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Greening India: A Case Study On Reliance Jamnagar Green Hydrogen Initiative

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It is aimed at aggregating and helping co-create knowledge and information on environmentally responsive behaviours and concurrently pursuing result-oriented social media campaigns to encourage people and specifically the youth, to take proactive actions in promoting sustainable lifestyle and creating a positive impact on the environmental ecosystem in their surroundings

By: _VO**IS Planet**

Executive Summary

The worldwide energy system is standing at the threshold of new era of abundance that could bring about transformation in energy economics. This owes to the rapid decline in RE costs and technological advances which could make hydrogen a superior choice for transporting cost-effective and clean energy round the globe. Also the COVID-19 pandemic has brought acceleration in the trends towards net-zero and decarbonization by bringing down the hydrocarbons demand to a substantial level (19). Green hydrogen is becoming a major focus of international climate agenda. Owing to the fact that even the collective efforts of the Nationally Determined Contributions are falling short in contributing to the necessary reductions in omitting GHG emissions to limit global warming at or below 2°C by the end of this century (15). Many initiatives are being taken from the government as well as from the private sectors towards green economy for mitigating climate change. One such initiative is RIL's efforts to combat climate change. At the International Climate summit, Reliance announced the development of Dhirubhai Ambani green energy complex on the land of Jamnagar, which will be one amongst the largest RE manufacturing facilities around the world.Reliance's Management System has set up company-wide safety management objectives and processes for the improvement of operational discipline and evolving inherent safety measures for plant operation (8).

Table of Contents

Introduction

India is one amongst the world's worst polluted nations. Home to 22 of the world's 30 most polluted cities, India's toxic air is responsible for killing more than one million people annually (1).Rising urbanization, booming industrialization and many associated anthropogenic activities are the major factors leading to air pollution. Around 80% of the urban population is exposed to emissions that exceed the standard limit set by the World Health Organization (2,3). According to a report published by Health Effects Institute in 2019, particulate matter (PM) pollution was considered among the top three causes of death in 2017 and the rate was recorded highest in India (4). The continuous population growth is adding a lead to an extreme strain on the energy consumption thus affecting the atmosphere and air quality (5, 6).

The fact that fossil fuels need to become a thing of the past as they do not provide a sustainable solution to our energy needs, green energy looks set to be a part of the future of the world, offering a cleaner alternative to many of today's energy sources. These energy sources can readily be replenished, and are not only good for the environment, but are also leading to job opportunities and look set to become economically viable as developments continue (7).

Last year till April 23, 44 nations and the EU had announced net-zero commitment (8), assuring the reduction of their GHG emissions to zero or offset the residues that is hard to completely eliminate (8).

The politics on reducing emissions will carry on but the technological and financial challenge is to reduce the global industrial emission without deindustrializing fast growing and emerging economies. Around 25 per cent of GHG emissions worldwide in 2019 resulted from industrial emissions (8). Moreover, even the rapid industrial growth in the RE sector, could not bring down the net share of conventional fuels in the final energy utilization around the globe since it remains as high as it was a decade ago (9). Generally heavy industrial sectors (likely cement, steel, etc,) in addition to heavy-duty transport (shipping, aviation and road transport) which can be categorized under 'hard-to-abate' sectors are major contributors of India GHGs. Considering India as a developing country, there will be a continuous growth in industries in the near few decades. It is clearly imperative to decarbonize the power sector, but liquid fuels are clearly not easy to replace, particularly in the transport sector, or as an alternative for high-intensity heat in heavy industrial processes.

Hydrogen could probably play an essential role, necessarily if we are to make a transition in green energy in a way to achieve Paris Agreement goals. As an alternative for coal, be it in a blast furnace or as a source of energy in a fuel cell for powering a truck, hydrogen has remained to be one amongst the Holy Grails in energy revolution. Earlier attempts for the commercialization of hydrogen at industrial scale could not see much success. Additionally, hydrogen production is extremely energy-intensive which relies on burning considerable amount of coal or natural gas, ending up in more GHGs emissions (9).

With the adverse effects of pollution and climate change becoming more obvious, "Sustainability" has become the key component not only in government schemes and projects but also in the corporate sector thus proving that global enterprises are responsible, accountable and capable to act on the climate crisis. Many leading private players have engaged themselves in green initiatives that will not only help mitigate the adverse effects on the environment but are also profitable.

Reliance Industries Limited is one such global business that acknowledges the fact that investment in sustainability is a win for all. Change Agents for Safety, Health and Workplace Environment (CASHe), a project introduced by RIL was implemented with the aim of creating a culture of safety, health and environment (10). In addition Reliance is also committed to ensure environmentally sustainable and responsible operations so as to achieve the highest standards of excellence (10). The manufacturing divisions in Reliance have installed internationally accepted Environmental Management System relied on ISO-14001, and their operational sites are also integrated with Quality Management and Occupational Health & Safety Management Systems.

Green Hydrogen: An overview

The demand for hydrogen rose steadily from less than 19.3 million tonnes (MT) in 1975 to about 53.5 MT in 2000. After a stable period of a few years, the demand again lifted up to 73.4 MT in 2018 (IEA 2019). The global aim to reach a net-zero emission by 2050 also adds on to the significance of hydrogen in the energy mix.

Hydrogen that is solely produced from renewable energy resources is referred to as 'green hydrogen'. Green hydrogen is produced by the process of electrolysis that uses renewable energy and water. The process of electrolysis makes use of splitting water into oxygen and hydrogen. Green hydrogen possess vast and ever growing spectrum of applications. Diverse industries be it the chemicals or the steel industry can use green hydrogen as feedstock. It can also be used in fuel cells that can further be utilized across a broad range of stationary and transport applications.

Hydrogen is gaining demand as a potential energy source and has often been touted as future fuel. It possess the potential to emerges as a clean substitute to conventional fuels, especially if it is produced from renewable resources. A novel, green way of producing hydrogen might bring down the rate of global warming – causing GHG emissions and could provide nations a new direction to achieve their climate goals.

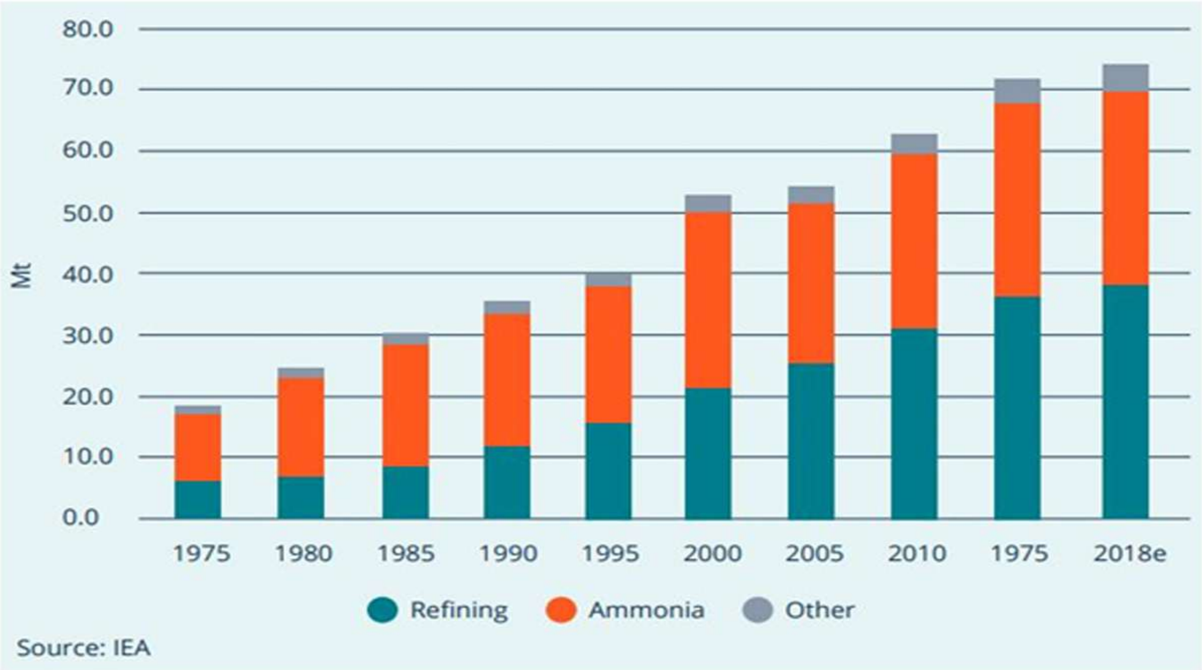

Fig: 1 Global demand for pure hydrogen (Source: ceew-study-on-a-global-green-hydrogen-alliance-for-clean-energy)

In India, the central government as well as many states has started initiatives in support of production and use of green hydrogen.

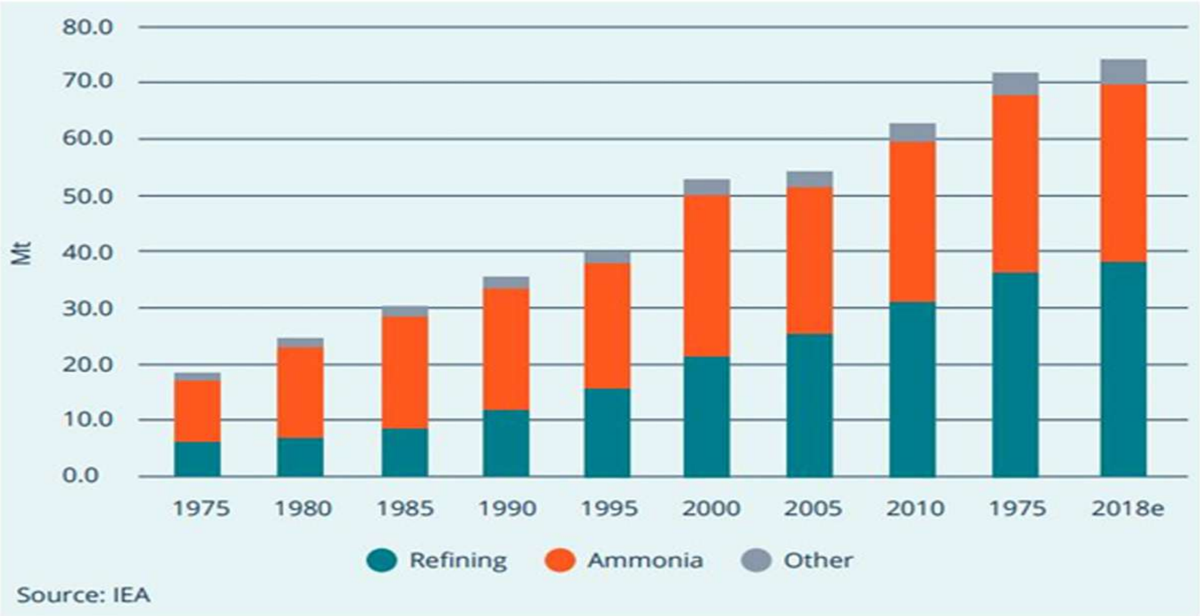

Fig: 2 Hydrogen use by region (Source: ceew-study-on-a-global-green-hydrogen-alliance-for-clean-energy)

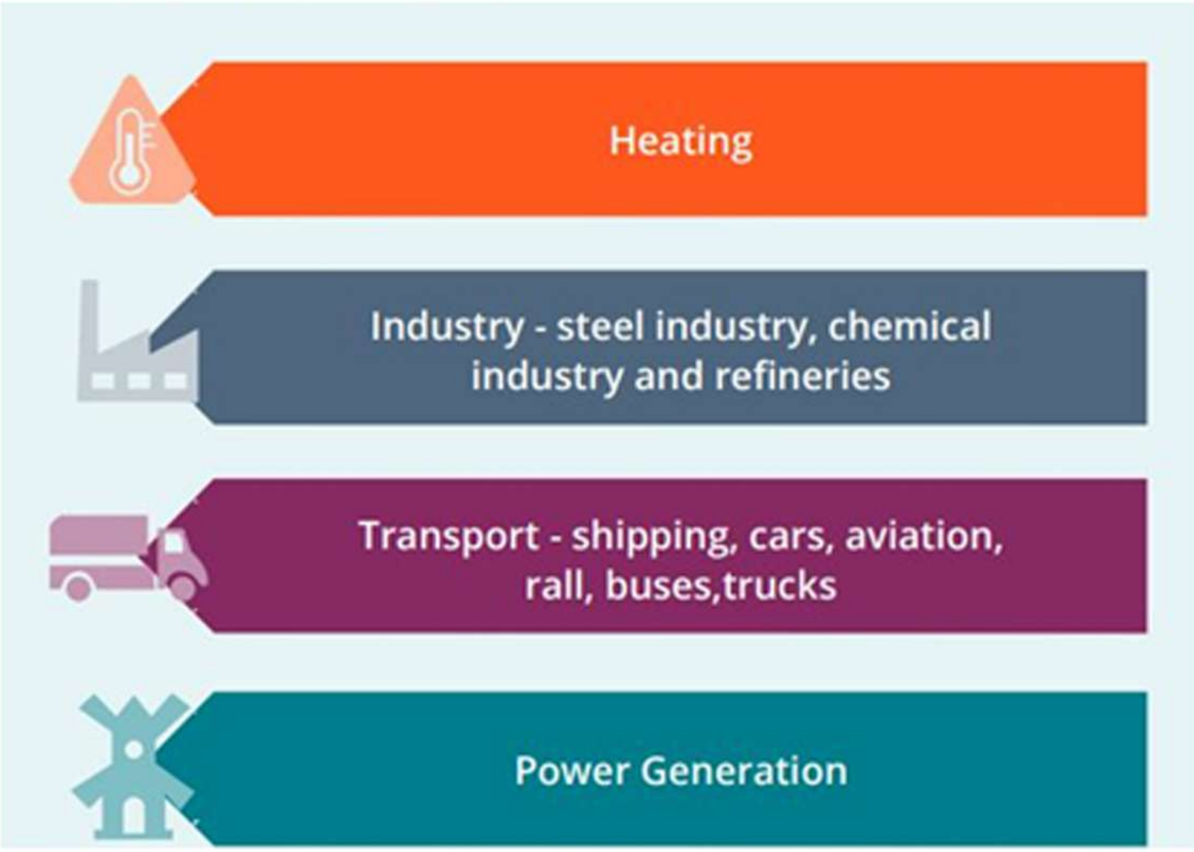

Fig: 3 Green hydrogen: end uses across the energy system (Source: ceew-study-on-a-global-green-hydrogen-alliance-for-clean-energy)

Reliance Industries Limited

RIL, one of the most prominent business organizations is headquartered in Mumbai, India. Having entities across domains like vitalities, retail, broadcast communications and petrochemicals, the organization was positioned 106th on the Fortune Global 500 rundown as the world's largest enterprises in the year 2019. Reliance Industries turned out to be the world's first Indian company to cross $100 billion market capitalization on October 18, 2007 (11).

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Fig : 4 Journey of RIL (Source: Startup Talky)

RIL is continuously contributing to national economy through its vision and commitments and holds belief that a joint contribution of the government and the industrial sector could create a world-class infrastructure which has now become a pre-requisite to achieve leadership in the global market.

In 2021, RIL has launched their new energy business with the aim of bridging the green energy divide in India and globally. RIL have established the Reliance New Energy Council with some of the finest minds globally which could help the industry validate their strategies and embrace disruptive pathways to achieve their goals. RIL is creating a coalition of partnership with leading global universities, best technology companies and the most promising startups in USA, Asia, Australia and Europe. In addition, the company is leveraging its existing strength and capabilities in digitization & platforms and large scale manufacturing. RIL is alreadyin motion for developing the Dhirubhai Ambani Green Energy Giga Complex on 5,000 acres land in Jamnagar. The complex is amongst the largest such integrated RE manufacturing facilities in the world.

The first section of the proposed plan is to build four giga factories, which will manufacture and wholly integrate all the critical components of the new energy ecosystem.

One, for the production of solar energy, there are plans on work for building Integrated Solar photovoltaic module factory.

Two, for the storage of intermittent energy, they will build an advance energy storage battery factory.

Three, for the production of green hydrogen, they will build an electrolyzer factory.

Four, for converting hydrogen into mobile and stationary power there will be a fuel cell factory.

Over the next three years, RIL is going to invest over 60,000 crores in the above initiatives.Hence Reliance will create an offer of a completely integrated end to end RE ecosystem. RIL will invest an additional Rs 15000 crores in value chain partnership and future technologies including upstream and downstream industries. Thus, their overall industrial investment from their own internal resources in the new energy business will be Rs 75,000 crores in the next three years.

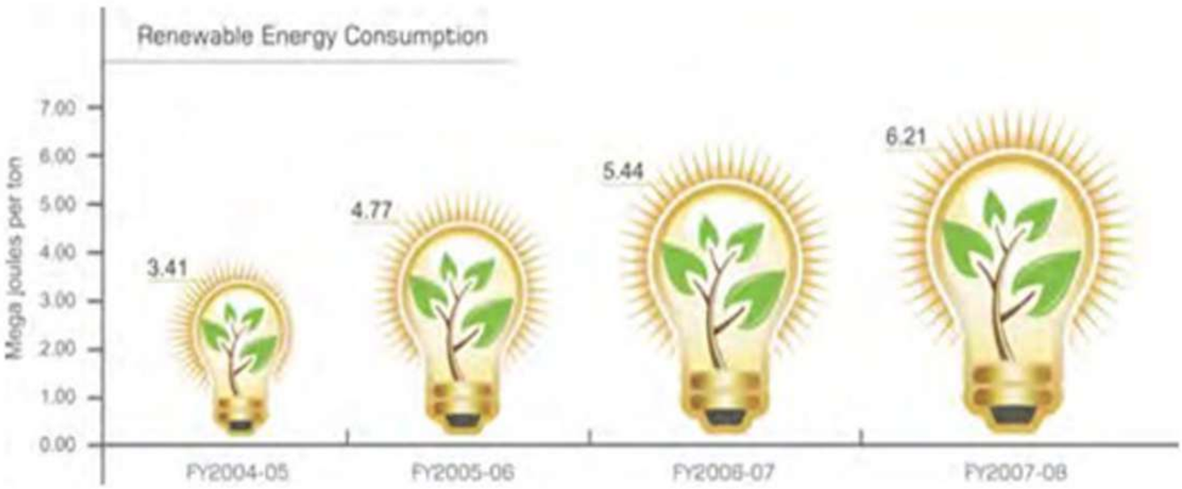

Fig: 5 (Source: RIL_SR2007_08)

RIL envisions a future where India will be transformed from a large importer of fossil energy to a large exporter of clean energy solution.

The Jamnagar refinery

Fig : 6 Jamnagar Plant (Source: RIL_SR2007_08.)

Location

Situated along the state highway, 35 kms from the Jamnagar district in Village Motikhavdi, is where "Reliance Greens" is spread into 750 acres Located along the coast of Arabian sea, the city of

Jamnagar

has become a money-operating system for Asia's richest man, Mukesh Ambani, processing crude oil.

RIL had already set up a petroleum refinery and petrochemical complex that is operational since 1999. The complex has the environmental clearance from the Ministry of Environment and Forest (MoEF) for the modernization and expansion of refinery capacity to around 60 MTPA, crude processing in the year 2005. This Jamnagar complex refinery was the first and the largest manufacturing complex of its kind that had a petroleum refinery, petrochemical complex along with a captive power plant and captive port (12). The Jamnagar refinery was set up with the purpose to fulfill the energy demand of Reliance's crude oil refinery (13). The refining capacity of the complex was over 33 MT annually and paraxyelene production was around 1.5 MT annually (12). Jamnagar holds the position of world's largest grassroots refinery and aromatic complex (12).

Jamnagar has been the "cradle of their old energy business" and now Jamnagar is going to be the "cradle for their new energy business".

RIL is recasting its gasification project into a completely- owned subsidiary as a step towards its plans of growth in hydrogen space. The refinery off-gases obtained from the project were earlier used as fuel which has now been repurposed as feedstock for refinery off-gas cracker (ROGC) (13). This step will enable the production of olefins at a combative capital and operating cost. Syngas as a fuel not only ensures reliability of supply but also contributes to the reduction of volatility in the cost of energy.

Fig: 7 (Source: RIL_SR2007_08)

Analysis of critical parameters at Jamnagar refinery

Air monitoring

The ambient air quality monitoring of the refinery showed the following analysis: AAQM was done on 24 hours average basis following the guidelines issued by CPCB and NAAQS. The conventional and the parameters specific to the project such as SPM, RSPM, SO2, oxides of Nitrogen, ammonia, CO, and NMHC were considered for monitoring at the AAQM location.

Specific parameters	Arithmetic Mean (in µg/m3)
SPM	87- 256
RSPM	6-114
SO_2	4.5-22
NO_x	6-20.33
Ammonia	10-192
CO and NMHC	263-1139

Table 1: The SPM and RSPM concentrations were noted to be exceeding the stipulated standards at majority of the ambient air quality monitoring locations.

Noise monitoring

The noise level ranges between 30-70 dBA during the day and around 38-60 dBA during the night hours.

Noise levels were also monitored at other major places like schools, hospitals and temples. The noise levels at these places varied from 47-55 dBA during daytime and 38-53 dBA during nighttime (14). The noise levels monitored for the respective places were seen to be within the stipulated standards of CPCB with the few places in exception (14).

Water Monitoring

- **Surface Water**

In order to calculate the groundwater and surface water quality, surface water sampling was done in triplets and groundwater sampling was done at 18 locations (14).

Parameters	Range
pH	8.6 – 8.8
Turbidity	7-12 NTU
Total dissolved solids (inorganic)	393-510 mg/l
Hardness	206-313 mg/l
Chloride	112-128 mg/l
Sulphates	25-32 mg/l

Table 2:

- **Ground Water**

The ground water quality had high mineral content present in the following forms and range.

Parameters	Range
Total dissolved solids	477-3024
Total hardness	259-1592
Chloride	123-1200
Sulphate	42-328
Sodium	36-500

Table 3: The groundwater from four villages namely Gagwa, Kanachikari, Nanikhavdi and Mungni was observed being faecally contaminated hence unfit for human consumption, unless properly treated.

- **Land Monitoring**

It was seen that soil texture varied from clay to sandy clay the land use/ land cover classification was based on remote sensing analysis. It indicated 6.65% sandflats, 0.68% fringe vegetation, 26.09% agricultural land, 24.19 uncultivated land, 2.65% seawater, 3.07% industrial land and 32.23% wasteland (14).

The Production Process

The production of blue hydrogen as planned by the Reliance industries will be about $1.2 - $1.5 per kg. The plant will initially make use of syngas produced by pet coke gasifies, for the production of blue hydrogen1 in Jamnagar Complex at Western Gujarat State. This set up will be under action until green hydrogen becomes cost-effective.

With this, RIL will be the first business in the market to establish a hydrogen ecosystem with the least incremental investment. The substitution of hydrogen from syngas by green hydrogen, will the entire syngas to be converted into chemicals (16, 17).

The production of hydrogen from the gasification process provides a high concentrated CO2 streamline which is a unique way to capture 15 MT of CO2 annually at a mere 30 per cent conventional cost of carbon-capture.

Green hydrogen possesses a high gravimetric energy density and it could be reconverted into heat and electricity with net-zero emissions.

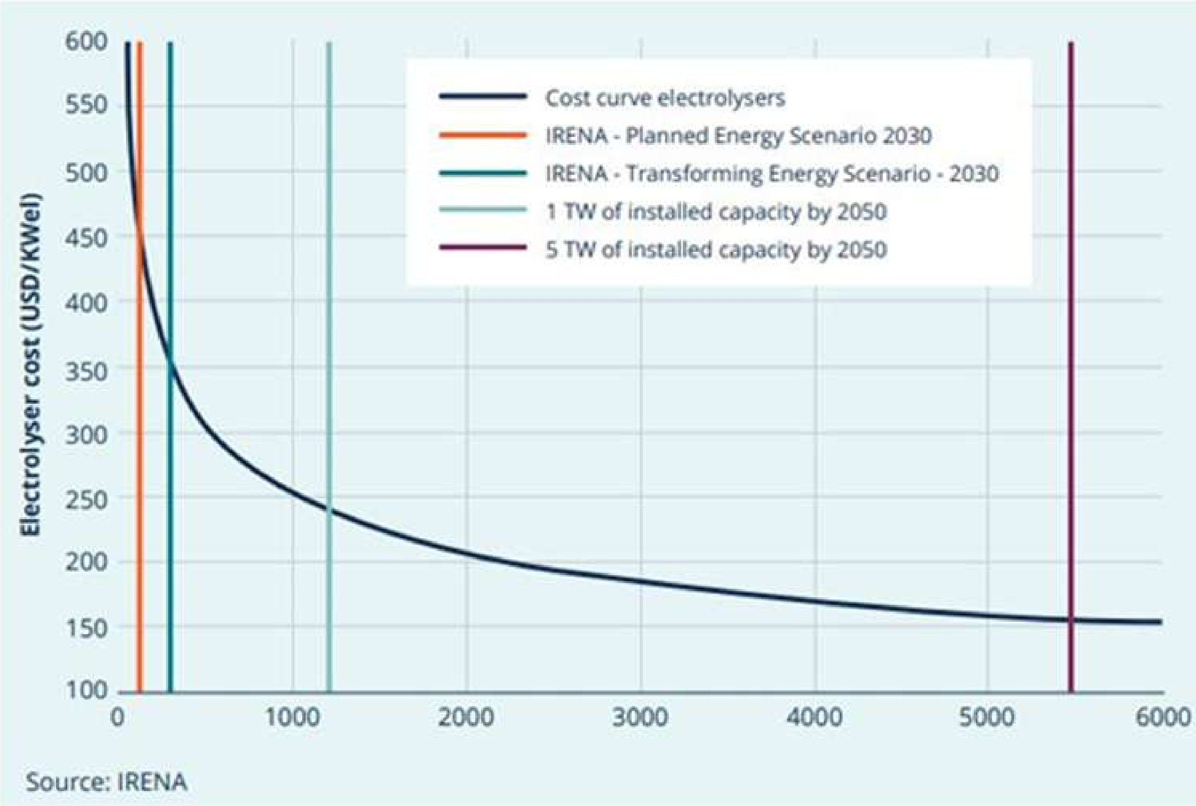

Fig: 8 Relationship between cost of electrolyzers and deployment of electrolyzers (Source: ceew-study-on-a-global-green-hydrogen-alliance-for-clean-energy)

For the hydrogen production in Jamnagar Refinery it was analyzed that electrolyzers accounted for about 45-47 per cent of the average cost of hydrogen in the year 2020. With a decline in technology cost, this share is estimated to go down to about 35 per cent by 2040, whereas the total cost is anticipated to decline from USD 3.6/kg in 2020 to USD 1.7/kg in 2040 (15).

Green hydrogen that is being produced from RE at present costs somewhere around $3-$6.5 per kg whereas the fossils fuels rate goes around $1.80 per kg. if we consider this rate in Indian currency, the rate for green hydrogen in present scenario comes around Rs 500 per kg (20).

1 Blue Hydrogen is produced from natural gas and it eliminates emissions by capturing and storing the emitted carbon.

The working technology of the refinery

Green hydrogen in the Jamnagar refinery will be formed by using RE to power electrolysis, where water is splitted into its constituent elements: hydrogen and oxygen. Electrolyzers are electrochemical devices which draw electrical power & water and make use of electrolytes & membranes to split hydrogen molecules (produced at the cathode) and oxygen molecules (produced at the anode).

The general principle on which the electrolyzers work have remained the same over the years. Commonly, there are four major technologies that differentiate each other over electrolytes and operational temperature, further leading to different materials and components used.

Water electrolyzers possess components at three basic levels:

1. The cell, comprises of two electrodes, the cathode and the anode that are emerged in liquid electrolytes or close to a solid electrolyte membrane, two porous transport layers and bipolar plates providing mechanical support and help into flow distribution.
2. The stack, including a number of cells that are connected in series with spacers, seals, frames and end plates.
3. The system level, has equipments for cooling, processing of hydrogen, conversion of electricity input and treating the water supply and gas output (9, 18).

The above system will be fed by purified water by using circular pumps or gravity. Next to this, the water reaches the electrodes where the water is splitted into hydrogen and oxygen ions that cross through an electrolyte. Moreover, the membrane present plays a very important role by maintaining the separation between the produced hydrogen gas and the oxygen (9).

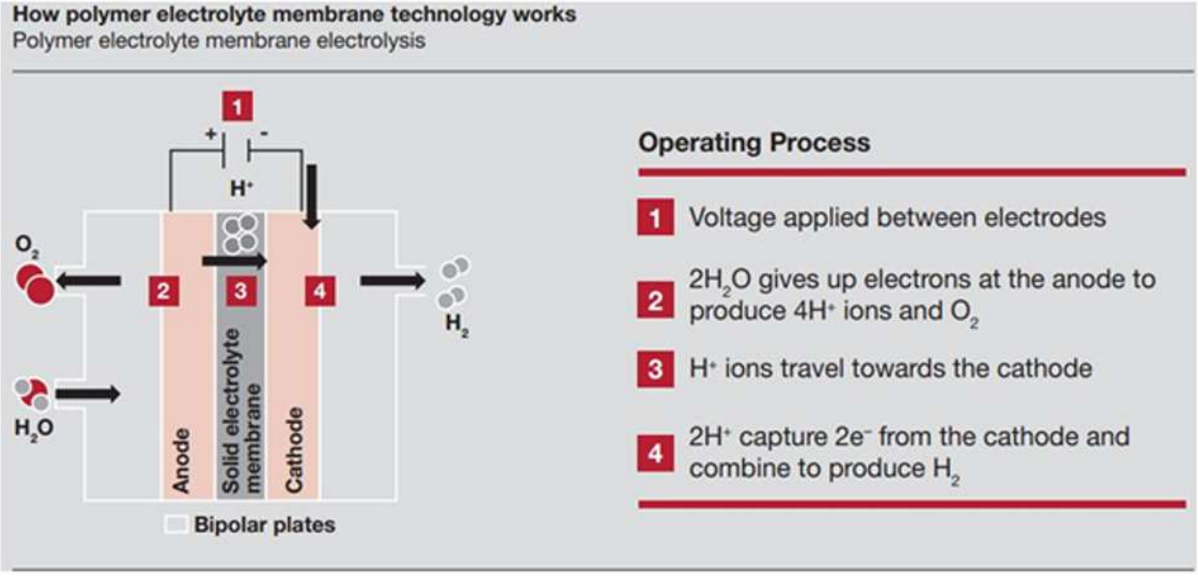

Fig: 9 Source: the-dawn-of-green-hydrogen

Production of hydrogen from the electrolyzer takes place at a pressure of 30 bar. The system is linked to a hydrogen line which is further connected to a storage system. The produced hydrogen is compressed using a compressor that works on an AC. It is then stored at a pressure of 100 bar in the storage tank (15). The green hydrogen thus formed by this process can be stored for a long period of time and can be transported over considerable distances.

The Marginal Production Cost

Currently, green hydrogen is more costly when compared to the other process. There are numerous factors like the investment cost of electrolyzers and the capacity utilization factors of electrolyzers that determine the cost of green hydrogen (15).

The cost of electricity generated from RE for carrying out the process of electrolysis is one amongst the major factors putting up the cost of green hydrogen. The above factors together set a value on the cost of green hydrogen that at present lies between USD 3-7.5 per kg (16).

The cost of electrolyzers followed by the cost of wind and solar power occupy the highest share in the complete production cost.

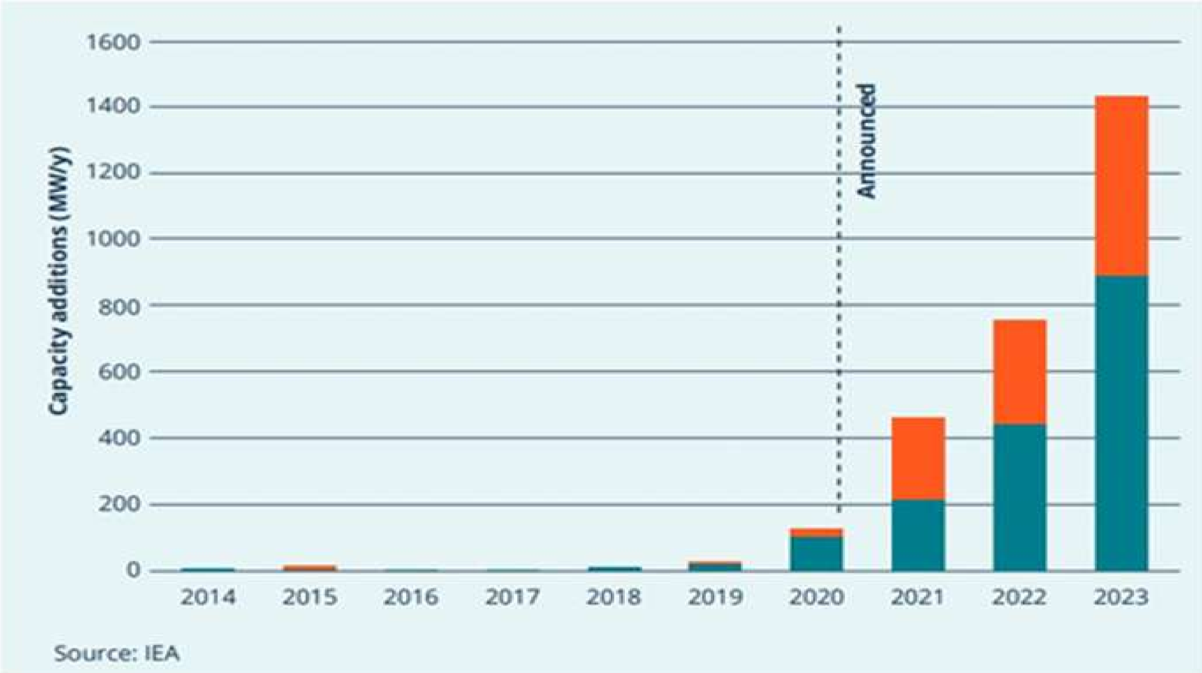

Fig: 10 Global electrolysis capacity becoming operational annually (Source: ceew-study-on-a-global-green-hydrogen-alliance-for-clean-energy)

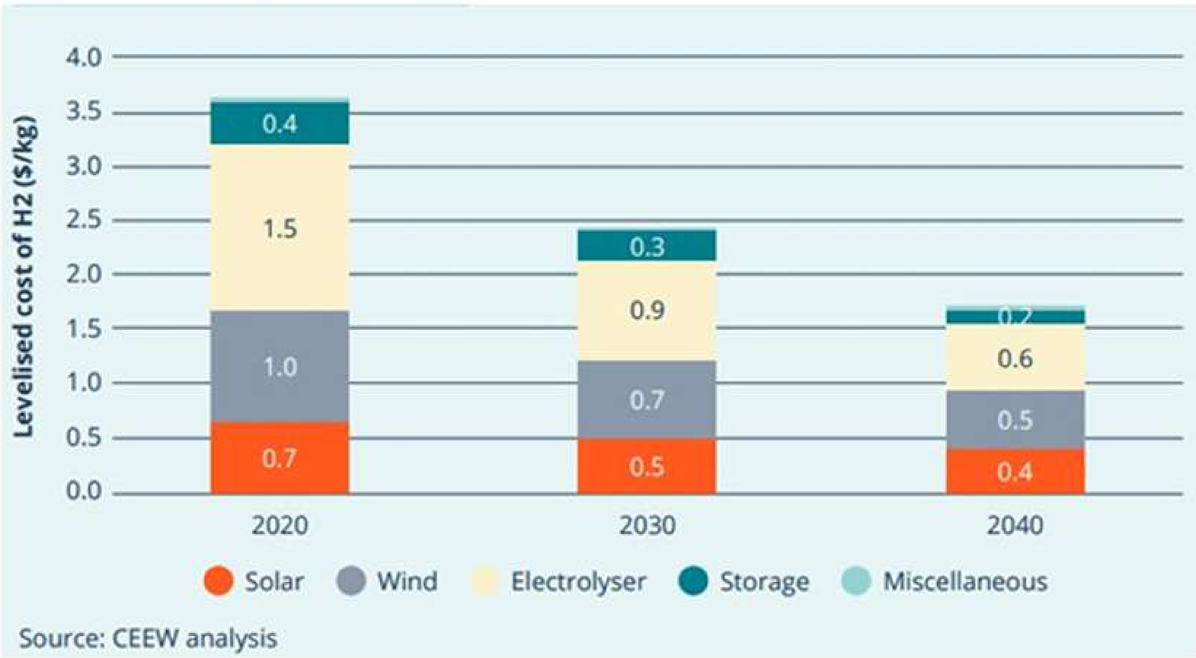

Fig:11 Production cost trend for Jamnagar (Source: ceew-study-on-a-global-green-hydrogen-alliance-for-clean-energy.)

At present, Alkaline and Proton Exchange Membrane (PEM) are being used commercially, and during the last two years, more electrolyzer technologies have been introduced on indutrial level such as AEM and SOE (9).

Estimated hydrogen production cost in future

RIL's objective is to produce green hydrogen at $1per kg by the end of this decade. The cost estimated for Jamnagar refinery complex includes a blend of solar and wind electricity. At the present scenario of RE and electrolyzer technology, the market value of green hydrogen is expected to be 3.5–4.5 USD/kg. However, the costs may slide down to o 2.5–3 USD/kg in 2030 which might see a further decline to 2 USD/kg in 2040 (15).

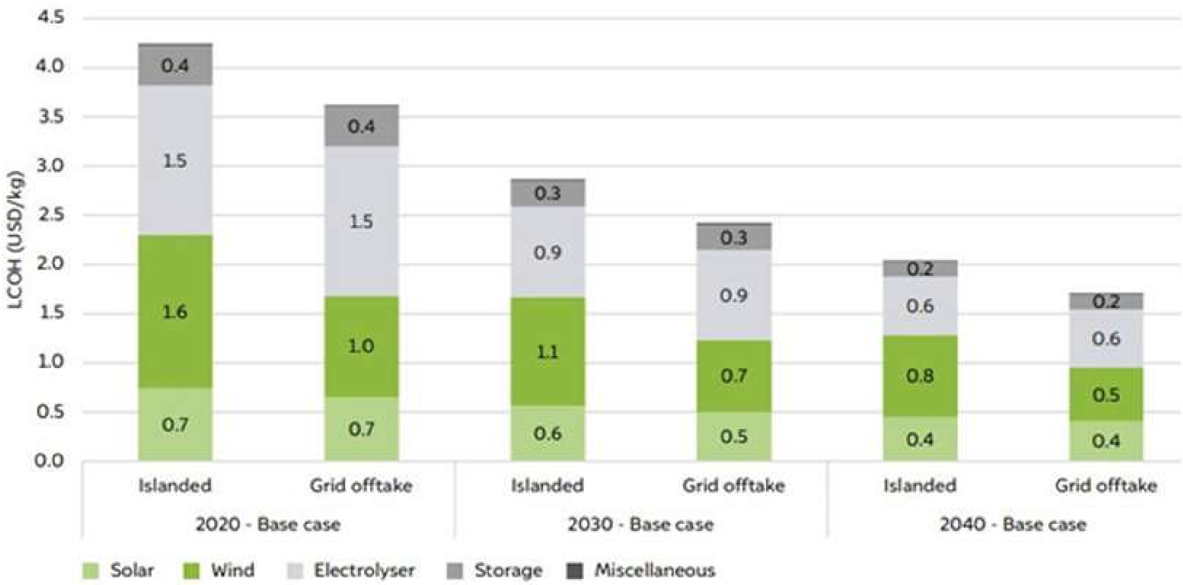

Fig: 10 Global electrolysis capacity becoming operational annually (Source: ceew-study-on-a-global-green-hydrogen-alliance-for-clean-energy)

Fig: 12 Variation in hydrogen production cost in Jamnagar (Source: ceew-study-on-a-global-green-hydrogen-alliance-for-clean-energy.)

Partners and collaborations

RIL's renewable energy arm has partnered with Denmark's Stiesdal for the production of hydrogen electrolyzers in India. Under this agreement, Reliance New Energy Solar Ltd. (RNESL) and Denmark based Stiesdal are collaborating to combine their specific strengths for the advancement of the technology development of hydrogen electrolyzers. Stiesdal, a Danish company is engaged in producing and advertizing technologies on mitigating climate change.

This latest technology for Hydrogen Electrolyzers possess the potential to manufacture cost –effective technologies thus paving the way for a rapid decarbonization process and commercialization of low cost Green Hydrogen- a major enabler in attaining India's green energy transition (17).

Sl. No.	Partnership	Description
1.	Portugal - Netherlands	A memo of understanding was signed between the two countries on green hydrogen exports from Sines electrolyser project in Portugal to Netherlands
2.	Germany - Morocco	A partnership agreement was signed between the countries which aims to develop production of green hydrogen and develop projects and research related to it
3.	Australia Germany	This is a research project which aims to study the potential for imports to Germany
4.	Germany USA	The partnership aims technical knowledge sharing (electrolysis research)
5.	Germany - France	France is planning to collaborate with Germany in the development of clean hydrogen technologies as a part of the Europe's green recovery plan.
6.	Japan - Australia	Japan got into a joint venture with Australia for development and demonstration of a liquified hydrogen supply chain
7.	New Zealand - Japan	A memo was signed between the countries to carry out green hydrogen pilot project
8.	Japan - Brunei	Japan's AHEAD launched its pilot project to bring hydrogen from Brunei to TokyoBay with the aim to use it as a fuel for power generation
9.	Japan - Norway	The main objective of this partnership is to show that liquid hydrogen can be produced using renewables in Norway and can be delivered to Japan on tankers. Under this partnership, Kawasaki Heavy Industries (KHI) has teamed up with Nel Hydrogen with backers including Mitsubishi Corp and Norway's Statoil. Nel aims
10.	United States - The Netherlands	This partnership aims to address the key hydrogen R&D areas and foster new hydrogen value chains worldwide
11.	Europe -North Africa	This regional partnership aims to speed up the deployment of green hydrogen projects and value chains
12.	Europe - Middle East	This regional partnership aims to speed up the deployment of green hydrogen projects and value chains

13.	Russia - Germany	The two countries are already working on hydrogen development for the energy sector. They expect the Nord Stream II pipeline to bring in Russian gas to Germany and will act as a future hydrogen import route

Fig: 13 Bilateral partnership on hydrogen (Source: ceew-study-on-a-global-green-hydrogen-alliance-for-clean-energy)

Challenges

Sl. No.	Country Name	Hydrogen Price	Electrolysis capacity Additions	Hydrogen Production	Infrastru-cture	Industrial Applications
1.	Australia	AUD 2 per KG and below				
2.	Chile	less than USD1.5 per kg	5 GW electrolysis capacity by 2025 & 25 GW target by 2030	0.2 MtH2/ year by 2025		
3.	European Union		6 GW of electro-lyser capacity by 2024 and 40 GW by 2030	1 million & 10 million tonnes of renewable hydrogen/ year for 2024 & 2030 respectively		
4.	Germany		5GW of electro-lyser capacity by 2030 & 10 GW by 2035-40	14 TWh of green hydrogen production by 2030-35	**Refueling station**: 400 by 2025	80 TWh of green hydrogen demand expected from steel production by 2050 and 22 TWh from German refinery and ammonia production
5.	European Union		6 GW of electro-lyser capacity by 2024 and 40 GW by 2030	1 million & 10 million tonnes of renewable hydrogen/ year for 2024 & 2030 respectively	**Refueling station:** 160 by 2020 & 320 by 2025	**FC Bus:** 1200 by 2030 **FC forklifts:** 10,0 00 by 2030 **FC Cars:** 800,000 by2030
6.	The Netherlands		500 MW of installed electrolyser capacity by 2025 & 3-4 GW by 2030		**Refueling station:** 50 by 2025	**FC Bus:** 300 by 2025 **FC Trucks:** 3500 by 2025 **FC Cars:** 300,000 by 2030

7.	Portugal		2-2.5 GW of electrolyser capacity by 2030			**Blending:** 2 per cent to5 percent blending in industries
8.	Republic of Korea				**Refueling station:** 1200 by 2040	**FC Bus:** 40,000 by 2040 **FC Trucks:** 30,000 by 2040 **FC Cars:** 2.900,000 by 2040
9.	India	Goal-oriented research & development		Creating volumes and infrastructure	**Refueling station:** 2 (current status) Framework for standards and regulation for hydrogen technologies	**FC Bus:** 10 (current status) Aims to demonstrate niche applications (including for transport, industry)
10.	China				**Refueling station:** 35 (current status)	**FC Cars:** 10,000 by 2020

2Grey hydrogen is produced from methane or coal by the process of SMR or gasification without capturing the GHGs produced in its process

Way Forward

The urge of reaching net-zero emissions is a scientific reality. The growth in net-zero target demands that political as well as the business leaders knows this to be true. Last year in 2021, as soon as India announced an ambition of establishing a National Hydrogen Energy Mission, a number of conglomerates (including Reliance, Adani, Deloitte, and others) forged another alliance. Moreover, one more platform proposed in August 2021, The Global Green Hydrogen Council (GGHC) is for the promotion of sustainable production and utilization of green hydrogen. GGHC is funded through corporate membership and government grants and is promoted by Australia-based Fortescue Future Industry (15).

RIL has presented a roadmap on their new RE business which could turn out to be a next level value creation engine not only for the company itself but also for India.

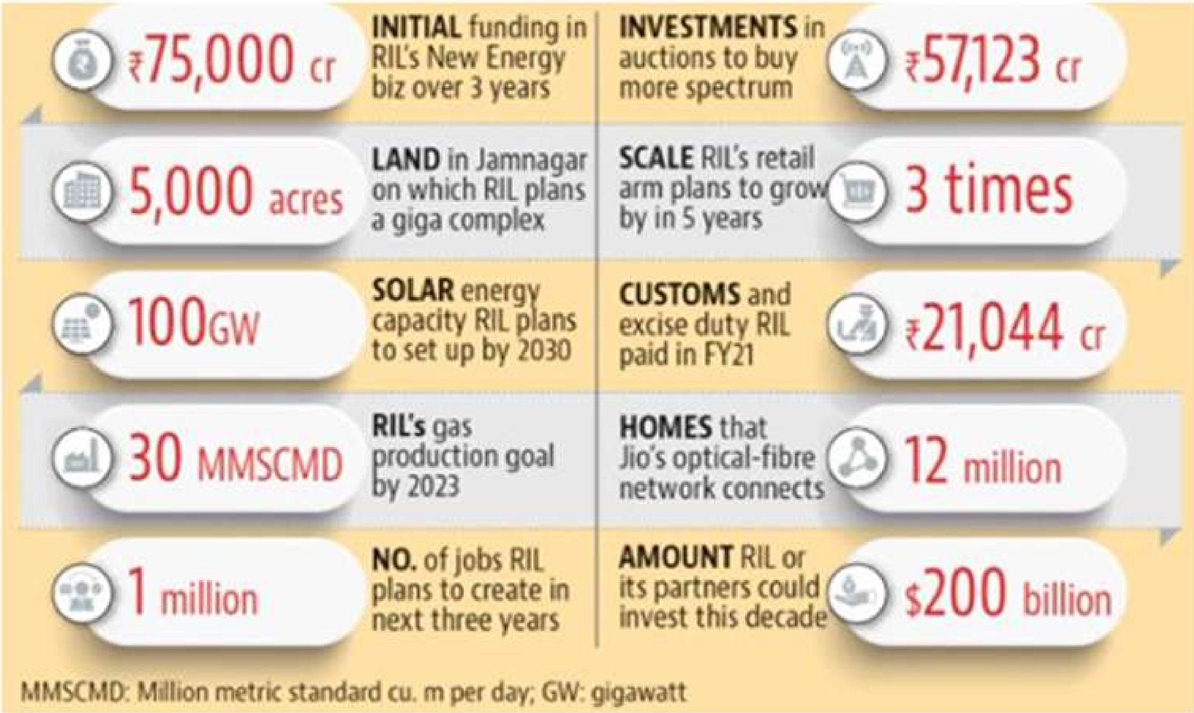

Fig: 15 (Source: RIL)

As the company is involved in energy and material value chain, their solo aim is to make responsible use of energy. Their systems and processing units establish optimum energy usage by regular surveillance of all forms of energy and enhancing the productivity of all operations. But the world requires more collaborative actions.

India could make its energy-intensive sectors particularly the industries and transportation sectors a less dependent on carbon-based fuels by using green hydrogen. A hydrogen economy will also improve the air quality, help mitigating carbon emissions and contribute to Atmanirbhar Bharat Vision.

Abbreviations

PM: Particulate Matter
EU: European Union
GHGs: Greenhouse gases
RE: Renewable Energy
RIL: Reliance Industries Limited
MoEF: Ministry of Environment and Forest
MTPA: Million tons per annum
ROGC: Refinery off-gas Cracker
AAQM: Air ambient quality monitoring
AC: Alternating current
GGHC: Global Green Hydrogen Council
SMR: Steam Methane Reforming
RNESL: Reliance New Energy Solar Ltd.
AEM: Alkaline Exchange Membrane
SOE: Solid Oxide Electrolyzer Cell
PEM: Proton Exchange Membrane

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