SPECIAL SESSION
ON
HYDROGEN MISSION

India Smart Utility Week 2023, 28 February - 04 March 2023

C P Tiwari
TATA Power

Lighting up Lives!

Index

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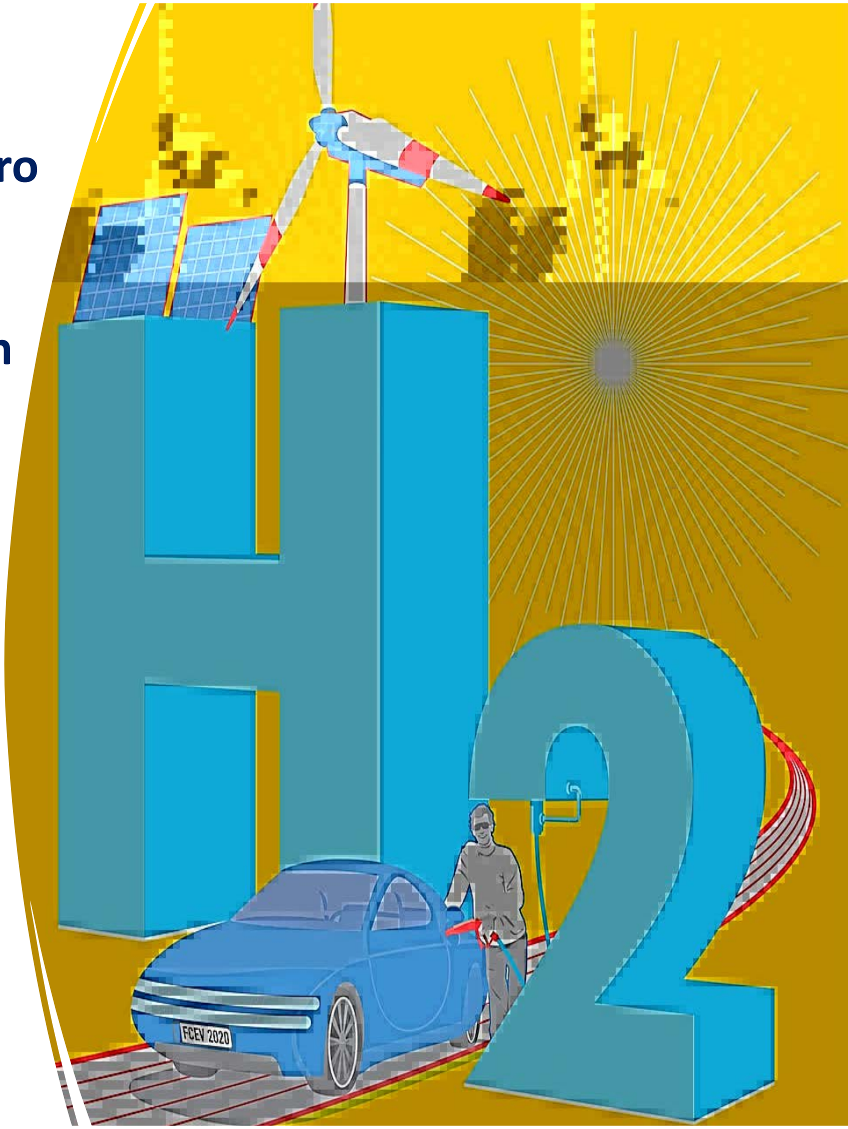
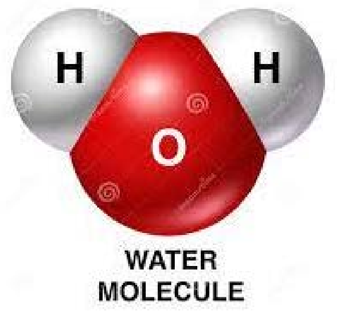
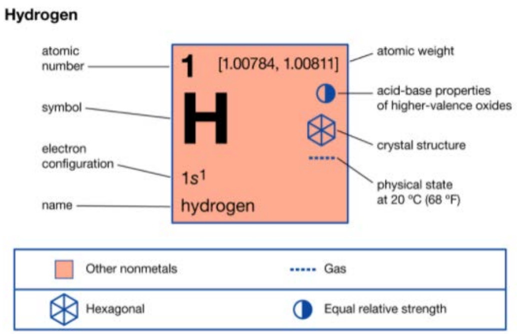
SUSTAINABLE IS ATTAINABLE



Hydrogen | Basic facts

Hydrogen was first identified in 1776 by British Scientist Henry Cavendish when Zn reacted with HCl to evolve H_2





Basic Facts:

- Hydrogen is Colorless, Tasteless & Odorless
- H_2 Density is 0.0899 kg/Nm^3 at NTP [0 ^{0}C, 1 atm], 1 kg H_2 requires ~ 11.12 m^3
- Exists as a gas @ NTP (2 H atoms combine to form 1 H_2 molecule
- LHV of H_2 : 33.3 kWh/kg, HHV of H2: 39.4 kWh/kg
- Flammability limits, LFL: 4% (H_2 by v/v), HFL: 75% (H_2 by v/v)
- For water splitting, (at room temperature), minimum voltage requires is 1.48 V (thermoneutral voltage)
- Stoichiometrically, 1 kg of H_2 requires 9 kg of pure water as input

High Carbon

Low Carbon

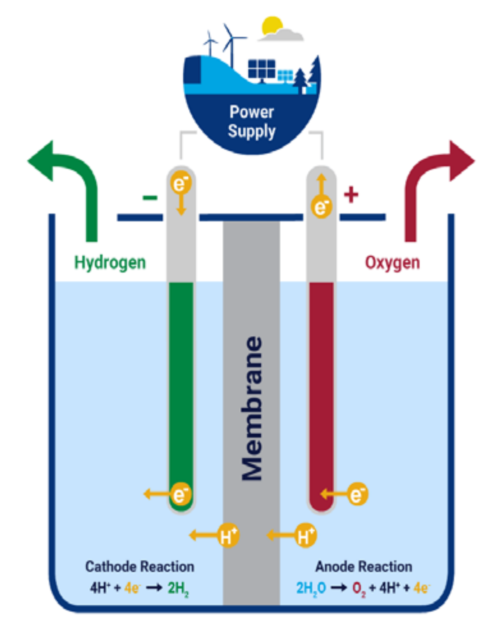
Zero Carbon

GREY HYDROGEN
(Steam methane reforming. CO_2 emissions not captured, CO_2 Intensity -9 – 10 kg CO_2 per kg of H_2)

BLUE HYDROGEN
(Steam methane reforming, Coal Gasification CO_2 emissions captured, CO_2 Intensity -2 – 4 kg CO_2 per kg of H_2)

TURQUOISE HYDROGEN
(Methane Pyrolysis. Solid carbon mass produced. No emissions to the atmosphere)

BROWN HYDROGEN
(Coal Gasification. CO_2 emissions not captured, CO_2 Intensity -19 – 20 kg CO_2 per kg of H_2)



GREEN HYDROGEN
(Hydrogen produced from water electrolysis. Completely green if renewable power is used)

PINK HYDROGEN
Pink hydrogen is generated through electrolysis powered by nuclear energy.

Hydrogen | Value Chain & Technologies

🟩 Green H_2 – Produced from renewable sources
🟫 Brown H_2 – Produced from fossil fuels
🟦 Blue H_2 – Produced from fossil fuels with CCS

Production Technologies

Thermochemical

- Steam methane reforming (SMR)
- Gasification
- Partial Oxidation
- Pyrolysis
- Autothermal reforming (ATR)

Mature technologies

Electrolysis

- Alkaline
- Polymer electrolyte membrane (PEM)
- Solid oxide electrolyzer cell (SOEC)
- Anion Exchange Membrane (AEM)

Other

- Dark fermentation
- Microbial electrolysis
- Photoelectrochemical

Supply & Logistics

Conversion

- Hydrogen gas
- Liquid hydrogen
- NH_3
- Liquefied organic hydrogen carrier (LOHC)

Transport

- Trucks & Trains
- Ships
- Pipeline

Storage

- Geological storage
- Storage tanks
- Chemical reconversion
- Liquefaction and regasification

Mature technologies

End Use Applications

Mobility

- Heavy & Light-duty vehicles
- Maritime
- Rail ; Aviation

Industrial

- Oil refining and chemicals
- Feed stock for Ammonia / Fertilizers
- Iron and steel production
- High-temperature heat

Power and Energy

- Co-firing NH3 in coal power plants
- Back-up and off-grid power supply
- Long-term, large-scale storage
- Blended ; pure $H_{2;}$ Methanation

Buildings

- Heating systems
- Cooling systems
- Fuel cell generators

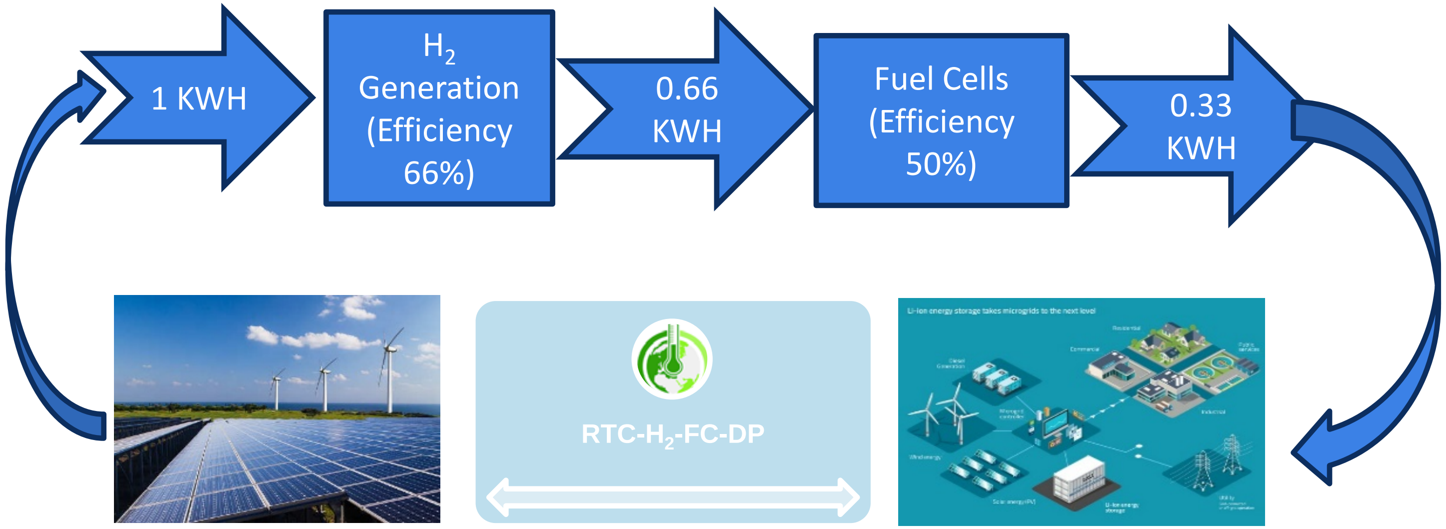
To produce hydrogen, it must be separated from the other elements in the molecules where it occurs. There are many different sources of hydrogen and ways for producing it for use as a fuel.

➡

The most common methods for producing hydrogen are steam-methane reforming. Electrolysis is also likely to become common method for hydrogen generation in future

Green Hydrogen | End Use Application

P2P [Power to Power]


1 KWH

H_2 Generation (Efficiency 66%)

0.66 KWH

Fuel Cells (Efficiency 50%)

0.33 KWH

- Conversion Efficiency of the Combined “Electrolyser - Fuel Cell” System – 33%
- This could be used to replace DG Power where DG utilization is very high, or for long duration energy storage solution where intra day or seasonal storage is required
- Other option of P2P include Green Ammonia firing in thermal units, using Green Hydrogen for Gas turbines etc.

P2G or P2C [Power to Gas or Power to Chemical]

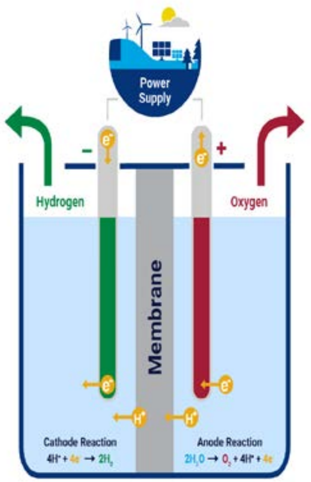
Possible use of Green H_2 include:

- **Mobility:** Heavy-Duty long-haul transportation, Maritime, Rail & Aviation
- **Refinery:** for desulphurization
- Green Steel Making
- Green Ammonia Making to be used in Fertilizer industry or for other application
- Methanol Production
- Buildings – heating, cooling etc.
- Blending H2 in NG

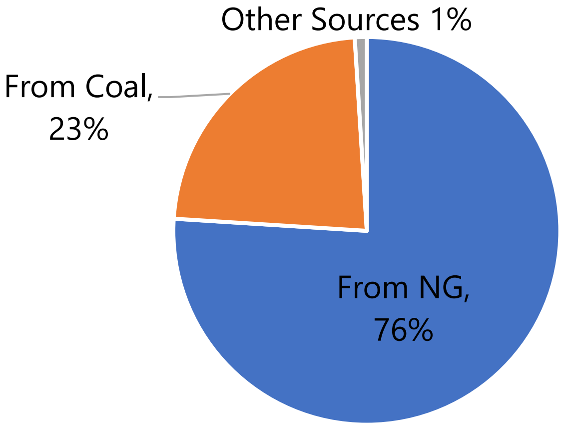
- Since conversion efficiency in P2P is around 33%, P2P projects will be required when deep decarbonization of power sector is required or for long duration energy storage solution.
- In near future, P2G & P2C Projects are likely to come-up with an objective of Decarbonization

Hydrogen | Production Methods & Use

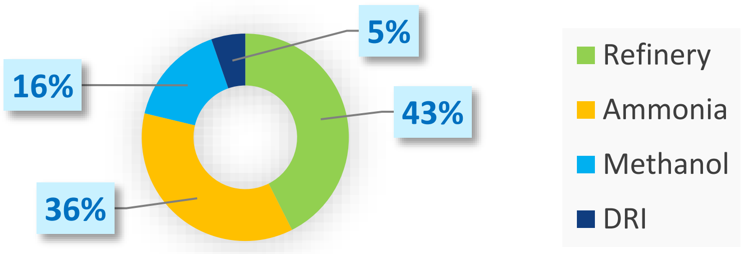
- **Hydrogen Production**
  - **Hydrocarbon**
    - **Fossil Fuel**
      - **Catalytic Reforming**
        - **Steam Reforming**
        - **Partial Oxidation**
        - **Auto Thermal Reforming**
  - **Biomass**
    - **Gasification, Pyrolysis**
  - **Water Splitting**
    - **Alkaline**
    - **PEM**
    - **AEM & SOEC**



Present H2 Production from different Sources[1]



Present Hydrogen Use by different sectors[2]



1 – As per IEA Report 2019 "The Future of Hydrogen"
2 – As per IEA Report 2022 "Global Hydrogen Review"

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Net Zero | Role of Green Hydrogen

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Ⓗ **Indicates pathways enabled leveraging H_2**

Decarbonization Pathways

India GHG emissions (2019[1])

Power

1.14 (42%) Gt CO_2

- Renewable Energy
- Carbon Capture Usage & Storage
- Demand Management
- H_2 based power applications and power storage Ⓗ

Transportation

0.33 (12%) Gt CO_2

- Zero Emission Vehicles (BEV, FCEV) Ⓗ
- Bio/ Low Carbon fuels
- Synfuels
- Efficiency Improvement

Steel

0.3 (11%) Gt CO_2

- H_2 based steel making Ⓗ
- Carbon Capture Usage & Storage
- Low carbon steel making
- Material & energy efficiency

Chemicals

0.24 (9%) Gt CO_2

- Green H_2 based feedstock Ⓗ
- Carbon Capture Usage & Storage
- Recycling & Reuse of plastic

Buildings

0.16 (6%) Gt CO_2

- High efficiency Combined Heat & Power Electrification
- Energy Efficiency & Smart Buildings
- H_2 based heating Ⓗ

Others

0.55 (20%) Gt CO_2

- Energy efficiency, Carbon Capture
- Alternate Materials
- Elimination of coal with H_2 biomass, natural gas Ⓗ

1. 2019 emissions taken due to sharp decline in industrial and transport emissions in 2020

Note: BEV – Battery electric vehicle; FCEV – Fuel cell electric vehicle

Green Hydrogen Equivalence | Sector Wise

Green hydrogen applications are expected to mature as a potential solution to decarbonize hard-to abate sectors such as refinery, ammonia, methanol, iron and steel, Transportation, Gas to Power etc.

100 KTPA

Refining

10 Mt PA Oil refining (**4%** of India's refining capacity

OR

No. of FCEV

1.6 Million Passenger Vehicle can run on hydrogen

OR

Power Generation

1.7 BU Power Generation (**1.5%** of India's Monthly Power Demand)

OR

Methanol

0.5 Mt PA Methanol Production (**20%** of total present use of Methanol in India)

OR

Urea

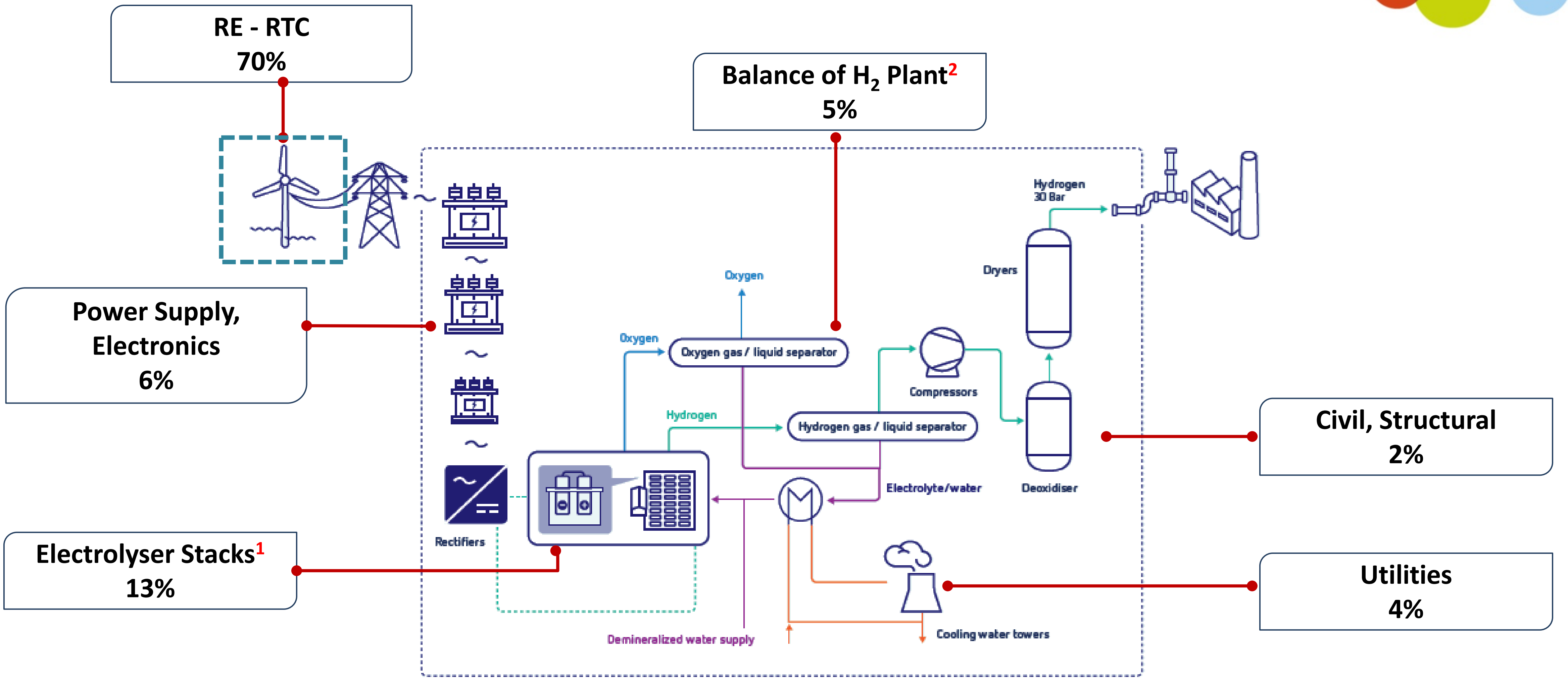
0.6 Mt PA Urea Production (**1.6%** of total urea consumption in India

OR

Steel

1.6 Mt PA Crude Steel Production (**1.4%** of India's Crude steel production)

Green Hydrogen | Cost Components of GH_2 & RE Plant (1/2)



RE - RTC
70%

Balance of H_2 Plant[2]
5%

Power Supply, Electronics
6%

Civil, Structural
2%

Electrolyser Stacks[1]
13%

Utilities
4%

70% of total cost is cost of RE RTC Solution

30% of total cost is cost of Green Hydrogen Plant

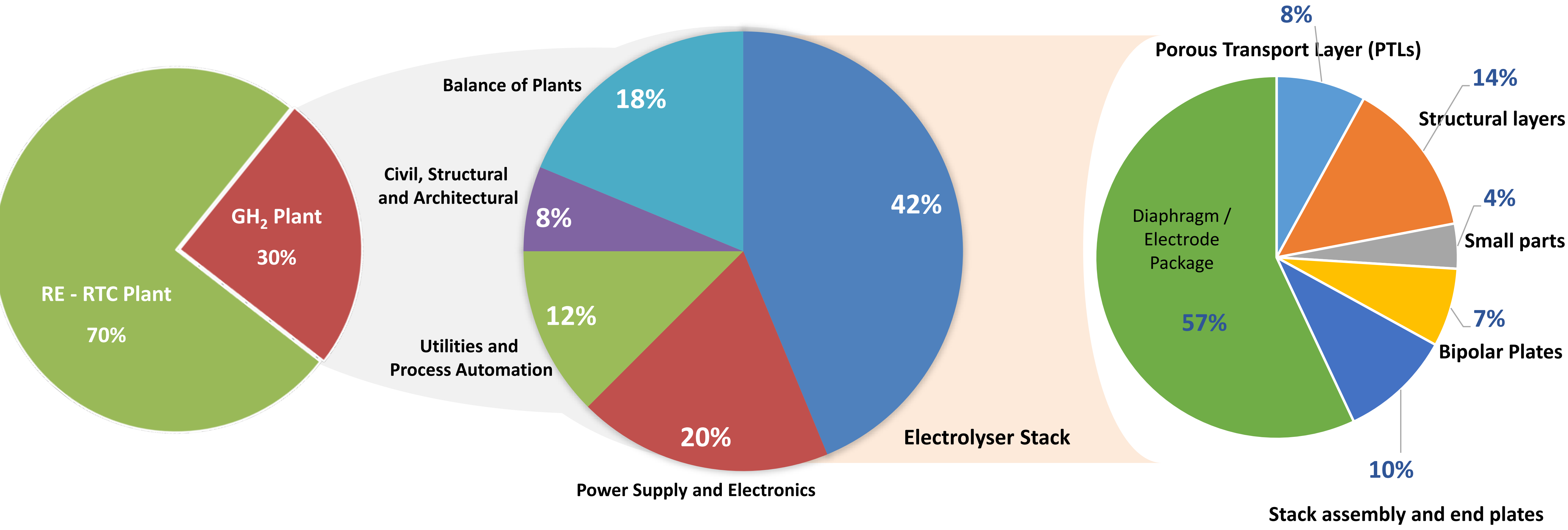
1. For Alkaline Electrolyzer; 2. BoP includes H_2 separators, compressors, Deoxidizers, Dryers; GH_2 – Green Hydrogen

Green Hydrogen | Cost Components of GH_2 & RE Plant[1] (2/2)

Cost Components RE RTC & GH_2 Plant

Cost Breakup – GH_2 Generation[2]

Cost Breakup of Electrolyser Stack (%)



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1 . Break-up indicated is considering approx. cost level

2. Cost Break-up for GH_2 Plant is as per estimate. Alkaline Electrolyser stack cost break-up is as per IRENA Report.

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GH_2 Cost Sensitivity – as per Hydrogen Council

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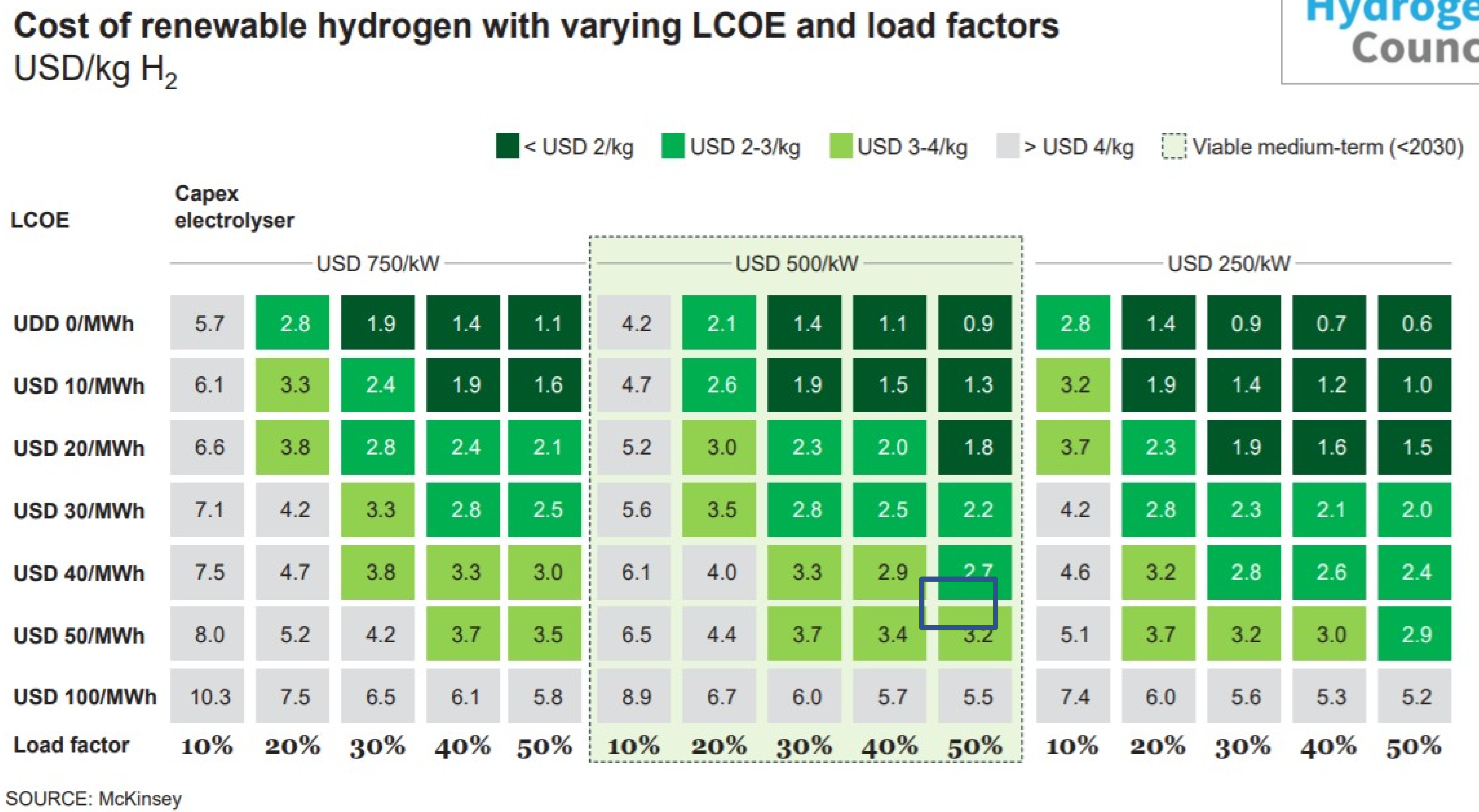
Renewable hydrogen from electrolysis production cost scenarios, USD/kg of Hydrogen

Hydrogen Council

Green Hydrogen Cost:

- Assumptions for 2025 deliveries
- Orders placed in 2023
- Capex \$500/kW (\$0.5m/MW)
- LCOE \$50/MWh (5c/kWh)
- 50% Load Factor
- Direct coupling to renewables



Cost of renewable hydrogen with varying LCOE and load factors
USD/kg H_2

■ < USD 2/kg
■ USD 2-3/kg
■ USD 3-4/kg
■ > USD 4/kg
☐ Viable medium-term (<2030)

LCOE	Capex electrolyser														
	USD 750/kW					USD 500/kW					USD 250/kW				
UDD 0/MWh	5.7	2.8	1.9	1.4	1.1	4.2	2.1	1.4	1.1	0.9	2.8	1.4	0.9	0.7	0.6
USD 10/MWh	6.1	3.3	2.4	1.9	1.6	4.7	2.6	1.9	1.5	1.3	3.2	1.9	1.4	1.2	1.0
USD 20/MWh	6.6	3.8	2.8	2.4	2.1	5.2	3.0	2.3	2.0	1.8	3.7	2.3	1.9	1.6	1.5
USD 30/MWh	7.1	4.2	3.3	2.8	2.5	5.6	3.5	2.8	2.5	2.2	4.2	2.8	2.3	2.1	2.0
USD 40/MWh	7.5	4.7	3.8	3.3	3.0	6.1	4.0	3.3	2.9	2.7	4.6	3.2	2.8	2.6	2.4
USD 50/MWh	8.0	5.2	4.2	3.7	3.5	6.5	4.4	3.7	3.4	3.2	5.1	3.7	3.2	3.0	2.9
USD 100/MWh	10.3	7.5	6.5	6.1	5.8	8.9	6.7	6.0	5.7	5.5	7.4	6.0	5.6	5.3	5.2
Load factor	10%	20%	30%	40%	50%	10%	20%	30%	40%	50%	10%	20%	30%	40%	50%

SOURCE: McKinsey

Green Hydrogen Cost Dominated by LCOE, Electrolyser Capex and Load Factor

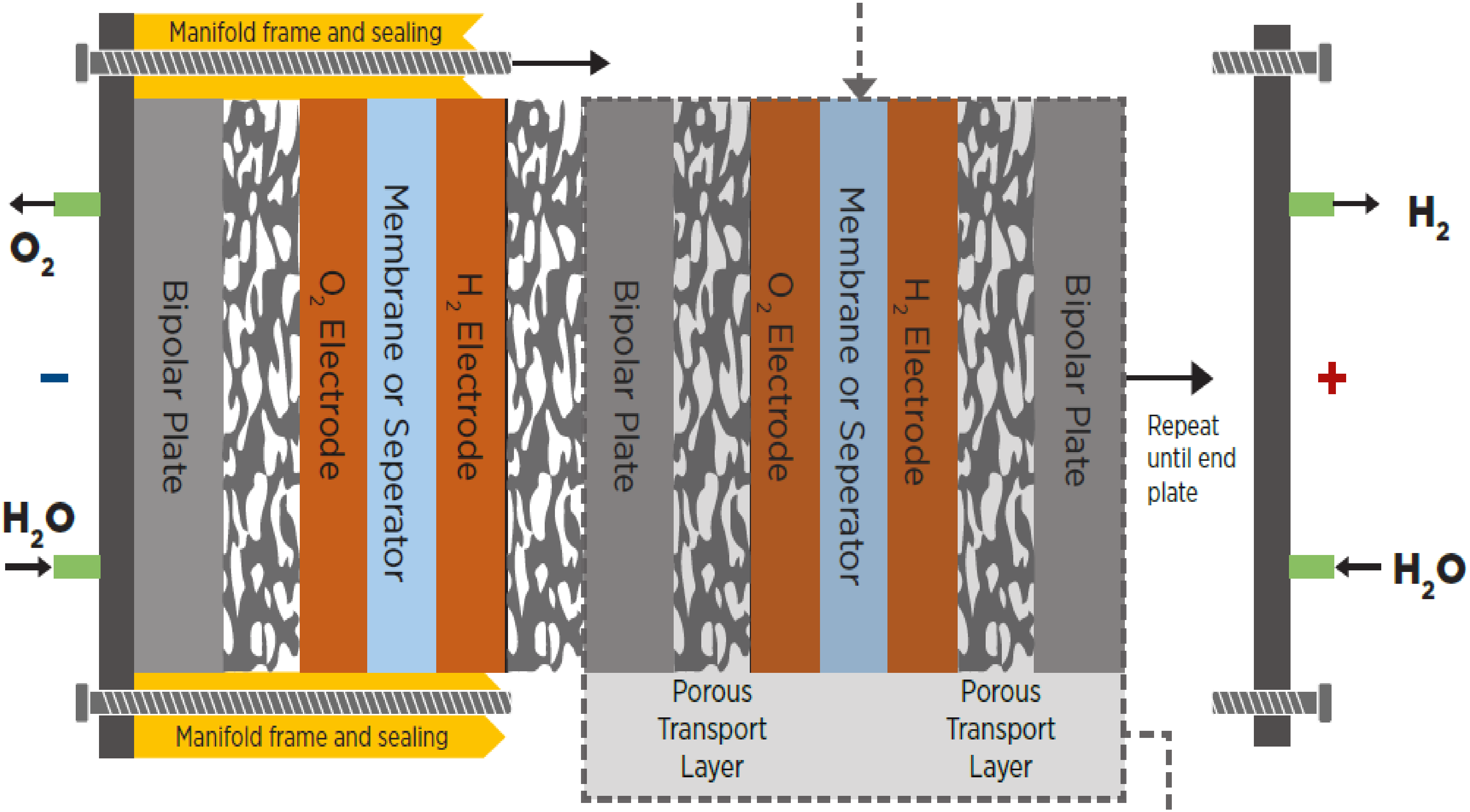
Electrolyzer | Comparison of Technologies

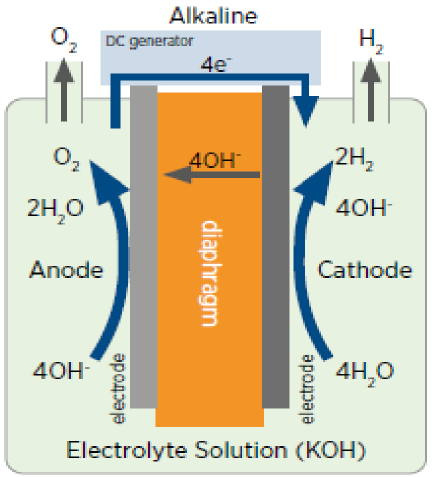
PARAMETERS	ALKALINE ELECTROLYZER	PEM ELECTROLYZER	SOLID OXIDE ELECTROLYZER
Electrolytes	KOH (20-30%)	Polymers	Yttria Stabilized Zirconium
Catalysts	Ni/ Co/ C-Pt, Non noble metals	Platinum/ Iridium	Nickel-Copper Alloys
Operating Temp.[1]	60-80 ºC	50-80 ºC	650-1,000 ºC
Efficiency[1]	63% -70%	56% -60%	74% - 81%
Life Span	Up to 90,000 hours	Up to 80,000 hours	Up to 40,000 hours
Pros	• Large capacity systems • Lower capital cost	• Quick startup time and dynamic operation • Compact & light-weight	• High efficiency and larger capacity systems • Lower energy requirement
Cons	• Corrosive systems (corrosive electrolyte) • Low dynamic operation	• Expensive membrane and catalysts • Low durability	• Limited dynamic operation • Mechanical stability issues
Key Challenges	• More dynamic and flexible operation	• Reduction of noble metal utilization • Efficiency, durability improvement	• Commercialization of technology
Key Players	nel AsahiKASEI Cummins McPhy	nel ITM POWER Energy Storage | Clean Fuel Cummins PLUG POWER SIEMENS energy ohmium	sunfire h2e POWER GOODENERGYSOLUTIONS Cummins HALDOR TOPSØE CATALYSING YOUR BUSINESS

Based on application type, load requirements, capacity, either PEM or Alkaline systems can be used

1. As per IEA Report - 2019

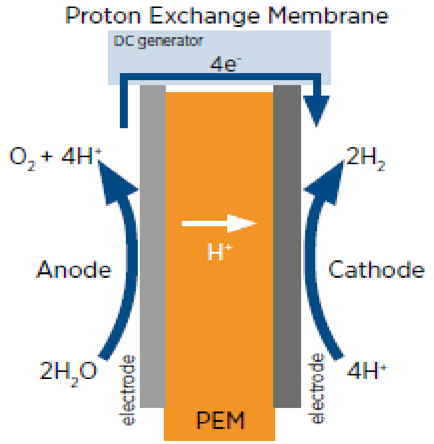
Electrolyser | Cell Level & Stack Level Architecture





Anode: $4OH^- \leftrightarrow 2H_2O+O_2+4e^-$

Cathode: $4H_2O+4e^- \leftrightarrow 2H_2+4OH^-$



Anode: $2H_2O \leftrightarrow O_2+4H^++4e^-$

Cathode: $4H^++4e^- \leftrightarrow 2H_2$

Alkaline Electrolyser | Design Improvement for Cost Reduction (1/2)

Parameters	2020	2050	R&D Focus
Nominal Current Density	0.2 – 0.8 A/cm2	> 2 A/cm2	Diaphragm
Voltage Range (Limits)	1.4 – 3 V	<1.7 V	Catalyst
Operating Temperature	70 – 90 Deg C	'> 90 Deg C	Diaphragm, frames, balance of plant components
Cell Pressure	<30 Bar	>70 Bar	Diaphragm, Cell, Frames
Load Range	15% - 100%	5% - 300%	Diaphragm
H_2 Purity	99.9% - 99.9998%	99.9% - 99.9999%	Diaphragm
Voltage Efficiency	50% - 68%	'>70%	Catalyst, Temperature
Electrical Efficiency (Stack) – LHV	47 – 66 KWh / kg of H2	< 42 KWh / kg of H2	Diaphragm, Catalyst
Electrical Efficiency (System) - LHV	50 – 78 KWh/kg of H2	< 45 KWh/kg of H2	Balance of the System
Life Time (stack)	60,000 Hrs	100,000 Hours	Electrode
Stack Unit Size	1 MW	10 MW	Electrode
Electrode Area	10,000 – 30,000 cm2	30,000 cm2	Electrodes
Capital Cost (Stack) – Min 1 MW	USD 270/KW	< USD 100/KW	Electrode
Capital Cost (System) – Min 10 MW	USD 500 – 1000 / KW	< USD 200/KW	Balance of Plant

Alkaline Electrolyser | Design Improvement for Cost Reduction (2/2)

Increase in Current Density

Current density can be increased to more than > 2 A/cm^2, with thicker diaphragm ➔ Thicker diaphragm leads to efficiency reduction.

The challenge is to increase thickness and at same time reduces ohmic resistance so as to keep efficiency at higher level.

Reducing Diaphragm Thickness

Reducing diaphragm thickness will improve efficiency however this may lead to gas permeability and lower mechanical robustness.

Presently diaphragm thickness is 460 microns. Decreasing this to 50 microns will lead to improvement of efficiency from 53% to 75% at 1 A/cm2 current density.

High specific surface area

Re-designing catalyst composition and electrode architectures for improved specific surface area

Porous Transport Layers

Design Optimization of Porous Transport Layers (PTLs)

Alkaline Electrolyser | Supply Chain of Raw Material

Material of Constructions

- **Electrolyte: KOH Solution**
- **Separator: ZrO2 [Zirconium Oxide] stabilized with PPS** [Polyphenylene Sulphide] **Mesh**
- **Cathode, Anode & Bipolar Plate: Nickle collated Stainless Steel**
- **Porous Transport Layer: Nickle Mesh**

Material Loading

No rare material in construction. Only Nickle is main material used in construction.

- **Nickel – 0.8 MT / MW**
- **Zirconium – 0.1 MT / MW**
- **Aluminium – 0.5 MT/MW**
- **Steel – 10 MT / MW**
- **Some amount of copper and cobalt**

Supply Chain –Nickel

- **World Nickel Reserve – 94 Million MT [Indonesia, Australia & Brazil]**
- **In 2020, more than 50% Ni Production was from Indonesia, Philippines and Russia**
- **In 2021, India's Nickel demand was 75 KMT, major qty is imported.**
- **In Dec 2021, Vedanta acquired Nicomet Goa which produces 7.5 KMT of Ni and Cobalt**
- **Major consumption of Nickel is in making stainless steel – 72%.**

No raw material supply constraints except for Nickle which can be sourced from Indonesia, Philippines and Russia.

PEM Electrolyser | Design Improvement for cost Reduction (1/2)

Parameters	2020	2050	R&D Focus
Nominal Current Density	1 – 2 A/cm2	> 4-6 A/cm2	Design, Membrane
Voltage Range (Limits)	1.4 – 2.5 V	<1.7 V	Catalyst, Membrane
Operating Temperature	50 – 80 Deg C	‘> 80 Deg C	Effect on durability
Cell Pressure	<30 Bar	>70 Bar	Membrane, Reconversion catalyst
Load Range	5% - 120%	5% - 300%	Membrane
H2 Purity	99.9% - 99.9999%	Same	Membrane
Voltage Efficiency	50% - 68%	‘>70%	Catalyst
Electrical Efficiency (Stack) – LHV	47 – 66 KWh / kg of H2	< 42 KWh / kg of H2	Membrane, Catalyst
Electrical Efficiency (System) - LHV	50 – 83 KWh/kg of H2	< 45 KWh/kg of H2	Balance of the System
Life Time (stack)	50,000 – 80,000 Hrs	100,000 – 120,000Hours	Membrane, Catalyst, PTLs
Stack Unit Size	1 MW	10 MW	MEA, PTLs
Electrode Area	1500 cm2	>10,000 cm2	MEA, PTLs
Capital Cost (Stack) – Min 1 MW	USD 400/KW	< USD 100/KW	MEA, PTLs, BP
Capital Cost (System) – Min 10 MW	USD 700 – 1400 / KW	< USD 200/KW	Rectifier, Water Purification

PEM Electrolyser | Design Improvement for cost Reduction (2/2)

Improving Current Density to 6 A/cm2

Improving electrode area from 1500 – 2000 cm2 to 5000 to 10000 cm2

Increasing stack size from 1 MW to 5 – 10 MW

Reducing membrane thickness from 125-175 microns to 20 microns – efficiency gain by 6%

Avoiding expensive coatings and redesign of PTLs and BPs: PTLs Anode Side: Platinum collated sintered porous titanium. Platinum provides passivation as well as resistance. This resistance causes efficiency drop of 4%. Also, Bipolar Plates are made of titanium coated with Platinum (cathode) and gold (anode). Alternative material & coating for Bipolar plates is being explored.

Redesign of Catalyst coated Membrane (CCM) / Membrane Electrode Assembly (MEA): economy of scale for CCM fabrication, more reliable and less expansive supply chain for catalyst and membrane

PEM Electrolyser | Supply Chain of Raw Material

Material of Constructions

- ☐ Electrolyte / Separator : Solid PFSA (Perfluoroalkylsulfonic acid) Membrane
- ☐ Cathode: Platinum nano particle on carbon black
- ☐ Anode: Iridium
- ☐ Bipolar Plate: Platinum coated Titanium (cathode), Gold Coated Titanium (anode)
- ☐ Porous Transport Layer: Anode side - Platinum coated sintered porous titanium, Cathode side - Sintered porous titanium or carbon cloth

Material Loading

PEM uses rare material like Platinum and Iridium.

- Platinum – 0.3 kg/MW
- Iridium – 0.7 kg/MW

It is expected that these quantities will reduce to 1/10th by 2030 due to design improvement

Supply Chain – PGM

- ☐ Globally Platinum and Iridium Supplies were 188 MT/Annum & 6.87 MT/Annum mainly from South Africa, Zimbabwe and Russia (As on 2019)
- ☐ Other important component in PEM electrolyser is Catalyst Coated Membrane (CCM) / Membrane Electrode Assembly (MEA)
- ☐ PFSA type membranes, such as Nafion, Flemion or Aquivion [thickness 125 – 175 microns] are manufactured in US, UK & Japan.

For PEM electrolysers, upstream supply chain is dependent on South Africa, Europe, USA & Japan

PGM - Platinum Group Material

Energy & Hydrogen |India's Energy Targets

2030

- 500 GW Non-Fossil Capacity
- 50% of Installed Capacity from non-fossil fuels
- Reducing emission intensity of GDP to 45% below its 2005 level

2047

- Energy Independence

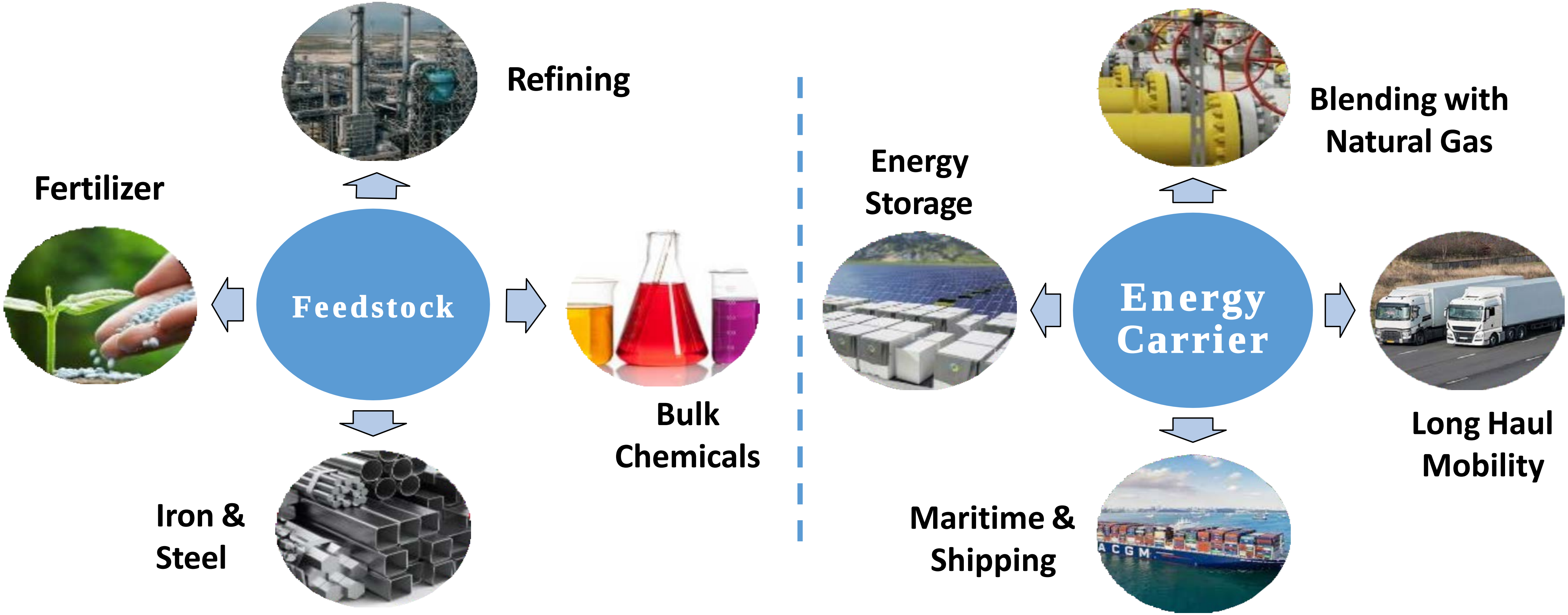
2070

- Net Zero

✓ Union Cabinet approved National Green Hydrogen Mission on 04th January 2023

✓ MNRE released National Green Hydrogen Mission document on 13th January 2023

National Green Hydrogen Mission | Sectors in Focus



Feedstock

Refining

Fertilizer

Bulk Chemicals

Iron & Steel

Energy Carrier

Blending with Natural Gas

Energy Storage

Long Haul Mobility

Maritime & Shipping

Green Hydrogen can replace fossil fuels in all of the above

National Green Hydrogen Mission | Major Component (1/2)

Demand Creation

Export Markets

Support in development of Infrastructure, hubs etc for export

Substituting imports

Substituting imported fertilizers with Green Fertilizers

Domestic Demand

Mandating minimum use of Green Hydrogen & its Derivative by different users

Financial Incentives

Strategic Interventions for GH2 Transition

Direct Financial Incentives for:

- ☐ Electrolyser Manufacturing
- ☐ Green Hydrogen Production

Total minimum domestic demand – 5 million MT PA. Total Production including export – 5 to 10 Million MT PA

National Green Hydrogen Mission| Major Component (2/2)

Compliance Monitoring: Guideline for monitoring compliance for minimum use of green hydrogen & derivative product shall be developed and implemented

Competitive Bidding for Procurement: MNRE will frame model guidelines for competitive bidding and develop regulatory framework for certification of Green Hydrogen and its derivatives.

Domestic Manufacturing of Green Fertilizers: Two plants each for production of Green Hydrogen based Urea and Green Hydrogen based DAP are targeted to be set up through competitive bidding route. By 2034-35, it is targeted to substitute all Ammonia based fertilizer imports [6 Billion USD] with domestic Green Ammonia based fertilizers.

Green Hydrogen Policy released in Feb 2022 which includes waiver of ISTS charges, renewable energy banking, granting open access in time bound manner, land in existing RE Part for Hydrogen generation plants etc. shall be implemented.

Development of Regulations, Codes and Standards, Research & Development initiatives, Skill Development initiatives, Public awareness and stakeholder’s outreach & International Cooperation

National Green Hydrogen Mission| Pilot Projects & Hydrogen Hub

Shipping

☐ Retrofit 2 ships to run on Green Hydrogen/derived fuels by 2027

☐ Development of Supply Chain, port infrastructure, Green Ammonia bunkers and re-fueling facilities

Transport

☐ Phased deployment of hydrogen fuelled buses & trucks

☐ Cost of hydrogen fuelled vehicles and associated infrastructure

Green Steel

☐ Support for blending/injection of Green Hydrogen in 2 steel plants

Setting up 2 Nos Green Hydrogen Hub

National Green Hydrogen Mission | Key Enablers

Key Enablers

Resources

Renewable energy - banking & storage, transmission, finance, land, water

R&D

Result oriented, time-bound, including through PPP, grand challenges

Ease of doing business

Simpler procedures, taxation, SEZ, commercial issues, single window

Infrastructure & Supply Chain

Ports, Re-fueling, Hydrogen Hubs, pipelines

Regulations & Standards

Testing facilities, standards, regulations, safety & certification

Skill Development, Public awareness

Coordinated skilling programme, online portal

National Green Hydrogen Mission | Financial Outlay

The initial outlay for the Mission will be Rs 19,744 crore

- ✓Rs 17,490 crore for the SIGHT programme
- ✓Rs 1,466 crore for pilot projects
- ✓Rs 400 crore for R&D
- ✓ Rs 388 crore towards other Mission components

Expected Deliverables by 2030

At least
5 MMT GH_2
annual
Production

60-100 GW
Electrolyser
capacity

125 GW RE Capacity for GH_2 Generation & associated Transmission network

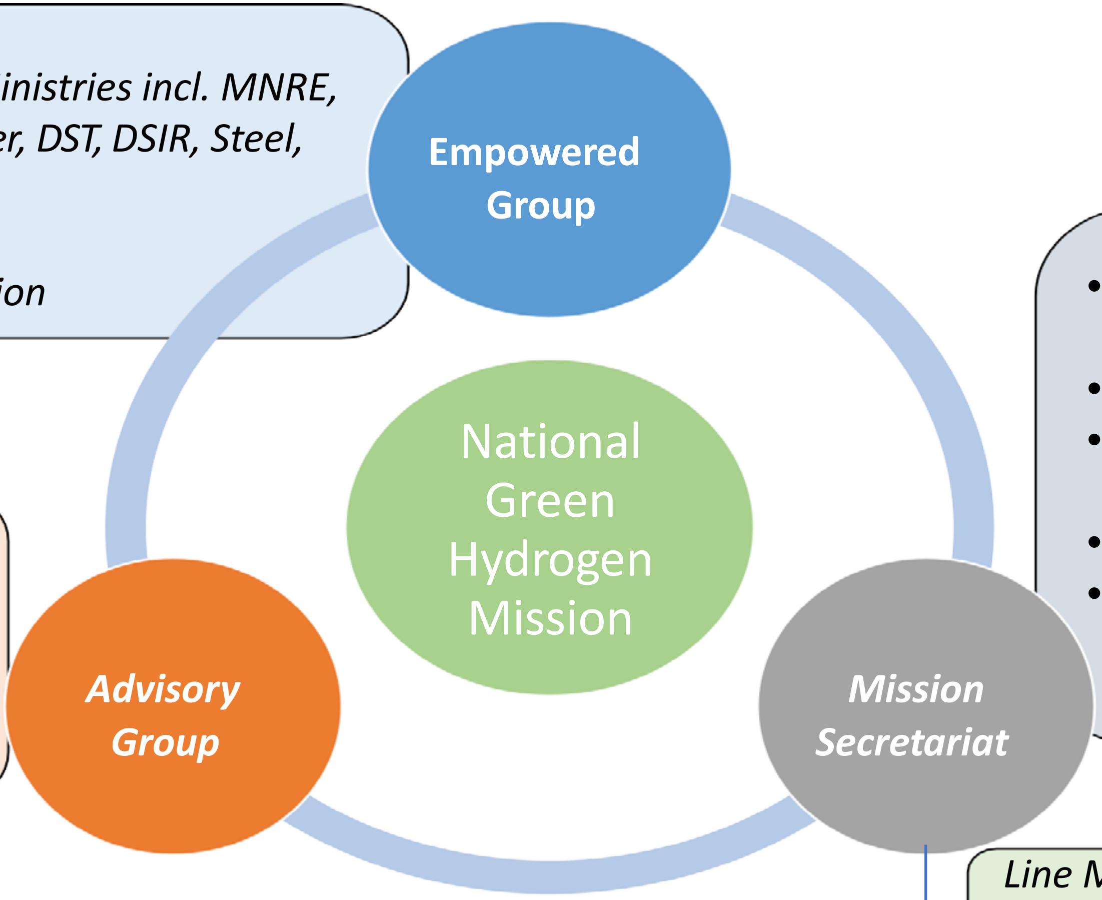
₹ 1 lakh crore
Import Savings

50 MMT CO_2
Annual
Emissions
Averted

6 lakh
Jobs

₹ 8 lakh cr
Investment

Mission Governance Framework



Empowered Group

- *Chaired by Cabinet Secretary*
- *PSA, CEO NITI Aayog, Secretaries of Ministries incl. MNRE, Fertilizer, MoPNG, MoRTH, MHI, Power, DST, DSIR, Steel, Shipping, DPIIT*
- *Experts from Industry*
- *Provide Guidance and Strategic direction*

National Green Hydrogen Mission

Advisory Group

- *Chaired by PSA*
- *Experts - academia, industry and civil society*
- *Technical advice to EGoS*

Mission Secretariat

- *Headed by Mission Director*
- *Anchored in MNRE*
- *Comprise professionals and domain experts*
- *Programme management*
- *Assist EG*

Line Ministries to create dedicated Green Hydrogen cells

Mission Secretariat will formulate or facilitate formulation of policies including guidelines for procurement of Green Hydrogen and its derivatives; schemes for incentives and projects; and undertake appraisal, funding and management of pilot and R&D projects. It will also assist the EG and the AG, as required.

Green Hydrogen | Actions Initiated

Policy Initiatives

- ✓ Green Open Access Rules notified – provisions for Open Access, Banking
- ✓ Hydrogen policy initiatives by States – UP, Rajasthan, Gujarat

Standards

- ✓ Standards for Hydrogen mobility notified
- ✓ MNRE is anchoring a Working Group to consolidate regulations and standards

Research & Development

- ✓ Long term roadmap for Research and Innovation under development

Demand Aggregation

- ✓ Model Bidding Guidelines for procurement of Green Hydrogen/Ammonia being formulated

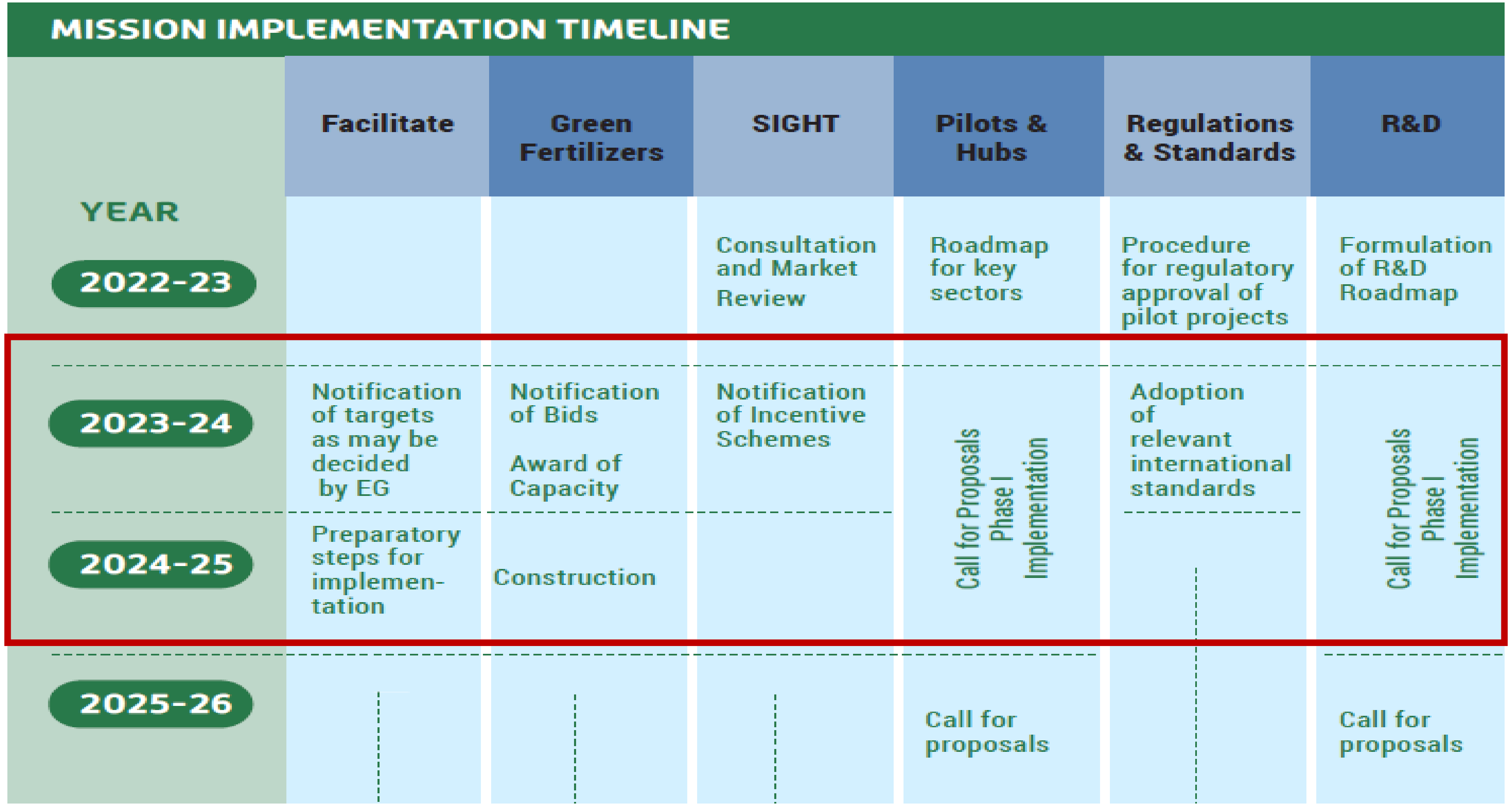
Pilot Projects

- ✓ PSUs and Private investors have initiated pilot projects for Green Hydrogen

International cooperation

- ✓ Cooperation initiatives: Germany, EU, Japan, US, UAE, Australia and multilateral institutions

Hydrogen Mission | key action and implementation timelines



MISSION IMPLEMENTATION TIMELINE

YEAR	Facilitate	Green Fertilizers	SIGHT	Pilots & Hubs	Regulations & Standards	R&D
2022-23			Consultation and Market Review	Roadmap for key sectors	Procedure for regulatory approval of pilot projects	Formulation of R&D Roadmap
2023-24	Notification of targets as may be decided by EG	Notification of Bids Award of Capacity	Notification of Incentive Schemes	Call for Proposals Phase I Implementation	Adoption of relevant international standards	Call for Proposals Phase I Implementation
2024-25	Preparatory steps for implementation	Construction				
2025-26				Call for proposals		Call for proposals

Hydrogen Mission | key action and implementation timelines

FY 2022 – 2023	FY 2023 – 2024	FY 2024 – 2025	FY 2025 – 2030
Consultation & Market Review for SIGHT, Roadmap for Key Pilot Projects & Hubs, Finalization of procedure for regulatory approval of pilot projects & Formulation of R&D Roadmap	Notification of Target for min use of hydrogen, Notification of Bid and award of capacity for Green Fertilizers, Notification of incentive scheme for SIGHT, For Pilot Projects and Hubs – Call of proposal and Phase-I implementation, Adoption of Relevant international standards, Call of proposal for R&D Proposal and Implementation	Call of Proposal for Phase-II Pilot, Hub and R&D Projects, start of implementation of Green Fertilizer Plant, start of implementation of incentives for SIGHT	Implementation of Phase-II Pilot, Hub & R&D Projects, implementation of Green Fertilizer Plant, implementation of incentives for SIGHT

Hydrogen Mission | Further Actions Required

Policy and Regulatory Interventions

- ✓ Obligation for domestic demand
- ✓ Relaxation in open access charges
- ✓ Provision of Banking up to 2030
- ✓ Extension of ISTS waiver beyond 2025
- ✓ Provision of carbon market to encourage green hydrogen use
- ✓ Facilitate central and govt agency approvals

Fiscal & Financial Interventions

- ✓ Concessional GST for Green Hydrogen & its derivatives
- ✓ RE to be covered under GST to allow input tax credit for Hydrogen
- ✓ Priority Sector lending for GH2 Projects
- ✓ GH2 and its related EPC Projects shall be included in the harmonized list of infrastructure projects
- ✓ Provision of accelerated depreciation for green hydrogen projects

Standards and Regulations

- ✓ Lifecycle assessment toolkits to enable estimation of emission from green hydrogen production at different locations and under different conditions.

Hydrogen Mission | Further Actions Required

R&D

- ✓ Establishment of facilitative R&D ecosystem for development and commercialization of GH2 technologies
- ✓ A collaborative framework must be developed to ensure coordination and collaboration between research institutes and industry

Incentive Scheme

- ✓ Manufacturing support may promote indigenization at component level for Green Hydrogen technologies
- ✓ Relaxation of import duties on machinery to produce electrolyser to enable cost competitiveness with global players
- ✓ Integrated development may be incentivized whereby critical components are developed and manufactured indigenously.

Hydrogen Hub

- ✓ Initiating development of green hydrogen hubs near ports including inter-alia Dahej, Mangalore, Kandla, Vishakhapatnam, Tuticorin, Machilipatnam and Paradip.
- ✓ Corridors for transportation of Ammonia
- ✓ Development of transmission capacity and ISTS connectivity at coastal hub locations
- ✓ Land in coastal regions for developing projects may be provided on concessional rates
- ✓ Enabling infrastructure including storage bunkers, handling facilities, pipeline, export terminals at identified ports

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Thank You!

Website: www.tatapower.com

Email Id: chandra.tiwari@tatapower.com

Contact:+91 9312072156 /7678237415