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The Role of Hydrogen in the Energy Transition

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Hydrogen demand trends

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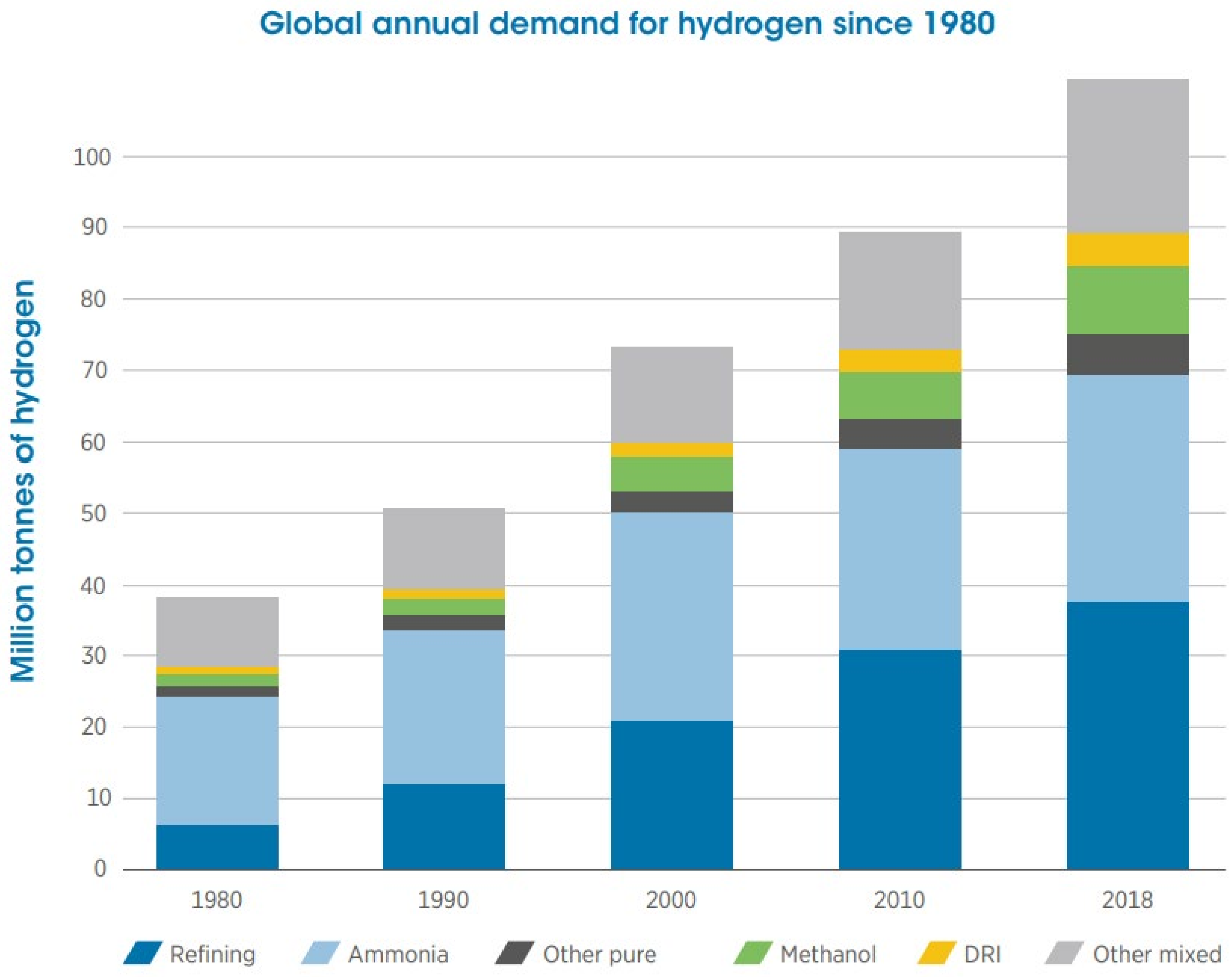

Opportunities for hydrogen in the energy transition

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Decarbonising options (30 EJ)

Industry:
Replace fossil-fuel produced hydrogen
Replace fossil-fuel based feedstocks

Transport:
FCEV – to complement BEVs in decarbonising road transport

Gas grid:
Take advantage of low electricity prices
Provide seasonal storage for hydrogen
Use existing gas infrastructure

Electrolysers will provide short-term flexibility, helping to manage short-term fluctuations of VRE

Deep-Decarbonising options (> 30 EJ)

Transport:
FC/E-fuels for rail, aviation, maritime sector

Power:
Combined with seasonal storage

Buildings:
Distributed stationary fuel-cell for heat and power generation

Industry:
New commodities e.g. iron pellets (DRI)

Products and global market potentials 2050: 375-600 Mt for existing and new markets

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- Ammonia as a commodity (N-fertiliser) and as a fuel (shipping) – market potential 300 Mt NH_3 – 75 Mt H_2
- Hydrogen for iron and steel production – market potential 400 Mt DRI – 50 Mt H_2
- Hydrogen for methanol production (as synfuel and chemical building block) – market potential 150 Mt CH_3OH – 30 Mt H_2
- Hydrogen for aviation synfuel – 10 EJ – 80 Mt H_2
- 20% gas systems – 13 EJ – 110 Mt H_2
- Synthetic diesel and naphtha – 100 Mt CH_2 – 30 Mt H_2
- Road transportation fuel (freight + passenger cars) could increase this total by 50%
- Hydrogen and ammonia for electricity storage (e.g. Japan plans)

5 Measures for Reaching Zero – key role for renewables

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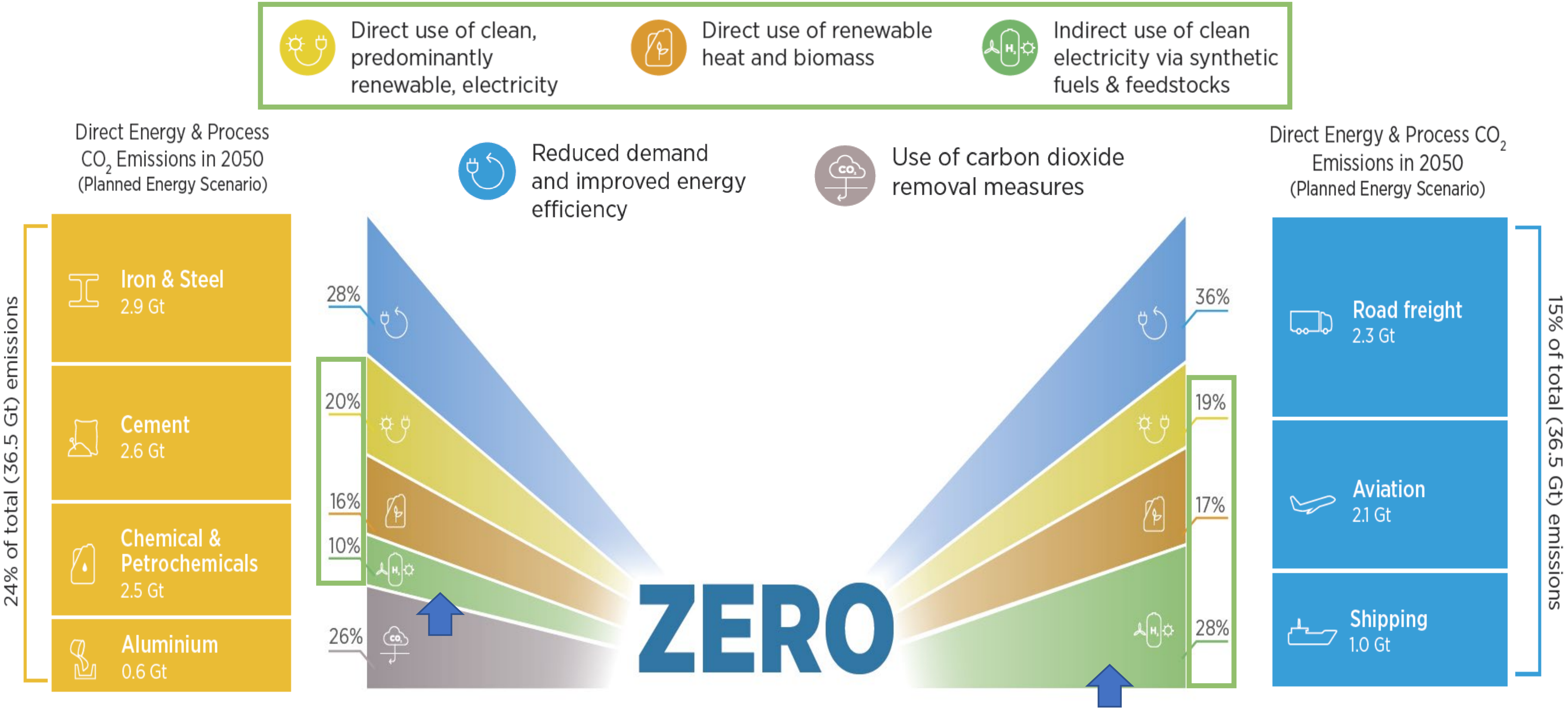
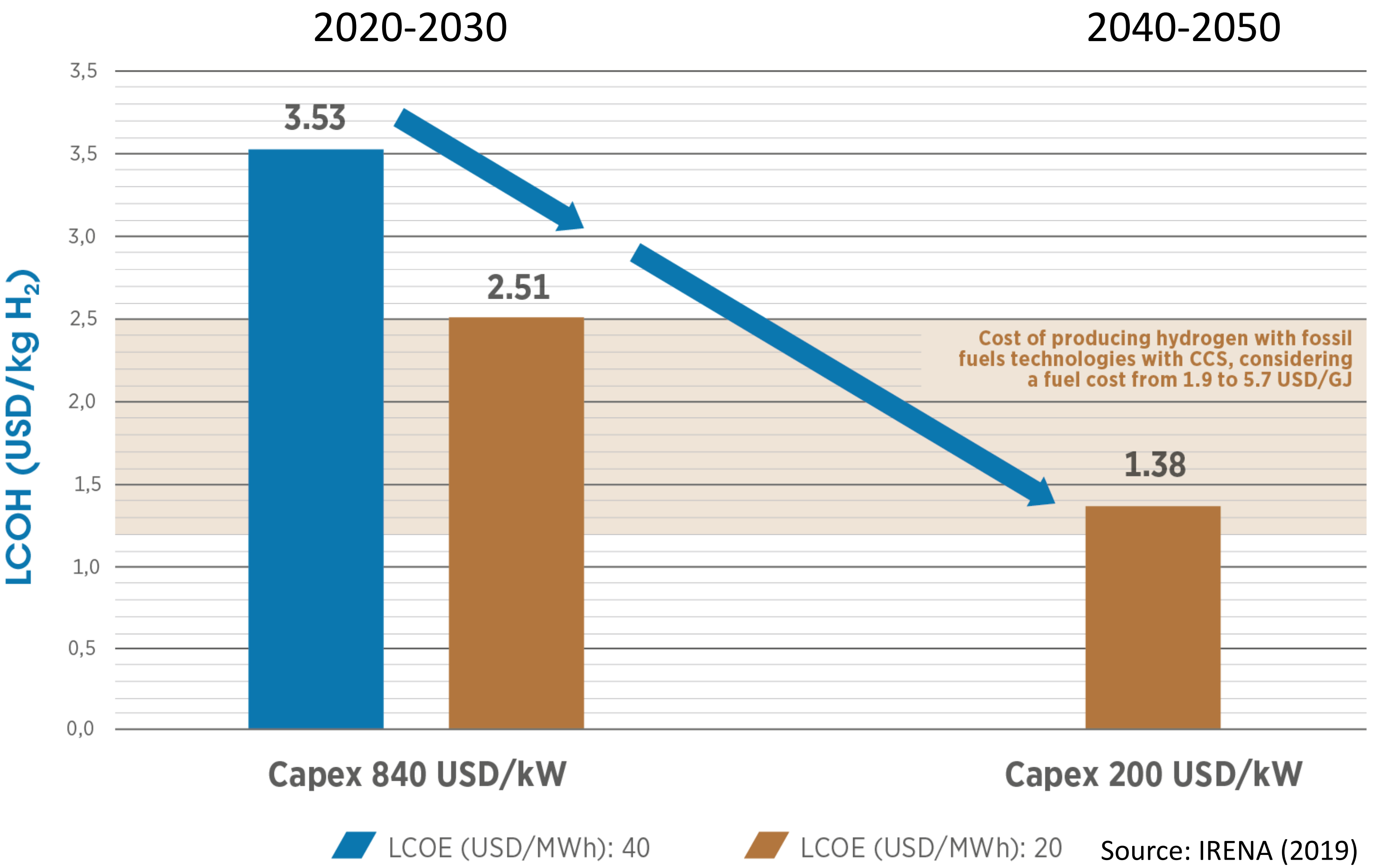


Green hydrogen and E-fuels
Low-cost renewable electricity is key

Green hydrogen will be cheaper than blue hydrogen

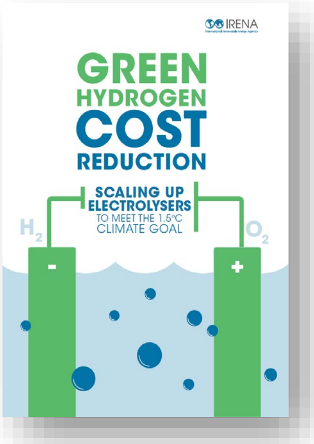


Source: IRENA (2019)

Key assumptions electrolyser: Load factor: 4200 hours (48%), conversion efficiency 65% (today), 75% (2050)

Today:

- 98% grey hydrogen supply
- 1% of all hydrogen supply is green and 1% is blue
- 0.3 GW electrolysers
- 60 -80 GW pipeline of electrolysers



December 2020

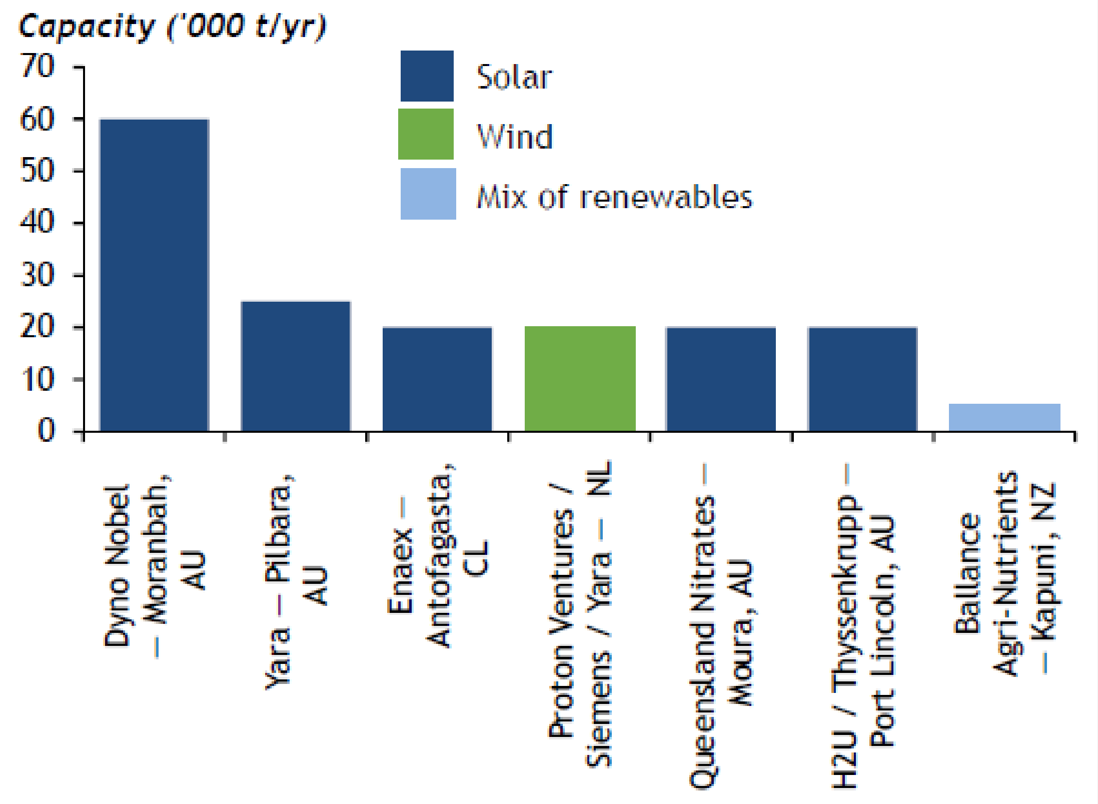
2050:

- 2/3 of supply is green and 1/3 is blue – 2 - 4x today's hydrogen demand
- Electrolyser system cost may drop to 200 USD/kW in 2050
- Electrolyser efficiency may improve to 45 kWh/kg
- Hydrogen production can increase RE power demand significantly and provide additional flexibility
- *1.5 USD/kg H2 translates into 12 USD/MBTU – vs 2-4 USD/GJ natural gas !*

Example Ammonia

- Blue and green supply is being developed – currently approx. 2% blue (EOR projects)
- A Mt-scale green ammonia plant for export is under development in Saudi Arabia (NEOM in cooperation with Air Products)
- Various plants planned in Australia
- Availability of low-cost green hydrogen and low-cost renewable electricity is a precondition
- Current LCOA green ammonia USD 475/t, by 2030 USD 350/t (compared to current ammonia price USD 200-300/t)
- A few Ammonia fuelled ships are being built
- Early use probably for ammonia tankers

List of green ammonia projects



Source: Ammonia Energy Association, Argus Media, 2021

Example Direct reduction of iron ore with hydrogen

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- The bulk of direct CO_2 emissions is related to iron making process
- Today iron making is coke and coal based
- Interesting opportunities to use green hydrogen
- Hydrogen-based Direct Reduced Iron (DRI) production is technically feasible
- DRI is a bulk commodity
- Solution: replace iron ore imports with imports of DRI produced at the mining site
- Consider import of DRI that is produced with renewable H_2 from countries such as Australia and Brazil
- >5 projects in Europe at various stages

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