सत्यमेव जयते

Centre For High Technology
Ministry of Petroleum & Natural Gas
Government of India

GREEN HYDROGEN

Key to Decarbonization

By

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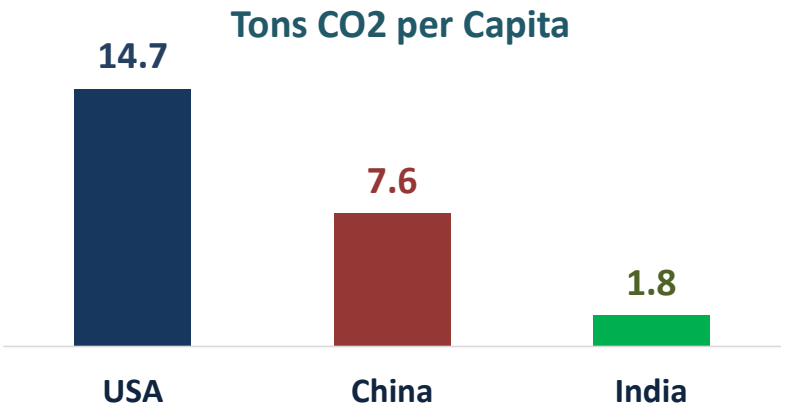
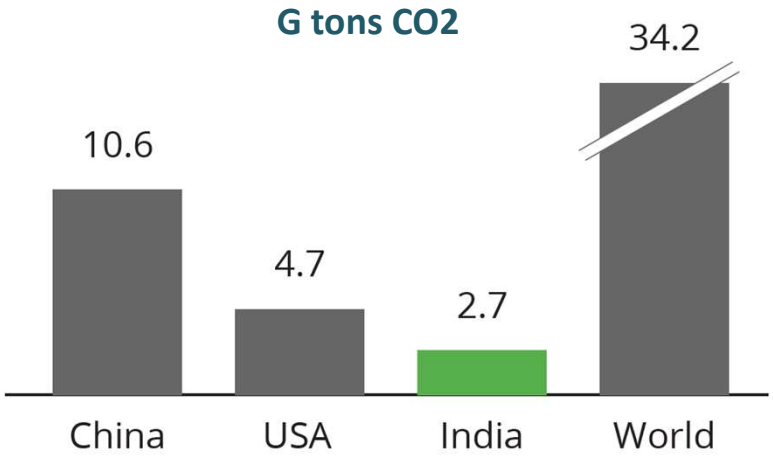
EMISSION SCENARIO





INDIA has the 3rd Highest Total CO2 Emissions Globally

Emissions are expected to grow by 5x to ~13.6 Gton per year if emissions continue to grow at historical rate of 5%.

INDIA'S PATHWAY

COP26 (Glasgow)- India made two significant commitments:

50% of its energy needs from renewable fuels by 2030

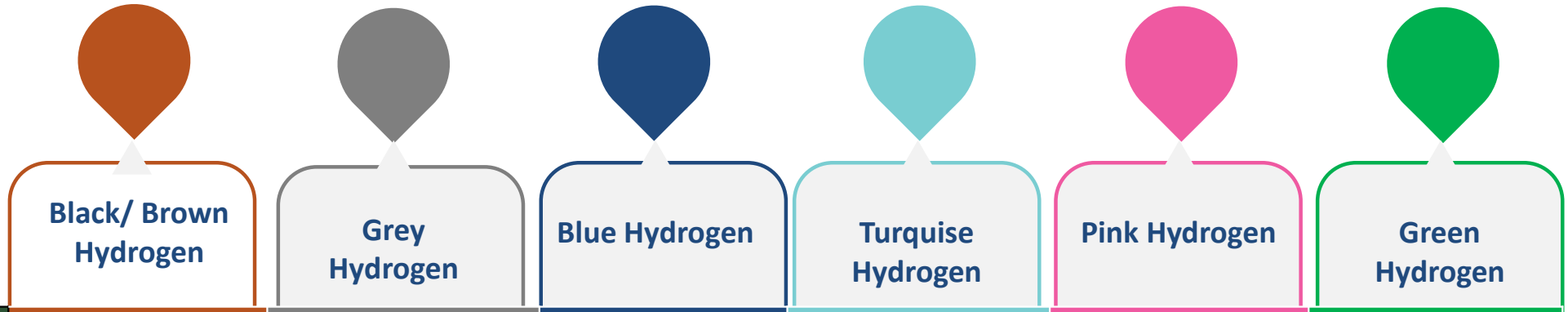
Transition to a net zero carbon economy by 2070.

Become Energy Self-sufficient By 2047

Localise India's Energy Requirement.

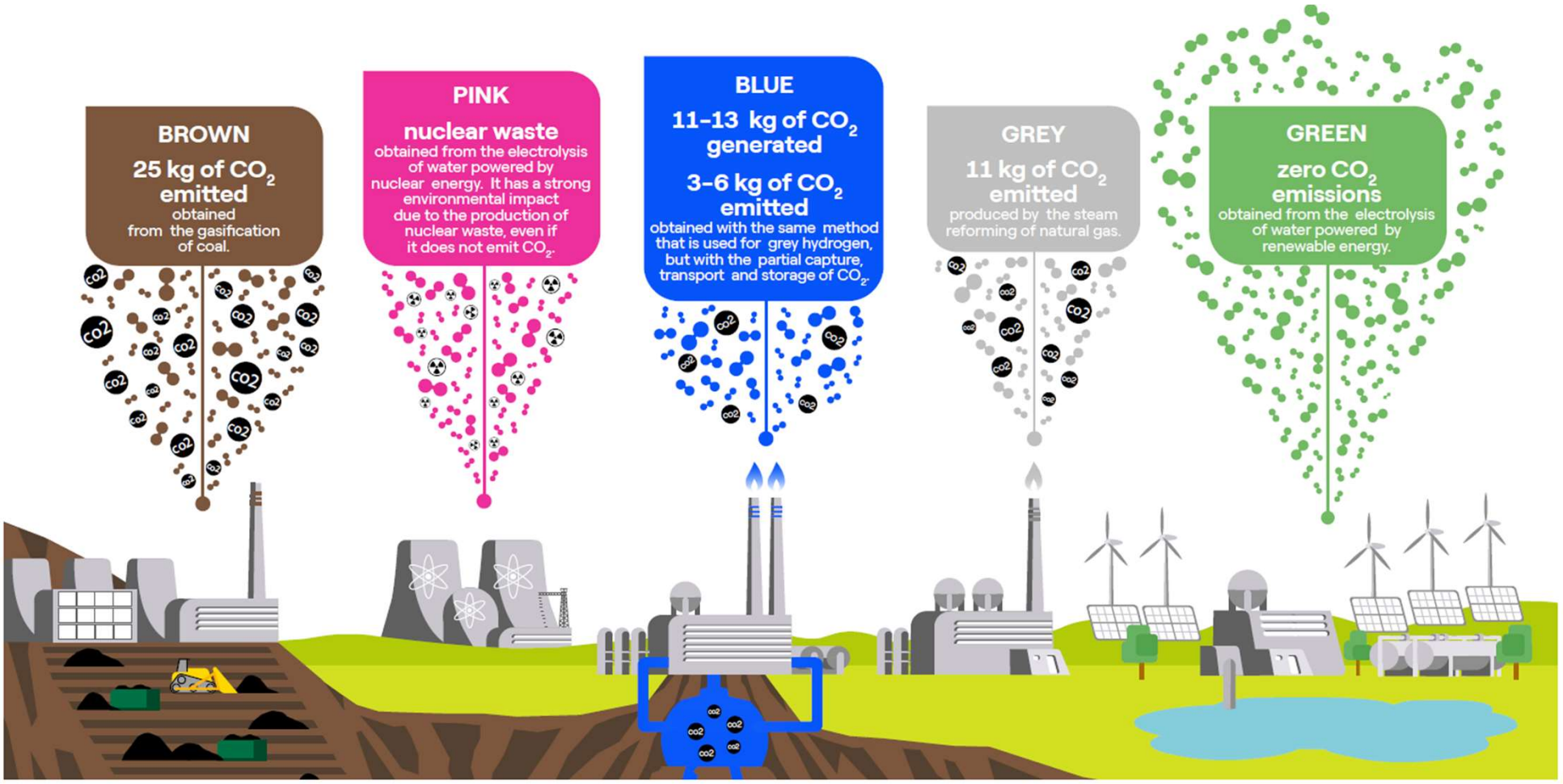
Hydrogen will also play a critical role along with CCUS in converting CO_2 to E-fuels through production of syn gas

COLORS OF HYDROGEN

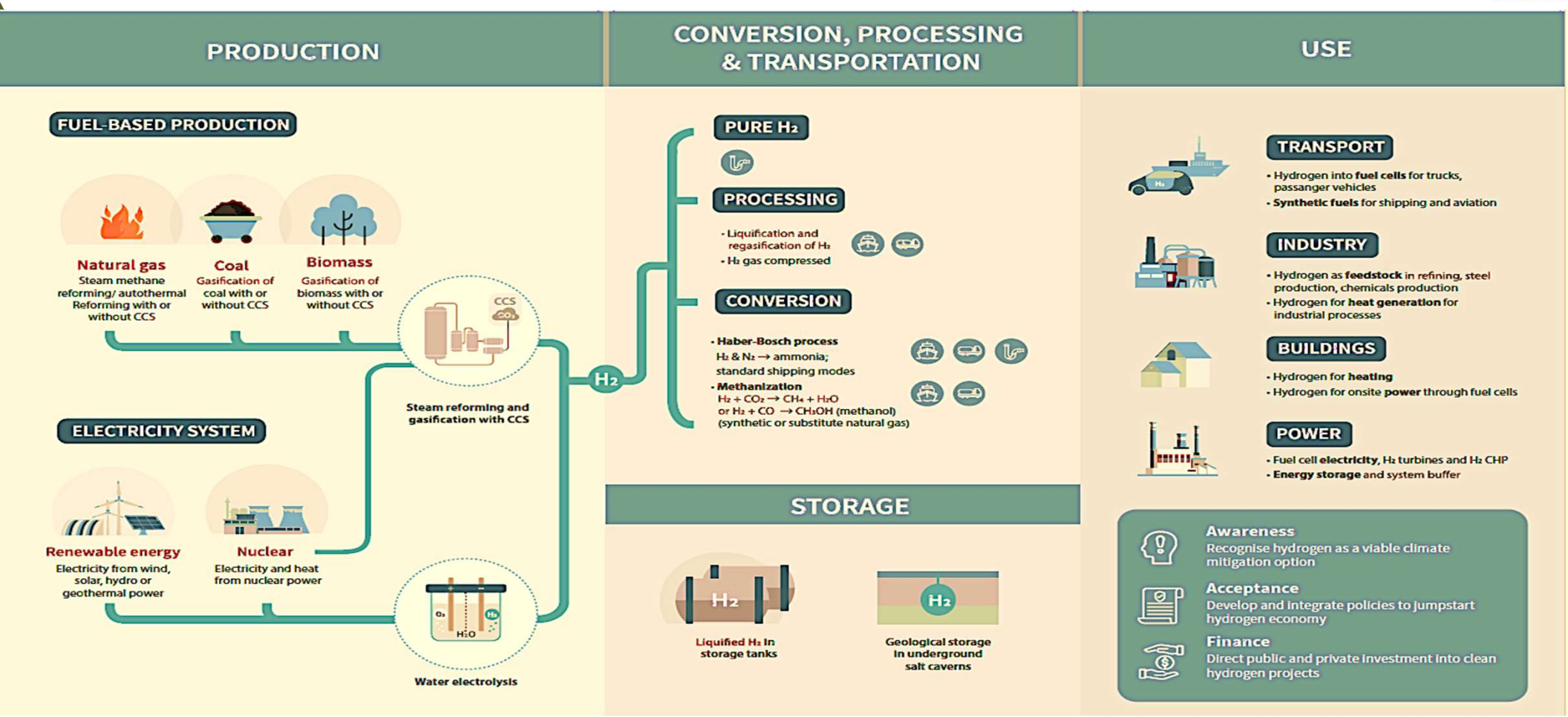


	Black/ Brown Hydrogen	Grey Hydrogen	Blue Hydrogen	Turquise Hydrogen	Pink Hydrogen	Green Hydrogen
Colour						
Process	Coal Gasification	Methane Reforming	Coal Gasification & Methane Reforming with CCUS	Pyrolysis	Electrolysis	Electrolysis / Biomass Gassification
Source	Coal	Natural Gas/Naphtha	Fossil Fuel	Methane	Nuclear Energy	Renewable Energy

COLORS OF HYDROGEN

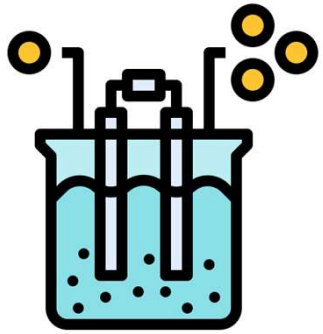


Hydrogen Value Chain



Source: UNECE TECHNOLOGY BRIEF-HYDROGEN

Indian Landscape – Green Hydrogen



Water Electrolysis

- PEM/Alkaline/ SOEC using Solar PV/ Wind Energy (utilization of cheap electricity)
- Water Splitting (Photo-electrochemical) Lab Scale

Waste to Hydrogen

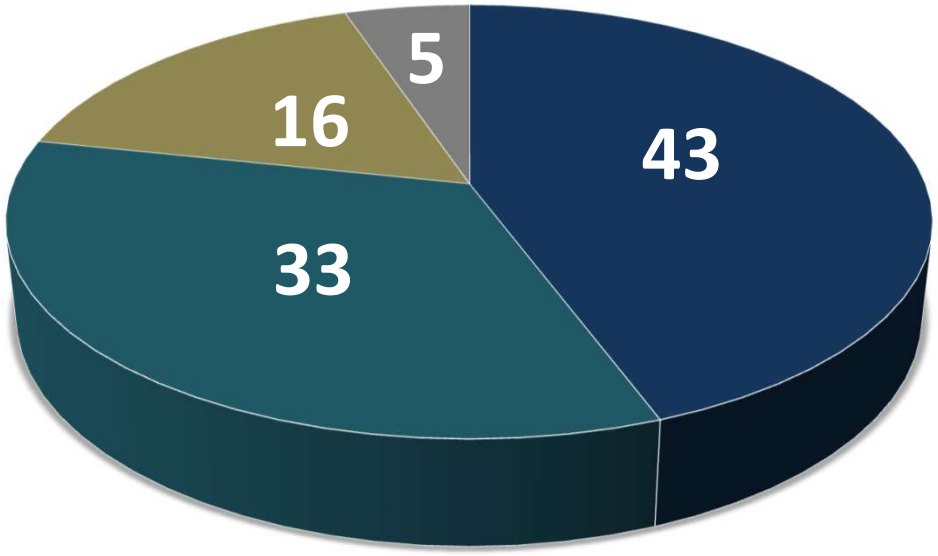
- Biomass Gasification Oxy steam (IOCL & IISc.) and Plasma Gasification (integration with Agro economy)
- Reforming of Compressed Biogas (extension to CBG)

Grey/ Blue hydrogen Already Produced by Refineries / Fertilizers

HYDROGEN IN INDUSTRIES

Global Scenario

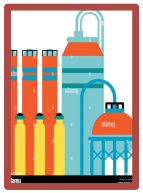
Total Hydrogen Used 97 MMTPA



Indian Scenario

Total Grey Hydrogen Production- 5.6 MMTPA

98% of Pure Hydrogen Demand Comes from Two Sectors



Refineries

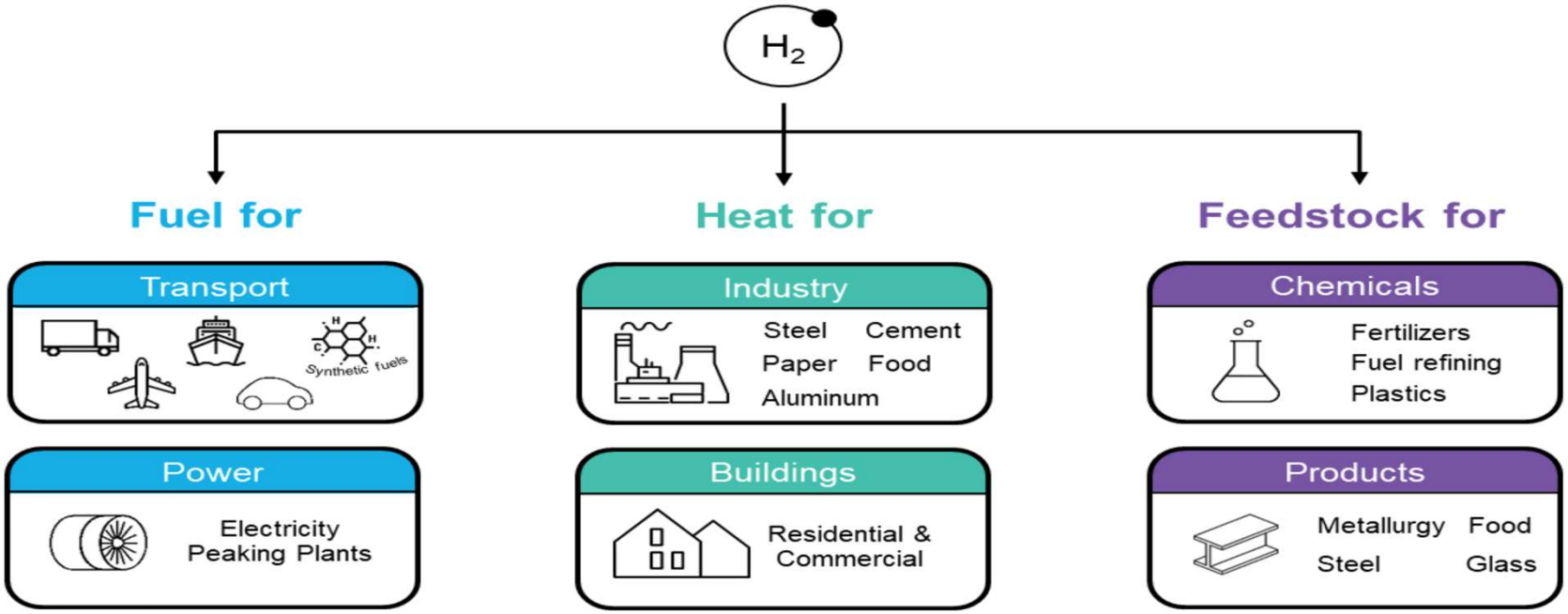
2.5 MMTPA

Fertilizers

3.1 MMTPA

Almost entire hydrogen in refinery and Fertilizers is produced through the SMR process using Natural gas or Naphtha

ROLE OF GREEN HYDROGEN IN DECARBONISATION

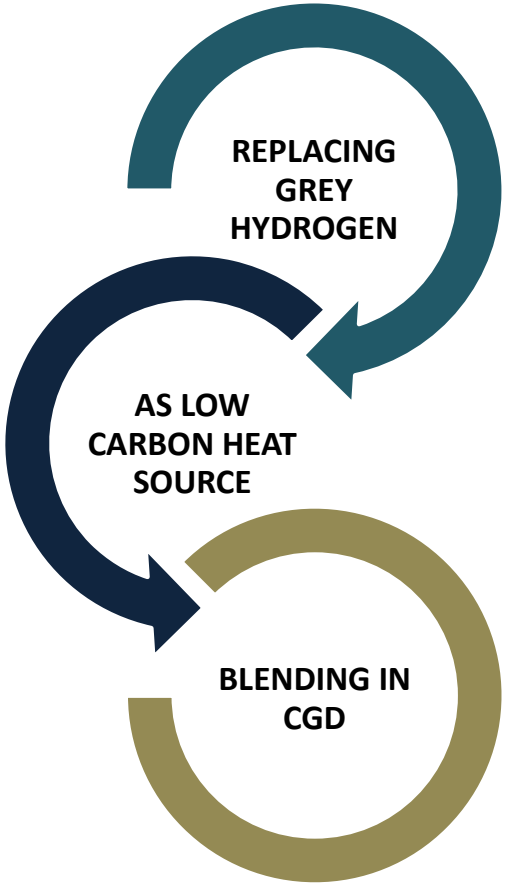


While we must electrify with renewable electricity in as many end use applications as possible, Hydrogen should be targeted at those sectors where direct electrification is not well-suited.

In industry, Hydrogen already plays an important role as a chemical feedstock.

ROLE OF GREEN HYDROGEN IN O&G SECTOR

1. REPLACING GREY HYDROGEN
2. AS LOW CARBON HEAT SOURCE
3. BLENDING IN CGD



- SMR process releases 10 times CO2 per unit of H2 produced

- Blending 1% hydrogen by volume would substitute about 0.3% of natural gas demand
- At 20% H_2 and 80% NG, the CO_2 reduction is approximately 7.4% less.

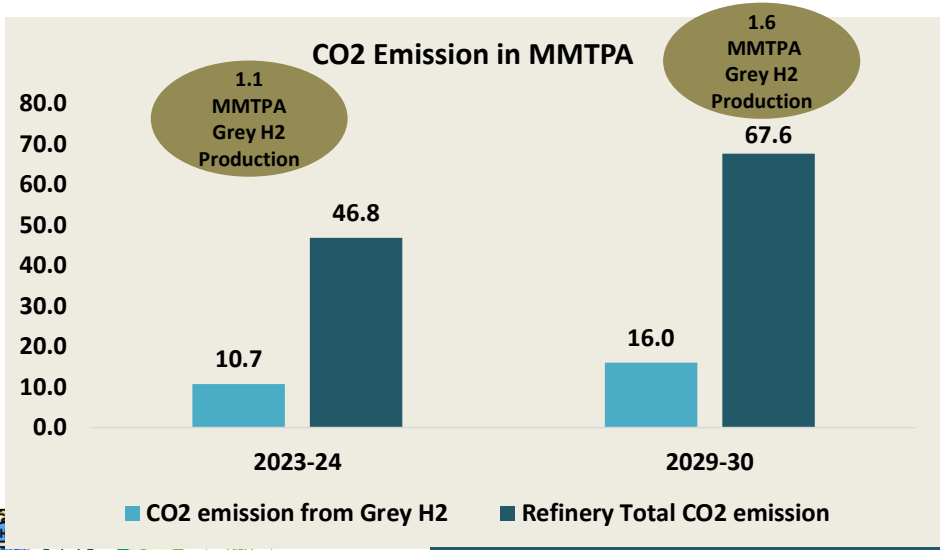
GAIL has launched India's maiden pilot project of hydrogen blending in CGD Network at Aavantika Gas Limited (a JV of GAIL and HPCL) which is blending 5% v/v hydrogen in its PNG network

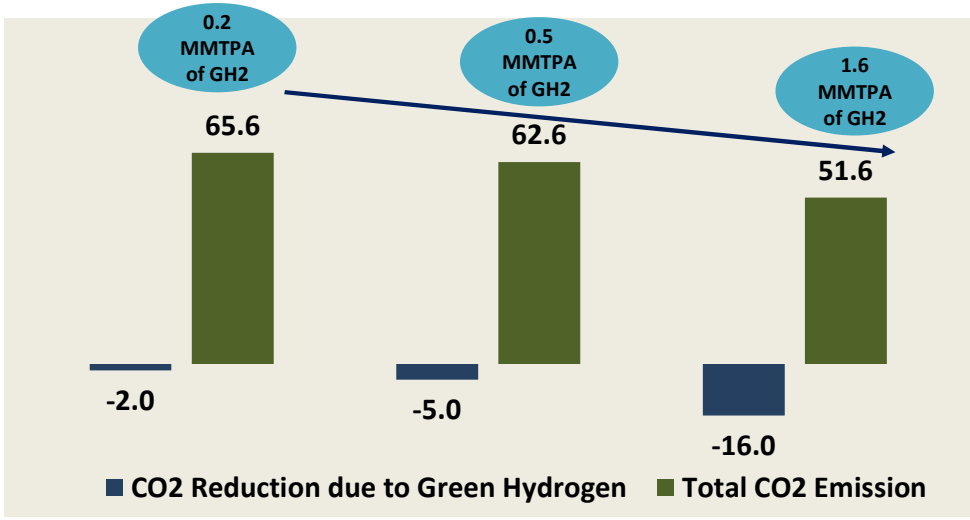
Impact on CO2 emission with Introduction of Green H2 in PSU Refineries

Refinery	Total Emission FY 2023-24	Total Estimated Emission till 2028-29
Total CO2 Emission from PSU Refinery	**46.83**	**67.56**
H2 Requirement through HGU only of PSU	**1.1**	**1.6**
CO2 emission due to Grey H2 in MMTPA	**10.7**	**16.0**

All fig in MMTPA

All Fig in MMTPA





Hydrogen in Mobility Sector

Technology	Desired Cost of Hydrogen	
Hydrogen IC Engine	80-100 Rs/Kg	Great Challenge
Fuel Cell	350-400 Rs/kg	Challenging but can be met

Hydrogen In Mobility Sector

Hydrogen Blended CNG

(Interim technology, Quantification of Benefits)

Hydrogen IC Engine

(Small Quenching Gap, Backfiring, Embrittlement)

RON= 130 / MON=30

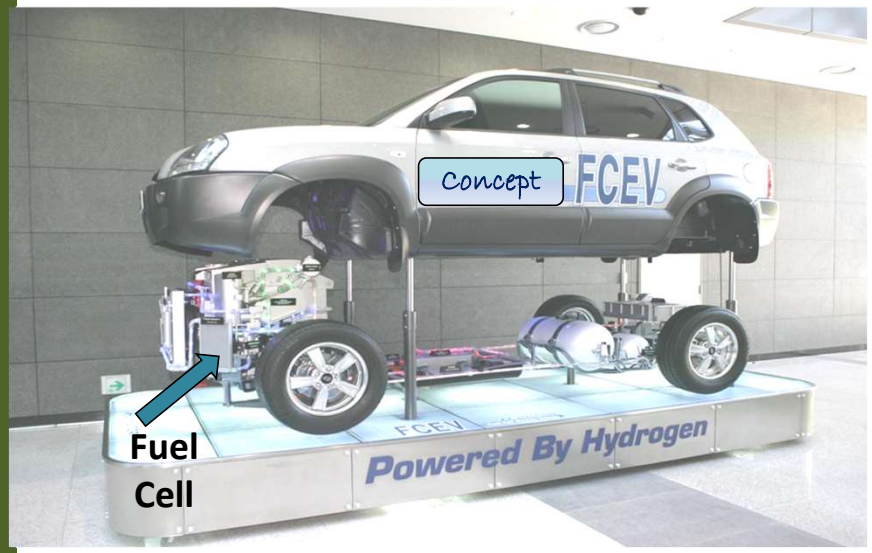
Very low sensitivity

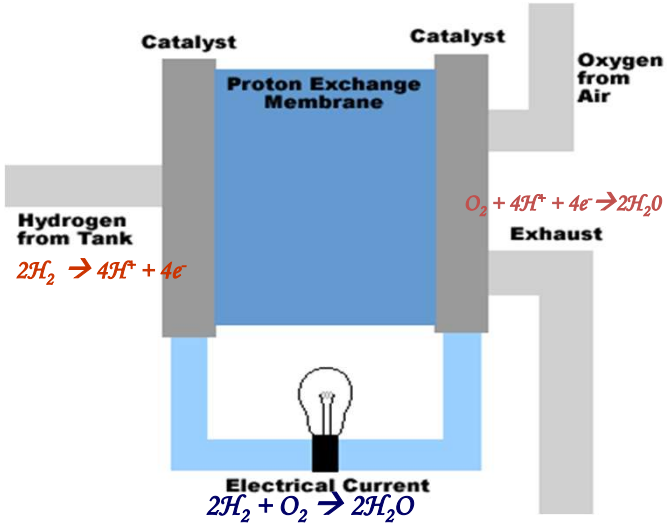
Fuel Cells

(best technology for using hydrogen,

Issues pertaining to cost, durability, fuel quality etc.)

Fuel Cell Introduction





Diesel Car → 18 km/lit. of diesel

Fuel Cell Car → 150 km/kg of Hydrogen

Expanded View - Fuel Cell System

Fuel Cell Development - Challenges

Besides technical superiority, fuel cell systems need to be competitive with existing technologies in cost and durability.

Challenges

- **Cost Current USD 4000/kw Target <USD1000/KW**
- **Durability - DoE 2020 Targets**
  - **Stationary 80,000 hrs**
  - **Transportation 5,000 hrs**
- **Hydrogen supply to Consumer**
- **Regulatory approvals**
- **Public Acceptance**
- **Safety**

CHALLENGES WITH GREEN HYDROGEN IN O&G SECTOR

- Cost of Green Hydrogen
- Power Requirement
- Storage
- Transmission

COST OF GREEN HYDROGEN

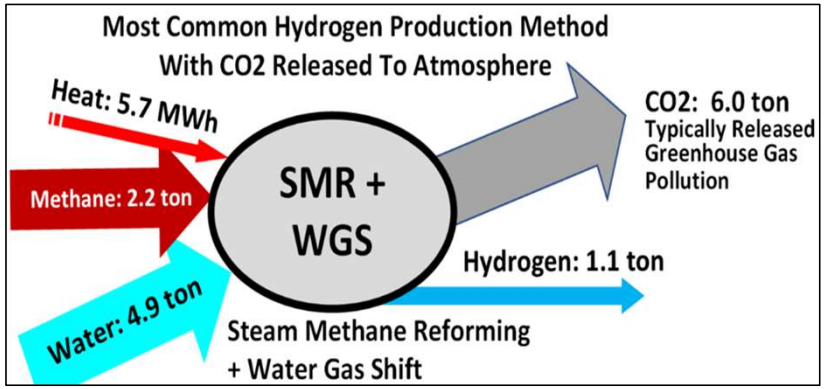
GREY HYDROGEN ECONOMICS

Hydrocarbon economics (LNG / fossil fuel landed cost + transportation) + Foreign exchange (if fuel is imported) + Transportation, Storage and Others

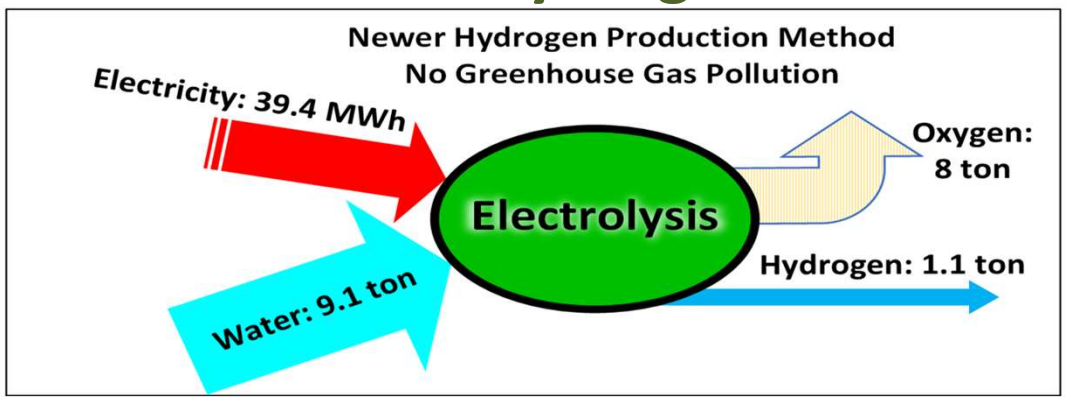
GREEN HYDROGEN ECONOMICS

Electricity Cost (Generation cost + utilization factor + T&D cost) + Electrolyser Cost (Capex + efficiency & degradation) + Transportation, Storage and Others

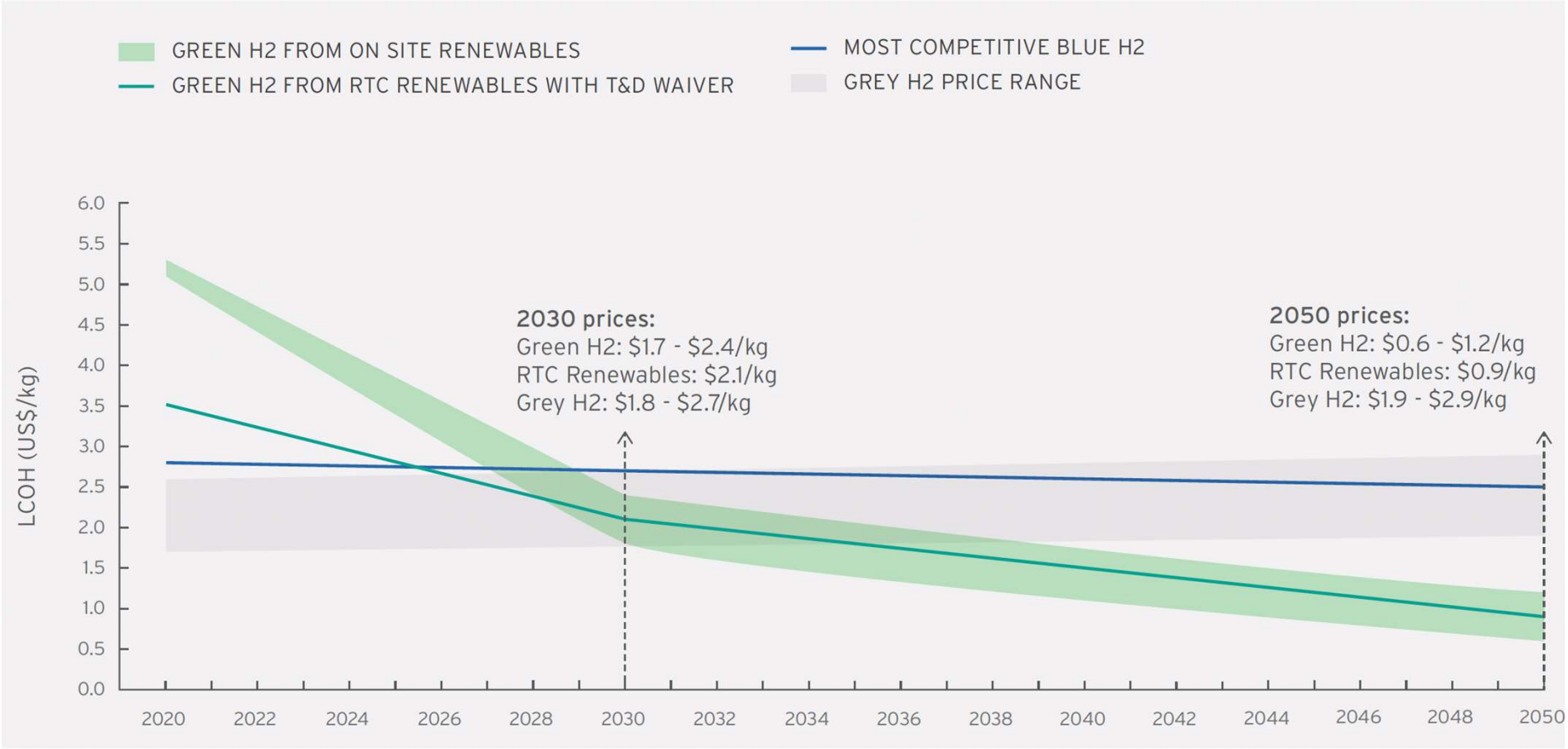
Grey Hydrogen



Green Hydrogen

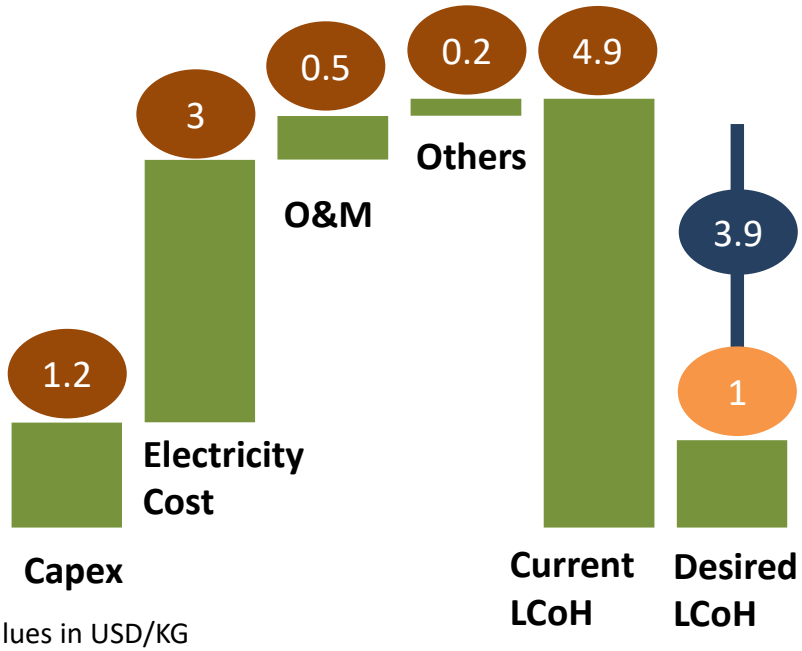


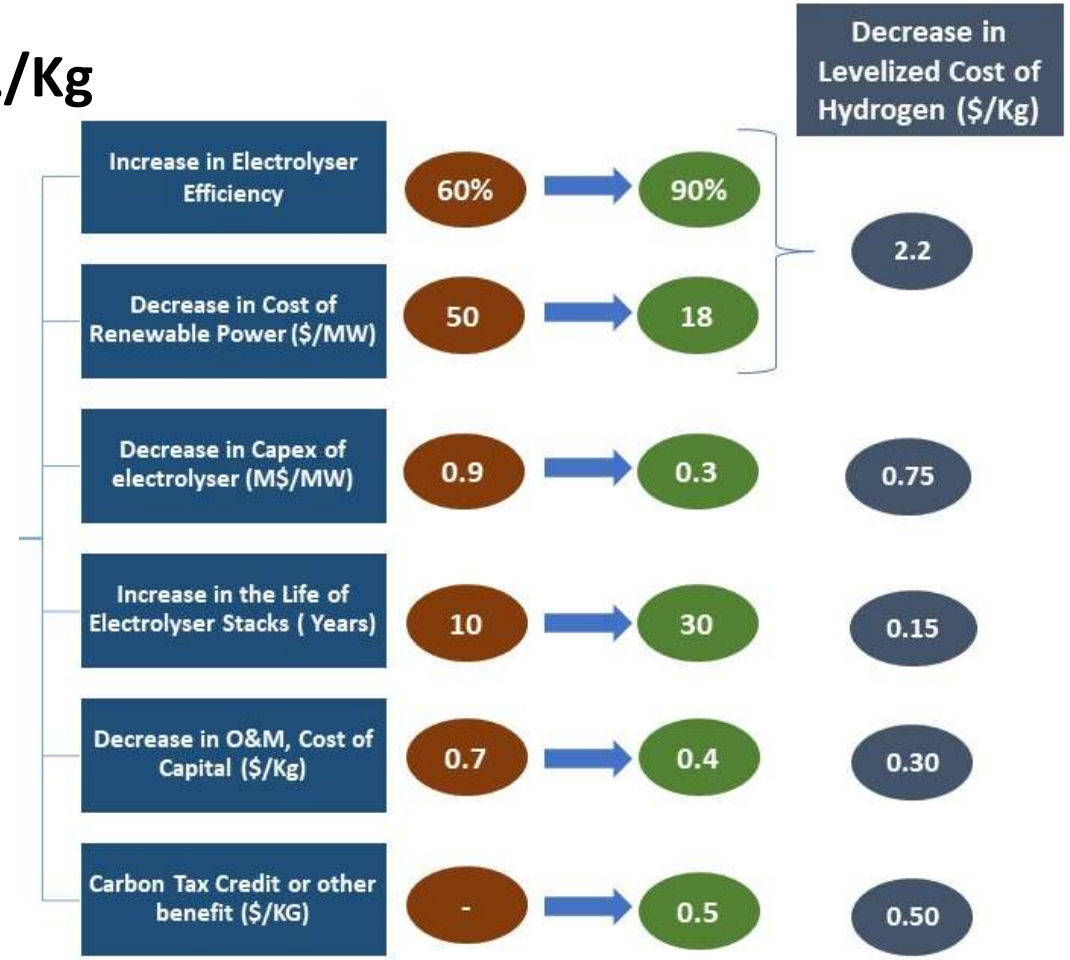
COST OF GREEN HYDROGEN



LEVELIZED COST OF HYDROGEN

Pathways to Green Hydrogen at $ 1/Kg





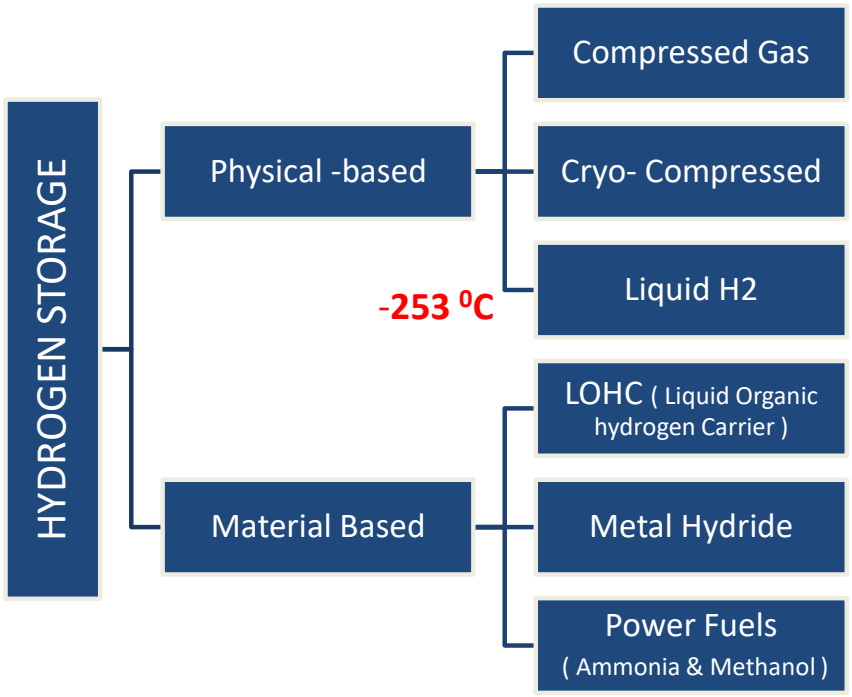
All values in USD/KG
LCoH- Levelized Cost of Hydrogen
O&M- Operation and Maintenance

HYDROGEN STORAGE

Being the lightest molecule, Hydrogen gas has a very low density:

- **1 kg of hydrogen gas occupies over 11 m^3 at room temperature and atmospheric pressure.**
- **Storage of hydrogen to be economically viable, its storage density must be increased**

Type of Storage



Type I:	**Pressure vessel made of metal**
Type II:	**Pressure vessel made of a thick metallic liner hoop wrapped with a fiber-resin composite.**
Type III:	**Pressure vessel made of a metallic liner fully wrapped with a fiber-resin composite.**
Type IV:	**Pressure vessel made of polymeric liner fully wrapped with a fiber-resin composite. The port is metallic and integrated into the structure.**

Volumetric Density	
Atms. Pr	.09 Kg/m3
350 Bar	26.1 Kg/m3
700 Bar	42 Kg/m3

H_2 as industrial gas is stored in Type I tanks, the pressure of which is from 150 to 300 bar (usually 200 bar).

Hydrogen Storage Challenges

Gaseous Cylinders

- Cost of compression
- Lower energy density

Liquid Hydrogen

- Boil off losses (as high as 0.5 % /day)
- Lower energy density

Metal / chemical hydride

- Low storage capacity
- Durability of material (1500 cycles)
- Regeneration
- Usage logistics

Besides Codes & Standards, Safety issues for Hydrogen Storage & Transportation are also major concerns

Hydrogen Transport

Mostly hydrogen is produced in decentralized locations and transported to place of use

Less than one fourth of world's hydrogen produced centrally and transported through

- **Pipelines – typically the cost of hydrogen pipeline is 80%-100% more than the natural gas pipeline**
- **High pressure cylinders and tube trailers**
- **Liquid hydrogen in cryogenic vessels**

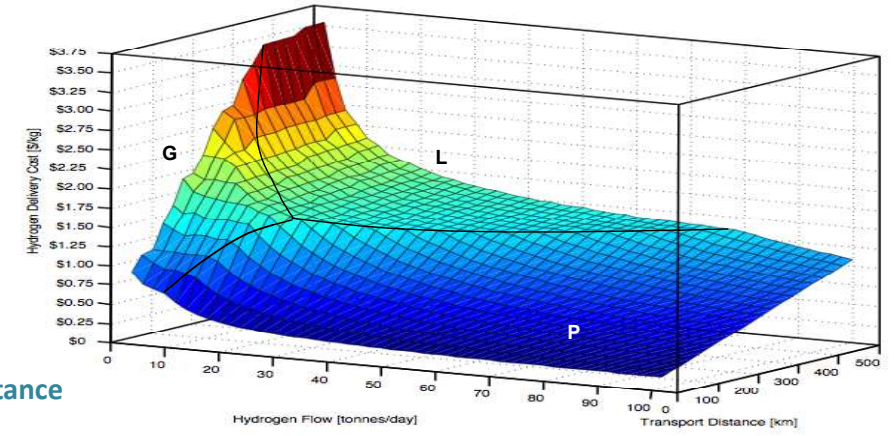
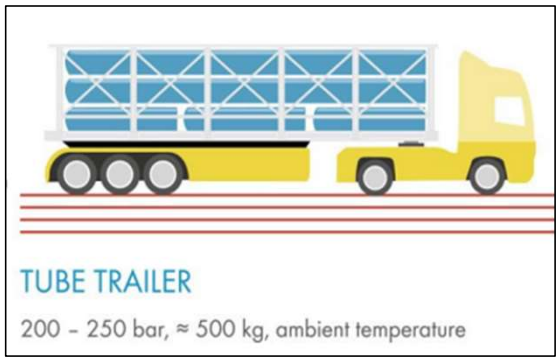
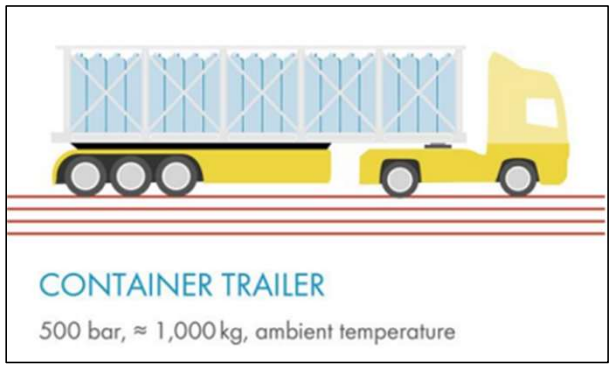


Fig. H_2 Delivery Cost vs. Flow rate and Distance

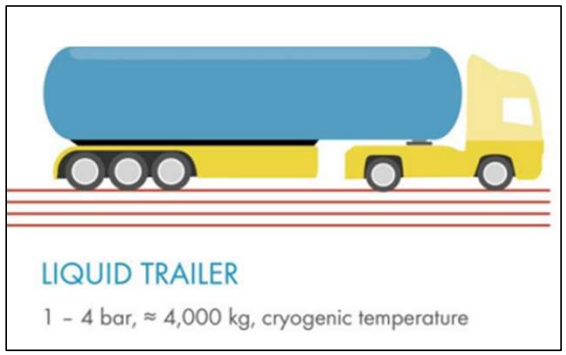
Hydrogen Transportation



Feature	Tube trailers
State of hydrogen	Gaseous
Pressure	Up to 700 bar
Energy density	Low
Cost	Less expensive
Range	Shorter
Size/ Weight	Large/ Heavy
Safety	More hazardous



Feature	Container trailers
State of hydrogen	Gaseous
Pressure	Up to 700 bar
Energy density	Low
Cost	More expensive
Range	Shorter
Size/ Weight	Medium / Heavy
Safety	Less hazardous

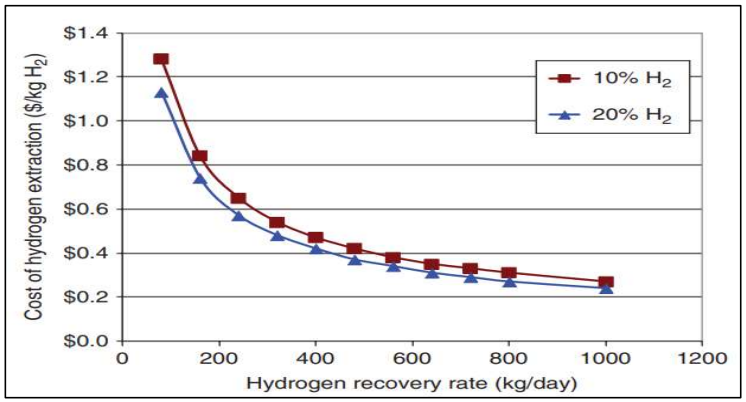


Feature	Liquid tanker trucks
State of hydrogen	Liquid
Pressure	Cryogenic (-253 Deg C)
Energy density	High
Cost	Most expensive
Range	Longer
Size/ Weight	Large / Very Heavy
Safety	Least hazardous

H2 Transportation in NG Pipelines

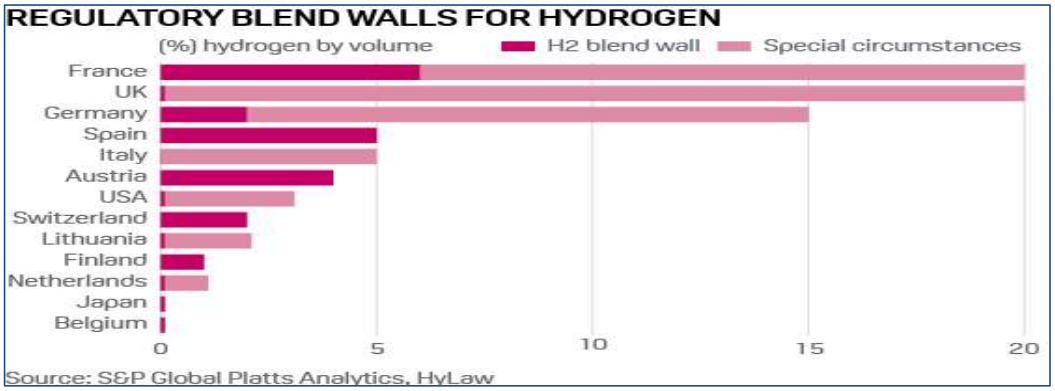
Many countries have started transporting hydrogen (low %age by volume) in the natural gas pipeline network

NG Pipelines - Long distance transportation option
H2 extraction at PR station brings down the cost

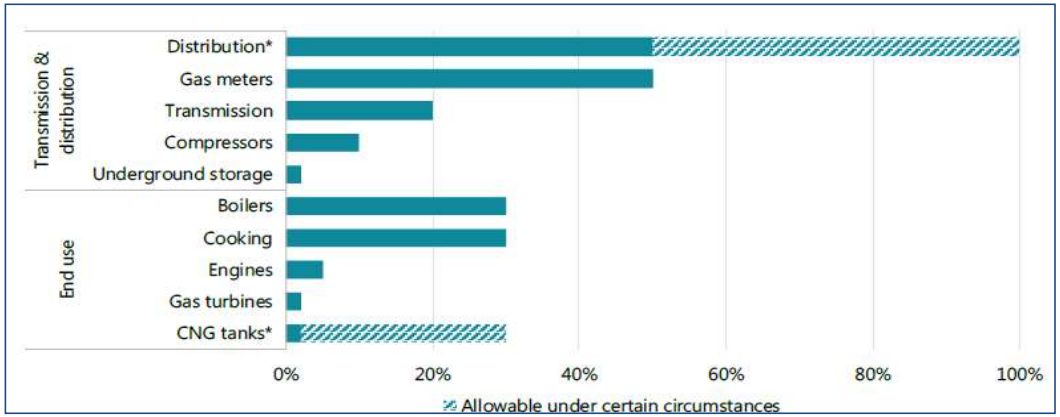


Source: Melaina et. al - NREL

- **CBG pipelines being setup under SATAT program in various GAs – potential carrier of hydrogen**
- **Studies underway to understand the impact of hydrogen transportation on pipeline metallurgy**

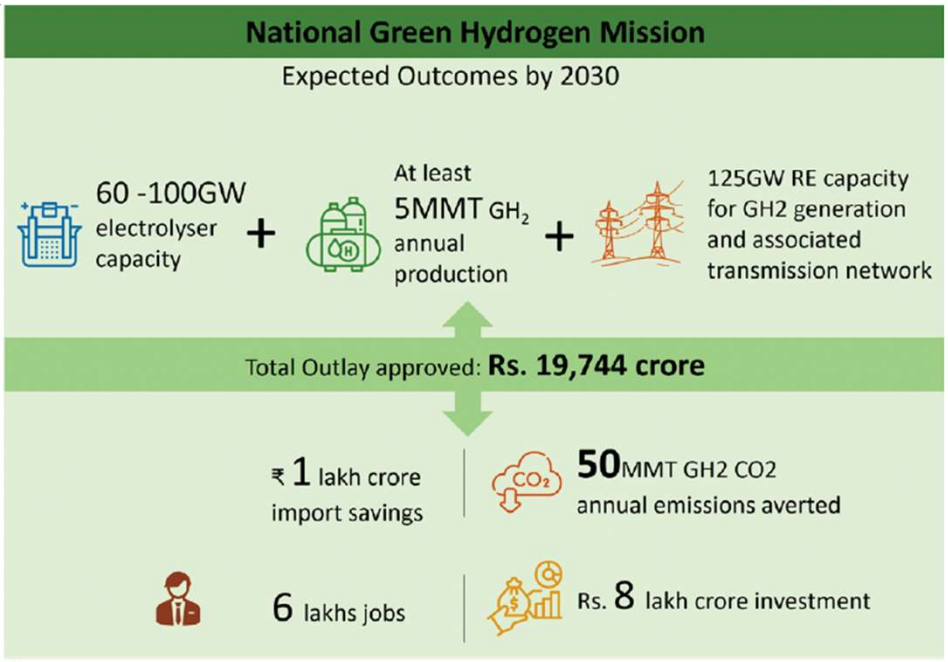


Tolerance of Existing Components for hydrogen blending in natural gas



Source: IEA Report 2019

National Green Hydrogen Mission



Phase-I (2023 TO 2026)

- Deployment in sectors that are already using hydrogen
- **Refinery , Fertilizer, CGD**

Phase-II (2026 TO 2030)

- Initiatives in new sectors of the economy
- **Steel, Mobility and Shipping sectors**

Strategic Interventions for Green Hydrogen Transition (SIGHT)

Component-I

- Total Outlay ₹ **4440 crore**
- Electrolyzer manufacturing incentives

Component-II

- Total Outlay ₹ **13050 crore**
- Green Hydrogen / Green Ammonia production

NATIONAL GREEN HYDROGEN MISSION

		Mission Components	Amount (₹ Crore)	Amount (₹ Crore)
Outlay recommended till 2029-30	i.	Strategic Interventions for Green Hydrogen Transition (SIGHT)	17,490	18,133
	ii.	Support for low-carbon Steel projects	455	
	iii.	Human Resource Development	35	
	iv.	Public Awareness and Outreach	70	
	v.	Program Management	83	
Outlay recommended till 2025-26	vi.	Support for Shipping and ports projects	115	1,611
	vii.	Support for Mobility projects	496	
	viii.	GH_2 production technologies, storage, hubs, etc.	400	
	ix.	R&D Projects	400	
	x.	Testing Facilities, Standards & Regulations development	200	
		Total		**19,744**

SIGHT -2B Scheme

Objective:

- Financial incentive mechanisms to support the production and use of Green Hydrogen.
- Major initiative by the GOI with an outlay of ₹ 2,400 crore under SIGHT -2B Program

SIGHT-Mode-2B- (Use of GH2 in Refineries)

- MNRE vide its letter dated 16th January, 2024 notified that the Scheme will be implemented by the Oil & Gas companies and CHT.

Tranche I of Mode 2B offers a bidding capacity of 200,000 Metric Tons per annum.

Responsibilities of CHT

- ❑ Secretarial, managerial and implementation support
- ❑ Develop supplementary tender guidelines along with OMCs to ensure uniformity
- ❑ To implement a review process involving claim verification, document reconciliation, and compilation of performance data.
- ❑ To submit comprehensive quarterly progress reports to MNRE via MoPNG

India's Potential as World Leader in Green Hydrogen

Favorable Factors:

- ❑Cheap Renewable Power
- ❑ Legislative Support
- ❑ Grid Stability
- ❑ Coastline and ports
- ❑Engineering, Procurement & Construction capability

❖ India has one of the largest synchronous grids in the world, capable of handling intermittent renewable energy and it has achieved 'One Nation-One Grid-One Frequency'.

KEY TAKE AWAY

O&G Sector has potential to become prime driver of Green Hydrogen in India

Green Hydrogen can help decarbonize the O &G sector

Cost competitive Green Hydrogen in future signals promising opportunities

Voluntary carbon market can play a significant role

Many countries are blending 5-12% hydrogen in natural gas; studies indicate that blending can be increased to 20% without any major infrastructural changes

THANK YOU!

Questions ?