Hydrogen Valleys/ Hubs in India

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India’s Green Hydrogen Mission Objectives

- Making India a leading producer and supplier of Green Hydrogen in the world
- Creation of export opportunities for Green Hydrogen and its derivatives
- Reduced dependence on imported fossil fuels and feedstocks
- Development of indigenous manufacturing capabilities
- Attracting investment and business opportunities for the industry
- Creating opportunities for employment and economic development
- Supporting R&D projects

Salient features of Green Hydrogen Mission

- Target to produce at least 5 Million Metric tonnes (MMT) of Green Hydrogen per annum by 2030, with the potential to reach 10 MMT per annum with the growth of export markets
- To make India a leader in the technology and manufacturing of electrolyzers and other enabling technologies for Green Hydrogen
- Reducing end to end clean hydrogen costs to USD $2 per kg by 2030
- Significant decarbonization of the economy
- Reduced dependence on fossil fuel imports
- Enable India to assume technology and market leadership in Green Hydrogen

Hydrogen Valleys/Hubs

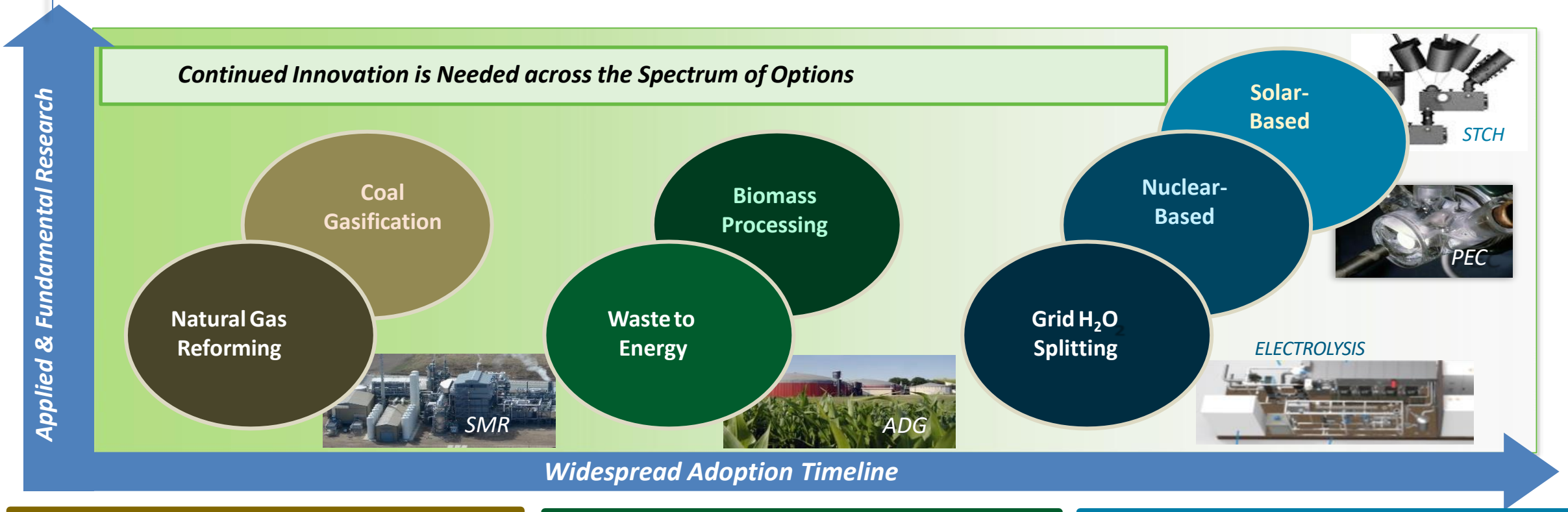
- Hydrogen Valleys/Hubs are Ecosystems that cover a specific Geography

- Should cover multiple steps of the value chain:
  - Hydrogen Production
  - Storage
  - Transport, supply & distribution
  - End use

- Multiple partners and stakeholders from industry, SMEs, academia & Government

- Public-Private partnership model & financing from multiple sources with Government to provide funds to cover gaps

Hydrogen production routes



FOSSIL RESOURCES

- Low-cost, large scale H_2 production with CCUS options
- New options offer scalability and byproduct benefits (e.g. CHHP)

WASTE/ BIOMASS

- Options included biogas reforming & fermentation of waste streams
- Byproduct benefits include clean water, electricity & chemicals

WATER SPLITTING

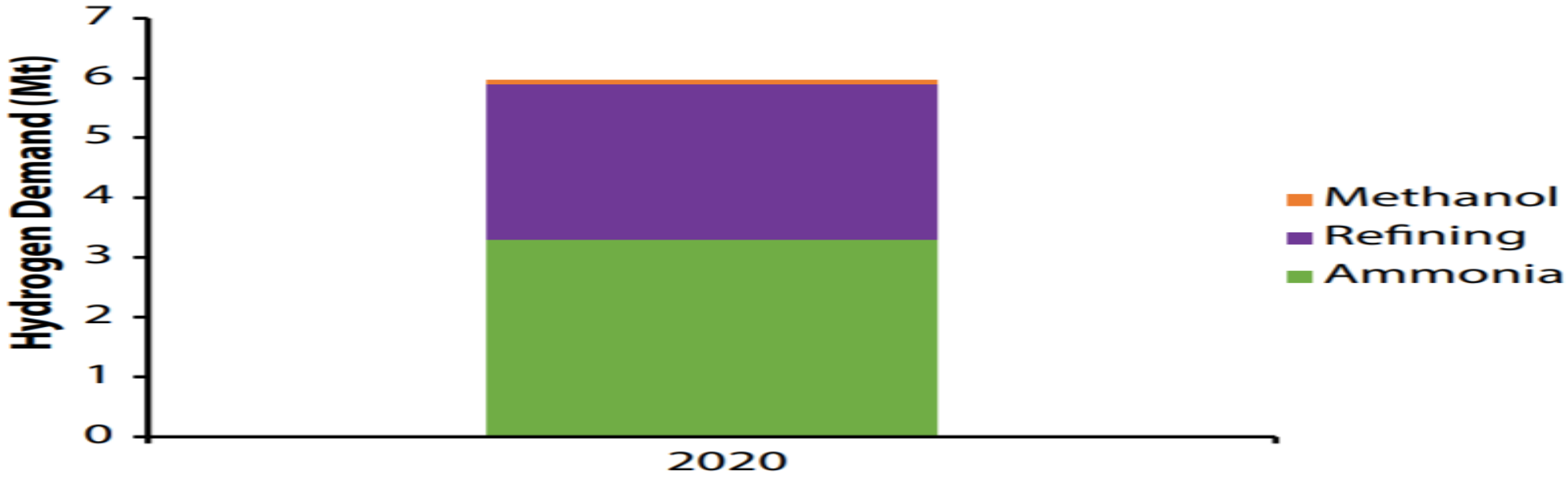
- Grid electrolysis is proven process being improved with innovation
- Emerging nuclear/solar options offer long-term sustainable H2

Presently more than 95% of total hydrogen production globally is from fossil sources mostly by reforming of natural gas

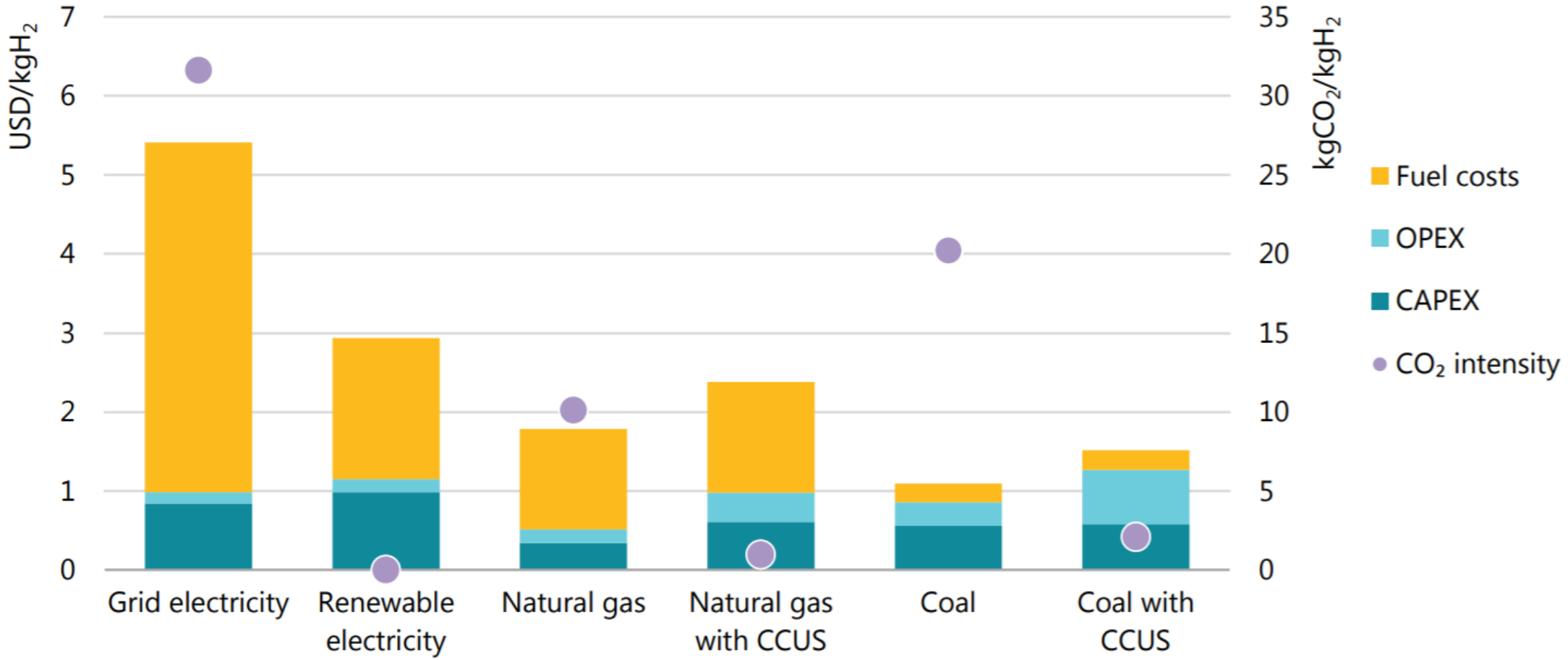
Source: US department of Energy

Hydrogen Demand / Production in India

- India Hydrogen Demand – 6.7 MT/Yr. (7-8% of Global demand)
- In India, Natural gas reforming accounts for nearly all hydrogen being produced and used, though Reliance is having Petcoke Gasification units to produce hydrogen for captive use.



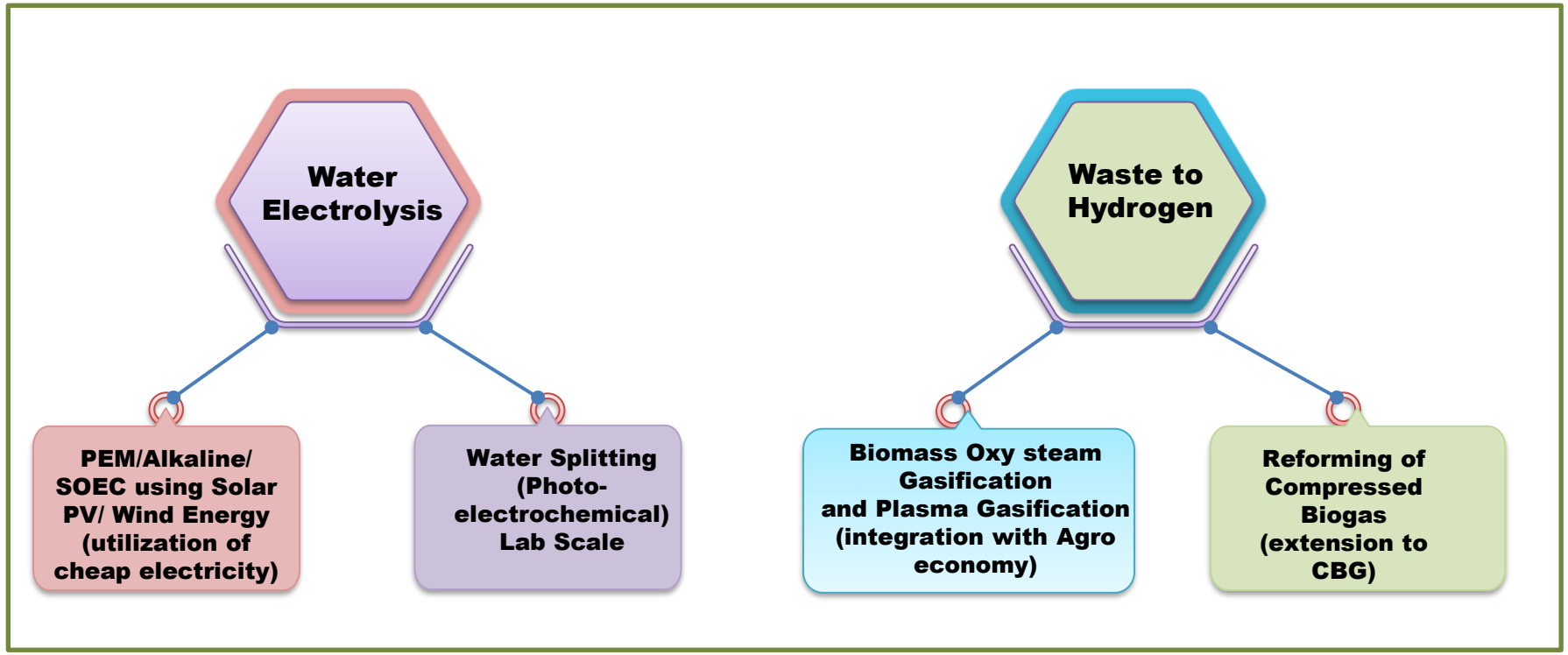
Cost of Hydrogen production



- The cost of hydrogen produced from coal (without CCS) in China is INR 80/kg
- Majority of hydrogen produced from coal goes to Ammonia production in China

Source: TERI Analysis based on BEIS, BNEF and IEA

Indian Landscape – Green Hydrogen



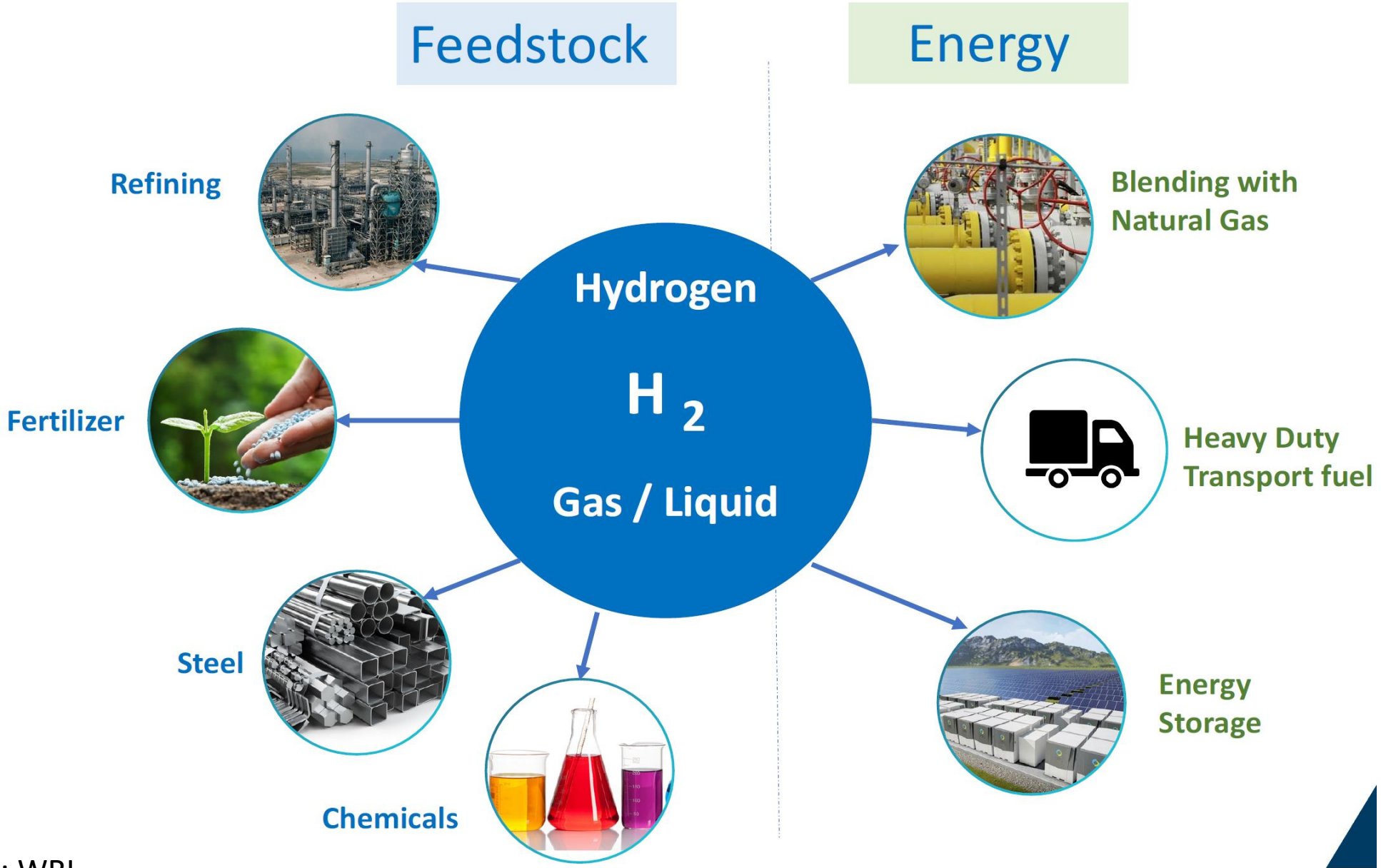
Grey/ Blue hydrogen Already Produced by Refineries / Fertilizers

Bio-mass / agro-residue gasification is another cost effective option

Carbon Capture, Utilization and Storage for Blue Hydrogen

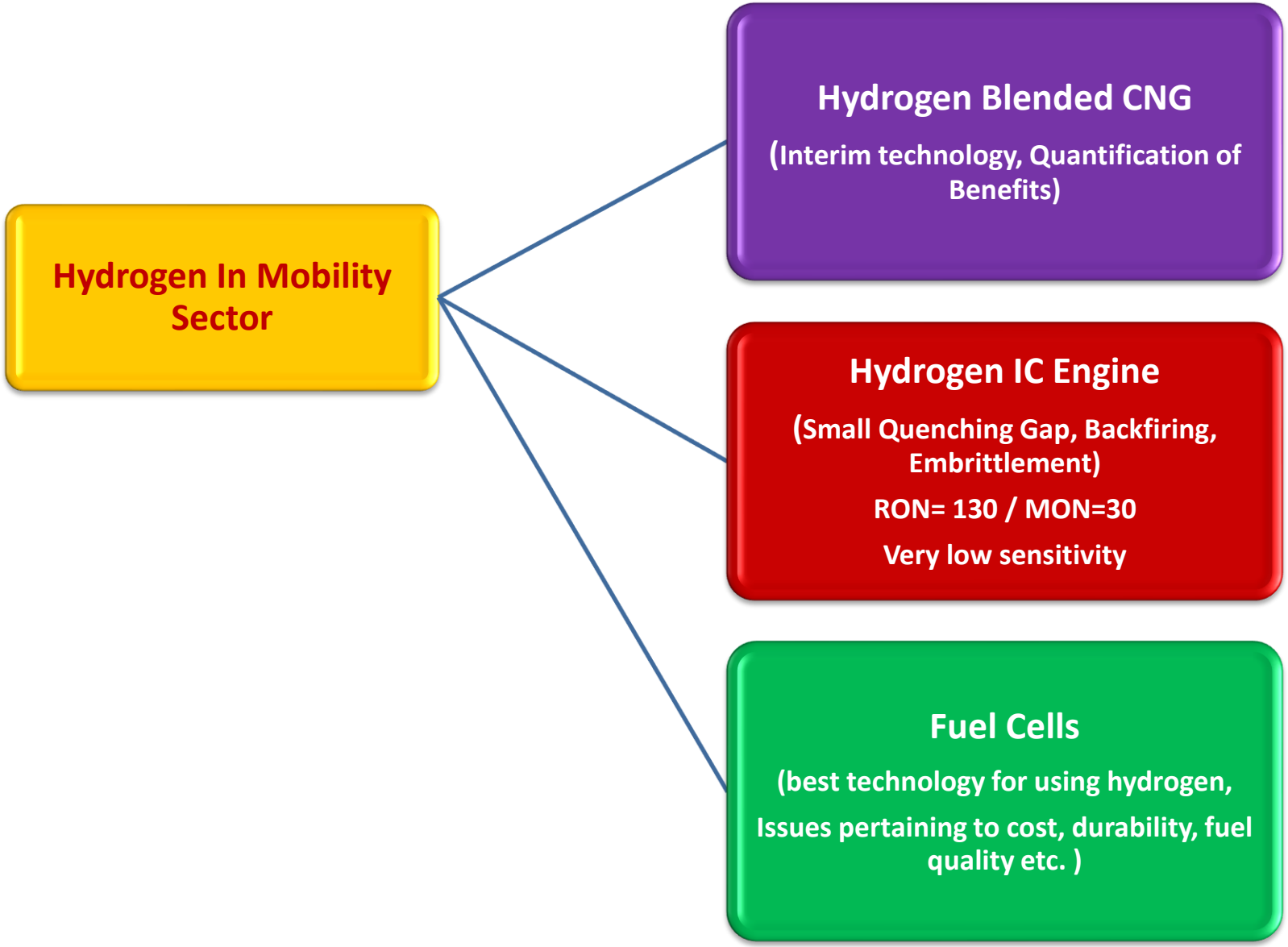
- Blue Hydrogen i.e. production of hydrogen from fossil sources with near zero CO2 emissions will need CCUS integration.
- CO2 captured can be stored in the ground or oil fields for Increased oil and gas recovery
- Technologies can be developed to convert CO2 to valuable products, chemicals and aggregates etc.
- Technologies involving capturing of CO2 directly from atmosphere rather than point of source can be looked into .
- Cost effective technologies for CCUS along with Carbon Credits and incentives for CCUS projects will make Blue Hydrogen to compliment Green Hydrogen usage.

Applications of Hydrogen



Source: WRI

Hydrogen in Mobility Sector



Hydrogen Storage

Most appropriate storage medium depends on the volume to be stored, duration of storage, required speed of discharge, and the geographic availability of different options

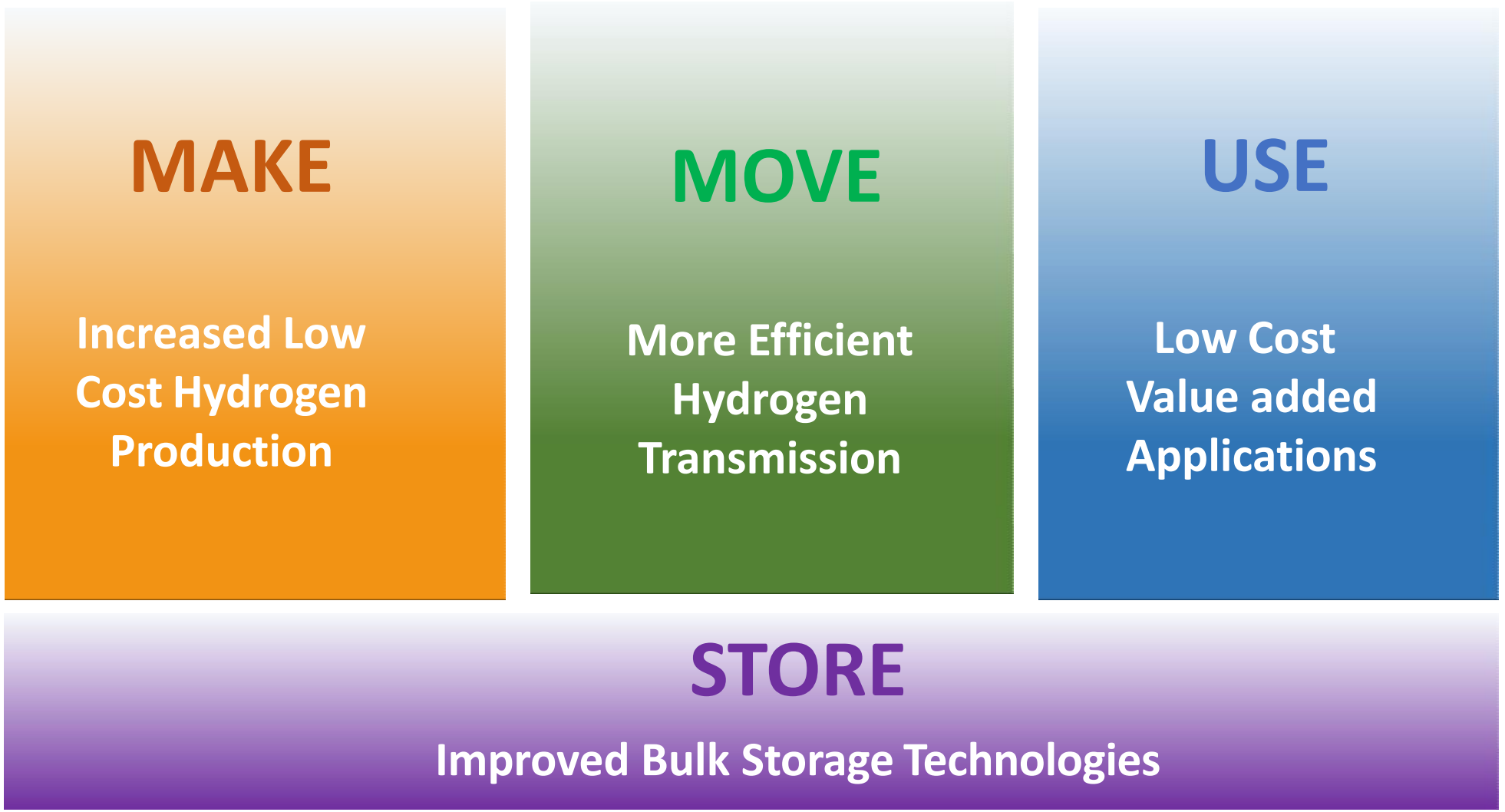
- Today hydrogen is most commonly stored as a compressed gas or liquid in tanks for small-scale mobile and stationary applications. The majority is either produced and consumed on-site (around 85%) or transported via trucks or pipelines (around 15%)

Large scale storage	Physical storage	Materials based storage
• Geological storage: Salt caverns, depleted natural gas or oil reservoirs and aquifers are all possible options for large scale and long-term hydrogen storage • Storage Tanks	• Compressed Gaseous hydrogen • Liquefied hydrogen • Cryo-compressed Hydrogen • Slush hydrogen (SH2) (stored at Hydrogen's melting point)	• Metal hydride storage systems (with materials such as Palladium, magnesium, etc.) • Liquid hydrogen organic carriers (LOHCs): LOHCs present an option for binding hydrogen chemically • Surface storage system (sorbents): hydrogen can be stored as a sorbate by attachment

Hydrogen Storage & Transportation Needs

- High pressure type IV cylinder materials - Carbon fibre etc.
- Liquid hydrogen storage system design for lower boil off losses
- Organic carriers for binding hydrogen chemically
- Metal hydrides and hydrogen Adsorbent materials
- Pipeline transportation of Hydrogen – materials/coatings for eliminating embrittlement of steel pipes
- Blending of H2 in CNG pipelines & separation near point of use

Key focus areas to realize the Hydrogen potential



Hydrogen Valleys/ Hubs

- The project scope should go beyond simply demonstration and should include several projects in itself for the purpose of understanding the issues related to roll out of hydrogen economy
- Geography for valleys/hubs should be clearly defined and selected so as to have ease of hydrogen, production, supply, distribution and utilization in multiple sectors in the region itself.
- Since Indian Government wants to make India an export hub for Green ammonia, some project geographies could be near the ports identified for the purpose
- Management of Hydrogen Valley/ Hubs require unique type of efforts including operations, maintenance, consulting services, regulatory support and finances including viability gap funding for capex and subsidy on hydrogen production cost from government to build up the infrastructure

SHRIRAM

THANK YOU

Ms. Shruti

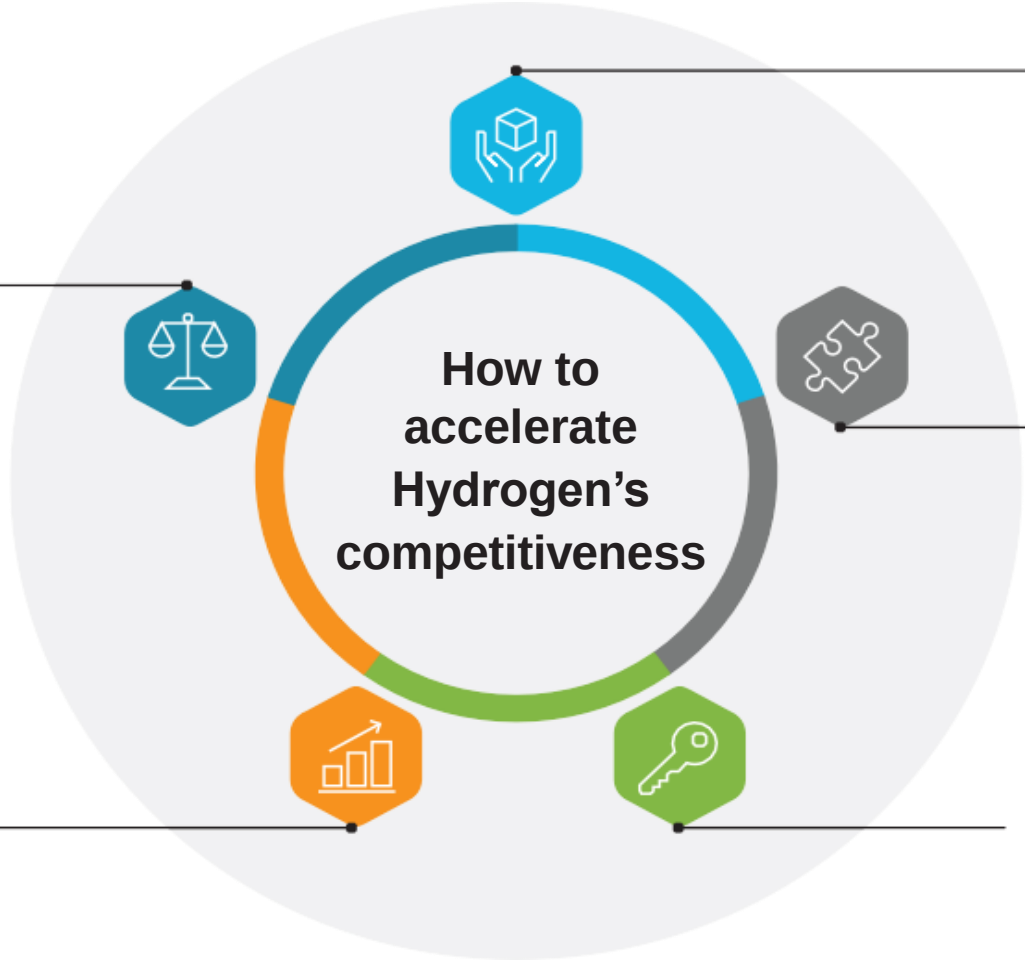
Enablers for Stakeholders to create a market

Scale

Focus on solutions with biggest 'improvement-for- investment', e.g. fuel cells and tanks

Utilisation

Focus on increasing utilisation of assets, e.g. through aggregation of demand and synchronisation of deployment



Reduce demand uncertainty

Reduce uncertainty, e.g. with long-term offtake agreements, feed-in tariffs, ZEV targets, captive demand

Complementarity

Deploy applications that start 'virtuous cycles' and positive spillover effects, e.g. hydrogen infrastructure on airports for refuelling, heating and power

Low-cost production

Push scale-up of hydrogen production, e.g. with ~40 GW of electrolysers, renewable hydrogen can out-compete grey in select areas

Source- Hydrogen Council