Section A-Review Paper
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Green Hydrogen Energy in India: Prospects, Status and Challenges

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Abstract:

The accelerations and intensification in the climate change with pollution is reaching high levels. To maintain a greener environment, a sustainable energy source is urgently required. Green hydrogen is one of the cleanest fuels with zero carbon emissions. Hydrogen has shown a ray of hope against climate change. As part of India's efforts towards sustainability in this review we aim to study Green Hydrogen Energy initiated by India, mainly focusing on National Green Hydrogen Mission 2023. This study also reviews the green hydrogen projects undertaken by several government and private companies. The initiatives and innovation carried out by India in the green hydrogen energy field also discussed. These studies will help to find a set of positive, balanced, and beneficial solutions for the future of green hydrogen as a cleaner fuel.

1. Introduction:

Renewable energy resources are regenerative hence not deplete over the period of time. Examples- solar energy, wind, and biomass. Renewable energy generally reduces carbon emissions and move towards more sustainable footing. Hence, countries energy security and support in economic development increases.[1] Renewable energy resources shares 18% of total energy consumption of whole world (Fig. 1).[2] India comprises sprightly expanding renewable energy proportions. Hence, in these days it has also coming out most favorite terminal for investors. India wishes for its energy independent and net zero by 2047 and 2070 respectively. These targets can easily be accomplished by increasing the use of renewable energy across all economic field in India's energy transformations. The demand of energy and resources significantly rises while India's unfurling progression. In the last 20 years the energy use has been doubled and will surely increase by another 25% by 2030.[3] India imports more than 40% of its yearly energy requirement. It amounts to roughly 90 b US Dollars. Our country is emerging as a front runner in its efforts to reduce global warming, The nation's commitment towards to substantial reduction in its carbon footprint in the near future is very clear.

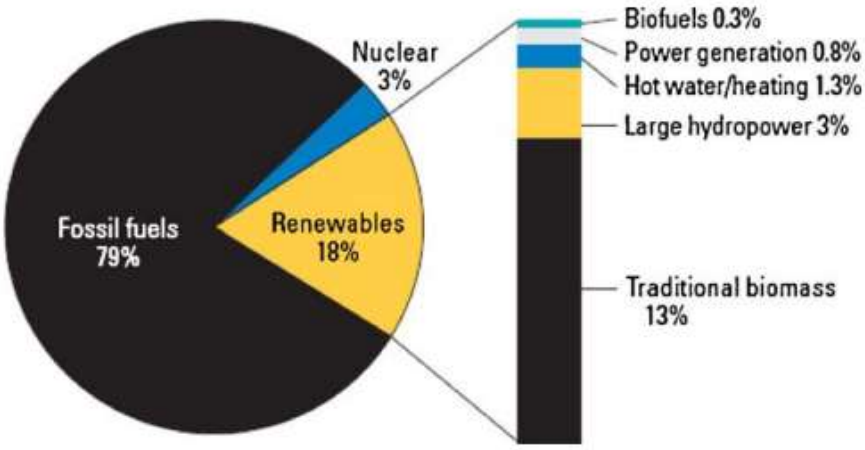

Fig. 1. Global energy consumption through renewable energy[2]

Hence, a switch towards innovation requires that enables the increased energy demand by increasing the percentage of renewable sources and reducing the dominion on fossil fuels. Present review discusses about the green hydrogen as energy source in Indian perspective.

2. Hydrogen as energy source:

As a good substitute of fossil fuels, hydrogen can be vastly use as an alternative. It is very useful renewable energy source because of its long-duration storage energy, immaculate transportation and industrial applications. It also used for aeronautics, reconcentration of power generation, and maritime transportation. On the basis of its extraction method, there are three types of hydrogen-

i. **Grey Hydrogen**: It can generate through steam reformation of fossil fuel - natural gas (methane) or gasification of coal (lignite). These are extensive carbon-intensive processes.
ii. **Blue Hydrogen**: It can generate through natural gas or gasification of coal which is combined with carbon capture storage or carbon capture use technologies. These helps reducing the emissions of carbon.
iii. **Green Hydrogen**: It can generate through electrolysis of water. The used electricity in this process is being generated by renewable energy (Fig-2).[4] The carbon intensity depends on the carbon neutrality of the source of electricity. While burning it generates energy and leaves only water as a byproduct. Hence, it is a source of clean and sustainable energy with no emissions. Hence, produced hydrogen is the green hydrogen.

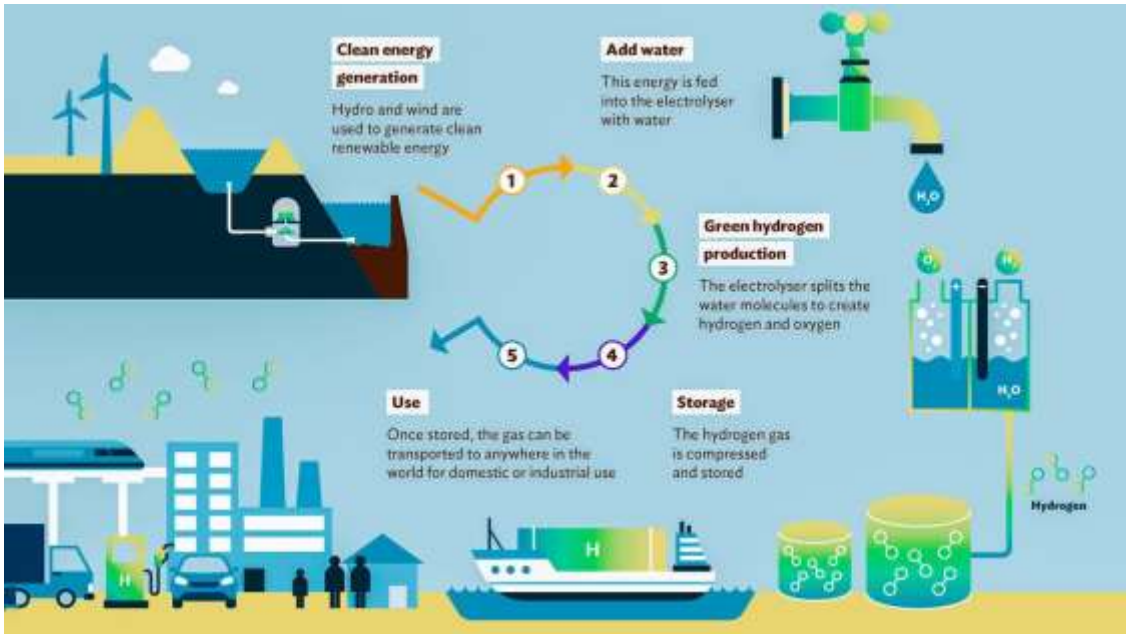

Fig. 2. Generation of green hydrogen through renewable energy[4]

3. Green Hydrogen: A sustainable future

India has been showing interest in green hydrogen as part of its efforts to promote clean energy and reduce carbon emissions. There can be several potential applications for green hydrogen such as:

- It can be used in various sectors such as industry, transportation, and power generation.
- It can be used as a fuel for fuel cell vehicles and for electricity generation through fuel cells.,
- It can be used as a feedstock for industries like fertilizers and refineries.
- It can also useful to meet energy requirements in all areas including remote geographies and islands.

4. Green hydrogen: Current scenario

Hence, to meet all these possibilities studies on the current scenario of green hydrogen in India is very important. Green hydrogen in India can be categorized in following four sections.

4.1 Policy Dynamism:

The Indian government has recognized the potential of green hydrogen and has taken some initial steps to support its development. The *National Green Hydrogen Energy Mission* was announced in the Union Budget for 2021-22, and approved by the Union Cabinet on 4th January 2022.[5] The leading aspects of this mission is significant decarbonization of the economy, reduced dependence on fossil fuel imports, and enable India to assume technology and market leadership in Green Hydrogen. To achieve the

above objectives, the Mission will build capabilities to produce at least 5 million metric tonne (MMT) of Green Hydrogen per annum by 2030, with potential to reach 10 MMT per annum with growth of export markets.

4.1.1 Objectives-

The overarching objectives of the *National Green Hydrogen Energy Mission* are-

- India should be globally front runner in pivot production, utilization and export of green hydrogen.
- Aim to fulfill Aatmanirbhar Bharat mission by using clean energy. It aspires to become a role model worldwide in this field.
- To play India as a leading role in significantly economic decarbonization and reducing the dependency on non-renewable sources.
- To represent India as a leader in manufacturing of technology embedded electrolyzers and with other validating technologies for green hydrogen.
- Create opportunities for employment and economic development.
- Support several Research and Development (R&D) projects.

4.1.2 Phases:

Implementation of mission will be in phased manner. Initial focus will be on the sectors which are already consuming hydrogen. In the later phase new sectors will be taken up.

First Phase (2022 to 2026)-

Focus areas will be –

- Foundational measures based on demand and enabling the competent supply of green hydrogen.
- Formation of regulations and implementation for the use of green hydrogen on the ground level.
- Through several projects green transition will be initiated in production of steel and shipping

Second Phase (2026 to 2030)-

Focus areas will be –

- Pilot projects to be taken up in sectors like aeronautics, railways etc.
- Enhancement in research and development activities along with potential sectors for continuous development of products for deep decarbonization.
- Implement more advanced technologies, based on green hydrogen in hard-to-subside sectors.

It is expected that through *National Green Hydrogen Energy Mission* nearly 50 million metric ton (MMT) of annual greenhouse gas emission will decrease till 2030. The summary of phase-I and phase-II is depicted in fig-3.

4.2. Pilot Projects:

Several pilot projects were initiated to explore the feasibility of green hydrogen production and applications. These projects involve collaboration between government agencies, research institutions, and private companies.

Following companies are participating in the race of producing green hydrogen.

4.2.1. IOCL - Indian Oil Corporation Ltd.

IOCL will built country's first 'Green Hydrogen' plant in its Mathura refinery. It will be instigating the introduction of green hydrogen in the Indian oil and gas territory.[7] By 2025, an electric power of 5 GW is being aimed by the corporation as a result of substituting ten percent of their fossil fuel consumption with hydrogen fueling.

4.2.2. NTPC - National Thermal Power Corporation Ltd.

NTPC will start India's first green hydrogen fueling station in Ladakh. Its completion is scheduled by November-December 2023. It is being set up at a height of 3,600 meters above sea level. The project will produce 80 Kg per day of 99.97 percent pure hydrogen that will be pure compressed stored and dispensed.[8]

4.2.3. RIL - Reliance Industries Ltd.

RIL will achieve target of net zero emission by 2035 via investment over $10 billion. It plans to cover 5,000 acres area in Jamnagar to construct a sustainable complex named Dhirubhai Ambani Green energy Giga complex. Several sustainable companies like Faradion, Lithium Werks, REC Solar Holding will assist them in this project and will be significant contributor to achieve the goal.[9]

4.2.4. GAIL - Gas authority of India Ltd.

GAIL will set up country's largest green hydrogen plant in Guna (MP). The project will be polymer electrolyte membrane (PEM) based water electrolysis. The per day production of plant will be 4.3 tonnes. This scheduled to be India's largest green hydrogen plant with capacity of 10 MW.[10]

4.2.5. ANIL - Adani New Industries Ltd.

ANIL will invest over US$50 bn in green hydrogen within coming 10 years. Before 2030, company will be able to produce green hydrogen @ 1 million tons/annum. It will work towards making green hydrogen the "fuel for future". Adani group has made the largest commitment when it comes to India's green energy push.[10]

4.2.6. L & T - Larsen and Toubro

L & T arranged a big green hydrogen plant in Gujrat's Hazira. It is planned to produce 45 Kg green hydrogen/day in this plant. The 500kW battery energy storage system and 990kW DC capacity will be used for generation of power from said production area.[9]

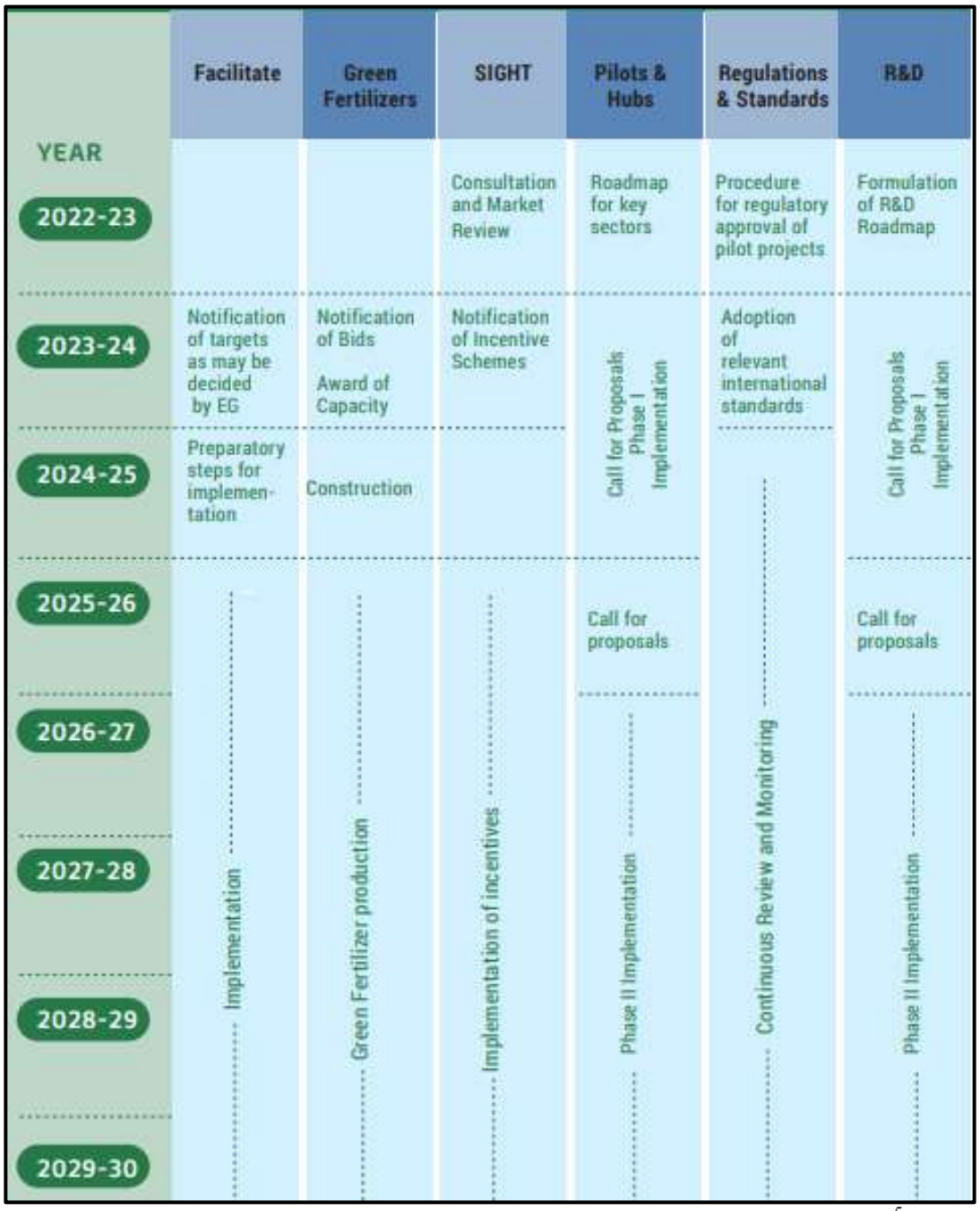

Fig-3. Green Hydrogen Mission First Phase and Second Phase timeline[5]

Fig.4. Larsen and Toubro-Hazira (Gujarat) green hydrogen plant[9]

4.2.7. ONGC - Oil and Natural Gas Corporation Ltd.

ONGC has been collaborated with Greenko (M/s Greenko ZeroC Private Limited-a renewable energy company) in July-2023 for two years. Its Hazira (Gujrat) green hydrogen plant is equipped with all the required essentials Fig.-5. This collaboration will surely open new opportunities for synthesis of green hydrogen and its derivatives.[9]

Fig.5. ONGC - Hazira (Gujrat) green hydrogen plant[9]

4.2.8. BPCL - Bharat Petroleum Corporation Ltd.

BPCL will initiate 5 MW electrolyzers in two major cities (Ahemdabad and Aurangabad) for green hydrogen production. Fig. 6 shows BPCL green hydrogen plant.[9]

Fig.5. BPCL green hydrogen plant[9]

4.2.9. Jindal Stainless

Jindal Stainless will establish green hydrogen plants and aiming to reduce carbon emission by 2,700 MT/annum. This project is its joint venture with Hygenco India Private Ltd. Jindal Stainless will be credited as India's first stainless company in the green hydrogen field.[9]

4.2.10. Thermax

To explore green hydrogen projects Thermax partnered with FFI-Fortescue Future Industries in March 2023. In the coming years, these two companies will develop fully integrated green hydrogen projects for Indians.[10]

4.3. Research and Development:

Indian scientists are actively involved in researching green hydrogen technologies. Ministry of new and renewable energy is continuously supporting research, development and demonstration (R&D) in this direction. Several projects are already running in academic, industrial and research institutions. Challenges associated with the production of hydrogen from renewable energy sources were also addressed. Scientist continuously trying to improve the efficiency of electrolysis processes, reduce the production cost, and developing infrastructure of storage and transportation.

4.3.1. Storage:

For long and efficient storage of green hydrogen different storage units are required. To fulfill these requirements, two hydrogen refueling stations have been established in Gurugram and Faridabad at NISE - National Institute of Solar Energy and IOCL - Indian Oil R & D Centre respectively.

4.3.2. Transportation:

M & M, Indian Institute of Technology and BHU have reported significant work in reference to transportation.[11] Hydrogen fuel was used as fuel to run small buses, 2 & 3 wheelers vehicles.

Govt. of India supported various projects for development of vehicles powered by hydrogen as fuel. Some projects are as follows-

- Tata Motors – 6-Cell buses
- IOCL – 50-H-CNG buses in NCT
- IIT Delhi – 2-ICE hydrogen fuelled buses

Fig. 6 ICE hydrogen fuelled -Auto[11]

Fig. 7. Diesel engine being run on hydrogen fuel[11]

Fig. 8. Genset using hydrogen fuel [11]

Fig. 9. Auto using hydrogen fuel [11]

4.3.3. International Conference by Govt. of India:

Govt. of India organized a 3-days International Conference on green hydrogen (ICGH-2023), held on 5–7 July 2023 in New Delhi. Shri Raj Kumar Singh, Union Minister for New and Renewable Energy addressed the conference. It was attended by delegates from India and abroad to explore new avenues in green hydrogen ecosystem.[12]

Global goals were reviewed for decarbonization with the help of green hydrogen. Global leaders discussed emerging technologies and recent developments to unlock the potential of green hydrogen.

4.4. Challenges:

Although green hydrogen is cleaner fuel yet its implementation as a universal fuel is not a easy task. Some specific challenges[8] are-

1. Green hydrogen is costly because of its high manufacturing cost. This restricts its adoption in India. NITI aayog says, green hydrogen utilising Round-The-Clock (RTC) renewable energy with transmission & distribution waiver is projected to cost $2.1/kg by 2030. On the other side green hydrogen using onsite renewable energy will be in the range of $1.8-$2.4/kg.
2. Uses of green hydrogen can only be achieved if we have inexpensive and steady supply. By 2030, India will be requiring 5 MMT of green hydrogen per year. The creation of green hydrogen requires a lot of power and water, with each kg of hydrogen requiring roughly 9 L of demineralized water.

Cheap green hydrogen can only be made available if we manufacture local electrolyser, use technologically advanced in electrolysers and low-cost renewable energy plants This will transform India into a pollution free nation and it will be global hub for investors very soon.[13]

5. Conclusion:

To achieve sustainability, India's green hydrogen energy will lay a significant role as cleaner and sustainable energy. It will reduce global warming and carbon footprints of the nation. The green hydrogen mission 2023, pilot projects and work in R & D laboratories are great initiatives and steps towards sustainability. Although green hydrogen demand, production and supply has some limitations but by overcoming these we can make India as global icon in clean energy.

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