UK INDIA
BUSINESS COUNCIL

GREEN HYDROGEN LANDSCAPE AND OPPORTUNITIES IN INDIA

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SUPPORTING BUSINESS SUCCESS

FOREWORD

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As India strives to achieve net zero emissions by 2070, and indeed to support its journey towards becoming the third-largest economy, it is imperative that it prioritises climate change mitigation and drastically reduces its carbon footprint.

Due to the abundance of wind and solar resources, India is well placed to explore and invest in greener fuels, including green hydrogen.

India has ~80% and ~20% import dependency on crude oil and coal, respectively, making it heavily reliant on other nations for its energy needs. Green hydrogen has the potential to help India reduce its import dependency on fossil fuels by providing an indigenous and theoretically infinite source of energy. Not only that, but green hydrogen will also enable the country to reduce greenhouse gas emissions, particularly from energy-intensive industries such as steel, petrochemicals, transportation, and fertilisers.

On 4 January 2023, the central government launched the “National Green Hydrogen Mission” with a budget of approx. INR 20,000 crore/GBP 2 billion. This programme intends to boost annual green hydrogen production capacity to at least 5 million tonnes and renewable energy capacity addition of 125 GW by 2030.

Currently, India produces about 6 million tonnes of hydrogen every year. This hydrogen is produced from fossil fuels and mostly used in the production of ammonia for fertilisers and petroleum refining.

The existence of a strong domestic consumption market would aid in the advancement of green hydrogen, and we anticipate green hydrogen demand to reach 2.85 million tonnes by 2030 as industries transition to cleaner fuels.

India has demonstrated its strength in developing supply chain ecosystems for various industries in the past and is capable of doing so in the case of green hydrogen as well.

In this report we highlight India’s endeavour to developing a green hydrogen ecosystem and how the country plans to achieve its environmental sustainability goals.

The report will provide readers with insights and analysis on demand outlook, key players, investment environment, regulatory scenario, end user analysis, and opportunity assessment. We have also focused on how India and the UK can work together to develop capabilities in green hydrogen. Sharing of technology, regulatory best practice, and investment will make us stronger together.

ABBREVIATIONS

- **AEC:** Alkaline Electrolysis Cells
- **AEM:** Anion Exchange Membrane
- **BARC:** Bhabha Atomic Research Centre
- **BHEL:** Bharat Heavy Electricals Limited
- **BPCL:** Bharat Petroleum Corporation Limited
- **CAGR:** Compound Annual Growth Rate
- **CGD:** City Gas Distribution
- **CNG:** Compressed Natural Gas
- **CO_2:** Carbon Dioxide
- **CY:** Calendar Year
- **DAP:** Di-ammonium Phosphate
- **DRI:** Direct Reduced Iron
- **EoI:** Expression of Interest
- **EPC:** Engineering Procurement and Construction
- **EU:** European Union
- **FCDO:** Foreign, Commonwealth and Development Office
- **FY:** Financial Year
- **GAIL:** Gas Authority of India Limited
- **GH_2:** Green Hydrogen
- **GOI:** Government of India
- **GW:** Giga watt
- **Gwp:** Giga watts peak
- **H_2:** Hydrogen
- **IEA:** International Energy Agency
- **IGL:** Indraprastha Gas Limited
- **IH2A:** India Hydrogen Alliance
- **JV:** Joint Venture
- **KOH:** Potassium Hydroxide
- **KG:** Kilogram
- **LCOH:** Levelised Cost of Hydrogen
- **LCOE:** Levelised Cost of Electricity
- **LOI:** Letter of Intent
- **L&T:** Larsen & Toubro Ltd.
- **MMT:** Million Metric Tonnes
- **MNRE:** Ministry of New and Renewable Energy
- **MoU:** Memorandum of Understanding
- **m/s:** metre per second
- **MT:** Metric Tonnes
- **MTPA:** Million Tonnes Per Annum
- **MW:** Mega Watt
- **NA:** Not Applicable
- **NaOH:** Sodium Hydroxide
- **NGHM:** National Green Hydrogen Mission
- **Nm3/h:** Normal Cubic Meter Per Hour
- **NLCIL:** Neyveli Lignite Corporation India Limited
- **NTPC:** National Thermal Power Corporation
- **NTPC REL:** National Thermal Power Corporation Renewable Energy Limited
- **OEM:** Original Equipment Manufacturer
- **ONGC:** Oil and Natural Gas Corporation
- **PEM:** Proton Exchange Membrane
- **PLI:** Production Linked Incentive
- **PNG:** Piped Natural Gas
- **PPP:** Public-Private Partnership
- **PSU:** Public Sector Undertakings
- **R&D:** Research and Development
- **SMR:** Steam Methane Reforming
- **SOEC:** Solid Oxide Electrolysis Cell
- **TBD:** To Be Decided
- **TPA:** Tonnes Per Annum
- **TPD:** Tonnes Per Day
- **TRL:** Technology Readiness Levels
- **VGF:** Viability Gap Funding
- **Y-o-Y:** Year on Year

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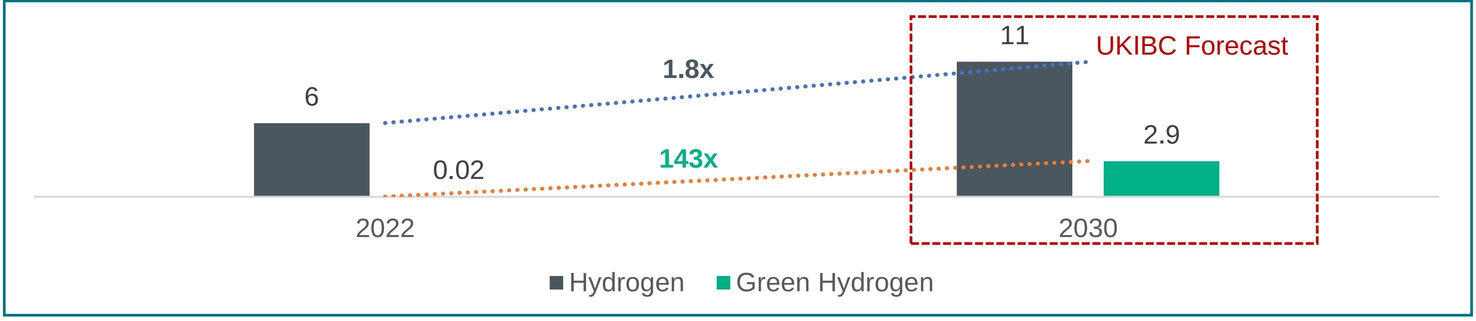
EXECUTIVE SUMMARY

India's National Green Hydrogen Mission aims to establish green hydrogen as a key energy source, reducing reliance on fossil fuels.

India currently produces 6 million metric tonnes (MMT) of hydrogen annually, which is primarily used in ammonia production and crude oil refining. At approximately 0.02 MMT production, the green hydrogen industry is completely nascent. By 2030, we expect green hydrogen production to reach 2.9 MMT. However, to become commercially viable, production costs must decrease to US$1 per kg from the present US$3-US$6.5 per kg.

PRODUCTION VOLUMES (MMT)



Green hydrogen in India is primarily produced via two methods — biomass gasification and water electrolysis. Of these methods, water electrolysis has greater potential in the Indian context.

In the short to medium term, water electrolysis technology is expected to be dominated by alkaline electrolyser technology, followed by proton exchange membrane (PEM), anion exchange membrane (AEM), and finally solid oxide electrolysis cell (SOEC).

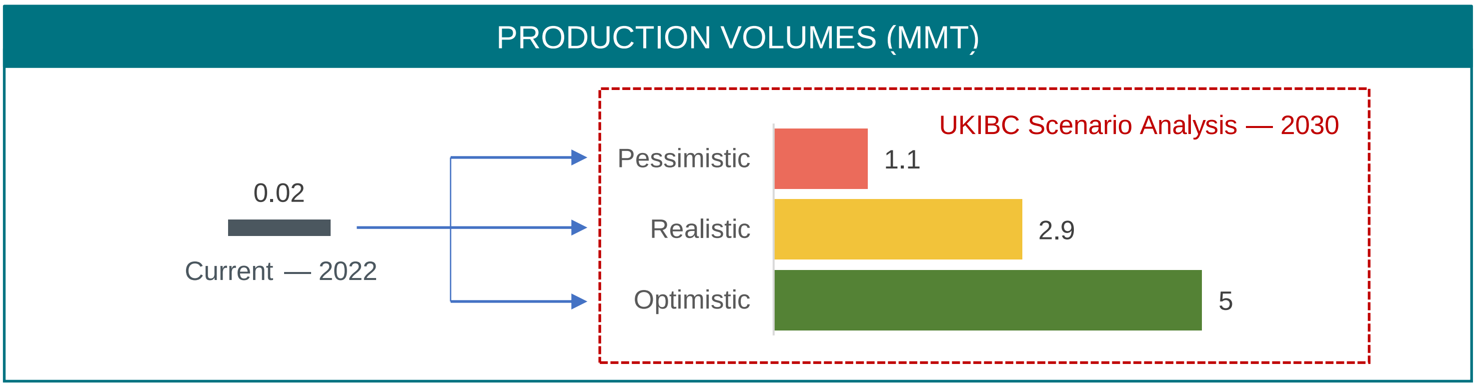
At present, India is gradually developing its upstream and midstream green hydrogen ecosystem. Prominent energy companies, oil and gas marketing companies, and engineering procurement and construction (EPC) companies are at the forefront. The electrolyser manufacturing part is the domain of smaller technology companies and start-ups, although larger companies do have stakes in these start-ups.

According to a Financial Express report, by 2033, businesses may invest up to US$193 billion (₹16 trillion) in the green hydrogen sector. There has been a steady increase in investment from domestic and global players including various green hydrogen production projects which include electrolyser manufacturing plants as well as pilot projects for green hydrogen and green ammonia production.

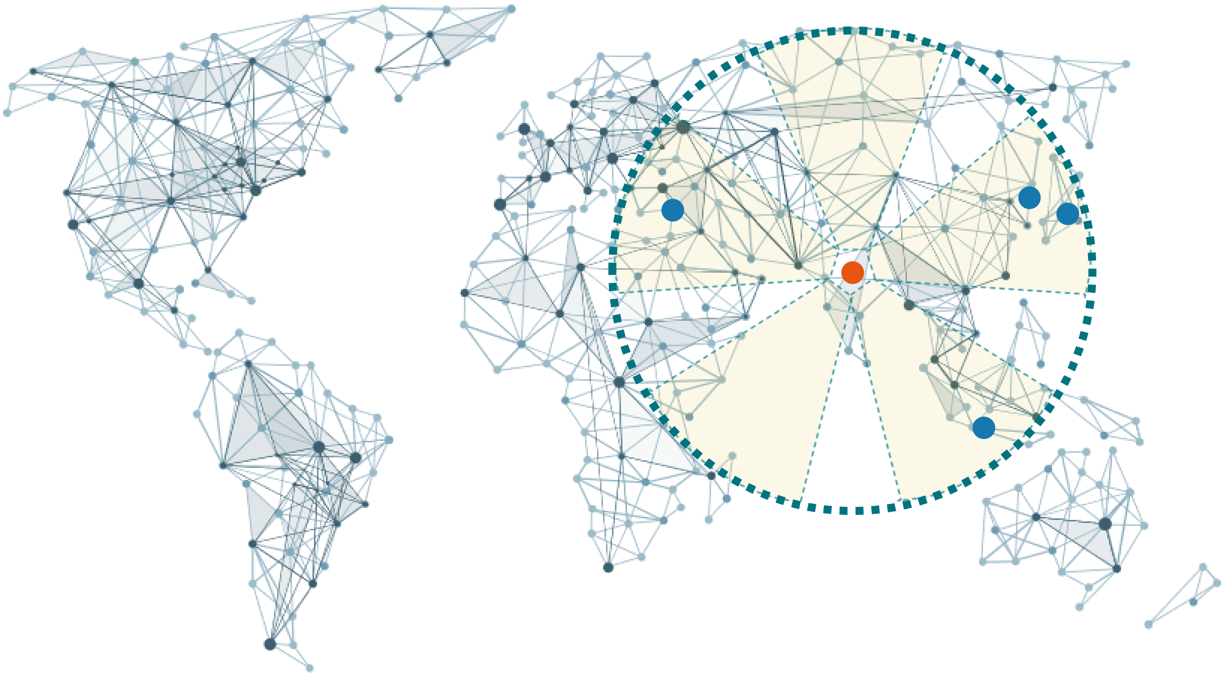
In terms of policy, India is among the first movers considering the central government has created a well thought out framework in the form of the National Green Hydrogen Mission. But interestingly, the government does not wish to mandate green hydrogen purchases to stimulate demand, leaving the demand offtake to market forces for now. Industry leaders believe that a green hydrogen purchase obligation is essential to jumpstart the nascent domestic green hydrogen industry in India. Along with it, better PLI schemes, wider R&D funds and support, easing of taxations, and smoothing of grid banking are necessary interventions to help the green hydrogen economy grow in the country.

We did a scenario analysis to estimate India's green hydrogen production capacity by 2030. Calculating the various alternatives and the present state of maturity of the ecosystem, our estimates suggest that by 2030, India's green hydrogen production capacity should be in the 2 to 3 MMT range. The base line is that to reach the aspirational level of green hydrogen production, end-use sectors, especially oil refining, fertiliser, energy, and transportation, must start using green hydrogen.

EXECUTIVE SUMMARY



India has a strategic advantage in the global green hydrogen value chain. It has abundant renewable resources in form of solar and wind energy, and it is geographically located at an ideal spot which gives it access to multiple export markets.



Japan, Singapore, South Korea and many other European countries may not be entirely self-sufficient in generating green hydrogen and thus might need to import. In such a situation in the future, India is well poised to export, provided its green hydrogen ecosystem matures and it is successful in achieving its production targets under the Green Hydrogen Mission. In such a situation, India could meet anywhere between 3% to 10% of the total green hydrogen import requirements of these countries.

One core aspect of this report is to highlight the immense collaboration potential that the UK and India have in this sphere. Both countries already have synergies in education, technology, and manufacturing. It is natural for the two countries to collaborate on green hydrogen technologies and value chain, including solar, wind, electrolyser technologies, alternative catalyst materials, and water desalination.

Not only on the technology front, but India and the UK can and must collaborate to build green hydrogen infrastructure, capacity and standards. What we choose now and how we collaborate could decide the energy security of both nations.

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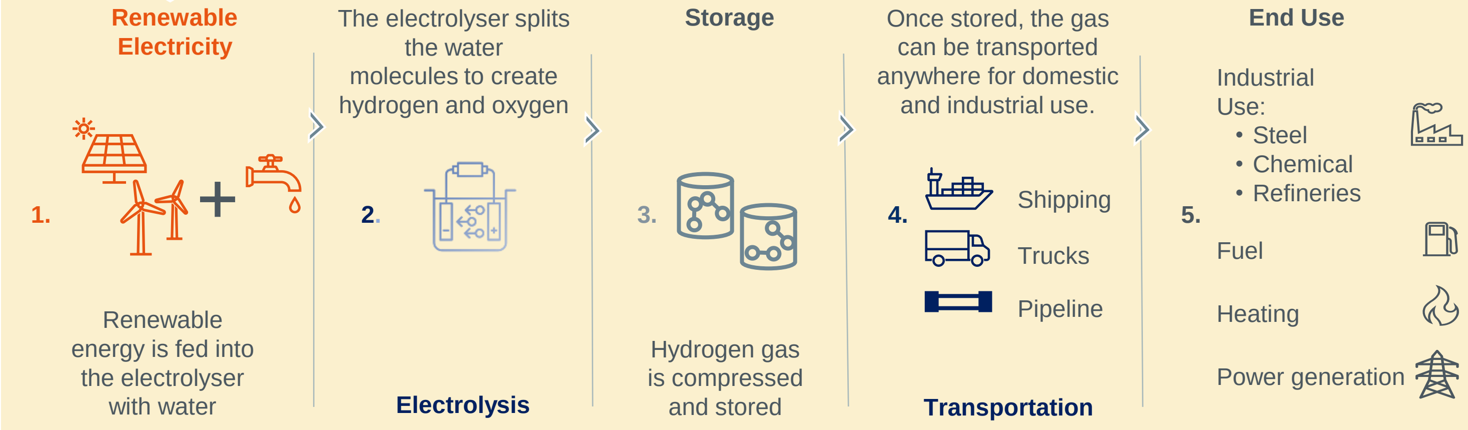
FROM NEGLIGIBLE PRODUCTION IN 2022 GREEN HYDROGEN PRODUCTION IS EXPECTED TO REACH 2.85 MMT BY 2030

	Green Hydrogen	Grey Hydrogen	Blue Hydrogen	Pink Hydrogen	Brown Hydrogen	Turquoise Hydrogen	Yellow Hydrogen	White Hydrogen
Sources	Renewable Energies	Natural Gas or coal	Natural Gas	Nuclear power	Fossil Fuels	Natural Gas	Solar Energy	Underground
Process	Electrolysis	SMR or Gasification	SMR or Gasification	Electrolysis	Gasification	Pyrolysis	Electrolysis	Fracking



Renewable Electricity

1\. Renewable energy is fed into the electrolyser with water

The electrolyser splits the water molecules to create hydrogen and oxygen

2\. **Electrolysis**

Storage

3\. Hydrogen gas is compressed and stored

Once stored, the gas can be transported anywhere for domestic and industrial use.

4\. Shipping

Trucks

Pipeline

Transportation

End Use

5\. Industrial Use:
- Steel
- Chemical
- Refineries

Fuel

Heating

Power generation

Why is there a push for green hydrogen in India?

- As fossil fuel imports currently supply more than 40% of India's energy needs (MNRE, 2023), green hydrogen and ammonia would be essential for establishing energy security and lowering India's reliance on fossil fuel.
- The “National Green Hydrogen Mission" — India's flagship programme for green hydrogen — was approved by the Indian Union Cabinet in January 2023. The goal of the mission is to make India a hub for the production, use, and export of green hydrogen and its byproducts.

India's Production	Total Hydrogen	Green Hydrogen
Actual 2022	6 MMT	0.02 MMT
UKIBC Projection 2030	11 MMT	2.85 MMT

As of 2022, total hydrogen production in India was 6 MMT and is expected to reach 11 MMT by 2030. However, for green hydrogen to become commercially viable in the presence of cheaper grey hydrogen in the market, its cost of production must reduce to US$1 per kg from the present US$3-US$6.5/kg.

> *“At present, India consumes roughly 6 MMT of hydrogen annually, which is generated from fossil fuels and used mostly in the production of ammonia for fertilisers and refining crude oil. The green hydrogen industry is still in its early stages of conceptualisation, with only small-scale pilot and demonstration plants operational. India would require 65 GW worth of electrolyser capacity by 2030 in order to produce 5 MMT of green hydrogen annually. However, the anticipated annual global commercial electrolyser manufacturing capacity is only around 2–4 GW. Moreover, domestic production of electrolysers is negligible now.” — UKIBC analysis*

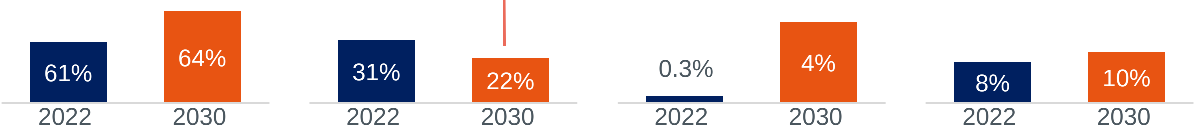
INDIA TO GO WITH ALKALINE ELECTROLYSER TECHNOLOGY IN THE SHORT TERM

Green hydrogen production can be achieved from two main sources, namely, **biomass gasification** and **water electrolysis**, with the latter technology projected to play a major role in the future. Water electrolysis can be further subdivided into four distinct technologies as detailed in the table below.

Electrolyser technology	AEC	PEM	SOEC	AEM
Method	• Uses aqueous KOH/NaOH solution as conducting membrane	• Uses sulfonated polysulfone membrane	• Uses solid ceramic membrane	• Uses ionomers membrane.
Key Players	Hydrogen Pro, Hygenco, Hild Electric, etc.	Greenzo Energy, Ohmium, etc.	h2e Power Systems etc.	homiHydrogen†
Pros and Cons	Pros: Mature technology and easy to set up. Low capex Cons: Low efficiency due to increased starting time. High opex.	Pros: High efficiency as it can start and stop instantly like a switch. Low opex. Cons: Complex technology and costly to set up. Capex is high.	Pros: Highly efficient but can be used only at very high temperatures. Cons: Technology is still at developmental stage.	Pros: Mix of alkaline and PEM technology with benefits of both. Cons: Currently at testing stage.
Market Penetration	High: Mature technology and commercially available	Medium: Operating at small pilot plants	Low: At R&D scale	Low: At R&D scale with plans to setup pilot plant in India

†JV of h2e Power Systems, BlueBasic AMA Engineering and Greenstat Hydrogen

Market Share Percentage - Current and Future Outlook



PEM market share will decrease as it is a complex technology and has high initial set up cost.

	AEC	PEM	SOEC	AEM
Global Technology Readiness Levels	9	9	7	6

> *"India is likely to stick to alkaline electrolysers because they have lower capital costs compared to PEM electrolysis and require fewer rare raw materials, despite a few drawbacks like limited operational flexibility (although this is improving), a larger area footprint, and low output pressure. Moreover, it is the most mature technology, being used in the fertiliser and chlorine industries for decades." — UKIBC analysis*

Please note that the TRL scale here is defined from 1 to 11:
1-4 is small prototype; 4-6 is large prototype; 6-8 is demonstration; 8-10 is market uptake; and 10-11 is mature technology.

GREEN HYDROGEN VALUE CHAIN ANAYLSIS (1/3)

UPSTREAM

Renewable Electricity +

Renewable energy is fed into the electrolyser with water

Electrolysis

The electrolyser splits the water molecules to create hydrogen and oxygen

ELEMENTS	REQUIREMENTS	GAPS	MITIGATION STEPS
ELECTROLYSER	• Precious metals — Platinum, Palladium, Iridium etc. • Non-precious metals — Nickel, Zirconium, Lanthanum etc.	• India does not have significant natural reserves of platinum and palladium, so it relies on imports. • Alkaline electrolyser production in India is now limited to a small number of indigenous companies, who are unable to meet the growing demand.	• Global tie-ups for exploration of raw materials. • Import contracts for regular and uninterrupted supply.
RENEWABLES	• Solar panels • Wind turbines	• In India, the supply of renewable energy is unstable and expensive. • There are issues such as wind power tariffs, payment delays by power distributors to power generation companies, grid integration, and land availability in the wind energy market. • Lack of R&D. • Lack of manufacturing infrastructure for the development of solar panels. • Modules used in solar panel are extremely expensive in India as its imports from China are subjected to very high duty rates.	• International tie-ups for technology transfer and local manufacturing. • Increase and improve indigenous manufacturing. • Invest in R&D and infrastructure development to improve efficiency and storage.
WATER	• Freshwater • Wastewater treatment • Desalination of seawater	• Limited availability of fresh water. • There is water shortage in states like Rajasthan, Karnataka, and Tamil Nadu, where solar installations are most prevalent. • In India, wind energy installations are mostly located close to the coast, where fresh water supplies are also scarce. • Lack of investment in R&D and technology for use of effluent-treated wastewater and desalination of sea water.	• Explore methods to convert wastewater into treated water. • Invest in large-scale desalination plants.
ECONOMIC FEASIBILITY	• Cost of electrolyser • Renewable LCOE • Hydrogen production (LCOH)	• High cost of solar energy production. • Cost of producing green hydrogen through electrolyser is way costlier than producing grey hydrogen.	• Incentives under PLI scheme, local manufacturing, and achieving economies of scale. • Improve the efficiency of electrolysers through R&D and collaborations for cheaper green hydrogen production.
PROVEN TECHNOLOGY	• Electrolysis - Productivity of electro-chemical reactions	• Limited manufacturers of electrolysers in India. • Inefficient technology.	• R&D for improving efficiency, stack life and reduction of water and power requirements for electrolysis.

India's Top Players

Reliance Industries Limited
adani
ohmium
HYGENCO
h2e

UK's Top Players

ITM POWER
HYDROGEN VENTURES
PROTIUM
GeoPura

GREEN HYDROGEN VALUE CHAIN ANAYLSIS (2/3)

MIDSTREAM

Storage

Hydrogen gas is compressed and stored

Transportation

Shipping

Trucks

Pipeline

Once stored, the gas can be transported anywhere for domestic and industrial use.

ELEMENTS	REQUIREMENTS	GAPS	MITIGATION STEPS
TRANSPORTATION AND DISTRIBUTION	• Retrofitment of pipelines • Laying new pipelines • Cryogenic liquid tanker trucks or gaseous tube trailers	• Lack of infrastructure for storage and distribution of green hydrogen. • Hydrogen can be transported in the form of ammonia, methanol and liquid organic hydrogen. However, this conversion is subjected to heavy costs and India's energy conversion costs are extremely high.	• Incentivising transmission, distribution and storage network. • Developing hydrogen hubs near demand centres can lower green hydrogen transportation costs.
STORAGE	• Pressurised tanks • Salt caverns	• Lack of storage and conversion infrastructure.	• More pilot projects should be initiated to develop ideal storage infrastructure. • Creating hydrogen valleys—integrated hydrogen value chains including the production, storage, and distribution of hydrogen to end-users.
SAFETY AND STANDARDS	• Hydrogen storage, transportation and distribution standards	• Lack of national and international compliance or standards for storage, transportation and distribution.	• Standardisation and documentation of existing processes. • Global collaboration

India's Top Players

GAIL

Oil India Limited

GSPC GROUP

Reliance Industries Limited

ASSAM GAS COMPANY LTD

UK's Top Players

ESSAR OIL UK

fluxys

bpa

storengy

centrica

"Even if India produces cheaper green hydrogen than most of the countries, transportation cost is still very high, which is a heavy added cost. So, while exporting, these added costs eventually makes the green hydrogen expensive, and we lose the competitive advantage. So, green hydrogen projects and renewable energy plants should be eligible for tax and duty waivers in order to encourage exports". — Deputy General Manager (Green Hydrogen and Renewables), Essar Power

According to Industry Body IH2A, funding agencies are eager to see the synergies across the green hydrogen value chain in project plans rather than standalone green hydrogen projects.

"Green hydrogen offers a bright possibility as India sets out on its path to a future powered by sustainable energy. Although there are obstacles to be solved, green hydrogen has the potential to transform India's energy system by lowering carbon emissions, boosting energy security, and stimulating the economy. Here, both public and private sector investment and involvement are essential to the mission's success. It is becoming clear that creating an ecosystem based on hydrogen takes time and must be done gradually." — UKIBC Analysis

GREEN HYDROGEN VALUE CHAIN ANAYLSIS (3/3)

DOWN-STREAM

End Use

Industrial Use:
- Steel
- Chemical
- Refineries

Fuel

Heating

Power generation

ELEMENTS	REQUIREMENTS	GAPS	MITIGATION STEPS
END-USE	• Transportation — Fuel for both ICEs (Internal Combustion Engines) and FCVs (Fuel-cell Vehicles) • Fertilisers • Blending with natural gas • Energy storage • Steel • Chemical • Refinery	• Lack of demand for green hydrogen due to availability of cheaper grey hydrogen.	• Private sector participation can be encouraged through government subsidies and tax incentives. • Policy interventions, such as enforcing purchase obligations, can be instrumental in creating demand. • Incentivising the supply side can also boost the ecosystem. • Industries can conduct pilot projects to assess the feasibility and benefits of green hydrogen adoption in order to meet net zero and carbon reduction objectives. • Raise awareness among industries about the benefits and misconceptions surrounding green hydrogen adoption through education campaigns.

India's Top Players

एन एफ एल NFL

CHAMBAL FERTILISERS AND CHEMICALS LIMITED

इंडियनऑयल Indian Oil Corporation Limited

सेल SAIL

JSW

Reliance Industries Limited

AM/NS INDIA

UK's Top Players

bp

CF

BRITISH STEEL

YARA

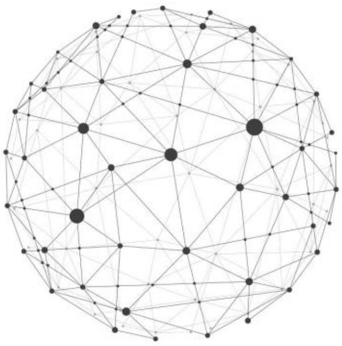
> *"Some of the industrial segments, whether it is refineries, or fertilisers and such, would be obligated to buy some of the hydrogen they consume from greener sources. That will jumpstart the virtuous cycle of creating a demand good enough in Indian terms, to make manufacturing producers then come into the equation.“ — Partner, Deloitte*

> *“Based on project pipelines and existing infrastructure, India is behind global leaders such as the US, China and the EU in ramping up its green hydrogen production capacity by two to three years. In order to catch up, the country must boost its green hydrogen production by setting a goal of 50k–100k tonnes of operational capacity by 2025.” — UKIBC Analysis*

> *“At present, the Indian government does not wish to mandate green hydrogen purchases to stimulate demand. The government has left the demand offtake on market forces for now. However due to the various challenges in the green hydrogen value chain, many industry leaders believe that a green hydrogen purchase obligation is essential to assure financiers of long-term demand. This could indeed act as a catalyst to jumpstart the nascent domestic green hydrogen industry in India” — UKIBC Analysis*

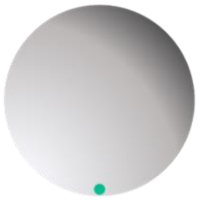
PETROCHEMICAL, CHEMICALS, AND FERTILISERS WILL BE THE FIRST SECTORS TO SWITCH TO GREEN HYDROGEN

HYDROGEN SCENARIO IN 2022



Market for hydrogen worldwide was estimated to be worth US$130 billion in 2021 and is anticipated to reach US$231 billion by 2030.

India's hydrogen production: **6 MMT**



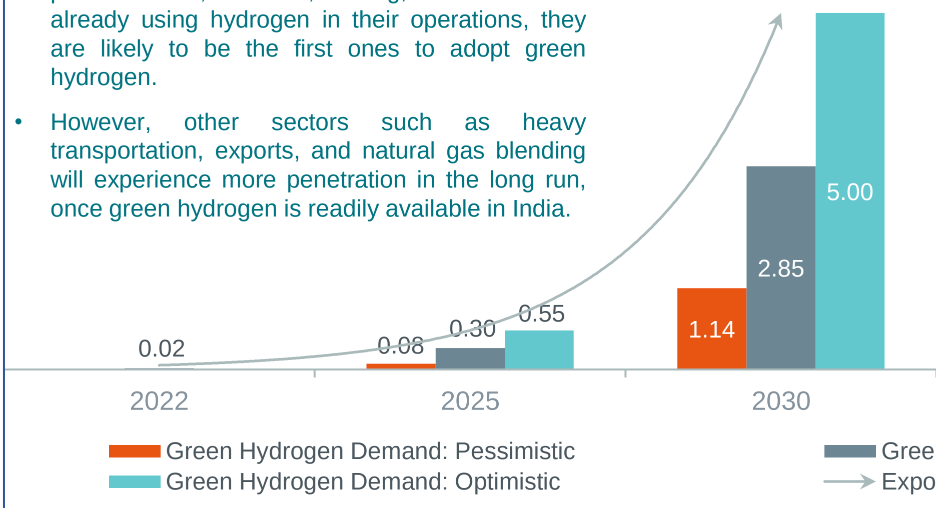
Global hydrogen production: **104 MMT**

India's green hydrogen production: **0.02 MMT**

- With a consumption of 6 MMT in 2022 (ranked 3rd internationally), India is one of the world's top consumers of hydrogen. By 2030, consumption is expected to increase to 11 MMT.
- Most of the hydrogen produced in India is grey hydrogen, which is made using natural gas or other fossil fuels.
- On the consumption side, it is mostly used in the manufacturing of methanol (1%), steel producing (5%), ammonia fertiliser (48%), oil refinery (46%), and other industrial production processes (1%).

India's Green Hydrogen Demand in MMT: Current and Forecast (2022-30)

- Since industries such as metallurgical and petrochemical, chemical, refining, and fertiliser are already using hydrogen in their operations, they are likely to be the first ones to adopt green hydrogen.
- However, other sectors such as heavy transportation, exports, and natural gas blending will experience more penetration in the long run, once green hydrogen is readily available in India.



CAGR	2022-25	2025-30
Optimistic	202%	56%
Realistic	147%	57%
Pessimistic	59%	70%

The high growth in the CAGR between 2022 and 2025 is due lower base effect.

KEY ADVANTAGES THAT WILL HELP GREEN HYDROGEN GROW IN INDIA

- India can harness its plentiful renewable energy sources. As of June 2023, India had solar and wind installations with capacities of 70 GW and 43 GW, respectively.
- Under the Green Hydrogen Mission, India has ambitious plans to significantly increase domestic electrolyser production capacity, with a target of 60–100 GW by 2030.
- Availability of land banks across different energy rich states for setting up green hydrogen plants unlike countries such as Japan and South Korea which face land scarcity.

"The presence of a robust domestic consumption market will be beneficial in promoting green hydrogen production in India, as substituting existing demand for grey hydrogen is expected to drive the green hydrogen market. However, it should be noted that any large-scale replacement will either require a hydrogen policy change or price parity between grey and green hydrogen." — UKIBC analysis

WHAT INDUSTRY EXPERTS HAVE TO SAY ABOUT GREEN HYDROGEN IN INDIA

Green hydrogen has US$19 billion market in India by 2030 as per McKinsey report. Indian government has announced Green Hydrogen Mission earlier this year and allocated US$2.4 billion under this mission. Our bureaucrats need to adopt a progressive mindset in implementing this mission. Already, India emits less CO2 compared to developed economies. By developing affordable green hydrogen technologies and equipment, we can further reduce emissions and accelerate our transition to net zero. — President, All India Association of Industries (AIAI)

The announcement of incentives under the National Hydrogen Mission Plan, along with the scale of likely hydrogen demand (25 MT by 2030) in the country, positions India as amongst the top 3 attractive nations globally for green hydrogen demand and production. It is a crucial policy measure in establishing India as a leader in manufacturing and production of green hydrogen. What will be required alongside this ambitious mission is to create adequate demand by transiting hard-to-abate user industries through incentives and obligations towards green hydrogen. — Energy, Resources and Industrials Partner, Deloitte India

The Cabinet's approval of the NGHM and the financial outlay & incentives for the SIGHT programme[1] *is an expected & welcome next step in India's plans for energy transition, decarbonisation, and to become a global hub for production of green hydrogen. The financial support from government will generate increased interest and investment from the private sector and help in making this presently expensive sector more viable. Having said that, the industry will now look forward to the introduction of a robust and enabling regulatory framework for the green hydrogen sector.* — Partner – Energy and Infrastructure, Induslaw

If we are to have a robust market for green hydrogen, we need to generate demand from end users, especially public procurement for industries like steel and cement that are currently carbon intensive. Although green hydrogen is now considered as a viable way to cut carbon emissions, major challenges remain in scaling up the technology and making it cost-effective. It is also not certain the demand will grow proportionately, and the fuel may not become the first choice in transport and industry. — Director, Department of Energy, United Nations Industrial Development Organisation

The priority of the steel sector today is to decarbonise and do it in a way that are both technologically and economically sustainable. While the current levels of carbon footprint from the steel sector is unsustainable, the available version of clean hydrogen faces numerous challenges like high operational cost and energy loss. We are committed to finding a solution to these challenges and have created a platform like 'Tata Steel – Sprint to Zero 2023' to ensure the best minds from academia and industry join hands in this effort. We are delighted to launch the Sprint initiative in partnership with the UK Government and look forward to a unique collation of UK and Indian innovation policymakers, R&D companies, start-ups, hubs and places, investors, research groups and Catapults. — Vice President, Technology and R&D, Tata Steel

India, thanks to its abundant renewable capacity, is set to be one of the lowest (cost) sources of green hydrogen. I think India, in my view, cannot afford to miss this historical opportunity to be a leader, to be a superpower in green hydrogen. India is making rapid strides in clean energy and energy transition, even as it remains a key growth driver for oil demand. — Executive Director, IEA

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[1] *SIGHT programme is a part of India's NGHM that will fund the domestic manufacturing of electrolysers and produce green hydrogen.*

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MAJOR PLAYERS IN GREEN HYDROGEN SPACE IN INDIA

Player type	Player	Electrolyser OEM	Technology	Size of investment	Investment details
Renewable Energy developers	Reliance	Stiesdal	Alkaline	US$10 billion total	Reliance has partnered up with Stiesdal to manufacture Hydrogen electrolysers.
	Greenko	John Cockerill	Alkaline	US$500 million	Greenko and John Cockerill entered a JV to manufacture electrolysers for green hydrogen and ammonia plants.
	Adani	Looking for partners	TBD	Not known	Adani group is planning to build a 5 GW electrolyser factory; that will produce 3 MMT per year of hydrogen by 2030.
	NTPC REL	Hild Electric	Alkaline	Not known	Hild Electric provides alkaline electrolyser technology to NTPC REL. Under the agreement, 600 MW capacity solution will be deployed across a range of industrial applications.
Oil and Gas	Oil India Limited	homiHydrogen	AEM	Not known	Oil India Limited and homiHydrogen have partnered to manufacture electrolysers in India.
	BPCL	Bhabha Atomic Research Centre	Alkaline	Not known	BPCL will work with BARC to scale up its alkaline electrolyser technology.
	GAIL	Looking for partners	PEM	Not known	GAIL released an EoI for partner selection for setting up of a 10 MW capacity PEM electrolyser, which will produce 4.3 tonnes/day.
Project EPC	L&T	Hydrogen Pro	Alkaline	Not known	L&T and Hydrogen Pro have signed an MoU for setting up GW-scale manufacturing of alkaline hydrogen electrolysers in India.
	BHEL	Looking for partners	TBD	Not known	On 29 March 2023, BHEL issued an EoI for technology tie-up to address upcoming tenders of electrolysers for hydrogen production.
Electrolyser OEMs	Ohmium		PEM	US$250 million funding	Ohmium has a production capacity of ~0.5 GW per year and is currently targeting US exports market; Planned expansion to 2 GW per year.
	H2e Power		SOEC AEM	US$50 million	Plans to establish 1GW manufacturing capacity of SOEC electrolyser in Maharashtra.
	Greenzo Energy Pvt. Ltd.		Alkaline and AEM	US$60.4 million	Plans to establish 250MW manufacturing capacity with an investment of US$61 million in Gujarat.

STEADY INCREASE IN INVESTMENTS FROM DOMESTIC AND GLOBAL PLAYERS

2023

- In May 2023, **ACME Group** and **IGL** signed a MoU to promote the adoption of green hydrogen and generate demand for it within India. Through this collaboration, they will explore the potential for hydrogen generation plants and electrolysers, with the aim of blending green hydrogen into IGL's existing pipeline networks.
- In April 2023, **NTPC** announced its plans to set up a US$13.4 billion green hydrogen hub in Pudimadaka in Andhra Pradesh.
- In March 2023, **L&T** and **McPhy** inked a legally binding agreement for a long-term partnership to investigate the potential in the developing green hydrogen industry. L&T will receive a sole license from McPhy to manufacture electrolysers using its pressurised alkaline electrolyser technology, including any upcoming product updates.
- In February 2023, Germany-based **Uniper** signed an MoU with **Greenko** to source green ammonia. Greenko's Kakinada (Andhra Pradesh) unit currently produces green ammonia using an electrolyser fuelled by electricity produced by 2.5 GW of renewable assets. This offtake agreement is for 8-10 years, starting from 2025. Under the agreement, the entities will negotiate a purchase agreement for 250,000 TPA of green ammonia for export to Europe.
- In February 2023, the **Department of Science and Technology** and Germany's **Fraunhofer Institute for Solar Energy Systems** signed a LOI for a long-term collaboration focusing on hydrogen and other green technologies.
- In January 2023, **NTPC** and **Gujarat Gas** commissioned India's first green hydrogen blending project in the PNG network of the NTPC Kawas township in Surat, Gujarat.

2022

In December 2022, **NLC India Limited** and **Grid Corporation of Odisha** signed an MoU to set up ground-mounted/ floating solar power, pumped hydro storage and green hydrogen projects in Odisha.

In October 2022, **Greenko** signed an MoU with **Keppel** Corporation to supply 250,000 tonnes of green ammonia per annum for Keppel's 600 MW power plant in Singapore.

In August 2022, **Shell India** and **Ohmium** signed a contract to assess hydrogen uses, markets, and project potential both domestically and internationally. Both parties will establish joint working groups in accordance with the MoU to evaluate potential from the technical, commercial, and safety aspects.

- In August 2022, **Jindal** Stainless Ltd. signed an offtake agreement with **Hygenco** India Pvt. Ltd. to build, own, and operate a multi-MW green hydrogen facility for 20 years. The plant is targeted to be commissioned in the Q3 CY 2023. The project will house an alkaline electrolyser with up to 75 TPA capacity in initial phase, expandable to 250 TPA.
- In May 2022, **GAIL** announced plans to set up a 4.3 TPD (~10 MW) green hydrogen plant in the state of Madhya Pradesh.
- In April 2022, **Oil India** commissioned the country's only pure green hydrogen pilot plant with an installed capacity of 10 kg per day at its Jorhat pump station in Assam.
- In February 2022, **Reliance** announced plans to invest US$75 billion in renewable energy and green hydrogen projects.

2021

- In December 2021, **L&T** and **ReNew** signed an agreement to jointly develop, own, execute, and operate green hydrogen projects.
- In August 2021, the **NGHM** was announced.

SOVEREIGN GREEN BONDS COULD BE GAME CHANGER WHEN IT COMES TO PROJECT FINANCING

GREEN HYDROGEN PILOT PROJECTS IN INDIA

- 5 Nm3/h green hydrogen project based on solar energy and electrolysis in Gurugram, Haryana.
- 6 Kg per hour green hydrogen production project based on biomass gasification in IISc (Indian Institute of Science) Bengaluru.
- ACME's green ammonia project in Bikaner, Rajasthan, produces green hydrogen at a rate of 500 Nm3/h or ~175 TPA.

KEY FOREIGN INVESTMENTS

- On 29 July 2023, the 'Green Hydrogen Electrolyser Manufacturing Ecosystem Assessment' project was launched. Through the project, the UK will help Indian companies develop a framework for manufacturing electrolysers in Tamil Nadu with a view to expand the production of green hydrogen as a source of power and heating in the state.
- On 8 February 2023, the European Investment Bank signed an MoU with the IH2A to provide US$1.06 billion to develop large scale hydrogen hubs and projects across India.
- Essar Group plans to invest US$1.2 billion in developing low carbon fuels in India, including green hydrogen and ammonia, which will be shipped from India to the UK, Europe and globally.

POTENTIAL SOURCES OF PROJECT FINANCING FOR GREEN HYDROGEN

TYPE OF ORGANISATIONS	DETAILS	POTENTIAL PLAYERS IN INDIA
Development Finance Institutions (DFI)	• DFIs, and multilateral development banks, are ideally situated to assist emerging economies like India in realising the economic and climatic potential of the green hydrogen industry. • Most global DFIs are present in India and have investments in the renewable energy sector.	European Investment Bank ADB ASIAN DEVELOPMENT BANK AIIB ASIAN INFRASTRUCTURE INVESTMENT BANK British International Investment IFC FMO Finance for Development KFW Norfund finnfund
Domestic and International Commercial Banks	• Domestic and foreign banks have become the primary source of financing for large-scale renewable energy projects. • Offer flexible terms when compared to DFIs.	ENERGY FOR EVER इरेडा IREDA ONCE IREDA ALWAYS IREDA SBI MUFG पी एफ सी PFC IDBI BANK standard chartered ICICI Bank
Export Credit Agencies (ECA)	• ECAs are a crucial source of liquidity for project financing transactions, especially in the energy sector, and have proven their ability and willingness to absorb risks (including technological and geographic/political risks) that commercial lenders are unable to accept.	EH EULER HERMES bpifrance UK Export Finance NEXI JBIC Korea Eximbank The Export-Import Bank of Korea
Green Bonds	• Green bonds can assist in mobilising cost-effective global finance for green hydrogen projects. • India has joined a growing number of nations that have issued sovereign thematic bonds in January 2023 by issuing its first pair of sovereign green bonds.	गाजियाबाद नगर निगम greenko इन्दौर नगर पालिक निगम
Venture Capitalist (VC) / Private Equity	• By 2026, Transition VC hopes to assist up to 40 early-stage startups in areas of e-mobility, green hydrogen, energy storage and net-zero, and climate-tech solutions with tickets ranging from US$0.5 to US$1 million. • To build green hydrogen projects, Hygenco has recently raised US$25 million funding from Neev II Fund, a private equity fund.	TRANSITION VENTURE CAPITAL NEEV FUND AVAADA

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INDIA IS ONE OF THE FIRST MOVERS WITH A COMPREHENSIVE FRAMEWORK IN PLACE

> *"India has set its sight on becoming energy independent by 2047 and achieving Net Zero by 2070. To achieve this target, increasing renewable energy use across all economic spheres is central to India's Energy Transition. Green Hydrogen is considered a promising alternative for enabling this transition." — GOI Green Hydrogen portal*

NATIONAL GREEN HYDROGEN MISSION

TOTAL OUTLAY

US$2.4 billion

(₹197.4 billion)

SIGHT PROGRAMME	PILOT PROJECTS	R&D	OTHER MISSION COMPONENTS
US$2.1 billion	**US$177.8 million**	**US$48.4 million**	**US$47.2 million**
(₹174.9 billion)	(₹14.7 billion)	(₹4.0 billion)	(₹3.9 billion)

The National Green Hydrogen Mission will be rolled out in two 'phases' — a foundational phase and a deployment phase. This will allow it to adjust to the dynamic nature of the evolving technologies and local needs.

PHASE 1 (2022–26)

- Deployment of green hydrogen in sectors already using hydrogen is the main emphasis of this phase.
- By catalysing R&D, this phase will lay the groundwork for future energy transitions in other hard-to-abate sectors.
- Scaling up production and use of green hydrogen under this phase will lower costs and hence allow wider deployment of green hydrogen in the subsequent phase.

PHASE 2 (2026–30)

- Green hydrogen costs are expected to become competitive with fossil-fuel based alternatives in refinery operations and the fertiliser sector.
- The potential of commercial scale use of green hydrogen in steel, mobility, and shipping sectors will be explored.
- Activities in the second phase would increase penetration across all possible sectors and promote a significant decarbonisation of the economy.

PROJECTED MISSION OUTCOMES BY 2030

Abatement of **50 MMT** of annual greenhouse gas emissions

5 MMT annual green hydrogen production capacity

US$97 Billion (₹8 Trillion) total investments

60-100 GW electrolyser capacity

600,000 jobs

125 GW renewable energy capacity for green hydrogen generation and associated transmission network

US$12 Billion (₹1 Trillion) reduction in fossil fuel imports

MAIN ASPECTS OF THE POLICY

Lowering the actual cost of green hydrogen by inclusion under RPO (Renewable Purchase Obligation), elimination of inter-state transmission charges, and enabling banking of surplus renewable energy for up to 30 days.

Initiate the set-up of **manufacturing zones** for production.

Creating a single platform for all necessary clearances and permissions to simplify market participation.

Increasing production flexibility by including **biomass** in the definition of the "green energy basket."

Free transmission for 25 years, if the production facility is commissioned before June 2025.

GREEN HYDROGEN MISSION LAYS THE GROUNDWORK BUT IT NEEDS TO BE FINE TUNED

Initiatives under the Green Hydrogen Mission such as the waiver of inter-state transmission charges, open access for sourcing renewable energy, creation of manufacturing zones for green hydrogen production, permitting banking of renewable energy etc. have been welcomed and immensely appreciated by the industry. However, experts and industry stakeholders have highlighted some aspects which, if addressed, can make the policy framework more robust.

INDUSTRY OPINION ON EXISTING POLICIES

Awaiting government mandates: Despite the obvious value of green hydrogen, PSU-dominated large end-use segments of refinery and fertiliser are likely to wait for stronger signals from the government in the form of **blending mandates, off-take guarantees** (e.g., SATAT — Sustainable Alternative Towards Affordable Transportation), or **minimum floor pricing**, before committing to a full-scale switch to green hydrogen.

Need clear guidelines on distribution of R&D funding: The mission/policies lack clear guidelines on dispersion of R&D funding and support, which is currently restricted to handful of large corporates capable of undertaking capital-intensive early investments.

Lack of planning and policy design: There are gaps in planning and policy design relating to industry relocation, land and water use, and local communities for renewables. Right now, renewables are concentrated in few states which will act as a pull factor for green hydrogen.

Clear guidelines regarding use of fresh water: Since large volumes of fresh water is needed for green hydrogen generation, there must be objective guidelines to ensure that the pursuit of clean energy does not negatively affect the availability of potable water.

Interstate taxes remain a key challenge: There are still problems with interstate taxes and accounting for transmission losses, among other things, despite the government's announcement that it supports abolishment transmission fees and permitting banking of green power.

Benefit of exporting green hydrogen needs to be weighed against its cost: The National Green Hydrogen Mission will lead to the creation of export opportunities for green hydrogen and its derivatives. Again, the benefits of exporting hydrogen need to be weighed against the costs in energy, greenhouse gas emissions and other resources.

UKIBC OPINION

- At present the production of green hydrogen in India is negligible. Production increase dependents upon conducive policy framework and offtake commitments from industries; the former is being worked upon, while the latter is missing.
- The central government's 25-year waiver of interstate transmission charges for solar and wind power projects which will be completed by the end of CY 2023 will also encourage capacity growth.
- Electrolyser manufacturing facilities with a cumulative capacity of 8 GW have been announced; to be operational by 2025. It is important for the government and the industry to work together to develop or commercialise technologies that cater to specific Indian conditions and needs. Moreover, electrolyser membranes (which is 30% of overall manufacturing cost) are imported to India. To increase electrolyser manufacturing capacity, India must become self-reliant for components and acquire the necessary technology to manufacture complete electrolysers.
- The current LCOH for green hydrogen production in India is estimated to be US$3,800-4,800 per tonne**.** For increased adoption of green hydrogen in the industry, there needs to be price parity between grey and green hydrogen. Costs must come down to less than US$2 per kg.

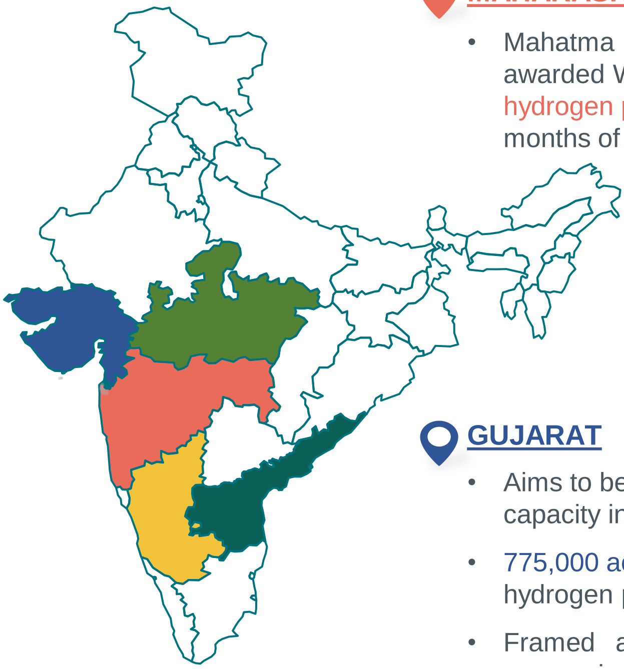
“As green hydrogen manufacturing and technologies are quite recent in India, manufacturers of renewable energy and green hydrogen need to have economies of scale coupled with strong support from the government like subsidies, investments, demand creation, better PLI schemes, removal of taxation on modules imports from China, smooth grid banking facility in order to be able to produce green hydrogen at a competitive price and at heavy scale. Given the absence of these support, achieving the government stated visionary level of 5MMT green hydrogen production in India seems impossible for now.” — Deputy General Manager (Green Hydrogen and Renewables), Essar Power

KEY ACTIVITIES IN GREEN HYDROGEN ENABLER STATES (1/2)

The government has identified 10 potential states that could be **the key enablers in manufacturing green hydrogen** in India to kickstart its NGHM. The identified states (in no specific priority order) are:

Andhra Pradesh	Gujarat	Karnataka	Kerala	Madhya Pradesh
Maharashtra	Odisha	Rajasthan	Tamil Nadu	West Bengal

> *"These states have been identified based on the existing steel and fertiliser industries, refineries and ports located there, along with the operational and potential renewable energy generation capacity in the regions. At some locations, we have also incorporated the CGD network as that is another sector that can offtake green hydrogen." — Senior Official, MNRE*



MAHARASHTRA

- Mahatma Phule Renewable Energy & Infrastructure Technology Ltd. has awarded Waaree Renewable Technologies Ltd. a LOI to execute a 1 MW green hydrogen project in Maharashtra. The project is expected to be finished within 12 months of receiving the LOI.

KARNATAKA

- As a part of centre's encouragement to produce and use green hydrogen, Karnataka, over the past three years, has signed agreements worth US$30.5 billion with firms manufacturing green hydrogen and its derivatives.

GUJARAT

- Aims to become the world centre for green hydrogen with 8 MTPA production capacity in another 10-12 years.
- 775,000 acres of land has been earmarked by the state government for green hydrogen projects.
- Framed a land policy where the government is allocating wasteland to companies for green hydrogen production, at a lease for 40 years with annual rent of US$183 per hectare with a 15% increase every 3 years.
- Ocior energy has signed a MoU with government to invest US$4.9 billion in Gujarat to set up a facility to produce 1 million tonnes of green hydrogen and ammonia per annum.

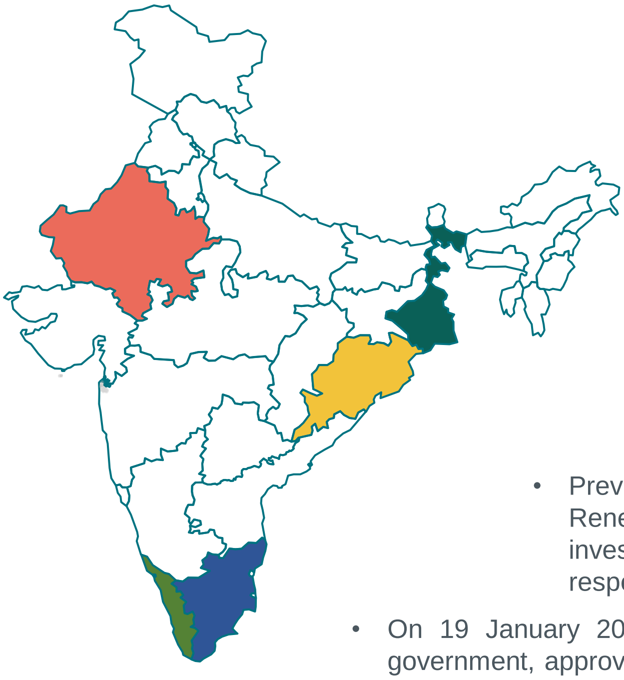
MADHYA PRADESH

- GAIL India Limited will set up India's largest PEM Electrolyser in Guna, which will start production of green hydrogen by the end of 2023.
- BPCL is setting up a 20 MW green hydrogen unit in Madhya Pradesh.
- A JV of Watomo Energies Ltd and Biezel Green Energy made an investment of US$2.9 million to put India's first commercial-scale biomass-based hydrogen plant in Madhya Pradesh which will produce a tonne of hydrogen per day, from 30 tonnes of biomass feedstock.

ANDHRA PRADESH

- Amplus Solar aims to set up 7,500 tonne per annum-distributed green hydrogen plants for industrial consumption with an investment of US$182 million.
- NTPC, which is setting up a more than US$12.2 billion green hydrogen hub in coastal Andhra Pradesh, will install 13.4 GW of solar power and 6.6 GW of pumped storage project (PSP).

KEY ACTIVITIES IN GREEN HYDROGEN ENABLER STATES (2/2)



RAJASTHAN

- Jakson Group has signed an MoU with Rajasthan government to roll out a US$2.7 billion project to set up a 365,000 TPA green hydrogen and green ammonia plant along with an integrated hybrid renewable power complex in the Kota district.
- For renewable energy, storage, and green hydrogen, the state government of Rajasthan has signed multiple MoUs with private and public players, with a total of at least US$14.85 billion investments by these companies.
- Some of the projects include building of 5 GW and 5.2 GW renewable energy projects by Tepsol Sun Sparkle and ONGC respectively; a 1.8 GW solar park by Malur Renewables; a 1.5 GW renewable energy and green hydrogen project by Aditya Birla Renewables; and others.

ODISHA

- Odisha aims to have 10 GW of installed renewable energy capacity by 2030.
- Previously it has also approved various proposals by Avaada Green H2, Renew Efuels and Ocior Energy to set up green ammonia plants entailing investments of US$2.9 billion, US$2.4 billion and US$0.9 billion, respectively.
- On 19 January 2023, the High-Level Clearance Authority committee of the Odisha government, approved the proposal of ACME Clean Energy, which entails an investment of US$7.1 billion to set up a green hydrogen and green ammonia plant with a capacity of 1.1 million tonne at Kujanga, and a renewable energy unit of 4,500 MW solar power plant at Koraput and Kalahandi district.

TAMIL NADU

- The ACME group is setting up a green ammonia and green hydrogen plant in Thoothukudi with an investment of US$6.4 billion.
- According to an MoU signed with the government, Tata Power is setting up a 4 GW solar cell and module manufacturing capacity in Tamil Nadu at an investment of US$366 million.
- Petronas is seeking 10,000-acre land parcel in Tamil Nadu to set up a green hydrogen plant.

KERALA

- Aims to become a 100% renewable energy powered state by 2040 and a net carbon neutral state by 2050.
- On 3 February 2023, the state government of Kerala announced a scheme of US$24.4 million for VGF, grant, equity support to set up green hydrogen hubs in Kochi and Thiruvananthapuram by 2025. The plan is to build a 60-TPD green hydrogen plant with a 150 MW electrolyser, storage and infrastructure.

WEST BENGAL

- The West Bengal Power Development Corporation Limited is planning to install a green hydrogen plant at Durgapur as a pilot project.
- Cabinet has approved a 500 MW floating solar plant at the Bakreshwar dam.

> *"From the above activities it is evident that green hydrogen investments and infrastructure even in the key enabler states is rudimentary at best. These forerunner states currently are in the process of increasing their respective renewable energy capacity. Therefore, it is obvious that it will be a few years before we see any complete or commercially viable green hydrogen infrastructure or value chain in any of these states." — UKIBC analysis*

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GROWTH LEVERS FOR GREEN HYDROGEN IN INDIA

SUBSIDY DEPLOYMENT

- The first step in establishing demand is to provide a subsidy for the use of green hydrogen.
- With a budget of US$1.59 billion, the government's mission paper proposes the Strategic Interventions for Green Hydrogen Transition (SIGHT), which will provide VGF for the generation of green hydrogen.
- As a result, the production cost of green hydrogen will go down due to subsidy on consumption, which will also generate demand from fertiliser and refinery units.

ENHANCE ELECTROLYSER MANUFACTURING

- SIGHT has allocated US$0.55 billion from its budget to support the production of electrolysers in India.
- This cash may be used to create PLI programmes for domestic electrolyser production and indigenisation. According to some estimates, India needs at least 40 GW of electrolyser capacity to produce 5 MMT of green hydrogen annually.
- PLI of up to US$70 per kW of manufacturing capacity will boost local production and add 850 GW of electrolyser capacity with export potential of US$425 billion from India.

PILOT PROJECTS

- The government has allocated US$0.18 billion from its budget for experimental projects including new uses for green hydrogen, such as steelmaking, mixing it with natural gas in pipelines, mobility, shipping, and aviation.
- Use of green hydrogen in these sectors will increase with successive drop in price of green hydrogen as the SIGHT initiative progresses.
- For instance, green steel is a growing market in industrialised nations, particularly in the automotive industry, despite being 50–70% more expensive than conventional steel. Having one of the lowest renewable energy tariffs and being the second-largest producer of steel, India has a lot of potential for manufacturing green steel.

UNIFORM STANDARDS

Focus on establishing norms and guidelines and coordinating India's green hydrogen programme with potential export markets and their standards.

The European Commission's new green hydrogen standard (effective February 2023) mandates the use of "additionality" of renewable energy in producing of green hydrogen. This means that the renewable energy must originate from a system that is no older than 36 months. This provision also mandates the monthly disclosure of information on the amount of renewable energy used and the amount of green hydrogen generated utilising that energy.

PPP

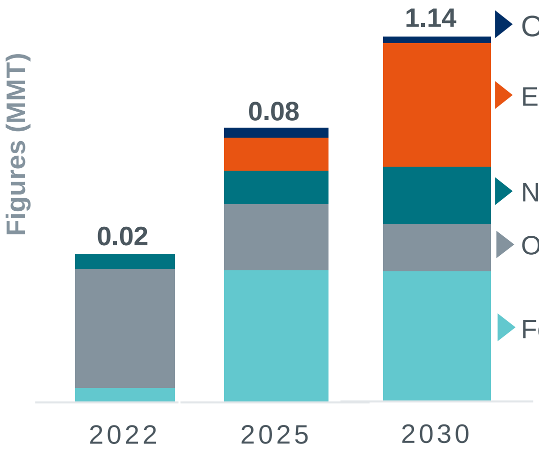
PPP models should be created to commercialise technologies which are still in the R&D or lower TRL tiers in Indian labs.

The National Green Hydrogen Mission budget includes US$48.78 million for R&D, which can be leveraged to create technology for every link in the value chain of green hydrogen. India's academic and research institutes have previously created green hydrogen technologies, but they lack the funding to commercialise then or move up the TRL tiers.

This grant should be used to create projects with specific goals to turn these emerging technology into finished goods.

END USER INDUSTRY ANALYSIS — PESSIMISTIC SCENARIO

ASSUMPTIONS: The base scenario here is the inability of green hydrogen to replace existing alternatives and only few technologies/concepts materialise. In this scenario by 2030, green hydrogen will replace 2.5% of total demand in oil refining industry; 5% green hydrogen will be blended into city gas pipelines; 20% of urea, DAP and ammonia imports will be substituted; and the country will meet ~3% of import demand of target markets (Singapore, Japan, Korea, and the EU, which are expected to have total import demand of 12.5 MMT by 2030.



	CAGR: 2025–30	DEMAND IN 2030	REQUIRED INVESTMENT
Other	46%	0.02 MMT	US$0.4 billion
Exports	108%	0.39 MMT	US$8.3 billion
Natural gas blending	78%	0.18 MMT	US$3.2 billion
Oil refining	50%	0.15 MMT	US$2.6 billion
Fertiliser	59%	0.41 MMT	US$8.7 billion

Total investment required until 2030 is **US$23.3 billion**

RE installations required
25 GW

Electrolyser installations required
12 GW

Carbon emissions avoided by 2030
24 MMT

TRENDS

- In a pessimistic scenario, green hydrogen demand in India is expected to reach 1.14 MMT by 2030, driven mostly by the oil refining, fertiliser, and natural gas blending.

Oil refining

- As hydrogen barely accounts for 2-4% of total raw material costs, the oil refining industry will be among the first to shift to green hydrogen due to its minimal influence on production economics.
- Even though not mandated by government, many oil PSUs have set internal targets for green hydrogen adoption.

Fertiliser

- Ammonia is the building block of all mineral fertilisers, which in turn uses hydrogen for its production. Green fertilisers can be produced, using ammonia made from green hydrogen.
- India currently imports 3 MMT ammonia annually. Furthermore, 26% and 55% of its urea and DAP requirements respectively are met through imports.

Natural gas

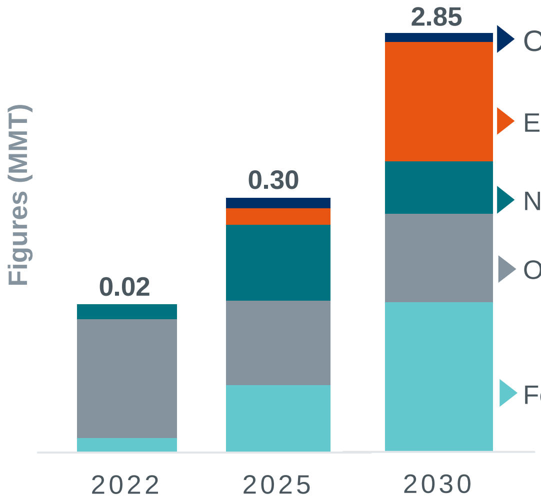
- Considering the significantly cleaner footprint of green hydrogen, the government is planning to blend natural gas in CGD projects.
- At present, multiple pilot projects are being carried out to assess the technical considerations of such blending.

> *“Indian state-run refiners are setting up projects to produce 30,800 tonne a year of green hydrogen by 2030. Refineries in the country already utilise hydrogen for internal consumption which has the potential to be converted into green hydrogen.” — Minister of State in the Ministry of Petroleum and Natural Gas, India*

> *“Oil refining and the fertiliser sector will be the first movers towards the adoption of green hydrogen in India. However, the adoption rate may be limited on account of initial high cost of green hydrogen, increased costs related to equipment upgradation and lack of support by the government.” — UKIBC Analysis*

END USER INDUSTRY ANALYSIS — REALISTIC SCENARIO

ASSUMPTIONS: In the realistic scenario it is assumed that the current momentum in public and private sectors will continue to grow, and most of the projects announced now will be implemented. By 2030, green hydrogen will replace 10% of total demand in the oil refining industry; 10% green hydrogen will be blended into city gas pipelines; 50% of urea, DAP and ammonia imports will be substituted; and the country will meet ~6% of import demand of target markets (Singapore, Japan, Korea, and the EU), which are expected to have total import demand of 12.5 MMT by 2030.



	CAGR: 2025–30[1]	DEMAND IN 2030	REQUIRED INVESTMENT
Other	38%	0.06 MMT	US$1.0 billion
Exports	110%	0.81 MMT	US$17.5 billion
Natural gas blending	32%	0.36 MMT	US$6.4 billion
Oil refining	43%	0.6 MMT	US$10.8 billion
Fertiliser	66%	1.02 MMT	US$21.9 billion

Total investment required until 2030 is US$57.6 billion

RE installations required
62 GW

Electrolyser installations required
29 GW

Carbon emissions avoided by 2030
61 MMT

TRENDS

- In a realistic scenario, green hydrogen demand in India could reach 2.85 MMT by 2030.
- Besides demand from early mover sectors such as oil refining and fertilisers, the energy sector is expected to witness considerable demand for green hydrogen. Moreover, export of green hydrogen is also expected to increase by 2030.

Natural gas

- India's natural gas consumption as of 2022 was 62 billion cubic metre, out of which 20% was used by CGD pipelines. Consumption is expected to increase to 200.75 billion cubic metre and 5-15% green hydrogen will be blended in CGD pipelines.
- GAIL has successfully blended up to 2% hydrogen in the Avantika gas pipeline (a CGD company in Indore, Madhya Pradesh). It further plans to gradually increase this mixing of hydrogen into natural gas system to 15%.

Exports

- Hydrogen is starting to play an important role the world's energy transition plans to achieve net zero targets. India, with its favourable renewable energy resources, is planning to ramp up production. This will cater to domestic demand as well as export to countries having less favourable renewable energy conditions but high decarbonisation targets.
- According to government reports, total hydrogen demand for Singapore, Japan, Korea and the EU will reach 12.5 MMT by 2030.

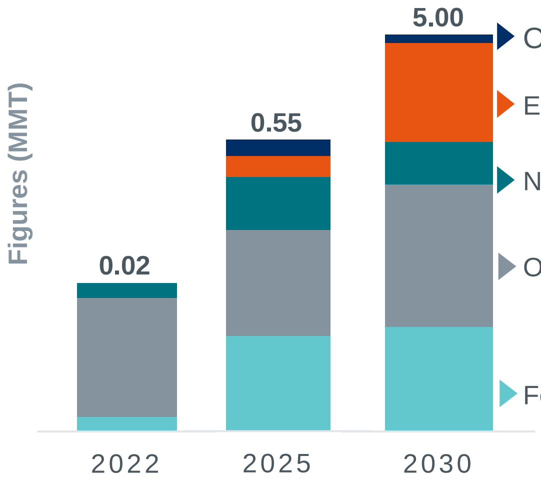
"The regulatory framework and standards of the green hydrogen export market need to be harmonised between India and the target countries. How these countries are defining green hydrogen and setting production standards and transportation infrastructure regulations around that will be a key aspect in this." — Partner, Cyril Amarchand Mangaldas

"To decrease reliance on imported natural gas and reduce carbon footprint, India intends to blend 5–15% hydrogen into CGD pipelines. However, this blending process has implications because of increased sensitivity of storage as well as the high cost of hydrogen production. Furthermore, blending hydrogen makes pipes brittle and its unstable nature makes it more susceptible to leaks as compared to natural gas. Therefore, it is important to closely monitor how this is resolved in the coming years and how businesses will cooperate to address these issues." — UKIBC Analysis

1) For some of the sectors, CAGR from 2025 to 2030 can be lower in the realistic scenario than in the pessimistic, owing to the better demand in 2025 for those sectors in realistic scenario, creating a higher base effect.

END USER INDUSTRY ANALYSIS — OPTIMISTIC SCENARIO

ASSUMPTIONS: In this scenario the assumption is that the government will impose large mandates, subsidies, and other incentives to stimulate demand and increase production capacity to at least 5MMT by 2030. In this scenario by 2030, green hydrogen will replace 30% of demand in oil refining industry; 15% green hydrogen will be blended in CGD pipelines; 65% of urea, DAP and ammonia will be substituted; and the country will meet ~10% of import demand of target markets (Singapore, Japan, Korea, and the EU), which are expected to have total import demand of 12.5 MMT by 2030.



	CAGR: 2025–30[1]	DEMAND IN 2030	REQUIRED INVESTMENT
Other	27%	0.1 MMT	US$1.7 billion
Exports	99%	1.25 MMT	US$26.9 billion
Natural gas blending	40%	0.54 MMT	US$9.7 billion
Oil refining	55%	1.8 MMT	US$32.5 billion
Fertiliser	49%	1.32 MMT	US$28.5 billion

Total investment required until 2030 is **US$99.4 billion**

RE installations required
109 GW

Electrolyser installations required
52 GW

Carbon emissions avoided by 2030
114 MMT

TRENDS

- In an optimistic scenario, green hydrogen demand in India could reach 5 MMT by 2030.
- This increase will be driven by higher demand from oil refining, fertilisers, natural gas blending, and exports. Additionally, multiple pilot and small-scale projects in other sectors such as steel, methanol, and transportation industry will contribute to short-term demand, with projections of large-scale demand after 2030.

Steel

- India's steel industry is the second largest producer of crude steel globally, which is expected to grow its capacity to 300 MMT by FY 2030-31.
- Green hydrogen can be integrated in the steel making value chain, which relies heavily on fossil fuels and is a major contributor of greenhouse gas emissions.

Methanol

- India is the third largest consumer of methanol. Methanol from green hydrogen is a promising low carbon liquid fuel and can be used as an alternative in areas like maritime transport. However, methanol ready transportation is limited, and any use cases based on green methanol replacement as a fuel will take years to reach large scale deployment.

Transportation

- India's transportation sector is responsible for 14% of energy-related CO_2 emissions
- Green hydrogen and green ammonia has the potential to drive medium- to long-term decarbonisation initiatives across road, railways, marine, and aviation sectors.

> *"India aims to produce 5 MMT of green hydrogen by 2030, with 70% earmarked for exports and the remaining 30% for domestic consumption. Five priority sectors, including fertilizer, refinery, long-haul mobility (with pilots already in place in industries such as steel, shipping, and long-haul transportation), have been identified for green hydrogen applications." — Secretary, Minister of New and Renewable Energy*

> *"India has strategic renewable energy advantage when it comes to green hydrogen, potentially and theoretically making it one of the most competitive green hydrogen generators in the world. Therefore, quite naturally, India is very serious about this alternative energy source. Green hydrogen could be India's panacea to its decarbonisation efforts, especially for energy intensive sectors such as iron and steel, chemicals, petroleum and transportation." — UKIBC Analysis*

1) For some of the sectors, CAGR from 2025 to 2030 can be lower in the optimistic scenario than in the realistic, owing to the better demand in 2025 for those sectors in optimistic scenario, creating a higher base effect.

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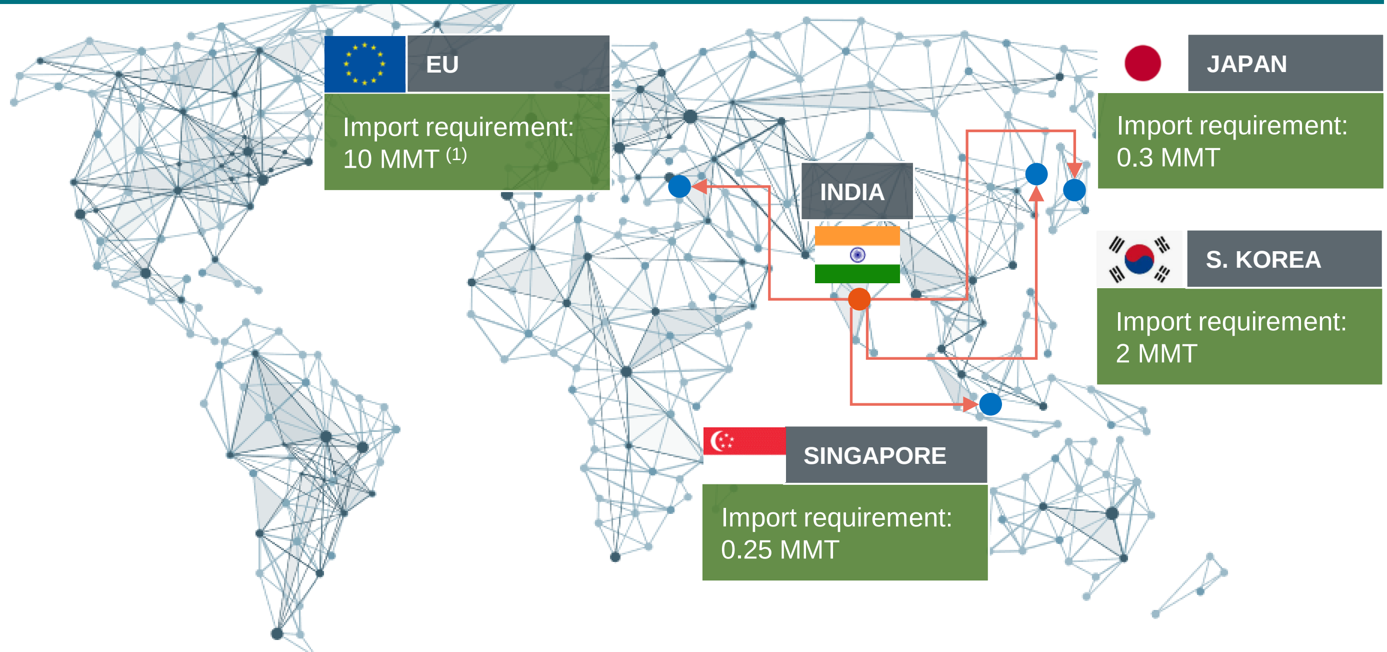
OWING TO HUGE GLOBAL DEMAND, INDIA COULD BE A MAJOR EXPORTER BY 2030

- According to forecast, by 2030, the import demand for green hydrogen from Singapore, Japan, South Korea, and the EU could cumulatively reach 12.5 MMT.
  - Based on their import requirement, distance from India, and current trade links, these nations may serve as India's primary export hubs.
  - Geographically, India has an advantage over other potential exporters such as the US and the UK.
  - Due to the lack of land and renewable resources needed to produce green hydrogen, many nations are likely to rely on imports. India may be able to export roughly 10 MMT of green hydrogen annually, capturing 10% of the global export market.
- Greenko, an Indian renewable energy company, already has an MoU in place to export 250,000 tonne of green hydrogen annually to Singapore from 2025-26.



1) Above mentioned import requirements refer to the import demand for green hydrogen by these nations by 2030.

INDIA EXPORT DESTINATIONS	SOUTH KOREA	EU	JAPAN	SINGAPORE	US	UK
RESOURCES AVAILABILITY	◔	●	◐	◔	●	◔
IMPORT REQUIREMENT	●	●	◐	◐	●	◔
TRANSPORTATION COST	◔	◐	◐	●	◔	◐

● HIGHLY FAVOURABLE ◐ FAVOURABLE ◔ UNFAVOURABLE

INDIA'S EXPORT SCENARIO ANALYSIS — 2030		GREEN HYDROGEN DEMAND	INVESTMENT REQUIRED (US$ BILLION)**
☹ PESSIMISTIC	Export up to 3% of the target markets'* total green hydrogen import demand.	**0.37 MMT**	**8.3**
🙂 REALISTIC	Export up to 6% of the target markets' total green hydrogen import demand.	**0.75 MMT**	**17.5**
😀 OPTIMISTIC	Export up to 10% of the target markets' total green hydrogen import demand.	**1.25 MMT**	**26.9**

**Target markets include the EU, South Korea, Japan and Singapore.*
***Investment required in export-oriented green hydrogen and ammonia projects for India to meet the export potential by 2030.*

> *"India is entering a technology field that is still in its infancy with the hydrogen mission. It is encouraging to see that a sizable portion of funding is going towards fostering production of electrolysers, related machinery, and green hydrogen. Although India appears to be headed in the right path, it is still too early to predict if India will be able to meet the green import demands of the EU, Japan, South Korea, and Singapore." — UKIBC Analysis*

Note: Please refer to the appendix for further information on why India can export to some countries but not others.

COLLABORATION COULD ESTABLISH BOTH INDIA AND THE UK AS GLOBAL LEADERS IN GREEN HYDROGEN

CORE GREEN HYDROGEN EXPERTISE

TECHNOLOGY → FUNCTION ↓	SOLAR TECHNOLOGY	WIND TECHNOLOGY	ELECTROLYSER TECHNOLOGY	WATER DESALINATION
	THE COUNTRY WITH MORE MATURE SYSTEMS, KNOW-HOW, AND TECHNOLOGY AND CAN MENTOR THE OTHER			
PRE-DEVELOPMENT	🇬🇧	🇬🇧	🇬🇧	🇬🇧
DESIGN AND DEVELOPMENT	🇬🇧	🇬🇧	🇬🇧	🇬🇧
CONSTRUCTION, INSTALLATION AND COMMISSIONING	🇮🇳	🇬🇧	🇮🇳 🇬🇧	🇮🇳 🇬🇧
OPERATIONS AND MAINTENANCE (O&M)	🇮🇳	🇬🇧	🇮🇳 🇬🇧	🇮🇳 🇬🇧

1. SOLAR POWER

🇬🇧 → 🇮🇳

- Knowledge transfer for choosing the best locations for installations, semiconductor materials and the substrate and for developing and sourcing solar modules.
- Selection and deployment of right technologies for integrating solar farms[1], storage and grid.
- Manufacturing support in developing more efficient thin solar cell modules.

🇮🇳 → 🇬🇧

- Support for engineering, design, and procurement for the development of steel ground-mounted and roof-mounted solar farm structures.
- Assistance with solar farm maintenance.

2. WIND POWER

🇬🇧 → 🇮🇳

- Knowledge transfer for choosing the right material (steel, composite fibres), coating materials and surface area for developing the blades of windmills.
- Selection and deployment of right technologies improving the efficiency and reliability of turbines and finding ways to handle intermittency in wind power supply.

3. ELECTROLYSERS AND WATER DESALINATION

🇬🇧 → 🇮🇳

- Knowledge transfer for designing and development of electrolysers, desalination equipment and on sub-technology areas (electrocatalyst material, diaphragms, membranes) and technology deployment for electrolysers and desalination.

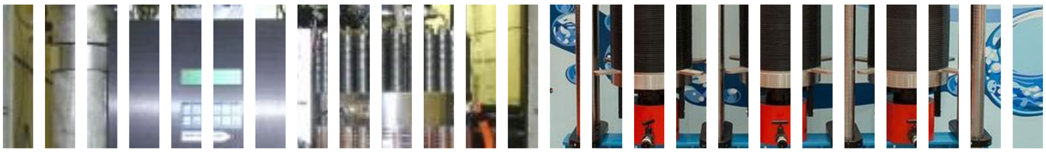
🇬🇧 + 🇮🇳

- It is possible for India and the UK to develop up their respective commercial production activities for electrolysers and desalination equipment as well as related maintenance activities through strategic collaboration.

Note 1: Applicable for wind farms as well.

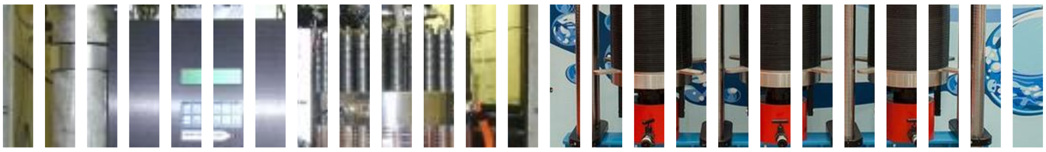
UK CAN HELP INDIA DEVELOP ITS OFFSHORE WIND CAPABILITIES; NEED TO COLLABORATE ON ELECTROLYSER TECHNOLOGY

OFFSHORE WIND	
COLLABORATION POTENTIAL	HIGH ★★★
GAPS IN INDIA	High installation cost, lack of local substructure manufacturers, installations vessels and trained workers.
	Lack of trained personnel with fundamental technical abilities, education, and specialisation in installation and maintenance.
	Limited R&D activities in offshore space.
	Lack of VGF.
UK ADVANTAGE	UK dominates the offshore wind market, owning 25% of the total global portfolio of offshore wind installations.
	Strong policy and regulation frameworks in place.
	Technical know-how, research and innovation capabilities and project development experience.
	Presence of companies with proven expertise of entire project lifecycle for offshore wind installation.
OPPORTUNITY	Policy support.
	Research and innovation (project design and development lifecycle).
	Manpower training and development.
	Green financing/project funding.
	Support in infrastructure development for renewable projects installation (including offshore wind).

ELECTROLYSER TECHNOLOGY	
COLLABORATION POTENTIAL	MEDIUM ★★☆
GAPS IN INDIA	India and UK are focusing on different electrolyser technologies; while UK is focused on PEM, India is more focused on alkaline, with few PEM experimental projects.
	Metals that are the most effective active catalysts in electrolysis — such as platinum and iridium — are not easily available in India.
	Not only the supply of catalysts, even providing the billions of litres of demineralised water for commercial electrolysis is a challenge.

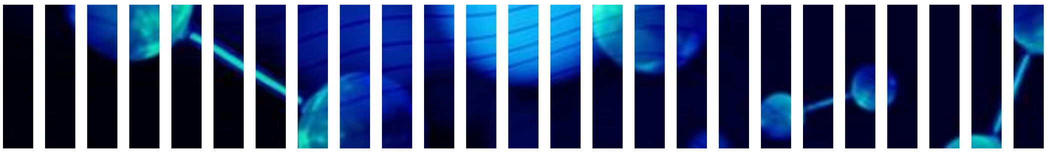
INDIA AND UK NEED TO LEVERAGE THE FORMAL COLLABORATIONS THAT ARE ALREADY IN PLACE

ELECTROLYSER TECHNOLOGY



UK ADVANTAGE	UK has created very effective electrolyser technologies, such as ITM Power's PEM technology, which is ideal for fluctuating renewable electricity from wind and solar power plants in India.
OPPORTUNITY	Joint research in exploring alternative catalyst materials. For example, combination of metal oxides that could be as effective and as corrosion-resistant as platinum and other expensive and rare metals being currently used as catalysts. Cost-effective ways of desalination or demineralisation of sea water. Given the scarcity of potable water in India, the only viable option is to use sea water. India has already initiated few pilot for PEM projects in collaboration with Spain and US. Similar opportunities with the UK on PEM technology should be explored.

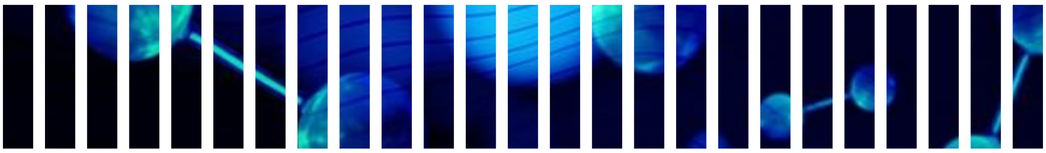
R&D



COLLABORATION POTENTIAL	HIGH ★★★
GAPS IN INDIA	A strategy defining India's R&D goals for producing and storing green hydrogen was announced in July 2023. The roadmap is still in the drafting stage and is seeking feedback from industry stakeholders. Lack of R&D in creating effective hydrogen storage techniques that enable leak-proof, high-density hydrogen storage and easy refuelling. There is little innovation in the material sciences domain with respect to hydrogen. There are limited options in terms of speciality materials such as high surface area materials, chemical hydrides, high entropy alloys, and composites to build compressed hydrogen tanks for solid state hydrogen storage. In terms of end-use, the amount of R&D and redesign of existing systems and equipment is not satisfactory. There is hardly any momentum even for processes and operations that can relatively easily adopt green hydrogen, such as blast furnaces and DRI processes, boiler and heat exchanger designs for using hydrogen and hydrogen-natural gas combinations, and specific types of internal combustion engines.
UK ADVANTAGE	UK is currently scaling up its electrolyser technology and has many R&D centres as well as testing facilities to develop next-generation products. The UK has already established itself as a global leader in integrating hydrogen into current energy systems. The H21 programme is a novel initiative to understand the effects of hydrogen in normal gas distribution network. UK universities such as University of Sheffield and University of Birmingham are undertaking research in areas of fuel cell, hydrogen generation via biomass gasification etc. In addition, UK has electrolysis testing and research facilities for PEM electrolysers with National Physical Laboratories (NPL), University College London (UCL), Oxford University, University of Southampton, University of Cambridge, Strathclyde, and other universities.

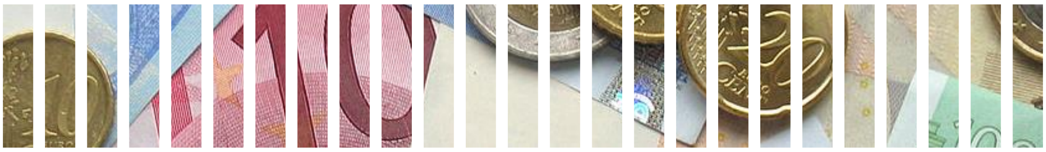
INDIA AND UK NEED TO LEVERAGE THE FORMAL COLLABORATIONS THAT ARE ALREADY IN PLACE

R&D



OPPORTUNITIES	The Hydrogen Innovation Initiative driven by UK's High Value Manufacturing Catapult is completely focused on the entire hydrogen value chain. Indian stakeholders stand to gain a lot by collaborating with this initiative.
	The Clean Hydrogen Mission (CHM) is a suitable platform for exchange of ideas. It is co-led by the UK and India is a core coalition member. Both countries need to leverage this platform better.
	Leverage the UK-India Green Hydrogen Hub and Accelerating Smart Power and Renewable Energy in India — a bilateral programme implemented by the FCDO in association with the Ministry of Power and the MNRE.
	Identifying areas that have applicability in both India and the UK and then joint funding such projects by both the governments.
	Joint research and partnership among academia and the industry in both countries for enhancing the functionality and durability of PEM electrolysers (priority area under India R&D roadmap). For example, the innovation centre at Oxford University have developed a novel electrode support coating that replaces platinum with silver-nanoparticles and is seeking industrial partners interested in further development of the technology.
	Opportunities for partnership, licensing, and co-development of innovative desalination method created by University of Birmingham which significantly reduces energy usage during desalination process.

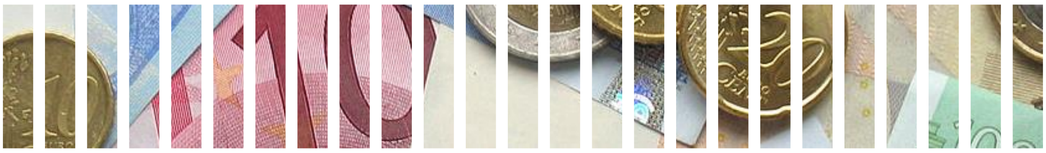
FINANCING



COLLABORATION POTENTIAL	MEDIUM	★★☆
GAPS IN INDIA	It would take an investment of about US$200 billion to produce 5 MTPA of green hydrogen by 2030. Whereas the government has announced an outlay of just US$2.25 billion. Therefore, there is a significant funding gap.	
	Commercial lenders (including banks) consider funding green projects risky. The reasons for such a view are because of issues such as possible delays in land acquisition, environmental approvals, scale and pace of development of necessary infrastructure, as well as the relatively smaller consumer base at present.	
	Public sector grants and other kinds of concessionary funding will be a crucial source of project finance during this early stage of development until enough private sector funding sources are available.	

INDIA AND UK NEED TO LEVERAGE THE FORMAL COLLABORATIONS THAT ARE ALREADY IN PLACE

FINANCING



UK ADVANTAGE	UK has a high emphasis on achieving net zero targets and has committed significant resources from both public and private sectors to offshore wind energy, hydrogen, and carbon collection, use, and storage. The British government has also announced funds worth US$1.25 billion (£900 million) to promote hydrogen projects in the UK, which they claim could result in the creation of more than 9,000 jobs by 2030.
OPPORTUNITY	Launching schemes for joint funding of green hydrogen projects in India and UK.
	Leverage the 'India Green Guarantee" announced by UK at COP26 (The UN Climate Change Conference in Glasgow) for funding the green projects across India.
	Leveraging the net zero commitments of UK companies present in India, and Indian companies present in India for funding requirements. The UK is home to leading oil and gas, and energy companies such as BP, Shell, EnQuest, Centrica etc. Such initiatives are already underway, for example, Essar Group investing US$1.2 billion in India's green hydrogen and low carbon fuels as a part of a total US$3.6 billion outlay for green energy for the UK and India.
	Attracting investment from PE, venture capitals and asset management companies. For example, India-based green hydrogen company Hygenco has received a US$28 million investment from SBICAP Ventures Ltd. in 2022. The company aims to deploy US$300 million in green hydrogen projects in India during 2023-25.
	India and UK are also committed to set up a world bank for green energy which could materialise the proposal for US$100 billion climate finance under the Paris Agreement.

OTHER OPPORTUNITY AREAS

1. **Policy and Regulation:** India and the UK can jointly create supporting legal and policy frameworks to promote green hydrogen projects. For example, through the Green Hydrogen Technical Assistance project, the UK will help Indian companies wanting to develop a framework for manufacturing electrolysers in Tamil Nadu, to expand the production of green hydrogen.
2. **Infrastructure Development:** India-UK collaboration could fast-track infrastructure development for green hydrogen production, storage, transportation, and distribution. This could involve sharing best practices, technological expertise, and funding for infrastructure projects.
3. **Capacity Building:** To develop human capacity in the area of green hydrogen technologies, the two nations can cooperate on training initiatives and knowledge-sharing platforms.
4. **Bilateral Agreements:** India and the UK can leverage existing agreements and enter into new bilateral agreements specifically focused on green hydrogen. These agreements could outline joint investment plans, technology transfer, and cooperation in R&D. For example, India and Germany entered into an agreement in 2022 to establish an Indo-German Green Hydrogen Task Force to strengthen cooperation in the production, utilisation, storage, and distribution of green hydrogen by creating enabling frameworks for projects, regulations and standards, trade, and joint R&D projects.

EVEN WITHIN THE ENABLER STATES THE LEVELS OF READINESS VARIES

STATES	INSTALLED CAPACITY OF SOLAR POWER	INSTALLED CAPACITY OF WIND POWER	FRESH WATER AVAILABILITY	PORT ACCESS (ACCESS TO EXPORT MARKET)	EASE OF DOING BUSINESS RANK	OVERALL ATTRACTIVENESS/ WEIGHTED AVERAGE
TAMIL NADU	2	5	3	5	5	● **3.7**
GUJARAT	3	5	2	5	5	● **3.6**
ANDHRA PRADESH	2	3	3	5	5	◕ **3.5**
KARNATAKA	3	3	2	4	5	◕ **3.3**
MAHARASHTRA	2	3	3	4	3	◕ **2.9**
ODISHA	1	1	3	5	3	◑ **2.6**
UTTAR PRADESH	1	1	4	1	3	◑ **2.3**
RAJASTHAN	5	3	1	1	1	◑ **2.2**
KERELA	1	1	3	5	1	◑ **2.2**
WEST BENGAL	1	1	3	3	1	◔ **1.9**
MADHYA PRADESH	1	2	2	1	3	◔ **1.8**

● VERY HIGH ◕ HIGH ◑ MODERATE ◔ LOW

“The states of Tamil Nadu and Gujarat are at the forefront of India's hydrogen production. At a cost of US$6.3 billion, ACME Green Hydrogen and Chemicals Pvt. Ltd. is setting up a green ammonia and green hydrogen plant in the port town of Thoothukudi, Tamil Nadu. This plant will be one of the largest plants in the world. Also, at ~10 GW capacity, Tamil Nadu has the maximum installed base of wind farms in the India — 25% of total installed capacity in India. The state has an additional potential of 60 GW of wind energy by 2030.

The state of Gujarat on other hand is leading in industrial development and has signed memorandums of understanding with several large corporations, including Reliance, Adani, ArcelorMittal, and Torrent. These firms together have committed to making significant investments in green energy projects. The state government has approved the allotment of 1990 sq. km of land in the Kutch-Banaskantha border areas for setting up green hydrogen projects. However, scarcity of freshwater continues to be a major issue and could be an opportunity for collaboration in wastewater treatment, desalination, and water conservation.” — UKIBC analysis

Note: Please refer to the appendix to know the methodology used for location assessment.

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PARAMETERS AND METHODOGY USED FOR LOCATION EVALUATION TO SETUP A GREEN HYDROGEN PLANT IN INDIA

Considered parameters and their weights for location evaluation:

PARAMETERS	WEIGHTAGE	RATIONALE
Freshwater availability	30%	Maximum weightage has been assigned to freshwater availability as it is a key ingredient used by electrolyser to produce green hydrogen and India is already facing water scarcity in many regions.
Installed capacity of Solar Power	25%	As India has vast solar energy potential, most of the green hydrogen production is likely is be done using solar power. So, for location evaluation, assessing solar power installed capacity is critical for location evaluation.
Ease of doing business rank	20%	This is taken as an important parameters for location evaluation as better EODB(1) indicates simpler business regulations, ease of getting clearances, hassle free allocations, etc.
Port access	15%	Easy access to the port ensures easy access to the export market. Export and local demand can be combined to achieve economies of scale.
Installed capacity of Wind Power	10%	As wind power is a capital-intensive form of power generation along with other problems such as seasonality and land availability, this parameter has been assigned the lowest weightage.

Methodology used to assign scores to each state for the above-mentioned parameters:

PARAMETERS	METHODOLOGY	SCORES				
		1	2	3	4	5
Freshwater availability	For this parameter, 1 represents the lowest and 5 represents the highest availability of fresh water.	Scarce	Limited Availability	Available	Easily Available	Abundance
Installed capacity of Solar Power	For this parameter, we captured the installed capacity of solar power in each state as on 31 July 2023, as published by MNRE. Intervals associated with each score are defined in the adjacent columns.	Less than or equals to 4,000 MW	4,001-8,000 MW	8,001-12,000 MW	12,001-16,000 MW	>16,000 MW
Ease of doing business rank	The BRAP (Business Reform Action Plan) 2020 report, released by Ministry of Commerce & Industry, groups Indian states into four categories based on their implementation of ease of doing business reforms. We used only three scores for this parameter. Which scores were assigned to which categories are mentioned in the adjacent columns.	States under “Aspirers” and “Emerging Business Ecosystems”, categories are all scored 1.		States under Achievers' category are all scored 3.	States under Top Achievers’ category are all scored 5.	
Port access (access to export market)	We have considered the distance of the nearest port from the main city center. Intervals associated with each score are defined in the adjacent columns.	Less than or equals to 200 Kilometres	201-300 Kilometres	301-400 Kilometres	401-500 Kilometres	>500 Kilometres
Installed capacity of Wind Power	For this parameter, we captured the installed capacity of wind power in each state as on 31 July 2023, as published by MNRE. Intervals associated with each score are defined in the adjacent columns.	Less than or equals to 2,000 MW	2,001-4,000 MW	4,001-6,000 MW	6,001-8,000 MW	>8,000 MW

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1. EODB refers to ease of doing business.

INDIA HAS AMBITIOUS PLANS TO EXPORT GREEN HYDROGEN TO THE EU, JAPAN, SINGAPORE, AND SOUTH KOREA BY 2030.

REGIONS	WHY INDIA HAS A POTENTIAL TO EXPORT? 👍
EU	• Due to energy deficiency and higher cost of energy generation in comparison to North African and Asian countries, the EU is inefficient in producing green hydrogen locally. • As part of the commitment to net zero emissions, there is increasing pressure in EU to reduce the use of fossil fuels in heavy industries and transportation and replace them with clean energy sources. • To eliminate the dependence on Russia for natural gas and other precursors used to make hydrogen. • Deployment of green hydrogen will allow the region to access cheap, clean energy from India. • It is very likely that the renewable energy potentials in Germany and the EU will not be sufficient to meet this demand cost-efficiently in terms of availability, economic efficiency and acceptance. Importing green hydrogen and synthesis products is therefore considered necessary.
JAPAN	• Japan is a country with limited domestic energy resources and has been actively seeking alternative energy sources to reduce its dependency on fossil fuels. India, on the other hand, has the potential to generate significant amounts of renewable energy, including green hydrogen. Exporting green hydrogen to Japan could be part of a larger energy cooperation strategy between the two nations. • India is working on a framework for carbon credit export with Japan. Japan has sent a draft on carbon trading. It is estimated that India can avert a loss of US$35 trillion because of unmitigated climate change over the next 50 years by allowing carbon credit exports. • Japan's topography and terrain doesn't allow setting up of large-scale green hydrogen and renewable energy plants. Due to which, Japan is looking to import at least 0.3 MMT per year of hydrogen by 2030.
SINGAPORE	• Since Singapore has very limited potential for producing renewable energy locally due to limited land availability and high urban density, it is expected to have significant import demand for green hydrogen by 2030. • Singaporean market is a prime target for India as transportation cost is expected to be low due to short distance. An MoU has already been signed to explore opportunities for an offtake of 0.25 million tonnes of green hydrogen per year to Singapore.
SOUTH KOREA	• In 2021, South Korea was the third-largest importer of liquefied natural gas in the world, and for many years, the nation's overseas dependence on energy was above 90%. • Production of green hydrogen in South Korea doesn't appear practical due to land scarcity. South Korea therefore intends to import hydrogen in order to fulfil its carbon reduction goals. • India can produce green hydrogen efficiently, whereas South Korea has advanced technology in fuel cells and hydrogen transportation. As a result, both countries can work together and have mutual synergies. • South Korea can import a large amount of Green Hydrogen, and with the help of South Korea, India can establish an advanced transportation sector.

OTHER COUNTRIES (NOT PRIORITISED CURRENTLY)	WHY DOESN'T INDIA CURRENTLY HAVE A POTENTIAL TO EXPORT? 👎
	• As the hydrogen transition plans are not yet determined in **Bangladesh** and **Sri Lanka**, these markets are not the prime target for India as of now. They could, though, turn into potential export destinations for India in the future. • Nations like **Chile**, the **MENA (Middle East and North Africa)**, **US**, **LATAM** and **Australia** are expected to be the green hydrogen exporters due to their enormous potential for effective green hydrogen production domestically. • Given that **China** produces over 33 MMT of hydrogen annually and has more than 120 green hydrogen projects in development, India is unlikely to sell green hydrogen to China. − China has already made significant investments in manufacturing capability, concentrating on the Alkaline electrolyser and dominating with 50% of the world's manufacturing capacity. Finally, unlike the EU, China has sufficient renewable resources to manufacture green hydrogen locally, so it is not required to import it. • **UK** also has laid down a firm strategy of achieving 10GW of low-carbon hydrogen by 2030. At the same time, UK is currently working on securing a “formal partnership” on hydrogen with Germany, which is gearing up to become a major importer of green H2 and its derivatives. − Moreover, UK has not set out any defined plan on importing green hydrogen from India or any other country, and rather stressing on become a global leader in green hydrogen production - thanks to its abundant renewable energy resources, strong industrial heritage, and skilled workforce.

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https://sarepenergy.net/wp-content/uploads/2023/05/GREEN-HYDROGEN-FINAL-Version.pdf
https://www.ceew.in/sites/default/files/ceew-research-on-hydrogen-decarbonisation-and-energy-secure-green-hydrogen-economy.pdf
https://pib.gov.in/PressReleasePage.aspx?PRID=1838178
https://mnre.gov.in/img/documents/uploads/file_s-1691583921213.pdf
https://timesofindia.indiatimes.com/business/india-business/india-to-export-green-energy-to-singapore-from-2025-greenko-keppel-sign-hydrogen-mou/articleshow/95076851.cms
https://www.financialexpress.com/business/industry-corporates-likely-to-invest-rs-16-trn-in-green-hydrogen-in-10-years-3012515/
https://www.eqmagpro.com/wp-content/uploads/2023/03/An-Ocean-of-Potential-Recommendations-for-Offshore-Wind-Development-in-India_compressed-1-5.pdf
https://mahaurja.com/meda/data/other/basichydrogentechnology.pdf
https://wri-india.org/blog/conventional-pathways-hydrogen-production
https://assets.ey.com/content/dam/ey-sites/ey-com/en_in/topics/energy-resources/2023/ey-accelerating-green-hydrogen-economy.pdf?download
https://assets.ey.com/content/dam/ey-sites/ey-com/en_in/topics/energy-resources/ey-unlocking-indias-green-hydrogen-ambitions.pdf?download
https://explore.mission-innovation.net/wp-content/uploads/2022/09/H2RDD-Global-FINAL.pdf
https://www.niti.gov.in/sites/default/files/2022-06/Harnessing_Green_Hydrogen_V21_DIGITAL_29062022.pdf
https://www.mecintelligence.com/mec-perspectives/articles/greening-India's-Hydrogen
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1092352/hydrogen-research-investment-brochure.pdf
https://static.pib.gov.in/WriteReadData/userfiles/India%20Country%20Status%20Report%20on%20Hydrogen%20and%20Fuel%20Cell.pdf
https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Nov/IRENA_Green_hydrogen_policy_2020.pdf?rev=c0cf115d8c724e4381343cc93e03e9e0
https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2022/Mar/IRENA_Green_Hydrogen_Industry_2022_.pdf?rev=720f138dbfc44e30a2224b476b6dfb77
https://cstep.in/drupal/sites/default/files/2022-09/Macroscopic%20Analysis%20of%20Hydrogen%20Economy_Final.pdf
https://mnre.gov.in/img/documents/uploads/file_f-1673581748609.pdf
https://www.teriin.org/sites/default/files/2021-07/Report_on_The_Potential_Role_of_%20Hydrogen_in_India.pdf
https://www.thehindu.com/news/cities/puducherry/nlcil-inks-mou-with-grid-corporation-of-odisha/article66214558.ece
https://www.larsentoubro.com/pressreleases/2023-03-22-lt-signs-agreement-with-mcphy-for-electrolyzer-manufacturing/
https://economictimes.indiatimes.com/industry/renewables/acme-igl-ink-initial-pact-to-explore-biz-avenues-in-green-hydrogen/articleshow/100003434.cms?from=mdr
https://www.uniper.energy/news/uniper-and-greenko-signed-exclusivity-for-green-ammonia-offtake-to-eu-from-indias-first-green-ammonia-project-in-kakinada
https://timesofindia.indiatimes.com/city/ahmedabad/gujarat-gas-ntpc-commission-indias-first-green-hydrogen-project-in-surat/articleshow/96733570.cms
https://www.thehindu.com/news/cities/chennai/uk-to-help-indian-companies-manufacture-electrolysers-for-green-hydrogen/article67135974.ece
https://www.knowesg.com/companies/essar-invests-usd3-6b-in-uk-and-indias-energy-shift-28022023#:~:text=Apart%20from%20investing%20US%242.4,global%20demand%20for%20green%20hydrogen.
https://timesofindia.indiatimes.com/city/bengaluru/green-hydrogen-in-3-years-pacts-worth-rs-2-5-lakh-crore-inked-in-karnataka/articleshow/97016996.cms
https://timesofindia.indiatimes.com/city/ahmedabad/green-hydrogen-projects-on-fast-track-in-gujarat/articleshow/96754863.cms
https://currentaffairs.adda247.com/indias-first-biomass-based-hydrogen-plant/
https://www.projectstoday.com/News/NTPC-to-install-20-GW-RE-capacity-at-hydrogen-hub#:~:text=NTPC%20will%20install%20a%20total,hub%20in%20coastal%20Andhra%20Pradesh.
https://solarquarter.com/2023/04/01/waaree-renewable-technologies-to-execute-1-mw-green-hydrogen-project-in-maharashtra/
https://energy.economictimes.indiatimes.com/news/renewable/kerala-announces-rs-200-crore-for-setting-up-green-hydrogen-hubs-over-next-2-yrs/97573710#:~:text=%E2%80%9CA%20scheme%20of%20Rs%20200,is%20also%20earmarked%20for%20this.
https://www.telegraphindia.com/business/bengal-to-add-capacity-in-renewable-energy/cid/1901812
https://www.cseindia.org/odisha-s-nod-for-green-hydrogen-re-projects-11613

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