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HYDROGEN AND RENEWABLE GAS FORUM / MARKET BRIEFING

Low-carbon hydrogen: Ready for take-off?

Global Clean Hydrogen Market Perspective

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May 30, 2024

Agenda

Hydrogen production

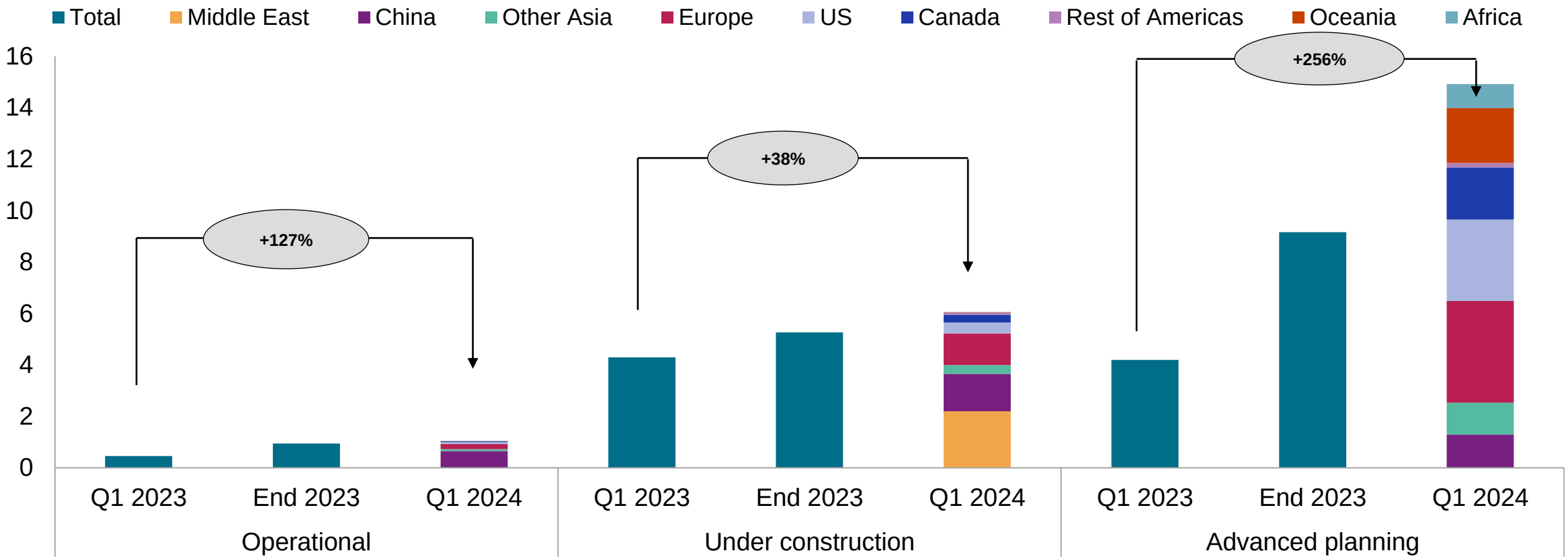
Global policies and willingness to pay

Signposts

Hydrogen production

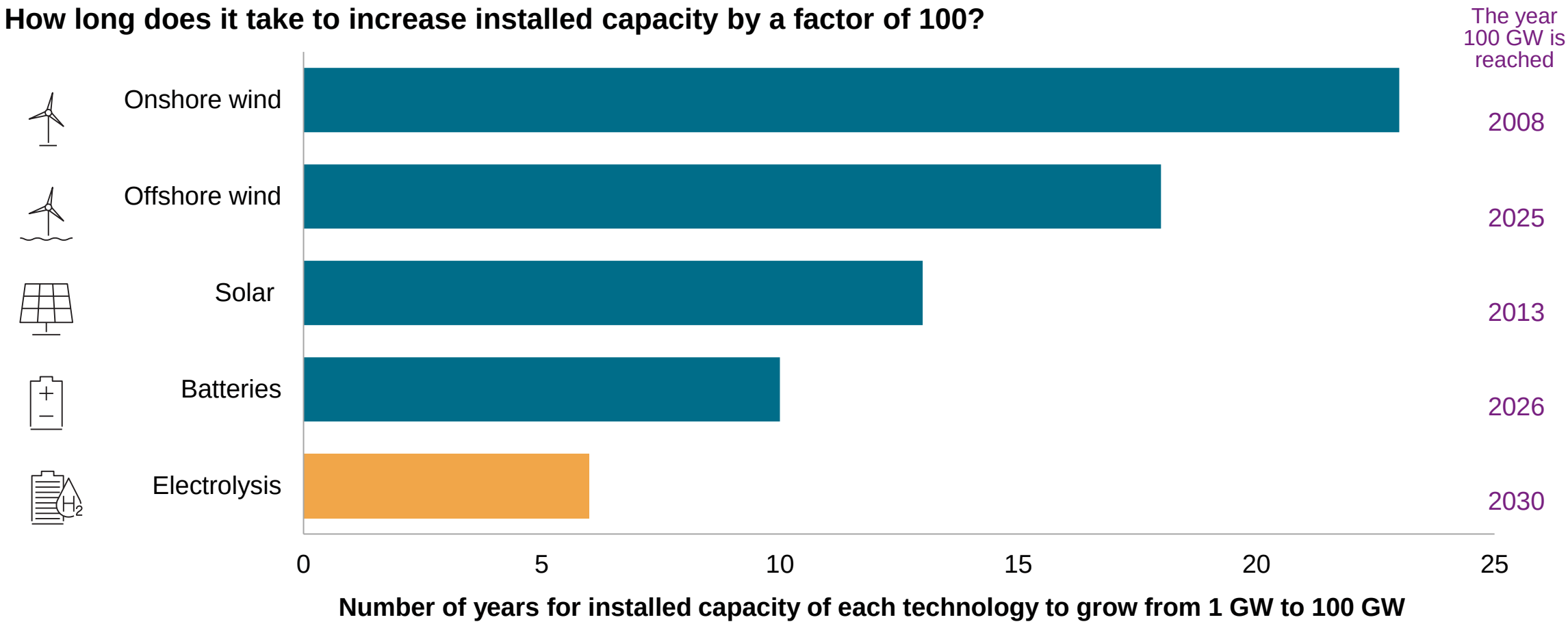
Renewable electrolysis projects around the world are maturing quickly

Advanced project status comparison: Q1 2023, end 2023 and Q1 2024 (GW_e)



Data compiled April 1, 2024.
GW_e = Gigawatt electrical.
Source: S&P Global Commodity Insights.

Electrolyser installed capacity increase is the fastest amongst clean technologies



Data compiled April 19, 2024.
Batteries for stationary applications only.
Source: S&P Global Commodity Insights.

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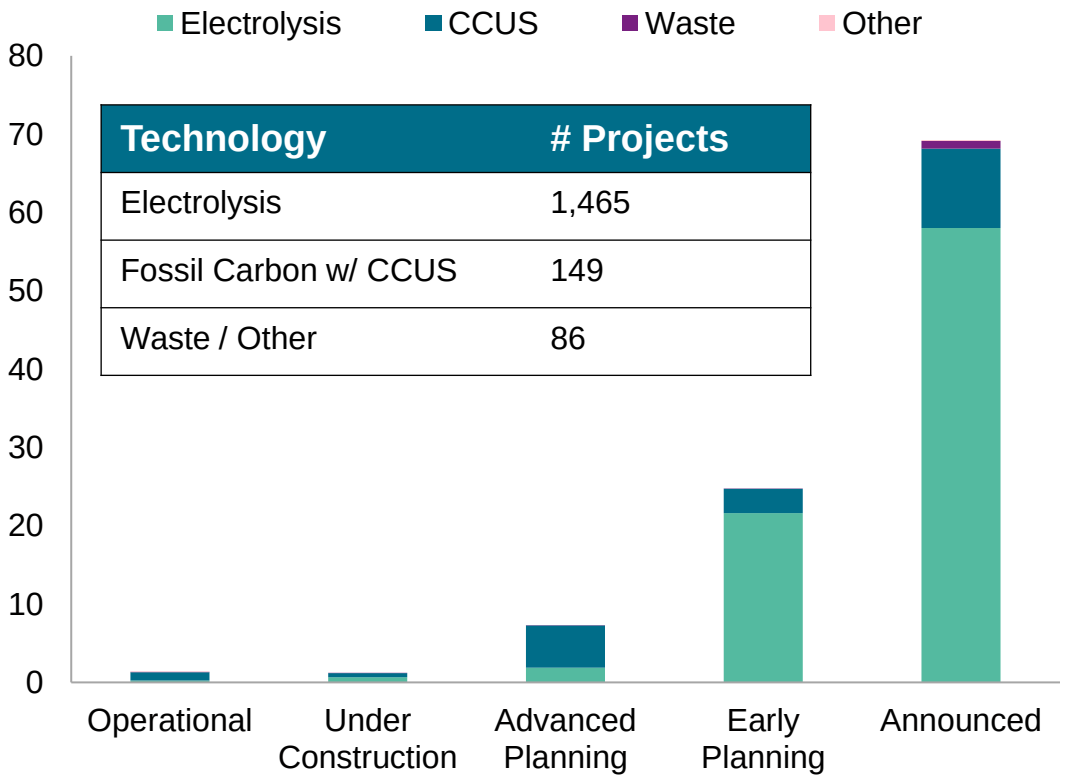
Risk profile of electrolysis and natural gas-based projects are very different

Announced clean hydrogen project capacity by status (MMt H_2/year)

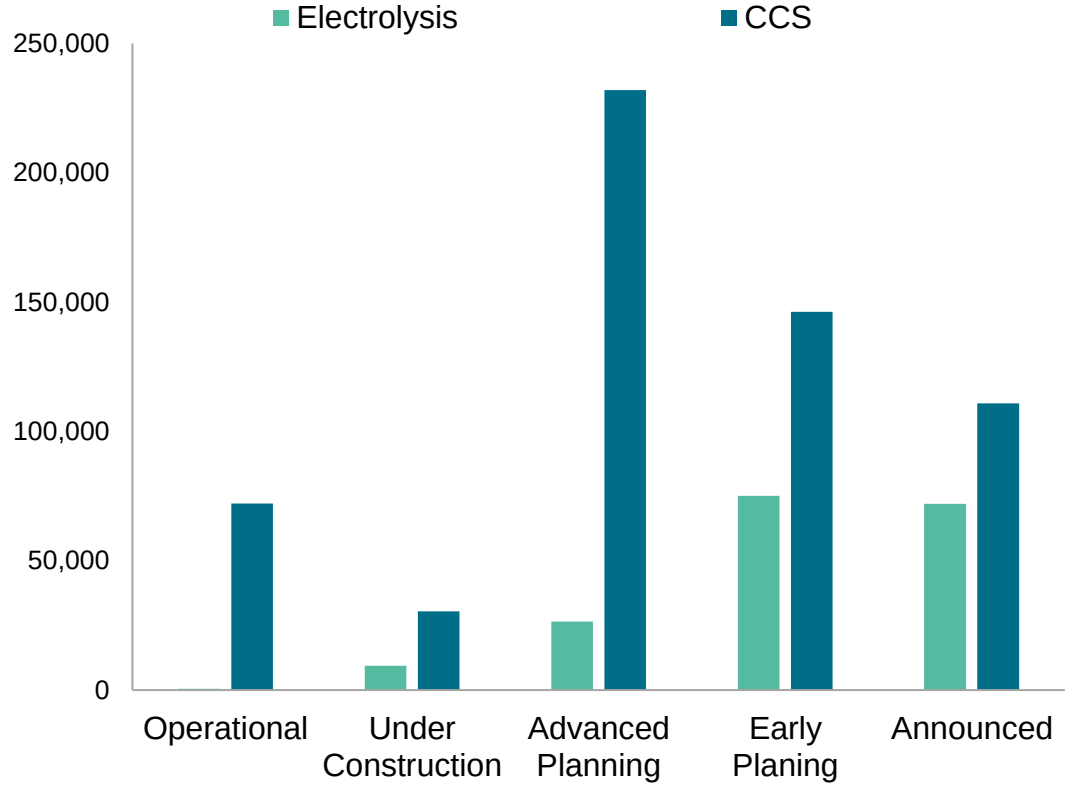


Technology	# Projects
Electrolysis	1,465
Fossil Carbon w/ CCUS	149
Waste / Other	86

Data compiled April 1, 2024
Source: S&P Global Commodity Insights.

MMt = Million metric tonnes; CCS = Carbon capture and storage

Average project size by technology and status (metric tonnes H_2/year)



Data compiled April 1, 2024
Source: S&P Global Commodity Insights.

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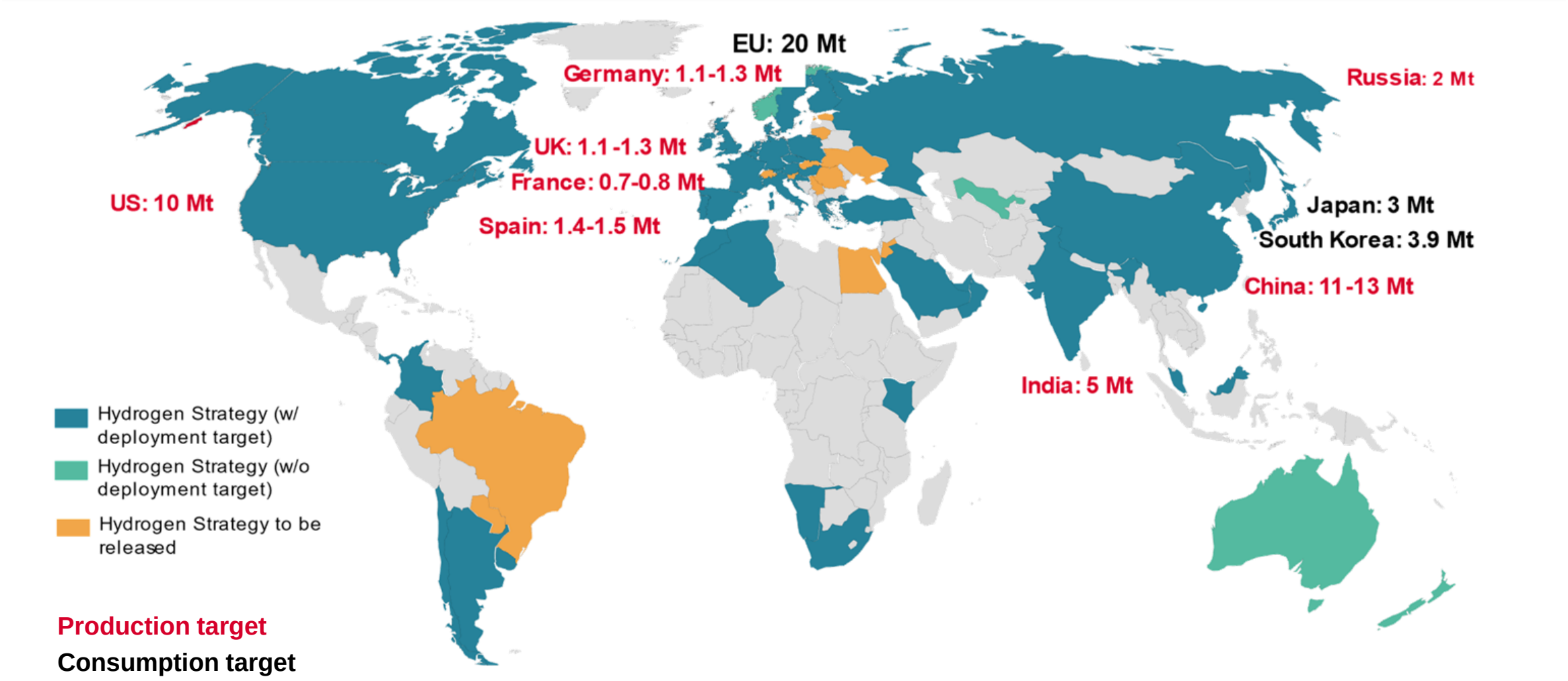
Global policies and willingness to pay

Ambition for 2030: More than 40 MMt of low-carbon hydrogen targeted in over 60 global national strategies despite high cost



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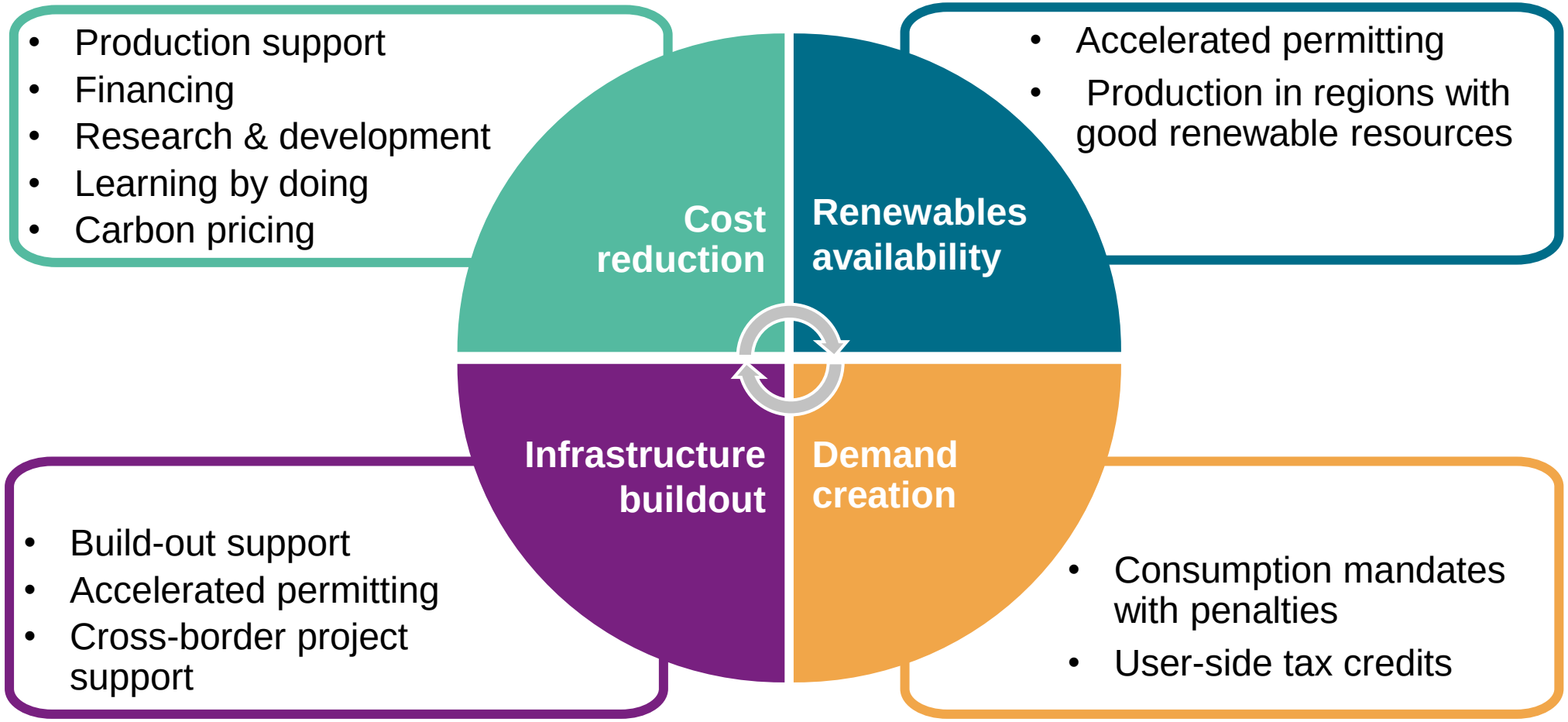
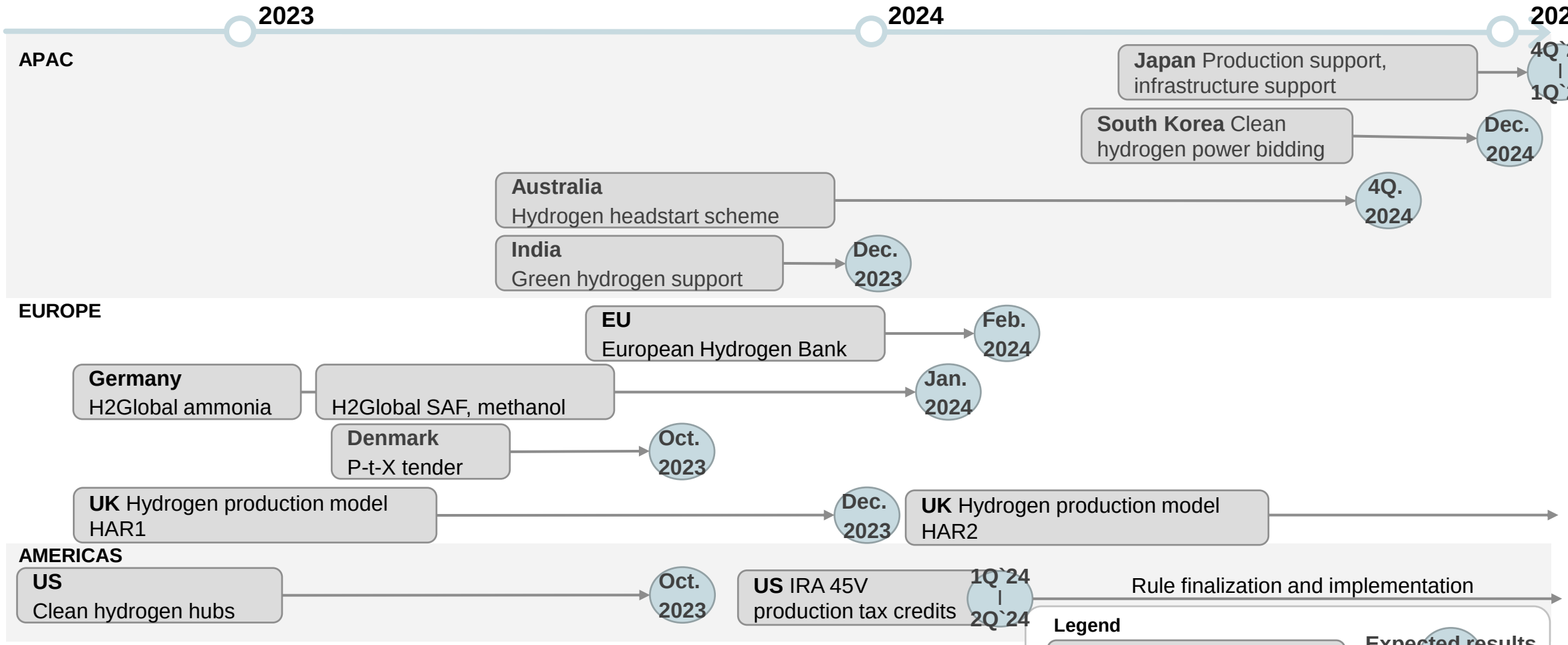
Policy makers propose various measures to develop low-carbon hydrogen market



Source: S&P Global Commodity Insights

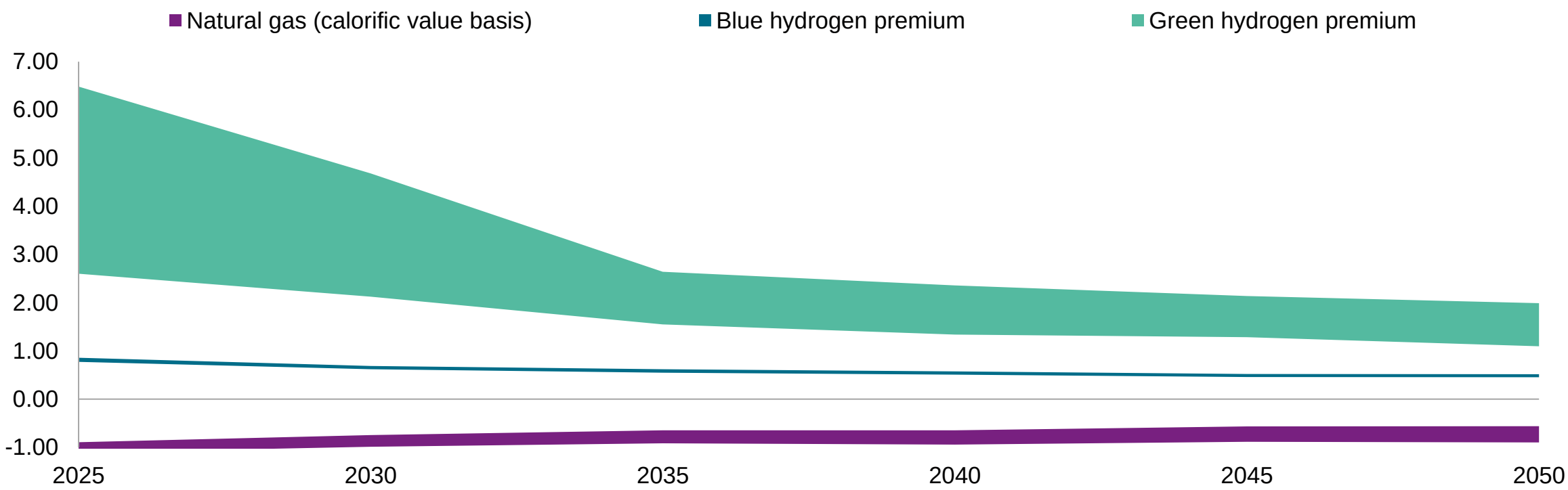
Major markets' production support schemes will go through the first round by the end of this year



The list is not exhaustive.
Source: S&P Global Commodity Insights.

Electrolysis costs will fall but green hydrogen remains more expensive than blue hydrogen

Production premium of low-carbon hydrogen over grey hydrogen excluding cost of emissions and subsidies ($2022/kg$H_2$)



As of May. 22, 2024.

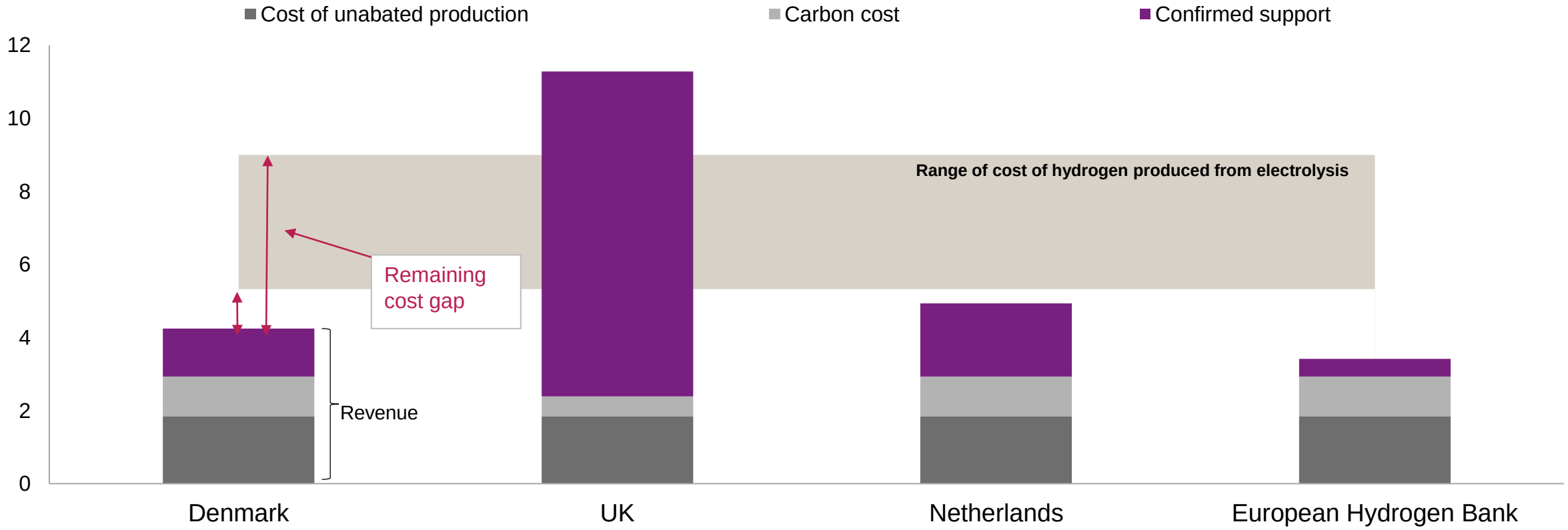
Premium calculation does not include CO_2 tax. Blue hydrogen based on ATR with 92% capture, green hydrogen based on alkaline electrolysis. The low range for renewables are provided by hybrid wind-solar system in Texas and Australia, as well as some hydro projects, and the upper range is provided by a dedicated solar plant from the UAE. The scale of production increases from 100MW in

Source: S&P Global Commodity Insights.

Closing the cost gap: Where can government play a role?

Will production support close the cost gap for electrolysis-based hydrogen?
Evidence from Europe auctions

Cost of hydrogen production from unabated gas and electrolysis and the effect of auctioned support has on bridging the cost gap (€/kg)



Data compiled April 2024.

*Where exact support values not provided, implied confirmed support values are calculated assuming a 70% electrolyzer efficiency, 65% renewables capacity factor, low heating value (LHV), and the lifetime of the subsidy. UK implied support is based on high heating value (HHV). The Netherlands support is assumed for 10 years of subsidy support and 70% capacity factor.

Source: S&P Global Commodity Insights.

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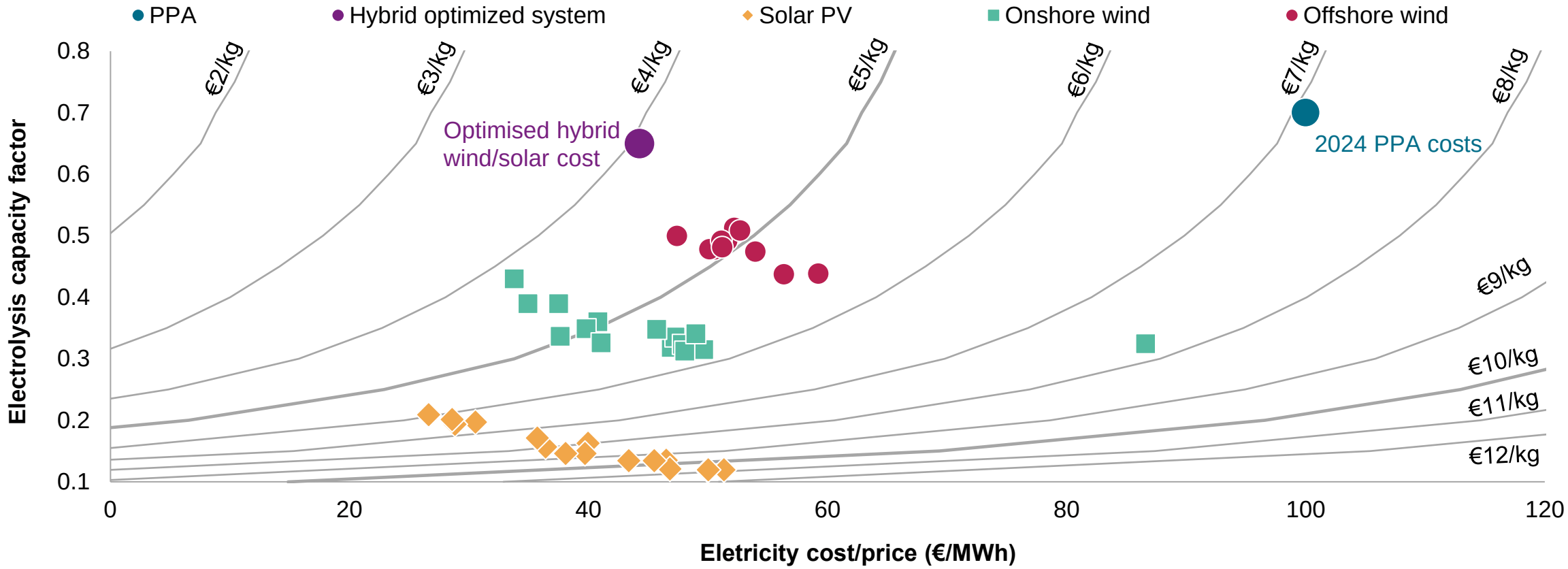
The most cost-effective projects likely to be “behind the meter”

Fully integrated and optimized project development needed to achieve <€4/kgH_2

Levelized cost of hydrogen based on electricity cost and capacity factor in Europe



As of May. 25, 2024
PPA = power purchasing agreement;
Source: S&P Global Commodity Insights.

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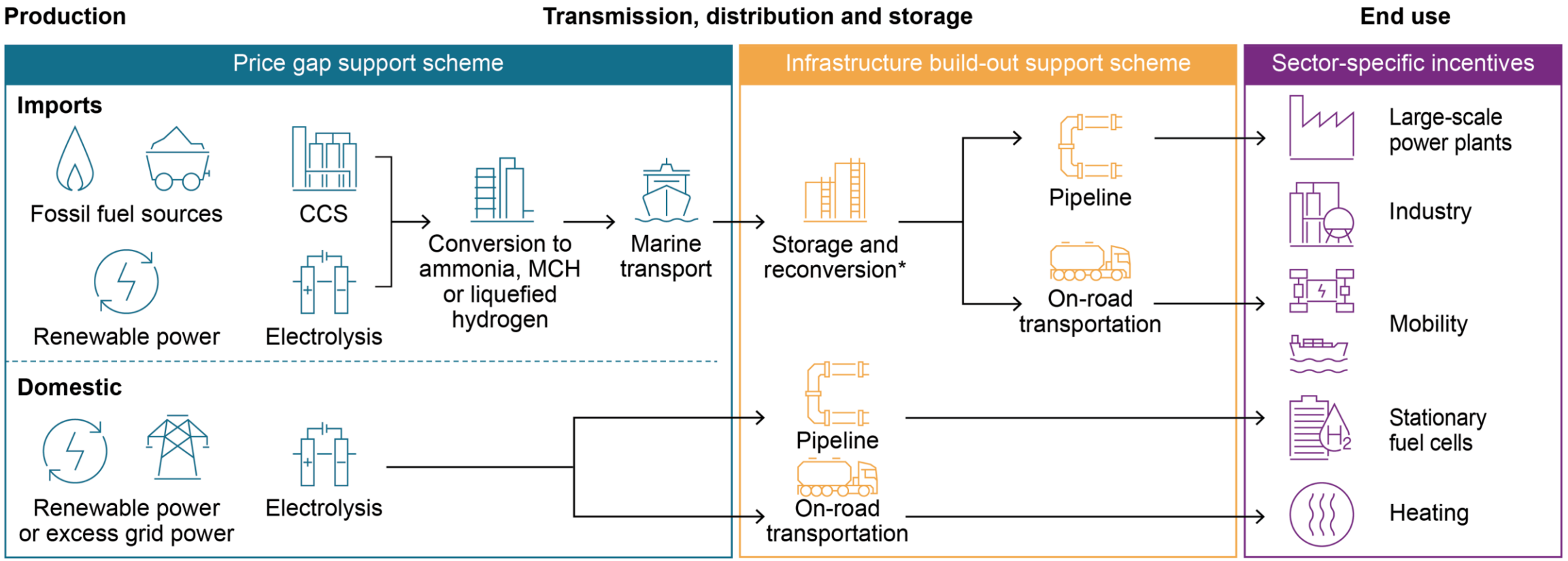
Closing the cost gap: What are the options?

	Revenue sources	Risks
Stacking revenues	• Geography • Level of government • Section of the value chain • ETS / RIN / LCFS credits	• Additionality • Auction rules • Misaligned timing: start date vs auctions • Misaligned scales: MW vs GW
Premium products	• “Green” steel • Chemicals	• Willingness to pay • Competition from bio-based products
Consumption mandates	• European RFNBO targets • Japan / South Korea: co-firing • Japan: e-methane	• “Firmness” of target: delay or lower ambition • Level of penalties: produce or buyout • Location of production: domestic vs imports

Data compiled April 24, 2024.
ETS = emissions trading scheme; LCFS = low carbon fuel standard; RFNBO = renewable fuel of non-biological origin; RIN = renewable identification number.
Source: S&P Global Commodity Insights.

Produce, move, use: the government plans to provide support throughout different low-carbon hydrogen value chains

Hydrogen supply pathways for Japanese consumption and the scope of coverage for different support schemes



As of Jan. 16, 2024.
MCH = methylcyclohexane.
*Reconversion facility in Japan may be covered under the price gap support scheme.
Sources: S&P Global Commodity Insights; based on interim summary, Ministry of Economy, Trade and Industry of Japan (https://www.meti.go.jp/shingikai/enecho/shoene_shinene/suiso_seisaku/pdf/013_01_00.pdf).

Signposts

Signposts to watch

- **Results of hydrogen auctions**:
  - ***European Hydrogen Bank results – May 2024***
  - ***South Korea and Japan results – Dec 2024***

- **Final investment decisions**:
  - Blue hydrogen and ammonia projects in the US
    - ***45Q sequestration credits: $85/tonne CO_2 for sequestration, $60/tonne CO_2 for Enhanced Oil Recovery***
  - Multiple GW-scale electrolysis projects in Europe or for export to Europe
    - ***H2 Green Steel 700 MW***
  - Natural gas-based projects — Netherlands and UK
    - ***2 FIDs in place in Netherlands***

- **Finalization of 45V treasury guidelines in the US – Q4**

- **Details of Australian production credits**

FID = final investment decision; RFNBO = renewable fuel of non-biological origin.
Source: S&P Global Commodity Insights.

Conclusions

- **Low-carbon hydrogen projects are moving ahead in all regions of the world.** Installed capacity for electrolysis and natural gas-based hydrogen with carbon capture is expected to double every year through 2030. US leads on blue.

- **Increased policy clarity and the launch of multiple support schemes have enabled projects to take FID.** Final policy frameworks in Japan, South Korea and the US should allow for more projects to reach financial closure.

- **Even with production support, low-carbon hydrogen is expected to be a premium product**. Compliance buying, offtake contracts linked to ESG targets and revenue stacking can provide the security required to advance projects.

- **Compliance buying will be a key driver of market development.** European RFNBO targets and associated penalties are defining willingness to pay. Many projects — domestic and international — are targeting Europe.

- **Consumption targets — even where penalties are undefined — are driving project development.** Companies headquartered in Japan and South Korea are taking a major role in projects in the US Gulf Coast and elsewhere.

FID = final investment decision; RFNBO = renewable fuel of non-biological origin.
Source: S&P Global Commodity Insights.

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