Charting the Future: Green Hydrogen Expansion and PNGRB's Pivotal Role

Stakeholder workshop

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Project Objective & Scope

- Task 1: Mapping demand-supply with respect to supply infrastructure
- Task 2: Technical Assessment of the Pipeline Sector
- Task 3: Commercial assessment of pipeline sector
- Task 4: Policy and Regulatory Framework
- Task 5: Roadmap for Transmission of Hydrogen Infrastructure (Pipeline)

PNGRB

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Exploring the possibility of blending low carbon hydrogen in existing and upcoming NG infrastructure

Develop roadmap and action plan for PNGRB to support low-carbon hydrogen in NG pipelines

Key stakeholders consulted for this study

Demand Assessment

- Centre For High Technology, Ministry of Petroleum & Natural Gas, Government of India
- IndianOil
- TATA
- SIAM – Society of Indian Automobile Manufacturers
- ESSAR
- GUJARAT GAS
- IFFCO – Indian Farmers Fertiliser Cooperative Limited
- Paradeep Phosphates
- The Fertiliser Association of India

OEMS

- Honeywell
- Cummins
- Bharat Heavy Electricals Limited – Powering Progress, Brightening Lives Touching Every Indian Home

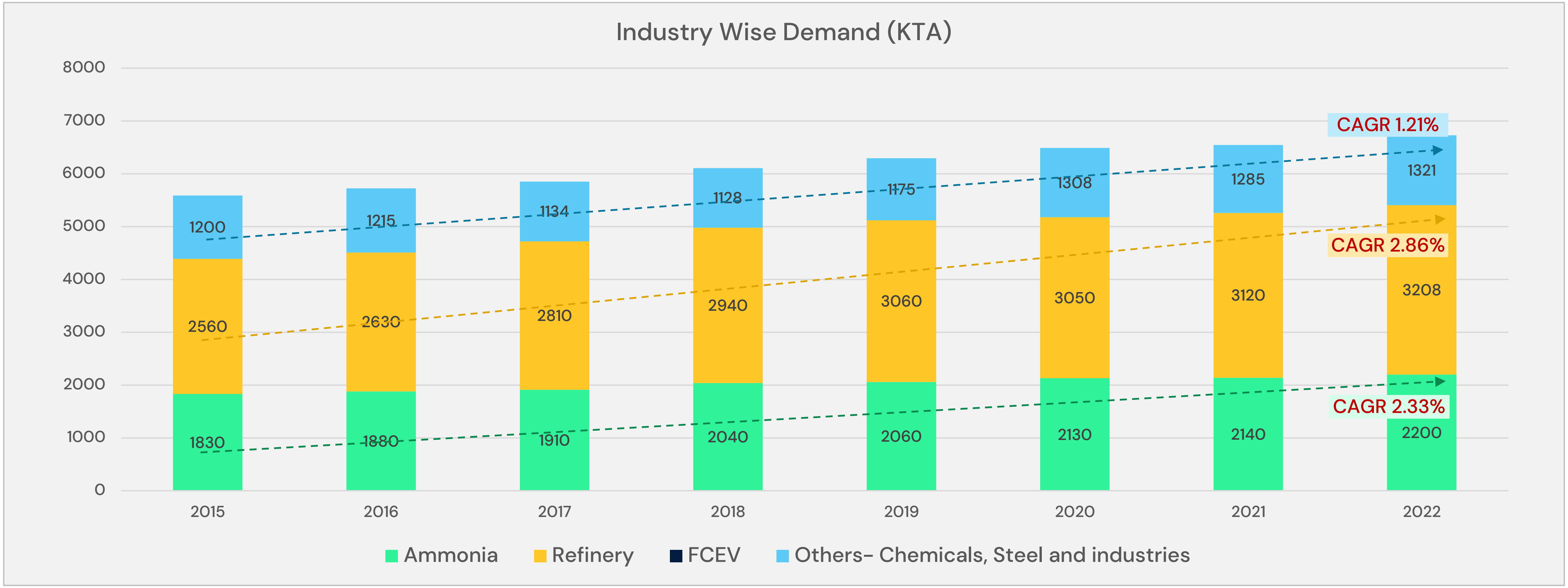
Regulators

- Petroleum & Explosives Safety Organization (PESO), Department for Promotion of Industry and Internal Trade
- PNGRB

Pipelines and CGD

- PIL – Pipeline Infrastructure Limited
- GUJARAT GAS
- GAIL

Hydrogen demand in India is ~6.7 MTPA as of FY 2022, growing steadily with CAGR of 2.7% from FY 2015- 2022



- Fertilizer & refineries remained the key demand drivers
- Demand in chemical and steel increasing rapidly

Historic H2 demand CAGR by sectors	
Ammonia	2.33%
Refineries	2.86%
Others- Chemicals, Steel and industries	1.21%

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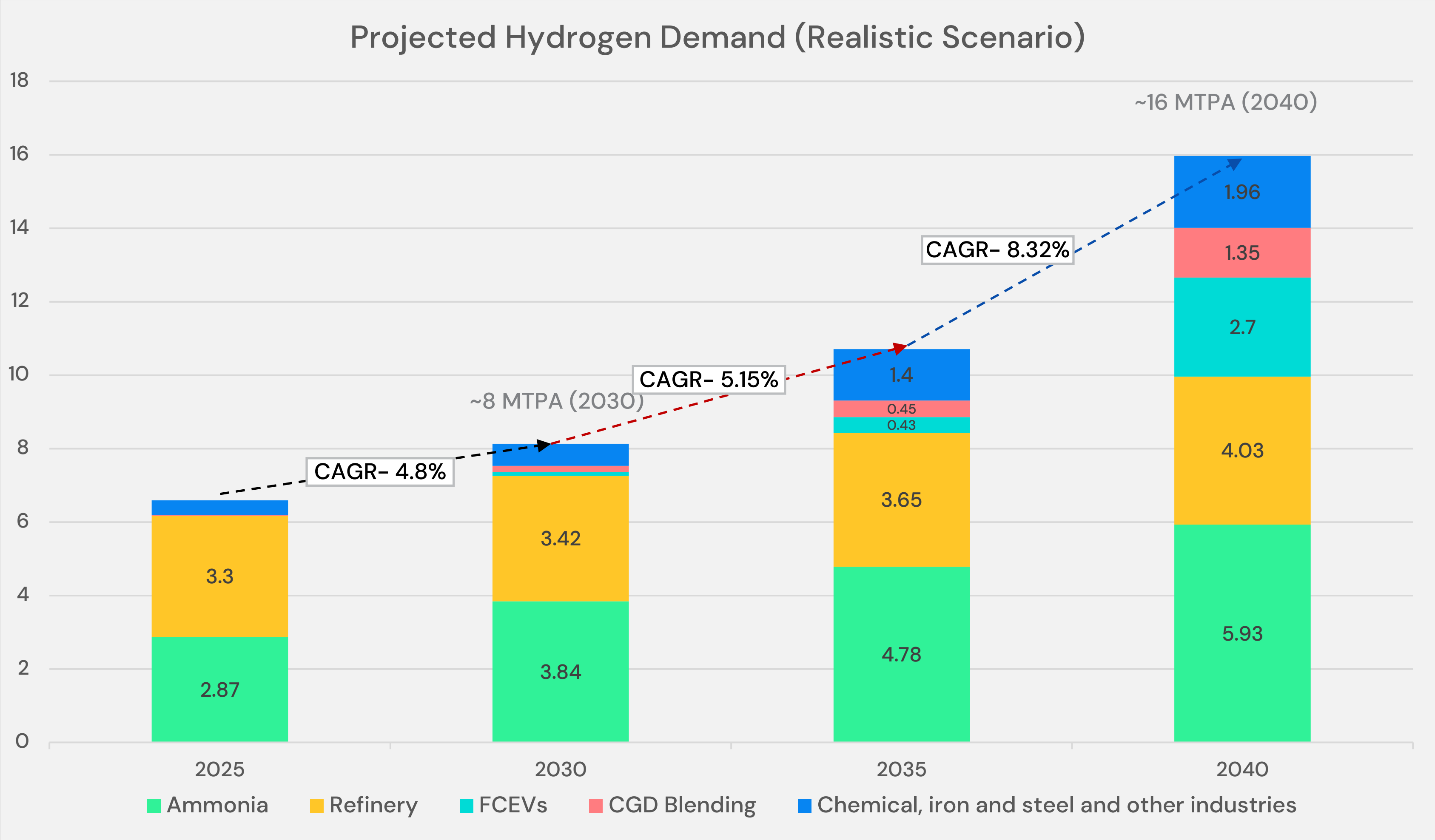
Hydrogen Demand is expected to increase at a faster pace due to new areas, to reach 16 MTPA by 2040



Projected H2 demand CAGR (2025-2040)	
Ammonia	**4.9%**
• Import reduction will drive demand	
Refineries	**2.10%**
• Forecasted CAGR is similar to historic	
FCEVs (2030-2040)	**39.04%**
• FCEV is a new sector which will drive H2 demand	
CGD Blending	**32.42%**
• New sector which drives H2 demand	
Others- chemical, iron and steel plants and industries	**21.94%**
• New iron and steel plants will contribute to the high growth rate	

Source: ICF analysis

Key Demand drivers in future

Sectors with existing demand

Ammonia

Historic CAGR (2015-2022)	Projected CAGR (2025-2040)
2.33%	4.9%

Demand Drivers:

- Expansion plans of current urea and ammonia plants
- GoI's plans to build India as an export hub for green ammonia
- For demand projections, we have considered:
    - Imports to reach zero by 2031-32
    - Exports (to far east and Europe) start from 2034-35 with 0.5 MMTpa

Refineries

Historic CAGR (2015-2022)	Projected CAGR (2025-2040)
2.86%	2.10%

Demand Drivers:

- New refineries would come up at a slower pace

New and upcoming Sectors

FCEV

Historic CAGR (2015-2022)	Projected CAGR (2030-2040)
NA	39.04%

Demand Drivers:

- TCO for FCEV will become competitive compared with ICE by 2035, driving demand for hydrogen
- Government support and incentive in FCEV sector

CGD Blending

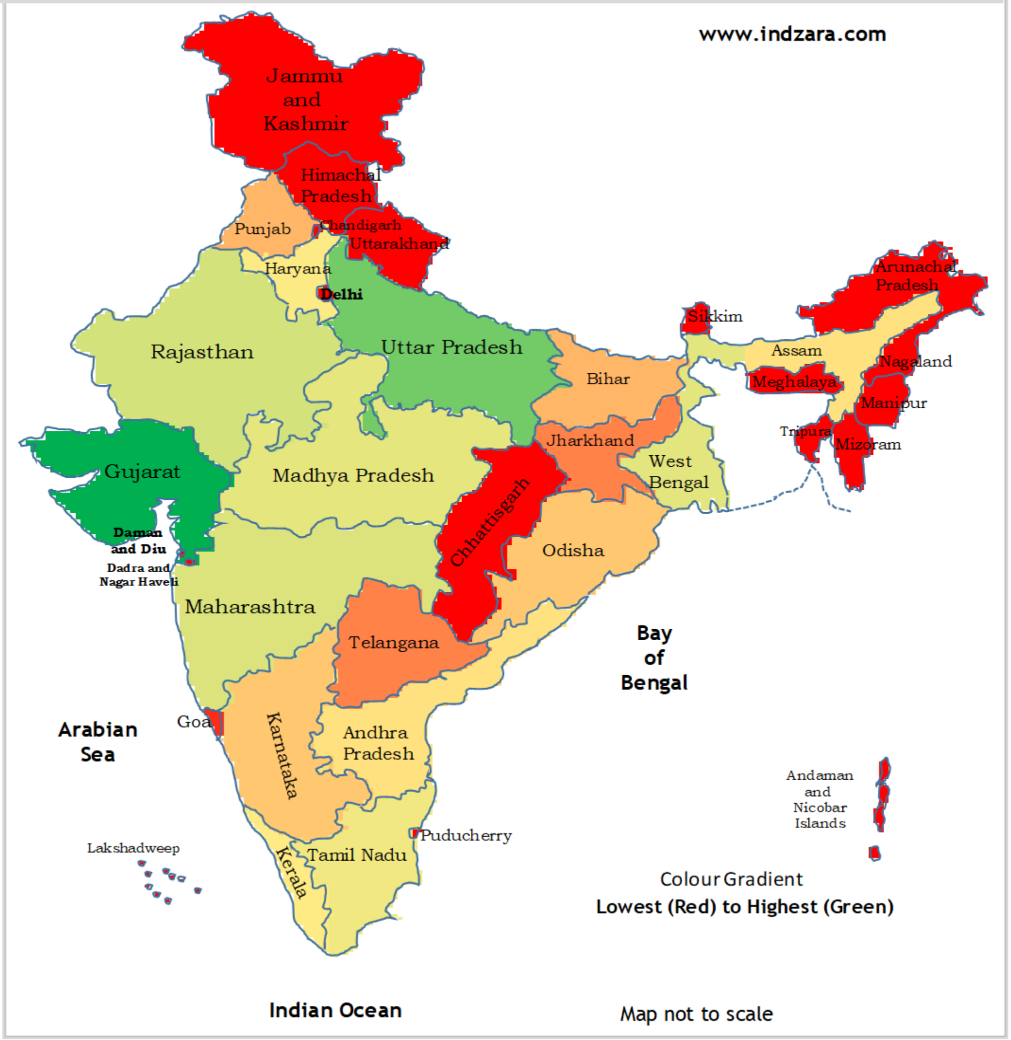
Historic CAGR (2015-2022)	Projected CAGR (2030-2040)
NA	32.42%

Demand Drivers:

- H2 blending in CGD will push demand
- Cost impact of blending is minimal

Uttar Pradesh and Gujarat are expected to be key hydrogen consuming states

H_2 demand in 2030



- Presence of current and upcoming refineries and ammonia/Urea in Uttar Pradesh and Gujarat
- Strong chemical belt in Gujarat potentially consuming H2 as feedstock

Green	Demand > 1 MTPA
Light green	between 0.5 to 1 MTPA
Yellow	between 0.2 to 0.5 MTPA
Red	Lower than 0.2 MTPA

GoI has come out with a detailed *Hydrogen Mission*, targeting GH_2 production capacity of 5 MMT Per annum by 2030

- To explore policy action to support the use of hydrogen as an energy vector and develop India into a global hub for hydrogen and fuel cell technology manufacturing.
- The mission would put forward specific strategy for the short term (four years), and broad strokes principles for long term (10 years and beyond)

NGHM Targets

GH2 CAPACITY	RE CAPACITY ADDITION
5 MMT Per Annum *India's GH2 production capacity target*	125 GW *RE capacity addition of 125 GW*
TOTAL INVESTMENT	**JOB CREATION**
8 Lakh Crore *Over 8 L Crore in total investment*	6 Lakh *Create over 6 Lakh full time jobs*

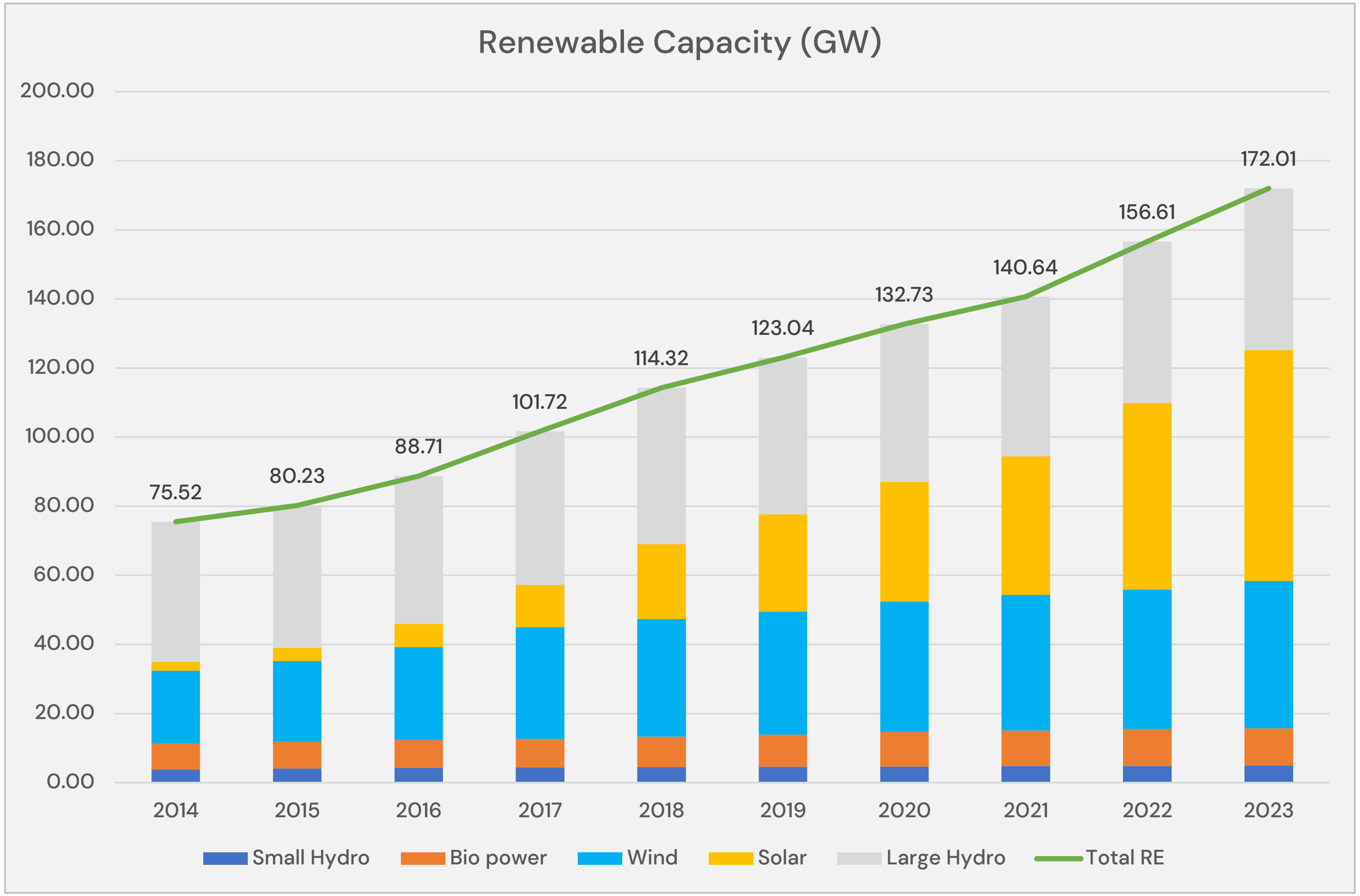
01 Production linked incentive scheme for electrolysers have been extended to domestic manufacturing for producing green hydrogen

02 GOI proposes to set up manufacturing zones and Green H_2/Green Ammonia production plants can be set up in any manufacturing zone.

03 Single portal for all statutory clearances and permissions in a time-bound manner of 30 days – manufacture, transportation, storage and transportation is proposed in the mission.

Source: ICF Research & analysis, https://powermin.gov.in/sites/default/files/Green_Hydrogen_Policy.pdf

India would have to increase its pace of RE additions; if sufficient RE capacity for NGHM 2030 target has to be met



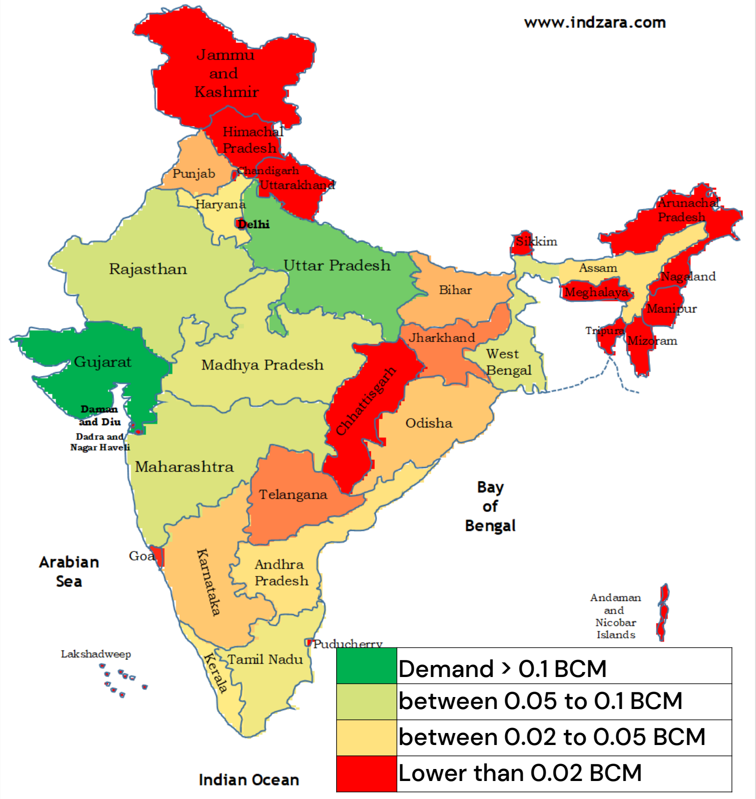
- India has green hydrogen production targets of 5 MTPA by 2030, for which the RE Capacity required is 125 GW
- India has targets to produce 500 GW of RE for decarbonizing the grid.

Case A: 500 GW additional RE includes the 125 GW for GH2	
Target by 2030	**500 GW**
• To achieve 500 GW by 2030, **~46 GW** of RE needs to be added every year, • Maximum RE addition pa in past 10 yrs= ~15 GW • **3X** time the historical best performance	
Case B: 500 GW additional RE is separate from the 125 GW for GH2	
Target by 2030	**625 GW**
• To achieve 625 GW by 2030, **~60 GW** of RE needs to be added every year, • Maximum RE addition pa in past 10 yrs= ~15 GW • **4x** time the historical best performance	

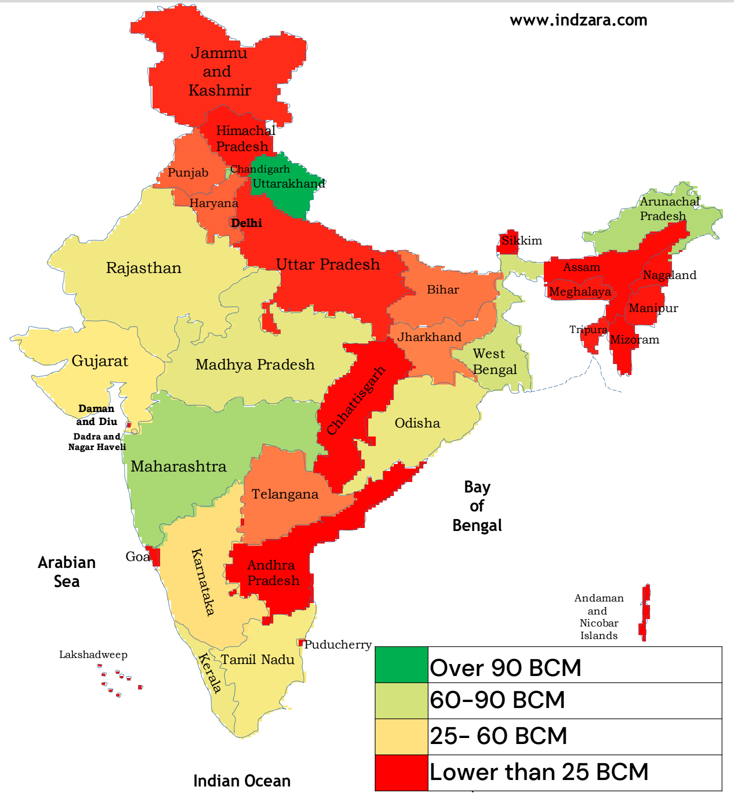
Source: Central Electricity Authority

Water requirement to meet 5 MT gH2 target is comparatively smaller compared to net water availability

Water requirement for GH2 in 2030 (BCM)



State wise Water availability (BCM)



Assuming water demand of 98kg/kg of GH2

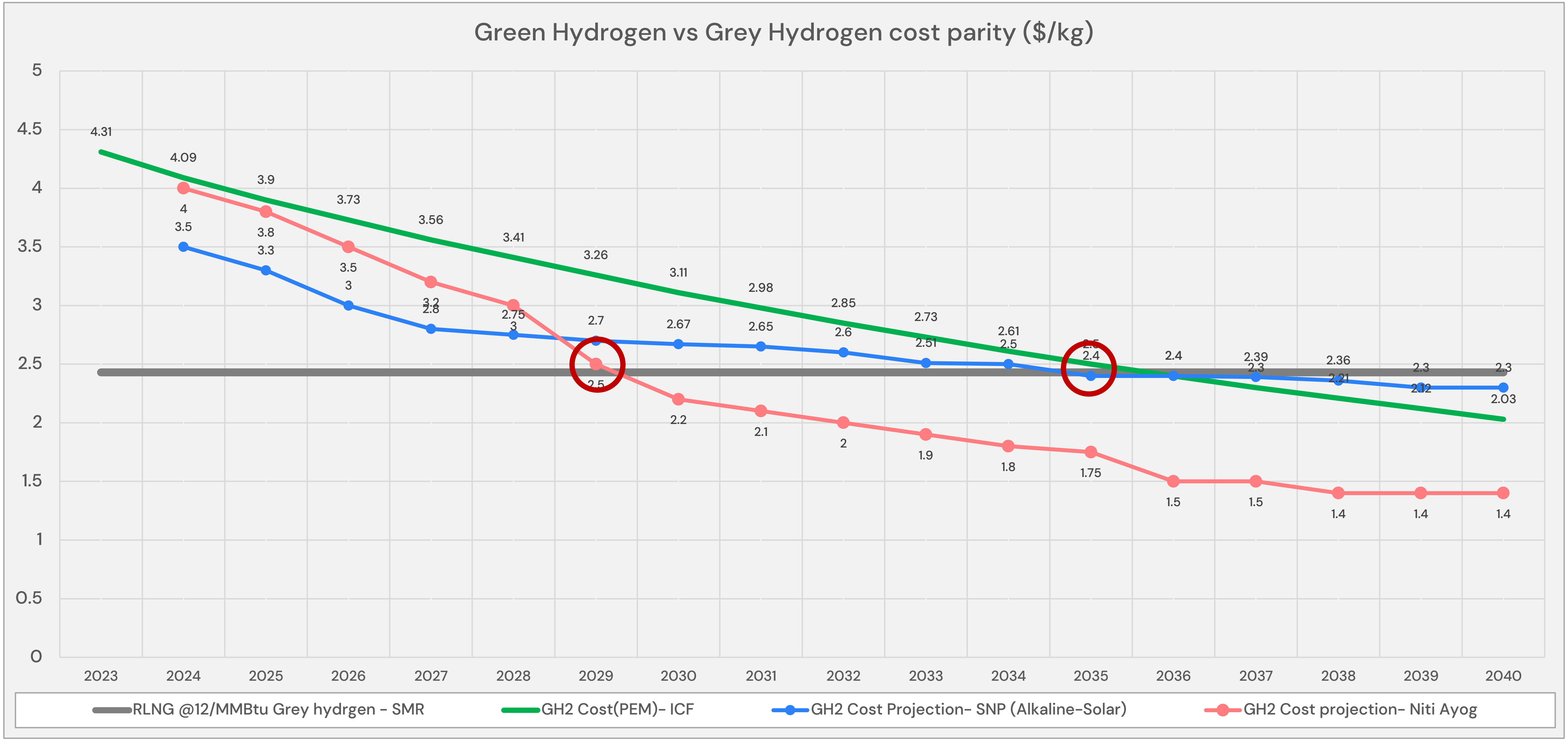
Water quantity required for production of GH_2

Parameters	Source of water	Kg/kg of H2	Water demand for 5 MTPA hydrogen demand by 2030
Minimum water consumption for hydrogen production	Deionised water	9 - 15	0.04 – 0.07 BCM
Water consumption including demineralisation and water cooled electrolyser	Ground water/Surface water	59 - 98	~0.29 – 0.49 BCM
Water consumption including demineralisation and air cooled electrolyser	Ground water/Surface water	18 - 30	~0.08 -0.15 BCM

Source: ICF Research & Analysis, India Climate and Energy Dashboard- NITI Ayog

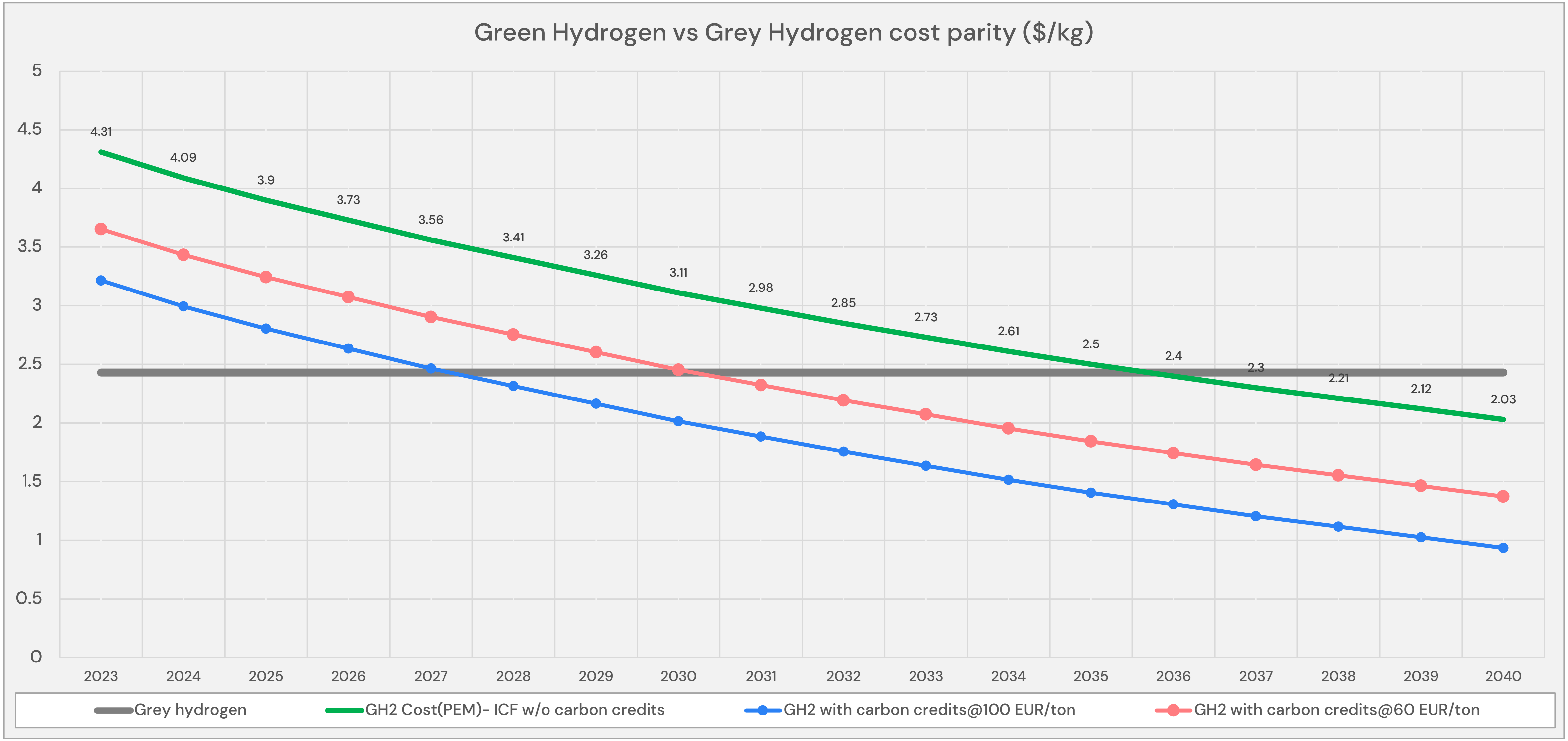
Green Hydrogen is not as competitive today due to its higher cost

Expected cost comparison of grey and green hydrogen with RLNG @$12/MMBTU- cost parity realization in 2030-35



Source: ICF Research & analysis, SNP, NITI Aayog

Considering Carbon Pricing and MNRE Incentives, cost parity may be realized earlier depending on prevalent carbon prices



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Recent demand creation tenders by GoI for gH2

“Selection of Green Ammonia Producers for Production and Supply of Green Ammonia in India through Cost-Based Competitive Bidding under Strategic Interventions for Green Hydrogen Transition (SIGHT) Scheme Mode 2A”

dated 07.06.2024

Total Capacity Offered

- 5,39,000 Metric Tonnes (MT)/annum of Green Ammonia (**100,000** Tonnes of GH2)

Incentives

- Rs. 8.82/kg of Green Ammonia in the first year of production and supply,
- Rs. 7.06/kg during the second year of production and supply,
- Rs. 5.30/kg during the third year of production and supply

Carbon Credits

- The Producer shall also be eligible for Carbon Credits under the Carbon Credit Trading Scheme, 2023 notified by Ministry of Power

Bidding Criteria

- Techno-commercial, financial bid evaluation
- Reverse auction

Locations

Project	Name of Procurer	Location of plant	Annual GA Requireme nt (MT)	Supply Schedule (Max. consignment size)
Project-I	Indian Farmers Fertiliser Cooperative Limited (IFFCO)	Kandia, Gujarat	1,00,000	25,000 MT per quarter
Project-II	Indian Farmers Fertiliser Cooperative Limited (IFFCO)	Paradeep, Odisha	1,00,000	25,000 MT per quarter
Project-III	Madras Fertilizers Limited	Manali, Chennai, Tamil Nadu	4000	350 MT per month
Project-IV	Gujarat Narmada Valley Fertilizers & Chemicals Limited (GNFC)	Bharuch, Gujarat	50,000	12,500 MT per quarter
Project-V	Paradeep Phosphates Limited (PPL)	Paradeep Odisha	75,000	23,500 MT per quarter
Project-VI	Paradeep Phosphates Limited (PPL)	Zuarinagar, Goa	25,000	4500 MT alternate month
Project-VII	Indorama India Private Limited (IIPL)	Haldia, west Bengal	20,000	1100 MT1200 MT per month
Project-Vill	Mangalore Chemicals & Fertilizers Ltd. (MCFL)	Panambur, Mangalore Karnataka	15,000	3,000 MT per quarter
Project-IX	Coromandel International Limited (CIL)	Vishakhapatn am, Andhra Pradesh	50,000	
Project-X	Coromande International Limited (CM)	Kakinada, Andhra Pradesh	85,000	
Project-Xi	Coromande1 International Limited	Ennore, Tamil Nadu	15,000	

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Recent demand creation tenders by GoI for gH2

MNRE /CHT Guidelines of Selection of Green Hydrogen Producers for Production and Supply of Green Hydrogen in India under Strategic Interventions for Green Hydrogen Transition (SIGHT) Scheme Mode 2B- BOO tenders

dated 07.06.2024

Capacity Allocation

- **2,00,000** Metric Tonnes (MT)/annum of Green Hydrogen

Incentives

- Rs. 50/kg of Green Hydrogen in the first year of production and supply,
- Rs. 40/kg during the second year of production and supply,
- Rs. 30/kg during the third year of production and supply

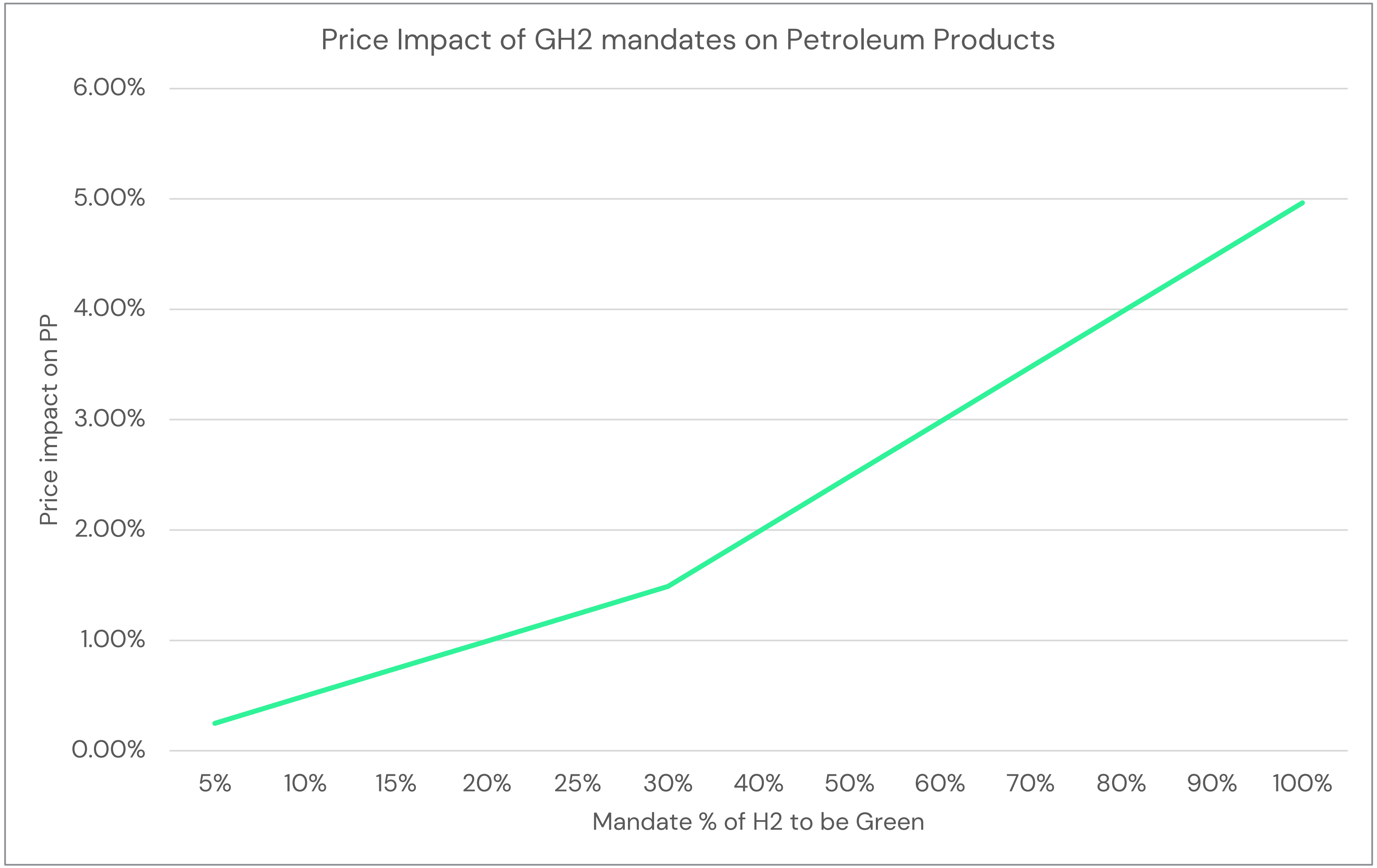
Selection Criteria

- Qualified bidders to be allocated capacities in order of quoted price of supply (in Rs/kg)

Tenders launched

Implementing Agency	Tender	Key Points
MRPL	Procurement of 10 KTPA of gaseuos green hydrogen (GH2) on build own operate (BOO) mode	Green Hydrogen transported upto Battery limit of the unit
HPCL and BPCL	Expression Of Interest (EOI) for supply of hydrogen gas to refineries of HPCL and BPCL at Mahul, Mumbai by installation of hydrogen generation unit (HGU) on Build–own–operate (B-O-O) basis near their refineries	
IOC	Green Hydrogen Generation Unit (GHGU) Of 10KTA Capacity on BOO Basis At Indian Oil Corporation Ltd – Panipat Refinery Petrochemical Complex, Panipat, Haryana, India	Reverse auction applicable Recent tender was cancelled.
CPCL	Green Hydrogen Generation Unit (GHGU) Of 2KTA Capacity on BOO Basis at CPCL Manali	

If green hydrogen mandates in refineries are introduced, they will have minimal implications on the final product prices



- Implementation of green hydrogen mandates in refineries will replace grey hydrogen which leads to increased cost for the refinery

- The GH2 mandates may lead to increase in prices of petroleum products, however this increase is minimal:
  - ➢ 2.5% increase at 50% GH_2 mandate

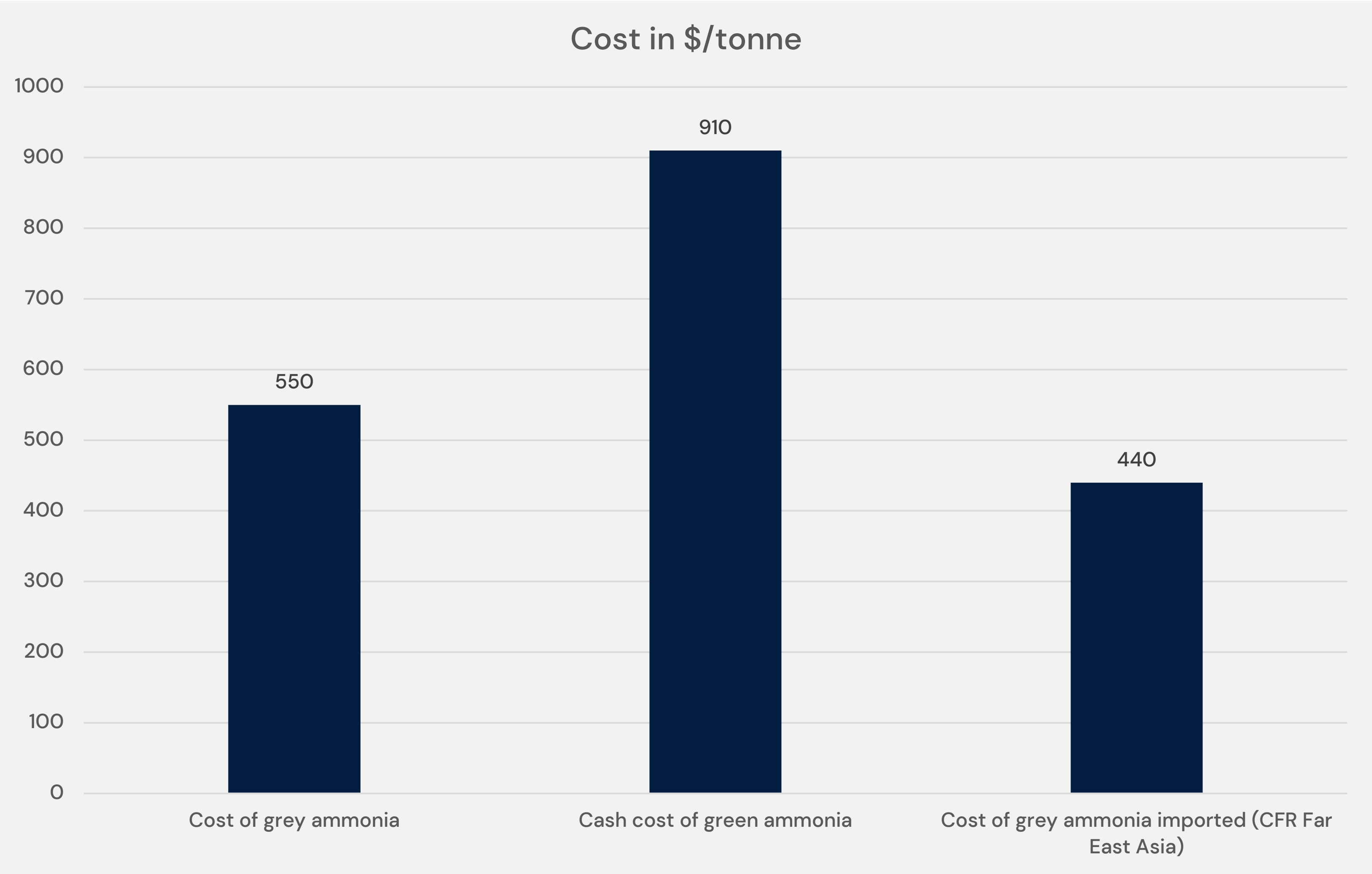
For context: At 50% GH2 mandates, price of petrol may rise from Rs. 100 to Rs. 102.48

- Assumptions taken for calculation–

Price of NG	12 US $/MMBTU
Price of Green Hydrogen	INR 380 / Kg
Price of crude	80
1 MMT to refining, hydrogen required	9000 tonnes

Source: ICF Research & analysis

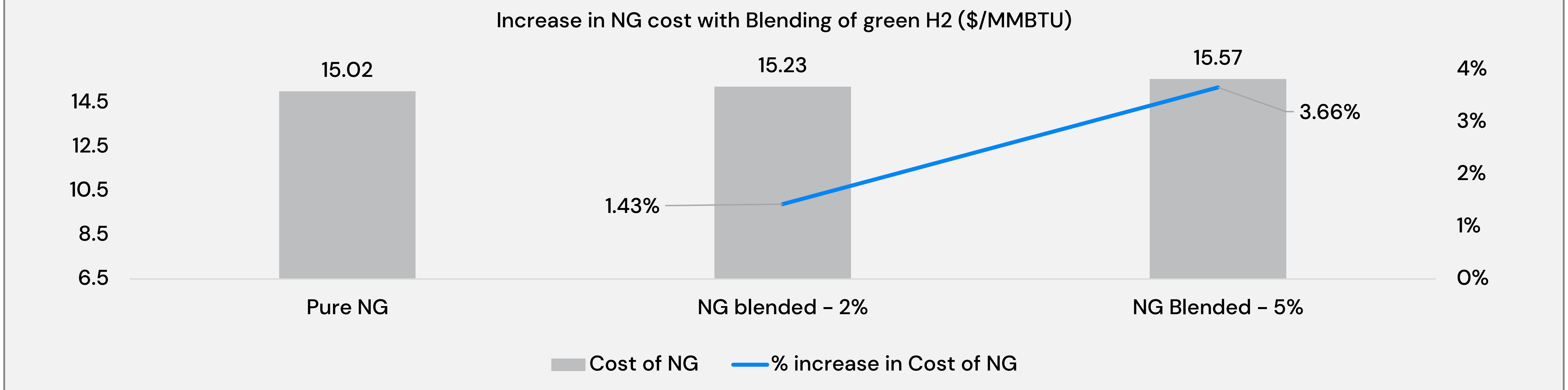
If green hydrogen mandates are implemented in ammonia sector, government support will be required



- Implementation of green hydrogen mandates in ammonia will have significantly higher costs.
- Green ammonia would require significant government support for the demand to materialize

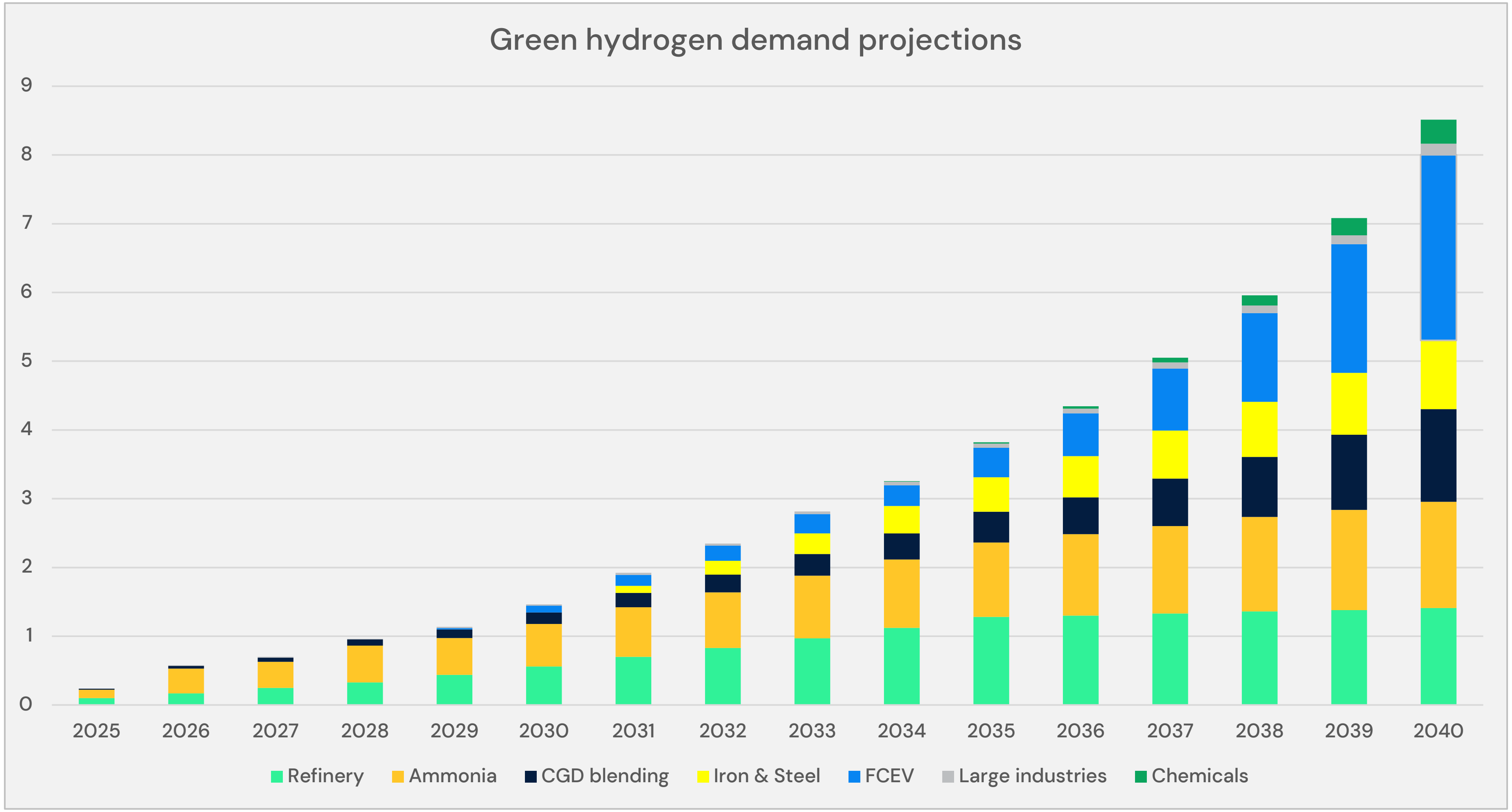
Hydrogen blending between 2% - 5% in Natural Gas pipelines would result in minor price increase

H2 Blending %(by Vol)	RLNG Price ($/mmbtu)	Green H2 Price ($/mmbtu)	Price of NG blended in H2 ($/mmbtu)	% Increase in Price
5% Blending	15.02	56.2	15.57	3.66%
2% Blending	15.02	56.2	15.23	1.43%



Base Price- RLNG - 15.02 $/mmbtu; Green H2 – 56.2 $/mmbtu (INR 509.45 /kg)

Green hydrogen may account for ~20 % of the total hydrogen demand by 2030 and ~50% by 2040



- Pre-2030, green Hydrogen demand is expected to be limited to Ammonia, Refineries and CGD blending (through mandates).
- Post-2030, green hydrogen is expected to become cost competitive against grey H2 so new supply of H2 will come from green hydrogen.

Source: ICF analysis

Hydrogen Blending in gas networks can create demand aggregation for gH2 suppliers

Leveraging Existing Infrastructure:

India's natural gas network can be repurposed for transporting the hydrogen blend, minimizing costs and implementation timelines.

Early Hydrogen Adoption

Development of a hydrogen ecosystem and applications like hydrogen-fueled vehicles

Economies of scale for suppliers

Decarbonization potential

Blending green hydrogen with natural gas lowers overall carbon footprint compared to just natural gas

Pilot Projects – H_2 Blending in India

- NTPC Project, Kawas (Blending of Green Hydrogen with PNG)
- Torrent Power Project-Green Hydrogen Blending in City Gas at Gorakhpur
- ATL Gas Blending Project (Green Hydrogen with Natural Gas) in Ahmedabad, Gujarat

Despite its potential, overcoming infrastructure and cost hurdles is crucial for hydrogen blending's success

Material Compatibility

Key factors such as material, age, operating pressure and pipeline cracks may result in lower limits of blending

Fertilizer industry (esp. Urea manufacturer) may face loss in efficiency for hydrogen blending more than 2% by volume (in its SMR process).

Current CNG storage tanks have blending limit of 2%.

Higher costs

Business models need to develop to provide for infrastructure changes required for hydrogen blending more than 2% by volume

While deblending is technically viable, commercially cost of deblending will result in approx. 20% increase in CNG price

Additionally, more CO2 is needed for production of Urea to accommodate for mass balance of Urea.

Leakage and safety concerns

Hydrogen's small molecule size makes it more prone to leaks than natural gas

Hydrogen can weaken existing pipelines (embrittlement) requiring inspections and potentially repairs.

Regulatory Framework

Current PNGRB Act has no provision for H2 blending or pure hydrogen in pipeline and thus modification is needed to regulate hydrogen in pipeline infrastructure

Multiple other PNGRB regulations needs modifications to allow for blended hydrogen or hydrogen.

Safety regulations need to be modified to allow for blended hydrogen/hydrogen in NG pipeline infrastructure.

Literature review and stakeholder interactions suggest a blending limit of 10% (by volume) with some upgrades/ retrofits

S.NO.	Element	Blending Limit (without modifications)	Blending Limit (with modifications)	Key Remarks
1	Compressor(Gas Driven)	2%-5%	15%-20%	Swapping gas turbines or internal combustion engines with electric motors
2	Compressor(Electrically Driven)	15%-20%	-	-
3	Valve	10%	-	Required new equipment
4	Gas Filter	10%		Required new equipment
5	Fuel Filter	10%		Required new equipment
6	Odorizer/Odorant	15%	-	
7	Insulation Joint	10%-20%		
8	Volumetric Meters	10%		Required new equipment
9	Process gas chromatograph	<=0.2%	10%-20%	Replace helium cylinders with Argon Cylinder
10	Gas Meters	10% - 50%		
11	Gas Turbine	1%-2%	15%-20%	Modifications to increase limit to 15% - 20%
12	Feedstock/Reformer	2%	-	Lower efficiency. Requires deblending solution
13	Burner/Gas Stove	10%	20%-100%	
14	CNG Vehicle fuel Tank	2%		Requires deblending solution
15	Domestic Appliances	20%		
16	Transmission pipeline (Steel)	5%-10%	-	-
17	Distribution pipeline (PE)	25%-100%	-	-
18	**Condensing and Steam Boilers**	5%-10%	20%-100%	

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Cost of retrofits to take blending up to 10%

S.NO.	Element	Blending Limit (without modifications)	Retro fitment solution	Additional cost
1	Compressor(Gas Driven)	2%-5%	Possible solution for retrofit of compressor is replacing gas/IC engine drive with electrical drive.	**6.5%-11% of Capex**
2	Compressor(Electrically Driven)	15%-20%	Requires replacement	
3	Valve	10%	Requires replacement	
4	Gas Filter	10%	Requires replacement	
5	Fuel Filter	10%	Requires replacement	
6	Odorizer/Odorant	15%	Requires replacement	
7	Insulation Joint	10%-20%		
8	Volumetric Meters	10%	Requires replacement	
9	Process gas chromatograph	<=0.2%	Replace helium cylinders with Argon Cylinder.	500 USD/Year/PGC
10	Gas Meters	10% - 50%		
11	Gas Turbine	1%		10% of Capex
12	Feedstock/Reformer	2%	Deblending	INR 3.2/kg of Urea
13	Burner/Gas Stove	10%		
14	CNG Vehicle fuel Tank	2%	Deblending	5.2 Cr/CNG station
15	Condensing and Steam Boilers	5%-10%	Majority of cost increase coming from a burner suitable to fire hydrogen that produces low NOx emissions	35%-40% of Capex

Recommended changes to the PNGRB Act to regulate hydrogen

The Petroleum and Natural Gas Regulatory Board (PNGRB) can be designated as the regulatory authority for hydrogen energy in India to support India's transition to a low-carbon economy

Section 11: Functions of the Board

- It is recommended that blending of hydrogen in natural gas is expressly included in the above section as part of the functions of the board

Section 2: Definitions

- Natural gas blends (with hydrogen) be notified under this section
- The definition to be expanded to include "Blended Natural Gas" within the umbrella term of "Natural Gas".
- It is also suggested to have a separate definition for blended natural gas.

Section 14: Register

- Incorporate hydrogen-related activities within the scope of the Petroleum and Natural Gas Register.
- Specifically, subparagraph (a) should include entities engaged in marketing hydrogen and establishing and operating hydrogen related infrastructure including storage infrastructure.

Section 17: Application for Authorisation

- Modify existing clauses (1) and (2): Include "or hydrogen" after "natural gas" to explicitly encompass hydrogen blending within the purview of authorization requirements for both common/contract carrier pipelines and city/local distribution networks.

Section 61: Power of the Board to make Regulations

- Technical specifications and safety protocols
- Blending ratios and quality standards for H2
- Monitoring and reporting requirements
- Certification and accreditation frameworks
- Economic and financial incentives

PNGRB Regulations for which ICF has recommended amendments

CGD Regulations

A.1 Authorizing Entities to Lay, Build, Operate or Expand City or Local Natural Gas Distribution Networks	A.2 Determination of Transportation Rate for CGD and Transportation Rate for CNG	A.6 Access Code for City or Local Natural Gas Distribution Networks

NGPL Regulations

B.1 Authorizing Entities to Lay, Build, Operate or Expand Natural Gas Pipelines	B.2 Affiliate Code of Conduct for Entities Engaged in Marketing of Natural Gas and Laying, Building, Operating, or Expanding Natural Gas Pipeline	B.4 Determination of Natural Gas Pipeline Tariff
B.6 Technical Standards and Specifications including Safety Standards for Natural Gas Pipelines	B.7 Determining Capacity of Petroleum, Petroleum Products and Natural Gas Pipeline	B.8 Integrity Management System for Natural Gas Pipelines

Other

F.5 Petroleum And Natural Gas Register

PNGRB Regulations for which we recommend pilots and testing

CGD Regulations

A.4 Technical Standards and Specifications including Safety Standards for City or Local Natural Gas Distribution Networks

A.7 Integrity Management System for City or Local Natural Gas Distribution Networks

A.8 Determining Capacity of City or Local Natural Gas Distribution Network

NGPL Regulations

B.3 Access Code for Common Carrier or Contract Carrier Natural Gas Pipelines

T4S

D.2 Emergency Response & Disaster Management Plan (ERDMP) Regulations

Regulations where change is not needed

CGD Regulations where change is not needed

A.3	A.5	A.9
Exclusivity for City or Local Natural Gas Distribution Network	Code of Practice for Quality of Service for City or Local Natural Gas Distribution Networks	Guiding Principles for Declaring City or Local Natural Gas Distribution Networks as Common Carrier or Contract Carrier

NGPL Regulations where change is not needed

B.5	B.9
Guiding Principles for Declaring or Authorizing Natural Gas Pipeline as Common Carrier or Contract Carrier	Imbalance Management Services Regulations

Roadmap for blending

2024- 2025

6 months

- Modification of PNGRB Act to allow PNGRB to regulate blended natural gas with hydrogen/pure hydrogen pipeline and storage infrastructure.
- Work with PESO for technical standards and regulations around hydrogen storage and dispensing

- Comprehensive technical study for major pipelines and CGD networks. This would involve collecting specific information about the material used for each segment of the gas network

6 months to set up the site and 6-12 months of testing

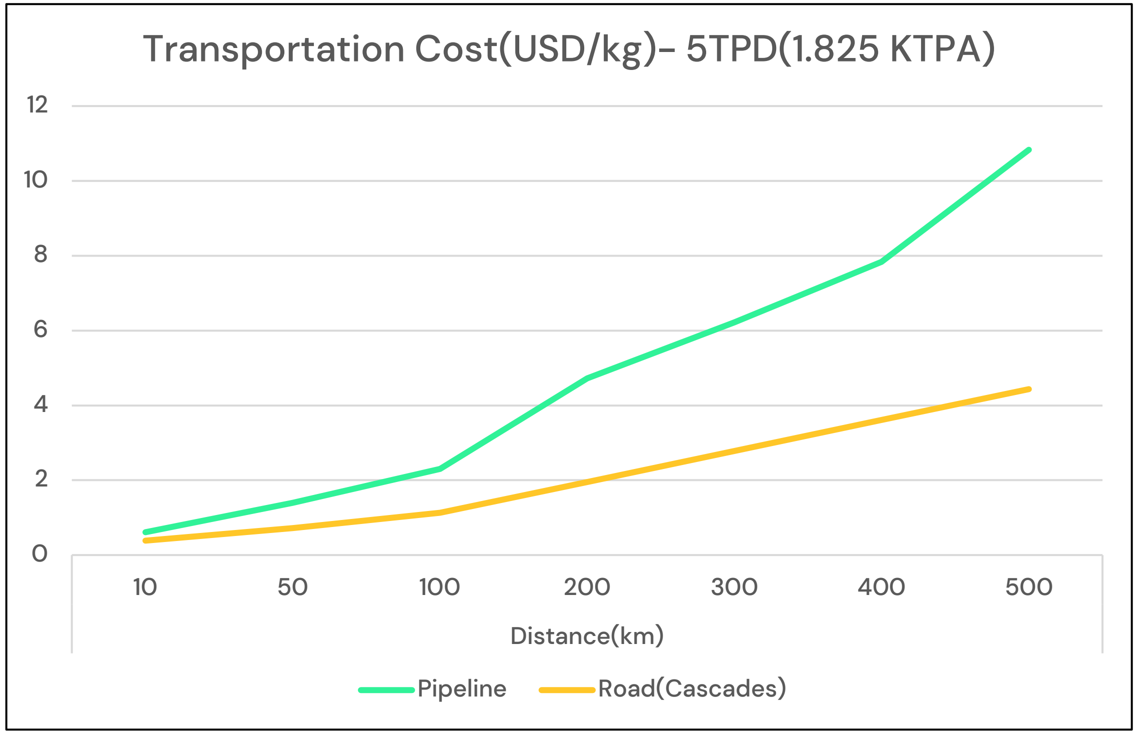
- Physical testing at a test site with different blend percentages (5%, 10%, 20%) in India where actual gas flow conditions will be simulated by installing small pipeline and CGD network sections with all materials as are in the real gas network (as identified from the technical study above).

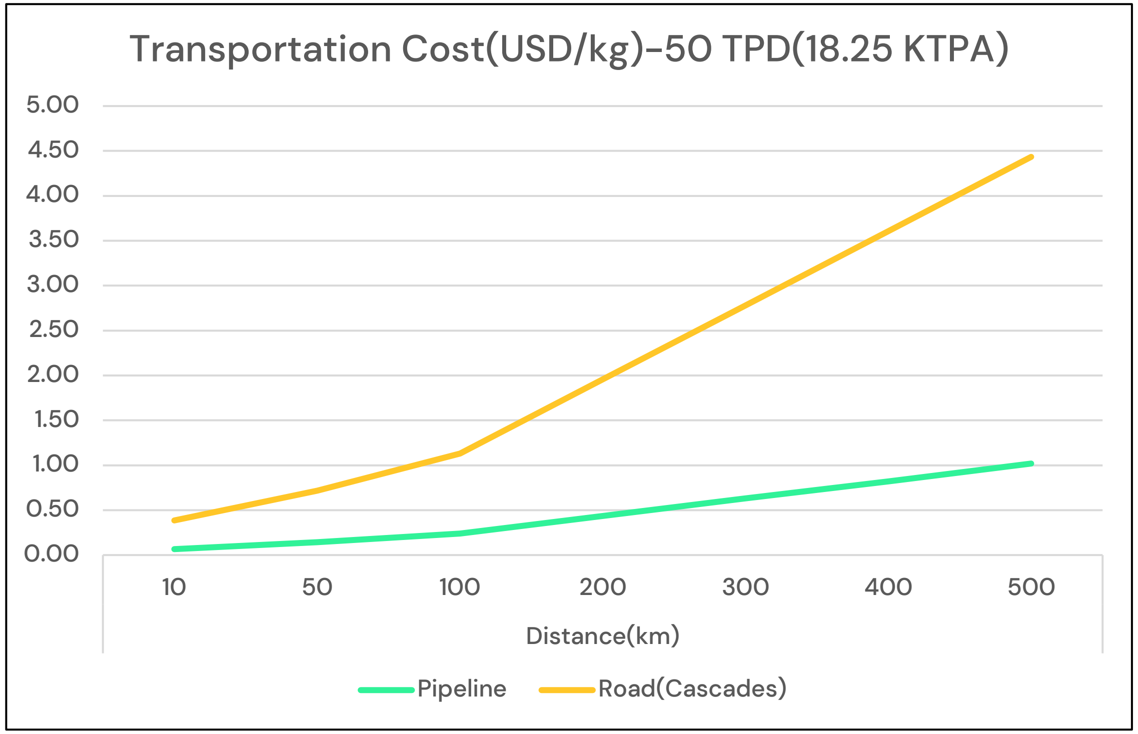
- Different percentage blends of hydrogen with natural gas will be tested under varying temperature and pressure conditions to simulate multi-year operations.

- Development of safety norms for accommodating different percentage of blending.

- Pilots of hydrogen blending in natural gas pipeline line network at different percentage (maximum upto 20%)

Transporting hydrogen through pipelines would make economic sense for distance less than 200 kms and higher capacity





- For lower capacities viz. 5-10 TPD, Transportation by road is more economical.
- For higher capacities(higher than 10 TPD) viz. 50 TPD, pipeline is more economic and suitable.

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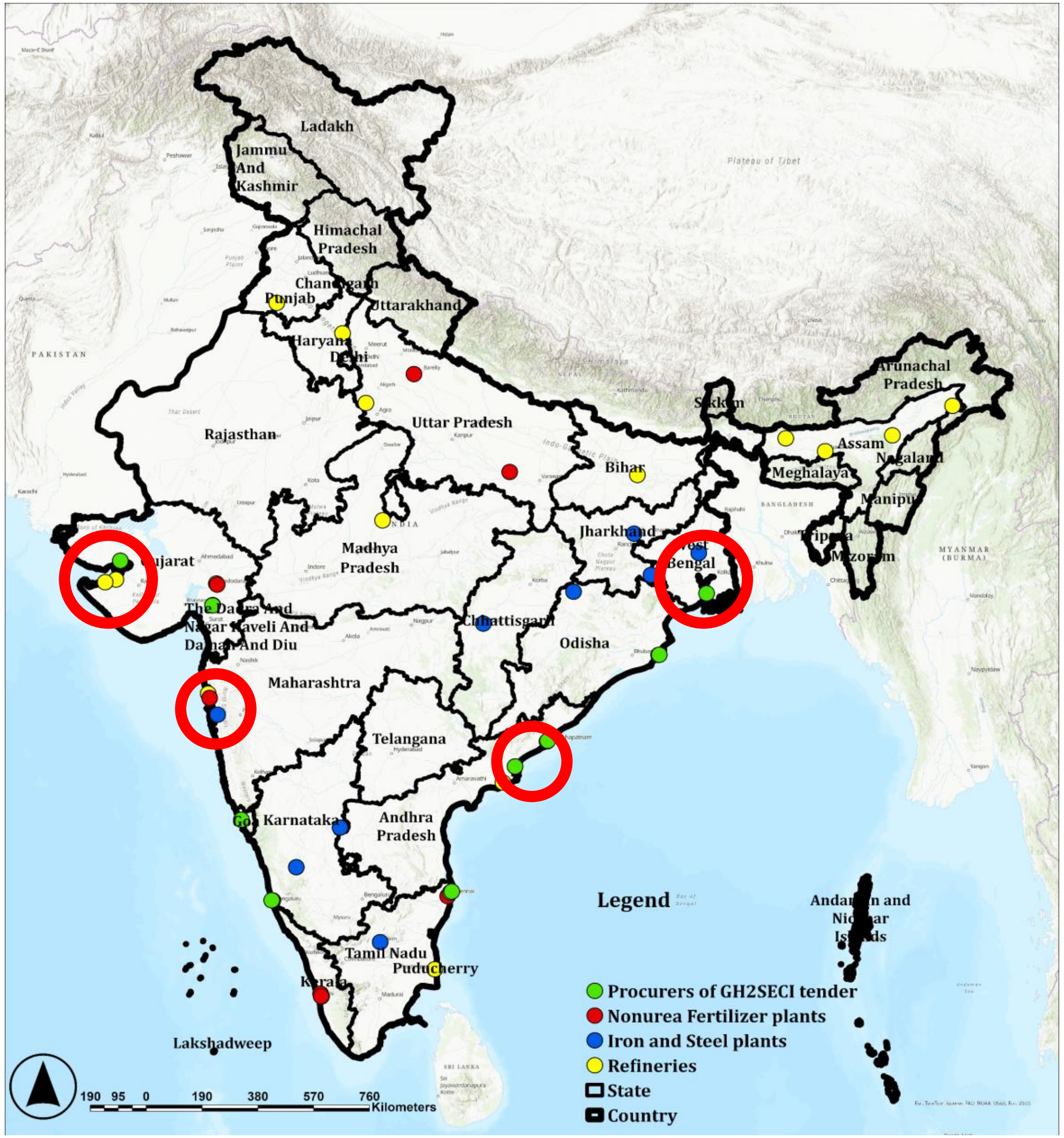
With green hydrogen production coming up at anchor consumers' locations, a distributed supply model will work



- SECI's tender has listed the locations of procurers of green hydrogen.
- These procurers have been mapped with existing refineries, non urea fertilizer plants, and iron and steel plants to identify clusters with high demand
  - Gujarat
  - West Bengal
  - Andhra Pradesh
  - Maharashtra

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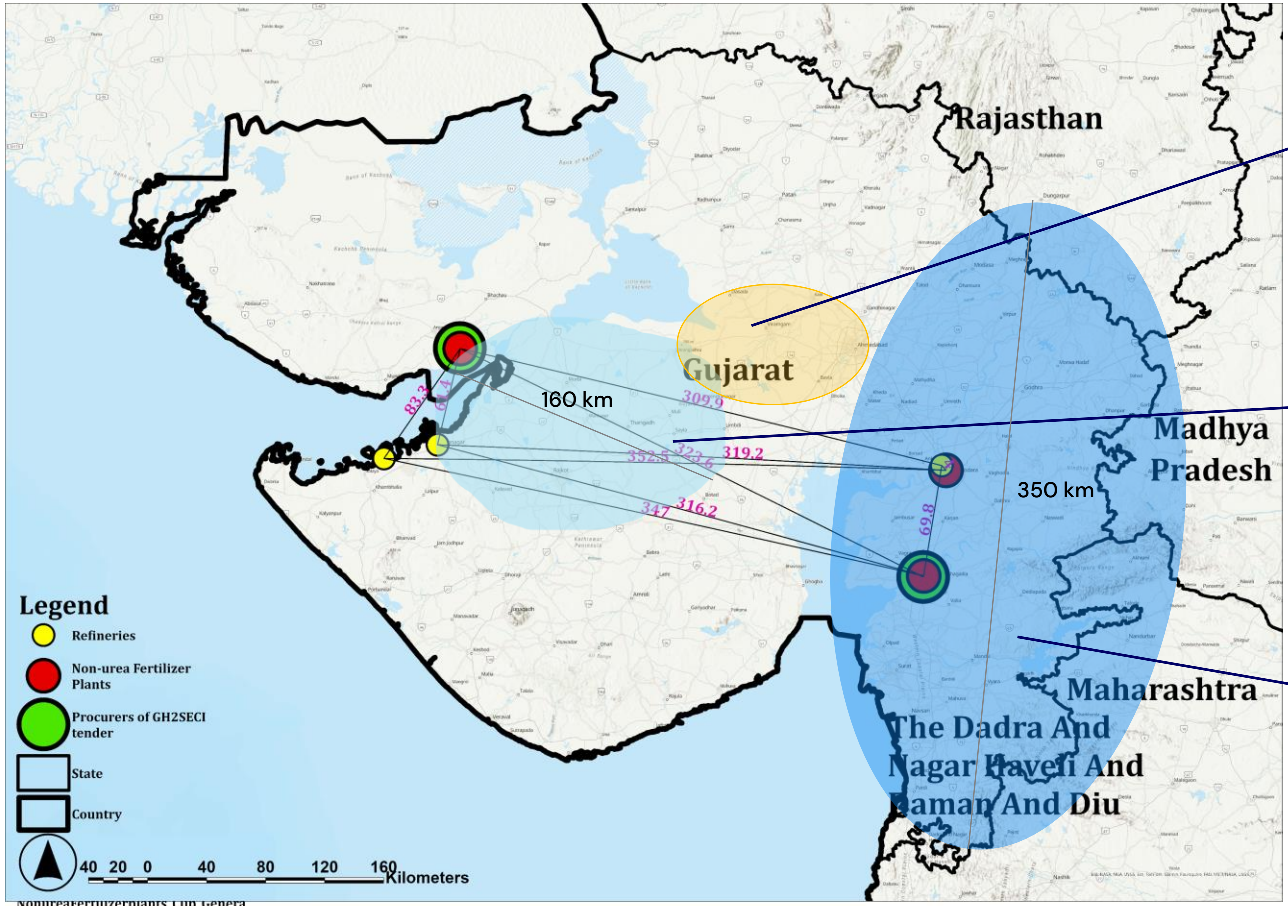
Industrial zones near anchor consumers may provide additional demand, thereby requiring hydrogen distribution network



Distances mentioned are in Km

Gujarat's **Morbi** district is home to the world's second-largest ceramic production cluster housing more than 1,000 units.

PNGRB is well placed to regulate such a hydrogen distribution network

Regulatory and Technical Expertise

- PNGRB is already a regulator for gas pipelines, so they are so are best placed to regulate hydrogen pipelines also.
- Current PNGRB regulations may be modified to support H2 only pipeline

Energy pipeline regulator

- PNGRB is the only body regulating energy pipelines in India
- PNGRB is also building additional capabilities and resources to support distributed hydrogen only pipelines

Similar Principles

- The economic and technical principles of H2 are similar to gas, which PNGRB already specializes in

Distribution Licenses

- Like CGD, there could be hydrogen distribution licensees as well near these anchor demand centres. PNGRB is fit to oversee the same

Way forward for setting up hydrogen distribution networks

Regulatory

- Modification of PNGRB Act to allow PNGRB to regulate pure hydrogen pipeline and storage infrastructure.
- PNGRB may provide hydrogen storage and distribution license, in line with CGD entities, for setting up common user facilities of storage and distribution hydrogen in hubs.
- Addition of regulations governing various aspects of pure hydrogen network, including authorization to develop hydrogen distribution network, capacity determination, tariff determination, technical standards and safety regulations.

Market development

- Demand assessment of hydrogen for industrial and chemical use near identified hubs.
- Development of business models to ensure capex recovery and usage of green hydrogen in local network.

Thank You