Green Hydrogen – India Perspective

Presented at

Savitribai Phule Pune University

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Overview of the Presentation

- Why Green Hydrogen
- Global Experience and Trends
- Existing Policy and Regulatory Framework
- Research and Development
- Hydrogen Strategies of different Countries

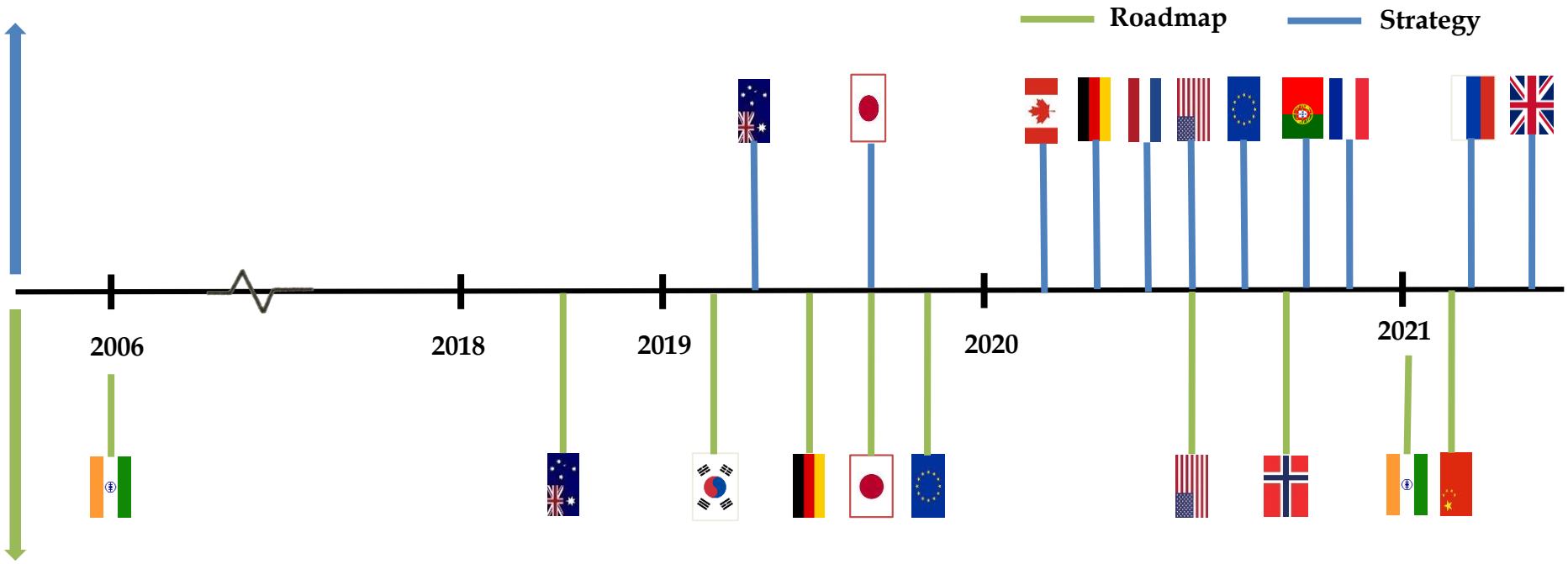
Why Green Hydrogen

- Decarbonising the planet is one of the goals that countries around the world have set for 2050.
- To achieve this, decarbonising the production of an element like hydrogen, giving rise to green hydrogen, is one of the keys as this is currently responsible for more than 2 % of total global CO2 emissions.
- Most experts agree that green hydrogen will be essential to meeting the goals of the Paris Agreement, since there are certain portions of the economy whose emissions are difficult to eliminate.
- 100 % sustainable: green hydrogen does not emit polluting gases either during combustion or during production.
- Storable: hydrogen is easy to store, which allows it to be used subsequently for other purposes and at times other than immediately after its production.

Global Experience and Trends

- Countries and their Progress on Hydrogen
- Country Wise Focus Areas and their Targets
- World's Largest Green Hydrogen Projects

Timelines of Strategy / Roadmap Issuance



Note: In India National Hydrogen Energy Board (NHEB) was established in 2003 and National Hydrogen Energy Roadmap (NHERM) was approved in 2006. National Hydrogen Energy Mission was launched in 2021

Country Wise Focus Areas

Countries	Transportation	Industrial Use		Heating for Building	Power Generation / Supply	Export	Import	Others
		Feedstock	Industrial Heating					
India	●	●			●	●		
Canada	●	●	●	●	●	●		
Germany	●	●		●			●	
Japan	●		●		●		●	Supply Chain
Australia	●	●	●		●	●		
Netherlands	●	●	●	●		●		Agriculture & Aviation
United States of America	●	●	●		●			
China	●		●					
Saudi Arabia		●				●		
European Union	●	●	●					Grid Balancing
France	●	●			●			Agri-food & Electronics
Russia	●	●		●	●	●	●	Robotics
South Korea	●			●		●		
Norway	●	●	●		●			
Portugal	●	●	●	●	●			
United Kingdom	●	●	●	●	●	●		

Countries and their Demand (1/3)

Country	Current Hydrogen Demand	Policy Target	Capital Allocated (US$)	Focused Hydrogen Source	Demand Focus			Export / Import Focus
					Industry	Transport	Others	
European Union		6 GW capacity by 2024; 40 GW by 2030; 10 MMTPA Green H2 by 2030	609 Billion	Low Carbon - Blue / Green	1. Chemical Feedstock 2. Refining	1. Medium & Heavy Duty 2. Buses 3. Rail		
Germany	1.65 MMTPA	2.7-3.3 MMTPA by 2030	15-20 Billion	Carbon Free – Blue / Green	1. Iron & Steel 2. Chemical Feedstock 3. Refining	1. Medium & Heavy Duty 2. Buses 3. Rail		Import
France	0.9 MMTPA	6.5 GW via Electrolysis by 2030	> 7 Billion	Low Carbon – Blue	1. Iron & Steel 2. Chemical Feedstock 3. Refining 4. Others	1. Medium & Heavy Duty 2. Buses 3. Rail 4. Aviation		Export
Netherlands	1.5 MMTPA	NA	40 - 55 Million/yr	Blue / Green	1. Iron & Steel 2. Chemical Feedstock 3. Refining 4. Others	1. Medium & Heavy Duty 2. Buses 3. Rail 4. Passenger Vehicle	1. Heating	EU Export / Import Hub
Hungary	160 KTPA	36 KTPA (Low Carbon) + 138 KTPA (Grey) by 2030	450 Million	Low Carbon – Blue / Grey	1. Chemical Feedstock 2. Refining	1. Medium & Heavy Duty 2. Buses	1. Heating	
Portugal	~150 KTPA	2 - 2.5 GW via Electrolysis by 2030 400 KTPA overall by 2030	No Dedicated Capital	Green	1. Iron & Steel 2. Chemical Feedstock 3. Refining 4. Others	1. Passenger Vehicle 2. Medium & Heavy Duty 3. Buses	1. Heating	Export

Countries and their Demand (2/3)

Country	Current Hydrogen Demand	Policy Target Demand	Capital Allocated (US$)	Focused Hydrogen Source	Demand Focus			Export / Import Focus
					Industry	Transport	Others	
Spain	0.5 MMTPA	4 GW via Electrolysis by 2030	No details	Green	1. Chemical Feedstock 2. Refining			Export
United Kingdom	0.7 MMTPA	5 GW/a Electrolysis capacity by 2030	2 Billion	Blue / Green	1. Chemical Feedstock 2. Iron & Steel	1. Medium & Heavy Duty 2. Buses 3. Rail 4. Aviation 5. Shipping	1. Heating 2. Power	Export
Norway			23 Billion	Clean	1. Chemical Feedstock	1. Maritime		
Japan	2 MMTPA	3 MMTPA by 2030 & 20 MMTPA by 2050 (5-30 by 2050)	935 Million/yr	Blue		1. Passenger Vehicle	1. Heating 2. Power	Import
South Korea	220 KTPA	3.9 MMTPA by 2030 and 27 MMTPA by 2050	653 Million/yr	Grey / Blue / Green		1. Passenger Vehicle 2. Medium & Heavy Duty 3. Buses	1. Power	Import
United States	10 MMTPA		> 15 Billion	Low Carbon – Blue / Green / Others	1. Refining 2. Others	1. Passenger Vehicle 2. Medium & Heavy Duty 3. Buses 4. Aviation	1. Heating 2. Power 3. Energy Storage	
Canada	3 MMTPA	20 MMTPA	1.2 Billion	Low Carbon Intensity - Grey / Blue	1. Iron & Steel 2. Chemical Feedstock 3. Refining 4. Others	1. Passenger Vehicle 2. Medium & Heavy Duty 3. Buses 4. Rail	1. Heating	Export

Countries and their Demand (3/3)

Country	Current Hydrogen Demand	Policy Target Demand	Capital Allocated (US$)	Focused Hydrogen Source	Demand Focus			Export / Import Focus
					Industry	Transport	Others	
Australia	650 KTPA		278 Million (annual support) /year	Clean - Blue / Green	1. Chemical Feedstock	1. Medium & Heavy Duty 2. Buses	1. Heating	Export
Chile	58.5 KTPA	5 GW/a (2025) 25 GW/a (2030)	50 Million	Green	1. Chemical Feedstock 2. Refining	1. Medium & Heavy Duty 2. Buses	1. Heating	Export
China	22 MMTPA	35 MMTPA (by 2030) 160 MMTPA (by 2050)	13 Million	Green (long-term)		1. Passenger Vehicle 2. Medium & Heavy Duty 3. Buses	1. Power	
Russia	2 - 3.5 MMTPA	7 MMTPA by 2035 and 33 MMTPA by 2050 (export only)	1.2 Billion	Low Carbon – Blue / Nuclear	1. Refining	1. Rail		Export
India	6.7 MT	5 MTPA of Green Hydrogen by 2030	156 Million for various end use applications and 21.5 Million for R&D by 2024	Green	1. Iron & Steel 2. Refining 3. Methanol 4. Chemical Feedstock	1. Heavy Duty Vehicles 2. Aviation 3. Shipping	1. Power	Export

World's Largest Green Hydrogen Projects

To understand the current global trends of Hydrogen production we have considered 14 Gigawatt scale projects from all across the globe which are under implementation and have analyzed on the following parameters:

- Countries with large scale Hydrogen projects
- Capacity of the projects
- Planned use of Hydrogen produced
- Expected output
- Expected cost of the Project

Project Code	Name of the Project	Country	URL
P1	NortH2	Netherlands	Link
P2	AquaVentus	Germany	Link
P3	Murchison Renewable Hydrogen Project	Australia	Link
P4	Beijing Jingneng Inner Mongolia	China	Link
P5	Helios Green Fuels Project	Saudi Arabia	Link
P6	Pacific Solar Hydrogen	Australia	Link
P7	H2-Hub Gladstone	Australia	Link
P8	HyEx	Chile	Link
P9	Geraldton	Australia	Link
P10	Greater Copenhagen	Denmark	Link
P11	H2 Sines	Portugal	Link
P12	Rostock	Germany	Link
P13	Asian Renewable Energy Centre	Australia	Link
P14	Hydrogen City Green Hydrogen Production Hub	Texas	Link

Details of the Project (1/3)

Project Code	Name of the Project	Location	Power Source	Developers	Planned used of H2	H2 Output	Planned Date of Completion	Expected Cost
P1	NorthH2 (At least 10 GW)	Eemshavan, Northern Netherlands	Offshore Wind	Shell, Equinor, RWE, Gasunie, Groningen Seaports	To help power Heavy Industry in the Netherlands and Germany	1 MT/yr	2040 (1 GW by 2027, 4 GW by 2030)	
P2	AquaVentus (10 GW)	Helioland, Germany	Offshore Wind	A consortium of 27 companies, research institutions and organisations, including RWE, Vattenfall, Shell, E.ON, Siemens Energy, Siemens Gamesa, Vestas Northland Power, Gasunie and Parkwind	General sale via a European Hydrogen network	1 MT/yr	2035 (30 MW by 2025, 5 GW by 2030)	
P3	Murchison Renewable Hydrogen Project (5 GW)	Near Kalbarri, Western Australia	Onshore Wind and Solar	Hydrogen Renewable Australia and Copenhagen Infrastructure Partners	A demonstration phase would provide H2 for transport fuels; an expansion stage would produce H2 to blend into local Natural Gas pipelines. A large expansion would produce H2 for export to Asia, with a focus on Japan and South Korea		2028	$10 - 12 bn
P4	Beijing Jingneng Inner Mongolia (5 GW)	Eqianqi, Inner Mongolia, China	Onshore Wind and Solar	Chinese utility Beijing Jingneng		400,000 - 500,000 tonnes per year	2021	$3 bn
P5	Helio Green Fuels Project (4 GW)	Neom, a planned city in Northwest Saudi Arabia	Onshore Wind and Solar	Air Products, ACWA, Neom	To produce green ammonia (NH4), which would be transported around the world and converted back into H2 for use as a transport fuel.	About 240,000 tonnes per year (to create 1.2 million tonnes of green ammonia annually)	Not stated, but first ammonia production due in 2025	$5 bn

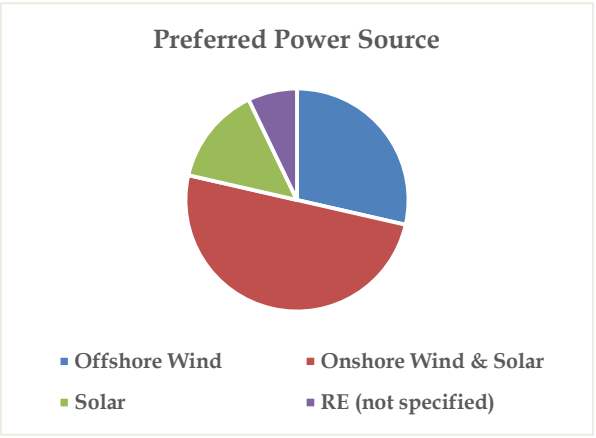
Details of the Project (2/3)

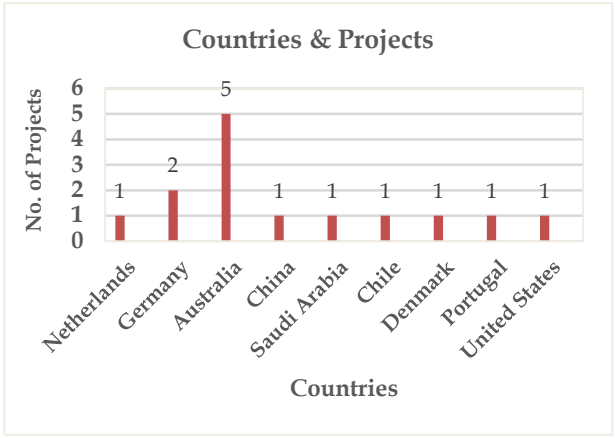
Project Code	Name of the Project	Location	Power Source	Developers	Planned used of H2	H2 Output	Planned Date of Completion	Expected Cost
P6	Pacific Solar Hydrogen (3.6 GW)	Callide, Queensland, Australia	Solar	Austrom Hydrogen, a start-up	Export to Japan and South Korea	More than 200,000 tonnes per year		
P7	H2-Hub Gladstone (3 GW)	Gladstone, Queensland, Australia	RE, but not otherwise specified	The Hydrogen Utility (H2U)	Green Ammonia for export to Japan and other countries	Up to 5,000 tonnes of Green Ammonia per day		$1.6 bn (not including sources of power)
P8	HyEx (1.6 GW)	Antofagasta, Chile	Solar	Engie and Enaex	Green Ammonia, half of which will be used at Enaex's Ammonia Nitrate plant; the remainder will be targeted for fuel, green fertilizer and export markets	124,000 tonnes per year (700,000 tonnes of Green Ammonia)	26 MW pilot by 2024	
P9	Geraldton (1.5 GW)	Geraldton, Western Australia	Onshore Wind and Solar	BP / BP Lightsource	Production of Green Ammonia for domestic and export markets	Around 1 MT of Green Ammonia per year		
P10	Greater Copenhagen (1.3 GW)	Greater Copenhagen area, Denmark	Offshore Wind	Orsted, Maersk, DSV Panalpina, DFDS, SAS	Hydrogen for buses and trucks, e-fuel (derived from Green Hydrogen and captured CO2) for Shipping and Aviation	250,000 tonnes of sustainable fuel per year	2030 (10 MW pilot as soon as 2023, 250 MW by 2027)	
P11	H2 Sines (1 GW)	Sines, Southwest Portugal	Onshore Wind and Solar	EDP, Galp, Martifer, REN, Vestas	Domestic consumption and Export		2030	$1.84 bn

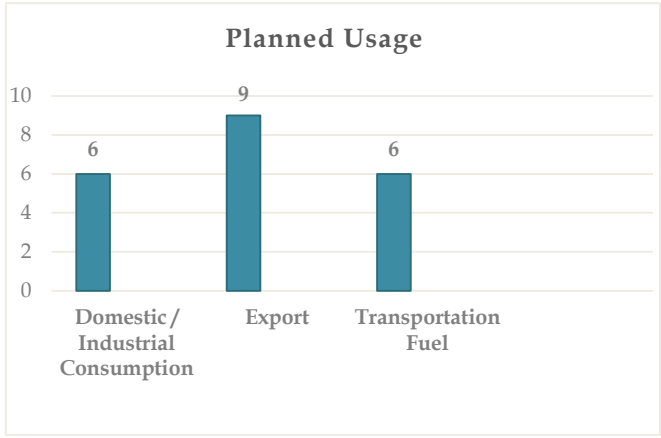
Details of the Project (3/3)

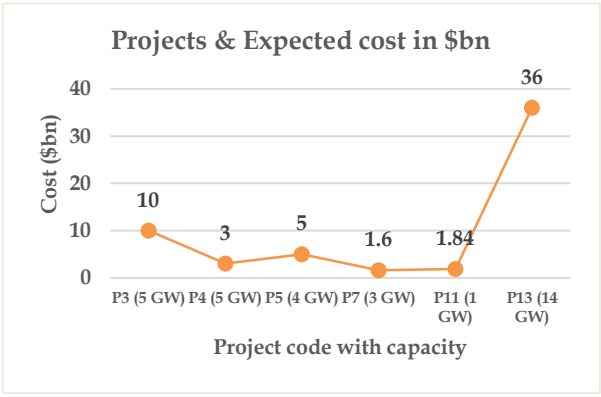
Project Code	Name of the Project	Location	Power Source	Developers	Planned used of H2	H2 Output	Planned Date of Completion	Expected Cost
P12	Rostock (1 GW)	Rostock, Germany	Offshore wind and other Renewable sources	Consortium led by RWE	All avenues being explored			
P13	Asian Renewable Energy Centre (14 GW)	Pilbara, Western Australia	Onshore Wind and Solar	Intercontinental Energy Corporation, CWP Asia Energy Corporation, Vestas Corporation, Macquarie Group	Export of Green Hydrogen and Green Ammonia to Asia	1.75 MT per year (9.9 MT of Green Ammonia will be produced)	2027-28	$36 bn
P14	Hydrogen City Green Hydrogen Production Hub (60 GW)	Austin, Texas, United States	Onshore Wind and Solar	Green Hydrogen International (GHI)	Pipelines will transport hydrogen from the plant to Corpus Christi and Brownsville nearby, where it will be transformed into green ammonia, sustainable aviation fuel, and other products. GHI also plans to build pipelines directly to other customer locations, and is exploring export options into Japan and Korea, as well as looking into the viability of a sustainable Green Methane Rocket Fuel for launch operations around South Texas.	2.4 MT per year	2026	

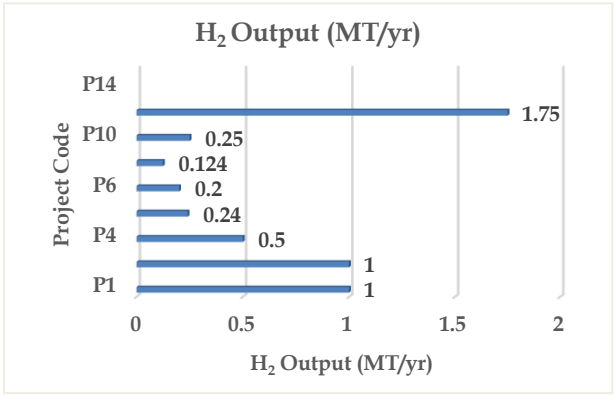
Analysis on World's Largest Green Hydrogen Projects

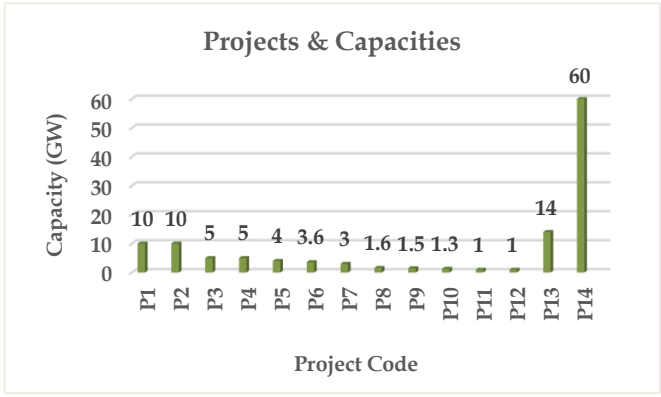












Green Hydrogen in India

- Setting up a Green Hydrogen Investment Fund of $100 million to be deployed in next five years till 2025, followed by a larger $500 million Hydrogen Fund to be raised for 2025-2030
- Blending Hydrogen production with use-cases across natural gas, exploratory natural gas and coal-gasified grey Hydrogen projects.
- Identify at least ten potential H2India national Hydrogen projects for large-scale demonstration projects.
- Setting fiscal incentives for large-scale national H2 projects among partnerships and industry consortiums.

Source: https://www.consultancy.in/news/3451/fti-outlines-eight-pillars-of-indias-green-hydrogen-roadmap

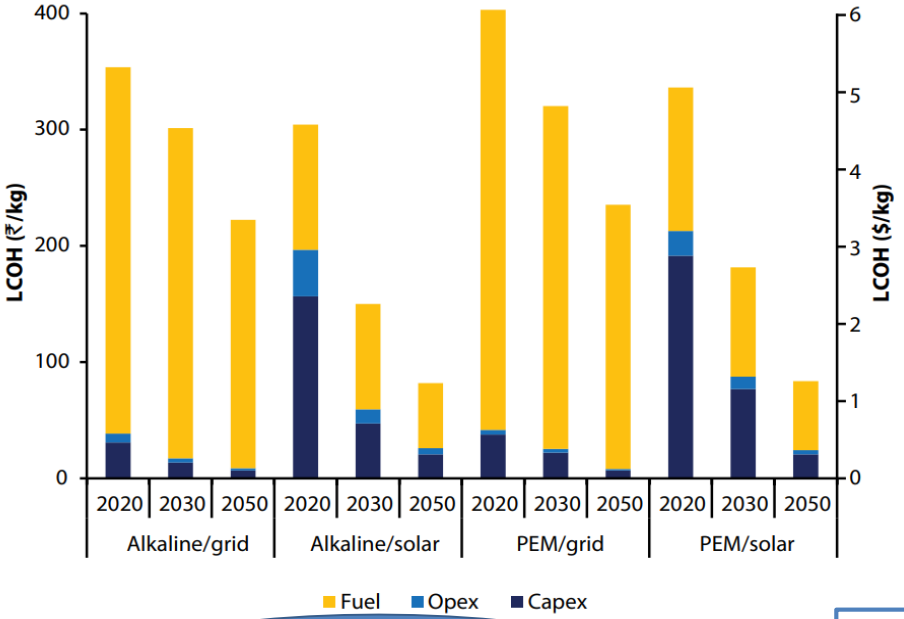
Green Hydrogen Production

- Globally, only 4% of Hydrogen is produced through Electrolysis, with most of this being by-product Hydrogen from the Chlor-Alkali Industry
- Efficiency of Electrolyzers range between 60 - 81% depending on the technology type and load factor [1]
- 1 kg of Hydrogen with Electrolyzers requires 50 - 55 kWh of electricity, assuming the electrical efficiency of 60- 70%. Hydrogen Energy Density is 120 MJ/kg [1] *(100% efficient electrolyzer required 39 kWh of electricity [2])*
- Amount of electricity required to meet the global demand for dedicated hydrogen production of 70 MtH_2 would be 3600 Terawatt Hours (TWh) [1]
- Amount of water needed for dedicated hydrogen production 70MtH_2 would be 617 million m^3 [1]
- In water stressed areas, freshwater access is an issue, salt water can be used but desalination would be required which increases the electricity demand and cost (3–4 kWh/m^3 of water, USD 0.7–2.5 per m^3 of water) [1]

Source: [1] IEA 2019. [2] http://www.renewableenergyfocus.com/view/3157/hydrogen-production-from-renewables/

Hydrogen Integration with RE

Cost of Green Hydrogen



India can achieve Green Hydrogen cost of $1/kg in a decade. This will make India the first country globally to achieve $1 per 1 kg in a decade – the **1-1-1 Target** for Green Hydrogen: **Mukesh Ambani**

Electrolyzer Assumptions

Tech/Input	Metric	Unit	2020	2030	2050
Alkaline	CAPEX	Rs/kW	66,600	29,600	14,800
	OPEX	%CAPEX	3	3	3
	Efficiency	%	67	68	75
PEM	CAPEX	Rs/kW	81,400	48,100	14,800
	OPEX	%CAPEX	2	2	2
	Efficiency	%	58	66	71
Grid Electricity	Cost	Rs/MWh	6,290	5,550	4,810
	CUF	%	95	95	95
Solar Electricity	Cost	Rs/MWh	2,146	1,628	1,258
	CUF	%	19	26	30

- Instead of using grid electricity, using renewable energy is the more economical form of operation. This is a result of the high costs of grid electricity in India when compared to buying renewable energy directly.
- The average CUF of solar plants, which is expected to increase from 20% now to 30% by 2050, will be another key factor in this cost decrease.

Source: Report on The Potential demand of Hydrogen in India, TERI, 2020

Electrical Energy demand Projection

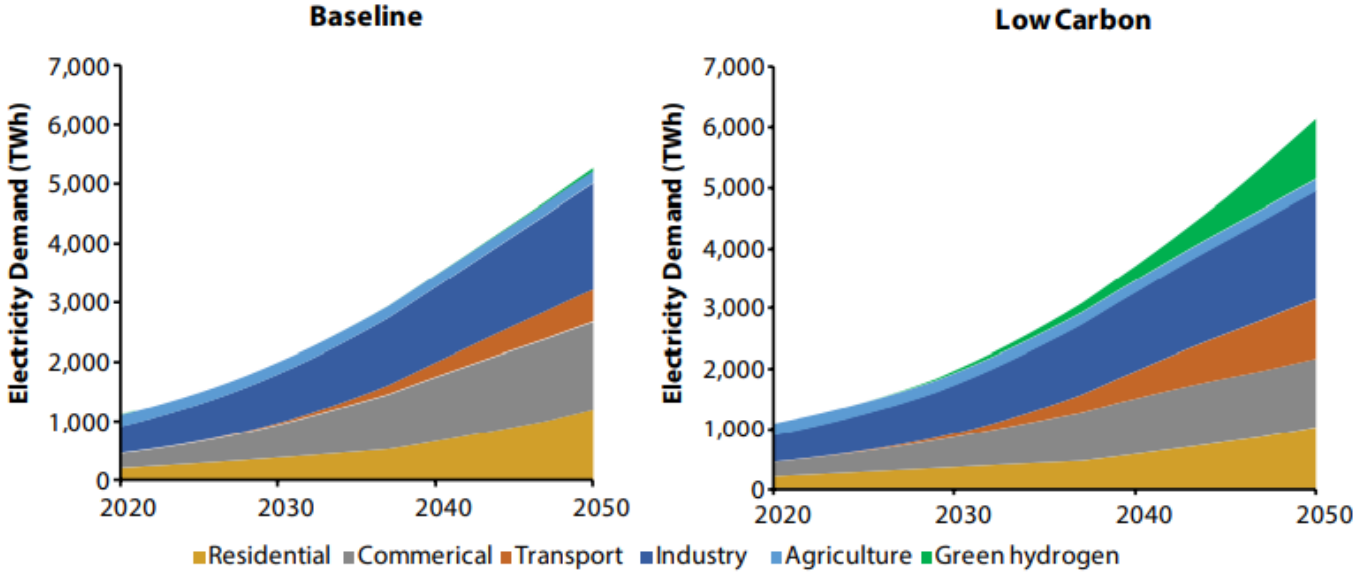


Fig: Annual electricity demand by major end-use sector, Baseline and Low-Carbon Scenarios

- Total electricity demand in India will continue to grow rapidly in the coming years, reaching approximately 5,300 TWh in 2050 in Baseline scenario.
- In the Low Carbon scenario, additional electricity required for green hydrogen production is around 1,000 TWh

RE Sources for Hydrogen Production

RE Technology	Solar Thermal	Small Hydro	Standalone Solar PV	Standalone Wind	Offshore Wind	Wind - Solar Hybrid
CUF	Average Annual Efficiency Linear Fresnal: 8-11% Central Receiver: 17-35% Parabolic Dish: 25-30% Parabolic Trough: 15%	45% CUF	16 - 19% CUF	32 - 35% CUF	40 – 50%	35 - 40% CUF
Levelized Tariff	Rs 2 .25/kWh	Rs 4.7– 5.15 /kWh	Rs 2 - 4/kWh	Rs 2 - 4/kWh	Rs 7 – 10/kWh	Rs 2.4 - 4.76/kWh
Co-Location Factor	Yes	No	Yes	Yes	Yes	Yes
CAPEX Cost	Rs. 12 Cr/MW	Rs. 11 Cr/MW	Rs. 4 Cr/MW	Rs. 5-6 Cr/MW	Rs. 6-7 Cr/MW	5-7% lower than Standalone wind and solar power plants
Life of Plant	25 Years	40 Years	25 Years	25 Years	25 Years	25 Years
Suitable Technology for Hydrogen Production	AEM/PEM	AEM/PEM	PEM	PEM	PEM	PEM

Existing Policy and Regulatory Framework

- India Policy Initiatives
- Key Policy Levers for Advocacy

India's Hydrogen Measures

Policy Initiatives

2006	2016	2017 - 2021	2020	2021	2021	2021 - 2022
National Hydrogen Energy Roadmap	Ministry of Road Transport and Highways notified Hydrogen as a fuel	MNRE - Renewable Energy Research and Technology Development Program	MoRTH safety and approval requirements- Hydrogen FCEV in Automotive Industry Standard (AIS) 157	**MoP – (Promoting RE through Green Energy Open Access Rules, 2021**	**National Hydrogen Mission**	**Green Hydrogen Policy**
Issued				Circulated	Announced	Launched

Future Plans

Viability Gap Funding For Green Hydrogen in Heavy Mobility

Can provide a push to India's Infrastructure – creation of plans through Public Private Partnerships

Mandates for Green Hydrogen Purchase Obligation

Refining and Fertilizers starting with 10% which will be increased later to 20-25%.

Bringing down the Cost

Bring down the cost of Hydrogen from around ₹350/kg to ₹160 /kg by 2029 - 30

Call bids and Develop PLI Scheme

Develop PLI Scheme to support indigenization of Electrolyzers with a target establishment of 10 GW domestic manufacturing capacity of Green Hydrogen. Calling bids for 4 GW Electrolyzer capacity

Government efforts to promotion of green hydrogen

India has taken following three imitative for the promotion of green hydrogen

- **Green Hydrogen policy**
- **The Energy Conservation (Amendment) Bill, 2022**
- **Renewable Purchase Obligation**

India's Green Hydrogen Policy

Hon'ble prime minister launched the National Hydrogen Mission on India's 75th independence to meet climate target and making India a green hydrogen hub. In line with the accouchement, MOP, GOI has framed Green Hydrogen policy dated 17th Feb 2022

The policy offers a range of incentives to lure Investors to bet on the development of Green Hydrogen and Green Ammonia:

- Under the policy, the Government is offering to set up manufacturing zones for production, connectivity to the ISTS (Inter-State Transmission System) on priority basis, and free transmission for 25 years if the production facility is commissioned before June 2025 (*The move is likely going to make it more economical for key users of Hydrogen and Ammonia such as the Oil Refining, Fertilizer and Steel sectors to produce green hydrogen for their own use*).
- The Government is set to provide a Single Portal for all clearances required for setting up green hydrogen production as well as a facility for producers to bank any surplus renewable energy generated with DISCOMS for up to 30 days and use it as required (*DISCOMS may also purchase RE to supply Green Hydrogen producers, but they must do so at a discounted rate that only includes the price of the procurement, wheeling fees, and a small margin as defined by the state commission. Such purchases would also contribute to a state's RPO, which requires it to obtain a specific percentage of its energy needs from Renewable sources*).
- Under the policy port authorities will also provide land at applicable charges to Green Hydrogen and Green Ammonia producers to set up bunkers near ports for storage prior to export (*Germany and Japan could be key markets for Green Hydrogen produced in India – R K*

What Next?
The Government is set to come out with mandates requiring that the Oil Refining, Fertilizer and Steel sectors procure Green Hydrogen and Green Ammonia for a certain proportion of their requirements. The mandate for the Refining sector could start at 15% - 20% of the sectors total requirement.

The Energy Conservation (Amendment) Bill, 2022

Obligation to use non-fossil sources of energy: Designated consumers to meet a minimum share of energy consumption from non-fossil sources

Carbon trading: Carbon credit implies a tradeable permit to produce a specified amount of carbon emissions.

Standards for vehicles and vessels: the energy consumption standards may be specified for equipment and appliances which consume, generate, transmit, or supply energy

Regulatory powers of SERCs: The Act empowers the State Electricity Regulatory Commissions (SERCs) to adjudge penalties under the Act.

Renewable Purchase Obligation

- Ministry of power, GOI has set total renewable purchase agreement of 24.61% in 2022-23 which will increase to 43.33% by 2029
- Government is considering Green Hydrogen purchase obligations for refineries and fertilizer plants, starting with 10 percent which will be increased to 20-25 percent.
- Government is also considering viability gap funding (VGF) for green hydrogen in heavy mobility and other sectors such as steel

Key Policy Levers

S.No.	Key Policy Lever	Purpose
1	Guarantees of Origin	For assurance of sustainable Hydrogen sourcing. Will enable International Trade
2	Establishment of Hydrogen Hubs	Optimization of cost of transport and storage due to easy access
3	Viability Gap Funding	Will enable private players to take up projects
4	Production Linked Incentives	Will promote Green Hydrogen production through establishment of Electrolyzers
5	Exemptions for Green Hydrogen	Most energy commodities produced are subject to taxation, excises, fees or levies. Concessions will make a case for utilization of Green Hydrogen
6	Bilateral Partnerships with importers	Access to International markets such as Japan, Republic of Korea, Singapore, and Taiwan
7	Carbon Fee and Dividends	Will cause energy companies, leading industries, and consumers will move toward cleaner, cheaper options
8	Carbon Contracts for Difference	Encourage Industries to look for more sustainable production methods
9	Zero Emission Vehicle Mandates	Force automakers to move towards cleaner vehicles, give consumers a choice and necessitate allied Infrastructure
10	Dollar denominated pricing	Allow developers to recover capex investment and financing costs incurred in Dollar terms, without impacting exchequer (as currently India imports Ammonia and Crude Oil and pay in Dollar terms)

India’s Hydrogen Strategy (1/2)

Objective	To make India a global hub for Green Hydrogen Production and Export, boost Energy Self-Reliance and Inspire Clean Energy Transition all over the world through Green Growth and Green Jobs
Target & Period	Production of 5 MT of Green Hydrogen by 2030 and the related development of Renewable Energy capacity
Phases	• Phase 1: Primarily focuses on Renewable Power procurement, Hydrogen production, storage, and distribution. • Phase 2: Currently under review, is expected to include details related to Hydrogen consumption. It may include regulations or mandates for the use of Clean Hydrogen in the Refining, Ammonia, and Steel sectors (5% - 10% of Clean Hydrogen use of total consumption.
Sectors	Industrial and Tranportation
Policy Instruments	• Green Hydrogen/Ammonia manufacturers may purchase Renewable Power from the power exchange or set up RE capacity themselves or through any developer, anywhere. • Open access will be granted within 15 days of receipt of the application. • The Green Hydrogen/Ammonia manufacturer can bank his unconsumed Renewable Power, up to 30 days, with the distribution company and take it back when required.

India’s Hydrogen Strategy (2/2)

Unique Features

- To ensure ease of doing business, a single portal for carrying out all the activities, including statutory clearances in a time-bound manner.
- Green Hydrogen/Green Ammonia manufacturers shall be allowed to setup bunkers near ports for storage of Green Ammonia for export/use by shipping. The land for the storage for this purpose shall be provided by the respective Port Authorities at applicable charges.
- The Government is offering to set up manufacturing zones for production, connectivity to the ISTS (Inter-State Transmission System) on priority basis, and free transmission for 25 years if the production facility is commissioned before June 2025.

Research and Development

- Indian R&D Landscape
- Public Sector Hydrogen Initiatives
- Private Sector Hydrogen Initiatives

Indian R&D Landscape

- R&D activities are mainly focused on:
  - Making the process more efficient
  - Replacing noble materials with durable and cost-effective substitutes
  - Finding newer materials and catalyst to speed up the reaction
- R&D related to Hydrogen storage is mostly focused on materials for light weight high pressure storage cylinders.
  - Metal, complex and chemical hydrides are being studied for their cyclability and reversibility
  - Novel materials like Carbon Nanotubes / Nanofibers, Graphene and composites are studied
- Fuel cell R&D projects are focused on the various components of the fuel cells such as catalysts, membrane, etc., to increase the scalability and affordability of fuel cells. Focus fuel cell technologies are PEMFC, DMFC, SOFC.
- Focus of R&D projects on materials research is expected to reduce pricing of Electrolyzers over the next decade.

Public Sector Hydrogen Initiatives

Organization	Domain	Partner	Project Details
National Thermal Power Corporation (NTPC) Limited	Transportation Feedstock Microgrids		• 10 FC buses and 10 FCEVs for Pilot Project – Intracity Leh, Ladakh and Intercity Delhi – Jaipur and Delhi - Agra • Blending 5% of Hydrogen in city gas terminal of Dadri • Setting Hydrogen based Microgrid in Ladakh catering 500 households • Setting up Green Methanol and Green Ammonia plants at various locations
Indian Oil Corporation Limited (IOCL)	Mobility	Tata Motors	• Procuring 15 PEM FC buses. Operation in Delhi NCR • Refuelling, generation and distribution of Hydrogen under the purview of IOCL
		Greenstat	• Centre for Excellence on Hydrogen
	Production		• Green Hydrogen plant at Mathura Refinery. Electricity supply from IOCL wind plant in Rajasthan
Oil India Limited	Commercial Applications		• First in India to use the Anion Exchange Membrane (AEM) technology • The Green Hydrogen pilot plant set up in central Assam's Jorhat. Green Hydrogen is being produced from the electricity generated by a 500-kW solar plant using a 100-kW AEM electrolyzer array.
Gas Authority of India Limited (GAIL)	Domestic Applications Automobiles	Hindustan Petroleum Corporation	• The Hydrogen will blend with Natural Gas, for retailing of CNG to Automobiles and Piped Natural Gas to Households in Indore
Bharat Petroleum Corporation Limited (BPCL)	Refineries Pipelines Depots Bottling Plants		• BPCL will put up 20 MW Electrolyzer at its Refinery in Bina, Madhya Pradesh to produce Green Hydrogen.

Private Sector Hydrogen Initiatives

Organization	Domain	Partner	Project Details
JSW Future Energy Ltd	Mobility Feedstock	Fortescue Future Industries	• Development of Green Hydrogen project for Steel sector, Mobility, etc.
Reliance Industries	Equipment Manufacturing		• Giga factories (4 factories envisaged for each component of ecosystem i.e., Fuel Cell, Solar PV, Battery Storage and Electrolyzers). 5000 acres complex at Jamnagar. 75,000 Cr Investment • 1-1-1 vision- to bring price of 1 kg of H_2 to 1 USD in 1 decade
		Chart Industries	• India H_2 Alliance
BGR Energy Systems	Feedstock	Fusion Fuel Green	• Production of Green Ammonia and Bio-Ethanol, and as a Feedstock for other Heavy Industrial applications
Acme Solar Holding Pvt. Ltd.		Lhyfe Labs SAS Exploring partnership with GAIL and IOCL	• Green Hydrogen will be produced using 5 MWp from the Solar Plant scalable to 10 MWp • Green Ammonia plant will be producing 5 tons per day of Green Ammonia with an annual output of 1,750 – 1,800 tons of Green Fuel • Located in Rajasthan. 3.5 MW Electrolyzer capacity
Adani Group		TotalEnergies SE	• France's TotalEnergies SE and Adani Group have agreed to invest $50 bn over the next 10 years in India to produce Green Hydrogen • In the initial phase, Adani New Industries will develop a Green Hydrogen production capacity of 1 MT per annum by 2030

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