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India's Hydrogen Mission

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Abstract: **Fossil fuels have been mankind's primary source of energy for centuries now. However, due to this heavy reliance on fossil fuels as our main energy source, their sources are depleting rapidly and will soon run out. This will create an extremely large void for which we need to start bracing immediately. Hence, the way ahead is renewable energy. Being one of the most abundant elements on Earth, Hydrogen is increasingly being sought not only as a potential solution to the problems of the present global energy system but also to scale up other renewable energies. This paper chiefly focuses on Hydrogen as a clean source of energy and India's great potential to become a leading exporter of Hydrogen in the future. The current scenario suggests that Hydrogen is a mixed bag with heavy R&D costs and elemental unavailability on one hand but, with strong advantages on the other hand in the form of zero carbon emissions and the scope of becoming the fuel that supports the country's industrial backbone.**

Keywords: **Hydrogen, Renewable, Energy, Technology, Economy, India.**

I. INTRODUCTION

Hydrogen is currently the global center of attention as a renewable energy source. Thirty-three countries, India included, have introduced Hydrogen strategies to be implemented gradually. However, this interest is not all new for Hydrogen. In fact, Hydrogen has intrigued scientists and governments as the elixir for all global energy problems since the 19th century. Belief in Hydrogen's potential has gone through its cycles of hope and despair. These cycles are also known as hype cycles.[1] The oil shock beset of the 1970s saw a surge in global interest for Hydrogen. This was followed by a resurgence of interests in the 1990s and early 2000s. With climate change and global warming taking center stage of global debate and policy making, interest in Hydrogen as a green fuel for the future is at its highest. By announcing the launch of the National Hydrogen Mission in the budget of 2021, the Indian government is reinforcing its interests in the potential of renewable energy sources and its commitment to achieving the expected emissions goals under the Paris Agreement.

The Ministry of New and Renewable Energy (MNRE) has also disclosed that the draft regulations for 'NHM' which will be finalized shortly and will thereafter await approval by the Union Cabinet.[2] Considering the challenges faced by India in implementing mass adoption of BEVs, Hydrogen fuel technology could be the answer to these energy problems as well as the propulsion needed to push the country towards zero carbon emissions.

II. HYDROGEN: DEMAND AND SUPPLY

Hydrogen currently finds its use as a feedstock in the chemical industry. The main sectors being petroleum refining, fertilizer production and methanol production. The demand from these sectors has increased over time.

However, usage of Hydrogen as an energy source remains marginal. Its use is restricted to specific areas such as fuel for rockets, powering space craft electric systems and in forklift trucks. Although, the Hydrogen fuel cell technology has made its way to the automobile and domestic power industries as well. Asian automobile giants Honda, Toyota and Hyundai have all launched their first mass-produced Hydrogen fuel cell cars.[3] Hydrogen cells are also being used to heat 225,000 homes (Staffel et al.2019, Energy and Environmental Science)

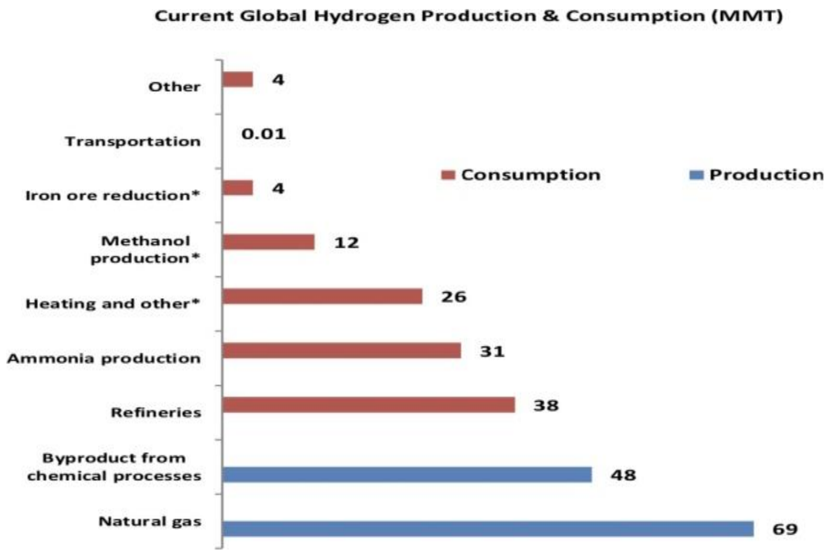

Fig.1. Hydrogen consumption comparison; Source: IEA

Owing to the unavailability of Hydrogen in its elemental state, it must be derived from compounds like water (H_2O) and hydrocarbons especially methane (CH_4). These compounds are broken down to obtain H_2 or the di-Hydrogen molecule. Most of the Hydrogen today is from fossil fuels, and 60% of the Hydrogen produced in "dedicated" Hydrogen production facilities use fossil fuels as their source of energy. These sources include natural gas, coal, and a small fraction from water electrolysis. According to the IEA report of 2019, one-third of the global Hydrogen supply is "bi-product" Hydrogen - obtained from facilities and processes designed primarily for other production purposes. The report further states that production of Hydrogen is responsible for 830 million tons of CO_2 emissions per year. 6% of the global natural gas consumption and 2% of global coal consumption.

III. CLASSIFICATION OF HYDROGEN

Hydrogen is classified depending on the nature of the method of its extraction. Hydrogen produced traditionally with CO_2 emission from natural gas is referred to as ***Grey Hydrogen*** while that produced from coal and petroleum is called ***Brown Hydrogen*.** Nowadays, past technologies have evolved to produce Hydrogen with reduced or no CO_2 emissions. Grey and brown Hydrogen produced with carbon capture and storage is known as ***Blue Hydrogen***. The Hydrogen produced through pyrolytic processes is referred to as ***Turquoise Hydrogen****;* and the Hydrogen produced from electrolysis or electricity from renewable resources (solar and wind) is called ***Green Hydrogen***. The latest addition to this colorful domain is ***White Hydrogen*** produced from plastics and biomass.

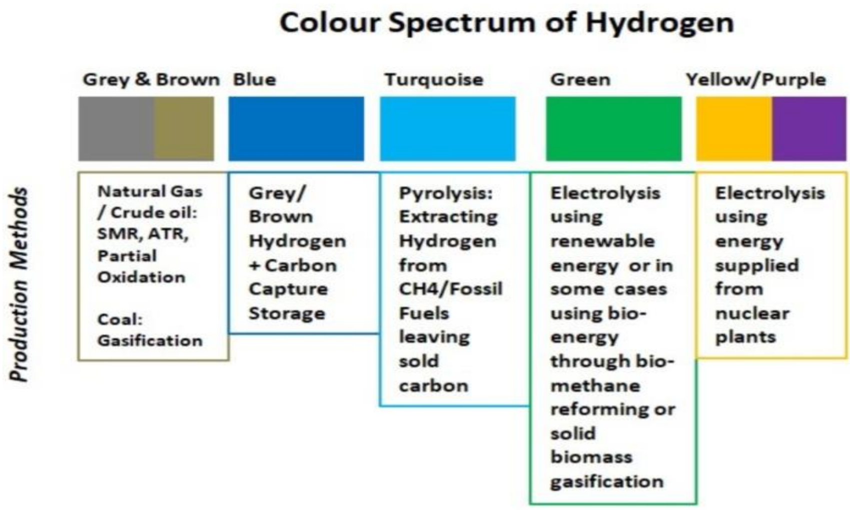

Fig.2. Source: IEA 2019

There is growing focus on increasing production of green and blue Hydrogen due to its no carbon emission and use of carbon offset technology, respectively. According to a report by the Hydrogen Council, green hydrogen could supply up to 25% of the world's energy demands by 2050. IEA's Future of Hydrogen Report 2019 shows that green and blue Hydrogen are competitive with grey Hydrogen, even today. Moreover, according to IRENA (2019) an expected fall in electrolyser costs and renewable costs along with additional measures like PV tracking, hybrid wind and solar plants and more technological improvements will decrease the cost of producing green hydrogen.

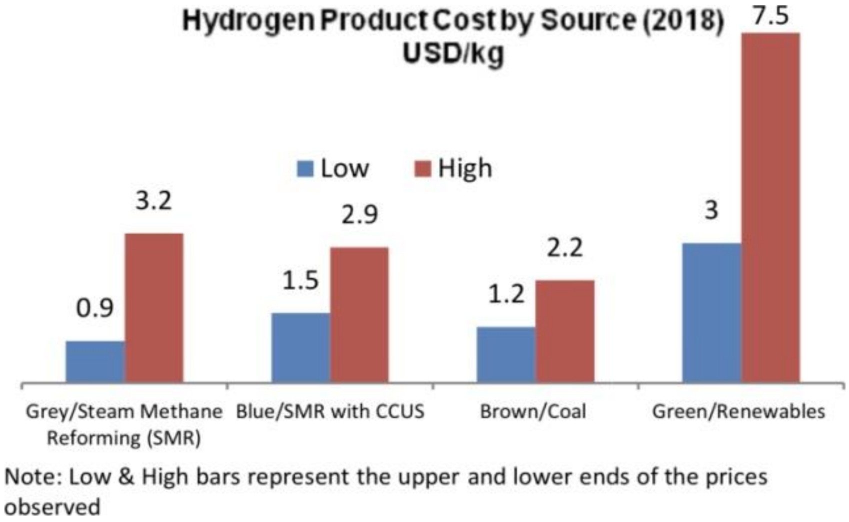

Fig.3. Hydrogen production costs; Source: IEA 2019

Further with carbon pricing picking up momentum, the latter could also improve the competitiveness of Green and Blue Hydrogen.

IV. HYDROGEN: THE FUTURE TRANSPORT FUEL

Hydrogen has many advantages as a transportation fuel over fossil fuels and batteries. Firstly, unlike fossil fuels and batteries that rely on scarce resources, Hydrogen is the most abundant element on Earth and this fact is the underlying cause of interest in Hydrogen as an alternative energy source.

Secondly, Hydrogen is a 'zero emission fuel' i.e., Hydrogen fuel cells release only water.[4] However, this only holds true if the Hydrogen itself is obtained from clean sources.

Thirdly, Hydrogen has low refueling times of about 3-5 minutes like normal transportation fuels - petrol or gasoline. This is a significant advantage over batteries which need hours to recharge.

Fourthly, Hydrogen fuel cells also score over batteries when it comes to weight and range. Energy density of electric batteries has been rising over time, but higher range calls for more than proportionate increase in weight of the batteries. On the contrary, like Internal Combustion Engines (ICEs), in case of Hydrogen fuel cells electric vehicles (FCEV) the weight and range progression is linear [Battery University].

Hydrogen also has its fair share of disadvantages compared to fossil fuels and electric cells. Firstly, when it comes to efficiency, while Hydrogen fuel cells score over ICEs[5], they are dwarfed by the high efficiency levels of battery electric vehicles (BEVs). This implies that efficiency of Hydrogen fuel cell electric cars is 25-35% much lower than that of battery electric cars.

Secondly, Hydrogen is the lightest gas. Thus, while Hydrogen has high energy on mass basis, it fares poorly on volume basis. According to IFPEN, Hydrogen releases 3 times more energy than 1 Kg of gasoline. However, for production of as much energy as 1 liter of gasoline it takes between 6.4 - 7 liters of compressed Hydrogen.

Thirdly, it is expensive. Due to its light nature, the transportation and storage of Hydrogen is a challenging process. This requires compression or liquefaction and special storage facilities, adding extra costs. Hydrogen liquefaction requires much lower temperatures than CNG or LNG. While LNG needs to be maintained at -163°C, liquid Hydrogen (LH_2) needs to be kept at -253°C [Escola Europa 2018], incurring higher liquefaction costs in both monetary and energy terms.

V. INDIA'S STAND ON HYDROGEN

India possesses less than 0.4% of the world's crude oil deposits and rising oil imports are a major drain on the country's economy. With a high population growth rate and consequently a steep rise in annual energy demand for power and transportation in the coming years, development of renewable energy technology options especially for the transportation sector has become a major area of concern.

However, in its zealous attempt for mass transition to battery operated/ electric technology and industry, India is facing stumbling blocks such as inadequate charging facilities, expensive battery technology, and scarcity of battery raw materials in the country. Comparatively, raw materials can be easily sourced for Hydrogen power cells. Moreover, India has a huge edge in Green Hydrogen production owing to its favorable geographic conditions and presence of abundant natural elements. The government has given special incentives to scale up the gas pipeline infrastructure across the country, and has introduced reforms for the power grid, including the introduction of smart grids.

Such steps are being adopted to efficiently merge renewable energy with the country's present energy mix. Upon making appropriate capacity addition to renewable power generation, storage, and transmission, producing Green Hydrogen in India can become cost effective which will not only guarantee energy security, but also ensure self-sufficiency eventually. If achieved, it will see India emerge as a Hydrogen driven economy. This could change geopolitical dynamics as many countries are investing or seeking to invest in this new energy system as a potential importer or exporter.

In the long run, as the global demand for Hydrogen increases, new exporters will emerge from different regions replacing the monopoly of the oil exporting countries. This will lead to major geopolitical realignments, presenting an excellent opportunity for India to become a net exporter of Green Hydrogen and cut down on oil and gas imports. Moreover, many leading organizations are researching technologies that can convert bio and plastic waste into Hydrogen. This provides a significant scope for investment in technology to mitigate India's combined problems of energy security and waste management.

VI. POLICY LIMITATIONS

The biggest challenge faced by industries to make the transition to a hydrogen powered economy is the economic sustainability of producing Green/ Blue Hydrogen. The technology used in the production of Hydrogen like 'Carbon Capture and Storage' (CCS) and hydrogen fuel cell technology are at an embryonic stage, which is expensive and tedious. Furthermore, maintenance cost for fuel-cells post installation can be costly too.

Commercial use of Hydrogen will require both the government and private players to heavily invest in R&D of such technology and infrastructure for production, transportation, and storage of Hydrogen. Policy makers also need to find a balance of adopting this technology which, on one hand, introduces Hydrogen energy to the masses and on the other hand, does not compromise on the safety requirements of this technology.

VII. CONCLUSION

At this stage, India can uniquely position itself as a strong player in the Hydrogen energy sector. The National Hydrogen Mission should aim to establish the required physical infrastructure, capacity building and legal framework required for the production and usage of Hydrogen as an alternative to fossil fuels to power our industries.

There needs to be a smooth working mechanism among the multiple regulatory authorities to ensure NHM can succeed. The draft guidelines for NHM should outline targets and capacity installation. Designated Hydrogen hubs can be established to attract investment by providing infrastructural support like pipelines and renewable electricity for production, storage, and transportation of Green Hydrogen.

Producers and major users of hydrogen can be placed in these hubs for logistical convenience. A "Hydrogen Valley Platform" to create an integrated hydrogen ecosystem covering everything from the production and storage to the distribution and end-use. This ecosystem is in development under the Department of Science and Technology. These initiatives can make India the leader of hydrogen exports across the globe.

APPENDIX

1. May like to refer to Concept Box on "Hype Cycle": Eco Track, May 2017. Available at http://10.18.65.156/intranet/view.aspx?cid=15

2. High temperature applications of Hydrogen in industry, Direct Reduction Iron (DRI) in steel industry, heating residential & commercial, which have high potential though are not covered here.

3. Hyundai Nexo – midsize SUV, Toyota Mirai, Honda Clarity-Sedan.

4. Fuel cells directly convert the chemical energy in hydrogen to electricity, with water vapour as the only by product.

5. A fuel cell is two to three times more efficient than an internal combustion engine running on gasoline (around 20% efficiency). Fuel cells convert the chemical energy in the fuel to electrical energy with efficiencies of up to 60%.

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