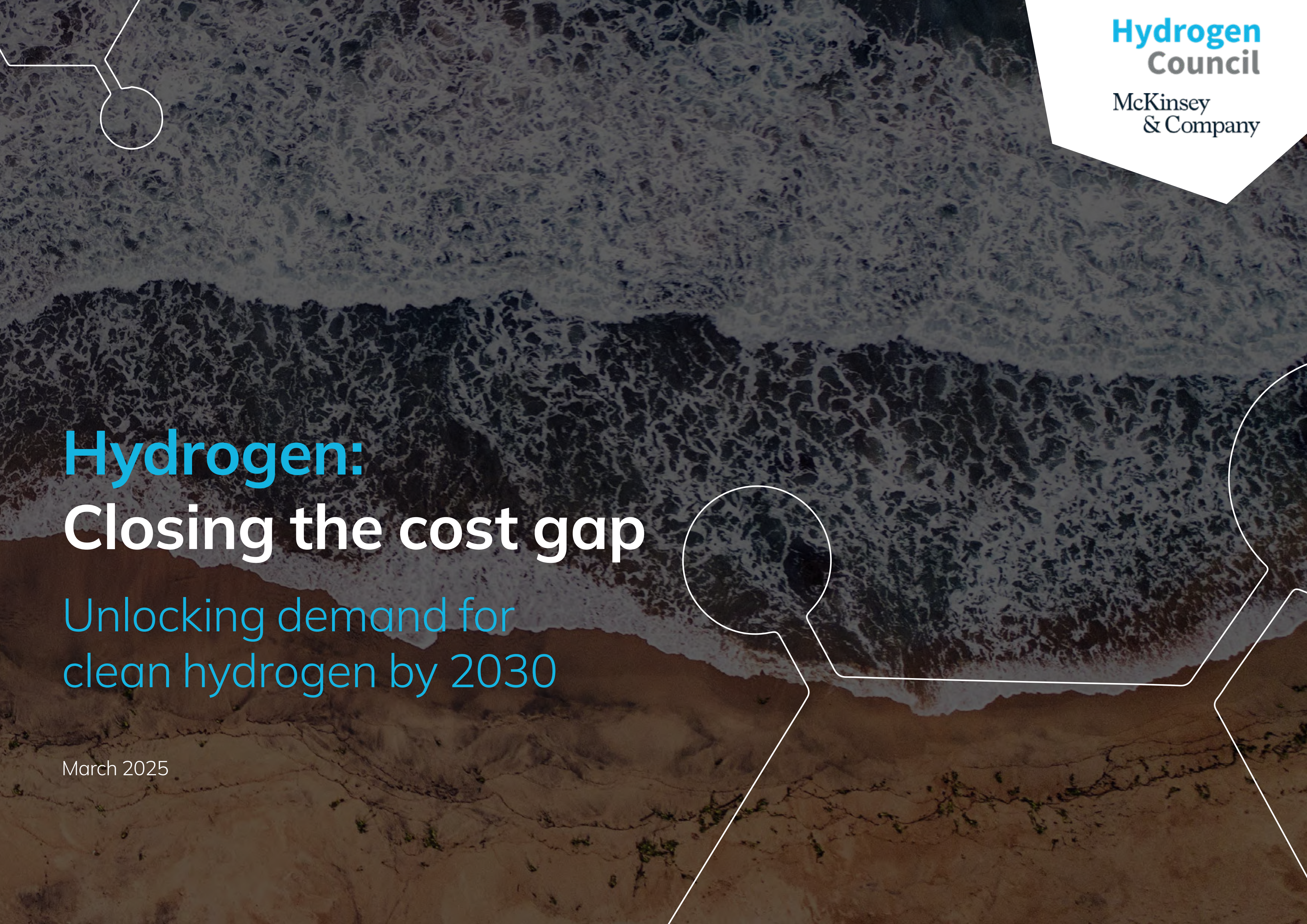


Hydrogen Council
McKinsey & Company

Hydrogen:
Closing the cost gap

Unlocking demand for clean hydrogen by 2030

March 2025

Published in March 2025 by the Hydrogen Council

Copies of this document are available upon request or can be downloaded from our website:

www.hydrogencouncil.com

This report was authored by the Hydrogen Council in collaboration with McKinsey & Company. The authors of the report confirm that:

1. There are no recommendations and / or any measures and / or trajectories within the report that could be interpreted as standards or as any other form of (suggested) coordination between the participants of the study referred to within the report that would infringe the EU competition law; and

2. It is not their intention that any such form of coordination will be adopted.

The calculations in this analysis were conducted based on regulations effective as of January 1, 2025. This analysis does not include calculations or hypothetical ranges based on future regulatory uncertainty or transitory trade measures (e.g., tariffs), nor does it seek to make any specific policy recommendations. It offers instead an estimate of the impacts of existing regulations on clean hydrogen demand and an indication of the cost and infrastructure gap that remains for other sub-sectors of potential 2030 clean hydrogen demand.

In this report, renewable hydrogen refers to hydrogen produced from renewable energy sources via water electrolysis. Low-carbon hydrogen refers to hydrogen produced with low-emissions technologies with significantly lower greenhouse gas emissions impact than conventional production pathways, based on robust life-cycle analysis-based methodologies for GHG emissions assessment. This includes i) hydrogen produced using natural gas as a feedstock with SMR or ATR coupled with CCS; ii) hydrogen produced through pyrolysis of natural gas into hydrogen and solid carbon; iii) hydrogen produced through gasification of coal with CCS; iv) hydrogen produced through electrolysis using electricity of non-renewable origin as feedstock. Renewable and low-carbon hydrogen are collectively referred to as "clean hydrogen". Grey hydrogen refers to hydrogen produced from unabated fossil fuels.

We recognize the varying national and regional approaches to GHG emissions intensity thresholds or bands and the criteria for qualifying hydrogen as 'clean', 'low-carbon', 'renewable', 'sustainable', 'low-emission' adopted across jurisdictions.

Whilst the contents of the report and its abstract implications for the industry generally can be discussed once they have been prepared, individual strategies remain proprietary, confidential, and the responsibility of each participant. Participants are reminded that, as part of the invariable practice of the Hydrogen Council and the EU competition law obligations to which membership activities are subject, such strategic and confidential information must not be shared or coordinated – including as part of this report.

The Hydrogen Council is a **global CEO-led initiative** with a united vision and long-term ambition for hydrogen to **foster the clean energy transition**

Steering members

adani, ADNOC, Air Liquide, Air Products, Airbus, AngloAmerican, aramco, AsahiKASEI, Baker Hughes, BMW Group, Bosch, bp, CF, Chemours, CHN Energy, Cummins, Daimler Truck, Enbridge, ENEOS, ENGIE, Faurecia, ExxonMobil, gm, Great Wall, Honda, Hyundai, IHI, InterContinental Energy, Iwatani, Johnson Matthey, Kawasaki, Linde, Masdar, Larsen & Toubro, Masdar, Michelin, Microsoft, MSC, NextEra Energy Resources, OCI, OPmobility, sabic, sasol, Schaeffler, Shell, Siemens Energy, Sinopec, Syensqo, SoCalGas, thyssenkrupp, Topsoe, TotalEnergies, Toyota, Weichai, Yara Clean Ammonia

Supporting members

3M, Advario, AFC Energy, AGFA, Alfa Laval, Alstom, Avaada, Ballard, Bekaert, Black & Veatch, Bloom Energy, Bureau Veritas, Casale, cellcentric, Chart, Chevron, CK Infrastructure, Clariant, Cryogenmash, Delek, Dover, Ebara, Electric Hydrogen, ElringKlinger, Faber Cylinders, FuelCell Energy, galp, gasunie, Gore, Heraeus, Hexagon Purus, Iljin Composites, IndianOil, Itochu Corporation, John Cockerill, KBR, Kogas, Komatsu, Liebherr, Mahle, MAN Energy Solutions, Mann+Hummel, Marubeni, Matrix Service Company, McDermott, McPhy, Mitsubishi Heavy Industries, Mitsubishi Corporation, Mitsui & Co., nel, Niterra, Parker, Petronas, Plug, Port of Rotterdam, Refire, Reliance Industries Limited, Sinocat, Snam, Southern Company, Sumitomo Corporation, Technip Energies, Tokyo Gas, Toyota Tsusho, TÜV SÜD, Uniper, Vallourec, Vopak, Westport Fuel Systems, Woodside

Investors

Antin Infrastructure Partners, Barclays, BNP Paribas, Crédit Agricole, FiveT Hydrogen, Mizuho, Natixis, Société Générale, SMBC Sumitomo Mitsui Banking Corporation, Temasek

Executive summary (1/2)

Framework and approach

Demand for clean hydrogen and its derivatives has taken center stage for decision-makers in industry and government over the past years, where a focus has been on project bankability and catalyzing supply chain development. The lack of demand-side visibility, rising energy and material costs, and prolonged regulatory uncertainty have been key factors inhibiting investment in the sector, in some cases leading to project delays and cancellations[1]. At the same time, some regions have begun implementing measures that could support the business case for clean hydrogen adoption. While the regulatory landscape is still evolving, this report looks at the current policy landscape and its resulting impact on the uptake of clean hydrogen. Actual uptake by 2030 is still contingent on the timing and effectiveness of implementing these policy mechanisms and is therefore subject to change.

This analysis considers the feasibility of serving existing and new sub-segments of hydrogen demand with clean hydrogen by 2030 in the EU, East Asia, and the US. These regions were selected due to the prominence and the early momentum of clean hydrogen policy initiatives and infrastructure development effective as of January 1, 2025.

Based on the potential total demand for hydrogen in these regions across all pathways, we categorize the millions of tons per annum (Mt p.a.) of demand into three segments, considering both the relative cost gap between clean hydrogen or its derivatives and conventional alternatives, as well as the extent of additional infrastructure needed for clean molecule deployment.

The following page presents details of these three segments which can be considered in ascending order of the effort necessary to serve the underlying sub-segments with clean hydrogen.

1. For detail as of October 2024, see Hydrogen Council: Hydrogen Insights 2024

Key messages

— In a <2°C warming scenario[2], ~34 Mt p.a. of total demand[3] for hydrogen and derivatives could materialize across the EU, East Asia, and the US by 2030, of which ~8 Mt p.a. could already carry a policy-supported business case for clean hydrogen.

— Around 75% is concentrated in established use cases (e.g., refining, ammonia), while initial adoption in new sectors (e.g. maritime and aviation) makes up the remaining 25%.

— Decarbonizing the full volume would equate to ~250 $MtCO_2e$ in annual abatement, equaling a quarter of Japan's total annual emissions or the total annual carbon footprint of Spain[4].

— Three pockets of demand could be unlocked with varying policy and infrastructure advancement covering energy-intensive sectors (refining, chemicals, power generation) and transport (trucking, aviation, maritime) across these regions.

Closing the cost gap for clean hydrogen: key actions

The following key measures[5] could be critical to unlocking this demand and bridging the cost gap with conventional alternatives: (i) effective implementation of existing policy measures in the EU, US, Japan and South Korea; (ii) expansion of midstream infrastructure to enable low-carbon supply for existing use cases; and (iii) net-new infrastructure deployment combined with measures to address the cost gap with higher-emission alternatives for new end uses.

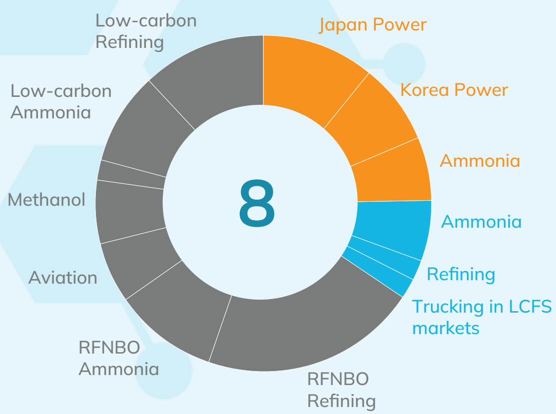
2. Analysis tied to McKinsey Global Energy Perspective 2024 Sustainable Transformation scenario with adoption of MEPC 80 guidance assumed for maritime demand
3. Includes demand across all hydrogen pathways
4. 2022 emissions data as per Worldometer
5. Includes policies announced as of January 2025 and does not preemptively consider potential policy changes

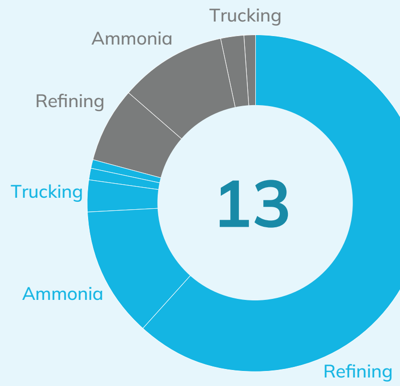
Executive summary (2/2)

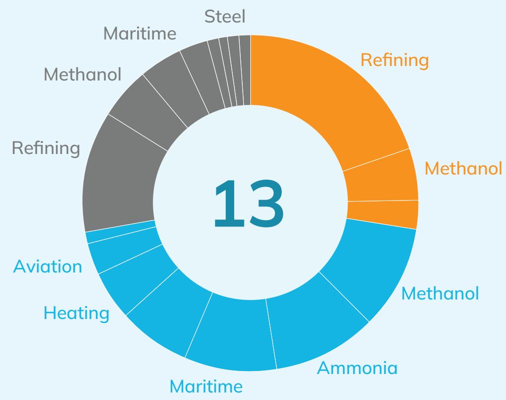
Three segments comprise 34 Mt p.a. of total potential 2030 hydrogen demand in the EU, US and East Asia[6]

Hydrogen demand split by end-use, segmented by current viability of adopting clean hydrogen, 2030, Mt p.a. H_2e

East Asia EU USA







Seizing Low-Hanging Fruit: Clean demand supported by current policies

Existing policy initiatives in these regions could enable the uptake of ~8 Mt p.a. of clean hydrogen by 2030 across the EU, US, and East Asia, either by reducing clean hydrogen production costs or by mandating or otherwise incentivizing its use. Specifically, the implementation of concrete measures including the EU Renewable Energy Directive (REDIII), Japan's Contracts for Difference mechanism (CfD), South Korea's Clean Hydrogen Portfolio Standard (CHPS) and the US Inflation Reduction Act (IRA) could support the business case for the first demand segments of clean hydrogen by 2030. The transposition of REDIII into national legislation at Member State level defines mandated demand for renewable hydrogen in existing industries in the EU. In the US, IRA 45Q already enables some industrial applications with access to carbon capture and storage (CCS). In East Asia, the CfD and CHPS could accelerate the co-firing of clean ammonia in the power sector.

Bridging the Gap: Clean demand enabled by feasible infrastructure scale-up

Some ~13 Mt p.a. of clean demand, largely in existing industry, could be unlocked by 2030 with further infrastructure deployment and cost decline. About 90% of this category is comprised of potential low-carbon refining and ammonia demand across the EU and US. Unlocking this demand hinges on the buildout of CCS infrastructure[7] in the US, the establishment of which could account for bridging ~0.1 – 0.3 USD/kg H_2e of the cost gap, depending on location. For sub-segments of demand in emerging sectors like trucking and industrial heat, the business case for clean hydrogen remains up to ~0.5 USD/kg short of break-even. Increased economies of scale from larger hydrogen production facilities, an established base of hydrogen refueling infrastructure, and/or reduced carbon intensity of low-carbon facilities to thresholds necessary to qualify for the IRA's 45V credit could minimize the cost gap for end uses in this segment.

High Stakes, High Rewards: Clean demand where few alternatives exist

The remaining ~13 Mt p.a. in demand, largely in new end uses, has limited decarbonization alternatives to hydrogen. However, existing policies and infrastructure do not yet support the clean hydrogen business case and a cost gap of at least 0.5 to over 5 USD/kg H_2e remains. In hard-to-abate sectors (e.g., aviation, non-mandated maritime fuels, high-grade industrial heat), hydrogen and its derivatives constitute the key decarbonization enablers, although under existing conditions, limited economic adoption is expected by 2030. Despite the significant cost gap and infrastructure requirements that define this segment, initial advancements in these sectors would set the groundwork for future industry growth. This early critical mass of infrastructure would be necessary for sectors like maritime and aviation, which could become some of the largest demand segments long-term.

6. Includes hydrogen demand from all pathways as modeled in McKinsey Global Energy Perspective 2024 (Sustainable Transformation Scenario with MEPC 80 guidance assumed for maritime demand; corresponding to a ~1.8oC warming scenario)
7. Including capture equipment, transportation pipelines, and storage infrastructure

01

Supply-side and demand-side policies serve to close the cost gap between clean hydrogen and conventional alternatives

~30%

Portion of global 2030 hydrogen demand in EU, Japan, Korea, and US, across all pathways under a Sustainable Transformation scenario. Given policy momentum, these regions could account for ~60% of clean demand[1]

~1-12 USD/kg H_2e

Potential range of policy-driven clean hydrogen and derivative "value-in-use" depending on end use segment and geography

~1-11 USD/kg H_2e

Range of landed supply costs for clean hydrogen and derivatives into the EU, East Asia, and US by 2030

8. McKinsey Hydrogen Insights Global Hydrogen Trade Model projection tied to McKinsey Global Energy Perspective 2024 (Sustainable Transformation Scenario with MEPC 80 guidance assumed for maritime demand; corresponding to a ~1.8oC warming scenario)

Exhibit 1

Despite a challenging environment for clean hydrogen, existing policies would catalyze 2030 demand

While the long-term outlook for clean hydrogen is strong, the near-term environment remains challenging. Demand for hydrogen is expected to grow 2 to 4 times by 2050[9] but recent cost increases, regulatory uncertainty, and a necessary filtering out of less competitive projects have created a challenging environment for clean hydrogen. In particular, 30-65% higher costs for renewable hydrogen (vs. prior estimates)[10] have delayed ecosystem take-off. Despite this, strong indicators of initial momentum are emerging, including 90% growth in investments in FID+ projects in the last 12 months and over 4.6 Mt p.a. of clean capacity already passed FID (+53% from 2023 to 2024)[11].

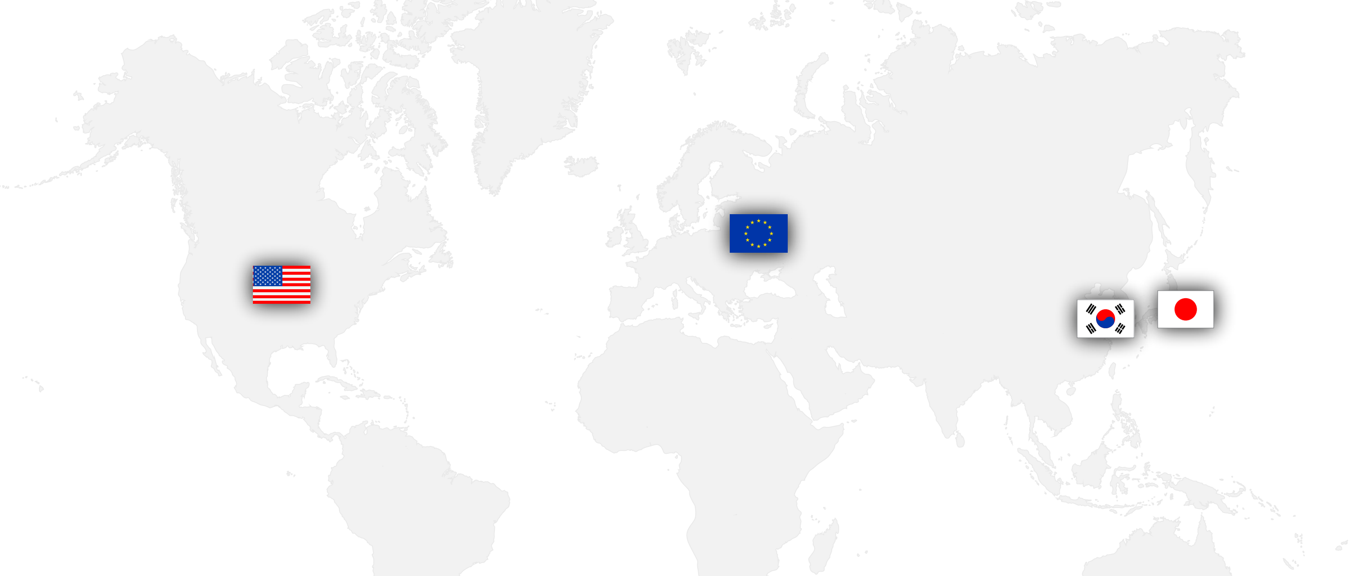
This perspective focuses on clean hydrogen uptake in three regions with established hydrogen support mechanisms that may already be firming an outsized portion of clean demand:

- **Initial renewable H_2 uptake in the EU is supported by REDIII** RFNBO quotas in industrial and transport applications, which increase from 42.5% by 2030 to 60% by 2035. Additional clean adoption could be supported by ETS / CBAM which puts a price on embedded CO_2. On the supply side, the EU has also created the EU Hydrogen Bank that awards capex support to projects constructed in the EU, worth ~1.2 USD/kg[12].
- **East Asian policies have initially focused on decarbonizing power.** The ~19 BUSD CfD program in Japan compensates clean H_2 / NH_3 buyers for the difference between clean supply and the reference price of conventional alternatives. In South Korea, CHPS sets up structured bids for H_2 / NH_3 -based power for electricity generation, either through ammonia co-firing with coal or direct hydrogen firing in gas turbines.
- **The IRA in the US would reduce clean H_2 production costs,** offering up to 3 USD/kg for up to 10 years depending on the Carbon Intensity (CI) score or carbon sequestration credits up to 85 USD/ton CO_2 for up to 12 years. Several states also offer low-carbon fuel standard (LCFS) programs that offer ~1.5 – 3 USD/kg for the use of clean H_2 in transport[13].

Across geographies, regulatory uncertainty could still impact how effective policies are at driving clean hydrogen demand. This analysis accounts for existing policies as of January 1, 2025.

9. McKinsey Global Energy Perspective 2024
10. Hydrogen Council - Hydrogen Insights 2023 December update
11. Hydrogen Council - Hydrogen Insights 2024
12. McKinsey Hydrogen Insights Global Hydrogen Trade Model
13. California Low Carbon Fuel Standard

Select regions with established clean hydrogen policies[1]



	EU		Japan	South Korea	US	
Policy Overview	Renewable Energy Directive (RED) III	Emissions Trading Scheme (ETS) & Carbon Border Adjustment Mechanism (CBAM)	Contract for Difference (CfD)	Clean Hydrogen Production Standard (CHPS)	Inflation Reduction Act[6]	
	>42%[2]	100-135 EUR/tCO$_2$[3]	19 USD billion[4]	9,500 GWh[5]	Up to 3 USD/kg H_2	85 USD/tCO$_2$
	Mandated volume of renewable H_2 use in industry (starting at 42.5% in 2030, and increasing to 60% by 2035), accompanied by penalties for non-compliance (i.e., each kg of H_2 below the 42.5% target carries a penalty on embedded emissions)	Penalty placed on CO_2 embedded in products (i.e., NH_3, H_2, methanol, etc.) produced inside of and imported into the EU Values expected to reach ~100-135 EUR/ton CO_2 by 2030 as free allowances phase out (from a 2024 range of ~55-75 EUR/tCO$_2$)	Budget for mechanism whereby government covers difference between the reference price of conventional fuel / feedstock (i.e., coal, grey ammonia) and the cost of clean NH_3 / H_2 for use in hard-to-abate sectors (e.g., power, industrial heat, steel)	Target for power produced from clean hydrogen and derivatives (e.g., co-firing of ammonia) by 2028, purchased via power procurement program; bids are selected on a competitive basis and evaluated according to delivered price and carbon intensity, among other metrics	Clean hydrogen production tax credit codified under section 45V of the Inflation Reduction act, with tax credit value per kilogram dependent on the carbon intensity of hydrogen	Carbon capture and sequestration tax credit codified under section 45Q of the Inflation Reduction Act. The tax credit is reduced to 60 USD/t if the CO_2 is used for enhanced oil recovery or other industrial uses

1. Country-level and regional targets and policies are still subject to change, the impact on clean hydrogen uptake would depend on the timing and effectiveness of implementation
2. European Commission Renewable Energy Directive
3. McKinsey Hydrogen Insights Global Hydrogen Trade Model
4. Japan Organization for Metals and Energy Security Hydrogen Society promotion Act
5. South Korea Ministry of Trade, Industry and Energy Clean Hydrogen Production Standard
6. United States Congress H.R.5376 - Inflation Reduction Act; includes additional tangential tax credits for low-emission fuels, low-emission vehicles, and renewable power

Exhibit 2

The EU, US, Japan and Korea account for ~30% of 2030 global demand but could drive most clean uptake due to policy momentum

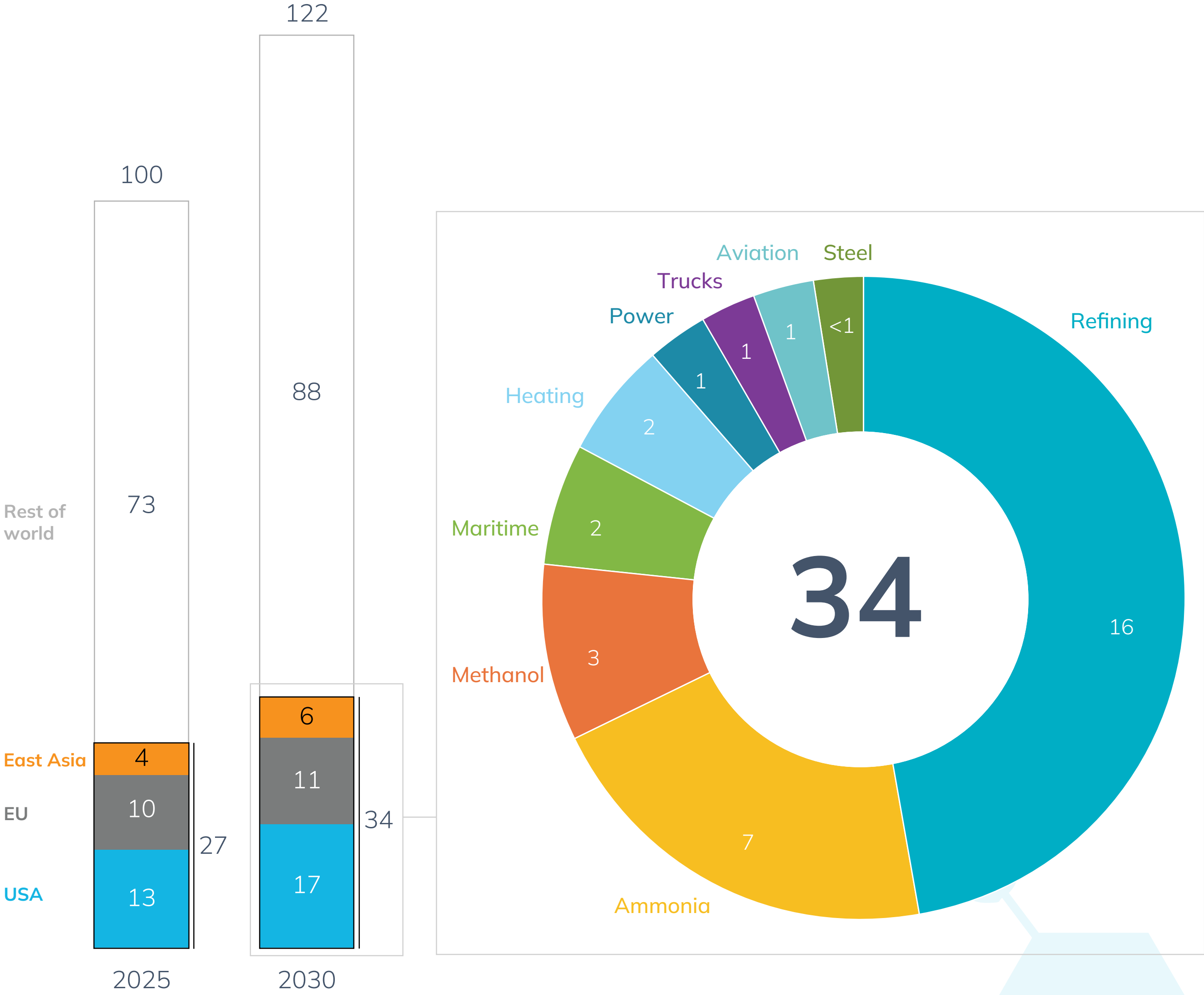
The EU, US, Japan and Korea could account for ~30% of 2030 global hydrogen demand and be the primary regions driving near-term clean hydrogen uptake.

In the McKinsey Sustainable Transformation scenario leveraged for this analysis, the EU, the US, Japan and Korea are expected to account for 34 Mt p.a. of the global 122 Mt p.a. of hydrogen demand across all pathways, up from a baseline of ~27 Mt p.a. in 2025[14]. Even in the less ambitious Continued Momentum scenario (not included in this report), demand for hydrogen in these regions could still reach 31 Mt p.a. out of a global 112 Mt p.a. by 2030[14]. Landmark policies supporting the cost parity of clean hydrogen in these regions are expected to underpin the first wave of global clean hydrogen demand. This analysis explores the viability of serving each sub-segment of the potential 34 Mt p.a. with clean hydrogen, including both new end uses as well as decarbonization of existing grey demand.

Near-term demand is concentrated in existing end-uses; emerging use-cases to see initial traction by 2030.

Existing applications (e.g., refining, ammonia, methanol) remain the largest demand segments through 2030, comprising ~75% of potential demand. Existing use cases are likely to be supplied by a mix of conventional and clean H_2. The combination of REDIII RFNBO quotas and ETS will drive decarbonization efforts in existing use cases in Europe while most US demand is concentrated in refining and ammonia production, which would require access to CCUS to decarbonize with low-carbon hydrogen. New applications (e.g., power, trucks, aviation and maritime) that could emerge by 2030 comprise the remaining ~25% of potential demand and would likely need to be supplied by clean H_2. However, uptake in these use cases depends on regulatory support in most cases.

EU, US, East Asia total hydrogen demand across pathways as a share of global demand in a Sustainable Transformation scenario, split by end-use, 2030, Mt p.a. H_2e[1]



1. McKinsey Global Energy Perspective 2024 (Sustainable Transformation Scenario; corresponding to a ~2°C scenario by 2050)

14. Analysis tied to 2024 McKinsey Global Energy Perspective scenarios; Sustainable Transformation ~1.8° warming estimate is an indication of global rise in temperature by 2100 versus pre-industrial levels (range 17-83rd percentile), based on MAGICCv7.5.3 as used in IPCC AR6 given the respective energy and non-energy (e.g., agriculture, deforestation) emission levels and assuming continuation of trends after 2050 but no net-negative emissions; continued momentum tied to a ~2.2° warming estimate; analysis includes assumption that MEPC 80 guidance is adopted for maritime sector

Exhibit 3

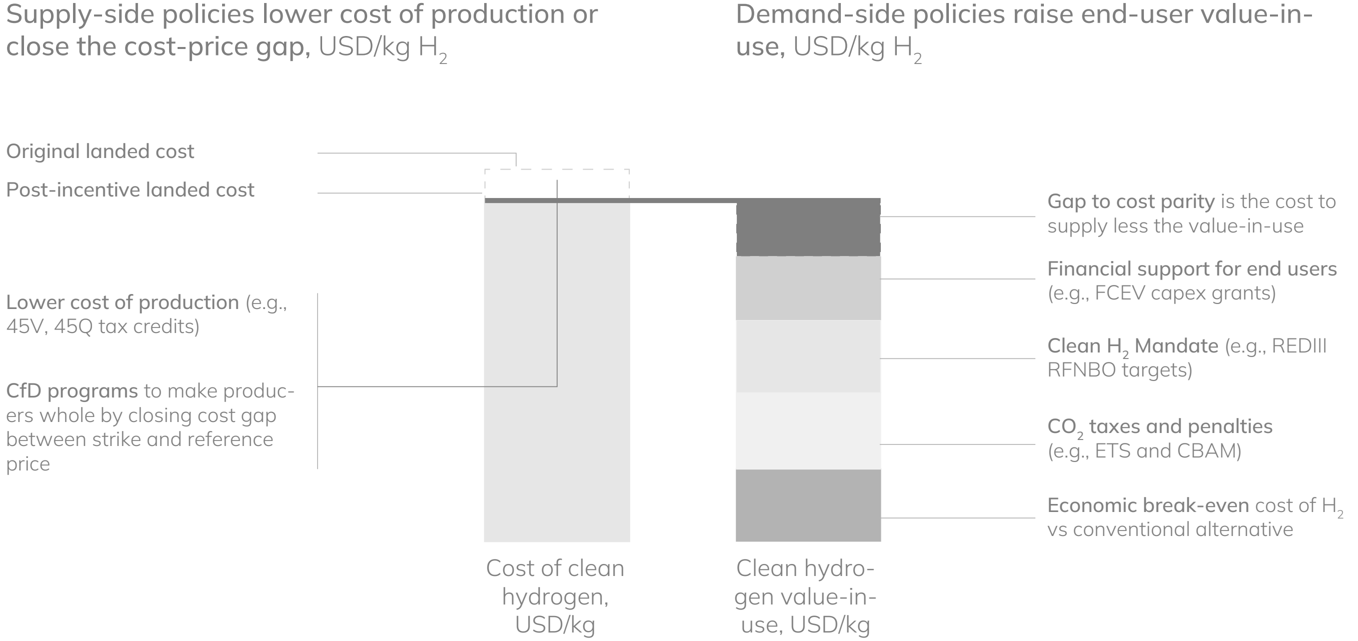
Emerging supply-side and demand-side policy mechanisms serve to close the clean hydrogen cost gap

Supply-side policies aim to lower the cost of production, typically through direct capex support (e.g., investment tax credit), a production tax credit (i.e., IRA 45V), a carbon capture credit (i.e., IRA 45Q) or a replacement-based mechanism that covers the cost gap for a low-carbon alternative relative to the reference price of the conventional alternative (i.e., CfD in Japan), thereby incentivizing wider availability of clean supply. These policies do not directly impact the end-user's value-in-use.

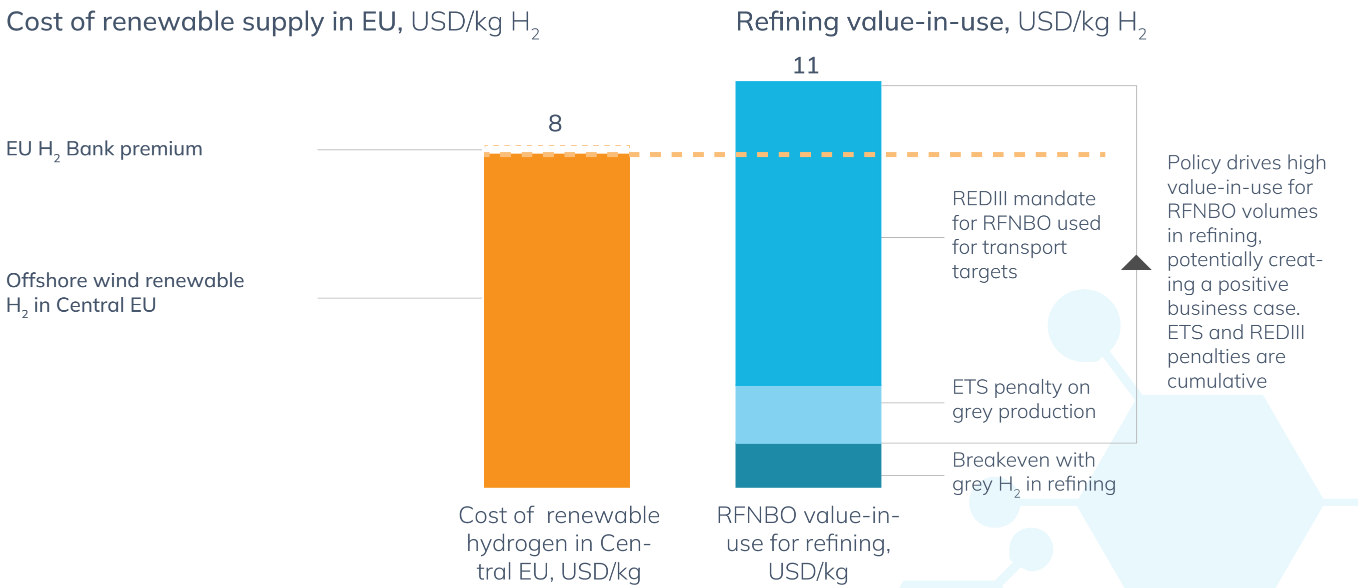
Demand-side policies accelerate end user adoption by raising the end-user's value-in-use beyond the direct economic breakeven cost of clean hydrogen compared to a conventional alternative. The full value-in-use can be broken down into the sum of its components: economic breakeven, emissions penalties, clean-use mandates and other end-use incentives designed to accelerate adoption (e.g., capex grants for H_2-based alternatives).

Positive business cases begin to emerge by 2030 when a combination of supply and demand incentives develop. Early demand cases include conventional sectors (i.e., refining and ammonia) adopting renewable H_2 to meet REDIII mandates. Gaps to cost-parity hinder clean H_2 adoption. In a case where the post-incentive landed cost exceeds the total value-in-use, widespread adoption of clean H_2 would likely not emerge beyond early movers.

Illustrative



Example: German refining under national fuel quota



Source: McKinsey Hydrogen Insights

Exhibit 4

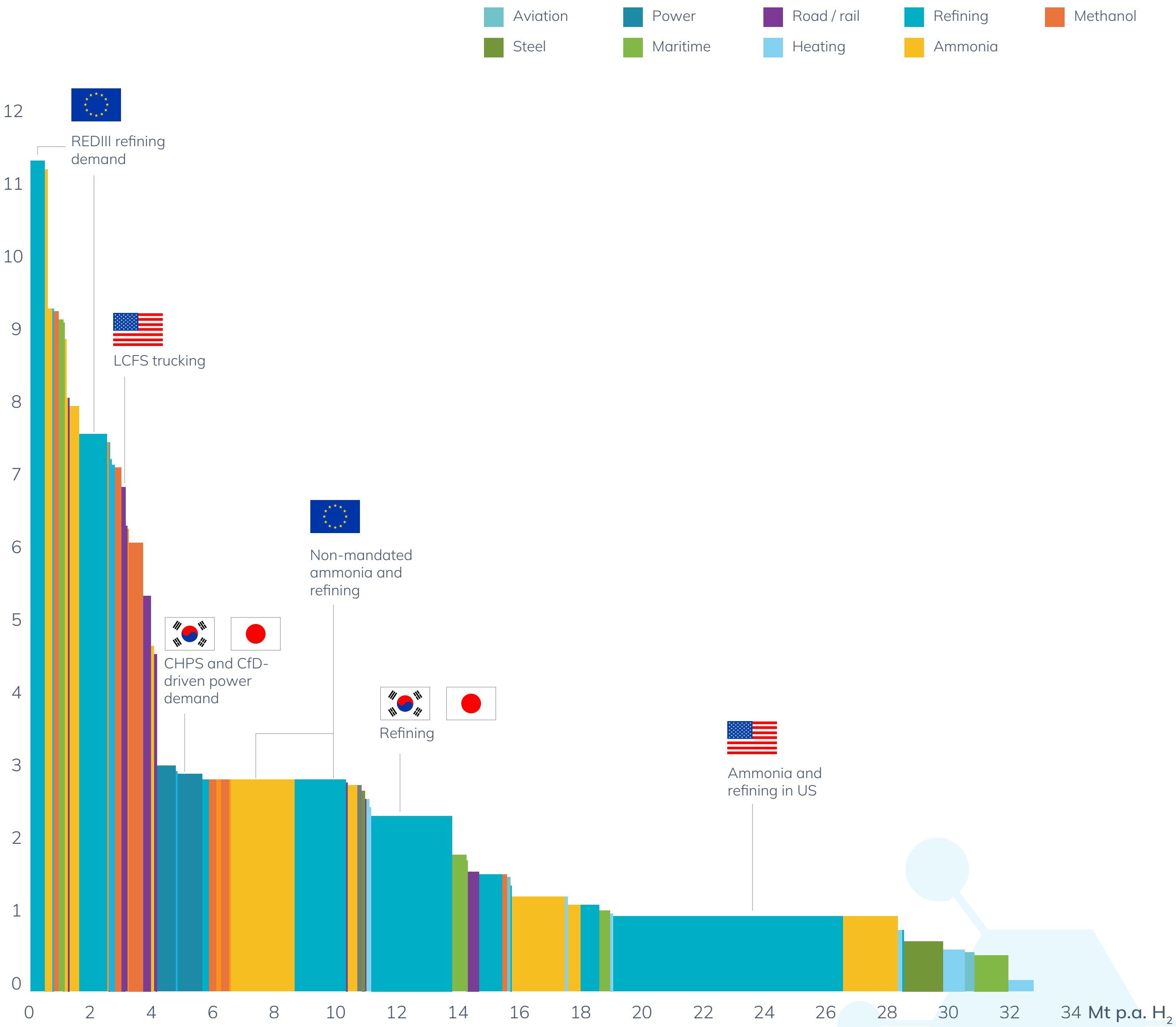
Demand curve: Policy impact could drive up value-in-use for clean hydrogen from ~1-2 USD/kg to over 10 USD/kg for some demand segments

Demand-side policies for clean hydrogen can contribute to value-in-use exceeding 10 USD/kg by 2030, depending on the specific segment and geography. The highest value-in-use emerges in the EU where REDIII, ETS and CBAM increase estimates by 2.4-9.4 USD/kg H_2 above economic breakeven commensurate with the implied cost of penalties for non-compliance with RFNBO mandates for end users seeking to reduce the carbon intensity of fuels and feedstocks. Nearly 5 Mt p.a. of the EU total of 11 Mt p.a. is impacted by REDIII.

Policies supporting decarbonization of power in East Asia could drive ~ 2 Mt of new demand by 2030 from a total baseline of 6 Mt p.a.. The implementation of CHPS in Korea and the CfD program in Japan could bridge a ~1.5 USD/kg H_2e gap to drive clean ammonia co-firing in coal plants. Additional demand for H_2 exists in the refining and ammonia sectors, though value-in-use outside of these programs remains too low to cover the cost of imported supply.

Nearly 50% of the potential demand is in the US, where legacy refining and ammonia production drive the largest portions of demand. However, limited demand-side support in the US leads to value-in-use of ~1-1.5 USD/kg. Nevertheless, supply-side policies like the IRA could reduce the levelized costs of low-carbon and renewable hydrogen by ~0.50-2.00 USD/kg H_2e, potentially making low-cost supply more widely available on the market. States with LCFS markets create a demand-side incentive that could increase value-in-use to ~6.5 USD/kg H_2e, potentially driving the first uptake of segments like fuel cell electric vehicle (FCEV) trucking.

EU, US, East Asia hydrogen demand and value-in-use split by end-use segment, 2030, USD/kg H2e[1]



1. Includes hydrogen demand from all pathways as modeled in McKinsey Global Energy Perspective 2024 (Sustainable Transformation Scenario with MEPC 80 guidance assumed for maritime demand; corresponding to a ~1.8oC warming scenario); value-in-use derived from McKinsey Hydrogen Insights Total Cost of Ownership modeling across end use sectors

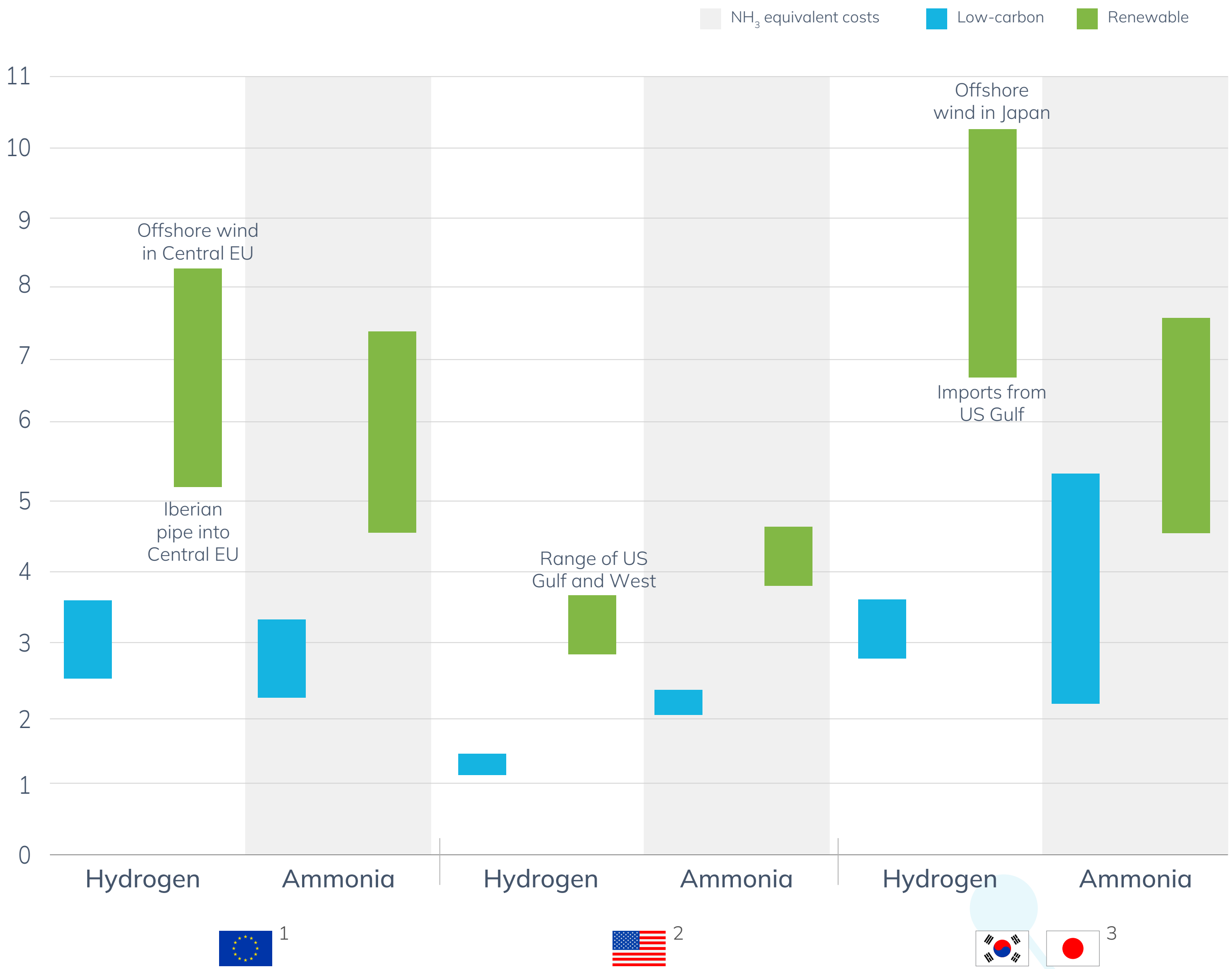
Exhibit 5

Supply costs: 2030 supply costs for clean hydrogen and derivatives in the EU, Japan, Korea, and US range from ~1-11 USD/kg H_2e

By 2030, production costs are expected to range from ~1.2-3.5 USD/kg for low-carbon and ~3-11 USD/kg for renewable hydrogen. Due to global cost disparities between regions with attractive resources (i.e., low-cost gas and CCUS or higher-quality renewables resources), initial trade corridors are likely to begin to emerge to supply clean demand centers in the EU and East Asia from low-cost production regions like the US, the Middle East, LATAM and Australia. Given existing infrastructure and trade routes, coupled with limited leakage during transportation compared to liquid hydrogen, derivatives such as methanol and ammonia are most likely to comprise the first wave of inter-regional clean molecule trade. Demand requiring clean H_2 molecule use is still likely to be supplied domestically, or intra-regionally (i.e., from Iberia to Central EU), although advancements in carrier reconversion technology could enable additional imports. Additionally, while ammonia from both low-carbon and renewable pathways could be generally less exposed to regional energy price fluctuations given access to established trade routes, locally produced low-carbon and renewable hydrogen could be more sensitive to fluctuations in regional gas prices and renewable power costs, respectively.

Supply-side policy mechanisms across the EU and the US incentivize the production of clean H_2 to be used domestically within these regions. Underlying resource constraints and growing demand for end-use H_2 in the EU also create initial import and re-conversion infrastructure (i.e., NH_3 cracking) that raises the cost of clean supply to ~8 USD/kg. The high cost of supply, particularly for re-converted renewable ammonia, could potentially limit further adoption by 2030.

Estimated landed supply cost ranges for low-carbon and renewable hydrogen and ammonia into the EU, US, Japan, Korea, 2030, USD/kg H_2e



1. H_2 ranges: Low-carbon (lower) domestic production in Western Continental Europe, (upper) imported NH_3 from USGC. Renewable (lower) imported from Iberia using pipeline, (upper) offshore wind in Central EU. NH_3 ranges: (lower) imported from USGC, (upper) domestic production in Western Continental Europe. Renewable (lower) imported from USGC, (upper) global median
2. Ranges between US Gulf Coast and US West for all costs (assuming fully domestic supply)
3. H_2 ranges: Low-carbon (lower) domestic production in Japan, (upper) imported NH_3 from USGC. Renewable (lower) imported from USGC, (upper) offshore wind in Japan. NH_3 ranges: Low-carbon (lower) imported from USGC, (upper) domestic production in Japan. Renewable (lower) imported from USGC, (upper) global median. All costs for renewable use 95% firmness and all low-carbon use new-built ATR, costs include supply-side incentives. Underlying assumptions: natural gas price ($/mmbtu): 4.4 (USGC), 5.5 (EU), 7.7 (East Asia); renewable power price ($/MWh): 90 (EU offshore wind), 130 (Japan offshore wind), 50 (USGC solar), 35 (USGC wind), 45 (Iberia solar/wind); cracking losses of ~1.9 $/kg

Source: McKinsey Hydrogen Insights Global Hydrogen Trade Model

Exhibit 6

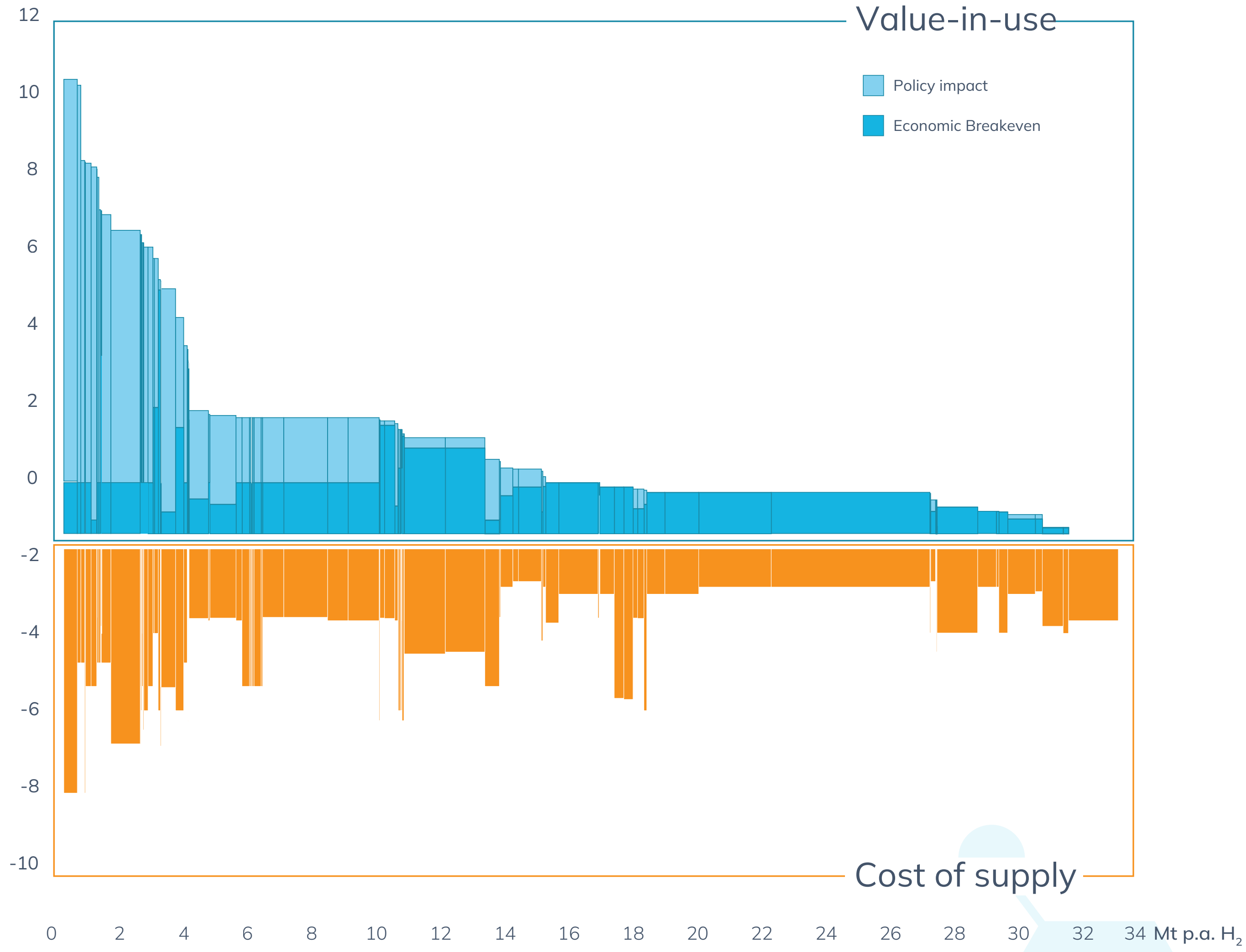
Each demand segment carries a specific landed supply cost based on location and sector

Assessing the viability of the clean hydrogen business case requires comparing each segment's value-in-use to its specific landed supply cost.

Value-in-use and landed supply cost were calculated for each sub-segment of potential hydrogen demand. Values for each segment account for imported vs. domestic production dynamics, the likely pathway (renewable, low-carbon), the molecule of use (e.g., hydrogen in refining vs. synthetic kerosene in aviation), and firmness requirements, as well as segment-specific policy impact. In the chart on the right, the value above the x-axis is the theoretical threshold hydrogen cost under which an end user would see an economic case for switching from a conventional alternative to clean hydrogen (i.e., clean hydrogen "value-in-use"). The respective bar beneath each segment is the likely cost of clean hydrogen that would serve that segment of demand by 2030.

The difference between value-in-use and supply cost determines whether there could be a positive business case for that end-use segment by 2030. High value-in-use or low supply cost alone does not dictate whether a given demand segment might materialize. Even a high value-in-use sector (e.g., long haul trucking in the EU) may not materialize if the cost of supply remains uncompetitive. Likewise, segments with relatively low value-in-use, if served by very low-cost supply, may still materialize (e.g., US refining).

EU, US, East Asia hydrogen demand: value-in-use vs. landed cost of clean hydrogen per segment, 2030, USD/kg H_2e[1]



1. Includes hydrogen demand from all pathways as modeled in McKinsey Global Energy Perspective 2024 (Sustainable Transformation Scenario with MEPC 80 guidance assumed for maritime demand; corresponding to a ~1.8oC warming scenario); value-in-use derived from McKinsey Hydrogen Insights Total Cost of Ownership modeling across end use sectors; supply costs sourced from McKinsey Hydrogen Insights Global Hydrogen Trade Model

Exhibit 7

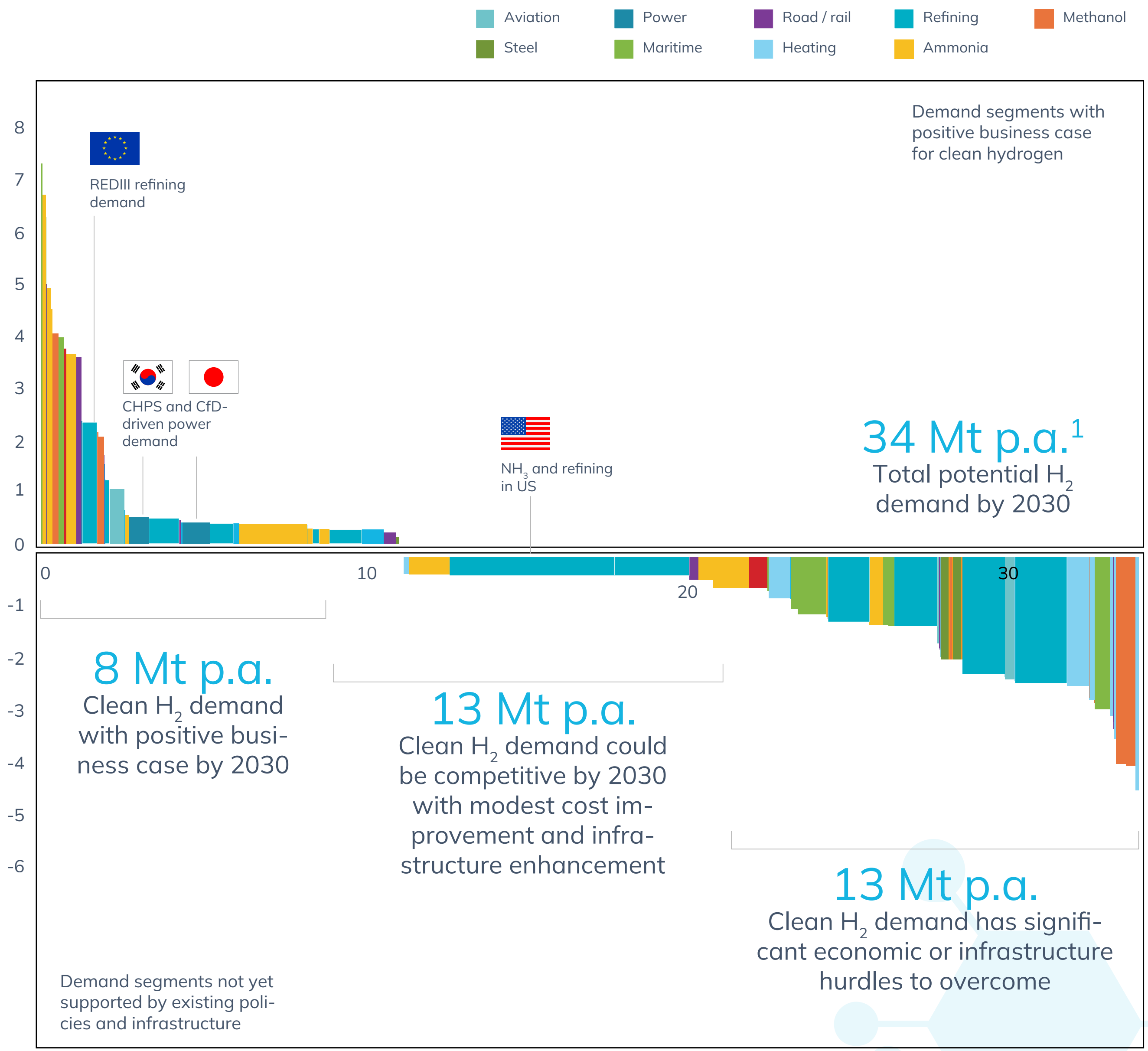
The difference between each segment's specific value-in-use and supply cost defines its competitiveness

After subtracting supply costs from value-in-use for each segment, three segments of demand emerge, defined by their relative cost competitiveness. The first segment, ~8 Mt p.a. of demand, appears to carry a positive business case. About 13 Mt p.a. of demand make up the next segment where the cost gap comes within ~0.5 USD/kg H_2e of breaking even for clean hydrogen vs. conventional alternatives. The remaining ~13 Mt p.a. in the third segment retains a cost gap of between 0.5-5.1 USD/kg H_2e, even after accounting for the impact of existing supply-side and demand-side policy measures.

A positive business case (i.e., a value above the x-axis) does not denote supplier or consumer margin per se but instead is an indication that switching to clean hydrogen could be economically viable by 2030, assuming an unconstrained clean supply market from known production centers. Demand volumes under RFNBO mandates implemented at country level in the EU carry some of the most positive potential business cases. A marginal competitiveness value indicates an end use that may be nearly economically viable but likely requires incremental support to close the cost gap and / or additional infrastructure to materialize (e.g., heavy duty trucking). A negative competitiveness value typically suggests a given end-use segment would not yet have a viable clean hydrogen business case by 2030 without extensive additional support (i.e., residential heating).

Existing use cases (refining and chemicals) make up 75% of positive business case demand. The majority of refining demand with a positive business case is driven by REDIII in the EU, much of which would be served by local or intra-regional supply. Chemicals demand in the EU, US, Korea and Japan could be served by US production to access both US supply-side incentives and either EU or East Asia demand-side financial support. The balance of demand with a positive business case comes from new use cases: power, maritime, trucks and forklifts. Each of these use-cases may appear in a specific region under the right mix of policy support and infrastructure availability.

Cost-competitiveness for clean hydrogen by use case, 2030,
USD/kg H_2e Δ between value-in-use and supply cost



1. Includes hydrogen demand from all pathways as modeled in McKinsey Global Energy Perspective 2024 (Sustainable Transformation Scenario with MEPC 80 guidance assumed for maritime demand; corresponding to a ~1.8oC warming scenario); value-in-use derived from McKinsey Hydrogen Insights Total Cost of Ownership modeling across end use sectors; supply costs sourced from McKinsey Hydrogen Insights Global Hydrogen Trade Model

02

The degree of clean hydrogen uptake by 2030 is contingent on a combination of policy mechanisms, underlying economics, and infrastructure enhancements

8 Mt p.a.

Demand with a policy-supported positive business case for clean hydrogen by 2030, largely to decarbonize existing end uses in the EU (e.g., refining, ammonia) and for co-firing of low-carbon ammonia for power in East Asia

13 Mt p.a.

Demand within ~0.50 USD/kg He vs conventional alternatives that could feasibly be unlocked by 2030 with incremental infrastructure enhancements, primarily comprised of low-carbon ammonia and refining demand in the US dependent on build out of CCS networks

13 Mt p.a.

Demand with significant remaining economic and infrastructure hurdles but few decarbonization alternatives to clean hydrogen (e.g., aviation, non-regulated maritime fuels, high-grade industrial heat)

Exhibit 8

Of the ~34 Mt p.a. of potential 2030 clean hydrogen demand, 8 Mt p.a. could carry a positive business case, 13-26 Mt p.a. requires unlocks

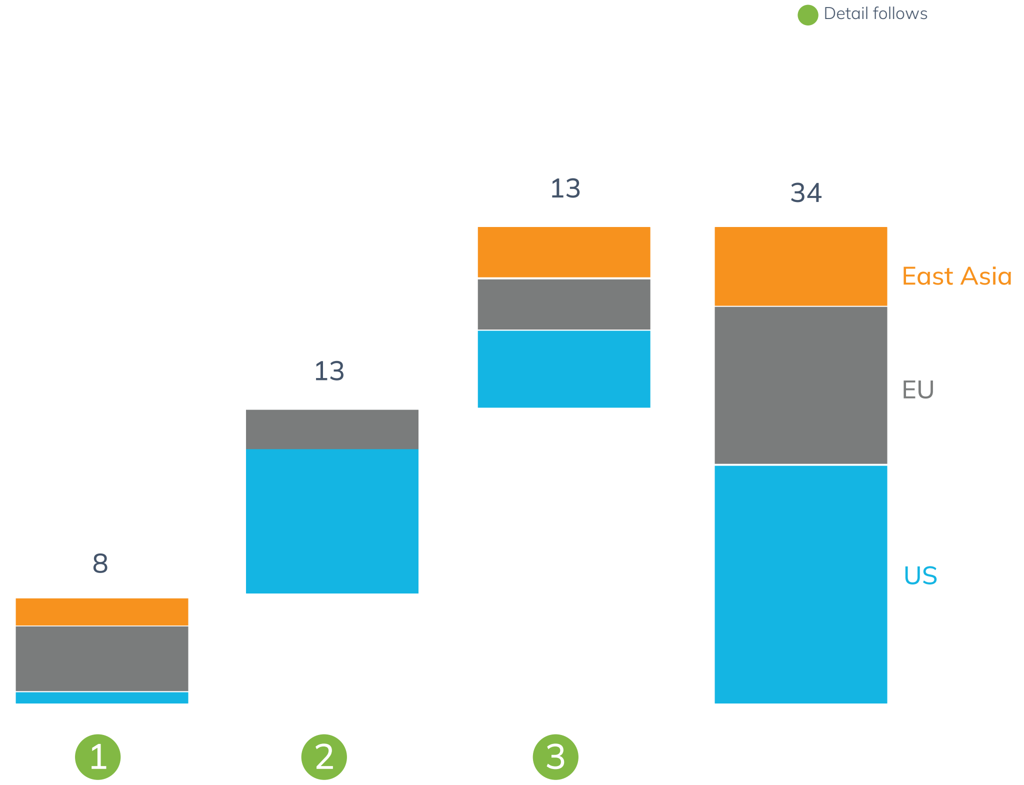
About 8 Mt p.a. of clean hydrogen demand appears to carry a policy-supported positive business case by 2030

The first 8 Mt p.a. segment of potential hydrogen demand relies on the effective implementation of policy (e.g., REDIII member state transposition, final 45V guidance, etc.) for the 'low-hanging fruit' to be realized by 2030. Inside this group, demand primarily consists of decarbonization of existing end uses driven by REDIII in Europe and co-firing clean ammonia in the power sector in East Asia. Throughout this segment, a positive business case could emerge, provided announced policies are fully realized.

Portions of demand in the second segment of 13 Mt p.a. could be unlocked by 2030 by establishing an initial base of new infrastructure to enable clean hydrogen for end uses close to cost-parity. The middle 13 Mt p.a. of clean H_2 demand could be unlocked largely through the expansion of at-scale infrastructure, including access to CCS, particularly in the US, and developing a base of commercial HRS ecosystem in the US and the EU. Establishing the foundation of infrastructure necessary to support this segment could more than double the clean H_2 demand with a positive business case by 2030.

The final segment of 13 Mt p.a. of demand faces significant hurdles to materialize by 2030, but near-term activation may be necessary to realize future potential demand. Investing in infrastructure and at-scale technologies can create proof points and initial baseline of demand on which later stage growth (through 2040+) would depend. This infrastructure includes scaling reconversion (cracking) to enable the import of clean H_2 molecules, expanding access to biogenic CO_2 and allowing industrial CO_2 use for methanol production, and establishing bunkering infrastructure and fueling infrastructure for transport (e.g., new maritime and aviation demand).

2030 hydrogen demand by geography and key unlock for clean adoption, Mt p.a. H_2e[1]



	1	2	3	
Description	Policy-supported positive business case by 2030	Feasible to unlock with incremental infrastructure	Significant economic or infrastructure hurdles	Total 2030 H_2 demand
Annual abatement potential, $MtCO_2e$[2]	60	90	100	250
Gap to cost parity, USD/kg H_2	~0	<0.5	0.5-5	

1. Includes hydrogen demand from all pathways as modeled in McKinsey Global Energy Perspective 2024 (Sustainable Transformation Scenario with MEPC 80 guidance assumed for maritime demand; corresponding to a ~1.8oC warming scenario)
2. McKinsey Hydrogen Insights Abatement Model

Exhibit 9

1.Seizing Low-Hanging Fruit: About 8 Mt p.a. of 2030 clean demand with a positive business case driven by REDIII quotas in the EU and clean power policies in East Asia

8 Mt p.a. of clean hydrogen demand in the EU, US, Japan and Korea could carry a policy-supported positive business case by 2030 but would rely on existing regulations being enacted. However, this demand has limited overall exposure to fluctuating energy costs given the majority is mandate-driven renewable demand in the EU. Coal prices could impact the total volumes supported by the Japanese CfD, but marginal shifts in natural gas and renewable power costs would not likely materially affect the total ~8 Mt p.a. in this category.

EU RFNBO applications could be made viable in industry, chemicals, and transport by state-level REDIII transposition, resulting in 3.3 Mt p.a. renewable demand carrying a positive business case in Europe by 2030. This demand is driven by existing use cases (ammonia, refining).

ETS and CBAM enable low-carbon refining and ammonia applications by raising value-in-use commensurate with the avoided penalties for non- compliance, enabling 1.6 Mt p.a. of low-carbon demand, a portion of which could already be served by mature low-carbon projects.

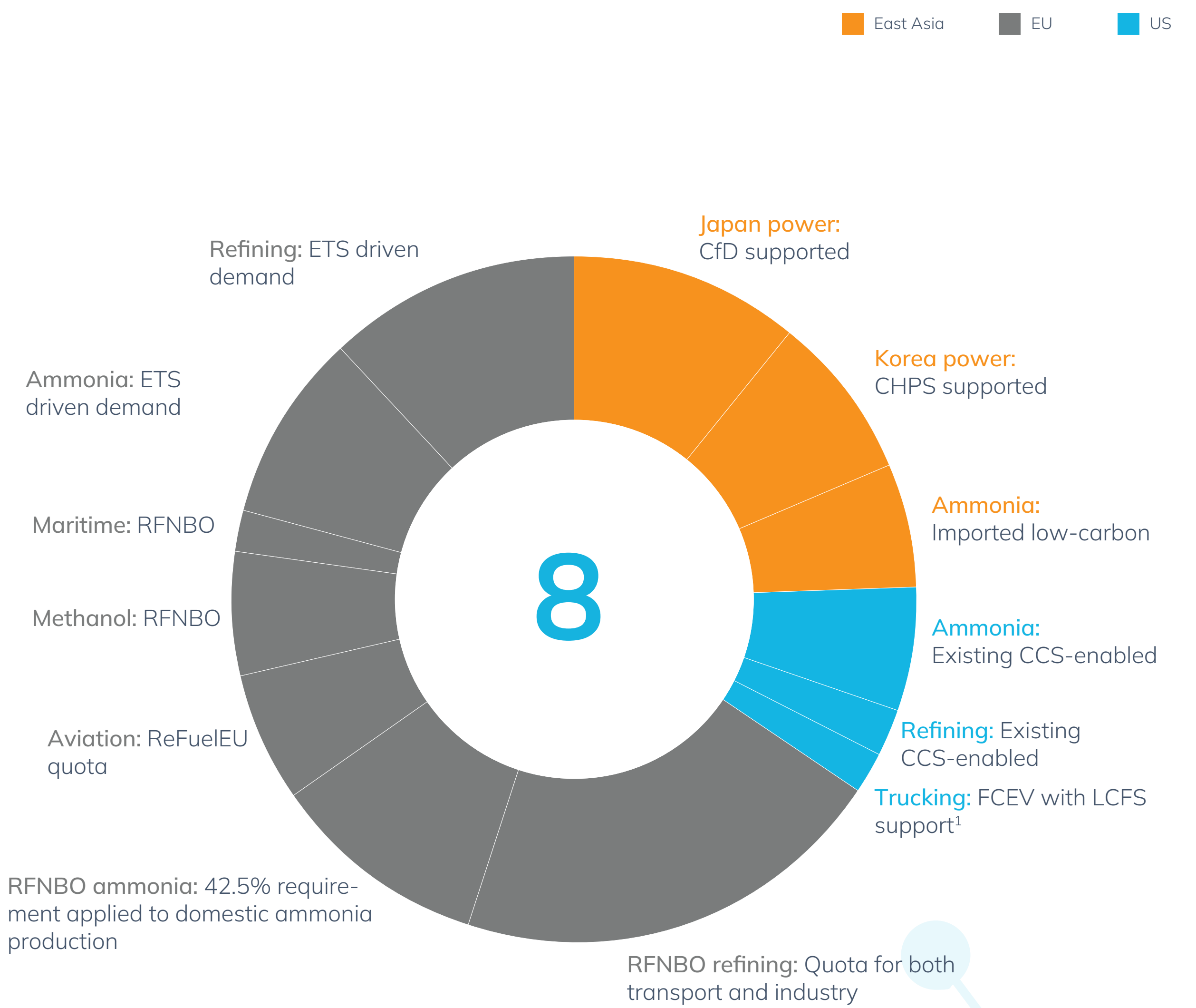
Outside of Europe, demand in power applications is supported by East Asian supply-side programs, enabling 1.4 Mt p.a. through ~19 BUSD of CfD funding in Japan over 15 years and a 9,500 GWh target for power from H_2/ NH_3 in the Korean CHPS[15]. Future rounds of Japan's Long-term Decarbonization Auction (LTDA) could enable additional power demand.

In the US, low-carbon applications with access to CCS are already enabled by IRA 45Q, creating 0.7 Mt p.a. of demand in operational ammonia production and refining. FCEV trucking is enabled by California LCFS and is already online, serving 0.1 Mt p.a.

Unlocking demand in this segment requires effective implementation of existing polices (e.g., REDIII, IRA) to decarbonize existing end uses (e.g., refining, ammonia) and allow initial uptake in emerging end uses (e.g., FCEV trucking). A delay or change in the adoption of existing policies could hinder the growth of the industry by 2030 and reduce confidence in investments across the ecosystem.

15. Formal guidance is currently 6,500 GWh but expected to increase to 9,500 GWh

Demand segments with a policy-supported business case by geography and sector, 2030, % of total Mt p.a.



1. California market includes the impact of Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP)

Exhibit 10

2. Bridging the Gap: Up to ~13 Mt p.a. of clean hydrogen demand could be unlocked by 2030 with the scale-up of enabling infrastructure, the majority in US refining and ammonia

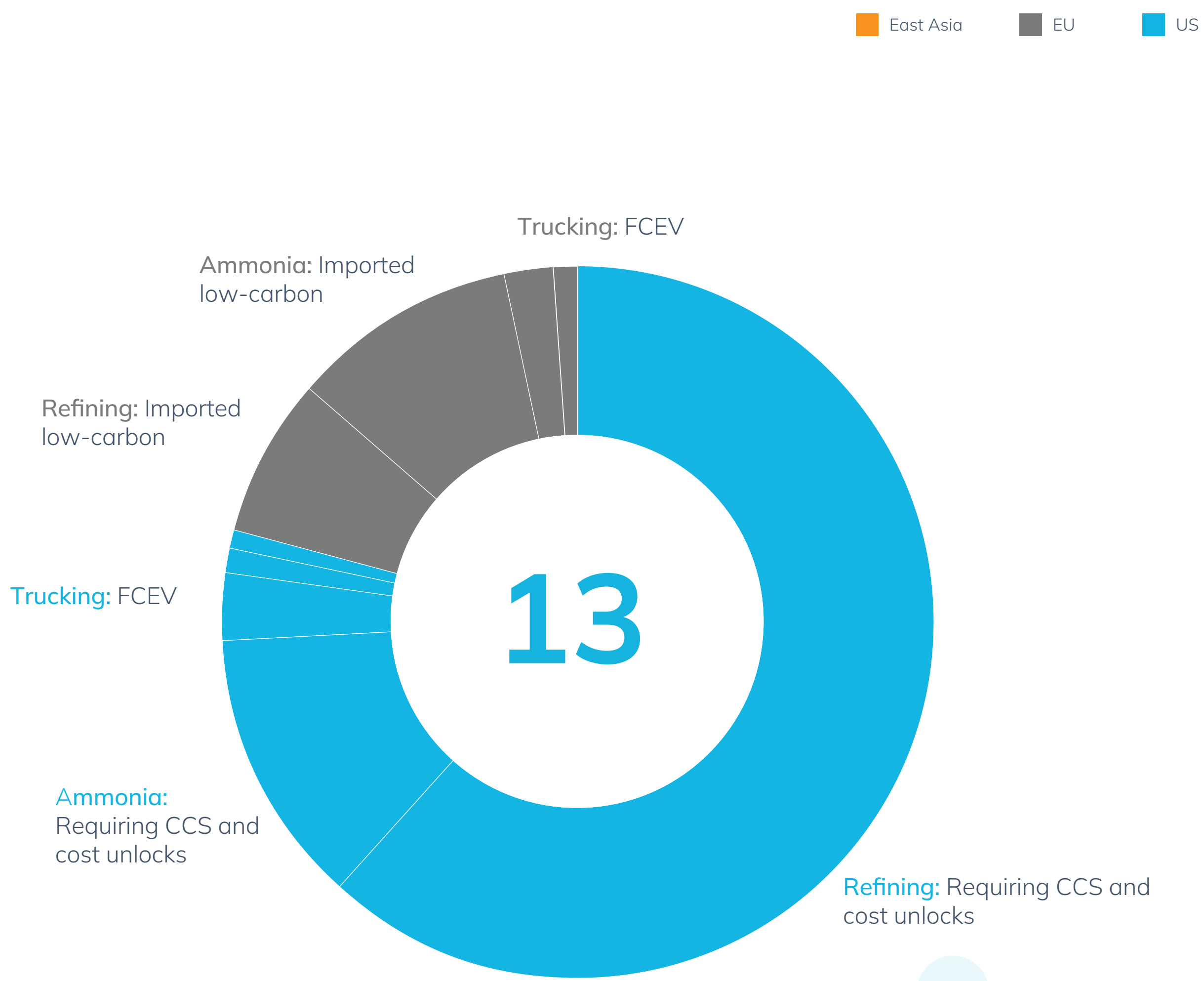
13 Mt p.a. of demand within 0.5 USD/kg H_2 of cost parity vs. conventional alternatives could be unlocked by 2030 but requires incremental cost and infrastructure support. The majority of this demand (~10.5 Mt p.a.) could be served by new low-carbon supply in the US, with an additional 1.4 Mt p.a. of low-carbon ammonia demand in the EU potentially served by domestic or imported supply. The business case for most of the demand in this category relies on establishing the requisite CCS network infrastructure in the US, including in large part along the US Gulf Coast, not only to support domestic US low-carbon refining and ammonia demand but also imports of low-carbon derivatives into the EU. While the current 45Q tax credit already brings US low-carbon supply nearly to parity with grey hydrogen on a cost basis, limited demand-side policies exist to close the remaining marginal gap for facilities sourcing hydrogen outside the most competitive production regions.

Refining in the EU requires the build out of CCS infrastructure in the North Sea to enable import to Central Europe without incurring conversion and re-conversion costs. This could unlock 1.0 Mt p.a. of low-carbon demand.

Trucking in US could be competitive in LCFS and non-LCFS regions compared to internal combustion (ICE) if HRS infrastructure is built to link low-cost supply with heavily utilized long-distance corridors.

EU trucking is supported by REDIII, and AFIR[16], and can be enabled by ETS 2 to drive FCEV uptake, while phasing out allowances. This could unlock 0.3 Mt p.a. of renewable demand.

Demand segments requiring incremental cost or infrastructure unlocks by geography and sector, 2030, % of total Mt p.a.



16. Alternative Fuels Infrastructure Regulation

Exhibit 11

3. High Stakes, High Rewards: An additional ~13 Mt p.a. of hydrogen and derivative demand has few clean alternatives but significant economic or infrastructure hurdles could limit adoption by 2030

Unlocking the remaining 13 Mt p.a. of hydrogen demand would require significant cost and infrastructure interventions, with some sub-segments inhibited by as much as a ~5.1 USD/kg cost gap between clean hydrogen and conventional alternatives. However, the hard-to-abate sectors that make up this category have few decarbonization alternatives to hydrogen and may therefore make up a large share of long-term clean hydrogen demand. In this 'high stakes, high rewards' category, near-term advancements to bridge the cost gap, coupled with a critical mass of infrastructure could set the groundwork for and potentially pull forward long-term demand.

2.6 Mt p.a. of low-carbon refining demand in Japan and Korea would require significant reconversion cost reduction and infrastructure enhancement given the reliance on imported hydrogen molecules.

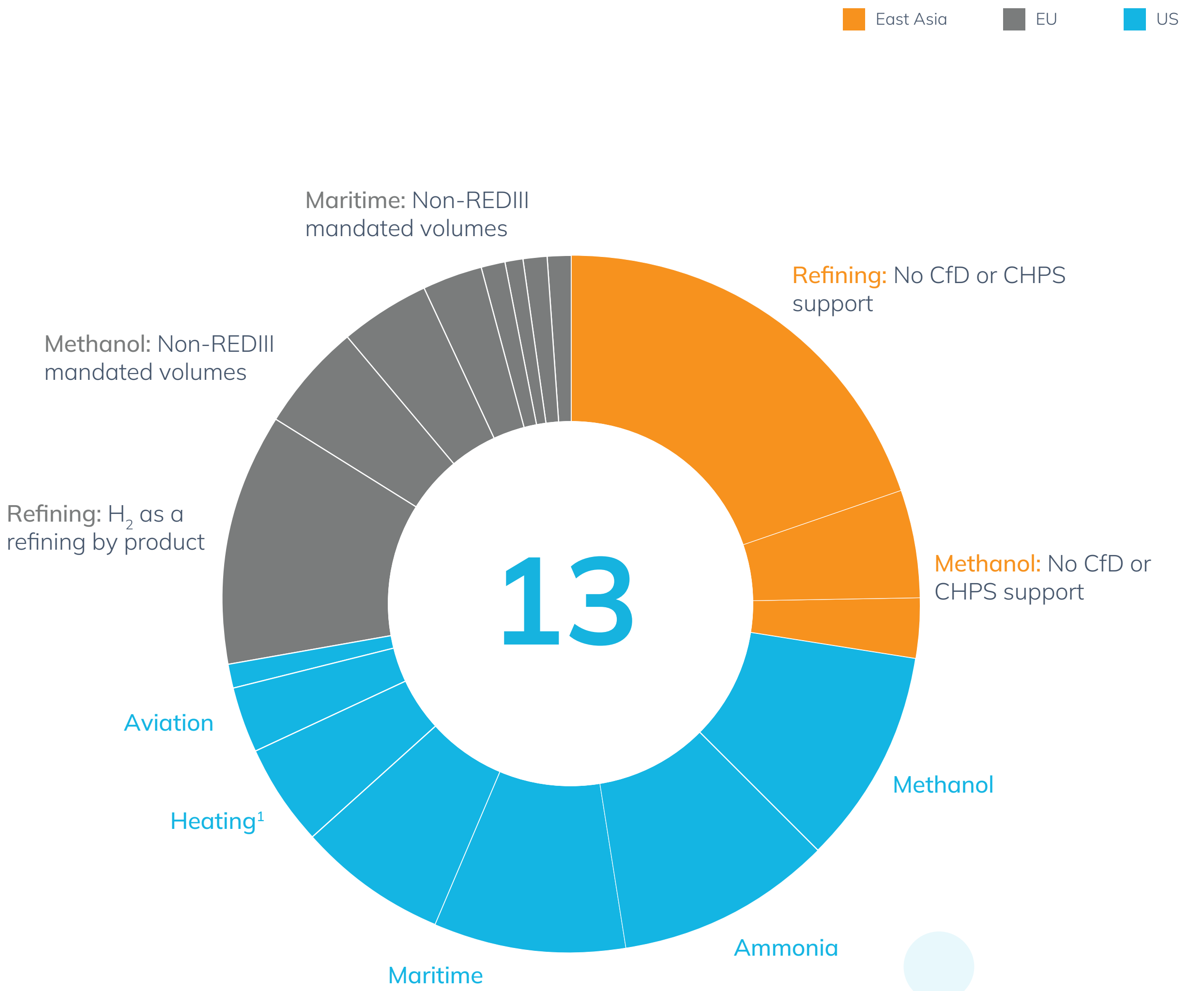
Maritime in the US and EU could be further enabled by GHG emission caps, an expansion of the FuelEU initiative, and full implementation of MEPC 80 guidance[17] to unlock 1.6 Mt p.a. low-carbon demand.

Clean **methanol** requires increased CCS infrastructure to supply CO_2 as well as low-cost green hydrogen, to enable 2.6 Mt p.a. of renewable demand in the US, the EU and East Asia.

US eSAF requires expanding mandates / demand levers (e.g., LCFS) while expanding cost side measures (e.g., stacking IRA 45V and 45Z tax credits) to unlock 0.4 Mt p.a. of renewable demand.

EU H_2-DRI steel requires investment in DRI facilities, secure supply, delivery infrastructure, and expansion of policy (e.g., LESS in Germany) to unlock 0.2 Mt p.a. demand.

Demand segments requiring significant cost or infrastructure unlocks by geography and sector, 2030, % of total Mt p.a.



17. Marine Environment Protection Committee; MEPC 80 requires at least 5% of fuel to be zero or near zero GHG by 2030

1. Combination of residential and industrial heating in US, limited long-term uptake projected as more cost-effective alternatives expected to advance

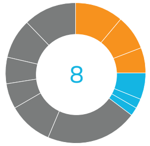
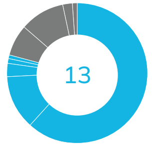
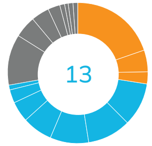
Exhibit 12

Unlocking additional clean hydrogen uptake by 2030 would require incremental policy and infrastructure measures

Unlocking a baseline of clean hydrogen demand in the coming decade requires the implementation of existing policy measures and enablers as initial support comes into place by 2030. Existing end uses (e.g., refining, ammonia) and an initial uptake in emerging end uses (e.g., FCEV trucking, power) are enabled by existing clean demand and supply-side policies (e.g., CfD, CHPS, REDIII, IRA tax credits). The majority (~75%) of potential clean H_2 demand is centered around supplying existing end-users with economically viable clean H_2 for adoption. These segments could comprise the first ~8 Mt p.a. of clean H_2 by 2030, and abate ~60 Mt CO_2e annually, equivalent to Austria's annual emissions[18]. However, this first segment of clean H_2 alone would be insufficient to achieve a sub-2°C warming scenario (falling closer in line with McKinsey's Continued Momentum scenario). Nevertheless, the ~4.6 Mt p.a. of committed 2030 clean supply, coupled with an additional ~3.5 Mt p.a. of supply from projects in FEED could effectively serve the first wave of demand[19].

Incremental infrastructure unlocks, including in large part enabling CCS and H_2 transmission networks and trade permits, would be required to support an incremental 13 Mt p.a. in clean H_2 demand. While increased adoption of low-carbon hydrogen and derivatives could support the first waves of infrastructure build-out, in parallel, renewable H_2 production would need to be scaled from pilots today to GW-scale projects by 2030 to realize cost declines needed to unlock additional demand in the third segment.

Scale-up of policy support would likely be required to unlock additional demand by 2030 and set the groundwork for future uptake of clean hydrogen in the hard-to-abate sectors. For sectors with a significant cost gap like aviation, maritime and e-methanol, additional consumption quotas, new mechanisms to de-risk offtake, expanded emissions trading schemes and other net-new mechanisms may be necessary in some regions to address cost gaps ranging up to 5.1 USD/kg H_2e.

Demand segment	 Policy-supported positive business case by 2030	 Feasible to unlock with incremental infrastructure	 Significant economic or infrastructure hurdles
Abatement potential, $MtCO_2e$[1]	60	90	100
Cost parity gap, USD/kg	~0	~0-0.5	~0.5-5
Effort for unlock by 2030	Effective imple-mentation of ex-isting policies	Incremental ex-pansion of exist-ing mid-stream infrastructure	Significant policy front-loading and establishment of infrastructure base to unlock new end uses

18. Estimated CO_2 emissions from fuel combustion in Austria as per IEA emissions accounting
19. Figures as of October 2024 as outlined in Hydrogen Insights 2024; assumes 50% completion of ~7.1 M.t. pa of clean supply currently in FEED stage

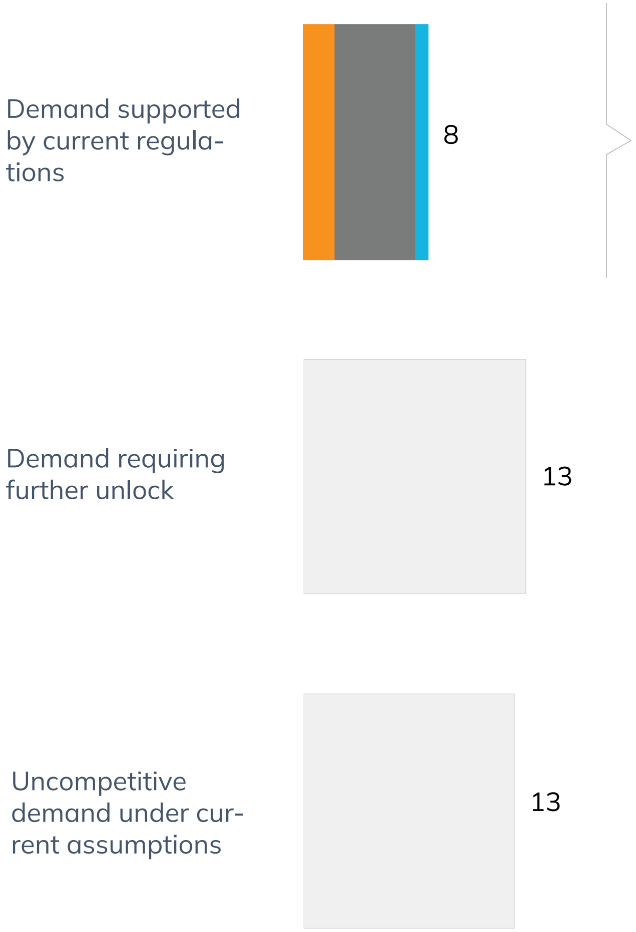
1. McKinsey Hydrogen Insights Abatement Model

Appendix

~8 Mt p.a. of clean H_2 demand could have a positive business case if currently proposed policies are enacted in EU, Japan Korea, and US

Mandated or likely renewable demand · Pathway agnostic (likely low-carbon) demand · East Asia · EU · USA

Hydrogen demand in 2030 for EU, Japan, Korea, and US, Mt p.a. H_2



Sectors / regions driving demand	Mandated or likely renewable demand	Pathway agnostic (likely low-carbon) demand	Activation levers	Gap to cost parity, USD/kg H_2
Refining	1.6	0.9	State-level REDIII transposition can enable RFNBO applications in industry, chemicals, and transport	~ 0
Ammonia	0.8	0.7	CBAM / ETS enable imports of low-carbon ammonia in addition to REDIII mandated renewable ammonia	
Aviation	0.5		ReFuelEU sub quota for RFNBO targets	
Methanol	0.4		REDIII RFNBO mandate for methanol production	
Maritime	<0.1		Fuel EU sub quota for RFNBO use in maritime	
Power		1.4	~19 USD billion support via CfD in Japan over 15 years; and a 9,500 GWh in H_2 / NH_3 target in Korea via CHPS	
Ammonia		0.5	Access to low-cost imported low-carbon NH_3	
Ammonia		0.5	IRA 45V and CCS-access enables US ammonia	
Refining		0.2	IRA 45Q and CCS-access enables US refining	
Trucking	0.1		California LCFS enables FCEV trucking	
Forklifts	<0.1		Clean H_2 is well suited to fuel forklift operations[1]	

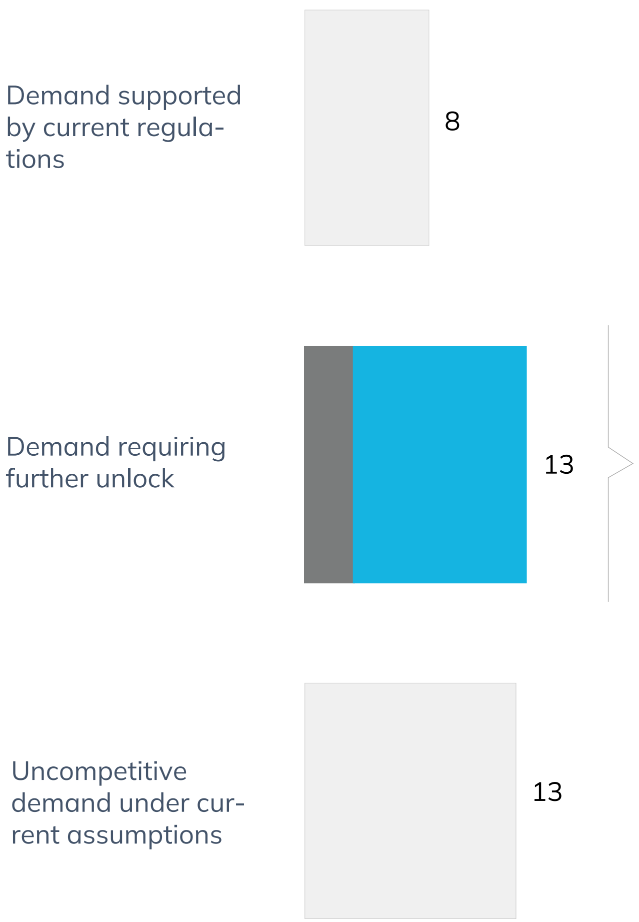
1. Infrastructure can be sized optimally to enable full equipment utilization

Source: Global Energy Perspective 2024, analysis leverages Sustainable Transformation Scenario with MEPC 80 guidance assumed for maritime demand; corresponding to a ~1.8°C warming scenario

~13 Mt p.a. of demand requires further cost and infrastructure unlocks to make clean H_2 demand viable

Mandated or likely renewable demand (green) | Pathway agnostic (likely low-carbon) demand (light blue) | East Asia | EU | USA

Hydrogen demand in 2030 for EU, Japan, Korea, and US, Mt p.a. H_2



	Sectors / regions driving demand		Activation levers	Gap to cost parity, USD/kg H_2
EU	Refining	1.0	Expand CCS infrastructure, CBAM / ETS make low-carbon hydrogen competitive	~0
	Ammonia	1.4		
	Trucking	0.3	REDIII, AFIR[1] and ETS 2 which could drive FCEV uptake, while phasing out allowances	0.4
	Buses	0.1		
	Maritime	0.2	Low carbon quota for maritime fuel	~0
	Ind. Heat	<0.1	Invest in required infrastructure	
USA	Refining	8.1	Invest in additional CCS infrastructure, as well as expand supply side incentives	<0.4
	Ammonia	1.7		0.1-0.5
	Trucking	0.4; <0.1	Invest in HRS infrastructure built to link low-cost supply with heavily utilized corridors	~0
	Buses	<0.1		
	Maritime	0.2	LCFS incentive bridges cost-parity gap	
	Ind. Heat	0.2	Invest in required infrastructure	0.3
	Steel	0.1	Invest in required infrastructure	~0

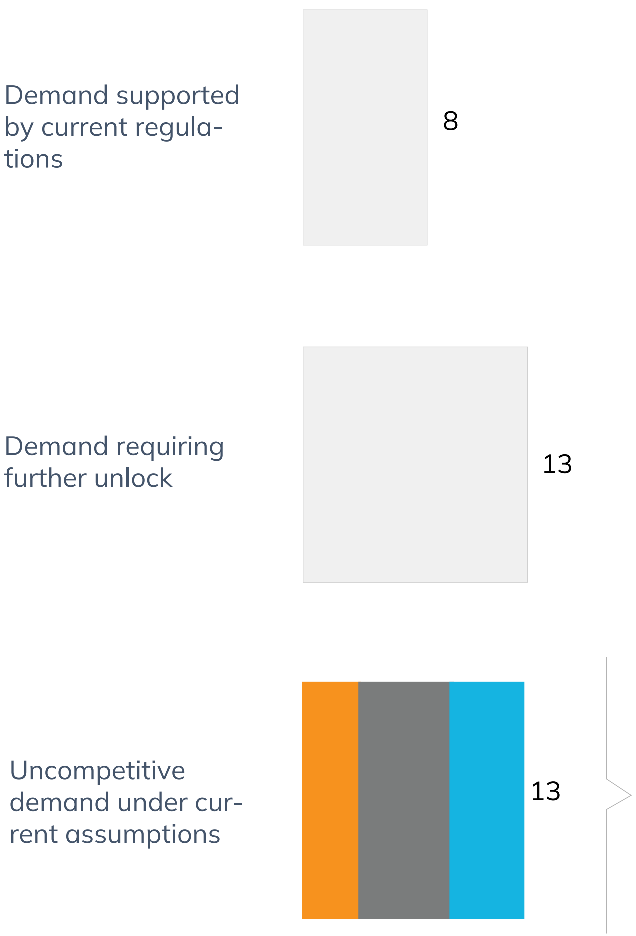
1. Alternative Fuels Infrastructure Régulation

Source: Global Energy Perspective 2024, analysis leverages Sustainable Transformation Scenario with MEPC 80 guidance assumed for maritime demand; corresponding to a ~1.8°C warming scenario

~13 Mt p.a. of demand is likely not viable by 2030, but requires action in the short term to unlock by 2040

Mandated or likely renewable demand | Pathway agnostic (likely low-carbon) demand | East Asia | EU | USA

Hydrogen demand in 2030 for EU, Japan, Korea, and US, Mt p.a. H_2



Region	Sectors / regions driving demand		Activation levers	Gap to cost parity, USD/kg H_2
EU	Refining	1.6	Increase CCS infrastructure	2.4
	Methanol	0.7		2.0
	Maritime	0.5	Emission caps and full implementation of MEPC 80[4]	2.9
	Ammonia	0.4	Promote adoption of clean fertilizers in industry	2.5
	Heat	0.2	Increase incentives to switch for res. and industrial	3.1 – 4.5
	Steel[1]	0.1 0.1	Invest in DRI facilities, delivery infrastructure, and expansion of policy (e.g., LESS[1] in Germany)	~0 – 2.9
	Other[2]	0.1	Varied by application	0.5 – 1.2
Korea, Japan	Refining	2.6	Drive conversion cost down	1.3
	Methanol	0.6	Increase CCS infrastructure; reduce H_2 cost	4.0
	Maritime	0.3	Emission caps and full implementation of MEPC 80[4]	1.3
	Other[3]	0.2	Varied by application	1.7 – 5.1
USA	Methanol	1.3	Increase CCS infrastructure	1.5 – 2.2
	Ammonia	1.3	Promote adoption of clean fertilizers in industry	1.5
	Maritime	1.1	Emission caps and full implementation of MEPC 80[4]	1.0 – 1.1
	Heat	0.8 0.1	Increase incentives to switch for residential and industrial heat applications	2.2 – 2.7 0.8
	Aviation	0.4	Expand demand (e.g., LCFS) and cost levers (E.g., stack IRA 45V and 45Z)	1.7 – 2.4

1. Green steel production may materialize by 2030 given 0.1 Mt p.a. by H2 Green Steel with COD by 2030 accounting for lower range of cost gap estimate
2. Forklifts and trains / rail
3. Residential heat, trucks, steel, industrial heat, buses, ammonia (urea), forklifts and aviation
4. Marine Environment Protection Committee

Source: Global Energy Perspective 2024, analysis leverages Sustainable Transformation Scenario with MEPC 80 guidance assumed for maritime demand; corresponding to a ~1.8°C warming scenario

Glossary of terms

CfD

Contract for Difference scheme in Japan that compensates the difference between the reference and replacement energy cost.

CHPS

Clean Hydrogen Portfolio Standard in South Korea that calls for clean hydrogen or ammonia-based power procurement.

ETS / CBAM

Emissions Trading Scheme / Carbon Border Adjustment Mechanism in the EU market that aims to place a price on the value of carbon within a product (i.e., ammonia takes into account the emissions from the production whether it is imported or produced domestically.

REDIII

Renewable Energy Directive III is the third piece of legislation aimed at promoting renewables within the EU. Among other factors, its sets volume targets for RFNBO based hydrogen and hydrogen derivatives (42.5% by 2030, 60% by 2035).

RFNBO

Renewable Fuel of Non-Biological Origin is the definition for renewable hydrogen or hydrogen derivative in the EU market. Traditional low-carbon hydrogen does not count as RNFBO.

IRA

Inflation Reduction Act in the USA that created the 45V clean H_2 production tax credit along with the expanded 45Q credit for carbon sequestration.

Renewable hydrogen

Electrolytic-derived clean hydrogen produced from renewable energy.

Low-carbon hydrogen

Hydrogen produced with low-emissions technologies with significantly lower greenhouse gas emissions impact than conventional production pathways, based on robust life-cycle analysis-based methodologies for GHG emissions assessment, including i) hydrogen produced using natural gas as a feedstock with SMR or ATR coupled with CCS; ii) hydrogen produced through pyrolysis of natural gas into hydrogen and solid carbon; iii) hydrogen produced through gasification of coal with CCS; iv) hydrogen produced through electrolysis using electricity of non-renewable origin as feedstock.

Clean hydrogen

Combined term referring collectively to hydrogen derived from either renewable or low-carbon pathways.

Grey hydrogen

Hydrogen produced from unabated fossil fuels.

Modeling and assumption details for core policies

Policy	Overview	Interpretation
REDIII	Renewable Energy Directive mandating the use of renewable H_2 in industry and the use of renewable energy across sectors, among other initiatives.	• Volumes of non-compliance are penalized on an emissions basis for each ton of CO_2 emitted by the conventional option. • Targets are assumed to be implemented on an industry basis. • Emission penalties based on REDII values, where available, otherwise average non-compliance value of USD 400/ton CO_2 applied.
ETS / CBAM	Penalty on emitting sectors based on amount of CO_2 released during production.	• ETS and CBAM values were applied on domestic and imported products at an ETS value of USD 135/ton.
US IRA	Created the 45V production credit for clean H_2 (up to USD 3/kg H_2) and expanded the CCUS credit to up to USD 85/ton CO_2.	• Final 'three-pillars' interpretation for "renewable H_2" released in January 2025 was used, resulting in a levelized ~2 USD/kg credit • For low-carbon costs, 45Q credit was used, resulting in a levelized cost impact of 0.5 USD/kg
LCFS	A program in select states aimed at reducing emissions in the transportation sector.	• An average credit value of USD 2.2/kg was added to the value in use for transportation segments. • Historical credit values have ranged from USD 1.5-3/kg.
CfD	Contract for Difference scheme where the government pays the difference between a reference price and the strike price.	• The total value of ~USD 19b would go towards decarbonizing the power sector with ammonia co-fired into coal power plants. • A total volume of ~0.8 Mt p .a. could be unlocked through the current program if spread over the 15-year lifetime of the program.
CHPS	A H_2 (or NH_3) based power procurement program that supports power producers in adopting H_2 based fuels.	• The CHPS program has announced a total of 9,500 GWh, translating in up to ~0.6 Mt p .a. in H_2 demand.


Hydrogen Council
McKinsey & Company