Innovative Thought Forum

Industries & Mines Department
Government of Gujarat

G20 भारत 2023 INDIA

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Transitioning towards a Green Hydrogen Economy for Net Zero 2070

Seminar Report

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Innovative Thought Forum

Co-organized by: IIMA, ITF and NDC Aspects
Under the aegis of Industries and Mines Department, Government of Gujarat

Date: 13th July 2023

Venue: JSW-SPP, New Campus, IIM Ahmedabad

❖ Context and Objective

At COP26, Hon'ble Prime Minister of India, Shri Narendra Modi announced the need to follow the mantra of LiFE, i.e., Lifestyle For Environment – A global movement to affect paradigm shift from mindless and destructive consumption to deliberate utilization. LiFE mission should be seen as a guideline by India as well as the world, towards achieving its objective of Net Zero emissions. India's Nationally Determined Contributions to the UNFCCC give impetus to energy transition towards renewable sources for achieving India's targets of becoming energy independent by 2047 and Net Zero by 2070. The role of green hydrogen is indispensable for enabling this transition. As a rapidly growing economy and a global leader in renewable energy, India, has the opportunity to spearhead the adoption and integration of hydrogen technologies into its energy sector.

Recognizing this potential, the Government of India has expressed its commitment to transitioning towards a clean hydrogen economy through the National Green Hydrogen Mission 2 on 4th January 2023. The mission aims to develop a green hydrogen production capacity of at least 5 MMT (Million Metric Tonne) per annum, alongside adding renewable energy capacity of about 125 Gw1 in India by 2030. The overarching objective of the Mission is to make India the Global Hub for production, usage and export of Green Hydrogen and its derivatives.

One of the key tenets of the mission is the allocation of Rs 17,490 crore under Strategic Interventions for Green Hydrogen Transition (SIGHT) programme, which will be distributed through a Production-Linked Incentive (PLI) scheme for manufacturing of electrolysers and production of green hydrogen.

The state of Gujarat is the hub of industrial units of various sectors. It is estimated that Gujarat will utilize 30%, i.e., 1.5 MMT of Government of India's target of 5 MMT of green hydrogen production by 2030[2]. Hence, there is a need to develop the production capacity of green hydrogen in the state through a robust policy framework. The Energy and Petroleum Department, GoG is in the process of formulating a draft green hydrogen policy to promote and facilitate development of green hydrogen projects.

Moreover, to incentivize green hydrogen investments and consequent production, the Gujarat government has announced a land allotment policy that offers several benefits to companies investing in the state's green hydrogen projects. The Policy 2023[3] for leasing out government fallow land for green hydrogen production using non-conventional energy sources such as solar, wind, wind-solar hybrid energy targets that companies must meet 50% of their green hydrogen production capacity within five years of plant commissioning and achieve 100% capacity within eight years.

Further, Government of Gujarat had already announced "The Aatmanirbhar Gujarat Schemes 2022 for Assistance to Industries" wherein large industries, thrust sectors & mega industries under Green Energy Eco system including Green Hydrogen / Ammonia, Electrolysers, RE equipment, BESS, Fuel cells etc will be getting financial assistance such as Interest subsidy, Net SGST reimbursement, EPF reimbursement, Reimbursement of Stamp duty & Registration fees etc.

The Ministry of New & Renewable Energy has released a document on Green Hydrogen as having a well-to-gate emission (i.e., including water treatment, electrolysis, gas purification, drying and compression of hydrogen) of not more than 2 kg CO2 equivalent / kg H2, further, it also outlines that these emission thresholds must be met in order for hydrogen produced to be classified as 'Green', i.e., from renewable sources.[4]

India's Green Hydrogen Roadmap presents a clear vision for transitioning towards a hydrogen powere

deconomy through a combination of policy movement and business interests to accelerate the deployment of green hydrogen projects and drive innovation in the sector. However, several challenges such as costs, infrastructure, skilled workforce, etc., need to be addressed for successfully implementing and scaling up the use of green hydrogen in the country. Thus, transitioning to a green hydrogen economy requires a collaborative effort involving stakeholders from industry, academia, research institutions, and both state and central governments. It demands a comprehensive understanding of the challenges and opportunities associated with hydrogen production, storage, transportation, and utilization. It also calls for the identification of viable business models, financing mechanisms, and regulatory frameworks to support the scaling up of hydrogen technologies.

The seminar's agenda sets the stage for meaningful discussions and deliberations on the various aspects of transitioning towards a green hydrogen economy in India as follows:

- How can the current technologies in green hydrogen be further improved to enhance efficiency and reduce costs?

  Indian private companies and government enterprises should acknowledge and promote indigenous/domestic hydrogen production units as the current cost of green hydrogen is in the range of USD 5-6 per kg, however, this cost can be reduced through localization of production resources. Moreover, we could also rely on financial aid provided through international agreements which could support significant reduction in costs of green hydrogen and green ammonia projects as they are highly capital intensive.

- What are the key challenges in integrating RE sources for green hydrogen production process, and how can these challenges be overcome?

  The key challenges associated with integration of RE for green hydrogen production are intermittency and variability of RE power generation, system balancing, backup and energy storage. Hybridization of storage technology would be the need of the hour. The combination of all types of RE power generation sources would bring down the cost of energy storage. One could take advantage of GoI's initiatives such as "Make in India" for manufacturing Solar PV panels/cells in India to increase green hydrogen production through solar energy. Also, pumped hydro power should be promoted as one of the energy storage solutions. The existing facilities of 1200 MW pump hydro power capacity of Sardar Sarovar Project in Gujarat could be utilized as it could be valuable energy storage. The abundance of agricultural waste present in India has a potential to convert it to several million tons of green hydrogen through gasification process.

- How can the production of electrolysers be increased to make India self-reliant in green/blue hydrogen production?

  Electrolyser manufacturing in India should be promoted in mission mode. Government of India (GoI) should emphasize more to boost business opportunities to electrolyser manufacturers in India. GoI has announced PLI scheme for both green hydrogen production and electrolyser manufacturing which will make the nation self-reliant in electrolyser production. Electrolyser units with small capacity (1-3 MW) could be beneficial to promote decentralized mode of green hydrogen production. Central Electro Chemical Research Institute (CECRI) and Central Salt & Marine Chemicals Research Institute (CSMCRI)

have developed new and highly efficient electrolyser technologies that could be scaled up for mass production. There is a need and opportunity for collaboration between academia and industry to boost more research & development in green hydrogen and electrolyser manufacturing space.

- What are some of the opportunities provided by green hydrogen from a demand side perspective?

  Green hydrogen offers a great opportunity for rapid decarbonization of the industry sector. It is RE storage for utilizing excess energy and to help stabilize grids while meeting peak demand. Furthermore, it can be used as a transportation fuel for fuel cell vehicles which would be a zero-emission alternative for the transportation sector and reducing reliance on fossil fuels.

- What are some global models of green hydrogen ecosystem in place? How well can these systems fit into the Indian scenario?

  Currently, the United States and European Union (EU) lead in policy/regulatory actions for green hydrogen, whereas China leads in the production or deployment of green hydrogen. Germany will create an international market for green hydrogen usage to maintain their industrial competitiveness through sourcing raw materials from imports. The EU desires to import green and clean energy instead of fossil fuels. However, as of now it lacks the development of supply chain needed for a low carbon world/ economy. Green hydrogen should be encouraged and accelerated as green product manufacturing in India which would abate Carbon Border Adjustment Mechanism (CBAM) imposed carbon taxation in future.

- How can policy frameworks and financial mechanisms be designed to incentivize investment in green/blue hydrogen infrastructure and promote the widespread adoption of hydrogen?

  Green hydrogen should be made economically competitive to ensure its growth as it is gaining prominence from both businesses as well as industries. India could leverage the digital prowess to further increase green hydrogen demand and supply instead of being only trader (importer and exporter) as real-time match of demand and supply could be possible through digital platforms. Further, electrolysers contribute to about 20-25% of total green hydrogen production cost which can be brought down to less than $1-2 per kg through more indigenous R&D activities and through collaboration between government, academia and industry. Initially, it is essential to support the production of hydrogen from a variety of sources, including renewable energy, fossil fuels with carbon capture, utilization & sequestration (CCUS) technologies and nuclear energy, under the umbrella of clean hydrogen in order to speed up the availability of hydrogen in the market. To ensure growth of clean hydrogen, a carbon intensity cap should be set in place instead of mandating renewable energy sources as the only source of clean/green hydrogen production.

- What are the regional or state level challenges that inhibit the promotion green hydrogen?

  Production of green hydrogen at state or regional level in India currently faces various challenges such lack of dedicated infrastructure for hydrogen production, transportation, and distribution which hinders the adoption and widespread use of green hydrogen technologies. High upfront costs for setting up electrolyser facilities and related infrastructure could deter potential investors and limit the growth of green hydrogen projects at the state or regional level in India. Availability of land and water is another big

challenge that should be resolved for decentralized green hydrogen production. Special support and incentives should be provided to small and medium enterprises (SMEs) to facilitate green hydrogen ecosystem such as earmarking a portion of the PLI scheme benefits at every stage of its supply chain.

- What are the critical success factors such as Land, Water, RE generation and Demand centers for H2 economy and how can global partnerships be fostered to accelerate progress?

  Scrutinizing and leveraging our diplomatic stature could promote a green hydrogen ecosystem globally. Developing countries like India should be included in green hydrogen discussions at the global level. The focus should be on creating an attractive investment environment for foreign companies and investors interested in green hydrogen projects in India, thus, promoting cross-border capital flows and technology infusion.

This seminar aimed to stimulate discussions to foster a deeper understanding of the challenges, opportunities, and future directions in this rapidly evolving field through the following sessions.

1. Green Hydrogen from Supply Side Perspective

   This session explores the current status of green hydrogen and barriers to creating a large supply. At present the supply chain for green hydrogen is minimal and the use of green hydrogen is limited. Thus, rapid growth is necessary, through R&D and policy support for the industry to scale up to the size needed to make a significant contribution towards energy transition.

2. Green Hydrogen from Demand Side Perspective

   This session will look into the demand-side potential of green hydrogen in India. It is essential to create supportive policies, provide incentives, and foster collaboration between industry, academia, and government to drive the adoption and integration of green hydrogen across various sectors.

3. Green Hydrogen from International Perspectives

   Several countries have a robust hydrogen strategy to support the sector. In this session, India can draw early lessons from the trailblazing countries in the green hydrogen sector and learn to implement the best practices through these insights.

4. Economics of Green Hydrogen and Way Forward

   This session will explore the ways to accelerate the adoption of green hydrogen through a focus on providing long-term market incentives, supporting R&D efforts, establishing favourable regulatory frameworks, and promoting international collaboration to drive scale, reduce costs, and unlock the full potential of green hydrogen as a key pillar of a low-carbon economy.

❖ **Speakers and Attendees**

The seminar was attended by a total of 45 participants. This consisted of 20 Speakers and 25 participants. The detailed list of speakers & participants is mentioned in Annexure-2.

❖ **Key Takeaways from all the Sessions**

- Green hydrogen is gaining prominence from both businesses as well as industries.
- Green hydrogen needs to be made monetarily competitive to ensure its growth.
- A good solution is to convert hydrogen into ammonia or methanol as their supply chains already exist in the market.
- India needs to stop being only trader (importing and exporting) of green hydrogen. We need to invest more in research & development for the development of green hydrogen technology. Government of India has already announced PLI scheme for both green Hydrogen Production and Electrolyser manufacturing on July 7, 2023.
- The price of Renewable energy at green hydrogen production site should be focus first. However, Renewable energy integration is intermittent; hence we can't focus on a single energy source in short to medium terms. Hybridization of storage technology is the need of the hour. The combination of all types of renewable energy sources is necessary to bring down the cost of hybrid RE with ESS.
- The long-term goal should be centralized storage, and short term is decentralized storage; both need to be in the right combination for an ideal energy mix.
- It is important to explore other metal based instead of Li based EV for example Aluminium Based (IOCL is already working on it) to make renewable energy sources dispatchable, we need storage technology.
- Adding appropriate additives to electrolyte will increase efficiency of hydrogen production of the same system whilst using less voltage.
- Indian private companies and government enterprises should acknowledge and promote indigenous/domestic hydrogen production units.
- Government of India (GoI) should focus on giving more business opportunities to electrolyser manufacturers in India, rather than imports.
- Advantage of GoI's initiatives such as "Make in India" should be emphasized more for manufacturing Solar PV panels/cells in India.
- Current cost of green hydrogen is in the range of USD 5-6 per kg. However, this cost can be reduced through localization of production resources.
- There is a need and opportunity for collaboration between academic institutions and industry for more research & development in green hydrogen space. There is certain patented research which are available with various institutions on renewable energy, Hydrogen production etc. Both Institution and Industries should come forward for commercialization. This is practiced followed in European countries like Germany and Netherlands. will both motivate the students and indigenization of technology.
- 20-25% of green hydrogen production cost is because of electrolysers, which can be brought down to less than $1 per kg with more indigenous R&D activities.
    - Provision of Electricity Banking Facility for Green Hydrogen projects owing to it large, unified Grid size with consumption of more than 210 GW and supply for more than 400 GW, will make it feasible to

utilize Electrolyser capacity at close to 100% levels, thus enabling the world to produce more Green Hydrogen with the limited capacity of Electrolysers.

- Moreover, the Production-Linked Incentive (PLI) scheme for manufacturing of electrolysers will help reduce electrolyser costs and increase production of green hydrogen.

- Pumped Hydro should be promoted as it might be low-cost solution for energy storage and utilization. It is possible to promote the same in a decentralised manner like KUSUM yojana.
- India produces an average of 500 million tons of agricultural residue every year; more than 200 million tons remains unutilized. This can be converted to several million tons of green hydrogen through gasification process.
- Apart from green hydrogen, gasification of biomass can also produce biochar or carbon dioxide which can be sequestered for high quality agricultural soil.
- A decentralized mode of green hydrogen is needed which also ensures 2 nd / 3rd generation biomass utilization. Electrolyser units with small capacity (1-3 MW) can be helpful to promote decentralized mode of green hydrogen production.
- Key strategies for creating green hydrogen demand:
  - Domestic consumption should be focused on rather than solely relying on exports.
  - Export capabilities should however be set up simultaneously efficiently.
  - Government could mandate for mandatory usage and production of green hydrogen in industries.
- We need to identify other industries apart from Iron & Steel under the hard to abate sectors such as chemicals and refineries.
- We need to identify other industries apart from Iron & Steel under the hard to abate sectors such as chemicals and refineries.
- For the steel industry, hydrogen is not a fuel but an energy carrier.
- The United States and European Union (EU) lead in policy/regulatory actions for green hydrogen, whereas China leads in the production or deployment of green hydrogen.
- The ideal course of action for India could be an increased focus on solar as primary source of energy and shifting a little bit to coal or nuclear as and when needed. This would ensure less dependence on imports of oil and gas in India.
- India could leapfrog from coal to green hydrogen as a complement to the already existing solar sources.
- We should preplan the integration of all stakeholders to make the green hydrogen plus solar set up and gradually move away from coal over the next couple of decades.
- It is extremely cheaper to decarbonize the EU steel sector by importing steel from other countries like South Africa, India and China.

- Focus on use of hydrogen for decarbonizing or reducing emissions in existing refineries and chemicals industries while substantial usage in iron & steel industries.
- Germany wants to create an international market for green hydrogen usage to maintain their industrial competitiveness by getting imports for their industries.
- The EU wants to import green and clean energy instead of fossil fuels. However, as of now it lacks the development of supply chain needed for a low carbon world/ economy.
- To facilitate demand side growth in EU countries, its green hydrogen strategy has established partnerships between EU countries and the industry to provide a level-playing field.
- Green hydrogen can help abate Carbon Border Adjustment Mechanism (CBAM) imposed carbon taxation on green products from India.
- It is important for developing countries to be included in green hydrogen discussions as the decisions linked to green hydrogen should not by developed countries only.
- Green hydrogen offers an opportunity to decarbonize the industrial sector rapidly.
- Policy paths don't necessarily always lead to market creation but fundamental improvements in technology will lead to better market creation.
- To achieve futuristic cost (USD 1 per kg) of green hydrogen from the current high cost, there should be increased focus on combination of different sectors wherever possible.
- We should leverage the digital prowess of our country to further increase demand of green hydrogen. Realtime matching of demand and supply could be possible through digital platforms.
- We should scrutinize on leveraging our diplomatic stature to promote green hydrogen ecosystem globally.
- R&D support by the GoI is needed to compete with international players in the market; specially for domestic manufacturing of electrolysers and fuel cells.
- The existing facilities of 1200 MW pump storage of Sardar Sarovar Project can be put to operations at the earliest to serve the grid with a huge battery of 1200 MW. Besides this, possibilities to create new pump storage in the existing medium / large dams in the State should be investigated.
- The Bilateral trade agreement with the European union or other countries who have CBAM for the import of hydrogen should discuss the technology transfer under the same. Such countries are getting huge profit when they transfer the technology to India.

Industries should explore the existing Bilateral agreement with countries like Singapore, Japan etc. instead focusing only on Western Countries.

❖ **Detailed Minutes of the Meeting:**

→ Inaugural Session

Speakers:

1. Amit Garg- Professor, IIM Ahmedabad

2. S.B. Dangayach- Founder Trustee, Innovative Thought Forum

Introductory address by Mr. S.B. Dangayach

- Green hydrogen is the key factor needed for achieving net zero goals for India.
- India is one of the pioneers of green hydrogen however there is still a lot to learn from around the world and to grow as a country.

Introductory address by Prof. Amit Garg

- Government of India has declared its Green Hydrogen Mission and several states such have also come up with their own green hydrogen policy.
- For achieving Net Zero goals, it is important to work on several fronts simultaneously.
- Need of the hour is how can India build a green hydrogen economy? What are the requirements of green hydrogen?
- How can we manage water resources within green hydrogen production as 1 kg of hydrogen requires 18 kgs of water because of which states at water risk like Gujarat or Rajasthan might be at a disadvantage.
- We also need to analyse transportation of green hydrogen; whether it will follow coal's pathway in transportation or be transported through pipelines like oil.
- Role of green hydrogen in freight vehicles is another crucial area to be explored.

→ Session One: Green Hydrogen from Supply Side Perspective

Speakers:

- Rashi Gupta- Managing Director, Vision Mechatronics
- Sudhanshu Sharma- Associate Professor, IIT Gandhinagar
- Jitendra Trivedi- Director, Aztech Composites Pvt Ltd
- Anil Agrawal- Founder, Airox Nigen Equipment Pvt Ltd
- Chintan Shah- Former Director, IREDA
- Pawan Mehndiratta- Strategic Business Unit Head, Thermax Ltd (Online)

Discussion by Mr. Chintan Shah

- Currently only 16% of energy in India's total supply is coming from electricity.
- The target set by Government of India is to achieve at least 40% of total electricity from renewable energy. A major challenge till now was to replace oil & gas by shifting to electricity.
- However, there are certain industries that will always require fossil fuels, because of dual purpose of fuel (i.e., fuel & raw material)

- The advantage of green hydrogen is that it can cross the electricity spectrum and directly replace oil & gas through hydrogen or its derivatives as an energy Swiss knife.
- Converting hydrogen into meaningful radicals for energy or derivates for industry or commodity purposes can be very useful and the future, such as:
  - manufacturing methanol can help make petrochemicals from hydrogen.
  - When hydrogen is produced ammonia is also produced, hence green hydrogen can help replace production of ammonia through fossil fuels.
- Ammonia is the largest industrial agent and green hydrogen can help cater to its market demand. Ammonia prices are between $500- $550.
- Green hydrogen needs to be made competitive to ensure its growth.
- There needs to be proper planning of green hydrogen transmission; ideally the plant should be close to its usage point.
- Transporting electrons of hydrogen instead of whole molecules of hydrogen.
- Government of India has made transmission free for green hydrogen till 2035.
- The biggest challenge for green hydrogen currently is electrolysers. The right technology for mass scale production of electrolysers needs to be evolved.
- There are several large questions that need to be answered to ensure green hydrogen growth, viz., where should hydrogen be stored? Should hydrogen be converted into ammonia or liquefication or regassification of hydrogen should take place?
- Hydrogen is voluminous but it is not dense, hence large amounts of storage space is required.
- The best solution is to convert the hydrogen into ammonia or methanol because the supply chain for them has already been established and is in place. For supplying hydrogen directly, a new supply chain would need to be made.
- A tolling model for ammonia and electrolyser can be set up.
- A growth in domestic demand can push more supply chain.
- Scaling up green hydrogen is key and there is a need to develop a robust supply chain.
- There is a need for university and industry linkages for research & development requirement understanding.
- Research & development will also result in a reduction in costs.
- 2070 is just a number but we can surely reach our targets even sooner.

Discussion by Dr. Rashi Gupta

- The current climate crisis is 1.5 degrees, by 2030 a 2.5 degree of difference is anticipated.

- We need to stop being traders and shift our focus from simply importing and exporting to more investment in research & development for manufacturing of green technology.
- Investment in skill development is needed to fasten the process.
- Renewable energy integration is intermittent; hence we can't focus on a single source. Hybridization of tech and hybridization storage is the need of the hour. The combination of all renewable energy sources is necessary.
- Investment into research and development is necessary.
- We need to plan out the right and clean energy mix by 2036.
- Even if pipelines are modified for green hydrogen, the capital investment costs can be reduced by 60-70% by using same transmission lines as oil, however the final LCOE effect would only be affected by 10-20% and the operations & management will be the same.
- Hydrogen storage is expensive and capital intensive as hydrogen has to be stored at high pressure and in carbon fiber storage capsules; manufacturing of those products is a challenge for India. There should be focus on developing these resources in India.
- India needs to innovate to become a superpower.
- The long-term goal should be centralized storage, and short term is decentralized storage; both need to be in right combination for the ideal energy mix.
- Hybridization is required at 3 levels- generation, transmission/distribution and storage of green hydrogen.

Discussion by Dr. Sudhanshu Sharma

- Focus needs to be on making electrolyser technology more efficient.
- A voltage of 1.23 is needed for water breaking.
- It is important to see the output from the hydrogen being produced.
- Adding additives to electrolyte can help to get more output of hydrogen from the same system whilst using less voltage.
    - It can double the efficiency of hydrogen and can produce 4 molecules of hydrogen instead of 2.
- Oxidizing ammonia to hydrogen makes hydrazine. It has 4 molecules and is easy to break. Hydrazine formation is useful for hydrogen storage.
- Hydrazine has no carbon footprint and increases the efficiency of hydrogen without harming the environment. It does not increase the cost of electrolysers, reduces voltage, and leaves no carbon footprint.

Discussion by Mr. Anil Agrawal

- Indian private companies and government enterprises are not recognizing and appreciating indigenous production units.

- Most domestic orders are from foreign sources.
- MSMEs hold a lot of potential that should be recognized.
- A lot of time gets wasted in following policy hierarchy.
- Government should focus on giving more business opportunities to Indian electrolyser manufacturers.

Discussion by Mr. Jitendra Trivedi

- Composites in renewables have changed a lot over the last decade with new materials being used.
- Composites offer a distinct advantage in strength to weight ratio in order to get better efficiency. There is always emphasis on reduction of weight.
- Green hydrogen storage systems are being developed heavily abroad, for e.g., high pressure storage cylinders.
- Composites play an important role in type 3,4 & 5 storage cylinders.
- We need to analyze where can raw materials be made in India.
- Most companies and countries want to be self-sufficient in their carbon fiber needs.
- The production is sufficient in India, however most of it is being exported. There is a need for a bigger market in India.
- Government initiatives such as Make in India should be taken advantage of or growing RE in India.
- It is essential to find out how end users can benefit for demand creation.

Discussion by Mr. Pawan Mehndiratta

- Corporates and government should prioritize indigenous technology and manufacturers.
- Current green hydrogen cost is $5-6 per kg; however, costs will reduce through localization of production resources.
- Other costs such as battery cost, storage cost, electrolyzer cost, etc. also need to reduce.
- There is tremendous research & development opportunity for India for reducing green hydrogen costs to become self-reliant and not rely on imports.
- Components and raw material of green hydrogen segment need to be focused on as they contain lots of opportunity such as membrane production.
- Apart from hydrogen, sustainable energy sources like pumped storage, nuclear waste heat, etc., also holds a lot of scope.
- Energy Storage System to RE - RTC power needs to be developed efficiently.
- India is well positioned in its overall energy scenario, just needs some streamlining of resources and activities.

- MNRE is very active along with institutes like CII and FICCI in developing India's energy ecosystem.

→ Session Two: Green Hydrogen from Demand Side Perspective

Speakers:

1. Prodyut Maji- Associate VP, Adani Enterprises Ltd
2. Ashok Chaudhari- Sr. VP, Ankur Scientific Energy Technologies Pvt Ltd
3. Biswajit Roy- Director General, GERMI
4. Partha Banerjee- Chief General Manager (Coal & Energy), SAIL

Discussion by Mr. Prodyut Maji

- Green hydrogen is made by using clean electricity from renewable energy sources.
- Blue hydrogen is produced from natural gas along with the use of carbon capture and storage (CCS) to trap and store the carbon produced in the process.
- Adequate green hydrogen production can replace oil and gas 100%.
- 98% of grey hydrogen goes into the refinery and fertilizer sector.
- Wind and solar powered hydrogen hubs should be developed.
- Instead of electron transfer, molecule transfer of hydrogen can be done for efficiency increase.
- A big pipeline of around 200 kms can be developed at green hydrogen generation sources till close to usage point like Mundra port.
- 10-12 hrs per day hydrogen can be stored in the pipeline itself.
- 20-25% of the cost in green hydrogen production is electrolysers, which can come down with more R&D to less than $1 per kg as the input costs reduce.

Discussion by Mr. Ashok Chaudhari

- We already have the technology needed to make green hydrogen.
- The green hydrogen mission will increase the demand for indigenous green hydrogen globally.
- Around 2 million Buses and 10 million Trucks are on-roads in India consuming approx. 32 million tons diesel annually – of these around 50% travel intercity. Their consumption can be displaced by 4 Mn tons of Hydrogen.
- As consumption of H2 in this case will be decentralized manner, distributed generation of Hydrogen from biomass will be the best fit.
- Biomass is a distributed resource and the best way to use it is in a distributed manner.
- India produces an average of 500 million tons of agricultural residue every year; more than 200 million tons remains unutilized. This can be converted to tons of green hydrogen.

- Potentially up to 5,000 plants of 2-2.5 TPD H2 capacity can be setup across India.
- Apart from generating H2, there are two important by-products – Biochar and Co2
- Biochar is a highly stable form of carbon derived from gasification of biomass.
- Biochar helps reduce concentration of GHG, and when returned to soil it enhances the soil properties, improves water retention property, provides benefits like increase in crop yield, nutrient, efficiency and several environmental benefits.
- Charcoal can be used for cooking in rural areas or for any thermal heat applications in industries in and round.
- Likewise, CO2 is another by-product, and its uses could also cut emissions.
- CO2 has various applications in many different industries as well.
- Thus, from a single biomass gasification-based project, we could generate electricity, hydrogen, biochar and Co2.

Discussion by Dr. Biswajit Roy

- Indian manufacturers of green technology should be incentivized and promoted.
- Private sector should monetize R&D in India.
- We need to analyse if supply capacity should be created first or demand for green hydrogen be given priority?
- USAID's SAREP estimates that by 2030 India will have demand of 2.8 million tons of hydrogen.
- The current production of grey hydrogen is 5 million metric tonnes per annum (MMTPA). Hence, the Green Hydrogen Mission was probably set at 5 MMTPA, ~125 GW of renewable energy is needed for producing that much green hydrogen.
- Will the green hydrogen production be utilized domestically or exported?
- If excess green hydrogen is produced, there has to be setup of domestic usage so we don't export all.
- We also need to tackle usage and distribution of green hydrogen in MSMEs.
- Department of Science and Technology needs participation of industries for producing more methanol and dimethyl ether.
- Sequestration of carbon and production of value-added products is needed in India.
- NITI Ayog states that by 2030 the GH2 demand can go up to 10 MMTPA, 15 MMTPA by 2040, and 30 MMTPA by 2050.
- Key strategies for creating a green hydrogen demand-- Domestic consumption should be focused on rather than solely relying on exports.
    - Export capabilities should be set up efficiently.

- Govt mandated should be set up for mandatory usage and production of green hydrogen in industries.

Discussion by Mr. Partha Banerjee

- Steel sector is considered a hard-to-abate industry due to its capital intensity, long-lived assets and, most importantly, limited commercially viable alternatives to greenhouse intensive production technologies.
- Steel and cement industries are operating in a buyer's market, i.e., their price is determined by the market, thus any increase in price affects the industry's survival. We have different types of technologies fighting to help reduce carbon footprint which can be broadly classified as Carbon Direct Avoidance (CDA) and Smart Carbon Usage.
- Making steel with hydrogen is a CDA technology, but questions are being raised as to why are we generating renewable energy-based power and converting it into green hydrogen and using that hydrogen to produce steel? It might be better to go for direct electricity. Molten oxide electrolysis is one such technology that is still evolving.
- CCUS technology needs to be evolved efficiently at large scale.
- For the steel industry, hydrogen is seen not only as a fuel but also as a reductant.
- Coal is converted into coke by pyrolysis for utilization in blast furnace, thereby generating hydrogen rich by-product gas in the process called Coke Oven Gas.
- This Coke Oven Gas, containing about 60% (mole/mole) of hydrogen is currently being utilized by the steel industry as a fuel and not as a reductant.
- Hydrogen's reaction with iron oxide is endothermic whereas carbon monoxide's reaction with iron oxide is exothermic, hence more energy is needed for reduction with hydrogen.
- In the PAT Scheme of GoI, energy efficiency is the key criteria notCO2 emission intensity. Hence, endothermic reduction reaction may not be preferred over exothermic reaction.

General Discussion Points

- GERMI has suggested that it is cheaper to run buses on green hydrogen. The problem is that a complete ecosystem for hydrogen has not been established.
- Green hydrogen is the lowest hanging opportunity for India.
- Decentralized model of green hydrogen is needed which also ensures biomass utilization.

→ Session Three: Green Hydrogen from International Perspectives

Speakers:

1. Saritha Sudharmma Vishwanathan- Post Doctoral Fellow, NIES (Japan)
2. Chris Bataille- Visiting Faculty, Columbia University, USA
3. Hilton Trollip- Visiting Faculty, University of Cape Town, South Africa
4. Ines Bouacida- Research Fellow, IDDRI, France

Discussion by Dr. Saritha Sudharmma Vishwanathan

- The United States and European Union (EU) lead in policy action of green hydrogen. Whereas China leads in the production or deployment of green hydrogen.
- Japan has invested around $100 billion in its hydrogen economy.

Discussion by Dr. Chris Bataille

- Hydrogen can be in India's critical advantage going forward.
- Energy security is the top priority for all countries. Development is the next priority. Climate action is the third priority. However, we need to stop treating climate as a later priority.
- India might soon reach a point where a lot more energy and raw materials would be required suddenly.
- India has access to three main forms of primary energy, viz., coal, nuclear and solar.
- Coal is the easiest source due to accessibility and the next reliance is on solar.
- The ideal course of action should be an increased focus on solar as primary and shifting a a little bit on coal or nuclear as and when needed. This would ensure less dependence on oil & gas for the country.
- Most countries will first rely on blue hydrogen and then develop green hydrogen. The EU might go back and forth between the two, whereas, the US will rely mostly on blue hydrogen.
- India can leapfrog from coal directly to green hydrogen as a complement to the already existing solar sources.
- Electricity market reforms will be needed in terms of transmission along with a hydrogen push. Relying on coal should be used as a backup.
- For now, the concentration should be on building electrolysers, storage (which can be shared by refineries, chemical, fertilizer, etc., that have hydrogen needs) and then anchor around these hubs as an affirming role on electricity.
- We should preplan the integration of all stakeholders to make the green hydrogen plus solar set up and move away from coal.

Discussion by Mr. Hiton Trollip

- The green hydrogen ecosystem in South Africa was explored four years ago as part of its Net Zero emissions strategy.
- Industries like coal, freight transportation, iron and steel are the highest energy utilizers.
- There are high amounts of iron resources in South Africa, but the country is not industrialized enough to utilize it all.
- The economy has gone stagnant and hence the steel production has decreased.
- The country's economy is energy intensive with lots of mineral, coal, solar and wind resources.

- A research study on green iron and steel making in Africa claims that all things remaining constant:
  - It would be cost compatible with the EU
  - Costs would be lower than the electricity prices in EU
  - PV integrated green hydrogen powered steel plants
  - Decarbonization of steel production
- For the South African or African market, producing steel using coal would be cheaper than using PV.
- Steel doesn't need to be replaced with anything else because its recyclable by itself.
- It is financially unviable for South Africa to give steel sectors incentives like the Europe or the US does.
- It is far cheaper to decarbonize the EU steel sector by importing steel from other countries like South Africa.
- The upstream steel making industry in Europe might see it as taking away the industry to another place, however downstream vendors will definitely benefit.

Discussion by Ms. Ines Bouacida

- Europe started green hydrogen in 2020 through several strategies. Lots of member states were involved in the process. The goal is to make Europe a hydrogen champion in the world.
- The EU set its main principles for hydrogen through a framework.
- Focus is on decarbonizing the existing uses of hydrogen for emissions reductions in refineries and chemicals and greater usage in iron & steel industries.
- The EU is relatively small for green hydrogen production and does not contain enough resources or raw materials needed for clean energy.
- Hence many member states started getting imports.
- Germany wants to building an international market for green hydrogen usage to maintain their industrial competitiveness by getting imports for their industries.
- The EU wants to import green clean energy instead of fossil fuels. However, as of now it lacks the development of supply chain needed for a low carbon world.
- Europe is mainly focused on green hydrogen not blue or grey hydrogen.
- Leadership is needed on electrolyser front in Europe to avoid importing from China.
- The green hydrogen production race is ongoing and no region is entirely leading; all are playing at same level.
- Having green electricity is also necessary as industries should have priority access to cheap green electricity for manufacturing to ensure green industrialization and green hydrogen production.
- To facilitate demand side growth, the EU has incorporated a framework of green hydrogen in industries.

- Germany, Netherlands and Belgium are looking at building import routes for hydrogen and low carbon energy products made through hydrogen.
- Not all member states in the EU have the same perspective on green hydrogen and political interference is high which stands in the way of policy development.

General discussion points:

- Green hydrogen can help abate CBAM imposed carbon taxation on products from India.
- Beyond demand the EU will also build clean energy partnerships with green hydrogen producer countries.
- Steel industry needs lots of coal and electricity. We need to analyze the amount of solar or wind power needed to run large industries like steel to decide how much green hydrogen would be needed.
- The amount of green hydrogen required for heavy freight or railways is still unknown as battery technology is still evolving.
- It is important for developing countries to enter this green hydrogen discussion so that only developed countries don't make all the decisions.

→ Session Four: Economics of Green Hydrogen and Way Forward

Speakers:

1. Rahul Walawalker- President & MD, India Energy Storage Alliance
2. Prasad Thakur- Strategy, Reliance Industries Ltd.
3. Santosh Gurunath- CEO & Co-Founder, Umagine
4. Shashi Shekhar- Director, ACME (Online)

Discussion by Dr. Rahul Walawalker

- Economics of green technology is always a prime priority to ensure its widespread utilization.
- Green hydrogen is an opportunity to quickly decarbonize the industrial sector.
- As demand for green hydrogen grows, the market will scale up and prices will go down.
- If we want to bring down hydrogen prices then we need to look into cost reduction through supply and demand instead of relying on other countries to innovate and bring down costs
- Policy directions don't always lead to market creation, fundamental improvements in technology will lead to better market creation.
- Currently the only driver of green hydrogen is reaching net zero targets
- For the market to grow, overall cost at user level should be recognized, not individual level prices.
- Renewable energy prices need to be managed along with transmission charges.

- Economic models for green hydrogen should not be based on low electricity costs which are not real or perceivably unattainable.
- The cheapest pathway for green hydrogen production is through a solar wind storage hybrid.
- Transportation of green hydrogen to its ultimate utilization location needs to be organized. The difference between transportation of hydrogen as a fuel compared to transmission of hydrogen converted as electricity needs to be studied in Indian perspective to see which option is most feasible.
- Hydrogen's battery making infrastructure needs to develop to promote industrial usage as fuel cell.
- We need to have realistic goals at the current cost structure. There should be increased focus on blending in different sectors wherever possible.
- The technology readiness levels and the manufacturing readiness levels need to match each other.
- Value chain needs to be developed for green hydrogen which looks into:
  - How to structure electricity usage
  - Demineralizing water and its cost structure
  - Transmission details
- Usage of renewable energy as a dispatchable storage is not possible without storage.
- Skill development and human resources training need to be developed.

Discussion by Mr. Prasad Thakur

- There should be development of green hydrogen hubs to match the demand and supply network.
- We should leverage the digital prowess of country to further the green hydrogen demand.

  Realtime matching of demand and supply can take place through digital platforms.
  - Can be rolled out at regional level followed by state and national level.
  - Will help in global market creation in digital space
- India can become technological spokesperson of developing world by assisting technological transfer across borders.
- We should analyze how to leverage our diplomatic stature to promote our green hydrogen ecosystem.

Discussion by Mr. Shashi Shekhar

- Hydrogen is a must for reaching net zero targets and decarbonizing the country.
- Costs of green hydrogen is the main question.
- Policy requirements for cost reduction of green hydrogen are:
  - land accessibility in places with the best solar GHI.

  - 60% of the green hydrogen cost is solar power equipment. If solar energy productions costs decrease then green hydrogen can also decrease to less than Rs. 2.

- Govt of India has introduced 40% duty on import of on solar panel
  - We need proper manufacturing of solar panels and cells in India itself
  - Lower duty on solar equipment
- The Article 6.2 of the Paris Convention states that there should be assistance given to developing countries for setting up projects which can reduce carbon emissions. This can help with a significant reduction in costs as green hydrogen and green ammonia are highly capital intensive.
- Costs also depend on land pricing and Gujarat already has a policy in place to get cheap land for green hydrogen production.
- If costs of green hydrogen come down the market will start demanding, as it happened with solar energy.
- The private sector knows how to innovate and bring down costs with an increase in demand.
- We need to generate volume. Sectors like steel, transport, hydrogen power storage, etc., can also significantly create demand.
- Replacing ammonia in urea entirely is not ideal but some measures should be taken.
- R&D support by the government is needed to compete with international players in the market; specially in electrolyser and fuel cell.
- Pumped storage and repowering of wind plants should be reserved entirely for green hydrogen.
- When costs will decrease, a huge market space for green hydrogen will open up this demand will handle costs.

→ Concluding Session

Speakers:

1. S.B. Dangayach- Founder Trustee, Innovative Thought Forum
2. Biswajit Roy- Director General, GERMI
3. Amit Garg- Professor, IIM Ahmedabad

Concluding Remarks

- Lack of land availability in India is a myth. India's total land mass is 325 million hectares out of which 55 million hectares is wasteland.
- Gujarat has come up with a policy for the allocation of fallow land, other such policies can aid land availability for green hydrogen.
- All green hydrogen policies should be made available to all stakeholders.
- R&D institutes should be perceived as business outlets and be incentivized in that regard.

- On the supply side, large corporations have supply equipment set up or being developed.
- On the demand side, the market rules, hence when the prices reduce, the demand will increase.
- We will have to focus on a basket of renewable energy resources; green hydrogen will be a part of this larger basket.
- Policies need to be crafted whilst keeping in mind the economic conditions of the people of the country. Hence, prices can't be too high or else will be less integration on the ground.
- Different sources like research institutes, government and private companies need to come together for best solutions to energy scenario of India.

❖ **Group Photograph**

9:30 -10:00	**Registration**
10:00 - 10:15	**Inaugural Session** • S.B. Dangayach- Founder Trustee, Innovative Thought Forum • Amit Garg- Professor, IIM Ahmedabad
10:15 -11:00	**Session One:** Green Hydrogen from supply side perspective **Session Coordinator:** Mr. Chintan Shah- Former Director, IREDA **Speakers:** • Rashi Gupta- Managing Director, Vision Mechatronics • Sudhanshu Sharma- Associate Professor, IIT Gandhinagar • Jitendra Trivedi- Director, Aztech Composites PvtLtd • Anil Agrawal- Founder, Airox Nigen Equipment PvtLtd • Chintan Shah- Former Director, IREDA • Pawan Mehndiratta- Strategic Business Unit Head, Thermax Ltd (Online)
11:00 - 11:45	**Session Two:** Green Hydrogen from demand side perspective **Session Coordinator:** Partha Banerjee- Chief General Manager (CC&EE), SAIL **Speakers:** • Prodyut Maji- Associate VP, Adani Enterprises Ltd • Ashok Chaudhari- Sr. VP, Ankur Scientific Energy Technologies PvtLtd • Biswajit Roy- Director General, GERMI • Partha Banerjee- Chief General Manager (Coal & Energy), SAIL • Sujit Gulati- Reliance New Energy Ltd (TBC)
11:45 - 12:00	**Tea Break**
12:00 - 12:45	**Session Three:** Green Hydrogen from international perspectives **Session Coordinator:** Dr. Saritha Sudharmma Vishwanathan- Post Doctoral Fellow,NIES (Japan) **Speakers:** • Chris Bataille- Visiting Faculty, Columbia University, USA • Hilton Trollip- Visiting Faculty, University of Cape Town, SouthAfrica • Ines Bouacida- Research Fellow, IDDRI, France
12:45– 13:30	**Session Four:** Economics of Green Hydrogen and way forward **Session Coordinator:** Mr. Rahul Walawalker- President & MD, IESA **Speakers:** • Prasad Thakur- Strategy, Reliance Industries Ltd. • Rahul Walawalker- President & MD, India Energy Storage Alliance • Santosh Gurunath- CEO & Co-Founder, Umagine • Shashi Shekhar- Director, ACME (Online)
13:30– 13:40 13:40	**Concluding Remarks** • S.B. Dangayach- Founder Trustee, Innovative Thought Forum • Amit Garg- Professor, IIM Ahmedabad onwards Group Photo followed by lunch at **IMDC Dining Hall**

Annexure 2: List of speakers and participants present at the seminar

Sr. No.	Name	Affiliation	Speaker/ Attendee
1	Amit Garg	IIM Ahmedabad	Speaker
2	Anil Agrawal	Airox Nigen Equipment Pvt Ltd	Speaker
3	Ashok Chaudhari	Ankur Scientific Energy Technologies Pvt Ltd	Speaker
4	Bharat Jain	Gujarat Cleaner Production Centre	Participant
5	Biswajit Roy	Gujarat Energy Research and Management Institute	Speaker
6	Chintan Shah	Indian Renewable Energy Development Agency	Speaker
7	Chris Bataille	Columbia University (USA)	Speaker (Online)
8	D J Yadav	Arvind Envisol Ltd	Participant
9	Dhara Thakkar	IIM Ahmedabad	Participant
10	Divya Arora	IIM Ahmedabad	Participant
11	Hilton Trollip	University of Cape Town (South Africa)	Speaker (Online)
12	Ines Bouacida	IDDRI (France)	Speaker (Online)
13	Jigar Shah	IIM Ahmedabad	Participant
14	Jitendra Trivedi	Aztech Composites	Speaker
15	Jyoti Maheswari	IIM Ahmedabad	Participant
16	Kajal Mahabari	PDEU	Participant
17	Kandarp Mistry	GUVNL	Participant
18	Karan Kaushal	IRM Energy Pvt. Ltd	Participant
19	Kayan Kalthia	Kasol Energie Pvt. Ltd.	Participant
20	Ketan Shah	Ex CEO-GACL-NALCO Alkalies & Chemicals Pvt. Ltd	Participant
21	Neel Shukla	Umagine	Participant
22	Nirav Patel	Indian Space Research Organiation	Participant
23	Pallavi Rachel George	IIM Ahmedabad	Participant
24	Paresh M. Shah	Sardar Sarovar Narmada Nigam Ltd	Participant
25	Partha Banerjee	Steel Authority of India Ltd	Speaker
26	Pawan Mehndiratta	Thermax Ltd	Speaker (Online)
27	Prasad Thakur	Reliance Industries Ltd	Speaker
28	Priya Singh	ArcerlorMittal Nippon Steel	Participant
29	Prodyut Maji	Adani Enterprises Ltd	Speaker
30	Rahul Walawalker	India Energy Storage Alliance	Speaker
31	Rashi Gupta	Vision Mechatronics	Speaker
32	Ritwika Verma	IIM Ahmedabad	Participant
33	Rutva Patel	IIM Ahmedabad	Participant
34	S B Dangayach	Innovative Thought Forum	Speaker
35	Samir Shukla	Umagine	Participant
36	Sanjay Kumar Jain	IIM Ahmedabad	Participant
37	Santosh Gurunath	Umagine	Speaker
38	Saritha Sudharmma	Vishwanathan NIES (Japan)	Speaker (Online)
39	Shashi Shekhar	ACME Group	Speaker (Online)
40	Shwetal Shah	Climate Change and Sustainability Expert	Participant
41	Sneha Lavate	PDEU	Participant

Annexure 2: List of speakers and participants present at the seminar

Sr. No.	Name	Affiliation	Speaker/ Attendee
42	Srinivas Cherla	Research and Innovation Circle of Hyderabad	Participant (Online)
43	Sudhanshu Sharma	IIT Gandhinagar	Speaker
44	Vidhee Avashia	IIM Ahmedabad	Participant
45	Yogesh Thakkar	Indian Society of Heating, Refrigerating and Air Conditioning Engineers	Participant