ignition and fire.

The transportation of liquid hydrogen necessitates rigorous safety protocols. Risk assessments must account for the substance's high flammability, wide combustion range, and invisibility of flames. Leak detection systems, utilizing hydrogen sensors and infrared cameras, are critical components of any liquid hydrogen transport system. Emergency response protocols must be well established, with specialized training for handling cryogenic spills and potential fires.

The European Industrial Gases Association (EIGA) recommends minimum separation distances for liquid hydrogen vessels: 60 m in public spaces, 20 m from occupied buildings, and 10 m from combustible liquid or solid stores. EIGA also advises against installing liquid hydrogen storage vessels inside buildings and recommends a minimum distance of 10 m from overhead lines.

Green Hydrogen

While hydrogen itself is a clean energy carrier, its production and transport can have significant environmental impacts. The energy-intensive liquefaction process, if powered by fossil fuels, can result in substantial carbon dioxide emissions. However, when renewable energy is used for both hydrogen production and liquefaction, the green hydrogen thus generated reduces environmental footprint drastically. Lifecycle assessments of liquid hydrogen transport systems are crucial for understanding and minimizing their overall environmental impact.

Future of Liquid Hydrogen

The transportation and logistics of liquid hydrogen represent a critical link in the hydrogen economy chain. While challenges remain, particularly in terms of energy efficiency and economics, the rapid advancements in technology and growing investment in hydrogen infrastructure are paving the way for more widespread adoption. As the world continues to seek clean energy solutions, the ability to efficiently transport and distribute liquid hydrogen will play a crucial role in realizing its potential as a versatile and sustainable energy carrier.

The outlook of liquid hydrogen logistics looks promising, with several technological advancements on the horizon. Researchers are exploring more efficient liquefaction processes, such as magneto caloric liquefaction, which could significantly reduce energy consumption. In transportation, the development of larger, more efficient carriers for both marine and land transport is underway. The concept of "hydrogen hubs"—centralized production and distribution centers—is gaining traction, potentially streamlining the logistics chain.

The future of liquid hydrogen logistics will likely see a combination of different transport methods, tailored to specific distances and quantities. As production scales up and technologies improve, the costs are expected to decrease, making liquid hydrogen a more competitive option in the global energy market. With continued research, investment, and international cooperation, liquid hydrogen could indeed become a cornerstone of our future energy systems, helping to decarbonize industries and power a cleaner world.

The economics of liquid hydrogen transport are currently challenging, primarily due to the high energy costs of liquefaction and the expensive specialized equipment required. A cost analysis reveals that for distances under 1,500 km, trucking liquid hydrogen is often more economical than transporting gaseous hydrogen. Marine transport is emerging as a crucial method for international hydrogen trade. Purpose-built ships, similar to LNG carriers but with more advanced insulation, are being developed to transport liquid hydrogen across oceans.

Savir has been in the Core Engineering Industry for over three decades, with ~25 years in the Industrial & Medical Gas Industry. He serves as the Global Head of IG Equipment & Application, at INOX India Ltd. (INOXCVA), engaging with global MNC accounts, EPC and consulting firms, developing international business for Standard & Engineered Cryogenic storage & transport equipment, vaporization system packages, and most significantly, LNG & Liquid Hydrogen systems.

Savir holds a bachelor's in mechanical engineering, and PG Diplomas in Marketing, Sales, and International Business Operations.

Courtesy:
INOX INDIA LIMITED
9th Floor, KP Platina, Race Course
Vadodara 390007, Gujarat, India
Tel: +91-265-6160100
Web: www.inoxcva.com

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Biomass to Hydrogen: Powering India's Green Future

Photo Source: Hydrogen from biomass gasification (IEA Bioenergy: Task 33: December 2018)

India's transition to green hydrogen is a crucial step in its clean energy ambitions, with the **National Green Hydrogen Mission (NGHM)** aiming for 5 million metric tons of production by 2030. While electrolysis powered by renewable energy has dominated discussions, biomass-based hydrogen offers an alternative that could support India's transition to a low-carbon economy. Biomass supply chains, which involve the collection, processing, and distribution of agricultural and organic residues, can be instrumental in producing biohydrogen and strengthening India's energy security.

The NGHM has been structured around incentivizing green hydrogen production through **Strategic Interventions for Green Hydrogen Transition (SIGHT)** programs, demand-side incentives, and research and development (R&D) initiatives. The mission has a **target of 5 MMT (Million Metric Tons) of green hydrogen production annually by 2030**, with an associated renewable energy capacity of about **125 GW**.

Untapped Opportunity

Agricultural residue, including **paddy straw, sugarcane bagasse, and other lignocellulosic biomass**, presents a significant untapped opportunity in this mission. While the mission primarily emphasizes hydrogen production through electrolysis powered by solar and wind energy, **biomass gasification and anaerobic digestion of agricultural residues** can be integrated into India's broader green hydrogen roadmap.

India produces approximately **500 million tons**[1] **of agricultural residue annually**, with a substantial portion being burned, contributing to severe air pollution and carbon emissions. By utilizing this waste for hydrogen production, India can both mitigate environmental concerns and create an **additional revenue stream for farmers,** while reducing reliance on fossil-fuel-based hydrogen sources.

Biomass-derived hydrogen (also known as **biohydrogen**) is produced through thermochemical and biochemical processes. The key methods include **biomass gasification**, a thermochemical conversion process where biomass is heated in the presence of limited oxygen to produce syngas, which can then be purified to extract hydrogen. Studies conducted in **Germany and the Netherlands** have demonstrated that gasification can achieve **hydrogen yields of 80-100 g per kg of biomass**, depending on the feedstock used. A pilot project in **India's Punjab region**[2] has also successfully converted paddy straw into hydrogen through gasification, reducing carbon emissions by **30% compared to conventional methods**.

Steam reforming of biogas, where methane and carbon dioxide are reformed using steam to produce hydrogen, aligns with circular economy principles. Research from **Stanford University and the Indian Institute of Science (IISc), Bangalore**, indicates that steam reforming of **biogas from agricultural waste** can produce **99.99% pure hydrogen**, with efficiency rates exceeding **65%**. Brazil's **bioenergy sector** has successfully integrated biogas reforming into its **ethanol production plants**, achieving **a net-positive energy balance** while significantly lowering greenhouse gas emissions.

Additionally, **dark fermentation and photo fermentation**, biological processes involving microorganisms breaking down organic material in the absence or presence of light, can also be used for hydrogen production. **Studies at the University of Tokyo** and **the National Renewable Energy Laboratory (NREL) in the US** have shown that genetically engineered bacteria can improve hydrogen yields by **30-40%**, making biohydrogen a more viable commercial option. A pilot project in **China's Jiangsu province** demonstrated that photo fermentation using wastewater and agricultural residues could yield **3.5 mol of hydrogen per mol of glucose**, making it a scalable solution for industrial applications.

To assess the viability of agricultural residues in hydrogen production, factors such as hydrogen yield efficiency, energy efficiency, and environmental impact must be considered. **Paddy straw** can produce **80-100 g of hydrogen per kg** through gasification, while **sugarcane bagasse** yields **90-110 g of hydrogen per kg**, making it one of the most efficient sources. **Rice husk**, with **60-90 g of hydrogen per kg**, is another viable option. Gasification of agricultural residues has an energy efficiency of around **60-70%**, while anaerobic digestion for biogas conversion has an efficiency of **40-50%**, though it also produces biofertilizers. Utilizing **1 million tons of paddy straw for hydrogen production** can prevent **~2.5 million tons of CO_2 emissions**, significantly reducing environmental pollution.

[1] NITI Aayog EOI dated 19 February 2019

[2] The Punjab Experiment, which successfully converted paddy straw into hydrogen through gasification, was conducted by Prof. S. Dasappa of the IISc Bangalore. PRESPL has had a longstanding association with IISc and Prof. Dasappa, collaborating on multiple research initiatives related to biomass utilization.

Source: thebetterindia.com

Challenges & Solutions

Despite the potential, several challenges exist in the biomass supply chain, including feedstock collection, logistics, storage, standardization, and economic viability.

Seasonal availability, high moisture content, and decentralized production create inconsistencies in feedstock supply. Structured aggregation models with farmer cooperatives and the establishment of biomass storage depots near hydrogen production units can mitigate these issues.

Raw biomass has a high moisture content, leading to inefficiencies in hydrogen production. Drying and torrefaction (a mild pyrolysis process) can enhance the calorific value of biomass, making it a more efficient feedstock.

Standardization and quality control are crucial, as variability in feedstock composition affects hydrogen yield. Implementing quality control mechanisms at biomass processing centres can ensure consistency in input parameters.

Given the capital-intensive nature of these technologies and the price competitiveness of fossil fuels, government policies and subsidies for biomass gasification units and integration within the Renewable Purchase Obligation (RPO) framework can incentivize adoption.

Global Experiences

Several countries have successfully integrated biomass into their hydrogen strategies. **Japan** utilizes waste biomass for hydrogen production in fuel cells, backed by government-funded R&D investments. The **European Union** (EU) supports biohydrogen pilot projects through the Horizon 2020 program. **Brazil** leverages sugarcane bagasse extensively in biohydrogen production. India can adopt similar models, leveraging its agricultural sector to create an economically viable and environmentally sustainable hydrogen supply chain.

R&D work on converting agricultural residue to green hydrogen is gaining traction worldwide. In **the US**, the Department of Energy (DOE) has been actively funding projects focusing on biomass gasification and fermentation technologies for hydrogen production. The **EU** has initiated multiple research programs under Horizon Europe to develop scalable and efficient biohydrogen production processes, particularly focusing on agricultural waste conversion. In **China**, state-led pilot projects are exploring anaerobic digestion and thermochemical pathways for utilizing crop residues to produce hydrogen, aiming to integrate these methods into the country's broader decarbonization strategy. These global initiatives provide valuable insights for India to enhance its R&D capabilities and create a technology roadmap tailored to its vast biomass resources.

Conclusion

To maximize the role of biomass in green hydrogen production, India needs an integrated approach. **Incentives for biomass-based hydrogen** should be established, similar to those for electrolysis-based hydrogen. **Infrastructure development** is necessary, with decentralized biohydrogen hubs in agricultural regions minimizing transport costs and carbon emissions. **Public-private partnerships (PPP)** can encourage investment from energy companies and startups to develop commercially viable biomass-based hydrogen projects. **Technology R&D** funding can accelerate innovations in catalytic gasification and advanced fermentation techniques.

Biomass supply chains can play a pivotal role in India's green hydrogen ecosystem by providing an alternative feedstock that complements renewable energy-driven electrolysis. With the right policy interventions, infrastructure investments, and technological advancements, biohydrogen can emerge as a key pillar in India's clean energy transition. By leveraging its vast biomass resources, India can move closer to its energy security and net-zero emissions goals while creating sustainable livelihoods in rural areas.

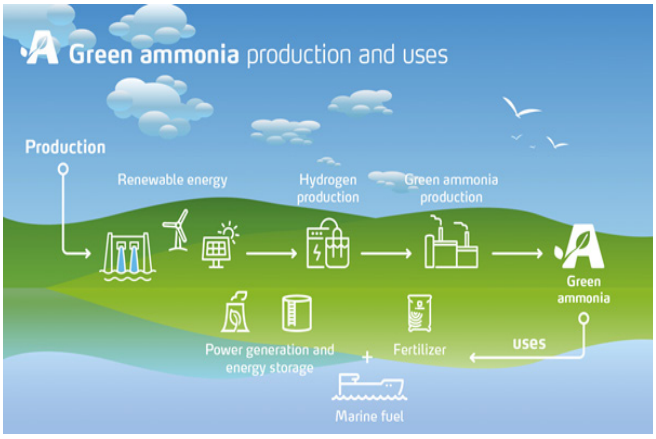
Courtesy:
Colonel Pronob Roy (Retd)
Senior Vice President (East & North Zone)
PRESPL
Zonal Office: 500-504, Elgin Works
Level 5, 9 Elgin Road, Kolkata 700020
Corporate Office: Mayuresh Square, Office No. 1008 & 1009, Plot No. 17, Sector 15, CBD Belapur
Navi Mumbai 400614, Maharashtra
Tel: +91 (33) 44113839; Cell: +91 9769451345/9360704953
Email: pronobroy@prespl.com
Web: www.prespl.com

Sembcorp Forays into Green Hydrogen Sector in India

Sembcorp Industries (Sembcorp) is a leading energy and urban solutions provider, led by its purpose to drive energy transition. Headquartered in Singapore, Sembcorp delivers sustainable solutions to support energy transition and urban development by leveraging its sector expertise and global track record.

Sembcorp has a balanced energy portfolio of 21.2 GW, including 14.4 GW of gross renewable energy capacity, across 10 countries.

Green Ammonia Project



Sembcorp Green Hydrogen Pte. Ltd., a wholly-owned subsidiary of Singapore-based energy and urban development company Sembcorp Industries (Sembcorp), together with Kyushu Electric Power Co. Inc and Sojitz Corporation, announced Nippon Yusen Kabushiki Kaisha (NYK)[1] as a shipping partner for the export of green ammonia to Japan (the Proposed Project). Under the agreement, as per the Sembcorp press release of 21 August 2024, the partners aim to produce "highly competitive" green ammonia in India.

The four parties signed a Heads of Terms (HoT) in relation to a cross-border green ammonia supply from India to Japan, in the presence of Shri Pralhad Joshi, the Hon'ble Cabinet Minister of New and Renewable Energy, Government of India; Mr Simon Wong, the High Commissioner of Singapore to India; and Mr Yuta Hikichi, First Secretary, Embassy of Japan in India.

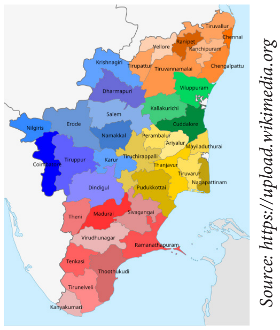
Under the HoT, NYK will oversee the maritime transportation of the green ammonia, to establish a robust supply chain from production in India to supply in Japan, particularly in the Kyushu region. Sembcorp, as the lead developer of the Proposed Project, will leverage its strong capabilities demonstrated through its existing renewables portfolio of 4.7 GW in India, to produce competitively priced green ammonia in India.

[1] https://www.offshore-energy.biz/sembcorp-eyes-new-renewables-and-green-hydrogen-collaboration/

The front-end engineering and design work for the green ammonia plant in Tuticorin, Tamil Nadu, has commenced.

According to NYK, the deal is based on the premise that approximately 200,000 MT of green ammonia will be produced annually through this project and transported to the Kyushu region.

In addition, as per an update in January 2025[2], four global majors — Malaysian government-owned oil and gas giant Petronas-backed Amplus Ganges Solar, Sembcorp Industries' Green Infra Renewable Energy, Gurugram-based Acme Green Hydrogen and Chemicals, and ReNew Energy's subsidiary ReNew E-Fuels — are set to propel India's green hydrogen ambitions in South India.



Source: https://upload.wikimedia.org

Tamil Nadu

Sembcorp had also signed an MoU[3] with the State government of Tamil Nadu, at the Global Investors Meet in January 2024, to develop a green hydrogen hub in the state. The hub, located at VO Chidambaranar (VOC) Port in Thoothukudi, Tamil Nadu, is South India's only hydrogen hub, and is projected to attract an investment of INR 41,860 crore[4] in its first phase, with commissioning slated for 2028. The project will create around 1,511 jobs in the Thoothukudi area.

Following this initiative, the green hydrogen unit of Sembcorp had started signing initial contracts for a green hydrogen hub in Tamil Nadu, in July 2024. Tecnimont (Integrated E&C Solutions), through its Indian subsidiary Tecnimont Private Limited (TCMPL), together with NextChem (Sustainable Technology Solutions), has been awarded an engineering design study (first phase of the front-end engineering design) contract by SGHIPL, for a green ammonia plant to be located in India.

The study will leverage NextChem's digital tool ArcHy (Architecture of Hydrogen systems) to overcome the challenge of the intermittency of renewable power usage, resulting in capex and opex efficiency of the plant lifecycle, said a statement by Maire.

In particular, the ArcHy digital tool will use renewable energy production profiles, collected over a one-year period in different weather scenarios, to determine the size of the

[2] https://www.business-standard.com/industry/news/petronas-sembcorp-others-to-fuel-thoothukudi-s-green-hydrogen-hub-by-2028-125012600454_1.html

[3] https://energy.economictimes.indiatimes.com/news/renewable/sembcorps-ammonia-plant-would-make-tn-a-global-hub-for-green-hydrogen-production-cm/112696196

[4] 1 crore = 10 million

plant's components like the electrolyzers, storage systems, and green ammonia production facilities with the aim of minimising the levelised cost of ammonia.

Based on the results of this analysis, TCMPL will design all the elements of the facility by providing highly specialised engineering services.

The partners may soon get a formal letter of award for the hydrogen hub at VOC Port, for which a pilot project is expected to be operational in 2025.

Odisha


https://upload.wikimedia.org

As per another press release[5] on 17 January 2025 by Sembcorp, the company has also signed agreements with the Indian state of Odisha to develop a green hydrogen plant and industrial park.

Sembcorp, through its wholly-owned subsidiaries – Sembcorp Green Hydrogen India Private Limited (SGHIPL) and Sembcorp Development Ltd., signed two non-binding Memoranda of Understanding (MoUs) with the Government of Odisha. These MoUs were signed by representatives of the Government of Odisha and Sembcorp, in the presence of Singapore's Minister for Transport and Second Minister for Finance Chee Hong Tat, and Shri Mohan Charan Majhi, Honourable Chief Minister of Odisha, along with other dignitaries. The MoUs exchange took place at the side-lines of the Presidential State Visit of His Excellency Mr Tharman Shanmugaratnam, President of the Republic of Singapore, to India.

Under the MoU signed with Industrial Promotion & Investment Corporation of Odisha Limited, SGHIPL will explore the development of a production facility for green hydrogen and its derivatives, with an anticipated production capacity of 720,000 metric tonnes (MT) per annum. The facility, to be strategically located in Odisha, is expected to generate over 2,000 employment opportunities during its operational phase.

Sembcorp Development Ltd. has also signed a non-binding MoU with Odisha Industrial Infrastructure Development Corporation to assess the potential for the development of an industrial park in Odisha, India.

These MoUs build upon the framework outlined by the Governments of Singapore and India to enhance bilateral collaboration, with a focus on six key pillars, including sustainability. With abundant resources and investor-friendly policies, Odisha is pivotal to India's transition to a low-carbon future.

Sembcorp continues to explore opportunities to deepen its presence in India, with the support of partners like Enterprise Singapore.

Other Partnerships

Earlier, in September 2024[6], SGHIPL was in discussions with Bharat Petroleum Corporation Limited (BPCL) to enter into a definitive joint venture (JV) agreement for renewable energy and green hydrogen projects across India. The proposed partnership aims to support India's long-term development goals, with Sembcorp claiming that it is well-positioned to spearhead decarbonization initiatives with BPCL to drive India's energy transition.

Conclusion

These agreements come on board as India boosts investments in renewable energy to meet its 2030 clean energy target after missing its 2022 goal. As the world's third-largest greenhouse gas emitter, India is aiming for net-zero emissions by 2070 and a 500 GW renewable energy target by 2030.

Major power producers in India are also significantly investing in renewables to support the government's efforts to expand clean energy and cut emissions.

About Sembcorp Industries

Sembcorp Industries (Sembcorp) has a balanced energy portfolio of 21.2 GW, including 14.4 GW of gross renewable energy capacity, across 10 countries. Its urban development projects span over 14,000 hectares across Asia and have generated over 377,000 employment opportunities and attracted close to US$50 billion of investment capital.

Backed by Singapore state-owned investor Temasek, Sembcorp is listed on the main board of the Singapore Exchange. It is a constituent stock of FTSE Russell Index, MSCI Singapore Index, Straits Times Index as well as sustainability indices including FTSE4Good Index, iEdge SG ESG indices and several MSCI ESG indices.

Sembcorp Green Hydrogen India Private Limited (SGHIPL) factors in the strong credit profile of its ultimate parent – Singapore-based Sembcorp Industries Ltd (SCI) – which has a strong renewable portfolio, a diversified asset profile and a strong parentage with a 49.5% shareholding by Temasek Holdings (Private) Limited, rated Moody's Aaa (Stable). SGHIPL is the Indian Holdco of the Sembcorp Group for green hydrogen and green ammonia in India. SGHIPL has three SPVs (100% ownership) in India – Green Infra Renewable Energy Farms Private Limited (GIREFPL), Green Infra Clean Wind Ventures Private Limited (GICWVPL) and Sembcorp Green Hydrogen (Gujarat) Private Limited (SGHGPL).

For more information, please visit www.sembcorp.com/in

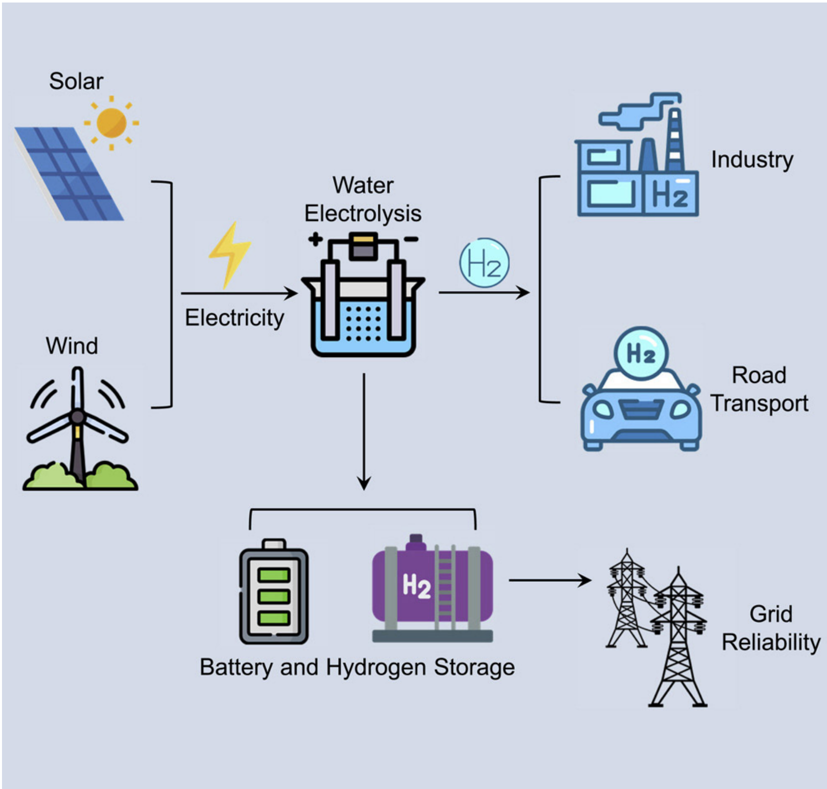
[5] *https://www.sembcorp.com/in/news-and-insights/news/2025/sembcorp-inks-mous-with-government-of-odisha-during-singapore-presidents-visit/*

[6] *https://www.offshore-energy.biz/sembcorp-eyes-new-renewables-and-green-hydrogen-collaboration/*

India's Renewable Energy Transition & SECI's Role

Viewpoint Article by Mr. Sanjay Sharma, Director (Solar), Solar Energy Corporation of India Ltd. (SECI)

India has set an ambitious target to achieve net-zero emissions by 2070. At the Conference of Parties (COP)26, the country announced its 2030 decarbonization goal, which includes increasing non-fossil fuel energy capacity to 500 GW and ensuring that 50% of its energy comes from renewable sources. These commitments go beyond India's Paris Agreement pledges, reaffirming India's leadership in the global energy transition.



Source: www.cell.com

To achieve these targets, the Ministry of New and Renewable Energy (MNRE) is spearheading various initiatives, in alignment with the Hon'ble Prime Minister's *Panchamrit* commitments – Achieving net zero emissions by 2070; increasing non-conventional energy capacity to 500 GW by 2030; increasing the share of renewable energy in gross energy production to 50 percent by 2030; reducing emissions intensity by 45 percent; and reducing carbon emissions by 1 billion tons by 2030 – which has given a new direction to the whole world.

A key player in this transition is Solar Energy Corporation of India Limited (SECI), a government-owned enterprise under administrative control of MNRE, responsible for facilitating renewable energy projects across the country through competitive tenders.

Power Procurement & Capacity Expansion

SECI conducts a tariff-based competitive e-bidding process to select successful bidders. Once selected, it enters into 25-year Power Purchase Agreements (PPA) with the awarded developers and back-to-back 25-year Power Sale Agreements (PSA) with DISCOMs (distribution companies) and other buying entities. As of December 31, 2024, SECI has awarded a cumulative renewable energy capacity of 73.02 GW, of which 27.44 GW has already been commissioned.

Additionally, SECI is the implementing agency for Tranche-II of the Government of India's Rs 19,500 crore[1] Production-Linked Incentive (PLI) Scheme, which supports GW-scale manufacturing of high-efficiency solar PV modules, providing incentives for five years post-commissioning.

[1] 1 crore = 10 million

SECI's Role in Renewable Energy Development

India is at the cusp of an energy revolution, driven by the need to decarbonize its economy and reduce dependence on fossil fuels. SECI, a Navratna Central Public Sector Undertaking (CPSU), plays a crucial role in this transformation. Since its inception in 2011, SECI has expanded its operations across nearly all states and Union Territories, fostering market growth and developing a robust renewable energy ecosystem. Originally incorporated as a not-for-profit organization, SECI transitioned into a commercial entity in 2015 under Section 3 of the Companies Act, 2013. The company maintains strong financial credibility, holding the highest credit ratings of [ICRA]AAA for long-term and [ICRA] A1+ for short-term financial instruments.

Innovations in Renewable Energy Projects

Recognizing the intermittent and variable nature of renewable energy, SECI has pioneered innovative project configurations such as:

- Solar-Wind Hybrid Systems (with or without energy storage)
- Round-The-Clock (RTC) power supply
- Renewable Energy with assured peak power delivery

- Firm and Dispatchable Renewable Energy (FDRE)
- Standalone Battery Energy Storage Systems (BESS)

These models address the specific needs of various DISCOMs and industries by ensuring reliable and consistent power supply.

India's Push for Green Hydrogen

As part of its broader decarbonization strategy, the Government of India is implementing strong policy measures that leverage a mix of clean energy pathways and advanced technologies. In this context, Green Hydrogen emerges as a game-changer. Produced using renewable energy sources like solar, wind, hydro, and biomass, it offers a clean and sustainable alternative to fossil fuels.

The National Green Hydrogen Mission (NGHM), launched by the Government of India in 2023, aims to position the country as a global hub for green hydrogen production, utilization, and exports. With an outlay of Rs 19,744 crore for FY 2023-24 to FY 2029-30, the mission supports various initiatives, including:

- Rs 17,490 crore for the Strategic Interventions for Green Hydrogen Transition (SIGHT) Programme
- Rs 1,466 crore for pilot projects in hard-to-abate sectors
- Rs 400 crore for R&D and innovation
- Rs 388 crore for infrastructure, policy support, and skill development

By combining renewable energy expansion with Green Hydrogen development, India is positioning itself as a global leader in the clean energy transition.

SECI's Role in Advancing Green Hydrogen for India's Net Zero Transition

Green Hydrogen, produced via electrolysis using renewable electricity, is a crucial component of India's low-carbon transition. SECI is now playing a proactive role in advancing Green Hydrogen adoption, including facilitating production, demand aggregation, and infrastructure development to support large-scale deployment.

SECI is forging strategic partnerships with international agencies, research institutions, and private companies, which are crucial in addressing key challenges such as high production costs, infrastructure gaps, and policy uncertainties.

SECI has actively pursued collaborations with research organizations like C-STEP (Center for Study of Science, Technology and Policy) to drive innovation and technological advancements in the Green Hydrogen sector. A significant milestone was achieved on November 19, 2024, when SECI signed an MoU with H2Global Stiftung to collaborate on Green Hydrogen initiatives. These efforts also focus on developing global certification standards to ensure that India's Green Hydrogen production meets international carbon intensity benchmarks, making it competitive in global markets.

The SIGHT Programme: Incentivizing Green Hydrogen Adoption

One of SECI's flagship initiatives under NGHM is the SIGHT Programme. As the Implementing Agency (IA) for this program, SECI plays a key role in:

- Incentivizing Green Hydrogen production through government-backed schemes.

List of SECI's awarded tenders under SIGHT

Sl.	Scheme	Capacity (per annum)	Maximum Incentives (Rs crore)
1	Green Hydrogen Production (Tranche 1)	412,000 MT	3,055.38
2	Green Hydrogen Production (Tranche 2)	450,000 MT	2,238.59
3	Electrolyzer Manufacturing (Tranche 1)	1,500 MW	2,220
4	Electrolyzer Manufacturing (Tranche 2)	1,500 MW	2,220

- Promoting domestic electrolyzer manufacturing to reduce dependence on imports.
- Aggregating demand from key industries such as fertilizers, refineries, and steel.
- Developing policy frameworks and competitive tenders to accelerate adoption.
- Driving international collaborations to bring global expertise, investments, and best practices to India's Green Hydrogen sector.

Decarbonizing the Fertilizer Industry & Hard-to-Abate Sectors

In India's fertilizer industry, hydrogen is currently derived from natural gas (grey hydrogen), leading to significant carbon emissions and reliance on imported Natural Gas. SECI is actively working to replace grey hydrogen with Green Ammonia, helping to:

- Reduce carbon emissions in fertilizer production.
- Enhance energy security by reducing dependency on imported fossil fuels.
- Align with India's clean energy commitments under the Net Zero by 2070 and 500 GW non-fossil fuel energy target by 2030.

Beyond fertilizers, Green Hydrogen is a crucial solution for hard-to-abate sectors such as steel, cement, shipping, and aviation, where direct electrification is not feasible. SECI is leading initiatives in these industries to demonstrate technical and economic viability, ensuring a smooth transition to a clean energy economy.

Developing Renewable Energy-Linked Hydrogen Hubs

To support large-scale Green Hydrogen production, SECI is driving the establishment of Renewable Energy-Linked Hydrogen Hubs. These hubs will:

- Optimize energy utilization and lower production costs.
- Enable efficient Green Hydrogen production at scale.
- Strengthen India's position in the global clean energy market.

Economic & Energy Security Benefits of Green Hydrogen

- Reduces India's energy import dependency, mitigating risks from global fuel price fluctuations.
- Enhances energy storage capacity, ensuring a stable and resilient power supply.
- Creates new industries, jobs, and investment opportunities, driving economic growth.
- Positions India as a global leader in clean energy innovation and exports.

By leveraging its vast renewable energy resources, India has the potential to scale Green Hydrogen production cost-effectively.

Scaling Up Green Hydrogen Production & Green Ammonia Exports

Over the next decade, SECI aims to:

- Scale up Green Hydrogen production to several million tons per annum.
- Expand Green Ammonia production for both domestic use and exports.
- Develop infrastructure for large-scale Green Hydrogen-powered mobility solutions.
- Foster international collaborations to position India as a global leader in Green Hydrogen production and exports.
- Support research and development to lower costs and improve efficiency.

With continued policy support, industry collaboration, and technological advancements, SECI is committed to making Green Hydrogen a mainstream energy source for India's future. As the country progresses toward its 2030 and 2047 hydrogen economy goals, the integration of technological advancements, cost optimization, and global partnerships will be essential.

Mr. Sanjay Sharma holds a B. Tech in Electrical Engineering, an MBA (Energy Management), and is a certified Project Manager and Energy Auditor. He has over 36 years of experience in the power sector, with 27 years in Power Projects & Transmission Projects (23 years in Powergrid Corporation of India Ltd.) and over 9 years in the Renewable Energy Sector in Solar Energy Corporation of India Ltd. (SECI). He is currently working as Director, Solar since March 2022. During his tenure, he has formulated SECI's Procurement Policy solely, which is one of the most transparent policies across the globe, for which he received a Personal Commendation from MEDEF International-France (equivalence to CII of India).

Email: sanjaysharma@seci.co.in
Phone: 011-24666209 (O)

Hydrogen Transforms Small Utah Town

For more than three decades, the Intermountain Power Project (IPP) has served as a model of regional energy cooperation, generating and transmitting coal-fueled electricity to a diverse group of municipal utilities and rural electric cooperatives with operations across six US states. As these entities' current power purchase agreements near expiration, Intermountain Power Agency (IPA) is expanding its role as a regional energy hub, including utilizing renewable energy resources to produce and store hydrogen that can be drawn upon to generate carbon-free electricity.

Project Schedule at a Glance

- ✓ **November 2019** Gas Transportation Contract Award
- ✓ **February 2020** Gas Turbine-Generator Contract Award
- ✓ **October 2021** Site Preparation Begins
- ✓ **March 2022** Generation Engineer-Procure-Construct Contract Award
- ✓ **March 2022** Hydrogen Supply and Storage Contract Award
- ✓ **May 2022** Initial Financing Completed
- ✓ **November 2022** Synchronous Condenser Contract Award
- ✓ **March 2023** Converter Station Contract Award
- **July 2025** Generation Enters Service
- **April 2027** Transmission System Upgrades Enter Service

Currently, renewable energy, such as wind and solar power, is not dispatchable. The transition to a 100% clean energy grid will require generating resources that are dispatchable and energy storage resources with long-term, even seasonal, capabilities, such as hydrogen. IPP's proximity to the only major geologic salt dome formation in the west makes it the ideal location for siting and scaling up these emerging clean energy technologies.

The IMP Project on the outskirts of Delta, a small town of roughly 4,000 residents in Utah's West Desert.

Dubbed "IPP Renewed," this transformational project includes the retirement of the existing coal-fueled units at the IPP site; installation of new natural gas-fueled electricity generating units capable of utilizing hydrogen for 840 MW net generation output; modernization of IPP's Southern Transmission System linking IPP to Southern California; and the development of hydrogen production and long-term storage capabilities. Upon buildout of these facilities *(refer Project Schedule in box)*, IPP will use renewable energy-powered electrolysis to split water into oxygen and hydrogen, storing the latter in underground salt caverns for use as fuel to drive electricity-generating turbines. The new natural gas generating units will be designed to utilize 30 percent hydrogen fuel at start-up, transitioning to 100 percent hydrogen fuel by 2045 as technology improves.

Construction of two hydrogen-capable natural gas generators proceeds at the IPP site in July 2024.

Plans for IPP Renewed have been in development for over a decade by IPP participants. Going forward, these entities will continue to play key roles in the implementation of the project:

- Intermountain Power Agency–a political subdivision of the State of Utah with municipalities as members–is the project owner.
- Intermountain Power Service Corporation employs the people who work at IPP.
- Los Angeles Department of Water and Power—the largest purchaser of electricity from IPP—also serves as the Operating Agent and Project Manager.

The roads in and out of Delta, Utah, are dotted with ghost towns. The majority saw their heyday during the gold rush; now they mostly consist of stone markers and the occasional remnants of an old cabin. And like many of the towns that remain in Utah's West Desert, Delta has faced the very real possibility that it, too, could be relegated to the dustbin of history sooner rather than later. When it was announced in 2017 that IPP's coal plant was closing down, there were worried all around. Instead, the town today is experiencing something of a housing shortage. Faced with the possibility of losing its largest customer — the Los Angeles Department of Water and Power — if it continued to burn coal, the Intermountain Power Agency decided to replace the coal plant with a pair of gas-fired turbines with a combined capacity of 840 MW designed to run on 100% green hydrogen by 2045.

California got 40 years of good, reliable baseload electricity. The Utahns have got jobs, tax revenue and this sweetheart deal that gives them a front row seat at a world-class project they only pay for when they use it. It's been a tremendous success."
John Ward - *IMP Project spokesperson*

The ACES Delta site where Mitsubishi subsidiary MHI Hydrogen Infrastructure plans to make green hydrogen to supply the IPP gas plants. Mitsubishi anticipates the electrolyzer facility will create 20 permanent jobs, some of which have already been filled by former IPP employees.

Construction of the new plant and all the associated infrastructure reached peak employment last summer with some 1,200 workers on site. If construction on the plant remains on track — it's slated to open in 2025 — **the IMP project stands to become the world's first operational gas power plant designed and built to use 100% carbon-free hydrogen.**

Courtesy:
Intermountain Power Agency
10653 S. River Front Parkway, Suite 120
South Jordan, UT 84095
https://www.ipautah.com/ipp-renewed/

Photos Source: Emma Penrod/Utility Dive

National Green Hydrogen Mission (NGHM) Update

India's National Green Hydrogen Mission (NGHM) was launched on 04 January 2023 with an outlay of Rs 19,744 crores[1] up to FY 2029-30. It will contribute to India's goal to become Aatmanirbhar (self-reliant) through clean energy and serve as an inspiration for the global Clean Energy Transition. The Mission will lead to significant decarbonization of the economy, and enable India to assume technology and market leadership in the Green Hydrogen sector. The Mission aims to provide a comprehensive action plan for establishing a Green Hydrogen ecosystem and catalyzing a systemic response to the opportunities and challenges in this sunrise sector. As per the NGHM website, a global demand of over 100 MMT of Green Hydrogen and its derivatives like Green Ammonia is expected to emerge by 2030. Aiming at about 10 per cent of the global market, India can potentially export about 10 MMT Green Hydrogen/Green Ammonia per annum. The production capacity targeted by 2030 is likely to leverage over Rs 800,000 crore in total investments and create over 600,000 jobs. Nearly 50 MMT per annum of carbon dioxide emissions are expected to be averted as a result of these various initiatives, contributing to India's energy security and reducing a cumulative Rs 100,000 crore worth of fossil fuel imports by 2030.

Pilot Projects

Several pilot projects on hydrogen-fuelled buses and trucks, have been launched under the NGHM, as posted on 3 March 2025.

Earlier the Ministry of New and Renewable Energy (MNRE) had issued guidelines for implementing Pilot Projects in the Transport Sector under this Mission. Accordingly, proposals were invited for different types of hydrogen-based vehicles, routes, and hydrogen refuelling stations. MNRE has sanctioned five pilot projects consisting of a total of 37 vehicles (buses and trucks), and nine hydrogen refuelling stations. The vehicles that will be deployed for the trial include 15 hydrogen fuel cell-based vehicles and 22 hydrogen internal combustion engine-based vehicles.

These vehicles will run on 10 different routes across the country viz., Greater Noida – Delhi – Agra, Bhubaneshwar – Konark – Puri, Ahmedabad – Vadodara – Surat, Sahibabad – Faridabad – Delhi, Pune – Mumbai, Jamshedpur – Kalinga Nagar, Thiruvananthapuram – Kochi, Kochi – Edappally, Jamnagar – Ahmedabad, and NH16 Visakhapatnam – Bayyavaram. The above projects have been awarded to major companies like Tata Motors, Reliance Industries, NTPC, Agency for New and Renewable Energy Research and Technology Kerala, Ashok Leyland, Hindustan Petroleum, Bharat Petroleum, and Indian Oil.

The total financial support for selected projects made available will be around Rs 208 crore from the Government of India. These pilot projects are likely to be commissioned in the next 18-24 months, paving the way to the scaleup of such technologies in India. The thrust area for providing support under the scheme is the development of commercially viable technologies for the utilization of hydrogen in the transport sector as fuel in buses and trucks, and supporting infrastructure like hydrogen refuelling stations.

These pilot projects can demonstrate safe and secure operations, assess the effectiveness of hydrogen-based vehicles and refuelling stations, validate technical feasibility and performance, and evaluate their economic viability, thereby leading to such vehicles and refuelling stations under real-world operational conditions.

The Scheme Guidelines for the implementation of such pilot projects are available on the Mission website.

Out of the list of 131 projects mentioned on the Mission's website (as viewed on 05 March 2025), 113 have been announced, 9 are commissioned, 7 are under construction, 1 has been decommissioned, and 1 is under the planning stage.

From the commissioned projects, ACME Group has set up the world's first integrated pilot project for a green hydrogen and green ammonia plant at Bikaner in Rajasthan. In this project, green hydrogen is being produced using 5 MWp from the solar plant, scalable to 10 MWp. The plant will help in saving approximately 4,400 tons/annum of carbon dioxide emissions. This R&D pilot green hydrogen plant in India has enriched the company with knowledge, experience, and learning, which are being utilized in other large-scale green hydrogen and green ammonia plants under development:

- ACME Group and the Government of Karnataka have signed an MoU to invest about Rs 52,000 crore in the State to set up a 1.2 mtpa green hydrogen and green ammonia project. The project would generate over 2,000 employment opportunities, after completion of the plant in 2027.
- ACME Group also signed an agreement with the Government of Tamil Nadu to set up a green hydrogen and green ammonia project in the state. The project entails an investment of Rs 52,474 crore and will be set up at the port town of Thoothukudi. It will comprise a 5,000 MW solar PV plant, 1.5 GW electrolyzer plant, and 1.1 million tons of ammonia synthesis loop. The green hydrogen and ammonia produced in the plant will help in decarbonizing the fertilizers, power, refining and steel sectors.
- ACME Group and the Government of Odisha also signed an MoU to explore opportunities for setting up a 1.1 mtpa green hydrogen and green ammonia project in the state.

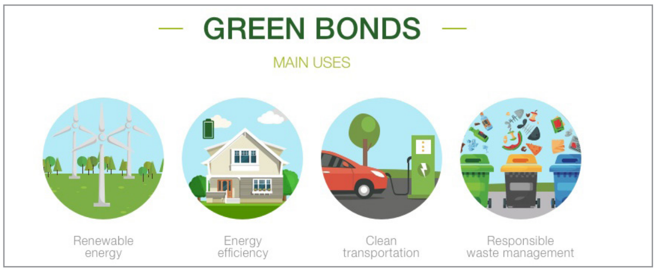
The NGHM website is https://nghm.mnre.gov.in/overviews.php

1 crore = 10 million

Financing the Decarbonization of the Indian Economy

India is poised for strong economic growth over the next few decades. However, as the world's third highest greenhouse gas (GHG) emitter[1], balancing economic growth with environmental impact is imperative. Moreover, the country has already committed to reducing the carbon emissions intensity of its gross domestic product (GDP) by 45% by 2030 and to net zero by 2070.

According to a Reserve Bank of India (RBI) study[2], the country needs approximately $1 trillion by 2030 to advance its decarbonization initiatives. Solar and wind account for the largest share at 25% of the total requirement ($250 billion[3]), followed by electric mobility, which requires approximately 18% ($180 billion[4]), and energy efficiency with 12% ($120 billion[5]) in capital investment.



Source: www.iberdrola.com

Challenges in Financing Decarbonization Projects in India

In mature sectors such as renewable energy, financing is gravitating towards renewable energy investment platforms and green bonds. However, in India, only large corporates have been able to issue green bonds – over 84% of green bonds have been issued by large private corporates.[6]

Growth segment technologies such as electric mobility and compressed biogas (CBG) have challenges accessing low-cost finance instruments that can fuel sector growth and enable future access to mature instruments such as green bonds, as observed in advanced economies.

Advanced economies have demonstrated investments in frontier segments such as green hydrogen, offshore wind, and carbon capture, in contrast to India, where these sectors are yet to gain traction in attracting early-stage capital. Here, these segments could be funded through similar instruments as in advanced economies.

Hence, decarbonization of the Indian economy requires that the following outcomes be realized:

1. Capital is to be made available at scale for mature sectors such as renewables, energy storage, and rooftop solar, as well as across the board for other decarbonization projects
2. Lower cost of capital is needed for growth sector technologies such as electric vehicles (EVs)
3. Concessional finance and equity capital is required to kick off investment in frontier sectors such as green hydrogen

Potential Decarbonization Financing Pathways

We suggest the following pathways to solve the financing challenge for India's decarbonization:

1. **Scaling up international financing:** Banks, insurers, asset managers, and asset owners globally managing $130 trillion in collective assets, have committed to achieving net-zero emissions by 2050 and staying on the path to limit temperature increase to within 1.5^{0}C[7]. India is among the top two emerging markets for international investment in the solar, wind and EV segments[8], and must leverage its favorable position to attract further international financing to decarbonize and scale up financing in these sectors.

   Gujarat International Finance Tec-City (GIFT City) in Gujarat is expected to help facilitate investment from international investors in Indian securities, in a regulatory regime comparable with any other leading jurisdiction and without currency risk. The IFSC's [a fully owned subsidiary company of National Stock Exchange Limited (NSE)] International Sustainability Exchange Platform[9] at GIFT City, will facilitate the listing and trading of a variety of sustainability products, including green bonds, voluntary carbon credits, sustainable bonds, green real estate investment trusts (REITs), and green equity among others, and promises to channelize the flow of sustainable finance to India and other markets[10]. Indian project developers and financial institutions must leverage this platform to secure international financing for decarbonization projects.

2. **Create headroom for domestic financial institutions to extend credit to decarbonization projects:** Domestic financial institutions are reaching their exposure limits to infrastructure lending[11]. Securitization of loan books allows banks to offload debt and create further headroom to finance infrastructure projects. Infrastructure Debt Funds (IDFs) are investment vehicles[12] through which banks can offload lower-risk operational assets.

   Additionally, domestic lenders can securitize their assets and sell their loan books to foreign commercial banks increasingly interested in India's clean energy growth. This will allow banks to manage sectoral exposure while reducing asset-liability mismatch and liquidity risks.

[1] WRI data
[2] RBI-Downtoearth article
[3] Bloomberg NEF report
[4] CEEW report on electric mobility
[5] BEE report
[6] World Bank
[7] GFANZ note
[8] BNEF Climetoscope
[9] NSE note
[10] Economic Times article
[11] ADB study
[12] RBI note

contd on pg 21

Natural Hydrogen: India's Next Frontier in Clean Energy

Hydrogen is critical in the global push toward decarbonization, particularly to achieve a low-carbon economy. Current hydrogen production processes emit around 1,200 million tons of CO_2 annually, accounting for ~3% of global carbon emissions. The majority of the 95 million tons of hydrogen produced in 2022 came from fossil fuels, with natural gas accounting for about three-quarters of the production and coal for nearly one-quarter (low-emission hydrogen represents just 0.7% of the total hydrogen demand globally) [1,2].

As India seeks to diversify its energy portfolio and combat climate change, the potential of hydrogen as a clean and sustainable energy vector is gaining significant attention. Among various hydrogen production methods, natural hydrogen (also known as geological, native, white, or gold hydrogen), stands out as a promising yet relatively unexplored avenue.

Understanding Natural Hydrogen

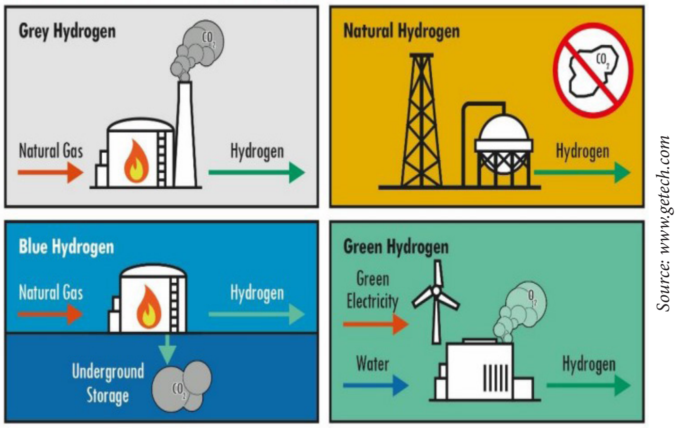
Natural hydrogen refers to hydrogen produced naturally in the Earth's subsurface through geological processes. Unlike hydrogen produced through methods such as water electrolysis or steam methane reforming, natural hydrogen is the product of deep-earth reactions—primarily water-rock interactions, radiolysis (breakdown of water molecules under the influence of ionizing radiation, resulting in the production of hydrogen), and the decomposition of hydrocarbons. This form of hydrogen is found in specific natural settings, including deep aquifers, gas fields, and rock formations [3,4]. It accumulates within the rock matrix or exists as free gas in rock fractures and pore spaces.

Global Exploration Efforts

Natural hydrogen exploration has been reported in various countries, including Mali, Turkey, Canada, Colombia, Spain, Australia, Albania, and the United States (US). However, there are no commercially exploitable deposits of natural hydrogen, with the exception of a small well in Mali (West Africa), producing ~5 tons per annum (TPA) of hydrogen used for electricity production.

The discovery in Mali, made in 1987, has continued to drive significant interest, leading to the establishment of over 40 companies, including Koloma (US), Hydroma (Canada), HyTerra & Gold Hydrogen (Australia), focused on extracting the resources with several securing substantial funding [5,6,7]. In fact, Koloma, a start-up based in the US that focuses on innovative methods for discovering and extracting natural hydrogen from underground mineral deposits, raised $245 million in funding from a group of investors, including Amazon's climate fund [8].

The Colors of Hydrogen



Prospective Sites for Natural Hydrogen in India

Recent studies by institutions such as Indian Institute of Technology (IIT) Gandhinagar (Gujarat) and IIT (Indian School of Mines), Dhanbad (Jharkhand) have predicted promising natural sites for natural hydrogen in India. According to the studies, areas with ultramafic and mafic rocks—such as those in Andaman, Ladakh, and the Himalayan regions,

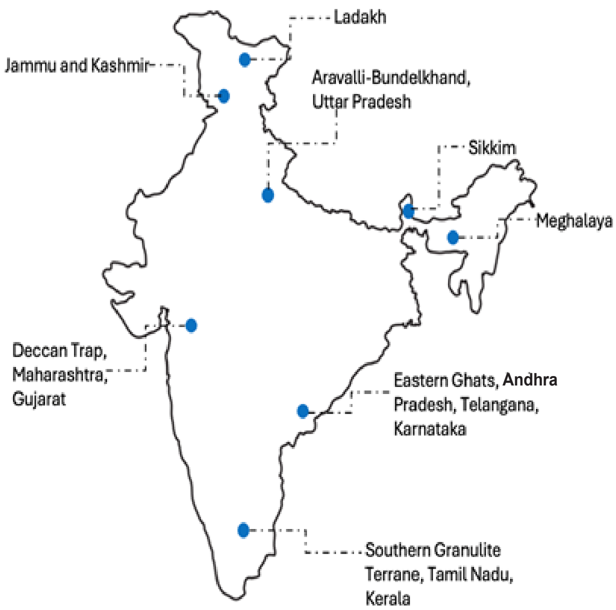


Fig. 1: Indian states/regions with potential for natural hydrogen resources and exploration[5]

[1] IEA, Global Hydrogen Reviews, 2023
[2] IEA, CO2 emissions in 2022
[3] H2, CH4, and Hydrocarbon Formation in Experimental Serpentinization
[4] Radiolytic H2 in continental crust
[5] Prospects of Natural Hydrogen in India
[6] The White Gold Rush, Energy Knowledge Institute
[7] Natural Hydrogen: The Race to Discovery and Concept Demonstration, Natural Society of London
[8] Bill Gates-Backed Hydrogen Startup Raises $245M in Investments

including Manipur and Nagaland—might be potential sites for natural hydrogen deposits. Additional prospective areas include volcanic-sedimentary formations in Bundelkhand, the Dharwar craton, and geothermal sites such as the hot water springs in Ladakh, Jammu & Kashmir, Maharashtra, Sikkim, and Meghalaya [5].

The Feasibility of Natural Hydrogen in India

While the potential for natural hydrogen is vast, its feasibility in India hinges on several critical factors:

- **Geological suitability**: India's natural formations, particularly in the states of Assam, Gujarat, and the Deccan Plateau region, may have the potential for natural hydrogen. However, comprehensive studies are required to map the locations, volume, and quality of hydrogen reserves. Natural surveys, seismic imaging, and other geophysical techniques must be deployed to assess the capacity of these formations.
- **Technological and economic viability**: Extracting natural hydrogen requires advanced technologies, including deep drilling and reservoir management techniques. Currently, the extraction process is costly and technologically challenging. Investment in research and development is essential to reduce costs and improve extraction efficiency. Collaboration with global experts and the establishment of pilot projects could help accelerate technology adoption.
- **Infrastructure development**: The logistical challenge of transporting and storing natural hydrogen is significant. India's existing infrastructure, including pipelines and storage facilities, may require extensive upgrades to accommodate large-scale hydrogen production. Public-private partnerships could play a key role in developing this infrastructure.

Primary Challenge

A key challenge in studying natural hydrogen in India is the limited availability of comprehensive and publicly accessible data. In-depth research and exploration are essential to map its distribution, identify occurrence patterns, and develop effective exploration techniques.

Inherent capabilities from the oil and gas industry, especially with organizations such as ONGC and Oil India, can be leveraged to develop robust public datasets that would enable further action from other stakeholders, catalyzing exploration and production of natural hydrogen.

Strategic Roadmap

India's roadmap to harness natural hydrogen must be multi-faceted, incorporating research, policy support, and infrastructure development.

Key steps for realising the potential of natural hydrogen include:

1. **Landscape assessment and geological mapping**:
   - National survey of geological formations to identify regions with the highest potential for natural hydrogen
2. **Policy framework**:
   - Robust policy and regulatory framework is essential to reduce risk exploration, extraction, transportation and commercialization of natural hydrogen
   - Environmental protection and sustainability will be crucial to ensure responsible development
3. **Investment in technology**:
   - Technological breakthroughs in hydrogen extraction, storage, and transportation must be prioritized
   - Public and private sector collaboration can foster innovation and help bring down the cost of production
4. **International cooperation**:
   - International collaboration with countries such as the US, Japan, and Canada, who are further along in hydrogen research, could provide valuable insights and enable joint technology development

Authors:
Varun Desai, Manager, and Dr. Bhaskar Jha, Consultant
Xynteo

Innovating for Tomorrow: Energy Leap's Clean Hydrogen Pioneers Shape a Sustainable Future

As Energy Leap continues to drive innovation in the clean hydrogen sector, we are proud to showcase three more groundbreaking companies from our inaugural cohort. These innovative startups are transforming different aspects of the hydrogen value chain with solutions ranging from waste-to-hydrogen production to industrial combustion systems and advanced electrolysis technology.

SBES Technologies: Revolutionizing Industrial Hydrogen Combustion

Based in Hyderabad and set up in 2021, SBES Technologies is pioneering a transformative approach to industrial heat processes through their patented HyFlex burner system. Under the leadership of Dr. Naresh Aluri and his expert team, the company has developed an innovative 3D-printed, fuel-flexible burner that can operate seamlessly with hydrogen blends up to 100% hydrogen.

What sets SBES's HyFlex burner system apart is its remarkable adaptability across different fuel types with Lower Heating Value (LHV) variations from 35 to 120 MJ/kg. The system offers power ranges from 100 kW to 5 MW, making it suitable for diverse applications in the energy sector, oil & gas, food industry, and chemical processing. Most importantly, their technology enables industrial facilities to transition to hydrogen without additional CAPEX for energy transition.

The HyFlex system has been validated at 200 kW in industrial furnace settings through the United Nations Industrial Development Organization (UNIDO) accelerator program at IIT Hyderabad, demonstrating both its technical effectiveness and commercial viability. With its flashback-resistant design, low emissions (<10 ppm NOx), and approximately 50% reduction in blower electricity consumption, SBES is well-positioned to serve a global industrial burner market worth $6.7 billion.

www.sbestechnologies.com

Hylan Power One: Breaking Cost Barriers in Solid Oxide Technology

Bengaluru-based Hylan Power One, set up in 2023, is revolutionizing the hydrogen sector through its pioneering work in Reversible Solid Oxide technology. Co-founded by Bharath Srivatsa and Achintya Venkat, this startup, registered as a micro, small and medium enterprise (MSME), is dedicated to making this advanced technology cost-effective

through complete local manufacturing under the "Make in India" initiative.

Hylan's mission addresses a critical challenge in the hydrogen economy — breaking the cost barrier traditionally associated with Solid Oxide technology to make it competitive with Proton Exchange Membrane (PEM), Alkaline, and Anion Exchange Membrane (AEM) electrolyzers. Their approach involves developing advanced cell architecture and stack designs that achieve exceptionally high efficiency, surpassing global standards in both performance and durability.

What gives Hylan's technology a unique edge is its ability to utilize industrial waste heat, making it particularly valuable for industries seeking comprehensive decarbonization solutions. The company is currently developing a 5 kW prototype complete with Balance of Plant (BOP) to demonstrate an end-to-end solution. Their ambitious roadmap includes establishing a MW-scale manufacturing setup within the coming year to achieve the necessary cost advantages through scale.

Combining experienced professionals with young talent, Hylan Power One has created a collaborative environment focused on technical excellence and innovation. Their commitment to developing high-efficiency, cost-effective Reversible Solid Oxide Cells (R-SOC) positions them as an important player in accelerating the global transition to clean energy.

https://www.hylan.in/

SunGreenH2: Supercharging Electrolysis Technology

Singapore-based SunGreenH2, set up in 2020, is revolutionizing green hydrogen production through their innovative approach to electrolysis technology. The company has developed breakthrough (AEM) technology that achieves platinum-like performance without using expensive platinum group materials (PGMs).

Their proprietary electrodes deliver remarkable efficiency gains, achieving 20% lower energy consumption while doubling hydrogen production compared to conventional systems. The company's technology stands out for its ultra-stable performance, promising decades of durability and significantly reduced operational costs.

SunGreenH2's innovation has already gained significant industry recognition, with successful deployments including a partnership with Naturgy in Spain. Their technology promises to reduce the levelized cost of hydrogen (LCOH) by 30-40% compared to commercial AEM electrolyzers, making green hydrogen more economically viable for wide-scale adoption.

The company has established a strong manufacturing presence with facilities in Singapore and Melbourne, supported by an experienced team led by CEO Tulika Raj and CTO Dr. Saeid Masudy Panah. Their 100 MW production capacity and partnerships with major energy companies position them well to scale their technology globally.

www.sungreenh2.com

The Path Forward

These three companies exemplify Energy Leap's commitment to accelerating the clean hydrogen economy through diverse technological approaches. From SBES's hydrogen combustion systems that enable industrial heat transition, to Hylan Power One's breakthrough in solid oxide cell technology, to SunGreenH2's innovations in electrolysis, they represent the kind of complementary solutions needed to establish a robust and sustainable hydrogen economy.

Together, they address critical points across the hydrogen value chain — from production technologies to industrial applications — helping to create a more sustainable and economically viable future for clean hydrogen adoption.

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

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Financing the Decarbonization .... contd from pg 17

Pension and insurance funds also need to finance the decarbonization of the Indian economy, given the scale of capital required. Life Insurance Corporation (LIC) has nearly $500 billion worth of assets; 95% of this fund is invested in securities[13]. Re-aligning these assets towards green securities, debt, and equity can also finance decarbonization.

In addition, private asset management firms can develop asset classes such as infrastructure investment trusts for mature assets such as wind and solar.

Most Indian financial institutions are not members of the Net-Zero Banking Alliance or similar collaborative platforms[14]. There is a strong need to establish a national net-zero financing alliance to initiate dialogue and build a sector-led financing strategy, or encourage financial institutions to participate in global alliances.

3. **Scaling up blended finance for Indian decarbonization projects**: There are typically four types of blended finance instruments used in India. These are concessional debt, credit guarantee or risk insurance, technical assistance (TA) and grants, and results/outcome-based financing. Typically, a partial credit guarantee instrument has 6-7x leverage. Sectors such as EV, renewable natural gas (RNG), and battery storage can benefit from the development of dedicated sector-based funds, using blended finance to fund the entire value chain of the sector through various instruments. Blended finance currently takes considerable cost and time to structure, and so far, there is a lack of a clear and robust regulatory and legal environment[15]. Also, there are no intermediaries to help structure and manage blended finance transactions. A collaboration platform to align multiple stakeholders could facilitate transforming and scaling up blended finance in India.

4. **Carbon markets**: India's proposed Carbon Credit Trading Scheme, set for 2026, includes voluntary and compliance-based elements. It aims to reduce net carbon emissions by allowing the trade of carbon credits. Compliance-based trading will set emission limits for sectors, incentivizing reductions, while voluntary trading allows companies to offset emissions for sustainability goals. Carbon markets will allow the project developers to access a new financing source while allowing corporates to hedge the price for carbon credits.

Ultimately, we believe that concerted and collaborative efforts are needed by multiple stakeholders in the financial ecosystem to unlock capital and realize the decarbonization opportunity in India.

Authors:
Varun Desai, Manager, and Dr. Bhaskar Jha, Consultant
Xynteo

13 LIC annual report
14 GFANZ member list
15 Report on Blended Finance by Asha Impact

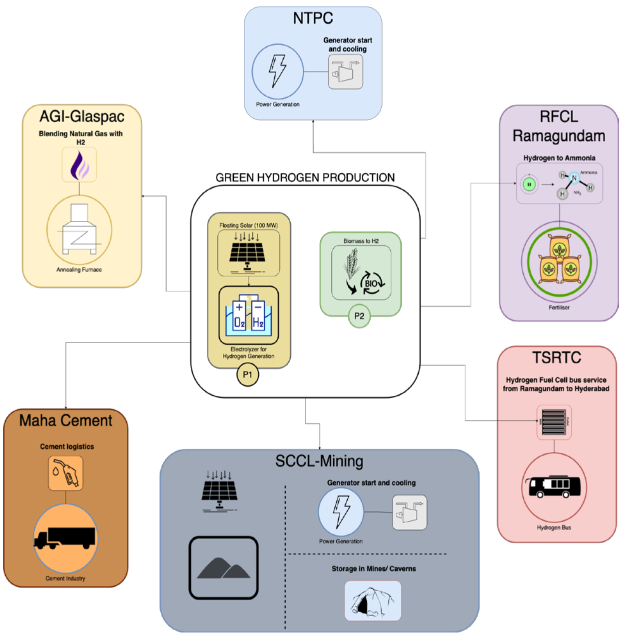
Ramagundam's Green Hydrogen Valley: A New Model for Integrated Industrial Decarbonization

In India's race toward industrial decarbonization, an innovative experiment is taking shape in Telangana's Ramagundam region. Unlike traditional industrial clusters that focus on a single sector, the Telangana Hydrogen Valley Innovation Cluster (THVIC) is pioneering a unique approach: creating an integrated ecosystem where diverse industries collaborate to transition to green hydrogen, while leveraging shared green hydrogen infrastructure and knowledge.

The Research and Innovation Circle of Hyderabad (RICH), as the nodal agency for this ambitious project, has crafted an approach that could become a blueprint for how industrial regions across India tackle their decarbonization challenges. What makes this model particularly interesting is its focus on solving real industrial problems, and working towards indigenization and innovating technologies in collaboration with ecosystem participation rather than simply deploying new technology.

The Power of Industrial Symbiosis

At the heart of THVIC's innovation is its focus on industrial symbiosis. The cluster brings together five distinct industry



sectors — Fertilizers (Ramagundam Fertilizers and Chemicals Limited or RFCL), Mobility (Telangana State Road Transport Corporation or TGSRTC), Cement (MyHome), Mining (Singareni Collieries Company Limited or SCCL), Energy (NTPC) and Glass/Ceramics (AGI Glaspac). Each faces unique decarbonization challenges, but together they create a critical mass of hydrogen demand that makes the infrastructure investment viable. Assisting the consortium on the technology

development and innovation side are IIT Hyderabad, Indian Institute of Chemical Technology (IICT) Hyderabad, and Xynteo (Energy Leap).

RICH, the nodal agency for the Hyderabad Science & Technology (S&T) Cluster, has played a pivotal role in developing THVIC, particularly in the Ramagundam region. As an ecosystem enabler, RICH, with the support of the Department of Science and Technology (DST), initiated discussions with key stakeholders and organized a stakeholder consultation event to consolidate various industries, research organisations, and policymakers. It also facilitated the formation of a diverse consortium and identified key industrial use cases for green hydrogen, including ammonia production, hydrogen blending, etc.

This diversity isn't just about spreading risk — it's about creating a living laboratory where different hydrogen applications can be tested and optimized simultaneously. When AGI Glaspac discovers a new way to apply and optimize hydrogen use in glass manufacturing, that knowledge doesn't stay siloed — it becomes part of the cluster's shared learning. When RFCL develops more efficient methods of integrating green hydrogen into fertilizer production, other industries can adapt these insights to their own processes.

A Phased Approach to Innovation

What sets Ramagundam's approach apart is its carefully structured implementation plan. Rather than attempting an immediate large-scale transition, the cluster will begin with a modest 2.62 tons per day of green hydrogen production in its pilot phase, and this hydrogen would be consumed in applications with low inertia to adoption. This will gradually scale up to 14.5 tons per day by 2030 and potentially 75 tons per day in the long term.

This measured approach allows for something crucial: learning by doing. Each phase of scaling up becomes an opportunity to optimize processes, test new technologies, indigenize and solve real-world implementation challenges. The pilot phase focuses on high-impact, readily achievable

applications — like using green hydrogen for natural gas desulfurization at RFCL and testing hydrogen fuel cell buses for TGSRTC.

Infrastructure as a Catalyst

The valley's physical infrastructure is being designed to catalyze collaboration. A centralized hydrogen production facility at SCCL will be connected to various end-users through a mix of pipelines and gas caskette via road. This shared infrastructure approach significantly reduces the investment burden on individual companies while ensuring reliable supply.

The project's location itself is strategic — situated near both renewable energy resources and water sources, with good connectivity to all major industrial users. This careful geographical planning ensures that the hydrogen valley can operate efficiently while minimizing transportation costs and safety risks.

Building a Knowledge Economy

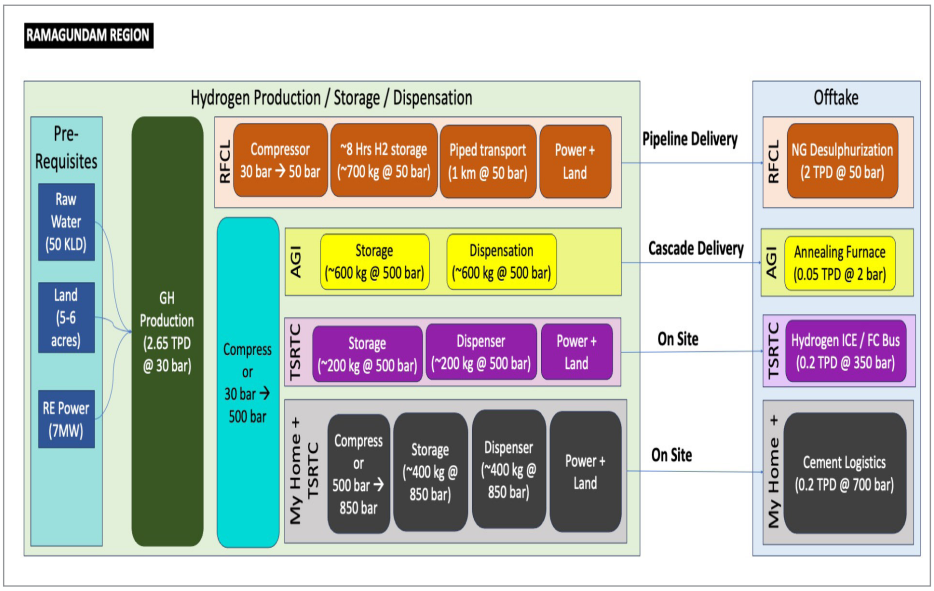
Perhaps the most forward-thinking aspect of THVIC is its emphasis on creating a knowledge economy around green hydrogen. Regular consortium meetings bring together industries, research institutions like IIT Hyderabad and CSIR-IICT, system integrators, and ecosystem enablers. These aren't just formal gatherings — they're dynamic problem-solving sessions where real industrial challenges meet innovative solutions in real-time.

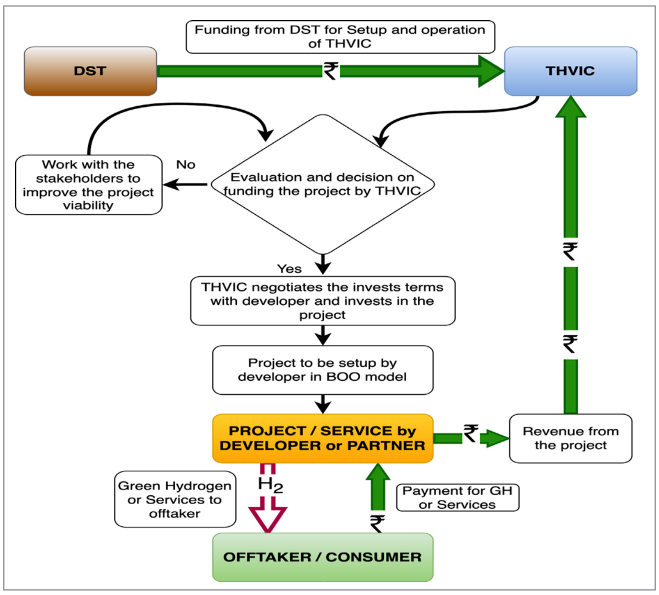
The Economic Innovation

The valley's economic model is as innovative as its technical approach. Rather than relying solely on government support, THVIC is developing a hybrid funding model that combines public support with private investment. The initial government support helps de-risk early investments, while the gradual scaling allows the project to become commercially viable as technology costs decrease and carbon regulations tighten.

Looking Ahead: A Model for Others

As India grapples with its ambitious green hydrogen mission, Ramagundam's approach offers valuable lessons. It demonstrates that successful industrial decarbonization isn't just about deploying new technology — it's about creating ecosystems where innovation, implementation, and learning can happen simultaneously.





The cluster's impact could extend far beyond its immediate geography. As more industrial regions in India and globally look to decarbonize, Ramagundam's integrated approach — combining diverse industrial applications, shared infrastructure, and knowledge creation — could provide a template for how to make the transition to green hydrogen both technically feasible and economically viable.

In the heart of Telangana, THVIC is showing that the most effective way to solve complex industrial decarbonization challenges is to create an environment where diverse industries can collaborate, innovate, and learn together. As this living laboratory continues to evolve, it may well become a model for industrial clusters worldwide.

Author:
Srinivas Cherla
Director of Sustainability,
Research and Innovation Circle of Hyderabad
Hyderabad
Email: dir-sa-rich@telangana.gov.in
Web: https://rich.telangana.gov.in/