Augmenting Value!

Demand potential of hydrogen in India – End use industry competitiveness

Hydrogen Competitiveness – End Use Application in India

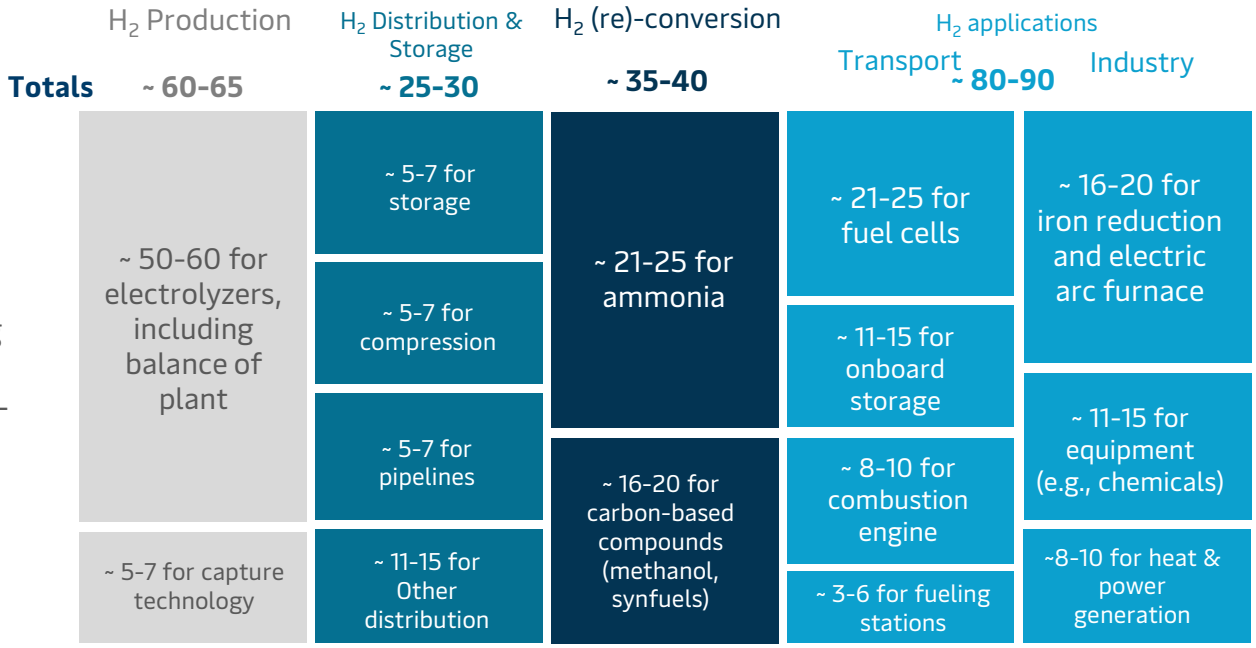
India will almost double in market size for hydrogen by demand from 2020 levels by 2030. The chief contributors to this growth shall be the ammonia based fertilizers, petroleum refineries and chemicals industries

MAKING LOW CARBON HYDROGEN IN INDIA – PRIORITY FOR COUNTRY

To maximize its environmental benefits, hydrogen must be "green"—made entirely from renewable-energy sources. Other methods, however, will also continue to be employed, some cleaner than others. Currently, the most common method, gray H2, involves using a fossil fuel to heat water into steam, mixing the steam with methane, and capturing the H2 released. Adding a filter to trap the GHGs emitted results in so-called "blue" hydrogen. Blue hydrogen is likely to remain economically favorable in places with an abundance of methane, especially once carbon capture technologies fully evolve.

Potentially by 2050, it is expected that around US$ 200 billion in annual capital pending shall be done which offers huge potential for machinery makers

Exhibit : 2050 Market Potential for Equipment & Components ($ Billions)



Source : eninrac research, channel checks, BCG

HOW MUCH HYDROGEN IS REQUIRED FOR TRAVEL, FUEL CELL & NATURAL GAS REPLACEMENT IN INDIA

1 kg of hydrogen is enough to travel up to **100km** in **Hyundai Nexo**

Travelling in a **Hyundai Santa Fe** uses **7.5L** of diesel or **9.3L** of petrol

Driving a **Hyundai Nexo** compared to a diesel **Hyundai Santa Fe** avoids 0.2kg CO_2-e/km driven or 20 kg CO_2-e/kg of hydrogen used

1kg of hydrogen in a fuel cell could power a **1,400-watt** electric split-cycle air conditioner for **14.5 hours**

Replacing Indian Grid electricity with electricity from **hydrogen** avoids **0.75 kg CO_2 – e/kwh**, of **15kg of CO_2 – e/kg** of hydrogen used

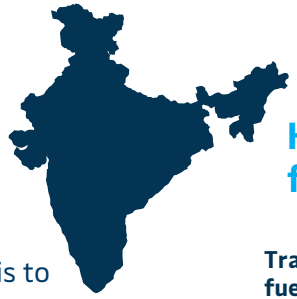
1 tonne of hydrogen is equivalent to around **3.4 times** the average annual consumption of Indian house with gas

Replacing **natural gas** with **hydrogen** avoids **0.052 tonnes CO_2-e/GJ** of **natural gas** or **6.2 tonnes CO_2-e/tonne** of **hydrogen**

Replacement Scenarios in India

Source : eninrac research, channel checks, Ministry of Natural Gas, Govt. Of India

For a country like India, full benefits of hydrogen and fuel cell technologies play out when deployed at scale and across multiple applications



2020-2022: Immediate next steps

In the first two three years, the aim is to establish dependable and technology-neutral decarbonization goals in a greater number of states in the country and at the central level produce comprehensive guide which will serve input to regulatory & policy dynamics.

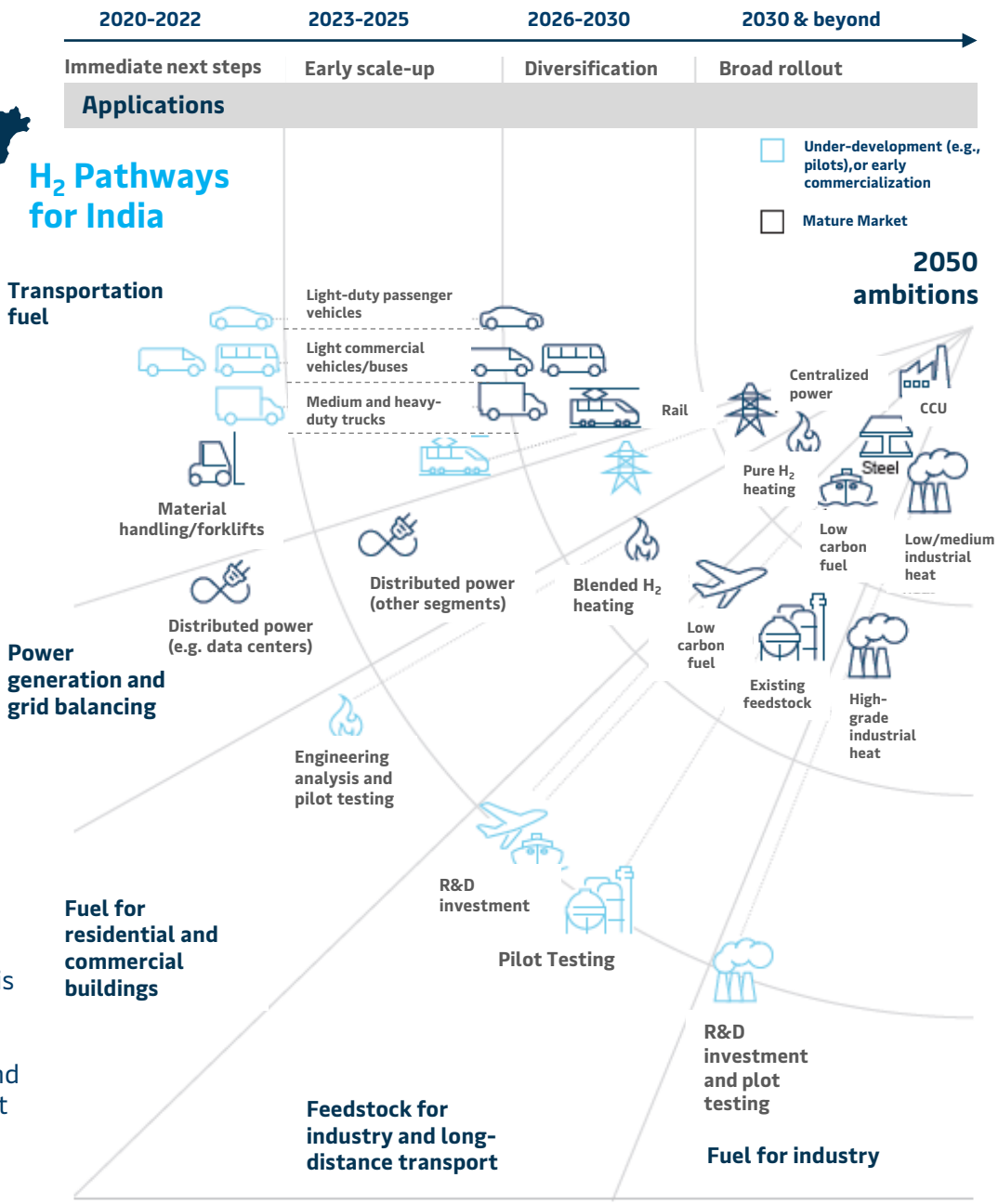
2023-2025: Early scale-up

By 2025, large-scale hydrogen production in the country is anticipated to be developed. This shall be done by bringing the cost down and kicking off scale up applications. Policy incentives in early markets being transitioning from direct support to scalable based mechanisms.

2026-30 & Beyond: Diversification & broad roll-out

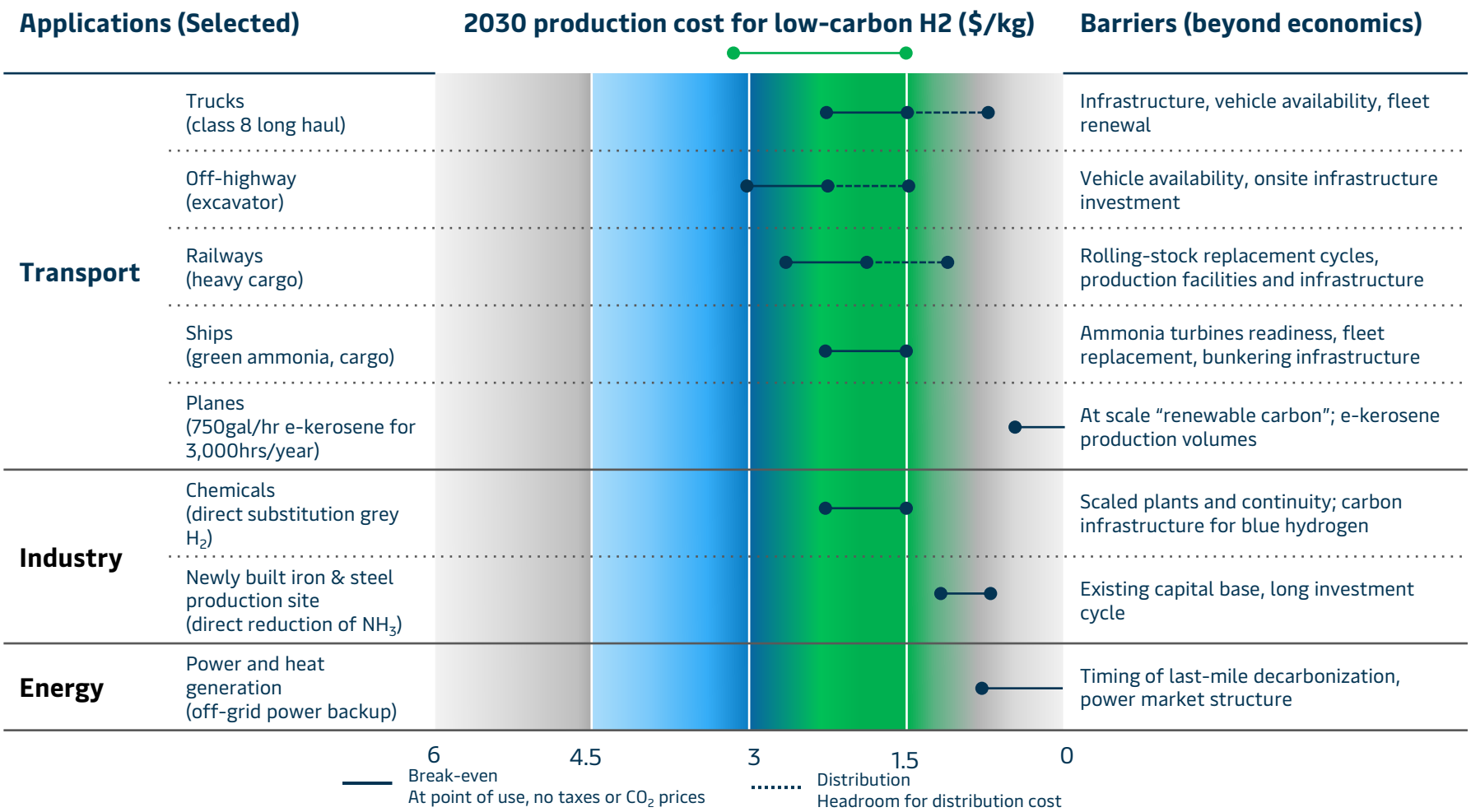
The 2026 to 2030 phase is about diversification beyond early adopter segments and early adopter states such as transportation and backup power, and about scaling up infrastructure across the country. After 2030, hydrogen is deployed at scale in India, across regions and industries. Most applications achieve cost parity with fossil fuel alternatives through sufficient pricing of externalities, and public support for market introduction can be phased out

Source : eninrac research & analysis, Channel checks



Economic viability holds key to hydrogen's success as a clean source of energy in India

Infrastructure, availability of vehicles and at-scale equipment are key barriers, beyond unit economics and the cost gap

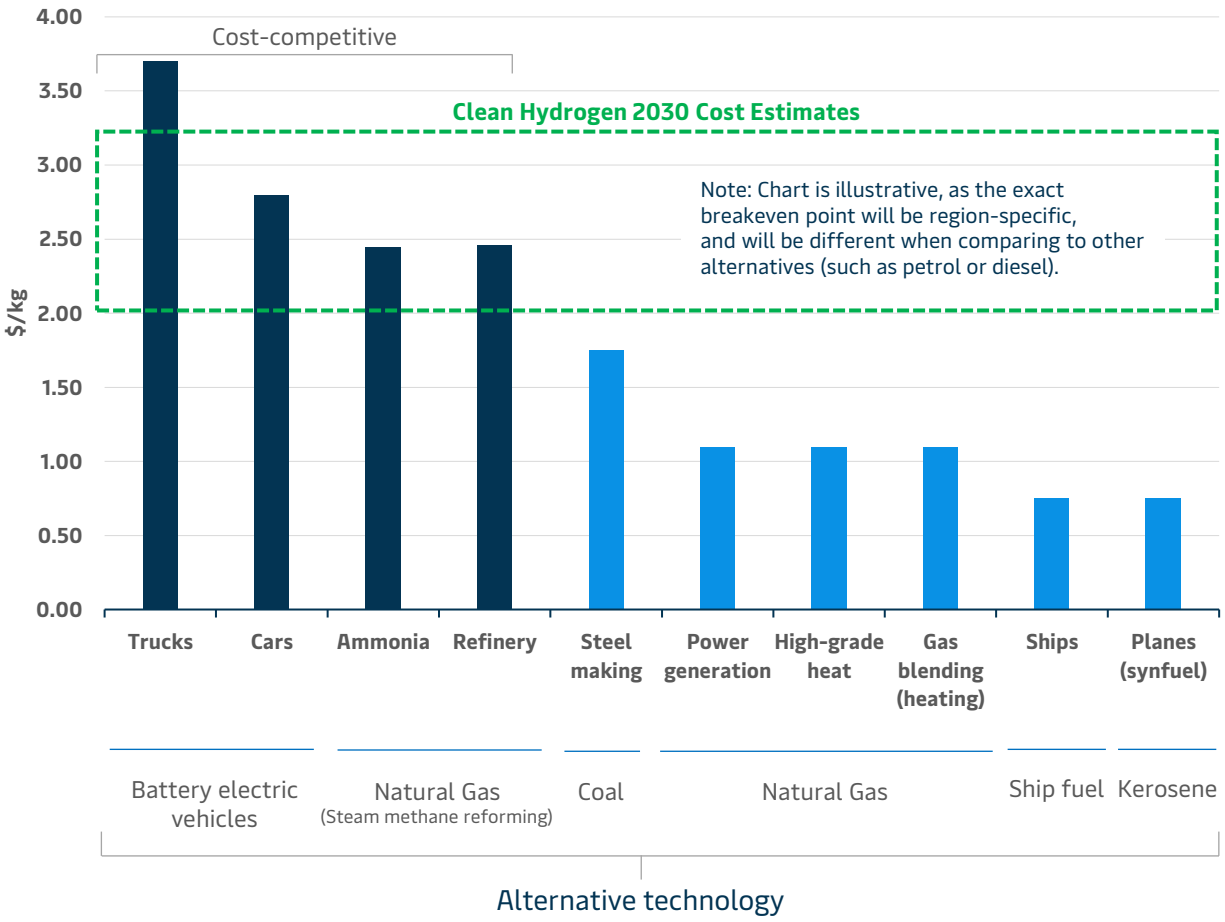


Source : eninrac research & analysis, Channel checks & BCG

Global attempt to increase momentum for clean H_2

Australia, Japan, China & Republic of Korea in Asia Pacific region have already made commitments to use clean hydrogen and decarbonize their energy systems. Clean hydrogen is gaining grounds in Europe as well as in US and is having good hopes in India as well for registering growth. Globally, industries such as shipping, steel making, and chemical production see hydrogen as a long-term alternative to their dependence on fossil fuels. Interest has been bolstered by the falling costs to produce and use hydrogen. Over the past decade, for example, the cost of generating electricity from wind has fallen by about 70%, and from solar PV by about 80%. The cost to make a hydrogen fuel cell, meanwhile, has fallen by about 60% since 2006. With foreseeable technology improvements and higher manufacturing volume, it is anticipated that the cost of fuel cells might fall by about another 30% by 2025. The cost of storing hydrogen will also become cheaper with scale, technology and efficiency improvements – by up to 40% as ammonia and up to 80% as liquid hydrogen. As costs fall, clean hydrogen will become increasingly competitive. When and where this occurs will also depend on factors such as the cost of alternatives.

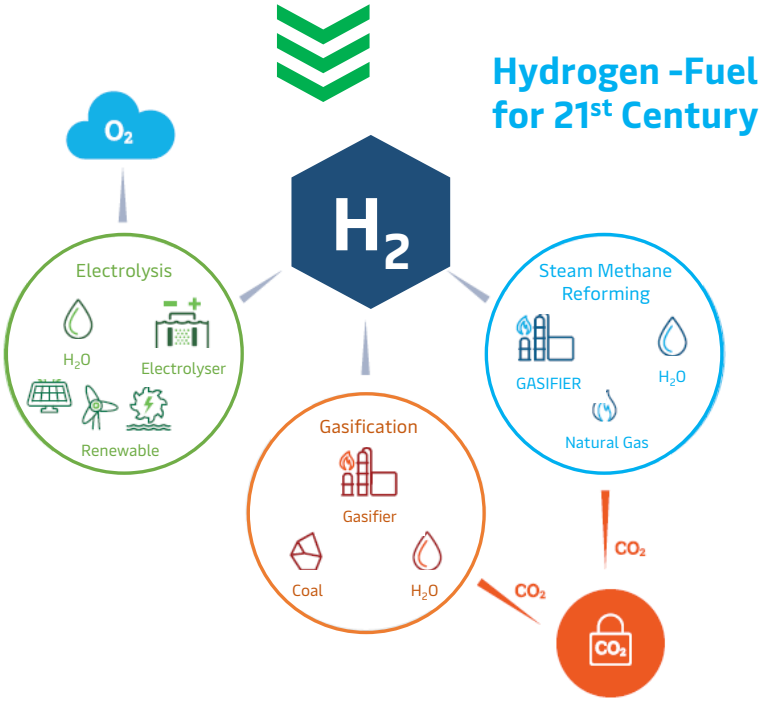
Exhibit: Breakeven cost of hydrogen against alternative technology for major applications, in 2030.



Source : eninrac research & analysis, Channel Checks & D2I Model Interpretations

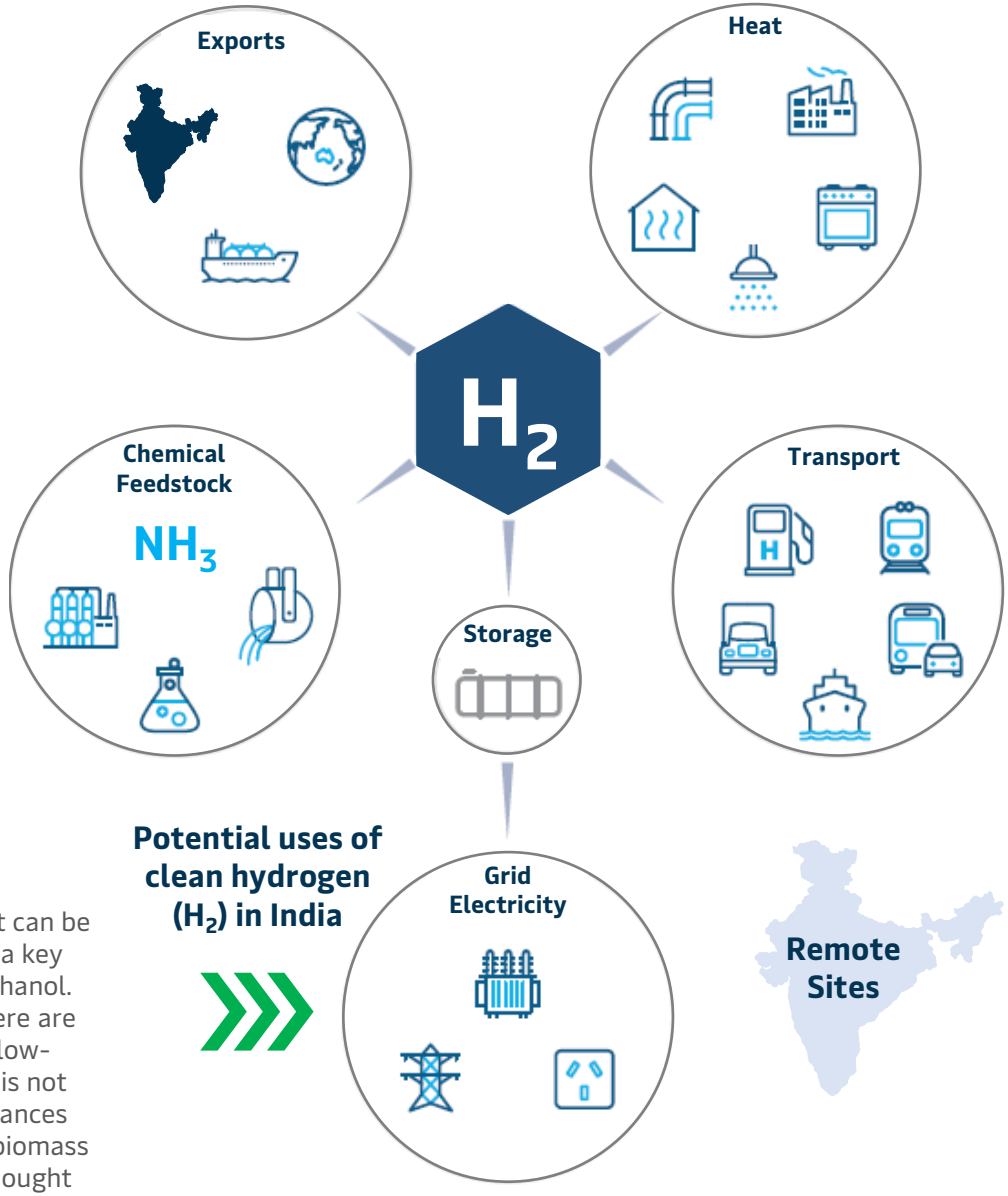
Production pathways of clean hydrogen (H_2) in India

Hydrogen -Fuel for 21st Century



Hydrogen is a flexible, safe, transportable and storable fuel. It can be used to power vehicles and generate heat and electricity. It is a key ingredient for producing chemicals such as ammonia and methanol. When used as a fuel, hydrogen's only by-product is water. There are no carbon emissions. But whether hydrogen is truly a zero or low-emissions fuel depends on how it is produced. Pure hydrogen is not found naturally on Earth. It must be extracted from the substances that contain it – water mainly, but also coal, natural gas and biomass – and this takes energy. Because of this, hydrogen is better thought of as an energy carrier than an energy source.

Potential uses of clean hydrogen (H_2) in India

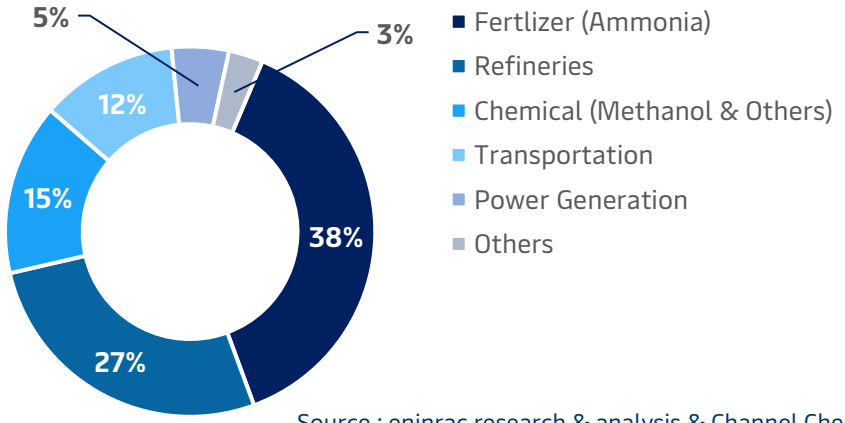


India – Potential & Vision for Hydrogen Economy

There is tremendous potential for low-cost, low-carbon production of H_2 in India and the Government along with industry identifies the same.

There is tremendous potential for low-cost, low-carbon production of hydrogen in India, which can enable broad adoption of hydrogen across sectors. Currently in India, hydrogen mainly serve as feedstock in ammonia and methanol production and in refineries. In transportation it is catching up but is in very nascent stages in the country. It is anticipated that good numbers of FCEVs and buses shall come into play in the big cities for public transport in the country. Also, under the mining segment also it is anticipated to evolve as an alternative source.

Exhibit : India Hydrogen Market Share (2021) – Consumption by key sectors in India



Source : eninrac research & analysis & Channel Checks

6 Million Tonnes

Of H_2 is currently consumed in Indian market

US$ 11 Billion

Is total worth of current H_2 market in India

Close to 80%

Is captured by fertilizer (ammonia), refineries & chemical segment in India

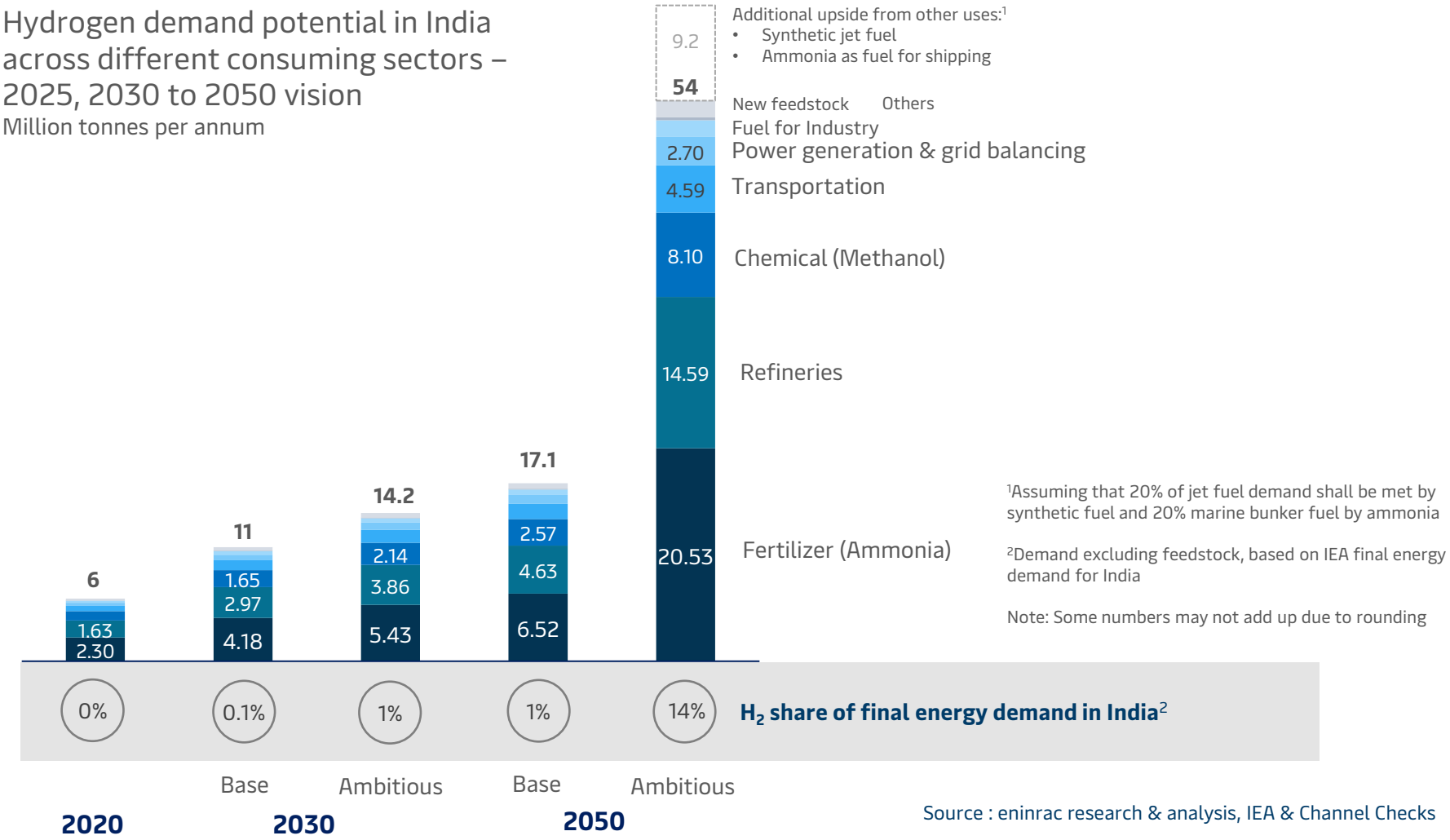
Only 20%

Is captured by transportation, power generation & other segment in India

India – Hydrogen demand potential across end use application sector – 2025, 2030 & 2050 vision

Hydrogen demand potential in India across different consuming sectors – 2025, 2030 to 2050 vision

Million tonnes per annum



[1]Assuming that 20% of jet fuel demand shall be met by synthetic fuel and 20% marine bunker fuel by ammonia

[2]Demand excluding feedstock, based on IEA final energy demand for India

Note: Some numbers may not add up due to rounding

Source : eninrac research & analysis, IEA & Channel Checks

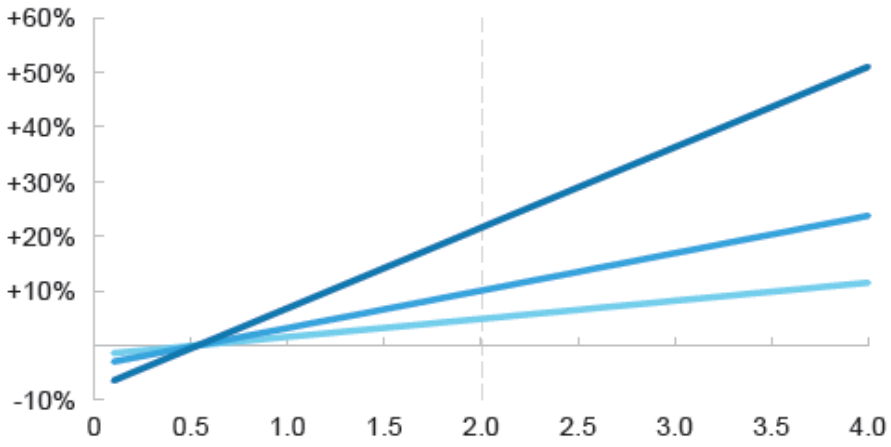
Hydrogen blending with natural gas in India – Use cases

Blending use cases with hydrogen in India

Companies can blend low percentages of hydrogen into existing natural gas networks without the need for major changes in infrastructure or new home appliances. The ability of utilities to blend hydrogen will be dependent on infrastructure and end-use characteristics, and each utility needs to assess its own pipeline systems on a case-by-case basis to determine actual acceptable levels of hydrogen blending without major changes or enhancements to existing pipeline infrastructure

Total hydrogen use in India in 2021
Million tonnes/year

Change in fuel price BTU
Variation in gas price for $/kg hydrogen, percent



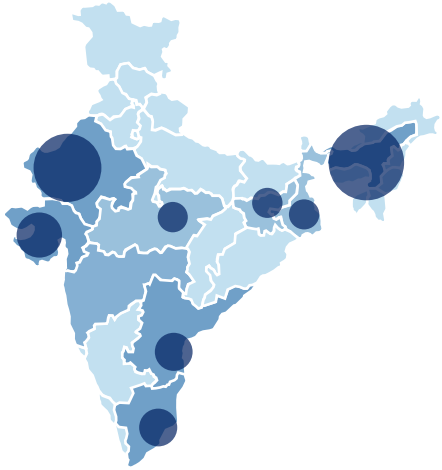
Energy cost increase blending $2/kg hydrogen with natural gas
Percent difference

20% blend in volume — 22%

10% blend in volume — 10%

5% blend in volume — 5%

Natural gas production in India (2021-22) MMSCM

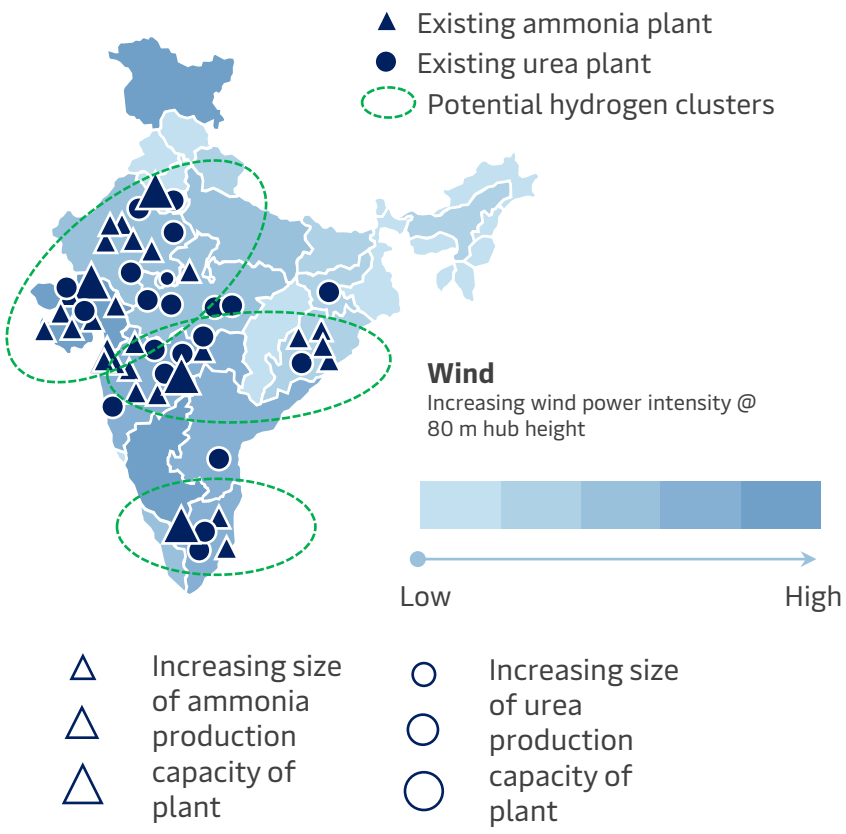


Note: Size of bubbles represents the extent of production in the states

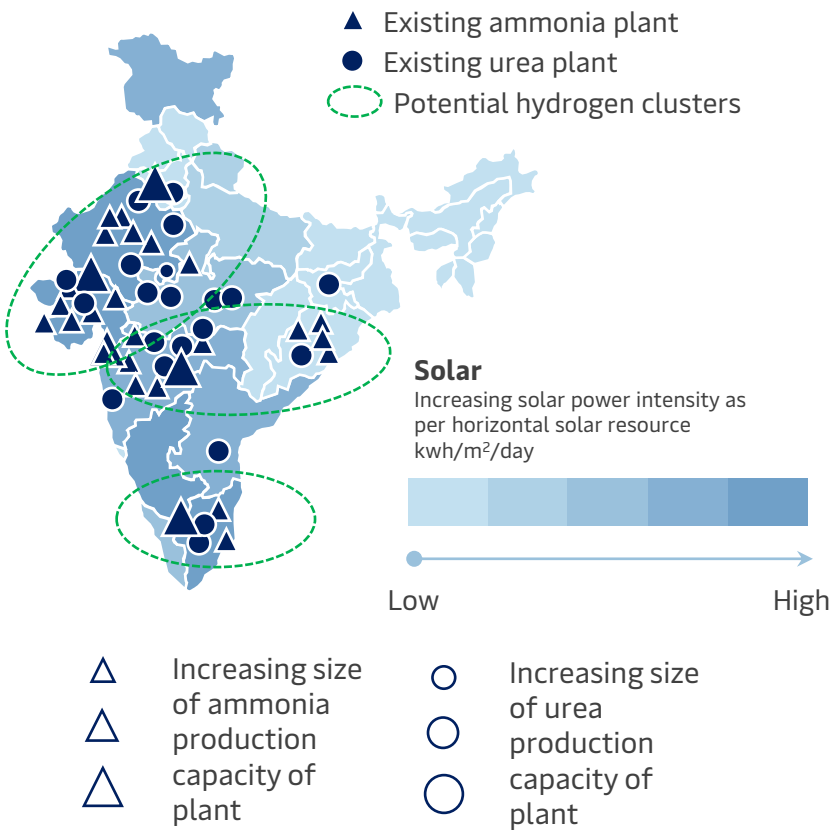
Source : eninrac research & analysis, D2I Model & Channel Checks

Hydrogen could play a pivotal role as a low carbon alternative to firm the national grid in India – with solar and wind power

Wind power intensity, existing ammonia and urea plants and potential hydrogen clusters in future for India



Solar irradiation intensity, existing ammonia and urea plants and potential hydrogen clusters in future for India



Source : eninrac research & analysis and Channel Checks

> Truth is ever to be found in the simplicity, and not in the multiplicity and confusion of things
>
> **- Sir Isaac Newton**

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