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Capacity Building Workshop for
Financial Institutions on Green Hydrogen

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Session: Introduction to Green Hydrogen Economy

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South Asia Regional Energy Partnership (SAREP)

https://www.123rf.com/

Agenda

- Applications & Demand of Hydrogen
- Why Green Hydrogen ?
- Green Hydrogen Value Chain
- Green Hydrogen in India
- Potential for adoption of GH2
- Demand Estimate & Investment requirement
- The Cost Challenge
- Potential challenges and mitigants

Consumption of Hydrogen: Existing Applications of Hydrogen

Hydrogen is being primarily used as a chemical agent

Chemicals – Ammonia, Methanol and Others

- Feedstock for the production of Ammonia and Methanol.
- NH_3 is used as fertilizer, an energy carrier, a refrigerant, chemical stabilizer

Oil Refining

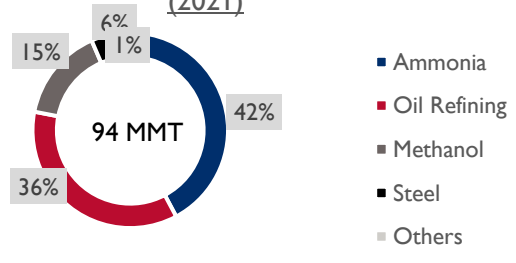
- Hydrotreating - Removal of contaminants such as sulfur
- Hydrocracking - To break hydrocarbons into smaller molecules

Steel Industry

- As a reducing Agent – Remove oxygen from iron ore
- As a fuel source – Not a prevalent application

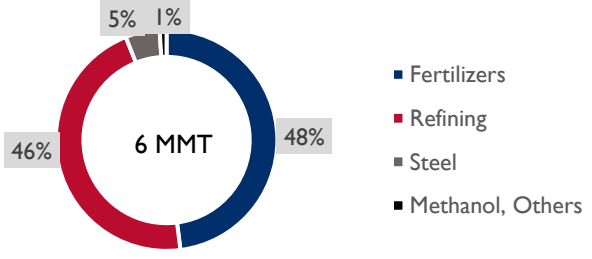
Hydrogen is mainly produced from Fossil Fuels – ' Steam Methane Reformation'

Global Hydrogen Consumption Break-up (2021)



Source: IEA

Hydrogen Consumption in India (2021)



Source: TERI

Projected Demand: Additional Applications of Hydrogen

Hydrogen expected to be adopted as Energy Carrier/Source

Transportation Sector

- Hydrogen fuel cell technology
- Hydrogen internal combustion engine (ICE) technology
- Road, maritime and aviation-based transportation

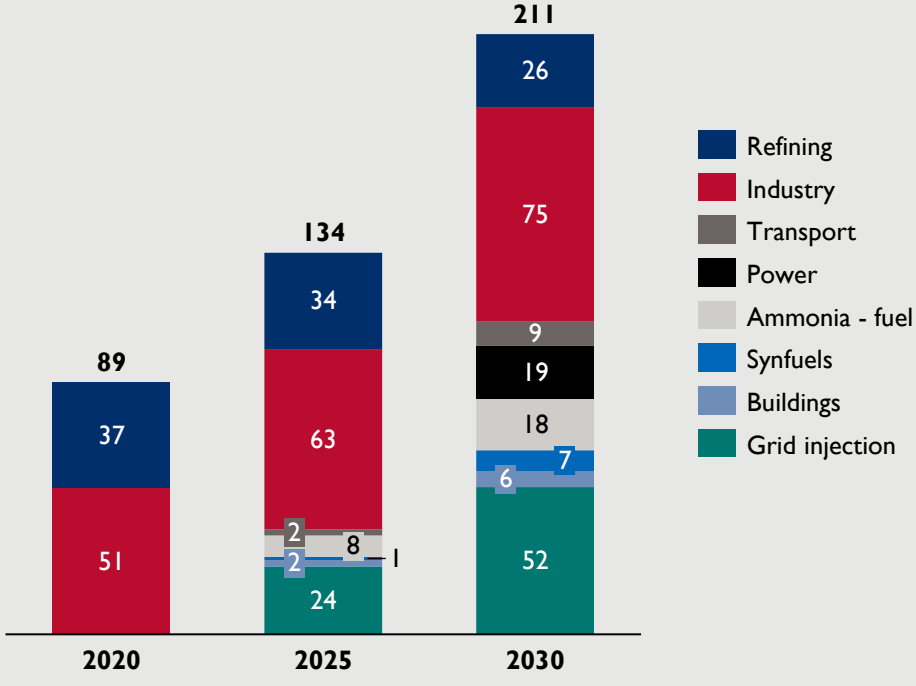
Energy and Heating Sector

- Domestic: Blending with Natural Gas Pipeline
- Industrial: Both High-grade & Mid-grade Heat

Electric Power Generation & Storage

- Production with Excess Renewable Power
- Grid Balancing/Stabilization Applications

These applications will constitute a 'new demand' whereas the existing applications will be a 'replacement demand'



Global Demand (MMT) by Sector in the Net Zero Scenario (IEA)

Why Green Hydrogen ?

Factors Driving Increased Adoption of Hydrogen – In Green Form

Increased Availability & Lower Cost of Renewable Power

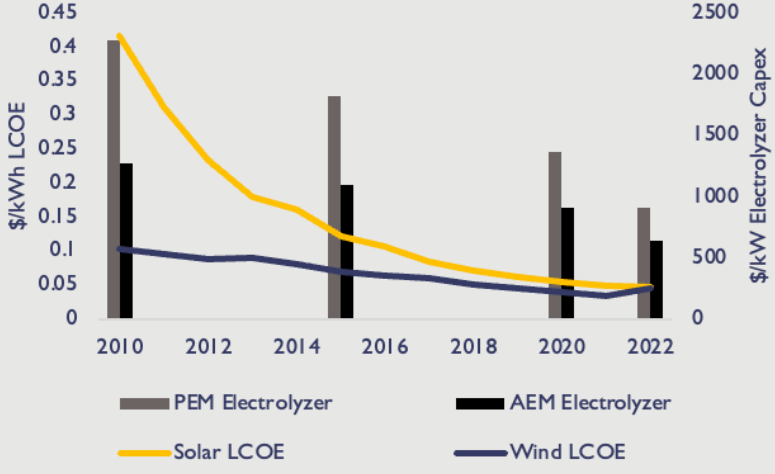
- Drastic Reduction in Prices of Renewable Power
- Renewable Energy can be stored in form of Hydrogen

Carbon Abatement Targets

- Critical for Hard-to-abate Sectors: Steel, Refining, Shipping
- Hydrogen Production contributes 830 MtCO2/year of emissions
- Adoption of Green H2 can avoid 60 GTCO2 in 2021-2050 (IEA)

Advancement in Technology

- Advancement in handling and usage of flammable and reactive H2
- Development of H2 based Industrial Processes, Fuel Cells, ICE
- Advancement in Production Technology based on Electrolysis



CO_2 emissions / Kg of H_2 ← → **No direct CO_2 emissions**

18 – 20 Kg	8 - 12 Kg	1.5 – 5 Kg			
Black / Brown H_2 produced from coal without carbon capture and storage (CCS)	Grey H_2 produced from fossil fuels without carbon capture and storage (CCS)	Blue H_2 produced from fossil fuels with CCS	Pink / Purple H_2 produced from nuclear energy	Turquoise H_2 produced from methane pyrolysis	Green H_2 produced from renewable electricity

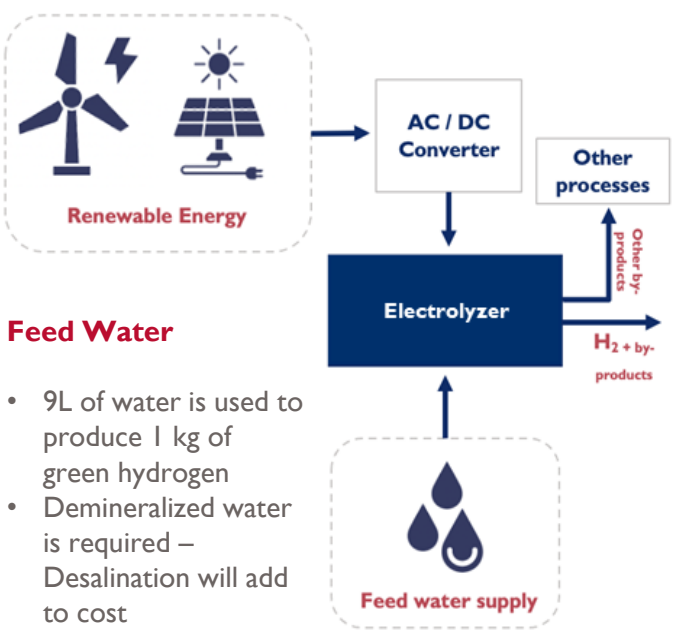
Green Hydrogen: Production, Storage & Distribution

Supply of Renewable Energy

- The supply of renewable energy can be through an integrated capacity of Solar/Wind/Storage or through the electric grid.
- On average, 50-55 kWh is required to produce 1 kg of hydrogen

Electrolyzers

- Electrolysis is an electrochemical process which breaks down water into Hydrogen & Oxygen
- Of 4 electrolyzer technologies, Alkaline & PEM (Proton Exchange Membrane) are being used at an industrial scale



Feed Water

- 9L of water is used to produce 1 kg of green hydrogen
- Demineralized water is required – Desalination will add to cost

Storage

- High flammability & Reactivity demand usage of high-cost specialized Storage Tanks
- Geological Storage for Large Volumes
- Chemical Storage increases energy density and reduces safety concerns, however, leads to loss of energy due to conversion.

Separator → Compressor → Storage

Transportation & Distribution

- Long distance Transport warrants conversion to NH3 & other derivatives
- Technologies in development stage for Pipeline, Maritime & Surface Transportation

India's Strategy: Green Hydrogen Mission

Potential & Policy Push

Renewable Potential

- Renewable Potential much higher than power demand
- Solar potential: 750 GW (PIB)
- Wind Potential: 695 GW (PIB)

RE Procurement Concessions

- Waiver on inter-state transmission charges for projects coming up till 2025
- Availability of grid banking for surplus renewable energy, up to a period of 30 days

Strategic Interventions for Green Hydrogen Transition

- Financial Incentives with an outlay of INR 17,490 Crore

> 5MMT	125 GW	50MMT	~$97B
Annual Green Hydrogen Production Capacity by 2030	Associated Renewable Energy Capacity Addition by 2030	Annual CO_2 emissions averted by 2030	Estimated total investments by 2030

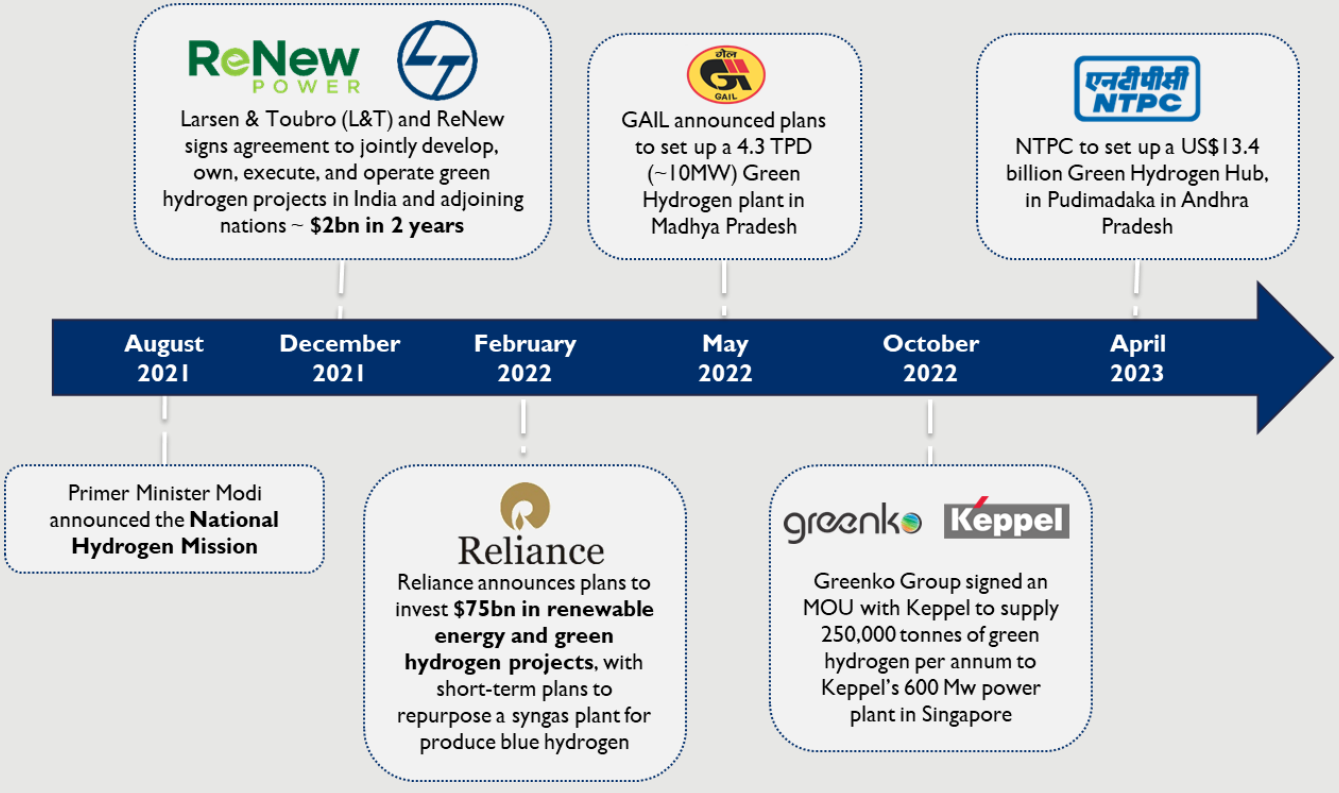
Phase 1 (2022-2026)

- Creating demand while enabling adequate supply through domestic electrolyzer manufacturing capacity
- R&D, pilot projects for future energy transition in hard-to-abate sectors (steel, heavy-duty mobility, shipping)
- Incentives aimed at indigenization of the value chain

Phase 2 (2026-2030)

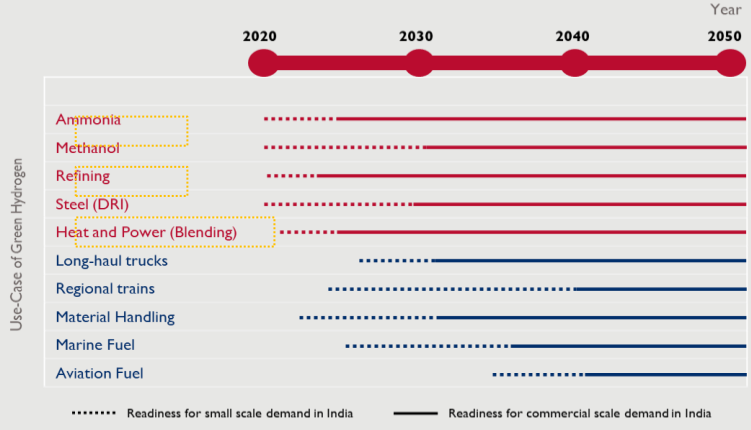
- Green hydrogen production costs to be competitive with alternatives in refining and fertilizers
- Depending on maturity, potential for commercial scale projects in steel, mobility, and shipping
- R&D, pilot projects for other potential sectors like railways, aviation etc.

The Industrial Response – India's Green Hydrogen Announcements



India's green hydrogen demand is expected to be driven by oil refining, natural gas blending and fertilizers due to better readiness for adoption

Readiness of Green Hydrogen Adoption by Use Cases



Most of the green hydrogen demand is India is expected to emerge from grey hydrogen replacement in oil refining, natural gas distribution and ammonia-based fertilizers, along with exports. The exact market potential and investment demand is expected to be driven by government incentives and disincentives, including potential subsidies to drive production, and mandates to drive consumption.

Oil Refinery
The sector is expected to transition rapidly given its relatively insignificant impact on output economics (~2-4%)

Natural Gas Blending
The Industry is poised to adopt significant volumes of green hydrogen, due to its limited upfront investments and demonstrable impact of the sector's carbon footprint

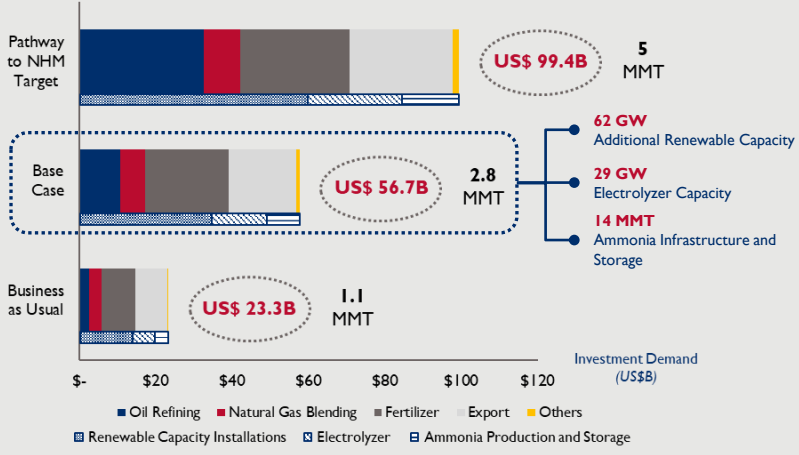
Green Ammonia and Fertilizers
The government has outlined its goal to replace all nitrogenous fertilizer imports with green alternatives by 2035, to support the decarbonization goals and reduce its dependence on import.

Exports
The NHM has set a clear target of capturing at least 10% of the global demand by 2030. India can primarily target the EU, Japan, South Korea, Singapore, among others as key export markets

Others
The steel, methanol and transport sectors are only likely to move beyond the pilot phase post 2030, when the techno-commercial feasibility improves

Under our ‘Base Case’, India is expected to achieve 2.8 MMT p.a. green hydrogen production with an investment potential of US$ 56.7B by 2030

Green Hydrogen Demand and Investment Demand



Under the ‘Business as Usual’ scenario, 2.5% of India’s refineries switch to green hydrogen, existing city gas distribution pipelines are blended with 5% green hydrogen, 20% of ammonia-based fertilizer imports are substituted by domestic green ammonia, and the country achieves 3% of demand from target importing countries

Under the ‘Base Case’ scenario, 10% of India’s refineries switch to green hydrogen, existing city gas distribution pipelines are blended with 10% green hydrogen, 50% of ammonia-based fertilizer imports are substituted by domestic green ammonia, and the country achieves 6% of demand from target importing countries

Under the ‘Pathway to NHM’ scenario, 30% of India’s refineries switch to green hydrogen, existing city gas distribution pipelines are blended with 15% green hydrogen, 65% of ammonia-based fertilizer imports are substituted by domestic green ammonia, and the country achieves 10% of demand from target importing countries

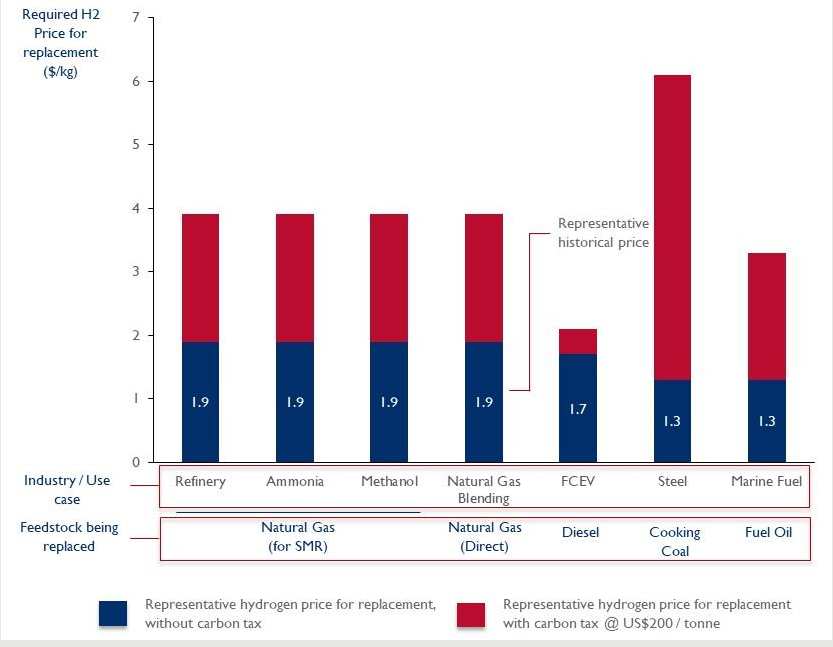
The Cost Challenge

US$ 3.8-4.8 / kg

Estimated Levelized Cost of Green Hydrogen in India

US$ 850-1,100 / MT

Estimated Levelized Cost of Green Ammonia in India



Adapted from: Decarbonising India: Charting a pathway for sustainable growth (McKinsey Sustainability)

Supporting GH2 Price

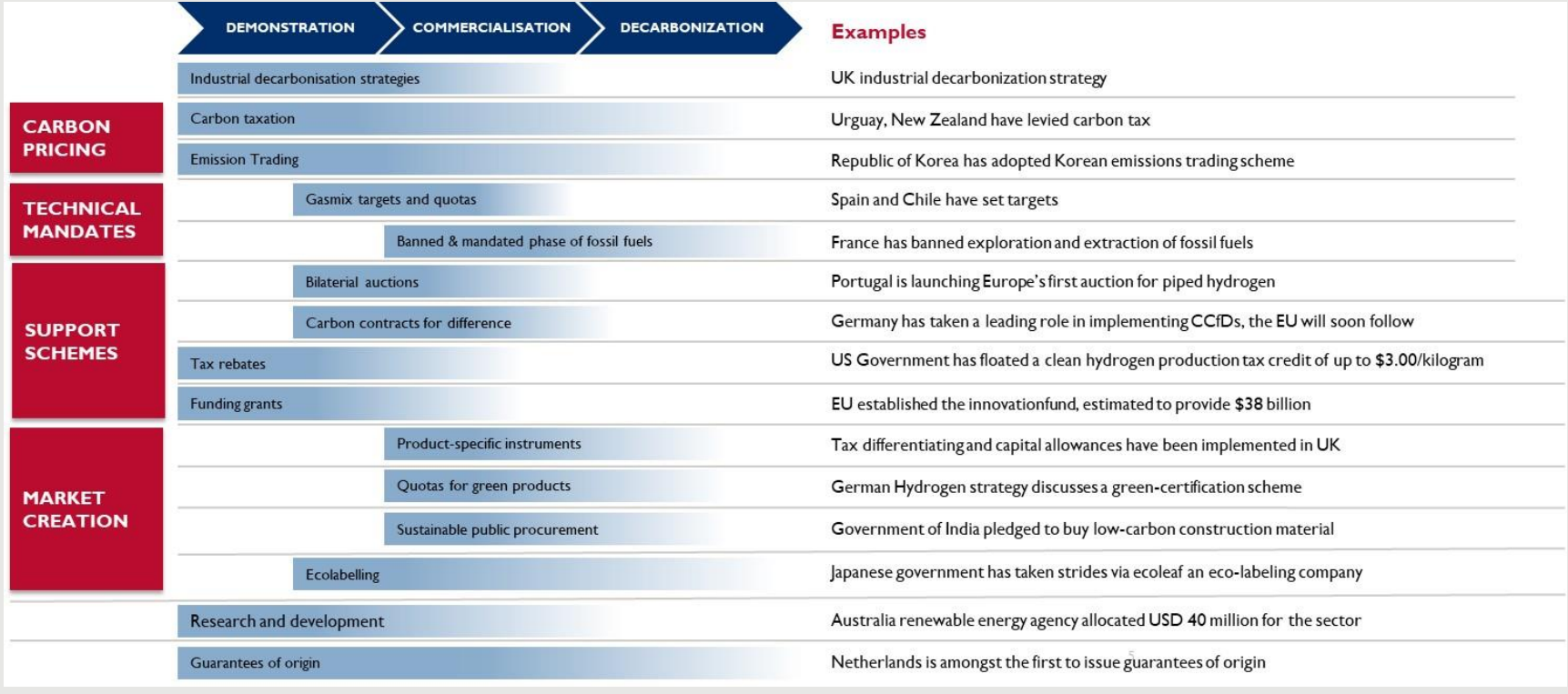
Through Carbon Tax

- Green Hydrogen will require pricing support
- A min. carbon tax of US$200/ton required to justify GH2 Cost of US$ 3.9/kg
- Refinery, Ammonia, Natural Gas Blending easier to justify
- Transport use case will require much higher carbon tax
- Other support options include government mandates (discussed later)

Government intervention in the form of mandates, incentives and ratification of regulations can also be pivotal in driving investments

	Potential Challenges	Potential Mitigants
Price and Volume Risk	**Absence of Strong Domestic Consumption Market -** India is currently not ready for large scale procurement because, green hydrogen is currently commercially un-viable, without any relief on the premium associated with it	• **Industry wide mandates to push demand** by setting green hydrogen purchase obligations • **Incentives such as green contracts for difference /PLIs** can be explored to reduce price disparity between grey and green hydrogen
	Uncertainty around pricing and offtake contracts The market is geared towards the spot price, however given the high-capex and project lifetime developers require long-term offtake contracts to access affordable capital	• Pricing could be calculated as a **weighted average of cost of production** (representing the seller's side), **cost of replacement** (representing the buyers side / cost of grey alternatives) **and a green premium** (for example pricing of emissions). Pricing challenges can be better addressed as trade volumes increase and price assessments become more market reflective.
Interface Risk	Green hydrogen projects involve integration of multiple technologies for a single project output, which could lead to delays / non-completion	• **Introduce a wrap guarantee** for overall plant operations, to be provided by project sponsors or third parties • **Introduce oversized liquidated damages** that compensate for lost cashflows of the overall project output
Uncertain Regulatory Framework	Grey and green hydrogen have the same physical characteristics. Hence, green hydrogen production needs to be supported with clear certification standards to define it as 'green'.	• **Introduction of frameworks for regulation and green certification that are well-harmonized with global equivalents** could address some of the ambiguity in the market and allow ease of global compliance for export-oriented projects.

Potential Policy Interventions



Source: IRENA 2022, SAREP Analysis

Thank You

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