**Green Hydrogen as Future Energy Source in India**

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**Abstract**

With continuous growth in development, the world energy demand is also increasing at a higher rate year by year. Fossil fuels still fulfil 80% of energy need. The Net Zero Emission scenario by 2050 has forced all nations to adopt clean and renewable energy options. In this context, hydrogen energy has already been assessed as a clean and renewable energy source. Due to its versatile nature and being an energy carrier, hydrogen is even more potent than other renewable energy sources. To meet the global challenge of climate change, India has announced National Hydrogen Mission on 15 August 2021. This mission  focuses on producing green hydrogen and green ammonia using electrolysis of water employing renewable electricity and hydrogen production through biomass. Targets of the Indian National Hydrogen Mission, India’s Green hydrogen policy, the cost and demand of hydrogen in India and green hydrogen initiatives undertaken by the Government of India have been discussed in detail. In short, National Hydrogen Mission will make India self–sufficient in energy needs. India may become a world leader in energy export, especially in green hydrogen and green ammonia.

**Keywords:** National hydrogen Mission, Green hydrogen, Green ammonia, Renewable electricity, Net Zero Emission

1. **Introduction**

Due to continuous and increasing development, world energy demand is growing daily. The world total energy supply in 1973 was 254 Exa Joule, in 2019, it was 606 EJ, while in 2021, the energy demand was 624 EJ. In 2019 total energy consumption in the world was 418 EJ and 439 EJ in 2021, while it was only 194 EJ in 1973. The share of fossil fuel in consumed energy is still 80% in 2021. Many policies have come forward to cut the emission of greenhouse gases. It is required to meet the goal of limiting global warming to well below 2 °C, preferably to 1.5 °C compared to pre-industrial levels in Paris agreement on climate change. The **Stated Policies Scenario (STEPS)** is about today’s policy settings. The **Announced Pledges Scenario (APS)** assumes that all aspirational targets announced by governments are met on time and in whole, including their long‐term net zero and energy access goals. The **Net Zero Emissions by 2050** **(NZE) Scenario** maps out a way to achieve a 1.5 °C stabilisation in the rise in global average temperatures, alongside universal access to modern energy by 2030. In 2021, the largest-ever annual increase in CO2 emission, as, 36.6 Gt was noticed. In STEPS, this emission will fall to a level of 32 Gt in 2050, and will lead to a 2.5 °C rise in global average temperatures by 2100. However, before the Paris agreement rises in global temperature was predicted as one °C higher than STEPS. Following the APS, emissions will fall to 12 Gt in 2050, resulting in a projected global median temperature rise in 2100 of 1.7 °C. In the Net Zero Emissions by 2050 (NZE) Scenario, CO2 emissions fall to 23 Gt in 2030 and to zero in 2050, increasing the temperature to less than 1.5 °C in 2100. The predicted temperature in the different scenarios is presented in Table 1.

**Table 1. Predicted global temperature and CO2 emission in various scenarios.**

|  |  |  |  |
| --- | --- | --- | --- |
| S.N. | Scenario | Predicted temperature in 2100 | Amount of CO2­ emission in 2050 |
| 1 | Before Paris Agreement | 3.5 °C | 36.6 Gt in 2021 |
| 2 | STEPS | 2.5 °C | 32 Gt |
| 3 | APS | 1.7 °C | 12 Gt |
| 4 | NZE | 1.5 °C | 0 |

* 1. **World Energy Scenario**

The total consumption of energy in 2021 around the globe was 439 EJ. This energy is derived through electricity, heat, liquid, gaseous and solid fuels. A major portion of energy, around 80% still comes from fossil fuels. The share of different energy sources is shown in Table 2. The major energy consumption sectors are industry, transport, building and others. These sectors consume 38, 26, 30 and 6 % of energy respectively globally (Table 2). In total CO2 emissions of 36.6 Gt, 39.2, 4.2, 25.4, 21, 8.3 and 1.9 % are emitted from electricity and heat, non-energy sector, industry, transport, building and other sectors, respectively. The emission of CO2 from the different sectors is given in Table 3. In 2021 total generated electricity was 28334 TWh around the globe. Among the total electricity generated, 28.4 % is derived from renewable sources and 61.5 % from fossil fuels. 9.8 % share is from nuclear energy. The composition of claims coming from different energy sources for electricity generation is shown in Table 4. Regarding the installed capacity for electricity generation (total installed capacity 8185 GW), 40 % is from renewable energy installation, and 54.5 % is based on fossil fuel installation. Nuclear energy installation has a share of 5% (Table 5).

**Table 2. World energy consumption in 2021 in STEPS.**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Type of fuel | Energy in Exa Joule | | | | |
|  | **Total consumption** | **Industry** | **Transport** | **Buildings** | **Other** |
| Total consumption | **439** | **167** | **114** | **133** | **25** |
| Electricity | **87** | **37** | **2** | **45** |
| Liquid fuels | **170** | **33** | **107** | **14** |
| Biofuels | 4 | - | 4 | - |
| Ammonia | - | - | - | - |
| Synthetic oil | - | - | - | - |
| Oil | 166 | 33 | 103 | 14 |
| Gaseous fuels | **72** | **31** | **5** | **31** |
| Biomethane | - | - | - | - |
| Hydrogen | - | - | - | - |
| Synthetic methane | - | - | - | - |
| Natural gas | 72 | 31 | 5 | 31 |
| Solid fuels | **94** | **59** | **-** | **33** |
| Solid bioenergy | 40 | 11 | - | 28 |
| Coal | 54 | 48 | - | 4 |
| Heat | **13** | **7** | - | **7** |
| Other | **3** | - | - | **3** |

**Table 3. Sector-wise CO2 emission in 2021 at global level.**

|  |  |  |
| --- | --- | --- |
| Sector | Amount of CO2 emission | |
| Gt | % of total emission |
| Total emission | 36.639 | 100 |
| Electricity and heat sector | 14.378 | 39.2 |
| Industry | 9.316 | 25.4 |
| Transport | 7.670 | 21.0 |
| Buildings | 3.045 | 8.3 |
| Others | 0.708 | 1.9 |
| Non energy sector | 1.522 | 4.2 |

* 1. **Indian Energy Scenario**

In India, total energy consumption in 2021 was 27.5 EJ, which is 6.26% of globally consumed energy. The maximum energy in India is consumed by the industry sector, which is 45.1%. In the transport sector the amount of energy consumed is less (15.3%) in comparison to the global status. Energy consumption in different sectors in India is reflected in Table 6. In 2021 total CO2 emission in India was 2.472 Gt, 6.75 % of world’s total CO2 emission. Among total CO2 emissions, 1.199 Gt (48.5%) are from the electricity and heat sector, while 1.205 Gt (48.7%) is emitted collectively from the industry, transport and building sectors. Among total electricity generation, India shares 1686 TWh of electricity, which is 5.95 % of total world electricity production. The share of renewable energy in India for electricity corresponds to 337 TWh, which is 20 % of home electricity production and 4.18 % of world renewable electricity production (Table 4).

**Table 4. Total electricity generated (TWh) in the world and in India in 2021.**

|  |  |  |
| --- | --- | --- |
| Type of technology | In world | In India |
| Total generation | **28334** | **1686** |
| Renewable | **8060** | **337** |
| Solar PV | 1003 | 73 |
| Wind | 1871 | 77 |
| Hydro | 4327 | 150 |
| Bioenergy | 746 | 37 |
| CSP | 15 | - |
| Geothermal | 97 | - |
| Marine | 1 | - |
| Nuclear | **2776** | **42** |
| Hydrogen and ammonia | **-** | **-** |
| Fossil fuels with CCUS | **1** | **-** |
| Unabated fossil fuels | **17436** | **1304** |
| Coal | 10201 | 1234 |
| Natural gas | 6552 | 70 |
| Oil | 683 | - |
| Other | **61** | **3** |

**Table 5. Total installed electricity (GW) in the world in 2021 in STEPS.**

|  |  |
| --- | --- |
| Total capacity | 8185 |
| Renewable | **3278** |
| Solar PV | 892 |
| Wind | 832 |
| Hydro | 1357 |
| Bioenergy | 173 |
| CSP | 7 |
| Geothermal | 16 |
| Marine | 1 |
| Nuclear | **413** |
| Hydrogen and ammonia | **-** |
| Fossil fuels with CCUS | **0** |
| Unabated fossil fuels | **4462** |
| Coal | 2185 |
| Natural gas | 1850 |
| Oil | 427 |
| Battery storage | **27** |
| Other | **5** |

**Table 6. Sector-wise energy consumption (EJ) in India in 2021.**

|  |  |  |
| --- | --- | --- |
| Sector | Energy consumption | |
| Amount | % |
| Total consumption | 27.5 | 100 |
| Industry | 12.4 | 45.1 |
| Transport | 4.2 | 15.3 |
| Buildings | 8.5 | 30.9 |
| Other | 2.4 | 8.7 |

1. **Indian Policy for different Scenarios**

To meet global clean energy efficiency in production and consumption, India has declared the following overall cross-cutting policy:

**STEPS**

* Energy‐related elements of the Self‐Reliant India Scheme (Atmanirbhar Bharat).
* 450 GW renewables capacity by 2030 and 50% of total installed capacity to be non‐fossil fuel‐based energy sources by 2030.
* Enhanced enforcement of energy efficiency policy under the 2022 amendments to the Energy Conservation Act.
* National Hydrogen Mission.

**APS**

* Updated NDC to reduce national carbon intensity by 45% by 2030 from 2005 levels, increased non‐fossil energy capacity to 500 GW by 2030, and reduce carbon emissions by 1 Gt CO2 by 2030.
* Net zero emissions by 2070.
  1. **Electricity Sector-**

**APS**

* Updated NDC ‐ 50% cumulative electric power installed capacity from nonfossil fuel‐based energy resources by 2030.
  1. **Industry Sector**

**STEPS**

* Perform, Achieve, Trade (PAT) Scheme to trade energy-saving credits.
* Make in India programme. Boost to industry sector by building 11 world‐class industrial corridors.
* Union Budget 2021‐2022, i.e., the national budget, includes USD 26 billion to enhance the manufacturing capabilities of 14 key sub‐sectors.
  1. **Building Sector**

**STEPS**

* Energy Conservation and Sustainable Building Code as part of the Energy Conservation (Amendment) Bill, comprising norms or energy efficiency and conservation, minimum use of renewable energy and other green buildings requirements.
* Cooling Action Plan. Standards and labelling for light commercial air conditioners, freezers and light bulbs.
* Energy efficiency labelling for residential buildings for renters and homeowners.
  1. **Transport Sector**

**STEPS**

* Urban and public transit investments.
* Partial implementation of a 20% bioethanol blending target for gasoline and 5% biodiesel in 2030.

**APS**

* Extension of FAME Phase II programme to support the target of 500 000 electric three‐wheelers and 1 million electric two‐wheelers.
* National railways target of net zero emissions by 2030.

1. **Need for Hydrogen Energy**

Well-known detrimental effect of fossil fuel has forced the world to move towards clean and renewable energy sources. Many countries are moving towards other energy options, including nuclear and renewable energy, to fulfil their energy demand. Hydrogen energy is now established as a potential candidate for a future energy sources. Key parameters for harnessing hydrogen energy at the fullest potential are production, storage, transportation and application. Hydrogen energy has many advantageous characteristics to establish it as a good energy source. Some of them are abundant quantity, renewable nature, environmentally clean, high energy content, storable, economically transportable, conveniently usable, socially compatible and even distributed around the globe.

* 1. **Production and Applications of Hydrogen Energy**

In 2021 hydrogen demand in the world was 11319 PJ. The demand in India was 1045 PJ. The major hydrogen productions routes are:

* Steam methane reforming using natural gas
* Liquified petroleum gas and naptha cracking
* Gasification of coal
* Gasification of biomass
* Water electrolysis

Hydrogen produced from different sources is coded with some colour, as mentioned in Table 7.

**Table 7. Colour coding of hydrogen production based on the production source.**

|  |  |
| --- | --- |
| Source of hydrogen  production | Colour code of  hydrogen produced |
| Coal | Black |
| Natural gas | Grey |
| Lignite | Brown |
| Fossil fuels with CCUS | Blue |
| Renewable electricity | Green |

Hydrogen is an energy carrier with versatile nature. It has wide applications not only as energy to replace fossil fuel, especially in transportation sectors, many more applications in other sectors. Some crucial sectors are listed below:

* Refining
* Power
* Transport
* Industry
* Buildings

In the industry, the categorized significant applications are:

* Ammonia
* Other pure chemicals

The above mentioned are specific applications requiring hydrogen with only small additives or contaminants tolerated.

* Methanol
* Steel industry-Direct Reduction of Iron (DRI)
* Other mixed applications

In the above three applications, hydrogen is required as part of a mixture of gases, such as synthesis gas, for fuel or feedstock.

Most of the  hydrogen demand increase came from traditional refining and industry uses. The first fleet of hydrogen fuel cell trains started operating in Germany. There are also more than 100 pilot and demonstration projects for using hydrogen and its derivatives in shipping, and major companies are already signing strategic partnerships to secure the supply of these fuels. In the power sector, hydrogen and ammonia are attracting more attention; announced projects stack up to almost 3.5 GW of potential capacity by 2030.

* 1. **Present Scenario of Hydrogen Energy around the Globe**

Hydrogen demand reached 94 million tonnes (Mt) in 2021 and contains energy equal to about 2.5% of global final energy consumption. The production of low-emission hydrogen was less than 1 Mt in 2021, practically all of it coming from plants using fossil fuels with carbon capture, utilisation and storage (CCUS). If all projects currently in the pipeline were realised, by 2030, the production of low-emission hydrogen could reach 16-24 Mt per year, with 9-14 Mt based on electrolysis and 7-10 Mt on fossil fuels with CCUS. In the case of electrolysis, the realisation of all the projects in the pipeline could lead to an installed electrolyser capacity of 134-240 GW by 2030. Expanding electrolyser manufacturing capacity is critical to rolling out hydrogen supply chains. Electrolysers using low-emission electricity are needed to produce low-emission hydrogen. Today, electrolyser manufacturing capacity sits at nearly 8 GW/yr and based on industry announcements, it could exceed 60 GW/yr by 2030. The analysis suggests that with today’s fossil energy prices, renewable hydrogen could already compete with hydrogen from fossil fuels in many regions. These regions have good renewable resources and import fossil fuels to meet the demand for hydrogen production. There is of course, uncertainty about how this plays out over the next few years. But if electrolyser projects in the pipeline are realised, and the planned scale-up in manufacturing capacities takes place, electrolyser cost could fall by around 70% by 2030 compared to today. Combined with the expected drop in the price of renewable energy, this can bring the cost of renewable-based hydrogen down to a range of USD 1.3-4.5/kg H2 (equivalent to USD 39-135/MWh). Global hydrogen demand was nearly 94 million tonnes (Mt) in 2021, a 5% increase from the previous year. Most of this demand growth was from traditional uses of hydrogen, particularly in refining and industry. But some new applications are also seeing accelerated deployment, such as fuel cell electric vehicles (FCEVs). By the end-2021, the global FCEV stock was more than 51000, up from about 33000 in 2020, representing the most significant annual deployment of FCEVs since they became commercially available in 2014. Most FCEVs are passenger cars, but several demonstration projects for fuel cell trucks and a strong push in China put nearly 800 hydrogen fuel cell heavy-duty trucks into operation in 2021.

In 2021, total global production was 94 million tonnes of hydrogen (Mt H2) with associated emissions of more than 900 Mt CO2. Natural gas without CCUS is the main route and accounted for 62% of hydrogen production in 2021. Hydrogen is also produced as a by-product of naphtha reforming at refineries (18%) and then used for other refinery processes (e.g., hydrocracking, desulphurisation). Hydrogen production from coal accounted for 19% of total production in 2021, mainly based in China. Limited amounts of oil (less than 1%) were also used to produce hydrogen. Low-emission hydrogen production was less than 1 Mt (0.7%) in 2021, almost all from fossil fuels with CCUS, with only 35 kt H2 from electricity via water electrolysis. While very small, the amount of hydrogen produced via water electrolysis increased by almost 20% compared to 2020. This reflects the increasing deployment of water electrolysers.

Bringing down production costs of low-emission hydrogen in 2021, in most regions, the cost of low-emission hydrogen production was more expensive than the fossil fuels without CCUS route. The average cost comparisons are USD 1.0-2.5/kg H2 from unabated natural gas; USD 1.5-3.0/kg H2 from natural gas with CCUS; and USD 4.0-9.0/kg H2 for production via electrolysis with renewable electricity. By 2030, hydrogen from solar PV could fall below USD 1.5/kg H2 and by 2050 below USD 1/kg H2 in regions with good solar conditions and thus low costs for electricity from solar PV, which account for around 55% of the total hydrogen production costs. Solar PV electricity costs must fall to USD 14/MWh by 2030 and USD 11/MWh by 2050 to reach these hydrogen production cost levels. Alongside cost reductions and efficiency improvements for electrolysers, this would make hydrogen from solar PV by 2030 in regions with good resource conditions competitive with hydrogen production from natural gas with CCUS. The US Hydrogen Earth shot initiative aims to achieve hydrogen costs of USD 1/kg H2 by 2030. Hydrogen demand in the different scenarios at the global level and in India is presented in Table 8. Similarly, sector-wise future hydrogen production, demand and consumption in various scenarios is demonstrated in Table 9.

**Table 8. Future hydrogen demand (PJ) across the world and in India.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Scenario | Present | | STEPS | | APS | |
| **2020** | **2021** | **2030** | **2050** | **2030** | **2050** |
| World | 10730 | 11319 | 13438 | 16822 | 15064 | 34575 |
| India | 975 | 1045 | 1342 | 2134 | 1284 | 3585 |

**Table 9. Sector-wise future hydrogen production, demand and consumption (Mt H2 equivalent) across the world and in India.**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Scenario | STEPS | | | APS | | NZE | |
| **2021** | **2030** | **2050** | **2030** | **2050** | **2030** | **2050** |
| Low-emission hydrogen production | **1** | **6** | **25** | **30** | **225** | **90** | **452** |
| Water electrolysis | 0 | 4 | 17 | 21 | 167 | 58 | 329 |
| Fossil fuels with CCUS | 1 | 2 | 8 | 9 | 57 | 31 | 122 |
| Bioenergy and other | 0 | 0 | 0 | 0 | 1 | 0 | 2 |
| Transformation of hydrogen | **0** | **3** | **10** | **14** | **95** | **50** | **186** |
| To power generation | 0 | 0 | 1 | 4 | 19 | 27 | 60 |
| To hydrogen-based fuels | 0 | 0 | 3 | 6 | 69 | 18 | 118 |
| In oil refining | 0 | 2 | 5 | 3 | 6 | 2 | 4 |
| To biofuels | 0 | 1 | 1 | 1 | 1 | 3 | 3 |
| Hydrogen demand for end-use sectors | **0** | **3** | **15** | **16** | **131** | **40** | **266** |
| Low-emission hydrogen-based fuels | **0** | **0** | **3** | **3** | **55** | **15** | **96** |
| Total final consumption | 0 | 0 | 1 | 3 | 39 | 7 | 68 |
| Power generation | 0 | 0 | 2 | 0 | 16 | 8 | 28 |
| Trade | 0 | 1 | 5 | 4 | 44 | 18 | 73 |
| Trade as share of demand | 0% | 10% | 22% | 13% | 19% | 20% | 16% |

1. **National Hydrogen Mission of India**

Addressing the nation on the 75th Independence Day, Prime Minister Narendra Modi announced the National Hydrogen Mission to make India a hub for producing and exporting green hydrogen. This mission is a step towards achieving net-zero India by 2070. This is geared to make India energy independent before it completes 100 years of independence in 2047.

* 1. **Targets of the National Hydrogen Mission of India**

India can achieve the following targets under the National hydrogen Mission:

1. The world’s most extensive electrolysis (green hydrogen generation) capacity of over 60 GW/5 million tonnes by 2030 for domestic consumption. It will help India meet the 500 GW renewable energy target.
2. The world’s largest producer of green steel at 15-20 million tonnes by 2030 — a pioneering effort to make green steel mainstream for the world.
3. The world’s largest electrolyser annual manufacturing capacity of 25 GW by 2028 delivering affordable ones for India and the world.
4. The world’s largest producer of green ammonia for exports by 2030 helping India’s allies to decarbonise. This may require up to 100 GW of green hydrogen.
5. $1 billion investment into hydrogen research and development to enable breakthrough technologies for the world at scale and the speed that is required.
   1. **Advantages of the National Hydrogen Mission**

With proactive collaboration among innovators, entrepreneurs and government, green hydrogen has the potential to drastically reduce CO2 emissions, fight climate change, and put India on a path towards net-zero energy imports. It will also help India export high-value green products making it one of the first major economies to industrialise without the need to ‘carbonise’. To further complement these ongoing efforts, India is prioritising green hydrogen as a potential solution to decarbonise hard-to-abate sectors such as refinery, ammonia, methanol, iron and steel and heavy-duty trucking. Adoption of green hydrogen can enable India to abate 3.6 Gt of CO2 emissions cumulatively between now and 2050. This can be a significant lever for the nation to contribute towards its recently announced climate targets and net-zero vision.

India is at a crucial juncture in terms of its energy landscape and green hydrogen has a critical role to play to make the nation self-reliant and energy-independent. Hydrogen can be an energy molecule that is true ‘made in India’ and that can contribute to the country’s energy security and long-term economic competitiveness. India has the unique opportunity to capitalise on this new technology and become a world leader in green hydrogen production and its applications.

* 1. **India’s Green Hydrogen Policy**

The government of India have declared several policy measures to facilitate the transition from fossil fuel, fossil fuel-based feedstock to Green Hydrogen / Green Ammonia both as energy carriers and as chemical feedstock for different sectors. After careful consideration, the Government of India have framed the policy on Green Hydrogen which provides the following:

1. Green Hydrogen / Green Ammonia shall be defined as Hydrogen / Ammonia produced by way of electrolysis of water using Renewable Energy; including Renewable Energy which has been banked and Hydrogen/Ammonia produced from biomass.
2. The waiver of inter-state transmission charges shall be granted for a period of 25 years to the producer of Green Hydrogen and Green Ammonia from the projects commissioned before 30th June 2025.
3. Green Hydrogen / Green Ammonia can be manufactured by a developer by using Renewable Energy from a co-located Renewable Energy plant, or sourced from a remotely located Renewable Energy plant, whether set up by the same developer, or a third party or procured renewable energy from the Power Exchange. Green Hydrogen/Green Ammonia plants will be granted Open Access for sourcing of Renewable Energy within 15 days of receipt of application complete in all respects. The Open Access charges shall be under the Rules as laid down.
4. Banking shall be permitted for a period of 30 days for Renewable Energy used for making Green Hydrogen/ Green Ammonia.
5. The banking charges shall be as fixed by the State Commission which shall not be more than the cost differential between the average tariff of renewable energy bought by the distribution licensee during the previous year and the average market clearing price (MCP) in the Day-Ahead Market (DAM) during the month in which the Renewable Energy has been banked.
6. Connectivity, at the generation end and the Green Hydrogen / Green Ammonia manufacturing end, to the ISTS for Renewable Energy capacity set up to manufacture Green Hydrogen / Green Ammonia shall be granted on priority under the Electricity (Transmission system planning, development and recovery of Inter-State Transmission charges) Rules 2021.
7. Land in Renewable Energy Parks can be allotted for the manufacture of Green Hydrogen / Green Ammonia.
8. The Government of India proposes to set up Manufacturing Zones. Green Hydrogen / Green Ammonia production plants can be set up in any of the Manufacturing Zones.
9. Manufacturers of Green Hydrogen / Green Ammonia shall be allowed to set up bunkers near Ports for storage of Green Ammonia for export/use by shipping. The land for storage purpose shall be provided by the respective Port Authorities at applicable charges.
10. Renewable Energy consumed for the production of Green Hydrogen / Green Ammonia shall count towards the RPO compliance of the consuming entity. The renewable energy consumed beyond the obligation of the producer shall count towards RPO compliance of the DISCOM in whose area the project is located.
11. Distribution licensees may also procure and supply Renewable Energy to the manufacturers of Green Hydrogen / Green Ammonia in their States. In such cases, the Distribution licensee shall only charge the cost of procurement as well as the wheeling charges and a small margin as determined by the State Commission.
12. Ministry of New and Renewable Energy (MNRE) will establish a single portal for all statutory clearances and permissions required for the manufacture, transportation, storage and distribution of Green Hydrogen / Green Ammonia. The concerned agencies/authorities will be requested to provide the clearances and permissions in a time-bound manner, preferably within a period of 30 days from the date of application.
13. To achieve competitive prices, MNRE may aggregate demand from different sectors and have consolidated bids conducted for procurement of Green Hydrogen/Green Ammonia through any of the designated implementing agencies.
    1. **Cost and Demand of Green Hydrogen in India**

In the future cost of Green hydrogen in India will be as follows:

**2030 prices:**

Green H2: $1.7 - $2.4/kg; RTC Renewables: $2.1/kg; Grey H2: $1.8 - $2.7/kg

**2050 prices:**

Green H2: $0.6 - $1.2/kg; RTC Renewables: $0.9/kg; Grey H2: $1.9 - $2.9/kg

From a price parity basis alone, green hydrogen’s share of this demand could grow from 16% in 2030 to almost 94% by 2050. This translates to an implied cumulative electrolyser capacity demand of 20 GW by 2030 and 226 GW by 2050, promising a sizeable opportunity for indigenous manufacturing of a global emerging energy technology. The cumulative value of the green hydrogen market in India could be $8 billion by 2030 and $340 billion by 2050. The electrolyser market size could be approximately $5 billion by 2030 and $31 billion by 2050. Adoption of green hydrogen will also result in 3.6 Gt of cumulative CO2 emissions reductions between 2020 and 2050. Energy import savings from green hydrogen can range from $246 billion to $358 billion within the same period.

Hydrogen demand in different sectors for end user is given as under:

**Fuel: Transport-**Maritime, Trains, Road, Freight, Aviation

**Power:** Flexibility, Seasonal Storage, Peaking Plants, Power backup

**Feedstock: Chemicals-**Fertilizer, Plastics, Fuel refining

**Feedstock: Products** -Metallurgy, Steel, Food, Glass

**Heat:** Space heating in buildings and industry

**Industry:** Steel, Paper, Cement, Aluminium, Food

Hydrogen demand in India in 10 years gap is estimated as follows:

In 2020=7 Mt, the share of green hydrogen =0

In 2030 =12 Mt, the share of green hydrogen =16 %

In 2040 = 17 Mt, the share of green hydrogen =70%

in 2040 = 28 Mt, the hare of green hydrogen =94%

* 1. **Current Green Hydrogen Initiatives in India** 
     1. **Green Hydrogen Initiatives by The Ministry of Petroleum & Natural Gas (MoPNG)**

MoP&NG has a Hydrogen Corpus Fund (HCF).  The Fund participates in funding R&D projects which are led by the oil industry.  Among the projects currently being funded are for finding Multiple Pathways for the production of hydrogen; H-CNG; and hydrogen production through the decomposition of natural gas.  Academic institutions are involved in these projects to leverage their knowledge in frontier areas. The ministry has the following programs:

1. The Ministry of Petroleum & Natural Gas (MoPNG) has already taken initiative to the greater use of hydrogen in the energy mix. The first pilot is based on Grey Hydrogen, where hydrogen is blended with compressed natural gas (CNG) to the extent of 18%, for use as a transportation fuel at Rajghat Bus depot. Under this pilot, 50 buses in Delhi are plying on blended Hydrogen in Compressed Natural Gas (CNG).
2. Five other pilots are planned based on Green Hydrogen where hydrogen produced is to be used as a transportation fuel as well as an industrial input to refineries. Following Pilots based on Green Hydrogen are being planned:
3. Two Pilot for Setting up of Solar hydrogen refuelling stations at two locations (locations to be identified upon consultation with the Green Hydrogen suppliers) for demonstration of fuel cell vehicles at tourist sites like Delhi-Agra, Gujarat (Statue of Unity), etc.
4. One Pilot for setting up a green hydrogen plant to explore an opportunity of replacing conventional hydrogen in a refinery with green hydrogen.
5. One Pilot for the production of green hydrogen and its blending with Compressed Natural Gas (CNG) at an appropriate site in Rajasthan for dispensing at retail outlets.
6. One Pilot for setting up green hydrogen infrastructure and pipeline injection of green hydrogen in the City Gas Distribution (CGD) network.

These pilots are at the preliminary stage of preparation and different modalities are being worked on to achieve the purpose of the pilots mentioned above.

The Multiple Pathways projects are an ambitious R&D project, with an outlay of approx.  ₹296 crores, of which one-third each is contributed by the HCF, IOC and other participating entities (original equipment manufacturers).  This is the first scientific project in India to address all aspects of the value chain of hydrogen-based mobility.  For this purpose, IOC R&D is procuring 15 indigenously manufactured/integrated hydrogen fuel cell buses to conduct a 20,000 km field trial in Delhi NCR.  4 demo units of hydrogen production units amounting to 40 tonnes per day will also be set up.  Of these, 3 plants are based on renewable sources (biomass gasification, reforming CBG and solar PV-based electrolysis) producing green hydrogen. IOC R&D has joined hands with the Indian Institute of Science, Bengaluru to develop biomass gasification technology, which is the most economical pathway to the hydrogen economy. Furthermore, MoPNG has constituted an expert committee headed by the Director, IOC (R&D) to study various techno-economical aspects of hydrogen production, storage and transportation. Results from these pilots will be utilized for the scale-up of these systems for use of Hydrogen as a clean energy source in the country.

* + 1. **Hydrogen-based Transport**

While Battery Electric Vehicles (BEVs) are dependent on imported raw materials like lithium and cobalt for lithium-ion batteries, the hydrogen fuel cell supply chain can be wholly indigenized, making India **Aatmanirbhar in the clean transportation segment.**

**Fuel cell electric vehicles (FCEVs)** run on hydrogen fuel and have no harmful emissions. Battery Electric Vehicles (BEVs) may be suitable for the light passenger vehicle segments for the shorter driving ranges. For heavy-duty vehicles with longer trip ranges, such as buses, trucks and other commercial vehicles, FCEVs are likely to become cost competitive in the coming years. Various hydrogen-powered vehicles have been developed and demonstrated under projects supported by the Government of India. These include 6 Cell buses by Tata Motors Ltd., 50 hydrogen-enriched CNG (H-CNG) buses in Delhi by Indian Oil Corporation Ltd. in collaboration with Govt. of NCT of Delhi, 2 hydrogen-fuelled Internal Combustion Engine buses (by IIT Delhi in collaboration with Mahindra & Mahindra).

* + 1. **Indian Oil Company Initiatives towards Green Hydrogen**

The government-led public sector undertaking (PSU), Indian Oil, is at the forefront of the green hydrogen revolution. It is planning to set up India’s first green hydrogen unit for the Mathura refinery, which will be used to process crude oil. Moreover, it plans to utilize low-cost wind power from Rajasthan (wheeling it to Mathura in Uttar Pradesh) to power this green hydrogen plant. The organization has also been conducting a pilot using hythane (H-CNG), a blend of compressed natural gas (CNG) and hydrogen. The pilot involved retrofitting 50 CNG buses to test the feasibility of the H-CNG-powered vehicles and their impact on emissions and fuel economy.

* + 1. **Green Hydrogen Initiatives by National Thermal Power Corporation**

Another government-run PSU, NTPC, has recently set up a tender to establish a first-of- its-kind hydrogen refuelling station to be powered entirely by renewables in Leh through a stand-alone 1.25 MW solar system.

* + 1. **GAIL to set up green hydrogen plant at Guna in MP**

The project has been designed to produce around 4.3 metric tonnes of hydrogen per day (approximately 10 MW capacities) with a purity of about 99.999 per cent. It is scheduled to be commissioned by November 2023.

* + 1. **National Thermal Power Corporation (NTPC) in association with Gujarat Gas**

Indian government-owned National Thermal Power Corporation (NTPC) in association with Gujarat Gas is also planning an ambitious project to blend hydrogen with piped natural gas (PNG). To begin with, NTPC aims to reach out to its 200-home housing colony at Kawas near Surat by using about 100 cm/d of PNG where it will initially blend hydrogen to the extent of 5% for domestic use, to be later ramped up to 20%.

The residential township project will be the first of its kind in the country where they plan to blend green hydrogen in the city gas distribution (CGD) network. Once this is successful, planning is to roll it out in various cities and towns in India.

* + 1. **Green Hydrogen Initiatives by Others**

Some of the prominent industrial mammoths such as Reliance Industries Limited (RIL), Gas Authority of India Limited (GAIL), National Thermal Power Corporation (NTPC), Indian Oil Corporation (IOC) and Larsen and Toubro (L&T) plan to foray into the green hydrogen space. RIL plans to become a net-carbon-zero firm by 2035 and invest nearly INR 750 billion over the next three years in RE.

India has declared its ambition to become an exporter of hydrogen to Japan, South Korea, and Europe.

1. **Conclusions**

In conclusion, it can be said that India may emerge as a powerful nation in the energy sector. India may be a leader in Green Hydrogen Technology across the globe. The reason behind this is that the technological cost of setting up renewable electricity is less in India in comparison to other developed countries. India has already shown its potential in the installation of solar and wind power technology across the country. Hence, in the future India will not only become self-dependent in the energy sector, instead, it will be on the front line in exporting energy to other countries, especially green hydrogen and green ammonia.

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### [All you need to know about India's first hydrogen-powered fuel](All you need to know about India's first hydrogen-powered fuel https://m.economictimes.com › Industry › Renewables (accessed on December 22, 2022).)

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