



# Green Hydrogen: The Green Energy Source of Future

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**Abstract:** Once fossil fuels are the main and major source of energy. But now we move away from it and looking for a renewable source. As the demand of energy is rapidly growing in all over the world, green hydrogen is one of the best and attractive substitute of the current carbon-based energy. ‘Green Economy’ is a new concept which can gain the attention of whole worldwide. This renewable energy is produced by the electrolysis of water and it will be the nature-friendly solution to store and use the excess energy to generate power, decarbonization of fuel which is used in transportation system and so on. To expand the applications of green hydrogen, we have to make it pocket-friendly. The production of hydrogen is mainly focus on to different aspects: (a) Electricity Conversion (b) Solar Energy Capture. Green hydrogen is a type of renewable energy sources which is clean and free from pollution. Achieving net-zero emission and to transit India into sustainable development some green hydrogen communities are built rapidly. India is in a way to grow renewable power generation capacity which can give the main advantages to manufacture green hydrogen from other green sources including wind at the time of lower demand and solar energy. Different states like Andhra Pradesh, Gujrat, and Tamilnadu have been declared as ‘Renewable Energy Plasters’ and their main aim is to develop green hydrogen project. Sea water can be utilize as a another source of water for electrolysis being a favorable geographical condition India has been unlimited potentiality for production of green hydrogen due to abundant energy sources. Some policies are invented by different countries like US, Germany, France, UK and Japan. This policy models are invented to scale-up and development of green hydrogen. Despite being a lots of blessing of green hydrogen the production and development of it is still have to face different technical challenges and economical and financial viability issues. Cutting down greenhouse gas emission enhance energy inclusion, eliminate energy poverty, expand job opportunities are the main objective of green hydrogen. Our present research work is mainly focused on production and to discuss about the opportunities of green hydrogen in all over the world. The potentiality of green hydrogen, economic system, enhance energy resources are also explained in this paper.

**Keywords:** Renewable Source, Green Hydrogen, Decarbonization, Green Economy, Electrolysis, Sustainable Development

## I. INTRODUCTION

The climate system of Earth is rapidly changing, from 1880 to 2012 we can observe the increment of the global mean temperature to 0.85 degree centigrade. The Intergovernmental panel on climate change assigns this warming to the unknown level of greenhouse gases along with Carbon Dioxide(CO<sub>2</sub>), Nitrous Oxide(N<sub>2</sub>O), Methane(CH<sub>4</sub>) mainly produced by human activities, expected to make our future worse. For this reason, low carbon technology and sustainable development are being focused by the countries [1]. As renewable energy is manufactured from Green Hydrogen (GH<sub>2</sub>), we can say it like a new kid of hydrogen block. It is Carbon Dioxide (CO<sub>2</sub>) free. In this age when global warming is one of the greatest issue, green hydrogen has the potential to significantly reduce greenhouse gas emission and integrating the impacts of carbon footprint from the climate. Without carbon capturing Green Hydrogen has been derived from the Fossil fuels. Significantly it has low carbon emission than grey hydrogen. For the production of Cements and Irons green hydrogen is use to decarbonizes sectors that are hard to electrify & it can also be used to produce green ammonia which is the basic component of synthetic fertilizer. It can also be used for long-duration grid energystorage, and for long-duration seasonal energy storage [2]. Green hydrogen production technologies are described as renewed wave of interest. This is because across multiple sectors, the possible uses of green hydrogen are expanding day by day including power generation, processes of manufacturing in industriessuch as steelmaking and production of cement, fuel cells for electric vehicles and heavy transport such as shipping, green ammonia production forfertilizers, cleaning products,refrigeration, and electricity grid stabilization [3]. One day green hydrogen will be progressively seen as the future of fuel in all over the world. And it can replace the fossil fuels in a range of high emission industry and sector. Reduction of emissions from electricity production and a portion of transportation can be done by Energy efficiency, renewable power, and direct electrification. But the last 15 percentage of economy, consist of aviation, long-distance trucking, shipping, concrete and steel manufacturing, is too hard to de-carbonize because these sectors need high energy density fuel or intense heat. Green hydrogen could meet these needs [4].

## II. HISTORICAL BACKGROUND

In today’s world fossil fuels are the main source of energy which are non-renewable and we cannot use it after exhaustion as it has some significance downsides for that this serves it’s impact on the environment [6]. As a result the demand of renewable energy sources are increasing day by day. Artificially hydrogen gas was first produced in 16<sup>th</sup> century and in 19<sup>th</sup> century electrolyzers and first fuel cells were made. It is noted by International Energy Agency (IEA) that since 1975 the global demand of hydrogen has tripled for using it as a fuel and it has reached 70 million tones in a year of 2018. In 1766 English physicist Henry Cavendish first



discovered Hydrogen. After first discovering in 1766, hydrogen gas was used to fly balloons in 1783. Before it was recognized as an element Scientists had been producing hydrogen for a long terms of years. At the time of experiment with iron and acids Robert Boyle first produced hydrogen gas as early as 1671 which is shown from an written records. Hydrogen fuel cell was first develop in 1838 to generate electricity. In 1960 General Electric (GE) comes up with hydrogen fuel cells for generating electricity. Hydrogen has a long lasting relationship with industry. Since the beginning of the 19<sup>th</sup> century this gas has been used to airships, fuel cars and spaceships and so on. The hydrogen –fuel cars were first declared in 1972 but their use was confined because of other relatively cheaper energy sources. Because in nature, hydrogen exists as a combinations of different molecules, unlike other source of energies such as coal, petroleum and natural gas energy should be intake to get pure hydrogen, so it is observe as an Energy Carrier or secondary energy source that can store and transport energy like electricity, rather than petroleum, which is a primary energy source. Since 2016, through the Certify Guarantee of Origin The European Union has certified hydrogen as eco-friendly renewable sources [7]. Low cost green hydrogen is coming up because as green electricity gets cheaper day by day. As system sizes and production volumes grow, while performance improves the cost of hydrogen production is falling exponentially.

### III. WHAT IS GREEN HYDROGEN?

Green hydrogen is produced by electrolysis which uses electricity to split the water molecules into their components that is hydrogen and oxygen. By the production of hydrogen and water splitting electrolyzers take place by proton exchange membrane [8]. Green hydrogen is a critical way to achieve net zero greenhouse gas emission by the help of electrolysis process and using renewable sources as fuel. Electricity is obtained in this process from renewable sources and the energy is generated without releasing carbon dioxide into the atmosphere. It is green when electricity for this is obtained from renewable sources such as solar cell or wind mill. It could be locally stored or transported with the help of limited pipelines. Greenhouse gas emissions play a critical role in the unknown climate crisis which has led the nations in all over the world to agree that urgent attention and instant solutions are necessary. Net zero transition will required to decarbonize the economy of all sectors. Green hydrogen generated from renewable energy sources and it poses little to no threat to the environment [9]. We can transform Green Electricity into transportation fuel using green hydrogen as the bridge or as feedstock in any industrial processes, where any types of climate- neutral alternatives processes are not exist currently. Putting wind power into the container shape fuel tank is allowed by green hydrogen. In this way, the potentiality of decarbonized hydrogen can significantly extend of renewable sources. There are a lots of advantages of green hydrogen, such as: (a) During combustion or during production green hydrogen does not emit the gases which are polluting in nature. (b) Green hydrogen can be changed into synthetic gasses or into electricity, to utilize it in any types of industrial, commercial and mobility purposes. (c) As hydrogen is too easy to store, for that it allows us to be used eventually for other purposes and at times other than instantly after it's production.

However green hydrogen is very much useful but there are few disadvantages too: we have some questions about the possibility of green hydrogen as it has a very high production cost; for the decarbonization of earth progresses the reasonable doubts will disappear; as a result the generation of green hydrogen becomes cheaper. This is identified by IEA that green hydrogen would save 830 million tonnes of annually emitted CO<sub>2</sub> when it's produced by using fossil fuels. Also in the world replacing all the grey hydrogen would require 3000 TWH/year from new renewable sources. Entirely established green hydrogen economy will operational and it's still a long way off. In spite of creation of a market about green hydrogen production, the International Energy Agency states that, the number of projects about electrolyzer and their installation capacity has reached less than 1 MW to more than 25 MW between 2010 to 2019. For renewable energy related technologies and electrolyzers this growth is mainly applicable to lower prices [10]. The green hydrogen production cost are basically governed by the available renewable energy sources and are dominated by energy consumption. However the one thing that should be consider is the production cost. Not only by the energy consumption but also we have to consider on storage expenses and transportation. At the location of renewable power production, large scale manufacturing of this renewable source will take place rather than at the demanding sides for this gas about production or import of hydrogen. By 2050, the demand for green hydrogen is projected to expand for obtaining 530 million tons replacing 10.4 billion barrels of an equivalent amount of oil. To reach 300000 employment in the field of hydrogen generation and renewable energy sources, this market is estimated to increase at a high rate. In spite of the benefits of green hydrogen associated with the reduction of greenhouse gas emission, for ensuring a sustainable future and bringing energy transition, it has low efficiency and high generation cost [11].

In some countries like United States, China, Germany, Russia and France Hydrogen is used as a fuel. Other countries like Japan is going even further and desire to become an economy which is totally depends on Hydrogen. Bellow we explain about some impacts of green hydrogen in future :- (a). Drinking water generator and electricity are obtained by the reaction of oxygen and hydrogen in a fuel cell. On space mission it is proved that this process is very useful, for e.g. water and electricity is provided by the crews in a sustainable manner. (b). Energy can be stored for a long periods of time in compressed hydrogen tank. As they are lighter it can also easy to handle than Lithium-Ion batteries. (c). The most relevant utility of hydrogen allows it to be applied in those consumption niches that are too hard to decarbonize, such as aviation, heavy transport and maritime transport.

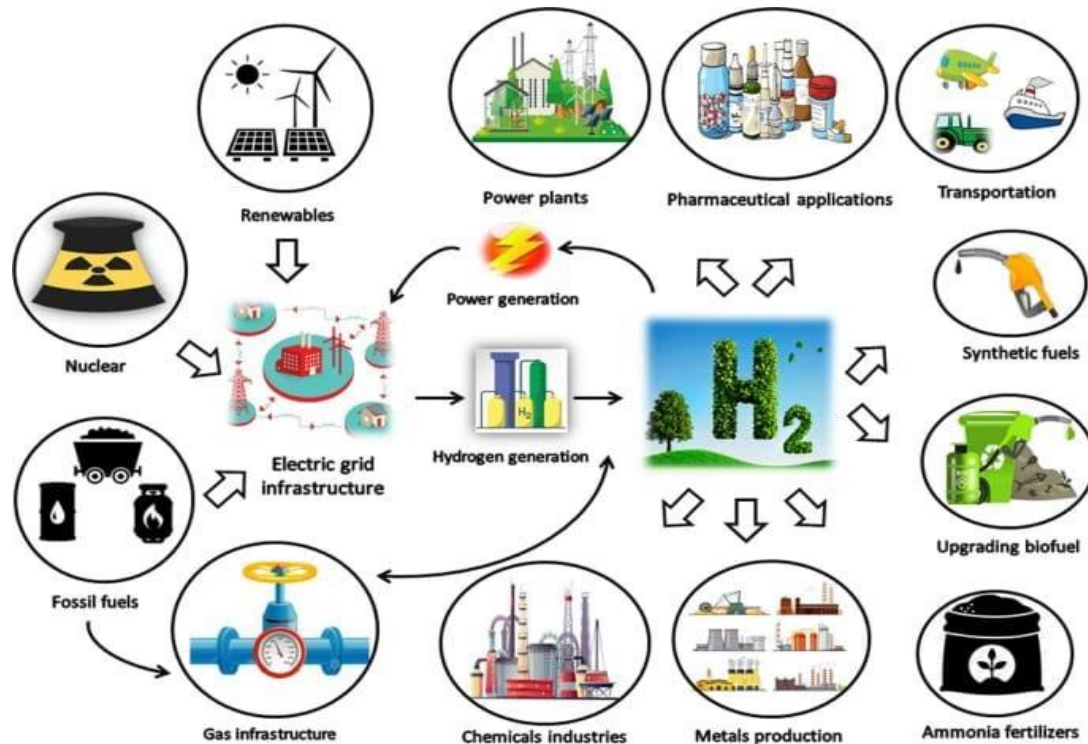


Fig. 1 Hydrogen production, storage, utilisation and environmental impacts [12]

#### IV. PRESENT RESEARCH WORK

The impact of the global conversion to the low carbon economy will significantly give it's existence to the energy value change, and the production will be transformed to the consumption life cycle, Among stakeholder it dramatically change in an interlinked way. We should thanks the versatile nature of Green hydrogen as a significant role could be played t reach a carbon free future within 2050. For decarbonizing the industrial processes, a adoption will be held. Especially like steel and cement production it's hard-to-abate. Over the past two years to meet climate target a proper intensify should be require. Demand for net zero achievement and securing of the climate targets by 2045, a discussion take place on executing and realizing this goals. Hydrogen has appeared as a climate neutral energy carrier. Over the last 1.5 years the roadmaps of hydrogen has been published by more than 25 countries. To encourage the development of hydrogen economy, different authorities have published various studies [13].

To supply the visualized hydrogen economy a major challenge which we have to overcome is the future viability of green hydrogen for large quantities. Some industrial countries developed ambitious national hydrogen strategies which heavily depend on green hydrogen which are imported from other countries. Including like the countries of global south those are rich in renewable energy sources [14]. Due to shortage of energy resources some countries have decided that depending on gases will not give the good impact, it's not the right solution [15].

In future green hydrogen market could be emerged as frontrunners by some develop countries like United States and China and they are in the way to lead in some industrial applications like methanol, ammonia, and the production of steel. Potentiality of hydrogen production is estimated to grow 248.56 million tonnes in Turkey. For increasing jobs and market shares import dependent industrial powers could be competed and upgraded along value chains by others developed rich countries.

A growth to geopolitical dynamic and dependencies will be given by the existing value chain. By 2050, from today's 70 million tons per year the demand of green hydrogen is expected to grow 700%. At this scale the applications of green hydrogen will significantly give a impression about existence of value chains and for creating economical opportunities for countries with ideally situated themselves in future green hydrogen market. Some industrial strategies are adopted by those countries like United States, China, and Norway to gain leadership. Green hydrogen adoption at scale is supported by this strategies and further innovation in industries [16].

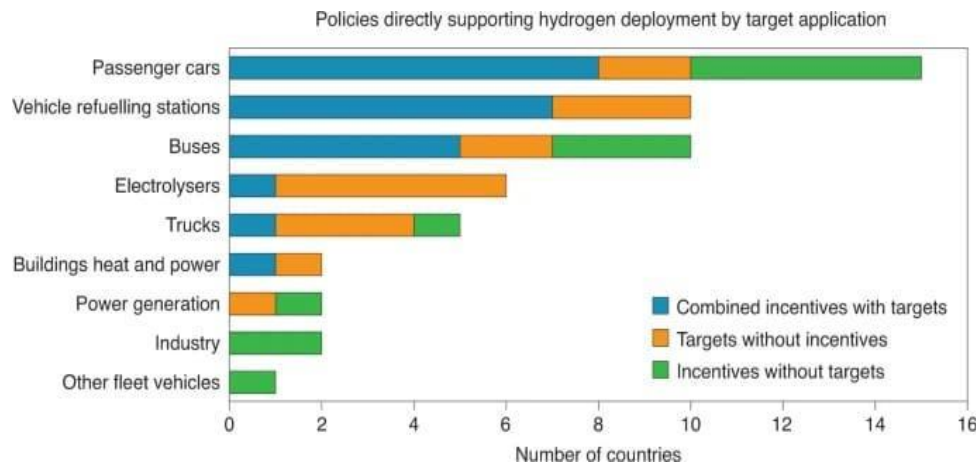


Fig. 2 Hydrogen as a solution for climate change [17]

### A. National Green Hydrogen Mission

In the Independent day speech in 2021 our honored prime minister announced about the national green hydrogen mission. For making India a net exporter of the fuel, it is a program to motivate the commercial production of green hydrogen. The demand creation, utilization, production and export of green hydrogen will be facilitated by this mission. Green hydrogen follows the policy that by 2030, for achieving the target of 5 million tonnes of clean fuel. To achieve this target for 50 billion liters of fresh water and 125 GW of installed renewable power sources will be needed by India. The main focus of this mission is to create some export opportunities about green hydrogen and it's production. For using in mobility application de-carbonization of this energy sector is needed and it's depends on fossil fuels; to develop the endemic manufacturing positions. The cost of renewable power generation is planned to bring down by the government and the electrolyzer which are used to construct green hydrogen by government-backed R&D push and also implicit subsidy support. By the help of associated renewable energy the scheme will want to increase the green hydrogen manufacturing capacity of 5 MMT per annum within 2030. An outlay of Rs. 35,000 crore has been approved by the government towards green energy which is declared in budget 2023 and towards green hydrogen mission additional charge Rs. 19,700 crore for decreasing dependency on fossil fuels. In June 2022, IRENA stated that more than 1500 green hydrogen projects will be executed globally. For green hydrogen projects many public and privately owned companies are investing in India. With Egypt an agreement has been signed by India for investing \$8 billion to produce 20,000 tonnes of green hydrogen in the Suez Canal economic zone annually. To make India greener and cleaner in 2016, the government launched Project Green Ports, for that the price of green hydrogen is affordable in the whole world. To reduce fossil fuels related activities these Ports are prepared to extend the production, and taking the renewable energy in an own grab. According to the Maritime India Vision, within 2030 the government take an initiative to expand the uses of renewable energy from less than 10% upto more than 60%. We can say, India, the center of a major green hydrogen production is in well position and also on accounts as low-cost renewable resource in the whole world. The share of green hydrogen could be increased potentially by the National Hydrogen Mission within 2030 to reach 46% and compare to 16% without any force. To take the right stage for scale and investment this states the importance of the mission about the green hydrogen ecosystem in India. Some companies and research institutions those who are working about the commercialization and development of these technologies get a lots of financial and technological support which is provided by the government. There are another important objective is to expand the usage of green hydrogen for different types of application including industrial processes, transportation system and power generation. To support the growth and ensure about the hydrogen industry, the government is working in this matter to increase the professional and technological skill. As hydrogen is a very clean and renewable energy source for that we can produce it from natural gas, biomass including water. For reducing greenhouse gas emission and to less dependent on fossil fuels, this mission about green hydrogen is generated. Developing transportation facilities and safe storage system will likely help to boost by the government and to use hydrogen-driven technology [18].

### V. INNOVATIVE IDEA

According to the renewable developers one day we can see green hydrogen as an emerging market and some transport sectors, though electric vehicles have started to catch the fascination of consumers today. To adopt green hydrogen policymakers have to take an initiative to analyze and plan the best model suited as a primary fuel. We can use green hydrogen in the steel making process to eliminate and reduce the emissions and prepare it as a low-carbon steel for different applications. Green fertilizers are manufactured in the agriculture sector by green hydrogen. One day from hydrogen some liquid fuels are prepared which can be used as a power air travel and shipping. Green hydrogen open a new path to develop various applications such as transportation, power generation, industry and to heat some materials. Production of electricity through turbines and fuel cells are done by green hydrogen.



Buses, trains, trucks and other power vehicles will be also some another applications. Some development and research going on to utilize of the blessings of green hydrogen. Gas players and oil industries from steel to fertilizers are the basic utilization of this, and more we can say chemical and transportation sectors and some energy-hungry industries are nothing without de-carbonization of green hydrogen. In spite of being some friendly outlook, and major challenges still have to face by green hydrogen. To overcome from it, this should be more accessible and competitive by improving the durability and efficiency of electrolyzer and we have to develop energy storage system, new hydrogen hub and corridors, to make it our future.

## V. CONCLUSION

As population is increasing day by day with the urbanization trends, recently consumption of energy will become more and more. So the global energy demand will also increase between some years [19]. At the time of Covid-19 pandemic the lives of millions of people had seriously affected in the whole world. As in this time the production of energy sources were decreasing day by day, to overcome from this situation renewable energy sources are the main path to expand the energy production. Regarding this problem some new policies were invented for low-carbon emission and to make the whole world as a pool of energy and green hydrogen is a type this renewable sources which give us a new way to build up our economical status [20]. In the current fossil fuels expansion phase hydrogen gas is constantly providing its power as a carrier of clean energy and sustainable with zero polluting and high specific energy sources. India has a lots of coal reserved and a huge biomass potentiality which have more tendency to combine higher energy production. Still India is in the early stage to commercialize fuel cell technologies and the other countries in all over the world are in this way. Some major unavoidable challenges is currently have to face by India such as regulation policies creating public acceptance etc. To overcome from this serious issues through clean gateways India will be able to face the lots of energy demands in the near future. For saving the fuels and to make India a more developed country hydrogen fuel cell decays were used which delivered us three times better economy than internal combustion in this. Now India has described hydrogen production process in the present research papers. To develop green hydrogen some paper-discuss policies are made by few countries like UK, France, Japan and Germany [21]. Green hydrogen will be used zero emission fuel decays for generating power and in aircraft. It has a major possibility for decreasing carbon emission in the whole world. The companies which are looking for providing green energy solution for them hydrogen will be a significant option for customer and themselves too. Using some extra care and by the help of talented human thoughts towards installation and operations this can be a beneficial and states energy carrier that will help advance sustainable operation. Promotions of green hydrogen technologies obeys the real promise because the threat of climate changes flatters more real. It could be the main opportunity of India for leading the world in a cutting edge, generating employment in manufacturing, growing space-by India's 'Atma Nirvor Bharat' campaign. For long term ambition, the hydrogen economy system can foster the energy transition of significant investment in the commercialization and development of the application for low-carbon hydrogen. It has the potentiality to make a transport system which can travel a long distance. India will be the major player in the green hydrogen market by the help of regulatory frame work and right political system [22]. For saving the cost on the economic viability of green hydrogen and make it as a long term facilitator, the rapid increase of this technology is too much needful [23]. Since 2017, the World Economic Forum is the main supporter of green hydrogen agenda. As the era of hydrocarbon is in a way to stop, green hydrogen has the main potentiality to dominant transportable and to become the world tradable energy medium.

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