

A close-up photograph of a hand holding a blue hydrogen fuel nozzle. The nozzle has a white top section with a diamond-shaped 'H2' label. Below that is a blue section with a white 'H2' label and a large blue circular logo containing a stylized white 'H2' symbol. The background is a solid blue color.

# Unlocking India's green hydrogen ambitions

The EY logo, consisting of the letters 'EY' in a bold, black, sans-serif font. A yellow diagonal line is positioned above the 'Y'.

Building a better  
working world

# Shifting global focus towards hydrogen

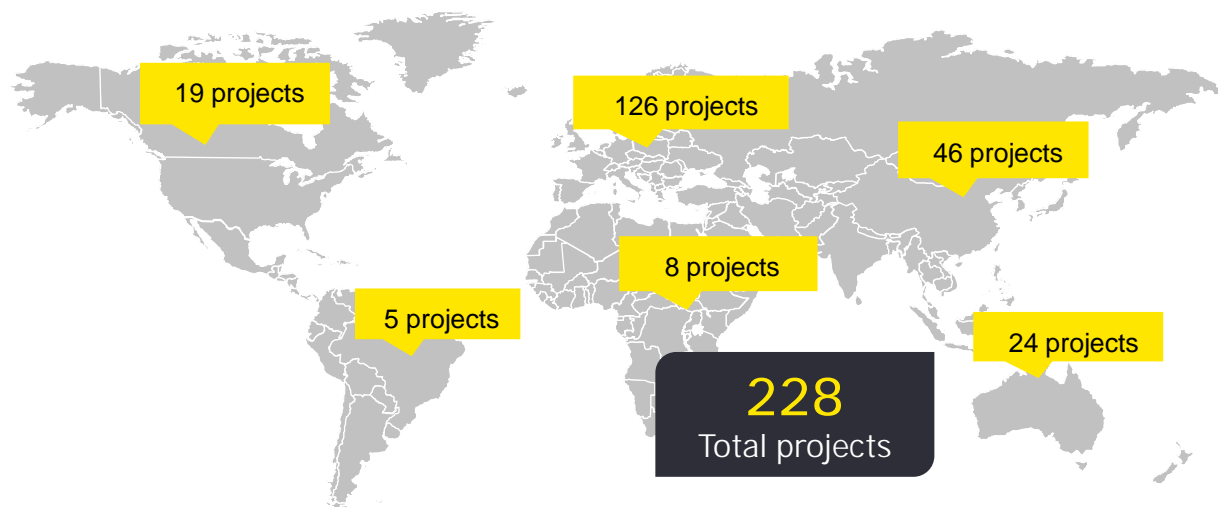
Hydrogen is a versatile source of energy that can contribute in decarbonization of global economy if produced using low-carbon emitting sources. The Government of India has recently shown interest and inclination towards developing Hydrogen as a future fuel and feedstock. The objective of this point of view paper is to bring insights from global hydrogen ecosystem, their key challenges and recommendations for India.

**Hydrogen – the missing link:** It has been realized that hydrogen will act as a critical enabler to achieve the global targets to limit the increase in temperature to 1.5-degree Celsius, adapt to adverse impacts of climate change and fostering low greenhouse gas emissions development. In 2020, there was an inescapable excitement around hydrogen. Globally, countries are proposing ambitious targets, pilot projects and huge amount of investments towards creating hydrogen ecosystem.

Exhibit 1: Global initiative towards hydrogen economy



Exhibit 2: Global hydrogen projects



Source: Hydrogen Council Report

## Growing hydrogen momentum: why now?

- u **Decarbonization targets:** Under the Paris agreement, countries have pledged to reduce national emissions and impact of climate change through “Nationally determined contributions (NDCs)” targets. It will help limit global temperature rises to 1.5°C. However, to meet such ambitions targets, countries will have to install large number of renewable energy systems. It is also essential to find an alternative fuel for applications where direct electrification is not feasible. Hence, hydrogen could be a viable fuel with huge potential to achieve global decarbonization targets.
- u **A complementary solution to renewable energy:** Renewable energy technologies have witnessed tremendous growth both in terms of technical and financial feasibility. It is required to store and utilize excessive energy produced during generation hours. Hydrogen can be the missing piece to complement renewable energy systems.
- u **Supporting grid load management via storage solutions:** The grid load requirements and better grid resiliency due to increasing distributed renewable energy installations can be managed with green hydrogen based energy storage system.
- u **Decarbonization of hard-to-abate sector:** Hydrogen is a potential fuel and feedstock to reduce carbon intensities of sectors such as transportation, industrial and residential applications.
- u **Technological advancement:** There is a significant improvement in the efficiency of electrolyzer and fuel cells technologies.
- u **Falling technology cost:** The cost of hydrogen produced from the electrolysis has fallen by ~ 60% since 2010. Also, the price of Fuel Cell Electric Vehicles has declined by ~ 65% over the past 10 years.

## Why is India betting big on hydrogen ?

- u **Energy security:** The global pandemic has taught the nations to diversify their energy demand as well as their geographical availability. The fluctuations in the oil & gas market have disrupted supply-demand chain and causes variation in the fuel cost. Developing countries like India needs to find out an alternative to strengthen it's national energy security.
- u **Emission targets:** India is the third largest global CO2 emitter (~7% of global CO2 emission) well below China & United States. It has also committed to reduce its emissions intensity by 33-35% under the Paris Agreement.
- u **Economic dependencies & balance of trade:** India is the world's third largest crude oil importer with import dependency of more than 80%. It also imports 54% of natural gas and 24% of coal requirements which largely affects India's financial account balance. India's oil import bill in FY20 and FY19 was approx. US\$101.4 billion and US\$111.9 billion, respectively.
- u **Energy Subsidies:** Along with the high cost of imported fuel, India gives away overall energy subsidies of approx. US\$30 bn / year on oil & gas, coal, transmission & distribution, renewable energy and electric vehicles. Some proportion of these subsidies can be diverted for the development of hydrogen ecosystem.

Hence, India can grab this early opportunity to capture entire value chain of hydrogen and look out for global exports.

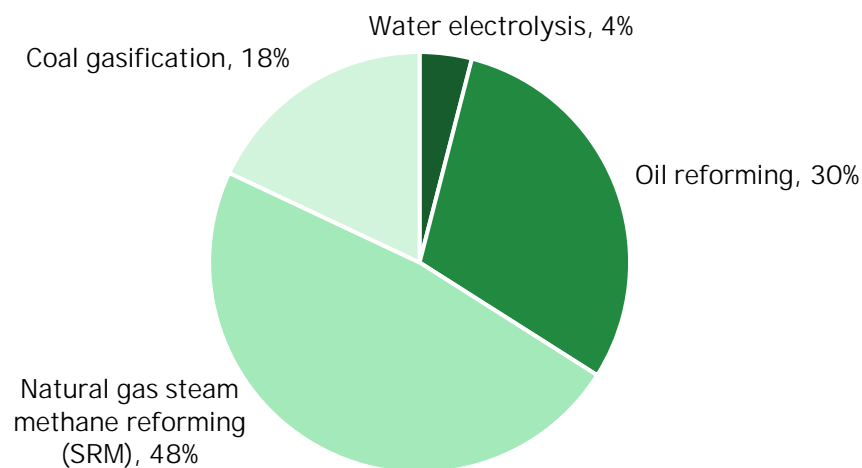
## Hydrogen: an energy dense fuel

- u The specific energy of hydrogen is between 120-140 MJ per kg while that of diesel and gasoline fuel is between 30-45 MJ per kg. Therefore, hydrogen specific energy is around 3X to 4X times higher than gasoline and diesel fuels.
- u Similarly, specific energy of hydrogen is around 30X to 90X times higher than batteries.
- u Also, diesel and gasoline emit approx. 75-85 g CO2 per MJ of energy produced along with other harmful substances such as nitrogen oxides, hydrocarbons and particulate matter. Whereas hydrogen only emits water as a by-product.

# Hydrogen production

Hydrogen can be produced using different technologies, but sustainable production technologies will create future possibilities of adoption and scale. Today, hydrogen is mainly produced from fossil fuels such as coal & natural gas. However, it can be generated from various feedstocks. The cost of hydrogen, market-competitiveness and market-timeframe is affected by location of production technology and its volume of production.

Exhibit 3: Global hydrogen production



Source: IRENA Report

### Insights

- Hydrogen can be obtained from fossil fuels, biomass, as well as a combination of water & renewables.
- Natural gas is now the most common source of hydrogen generation, accounting for roughly three-quarters of the total dedicated hydrogen production of around 70 million tonnes per year.

# Green hydrogen: an ultimate future winner

Exhibit 4: Types of hydrogen

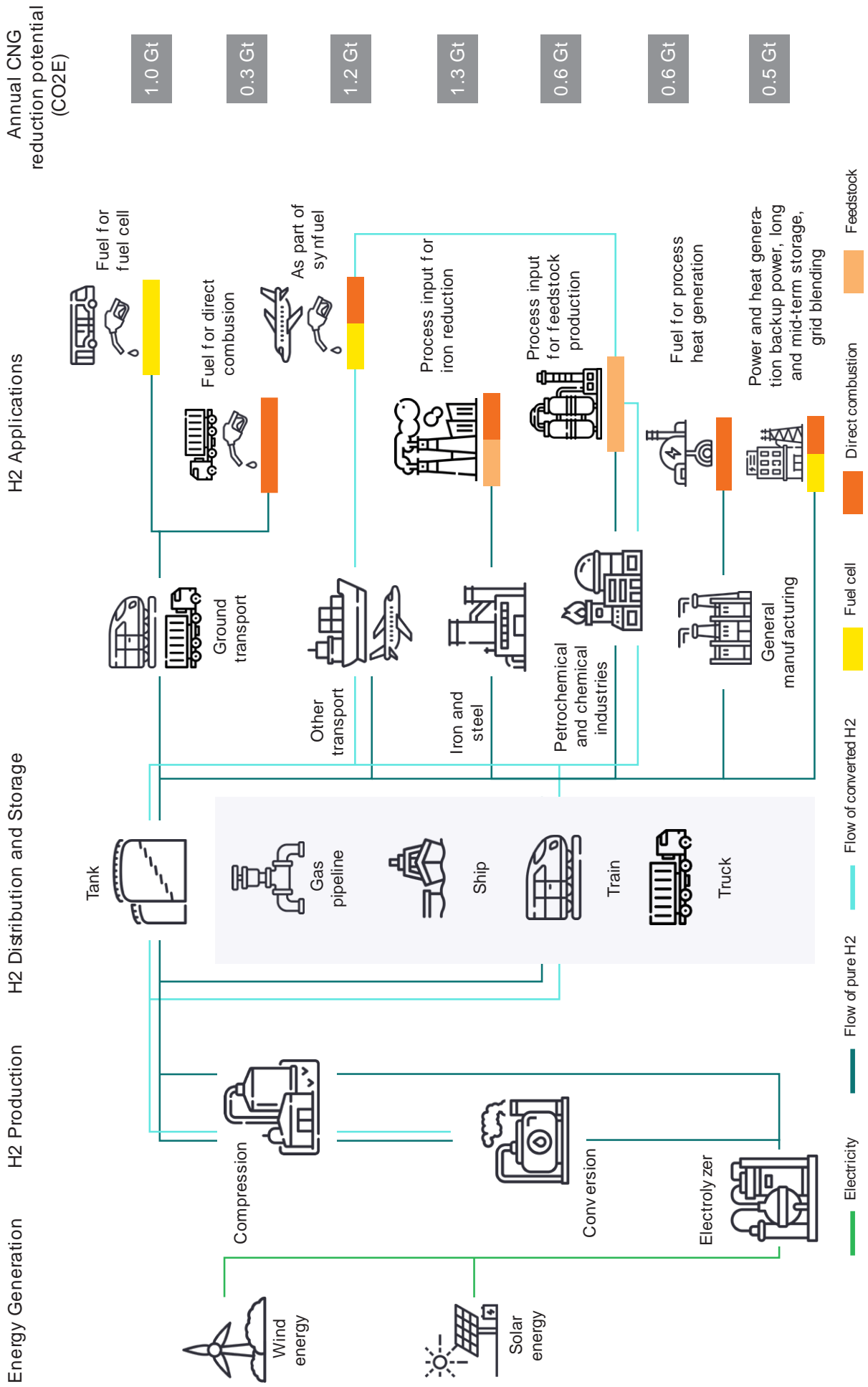
Color	Black/brown hydrogen	Grey hydrogen	Blue hydrogen	Turquoise hydrogen	Pink hydrogen	Green hydrogen
Type	Black/brown hydrogen	Grey hydrogen	Blue hydrogen	Turquoise hydrogen	Pink hydrogen	Green hydrogen
Process	Coal gasification	Methane reformation	Methane reformation or coal gasification with CCUS	Pyrolysis	Electrolysis	Electrolysis
Source	Coal	Natural gas	Fossil fuels	Methane	Nuclear energy	Renewable energy

Currently, most of the world's hydrogen is being produced from natural gas and coal. When hydrogen is produced using renewable energy sources, it is termed as green hydrogen. Water electrolysis is most matured technology to produce green hydrogen.

# An overview of hydrogen ecosystem

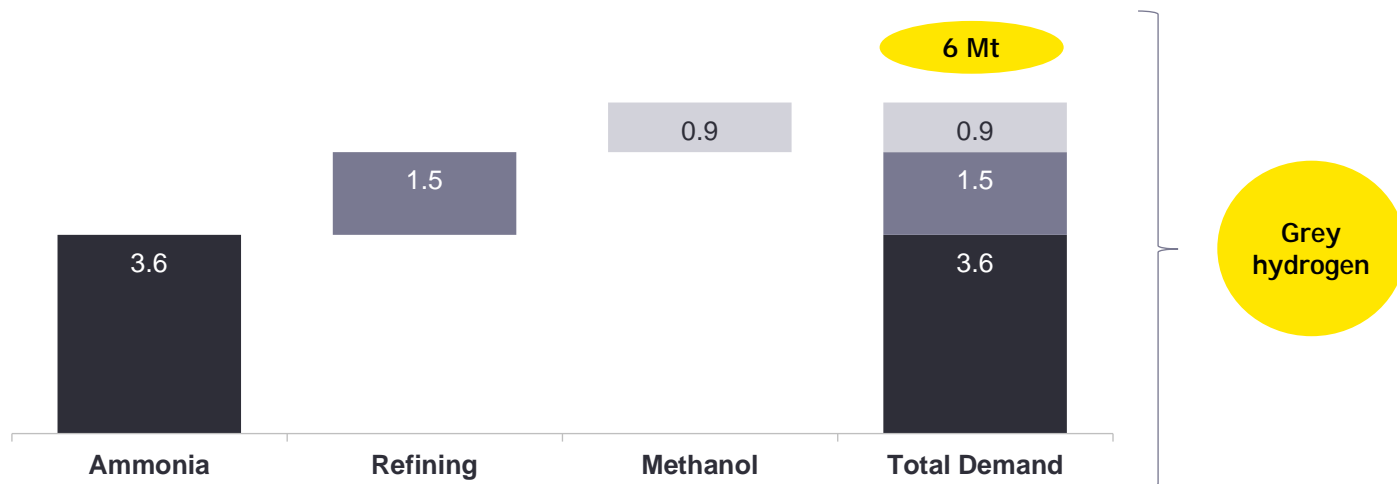
Looking at hydrogen's low-carbon energy portfolio, it has a potential to decarbonize hard-to-abate sectors such as industry, transport and buildings.

**Exhibit 5: Hydrogen ecosystem**



# Current hydrogen demand in India

Exhibit 6: India's current hydrogen demand (million metric tonnes)



Source: TERI Report, NITI Aayog

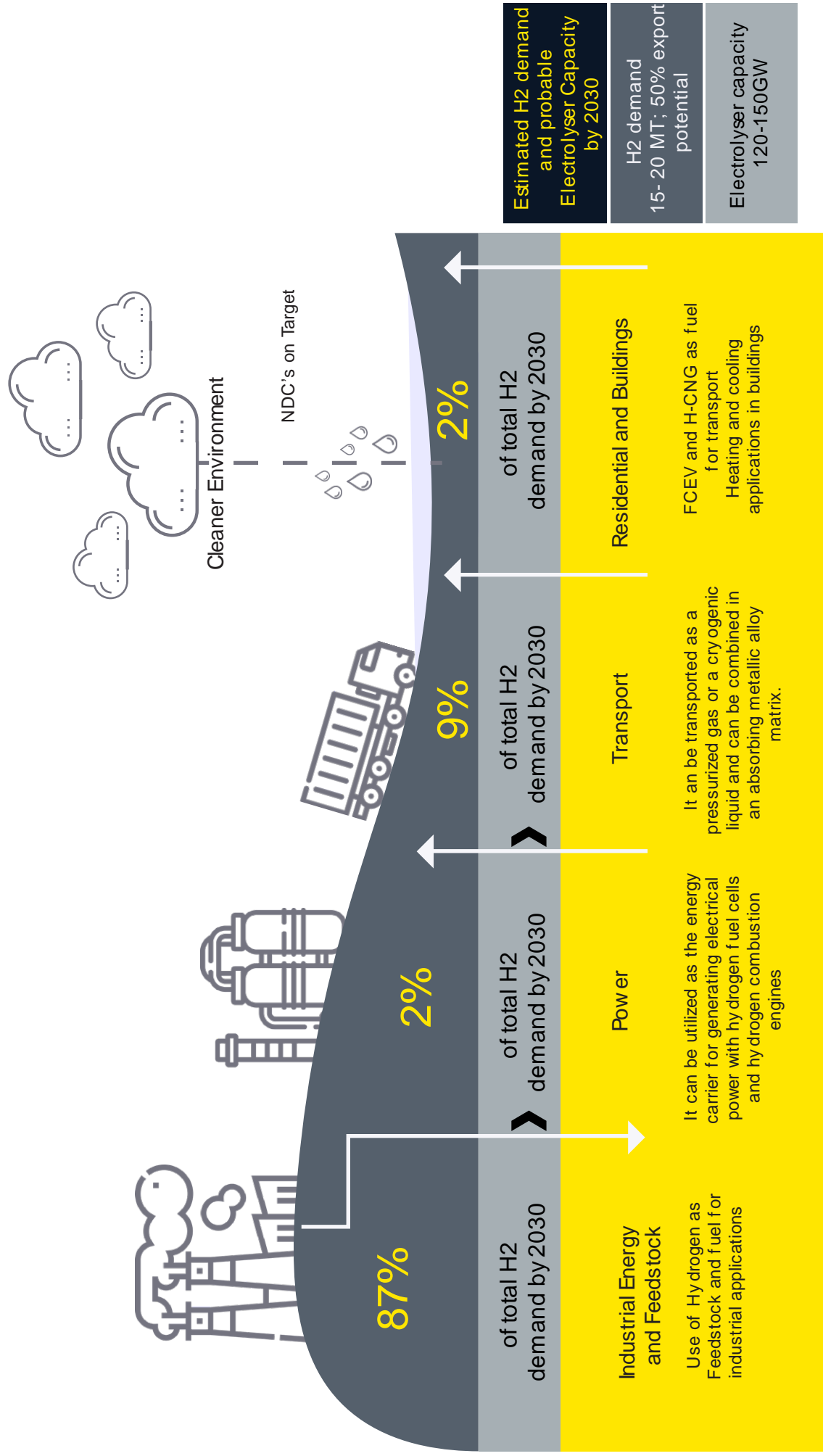
## Insights

- Industry sectors such as refineries and fertilizers accounts for major hydrogen demand in India mainly through grey hydrogen.
- Grey hydrogen is largely produced by natural gas therefore, emitting huge amount of CO<sub>2</sub> emissions.
- Hydrogen can be useful in the applications that require high temperatures (above 250 degrees Celsius), especially in the chemical, iron and steel industry . In such cases, hydrogen can serve as an excellent alternative to other energy sources.
- Also, It is essential to promote usage of hydrogen in sectors where direct electrification is not feasible.



# Market size of hydrogen in India

Exhibit 7: Projected hydrogen demand and electrolyser manufacturing capacity requirement



# Production cost for green hydrogen is projected to decline rapidly over the next decade

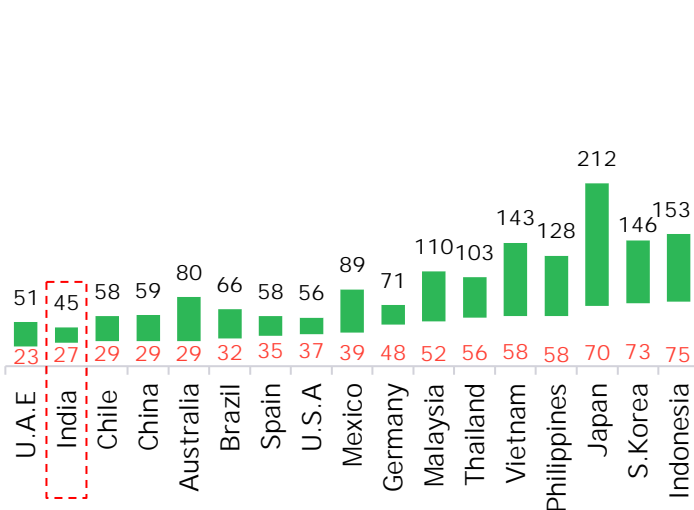
The major contributors in the production cost of hydrogen are as follows:

- i. Electrolyser cost
- ii. Renewable levelized cost of electricity

## Exhibit 8: Emerging trends

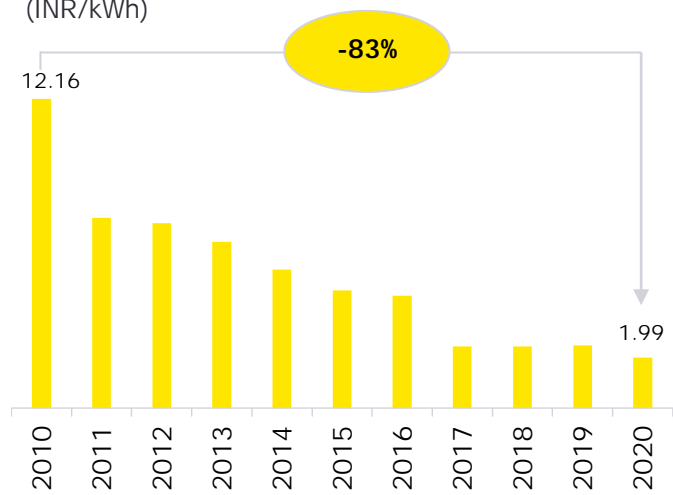
### Global LCOE for solar-pv

\$ per MWh (nominal)



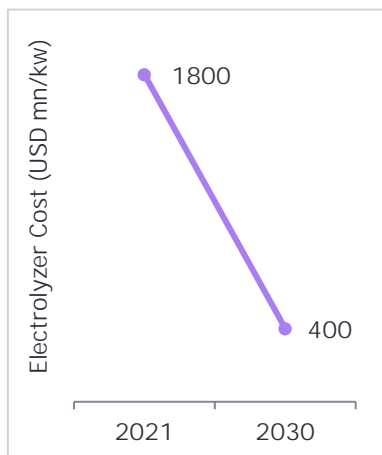
### Solar power tariff in India (INR/kWh)

(INR/kWh)

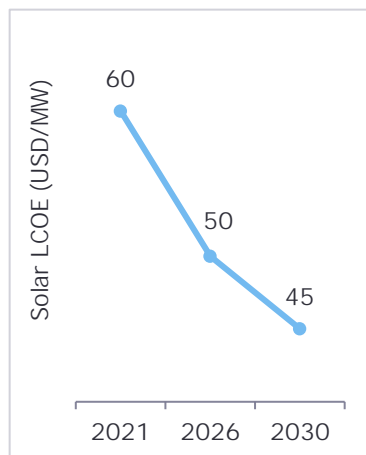


Source: EY Analysis 2020, BNEF

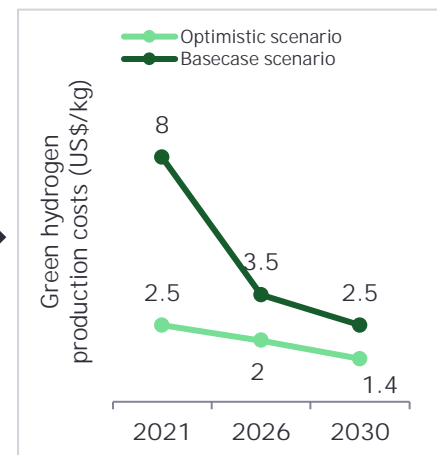
### Falling price of electrolyser



### Reducing renewable LCOE



### Probable Green Hydrogen cost



### Key factors and drivers

- u Increasing scale of production
- u Increasing efficiency of electrolysers
- u Decreasing cost of electrolysers

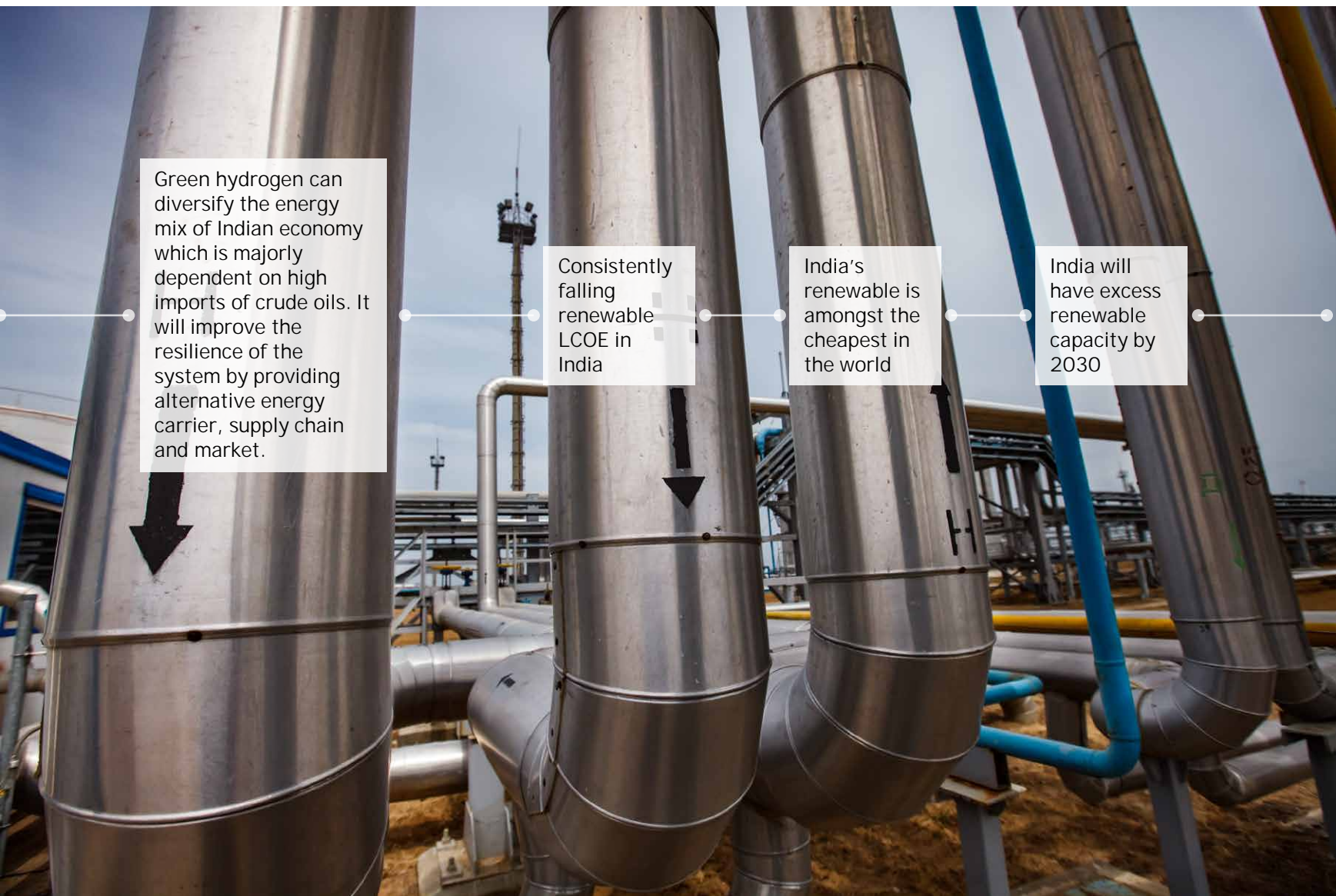
- u Decreasing cost of solar cells and panels
- u Giga projects
- u Policy stimulus, incentives and subsidies

- u Incentives and subsidies
- u Decreasing cost of renewable energy production
- u Decreasing cost of hydrogen production technologies

Source: IEA, BNEF, EY Parthenon analysis



# Green hydrogen – fuelling the self reliant growth engine



Green hydrogen can diversify the energy mix of Indian economy which is majorly dependent on high imports of crude oils. It will improve the resilience of the system by providing alternative energy carrier, supply chain and market.

Consistently falling renewable LCOE in India

India's renewable is amongst the cheapest in the world

India will have excess renewable capacity by 2030

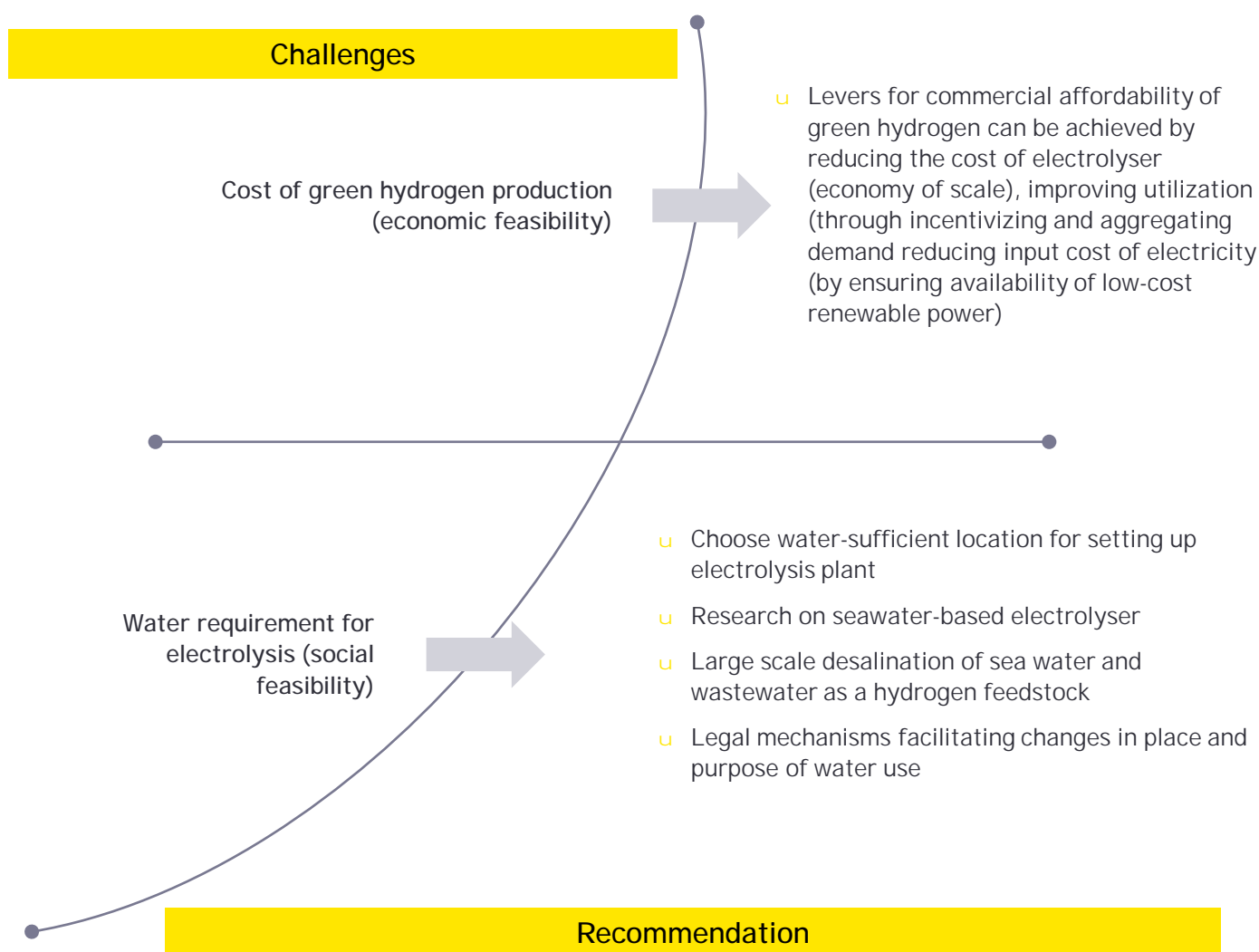
Following are the supporting pillars of green hydrogen economy in India:

- u The renewable energy in India is among the cheapest in the world. Hence, renewable LCOE will be minimum.
- u The national targets of achieving 500 GW of RE capacity by 2030 will further complement production cost and volumes of green hydrogen.
- u Despite having "Must Run" status, there is curtailment of renewable energy causing wastage of energy. This could further increase with increase in number of renewable energy installations in the coming years. This excessive generation of clean energy could either be stored or used for other purposes such as production of hydrogen through water electrolysis process.
- u Government of India's objective to cut its emission intensity by 33-35% of 2005 levels by 2030 requires more diversified approach. Sectors such as industries, transportation and buildings need to further reduce their carbon intensity. The techno-economic feasibility of green hydrogen production in the near future will provide a befitting solutions to decarbonize of hard-to-abate sectors.

# Reduction in green hydrogen cost is the key to deep decarbonization

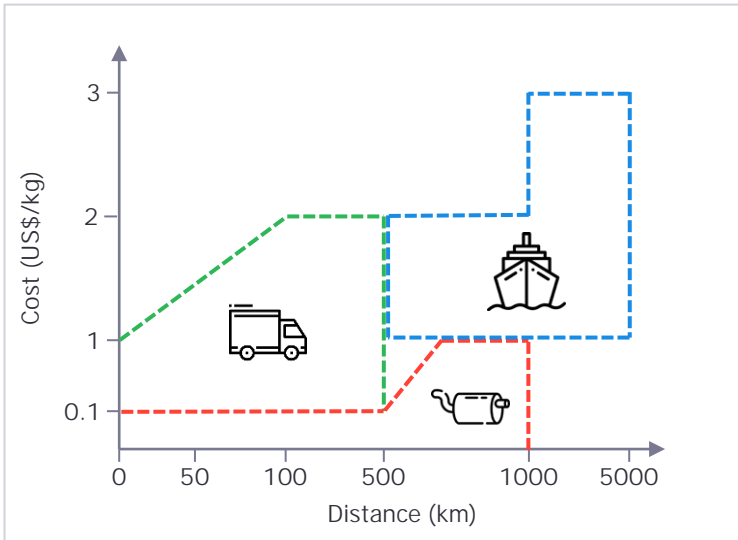
Since, India has cheapest renewable LCOE, It is essential to drive down the LCOH through capacity building of below mentioned points :

1. **Enhance domestic manufacturing:** To support domestic manufacturing, government should come up with policy interventions and provide incentives and subsidies for electrolyser manufacturing. The manufacturing scheme such as production-linked incentives can be extended for localized manufacturing of electrolysers in a phased manner.
2. **Economies of scale:** It is very essential to create enough hydrogen demand so that, the supply-side will penetrate at a much faster rate. It will require mass-production of electrolyser that can help in driving down its price and reaching at cost-parity with fossil fuel-based hydrogen.



# Expansion of infrastructure is also expected to accelerate, lowering costs across the value chain

Exhibit 9: Cost of Hydrogen transmission and distribution by option

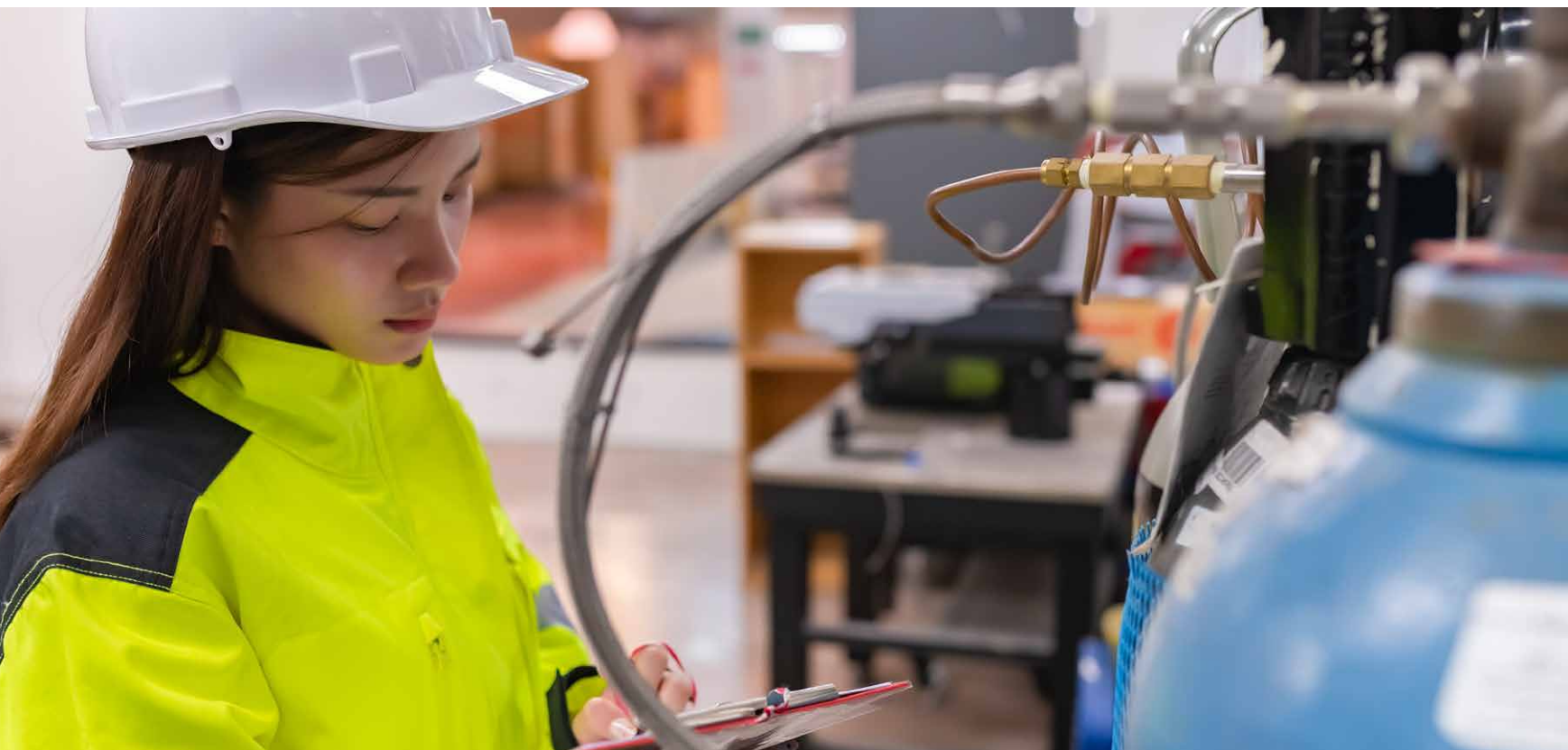


Source: EY Analysis

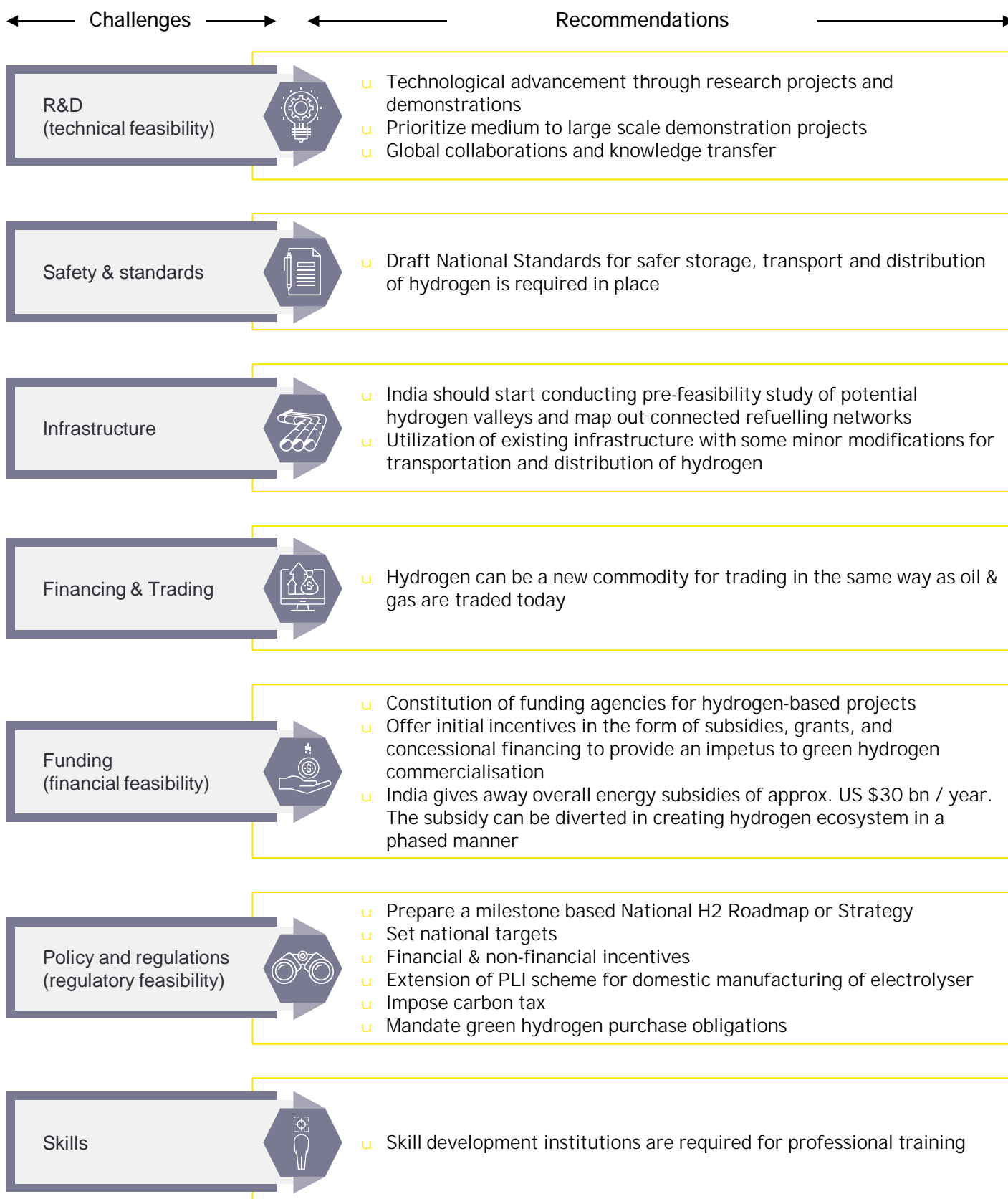
## Insights

- u 85% Hydrogen is produced and consumed on-site globally.
- u In India, Hydrogen delivery can be mainly by two modes of transportation, either pipelines or trucking.
- u Dedicated pipeline network will be a costly option and requires special material to prevent leakage of hydrogen. Also, retrofitting of existing steel pipeline infrastructure will require suitable modifications to prevent hydrogen embrittlement that causes formation of cracks.
- u Pressurized tube trailers can carry smaller quantities of hydrogen as compared to pipelines. But, it will be helpful in developing initial hydrogen supply-demand network.

- u Pipelines are the cheapest option for hydrogen distribution in local or regional networks (up to 5,000 km):
  - u Retrofitting is likely the cheapest option, but will depend on existing technical capabilities.
- u Transmission will play a critical role in determining where hydrogen is produced:
  - u In case of an on site installation, transmission takes ~20% of the total price of supply.
  - u For regional distribution, the infrastructure can represent up to ~50% of the total cost.
  - u For long range distribution, the infrastructure can represent up to ~75% of the total cost.

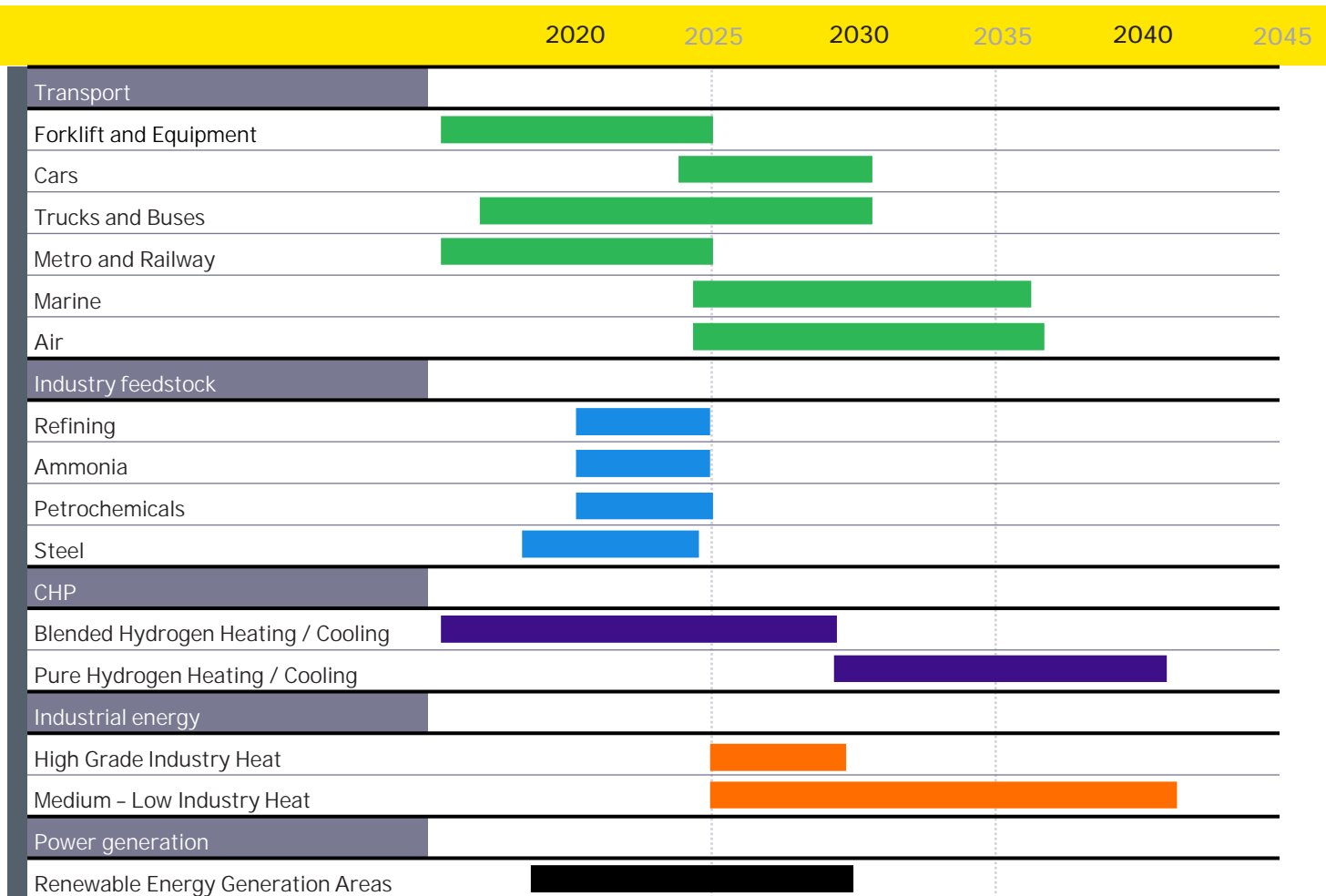


# Challenges and recommendations for accelerated proliferation of green hydrogen



# A timeline-based transition roadmap for Indian economy is shown below

Exhibit 10: Timing of expected rollout by application 2020



2020-2030



2030-2040



2040-2050



- ▶ Warehouse, Agriculture and Construction Equipment based on FCEV
- ▶ Industrial Feedstock - Ammonia
- ▶ Industrial Corridors in Petrochemical plants and Steel and Aluminium production

- ▶ FCEV Cars and Freight
- ▶ Public Transport
- ▶ Inland Waterways
- ▶ Power Grid for Storage and Transmission
- ▶ Residential Energy Storage

- ▶ Air Transport
- ▶ Marine Transport
- ▶ Defence
- ▶ Space
- ▶ Residential Heating and Cooling
- ▶ Other Manufacturing

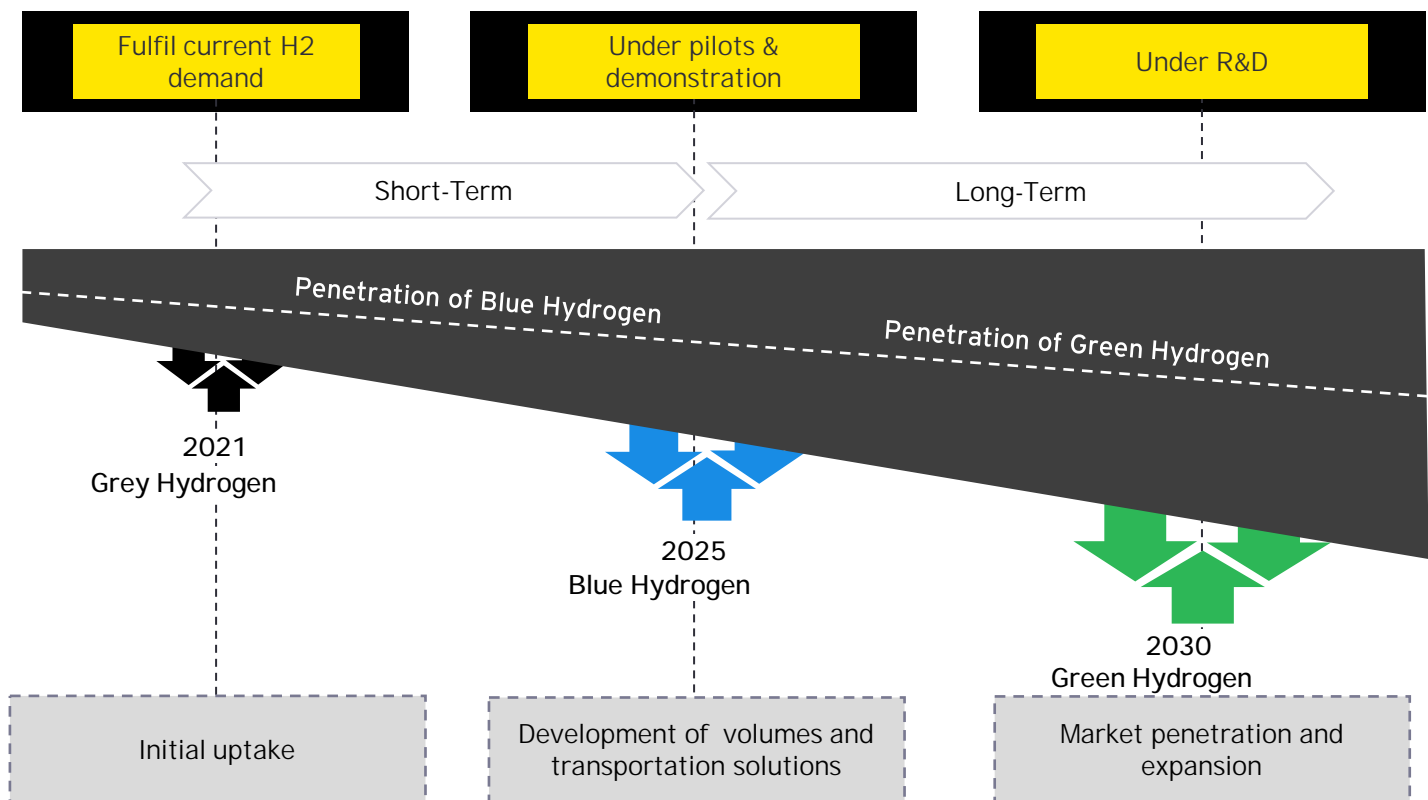


# Hydrogen economy in India: road to green could traverse the blue

It is highly debatable to discuss the adoption of fossil fuel based hydrogen rather than green hydrogen. But, both blue and green form of hydrogen will be necessary to drive hydrogen based economy. The path for deployment of hydrogen will require an amalgam of technological maturity and its cost competitiveness with other existing methods. Electrolysis is a matured technology but, the cost associated with production of green hydrogen is many times higher than blue or grey hydrogen. This will impact its deployment at an early stage of value chain development.

Also, India aims for 100 million tonnes of coal gasification by 2030. Therefore, India has an opportunity to support blue hydrogen using carbon capture, utilization and storage technology. A minimum subsidy can also be allocated for the same and this will create enough hydrogen demand and infrastructure for green hydrogen to enter the market.

Eventually, Green hydrogen will come and utilize existing storage, transmission and distribution infrastructure.



## Applications of hydrogen

Hydrogen can be used as a fuel or a feedstock in different forms of applications. This property of hydrogen has unveiled its true potential as an alternative source of energy. Following are the different applications of hydrogen:

### Industry

Currently, most of the India's hydrogen demand comes from two main industrial sectors, refinery and fertilizer industries (ammonia and methanol production). Hydrogen can be used as fuel or feedstock for industrial applications. In future, it has a huge potential to decarbonize petrochemical, cement and steel (India is world's 2nd largest steel manufacturer) industry which contributes to majority of the GHG emissions.

### Power generation

India's power sector is one of the most diversified sector in the world with coal, oil, natural gas, hydro-energy, nuclear, solar, wind energy and waste-to-energy as a sources of energy . With increase in the share of renewable energy, the grid is becoming greener day by day. However, looking at the cost and low power density of renewables such as solar energy, other sources of clean energy are required along with renewables. Fuel cell technology or natural gas engines can replace coal-based power plants for power generation. Improvement in the techno-commercial feasibility of above technologies can help in decarbonization of India's power sector. Hydrogen can also work as energy storage for variable renewable energy generation and can provide grid stability.

### Transport

India is world's fifth largest automobile market where trucks account for only 3% of the total vehicle fleet (passenger + freight) but it emits 41% of total vehicular CO<sub>2</sub> emissions and 53% of total vehicular PM emissions. In 2020, overall freight transport in India accounts for approx. 220 million tonnes of CO<sub>2</sub> emission. Due to collaborative support of OEMs, government and customers, Battery Electric Vehicles are penetrating at a notable pace in low and medium-duty vehicle. Still, the electrification of heavy-duty vehicles (HDV) such as buses and trucks is not significant enough. The other type of electric vehicle, Fuel Cell Electric Vehicle can decarbonize HDVs. The hydrogen-powered trains has already entered in the pilot phase in Europe. Marine and aviation mode of transport will soon witness the acceptance of hydrogen as a fuel.

### Hydrogen fuel cells:

It is device that converts chemical energy of hydrogen into electricity. The electricity produced can be utilized for automobile applications and power generation.

### Blending of hydrogen in compressed natural gas

Hydrogen-enriched compressed natural gas (HCNG) is being considered as the first step towards hydrogen economy in India. The blended fuel can be used in natural gas engine or combustion engine with minor modifications. Currently, approx. 20% of hydrogen is being blended in compressed natural gas in CNG buses that results in more fuel economy, reduction in CO and hydrocarbon emissions than CNG.

### Buildings

Space heating or cooling is more prevalent in the American and European residential and commercial buildings. For now, hydrogen can act as a cooking fuel in India. It can provide a substitute to the Indian cooking fuels such as LPG or PNG.

# India's capabilities and gap analysis across green hydrogen value chain

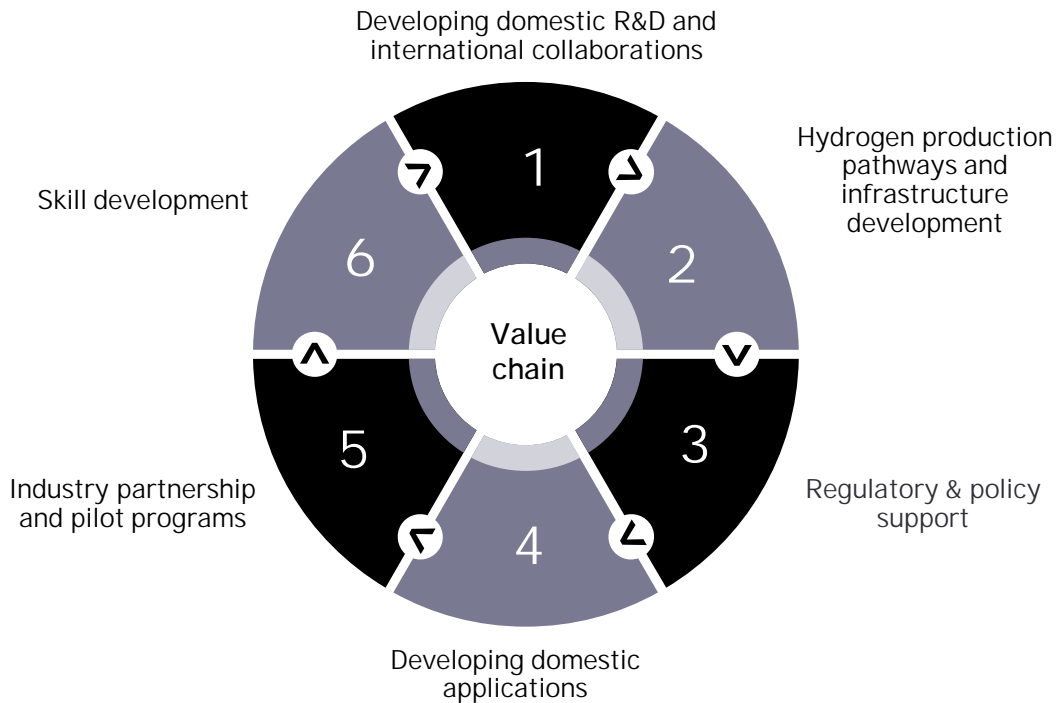
It is required to analyze the entire green hydrogen value chain before transitioning towards a new fuel type. Following are the key factors that are required to be considered with reference to green hydrogen penetration in India :

Up-stream		Requirements	Gaps	Mitigation steps	
Availability of Raw Materials	Electrolyzer	Precious metals: Pt, Pd, Ir	●	Explore geographies and increase R&D	
		Non-precious metals: Ni, Zr, La, Y	●		
	Renewables	Solar panels: Cu, Si etc.	●	Global tie-ups for exploration of raw materials & technology transfer and local manufacturing	
		Wind turbines: Cu, Mn, Cr, Zn etc.	●		
Economic Feasibility	Water	Freshwater	●	Explore methods to convert wastewater into treated water, Feasibility of large scale desalination plants	
		Wastewater treatment	●		
		Desalination of seawater	●		
Proven Technology	Cost of electrolyser		●	Incentivize under PLI scheme, local manufacturing, economies of scale	
	Renewable LCOE		●		
	Hydrogen production (LCOH)		●	Demand creation	
	Electrolysis	Productivity of electro-chemical reactions	●	Research & development for improving the efficiency of electrolyzer	
The produced hydrogen through electrolyser will be deoxidised, dried and purified before transportation or storage					
Mid-stream		Transportation & distribution	Pipelines	Retrofit	Incentivize transmission, distribution & storage network
Adequate Infrastructure	Hydrogen Infrastructure			New	
			Cryogenic liquid tanker trucks or gaseous tube trailers	●	
Safety and Standards	Storage		Pressurised tanks	●	Testing & pilots, create hydrogen valleys
			Salt caverns	●	
	Standards	Hydrogen storage, transportation and distribution standards	●	Global collaboration	
The transported hydrogen will be de-pressurized and converted as per the application requirements before end-use utilization					
Down-stream		Industrial	For domestic/local power generation	●	Repurposing of existing power supply units
End-Use	Transport	Fuel Cell Electric Vehicle		●	R&D, promotion through subsidies

● exist    ● not clear    ● Does not exist



# Key areas of focus and intervention for developing India's hydrogen ecosystem



## Action/ Focus points

- 1
  - u Promote research in hydrogen technologies through industrial & academic collaborations
  - u Knowledge & technology transfer
- 2
  - u Set out a target for hydrogen electrolyser capacity by 2030 & 2040
  - u Pre-feasibility study for conversion of existing pipeline infrastructure for hydrogen transportation
- 3
  - u Incentivize hydrogen production and usage through production and investment tax incentives
  - u Provide financing (debt, equity, grants) at lower rates
  - u Extension of production schemes such as PLI for electrolyser manufacturing
  - u Impose carbon taxing (cross-subsidy)
- 4
  - u Opportunity assessment for identifying hydrogen application - energy, feedstock, decarbonization, etc.
  - u Targets for % of energy share by 2030 & 2050
  - u Set out a target for FCEVs and HRS
- 5
  - u Technological and sectoral alliances along with PPP
  - u Identify hydrogen valleys, initiate and implement pilot projects and demonstrations
- 6
  - u Skilling and training for people in the related industries

## Key initiatives

### Government agencies

- u The GOI's Department of Science and Technology is encouraging translational research on carbon capture, utilization storage (CCUS)
- u Indian Oil corporation (IOCL) signed a pact with Greenstat Norway for setting up a centre of excellence on Hydrogen - Feb 2021
- u MNRE has been allocated INR 25 crores for R&D activities in Hydrogen
- u Green hydrogen purchase to be mandatory for some sectors: R K Singh
- u India will conduct green hydrogen auction in the first half of 2021 - Energy Minister RK Singh
- u NTPC organizing green hydrogen summit of BRICS nations - Jun 2021
- u IOCL may monetise Hydrogen units to raise INR 10,000 crores - May 2021

### Private Industries

- u Reliance Industries to invest US\$8bn for development of giga-factories for fuel cells and electrolysers
- u Tata motors, in collaboration with Indian Oil Corporation, developed country's first hydrogen fuel cell powered bus
- u Tata Motors bags order for 15 hydrogen-based fuel cell buses from Indian Oil Corporation.

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