research & innovation

Blue Hydrogen and Ammonia Production and Supply Pathways

SPE London Evening Programme

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where energy is opportunity™

who we are:

a fully integrated energy and chemicals enterprise

336.7 billion

barrels of oil equivalent reserves

10.2 million

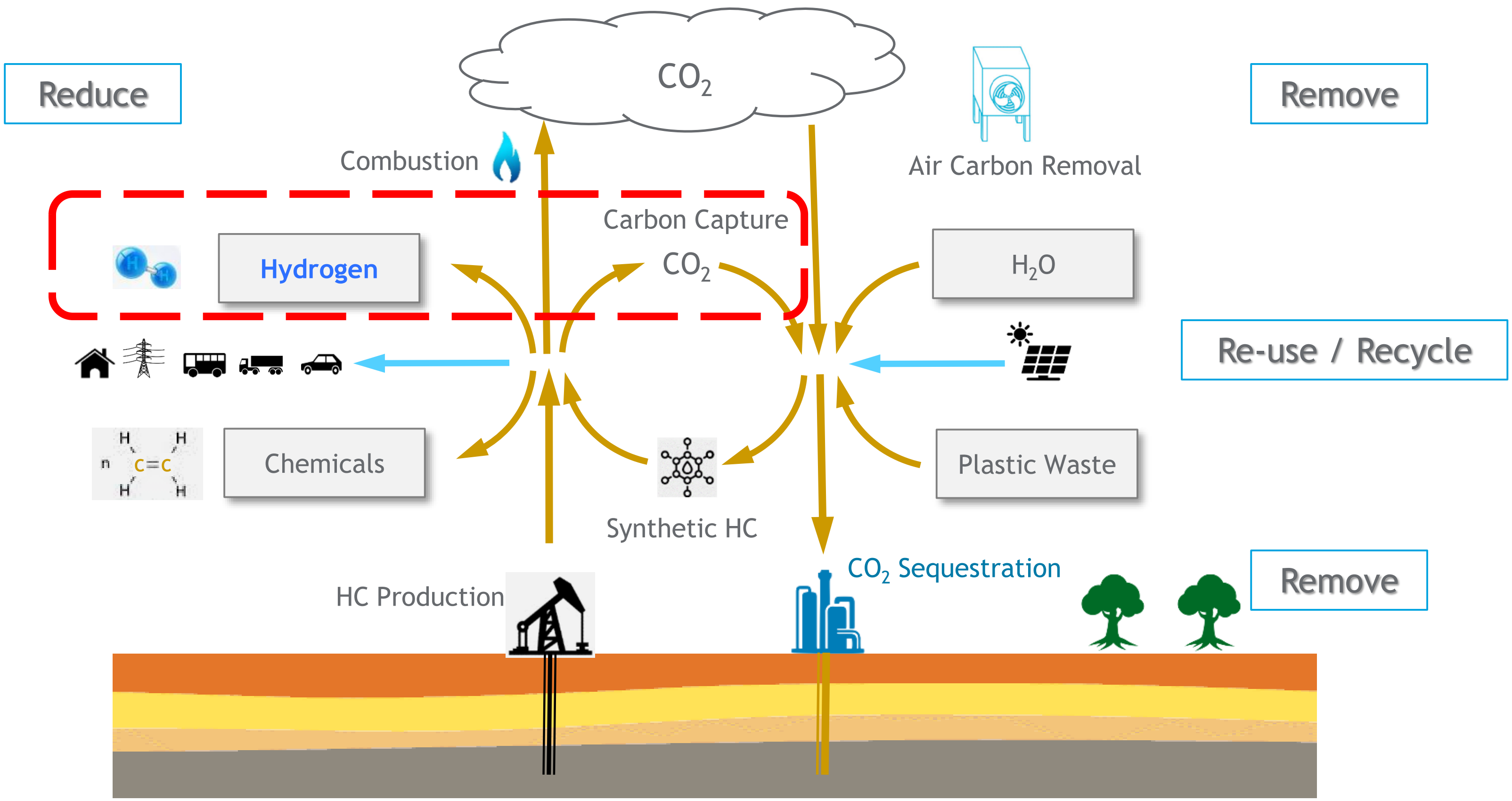
bpd crude with blended condensate produced

12.4 billion

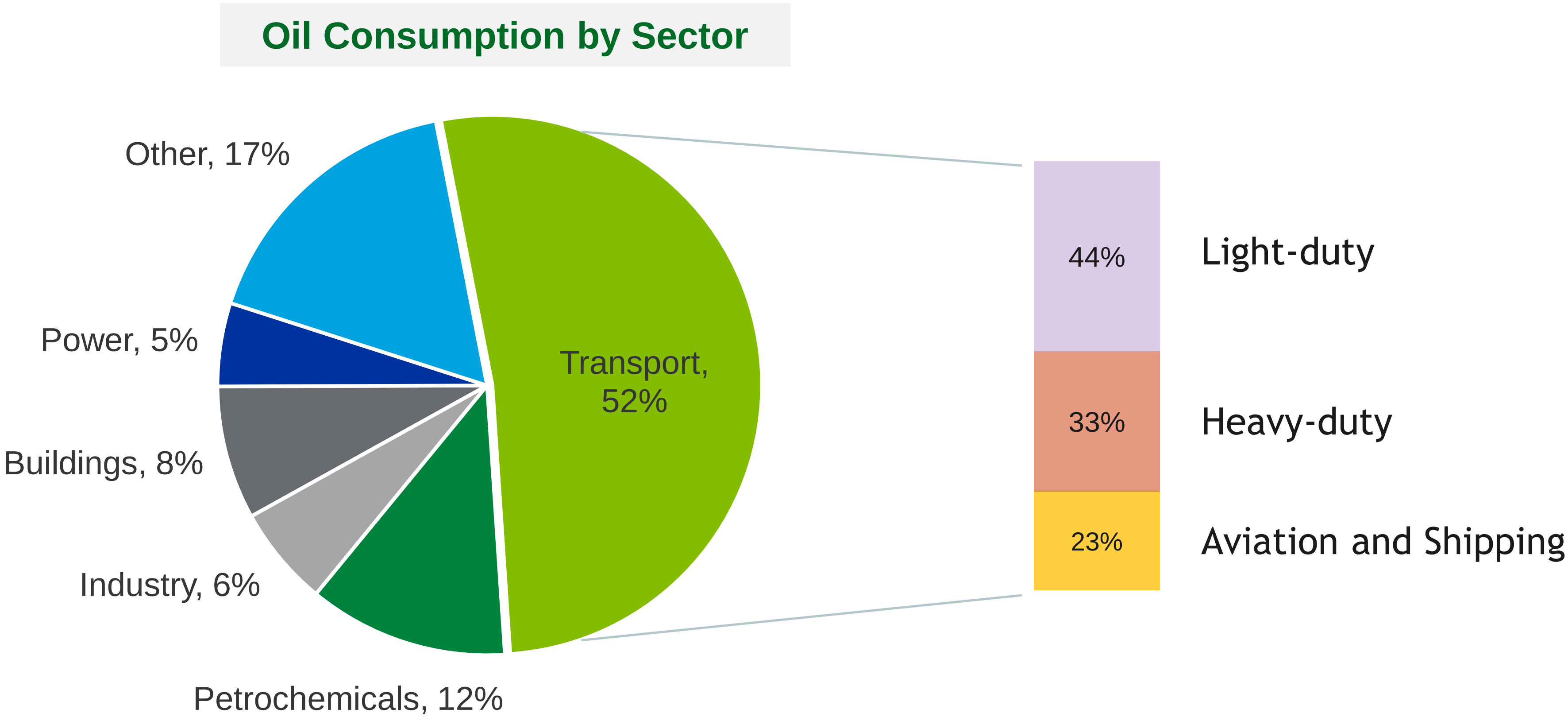
scfd of raw natural gas processed

A holistic approach to carbon emission reduction:

Circular Carbon Economy Framework

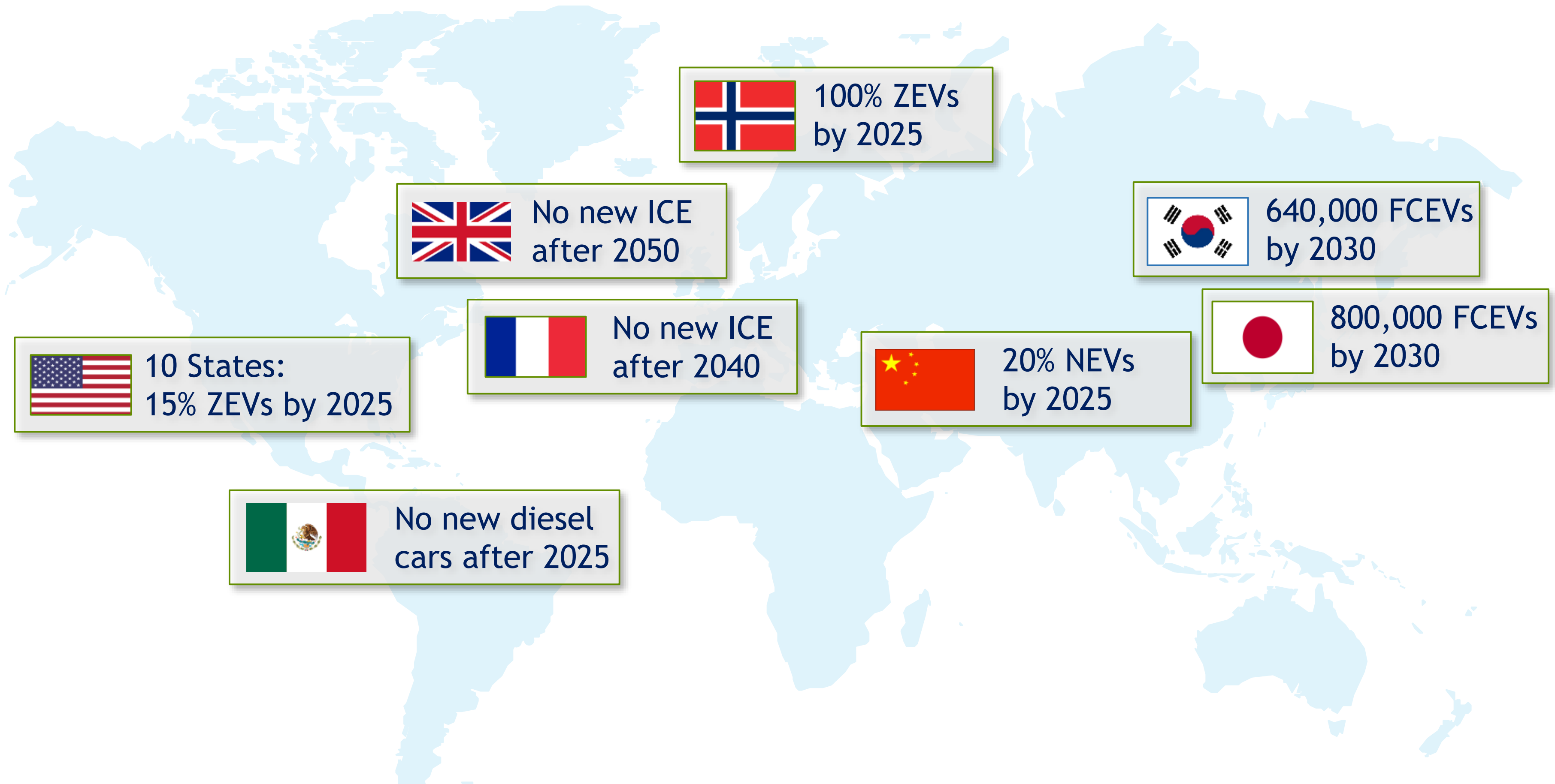


Global oil consumption by sector



Source: IEA World Energy Outlook 2018

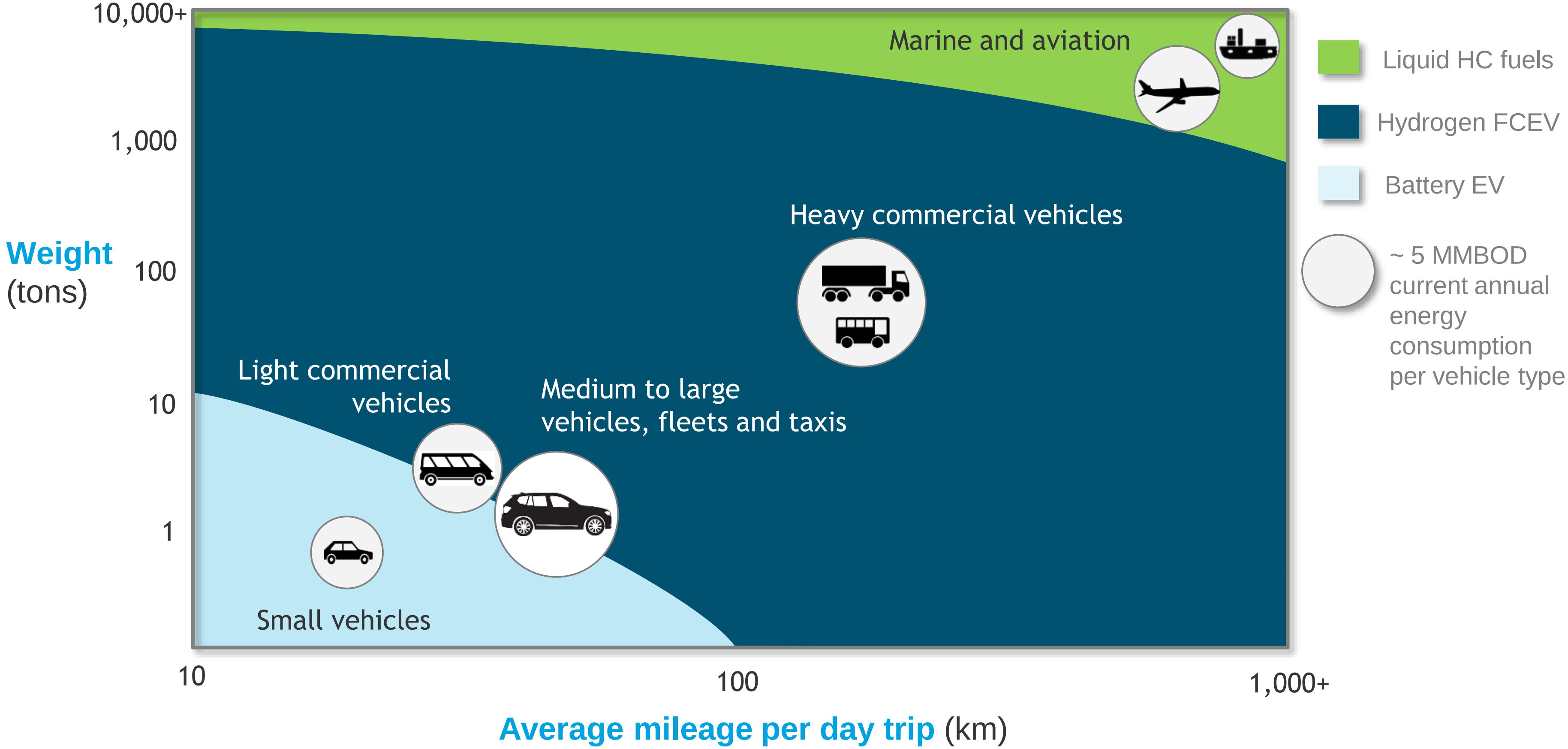
Strong policy push to decarbonize road transport



Zero Emission Vehicle (ZEV*) is being deployed globally

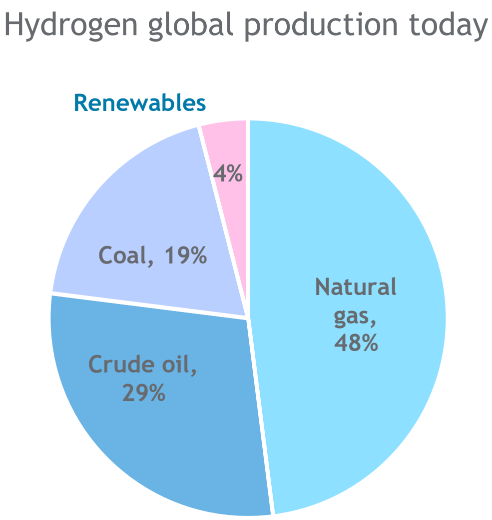
* Electric & fuel cell vehicles; NEV: New Energy Vehicle

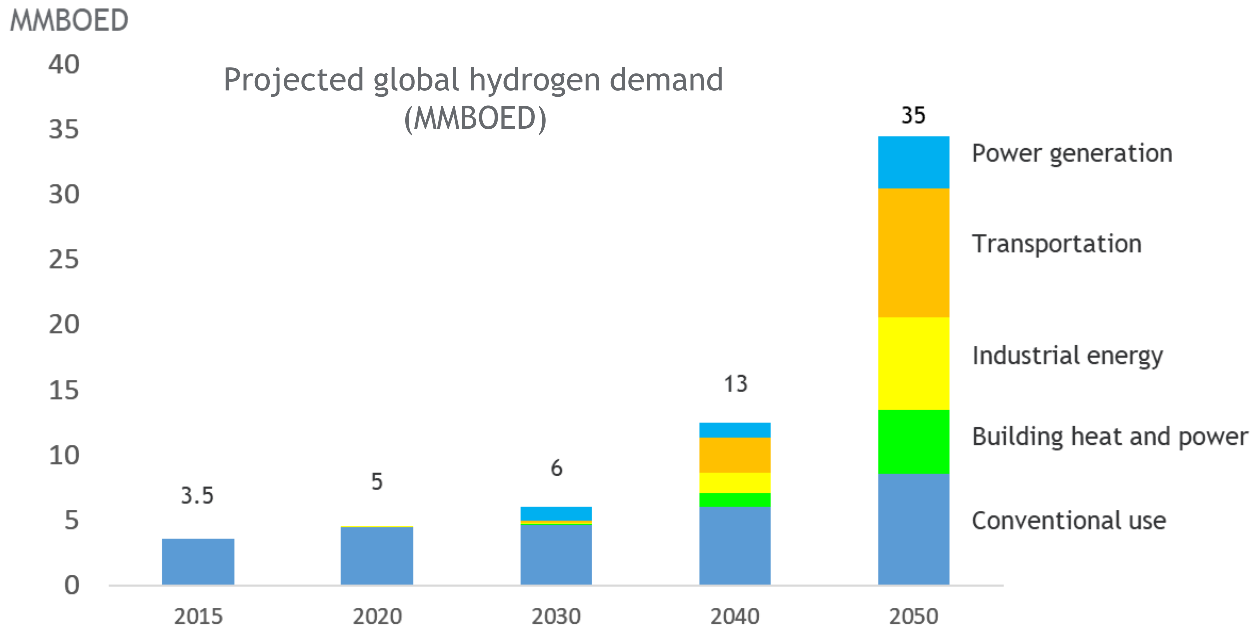
Hydrogen can be a viable option for the transport sector



Source: Hydrogen Council, "Hydrogen Scaling Up", (2017)

Hydrogen market





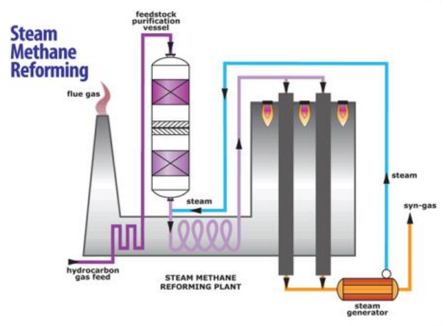
Hydrogen demand is projected to increase 10-fold by 2050

Source: Hydrogen Council, 2018

Key hydrogen production technologies

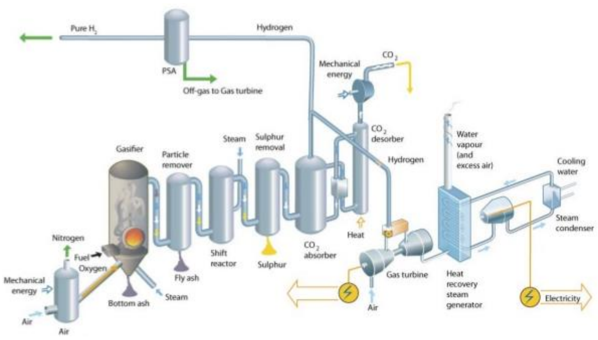
10-12 kg CO_2-eq/kg H_2

SMR

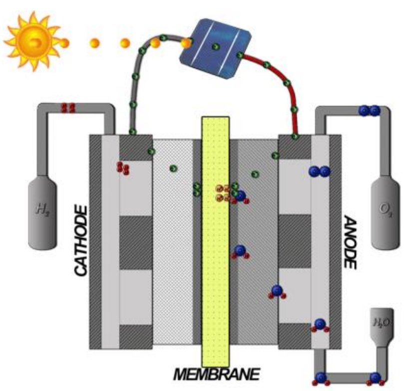


24 kg CO_2-eq/kg H_2 for coal

Gasification



Electrolysis



2-30 kg CO_2-eq/kg H_2
for renewable and non renewable power source

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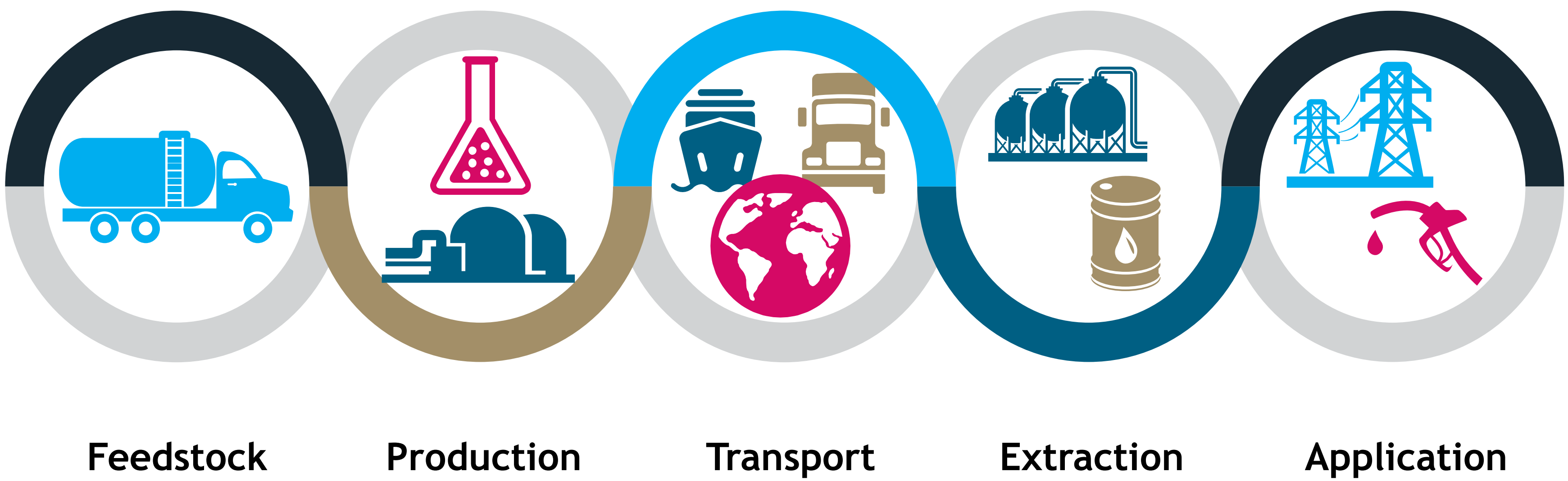
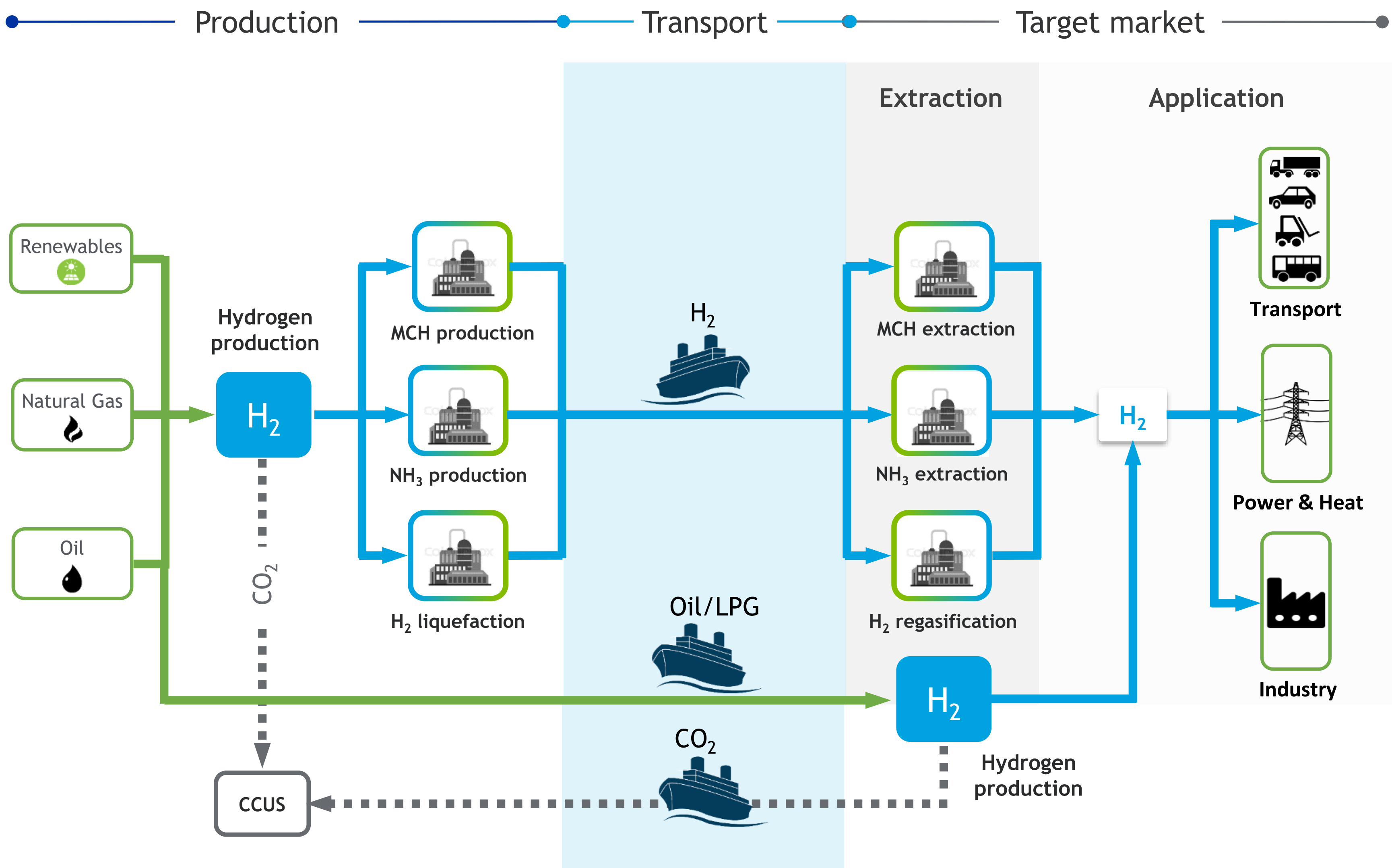
Hydrogen import options require new infrastructure and business models

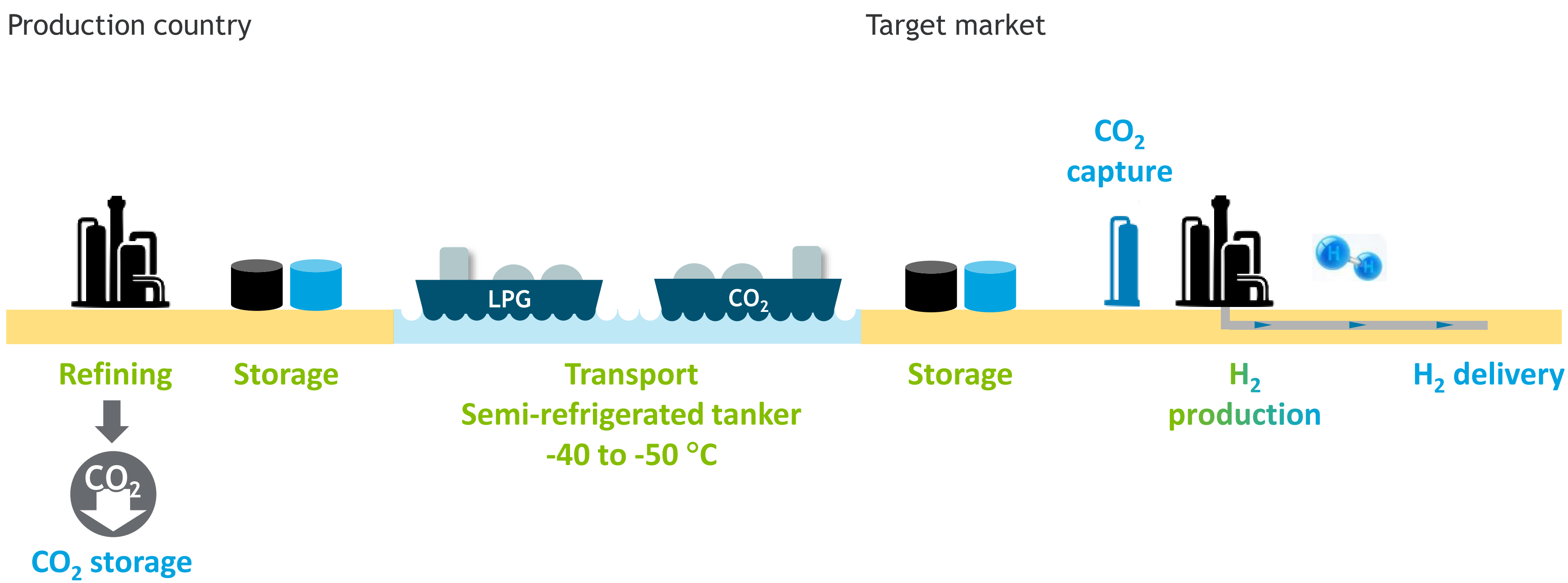


Hydrogen delivery options



MCH: Methyl Cyclohexane; NH_3: Ammonia; CCUS: Carbon Capture Utilization and Storage

LPG and CO_2 transport offer good synergies



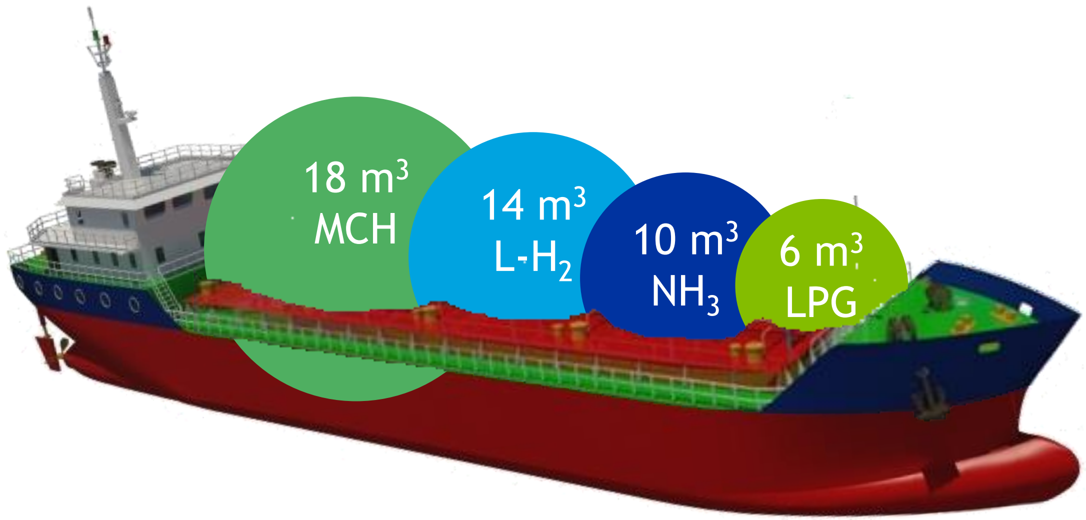
Reduced hydrogen production costs

- Usage of existing infrastructure
- Usage of same tankers

65% of CO_2 can be shipped back using the LPG tanker

Hydrogen carriers benchmark

Hydrogen carrier transport per ton of H_2



Transport Maturity	+	−	+	+
H_2 extraction	−	+	+	+
Toxicity	−	+	−	+

Manageable safety

LPG transport is an attractive option

Value chain for 200,000 t/yr H_2 sea transport in 50,000 m^3 ships

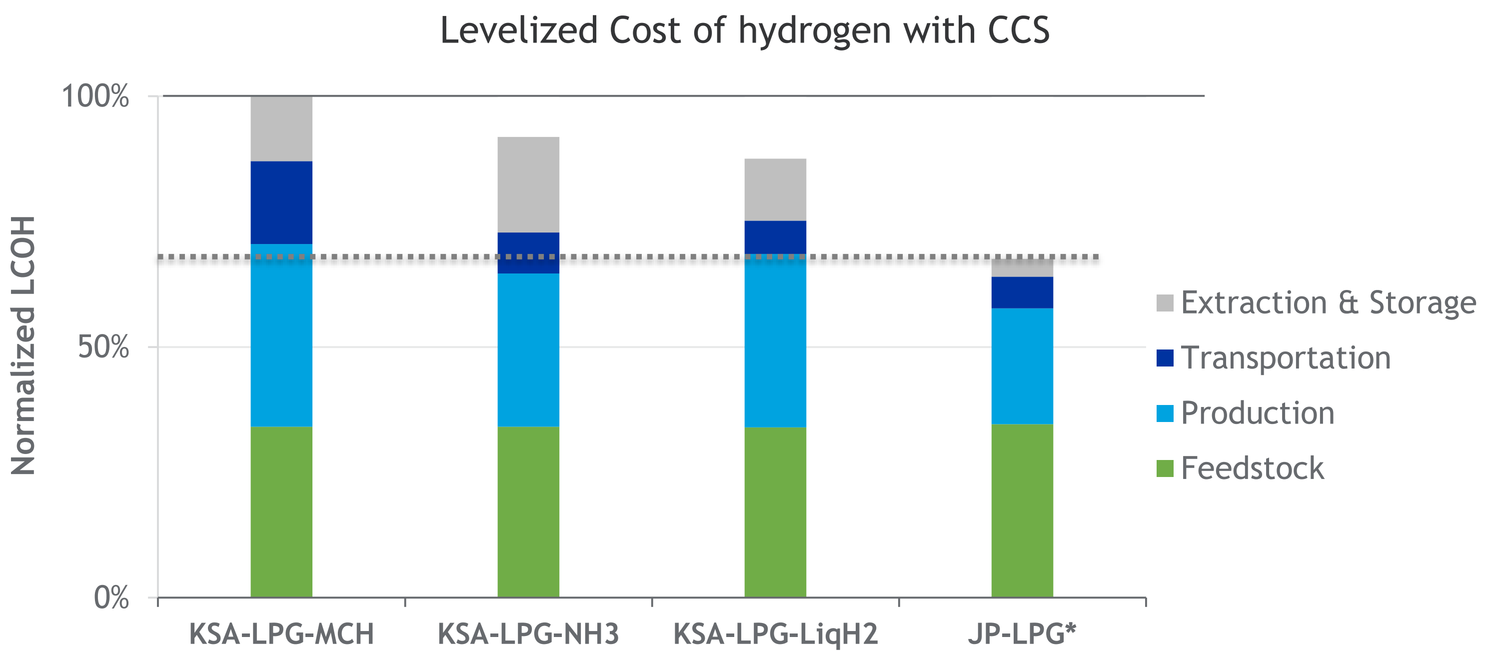
11 MCH ships

9 L-H_2 ships

6 NH_3 ships

4 LPG ships + 1 CO_2 ship

In-market hydrogen production is an attractive option

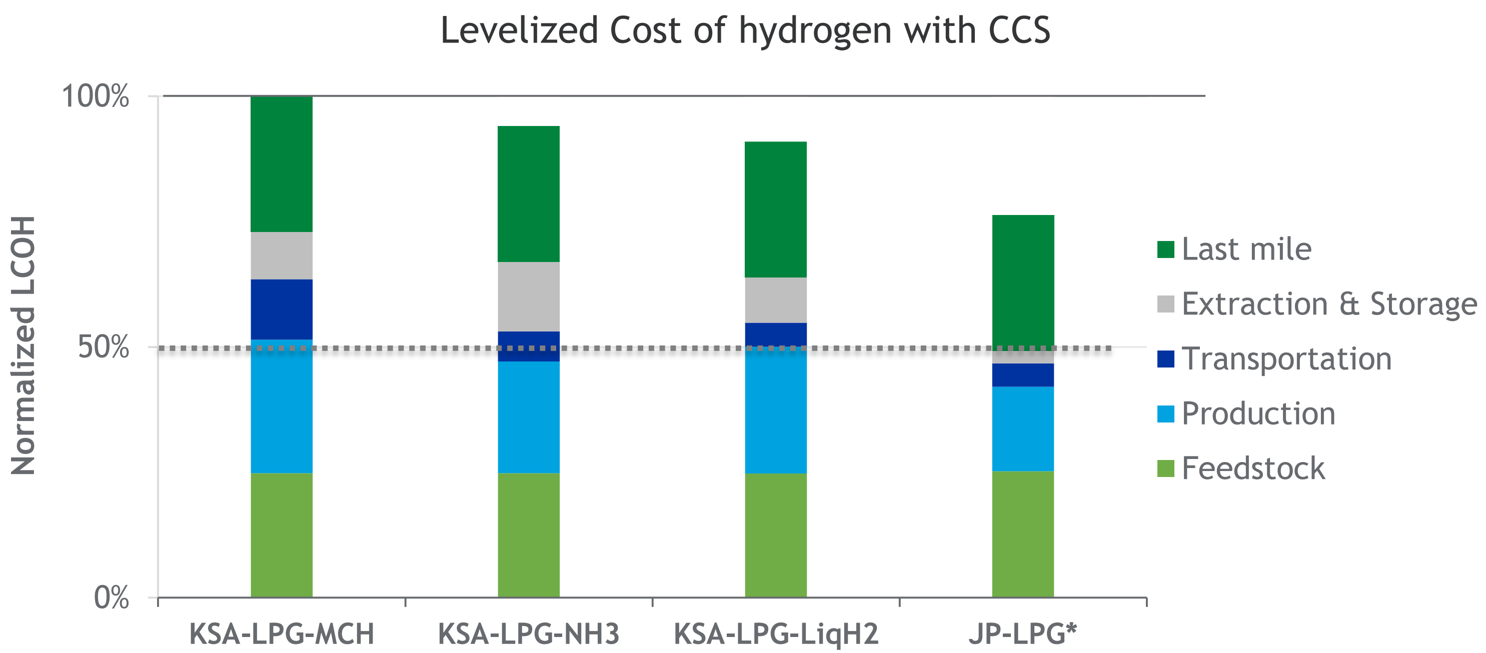


Need to demonstrate trans-ocean CO_2 transport

Short term projections; transport from KSA to Japan

*H_2 production in Japan with CCS and CO_2 shipping to Saudi Arabia

In-market hydrogen production is an attractive option

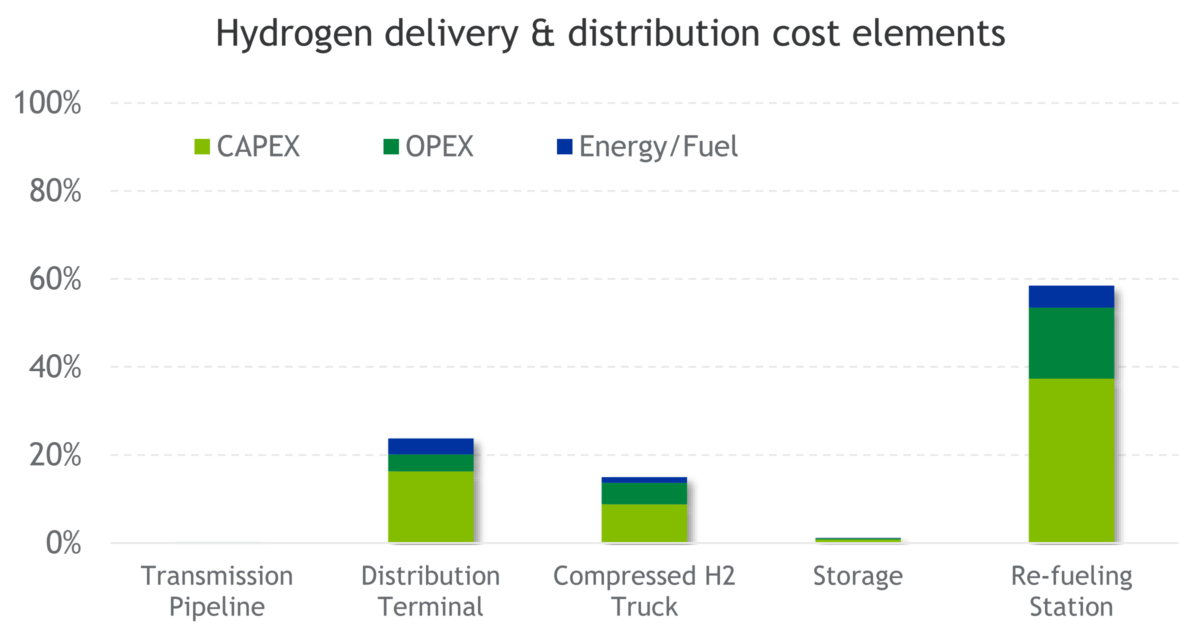


Last mile cost represents about 1/3rd of the total hydrogen cost

Short term projections; transport from KSA to Japan

*H_2 production in Japan with CCS and CO_2 shipping to Saudi Arabia

H_2 refueling stations and distribution terminal are biggest cost elements

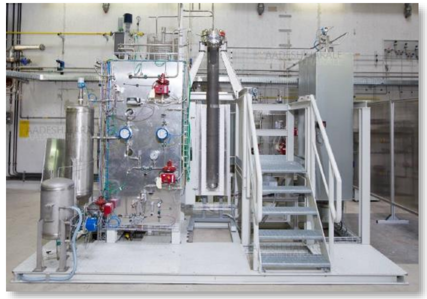


On-site hydrogen generation can potentially reduce the last mile cost

Simulated scenario is for 10km pipeline transmission from import terminal to distribution terminal, followed by tube trailer truck delivery to re-fueling stations which have hydrogen dispensing capacity of 1,000 kg/day at 700 bar and operate at 80% utilization.

Current R&D addresses oil based hydrogen competitiveness

Membrane reactor



- Maximize process intensification
- Improve CAPEX and increase conversion efficiency

Fueling station

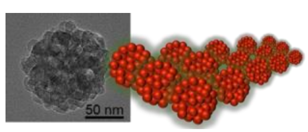
On-site packaged reformer

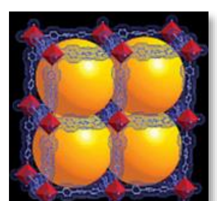
Electrochemical compressor

- Reduce hydrogen delivery cost
- Improve compression efficiency

CCUS

Novel MOF adsorbents & cryogenic CO_2 capture





- Enhance CO_2 capture and storage capacity

Need to demonstrate CO_2 capture and transport for on-site H_2 production

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Piloting the hydrogen supply chain in Saudi Arabia

aramco Hydrogen Fueling Station

- Onsite packaged hydrogen generation (heavy naphtha, LPG or NG)

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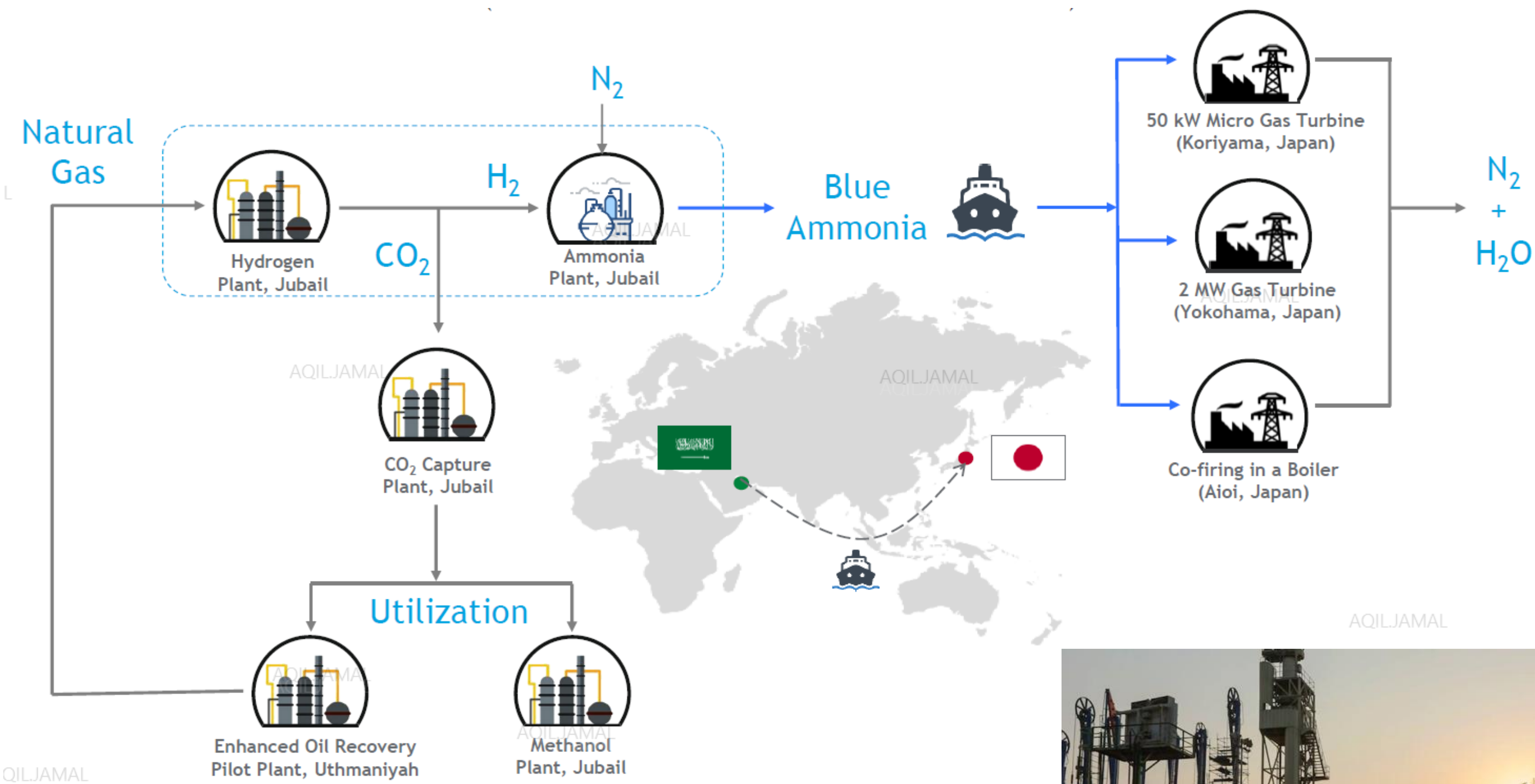
Saudi Aramco – Air Products Hydrogen Fueling Station, DTV*

- High purity H_2 delivered by tube trailer

*DTV: Dhahran Techno Valley

Piloting the blue hydrogen/ammonia supply chain



Thank you