Guidehouse

Evolving Viability of International Clean H_2 Supply Chains

MAY 2025

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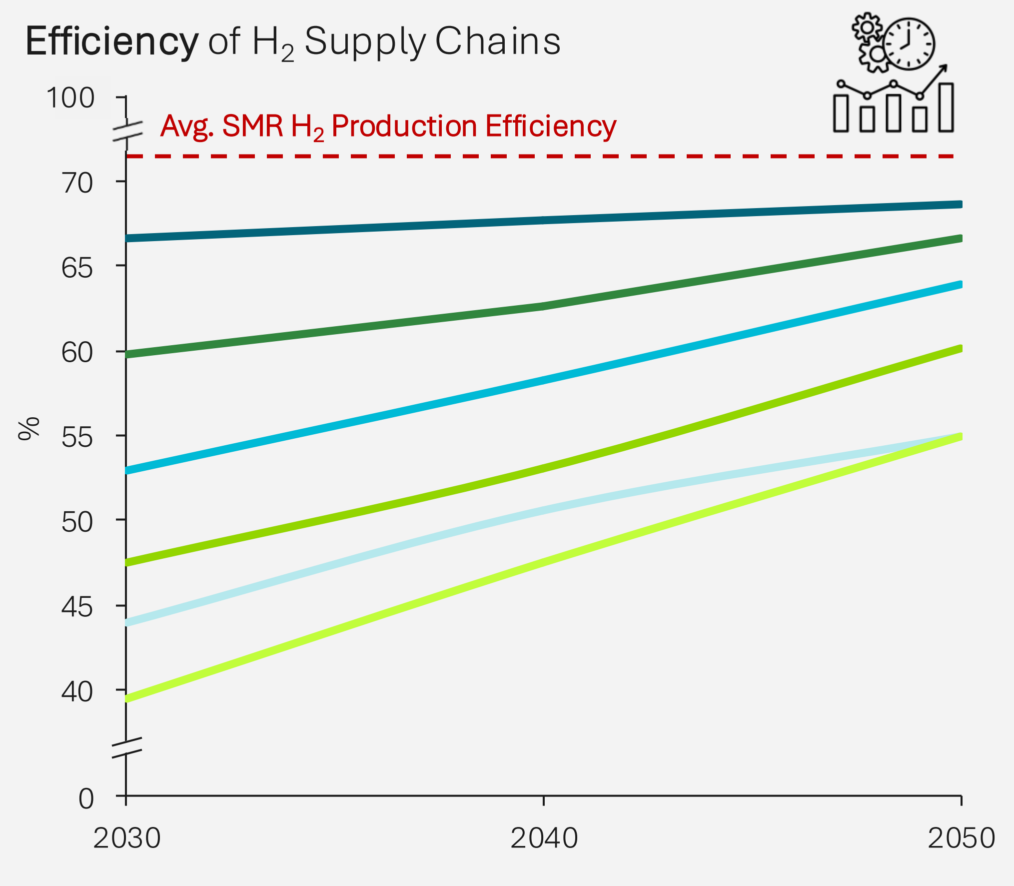
Key questions regarding intl. clean H_2 supply chains

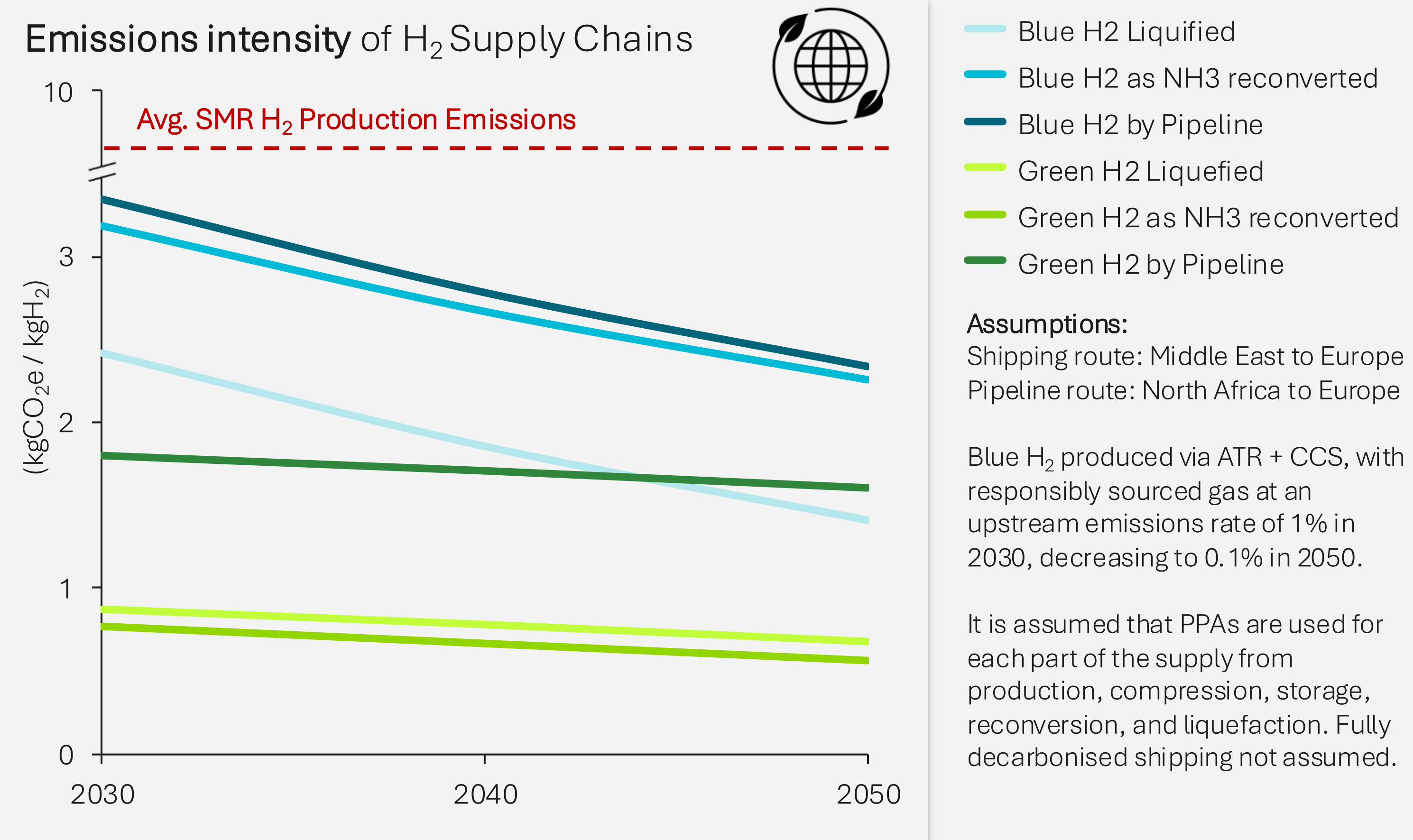
1. How will H_2 supply chain **efficiency** and **carbon intensity** evolve over time?
2. How will **LCOH** and **delivered cost** evolve over time?
3. What are the key **bottlenecks** for international H_2 supply chains?

Objective: Model the efficiency, carbon intensity, and delivered cost of exporting clean H_2 in various forms from high potential geographies and importing it in geographies with high demand potential from now until 2050.

1. H_2 Supply Chains will improve in both efficiency and emissions intensity over time, increasing their attractiveness as decarbonization vectors

Key takeaways: Over time, the largest drivers of efficiency improvements are expected in electrolysis, ammonia cracking, and liquefaction; efficiency improvements also lead to **reduced emissions intensity and delivery costs**. Blue H_2 supply chain emissions intensity is expected to decrease along with upstream emissions from natural gas flaring and leakage, however both blue and green H_2 supply chain emissions intensities would be **2-3x higher than depicted** if local grid emissions intensities were used **instead of green PPAs.**





Assumptions:
Shipping route: Middle East to Europe
Pipeline route: North Africa to Europe

Blue H_2 produced via ATR + CCS, with responsibly sourced gas at an upstream emissions rate of 1% in 2030, decreasing to 0.1% in 2050.

It is assumed that PPAs are used for each part of the supply from production, compression, storage, reconversion, and liquefaction. Fully decarbonised shipping not assumed.

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2. Delivered cost of H_2 to Europe - 2030

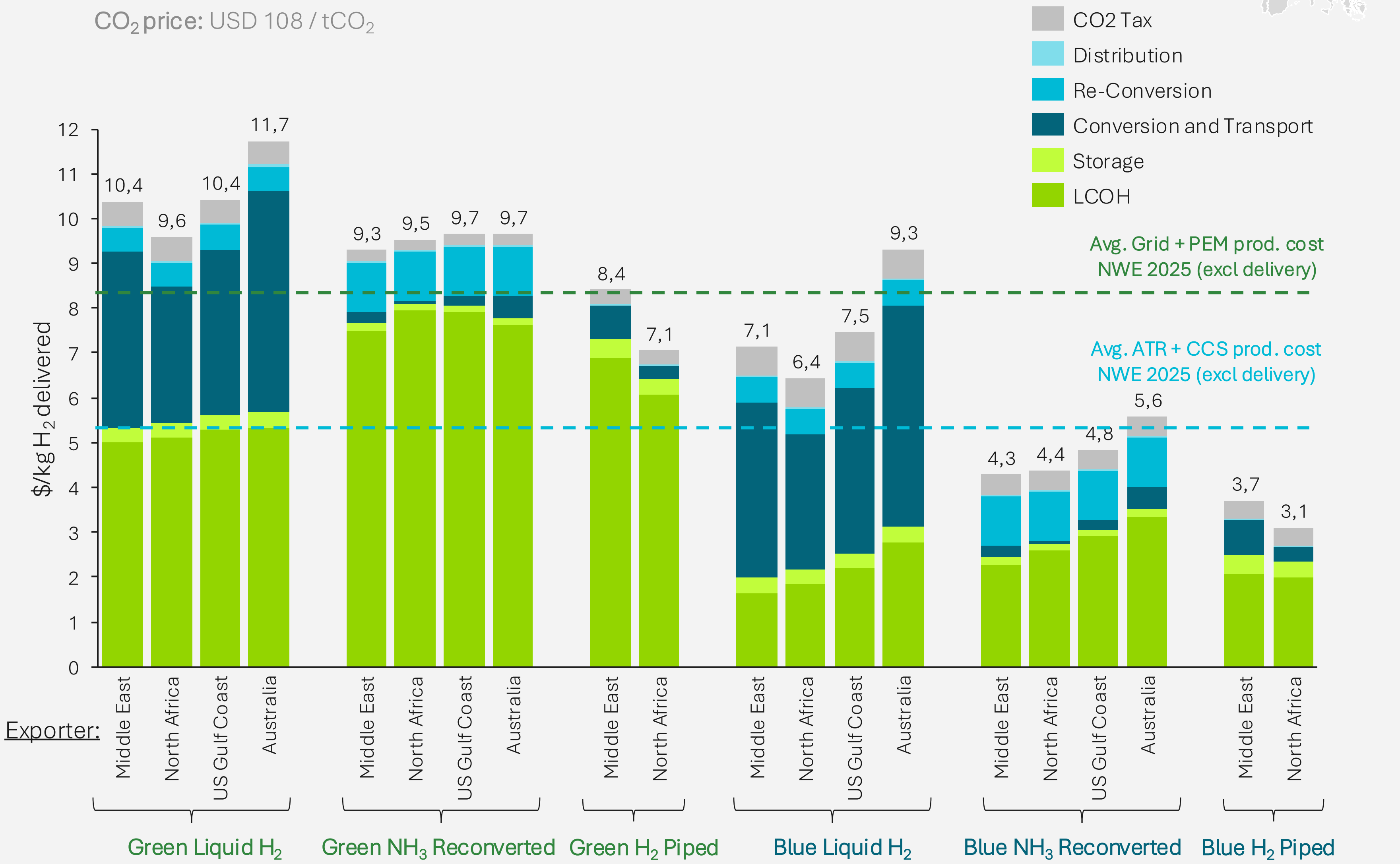
By 2030, the **cheapest H_2 imports are expected to come from North Africa and the Middle East**, driven by low-cost solar resource and shorter transport distances compared to US Gulf Coast and Australia.

Shipped green H_2 imports are not likely to be competitive with domestic production by 2030, but industrials may opt to be first movers and sign long term offtake contracts or benefit from policy mechanisms such as **H_2 Global and upcoming AggregateEU program.**

High boil off during transport makes liquid H_2 production costs higher especially over long distances. Liquefaction and ammonia cracking are **key levers to reducing delivered cost.**

In 2030, green and blue H_2 by pipeline as well as blue ammonia reconverted into H_2 is competitive with domestic production

CO_2 price: USD 108 / tCO_2



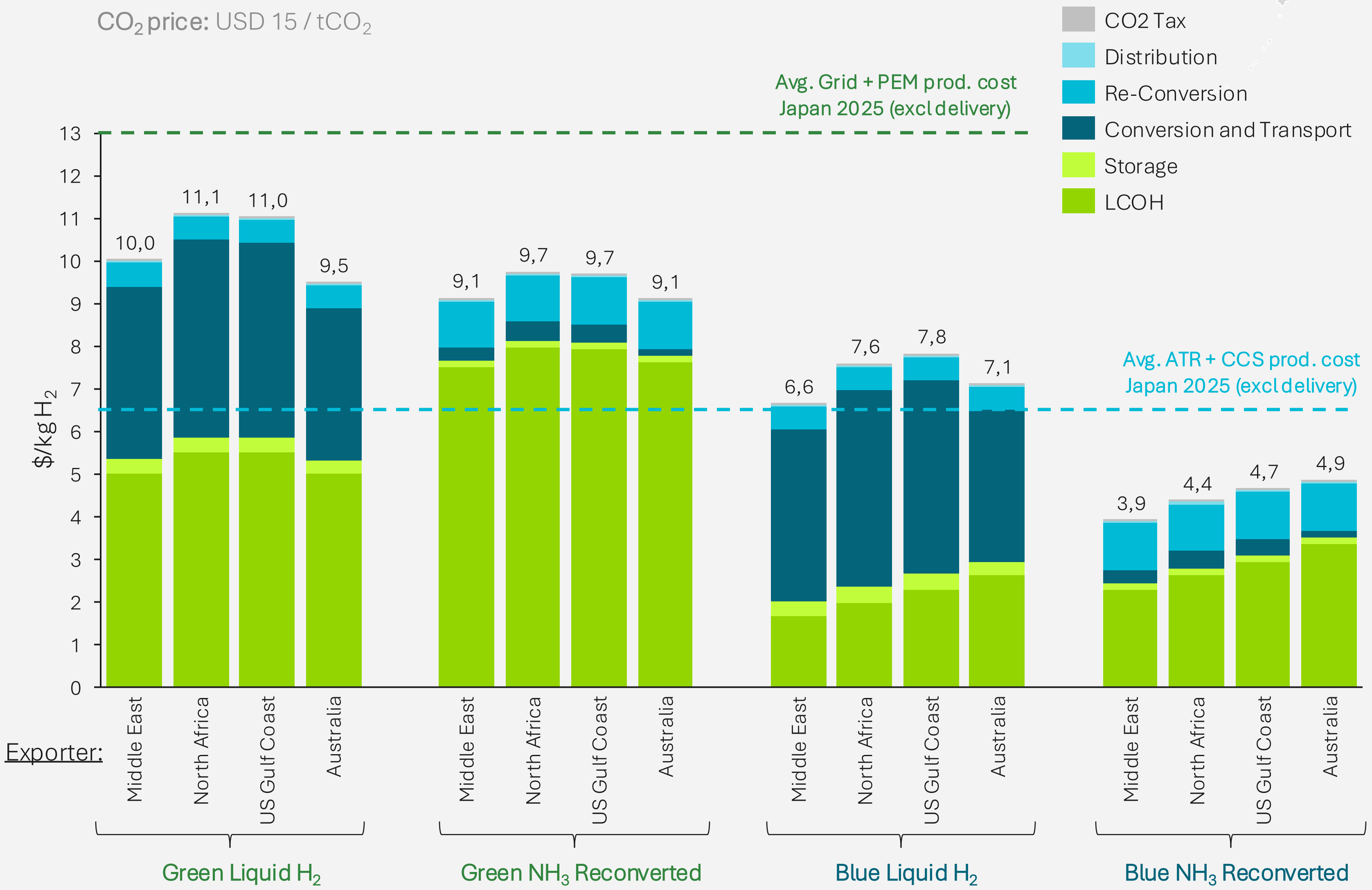
Energy prices and capacity factors vary by region. Oversizing dimensions are the same for liquified green H_2, and green ammonia at 2:1 RES to electrolysis. Cost estimates without subsidy. Electrolyser costs based on a weighted average of PEM and Alkaline electrolysis. Liquefaction of H_2 is included in the Conversion and Transport bar, re-conversion incudes regassification and ammonia cracking.

2. Delivered cost of H_2 to Japan - 2030

Green and blue ammonia reconverted into H_2 costs less than domestically produced clean H_2 in Japan, which could catalyze investment into key technological bottlenecks along the supply chain such as ammonia cracking, and the demand side such as ammonia co-fired power, green steel production, transport and more.

Japan also has a robust incentive framework for driving investment into clean H_2 and ammonia value chains. METI has allocated ~$51 billion for H_2 infrastructure, with ~$19 billion going to CfDs for H_2 and ammonia imports currently underway.[1]

In 2030, blue and green H_2 imports are both competitive with domestic production pathways especially as ammonia



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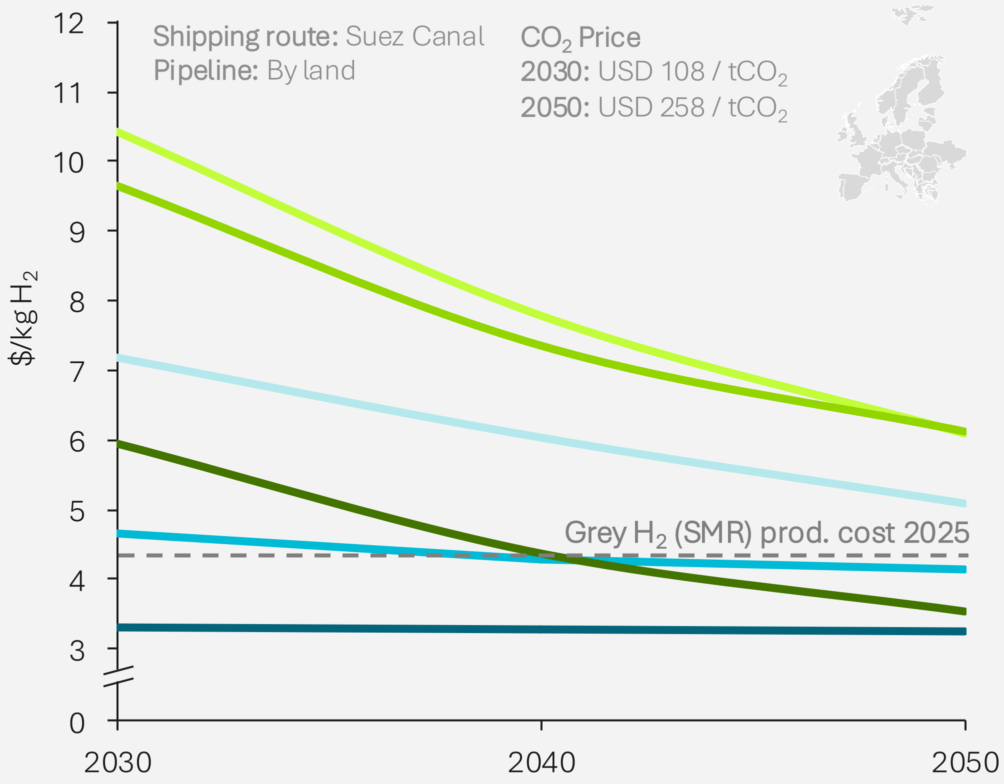
[1] The view from Japan: 2025 shaping as a pivotal year for ammonia energy

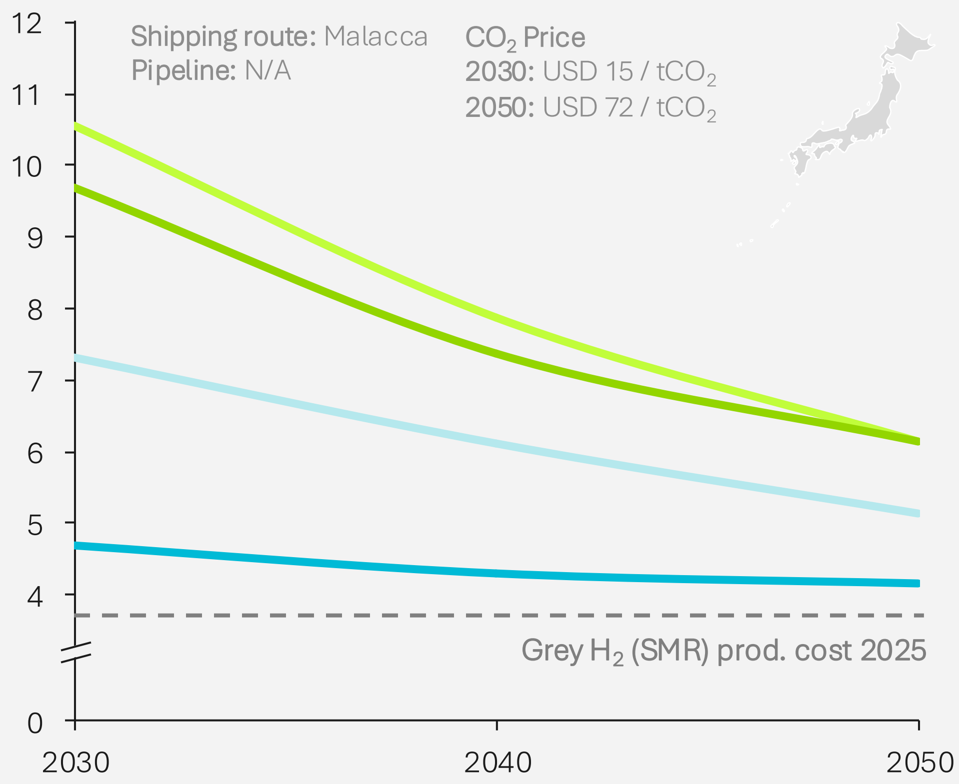
2. Although some clean H_2 supply chains may become competitive with local grey H_2 production, markets will need to adapt to price discovery

Key takeaways: Large cost reductions are expected for green H_2-based value chains due to marked improvements in **electrolyser CAPEX (from ~$1,150 in 2030 to ~$750 $/kW H_2 in 2050)** and efficiency **(from 72% in 2030 to 80% in 2050)**. As a result, reductions in OPEX and balancing costs (batteries and on-site H_2 storage) will occur, implying a need to implement flexible H_2 contracting reflecting economies of scale. However, the premium for green H_2 is not expected to disappear even by 2050, suggesting support schemes will remain crucial and/or lead markets for decarbonized product will need to absorb these costs.

Delivered cost of H_2 Middle East to Europe by year - $/kg H_2



Delivered cost of H_2 Middle East to Japan by year - $/kg H_2



- Blue H2 liquefied
- Blue H2 as NH3 reconverted
- Blue H2 by Pipeline (EU only)
- Green H2 Liquefied
- Green H2 as NH3 reconverted
- Green H2 by Pipeline (EU only)

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3. Bottlenecks for clean H_2 supply chains

Debottlenecking across technology, market, and policy are required simultaneously

01

Clean H_2 demand incentives are insufficient

Hard-to-abate industries such as refining, steel production, and transport will require clean H_2 to meet decarb targets, however they are not adequately incentivized.

02

Creative contracting is needed

Contracting of H_2 itself can be a driver for demand. Hybrid contracts with fixed base prices and adjustments indexed to fluctuations in subsidies, commodity prices, and feedstock costs are needed.

03

Political will and instrumentation is inadequate

Penalty regimes in compliance markets are showing preliminary success in markets such as maritime fuel and will be crucial for market development.

04

Much hinges on technological innovation

Cost reductions will not occur without development, and will require smart spreading as well as appetite for risk.

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