Hydrogen Council

McKinsey & Company

Global Hydrogen Compass 2026

Deploying at scale for resilience, industrial growth, and decarbonization

September 2026

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The Hydrogen Council's Global Hydrogen Compass report builds on nearly a decade of detailed reporting in collaboration with McKinsey & Company and examines where the hydrogen industry stands today, unpacks lessons learned from the first wave of mature clean hydrogen projects, and explores the impact clean hydrogen can have in strengthening energy security and resilience, enabling industrial growth, and unlocking deep decarbonization.

Representatives from the Hydrogen Council member companies were instrumental in delivering the report through ensuring project data is fully up to date, sharing insights around how companies are facing challenges and progressing projects, and volunteering to showcase how a representative sample of projects have come to fruition.

Analysis in this report includes unique qualitative and quantitative insights derived from interactions with over 60 Hydrogen Council members gathered through a sentiment survey and direct conversations with CEOs across the value chain. In the CEO Perspective that opens the report, insights from these interviews and survey results are distilled down into key emerging themes, bringing to light how leaders in the ecosystem are navigating the industry's opportunities and challenges today. The analytical body of the report that follows examines the renewed role of hydrogen in addressing key geopolitical priorities like energy security and resilience, the state of the clean hydrogen industry, including the near-term supply-demand balance, and the emergence of several clean hydrogen ecosystems across the globe.

Unless otherwise cited, analytical findings in this report are based on the Hydrogen Council & McKinsey Project & Investment Tracker – a comprehensive database of clean hydrogen projects that span the value chain from production to distribution to end use. Additional insights throughout the report are based on research delivered in collaboration with McKinsey & Company.

The authors of the report confirm that:

— There are no recommendations and/or any measures 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

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

The calculations in this analysis were conducted based on regulations as formulated in law and drafts as of August 1, 2026. 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.

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 greenhouse gas (GHG) emissions assessment.

This includes i) hydrogen produced using natural gas as a feedstock with steam methane reforming (SMR) or autothermal reforming (ATR) coupled with carbon capture and storage (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 decarbonized electricity of non-renewable origin as feedstock. Renewable and low-carbon hydrogen are collectively referred to as "clean hydrogen". Unabated 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.

While 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 European Union (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.

Hydrogen Council

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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

Supporting members

As of August 2026.

In this report

Building resilience with hydrogen: A letter from the Hydrogen Council Co-Chairs

At a pivotal moment for energy, hydrogen is receiving renewed attention for its ability to help address some of the hardest problems facing our economies and societies: energy security, food system resilience, industrial growth and deep decarbonization. While reducing emissions remains fundamental – and core to the Hydrogen Council's mission since its inception – additional drivers of investment have gained sharply in recognition and relevance, accelerated by recurrent energy crises, geopolitical shocks and market volatility. We are not alone in seeing this shift; it is a recurring theme in our conversations with other CEOs, and a clear message from the Compass.

As countries reduce dependence on narrow energy supply options and strengthen resilience, hydrogen becomes the indispensable partner to increased electrification and the growing use of renewables. It enables renewable power to be stored, transported and integrated across the energy system, helps manage variability and seasonality, and extends the reach of clean power into energy-intensive sectors such as steel, refining and fertilizers.

Around the world, the industry is moving. Committed investment in clean hydrogen has now reached $130 billion across more than 570 projects worldwide, representing 6.9 million tonnes per annum in committed capacity. Operational capacity has nearly doubled in the last 12 months alone, and global CEOs around the world remain focused on project delivery, with 70% of those surveyed for this report expressing continued or even increased investment appetite. We are proud of the investments being made today, and encouraged by the breadth of at-scale projects being delivered across our membership. You will find some of these illustrated throughout the report.

Importantly, the projects moving to construction and operation are concentrated where policy and infrastructure are the most robust – notably in China and Europe. China has identified hydrogen as a key strategic opportunity and is advancing rapidly in operational scale. Meanwhile, Europe has emerged as a primary demand center for clean hydrogen and its derivatives, showing encouraging year-on-year progress thanks to recent policy implementation in some countries. Full ecosystems are emerging on the back of viable business cases, shifting the debate from whether hydrogen could be produced and used at scale to how fast different countries choose to move amidst geopolitical shifts. Chapter 4 highlights four such ecosystems where we see this in action.

The experience of these leading markets also points to the industry's next challenge. Existing policies could unlock some 11 million tonnes a year of clean hydrogen demand by 2030. About 6 million tonnes of that demand is firm today, underpinned by enacted and enforced policy measures. The remaining 5 million tonnes does not need a technological breakthrough or a new strategy or pledge. It is waiting on the decisive and consistent delivery of existing policy commitments, such as the full transposition of RED III targets and implementation of robust carbon pricing mechanisms like ETS and CBAM in Europe. Every month of delay in implementing those measures is a month of investment that does not happen.

In our conversations with fellow CEOs across the Hydrogen Council, members have been consistently clear about what needs to happen next: urgent follow-through on policy implementation. Clear and predictable policies are essential to creating bankable demand, reaching final investment decisions, scaling hydrogen ecosystems, and delivering the solutions our world urgently needs.

These are the themes explored throughout this edition of the Global Hydrogen Compass. What this report makes clear is that hydrogen is no longer a future bet; it is being built now. However, unlike renewables, hydrogen is not a simple plug-and-play solution – it requires a patient, deliberate build-up across multiple layers of the value chain. For this reason, moving from commitments to full-scale deployment depends fundamentally on the stability of enabling policies. By building on what is working and executing on the commitments already made, we can accelerate hydrogen's role in delivering a clean, secure, competitive, and resilient energy future.

Jaehoon Chang

Vice Chair, Hyundai Motor Group

François Jackow

CEO, Air Liquide

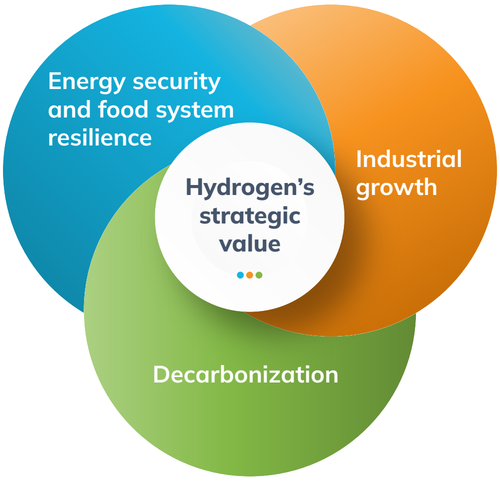
Key findings

Hydrogen has a renewed strategic value in enabling system-wide resilience and industrial growth alongside decarbonization

The drivers of hydrogen uptake are shifting as energy security, resilience, and industrial growth have gained importance alongside decarbonization. The combination of drivers varies by geography: over 60% of committed investment is in regions where security and growth match or exceed decarbonization as primary motivations. Localized clean hydrogen and derivative production could enable import-dependent nations to diversify energy and feedstock supply and develop strategic reserves. By providing alternative sourcing for agricultural and industrial bases, these solutions may reduce supply chain and critical mineral dependencies while shielding food and fuel systems from price spikes and shortages.

As ever more power is supplied by renewables, which now account for nearly 34% of global power generation,[1] the role of demand-response assets like electrolyzers and fuel cells to accelerate renewables integration may become more important. Hydrogen can enable cost savings via long-duration storage, reduced curtailment, and cost-effective transport of energy over long distances. Beyond supporting the energy transition, hydrogen also supports industrial growth as a vector for clean molecule production and new technology supply chains across mobility and industrial applications.

Drivers of hydrogen deployment



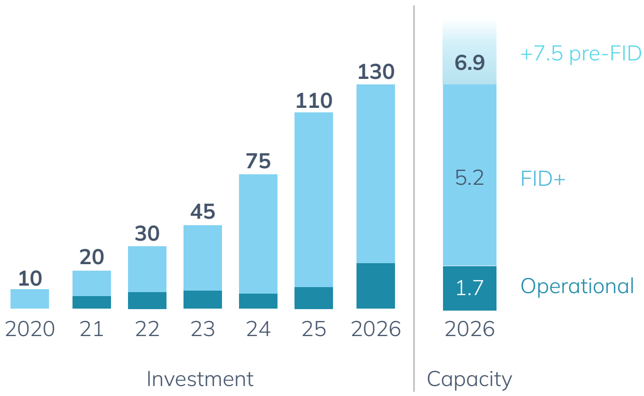
Investment and capacity continue to grow with majority of increases in China and Europe

This year, committed clean hydrogen investment increased to $130 billion, corresponding to 6.9 Mtpa of committed capacity across over 570 projects, of which 90% are under construction or operational. Operational capacity grew 70% to approximately 1.7 Mtpa and is projected to reach about 3.8 Mtpa next year as projects under construction come online.

China leads on renewable hydrogen: it accounts for over half of global committed renewable hydrogen capacity and the majority of new operational renewable capacity since 2025. Since 2020, annual growth in operational capacity in China has been double the global average in all other regions.

Europe now follows as the second-largest region by committed investment, and leads in overall project count. Investment grew by 35% in Europe, supported by the transposition of RED III transport targets in several Member States. The U.S. continues to lead in low-carbon deployment, making up over 75% of committed low-carbon capacity globally.

Global cumulative committed clean hydrogen investment and capacity by 2030, $ billion, Mtpa



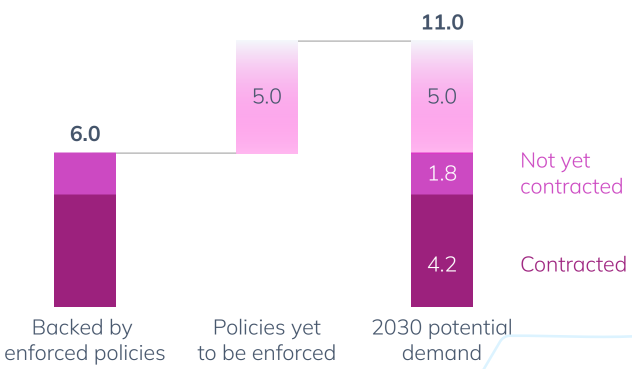
Implementing existing policies could nearly double firm demand by 2030

Hydrogen ecosystems are forming where supply, demand, and infrastructure connect under the right market-forming conditions to create viable business cases. Several such ecosystems are emerging, driven in part by the EU's RED III transport transposition, China's 15th five-year plan, the United States' energy incentives and the Gulf Coast's optimal export positioning, and India's renewable hydrogen and ammonia support mechanisms.[2]

By 2030, 6 Mtpa of demand is supported by policies already in force (e.g., RED III transport quotas transposed into national law, ETS/CBAM as currently implemented). The majority of this demand is matched to supply, with 4.2 Mtpa of binding offtake contracted, 75% of which for existing hydrogen uses like refining and ammonia.

In addition to these 6 Mtpa, another 5 Mtpa of demand could materialize if existing policies are fully implemented (e.g., RED III industry targets are transposed across the EU Member States) although timing and execution of policies would dictate whether such demand could still materialize by 2030.

2030 global clean hydrogen demand by degree of firmness, Mtpa



1. Ember, Global Electricity Review 2026
2. See appendix "Clean hydrogen policies considered" for detailed sourcing on key hydrogen policies

Progress across key regions

Committed investment ($ billion)

2026 2025[3]

China

Largest region by committed investment, deploying at pace on state support and falling costs

China's deliberate shift toward electrification, where hydrogen is an extension of the renewable power system, is reflected in the country accounting for the largest share of committed hydrogen investment at $44.5 billion, of which about $12 billion advanced to final investment decision (FID+)[4] over the past year. This represents a total of ~1.9 Mtpa of committed hydrogen capacity. Deployment continues at pace, accounting for the majority of new operational electrolysis capacity this year, while scale and domestic competition have reduced electrolyzer prices by about 45% since 2020.

Traction is broadening across equipment manufacturing, production, chemicals, mobility and exports, supported by the 15th Five-Year Plan's explicit recognition of hydrogen as a new source of industrial growth and energy security, as well as an enabler for greater resilience and flexibility of the electricity system. Today's demand remains predominantly domestic and driven by state support, although several projects are being positioned to export clean molecules.

Europe

Second-largest region by investment, emerging as the core renewable hydrogen demand center[5]

Europe's reorientation toward targeted hydrogen deployment to address both energy security and decarbonization priorities has supported the region's position as the second-largest region by committed hydrogen investment at approximately $30 billion, over half of which is dedicated to hydrogen end uses. Although projects remain smaller than those in China, Europe accounts for the most committed hydrogen projects globally, representing around 1 Mtpa of committed capacity to date. Given Europe's reliance on imports for a large share of its consumed energy (e.g., nearly 80% of natural gas consumption),[6] Europe's decarbonization ambitions are directly coupled with a renewed focus on energy security and resilience, given recent energy market disruptions.

By 2030, around 5.7 Mtpa of clean hydrogen demand could emerge, supported primarily by decarbonization-focused policies like the EU's Renewable Energy Directive (RED) III alongside carbon pricing signals from the Emissions Trading System (ETS) and Carbon Border Adjustment Mechanism (CBAM) as currently implemented.[7] The transposition of RED III transport targets in particular, including penalties of up to €14/kg in some Member States (e.g., Germany), facilitates competitiveness for renewable fuels of non-biological origin (RFNBO) hydrogen in refining. Implementation is still progressing unevenly across member states, and RED III industry targets remain stalled.

North America

Global low-carbon leader, anchored by the U.S. Gulf Coast

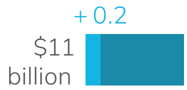
North America remains the global leader in low-carbon hydrogen, holding about 2.9 Mtpa of committed low-carbon capacity (over 75% of the global total). Renewable hydrogen deployment has been limited due to curtailment of the 45V tax credit[8] originally put forth in the Inflation Reduction Act, coupled with challenges in accessing low-cost upstream renewable electricity in some regions. The ~$26 billion in committed investment in the region is heavily concentrated in low-carbon projects that are the largest on average globally (~120 Ktpa), reflecting a scale-oriented purpose-built approach to capture the industrial growth opportunity that clean hydrogen presents.

The U.S. Gulf Coast sits at the center of this opportunity, where stable access to low-cost gas and existing and developing carbon capture, utilization and storage (CCUS) and domestic and export infrastructure combine with confirmed 45Q[9] credits, making it the world's lowest-cost low-carbon ammonia source (as low as $450/t post-45Q). Although growth will rely on further scaling CCUS infrastructure, these elements enable a regional ecosystem of projects advancing to delivery, with the first at-scale greenfield projects reaching FID, starting construction and coming online.

3. 2025 values adjusted to account for announced changes regarding project phasing, production capacities, and project timelines; net regional increases of $24 billion reflect changes measured against restated 2025 baseline
4. Committed investment includes projects that have taken final investment decision, are under construction or are already in operation
5. Includes the United Kingdom and Switzerland
6. See detailed sourcing in Chapter 2
7. Emissions Trading System; Carbon Border Adjustment Mechanism; CBAM implementation commenced in 2026, although several additions and proposed changes are under consideration and may impact the business case for several end-use sectors
8. Section 45V provides a clean hydrogen tax credit (up to $3/kg); originally open to projects starting construction before Jan 1, 2033, updated rules (as finalized in the 2025 federal tax reconciliation act 119-21) curtailed eligibility to require facilities to be under construction by the end of 2027
9. Section 45Q of the Inflation Reduction Act (preserved as part of the 2025 federal tax reconciliation act 119-21) provides a tax credit for capturing and securely storing carbon dioxide, offering up to $85/metric ton CO_2 for industrial point-source capture

Committed investment ($ billion)
2026 2025[3]

Middle East



Industrial-scale renewable production for export, with few new commitments this year

The Middle East is home to some of the largest committed individual hydrogen projects in the world, with approximately $11 billion committed across just 15 projects with a total of ~500 Ktpa. However, the region saw limited new committed investment in the last 12 months (+$200 million), in part due to the majority of projects awaiting a more mature export-oriented offtake market. Nevertheless, low-cost renewable power, competitive access to financing, backing through national programs, and abundant natural gas enable globally competitive renewable and low-carbon hydrogen production costs, positioning the region as a key potential exporter (~$1.5 billion annual export opportunity by 2030).

Japan and Korea

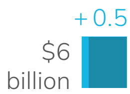
Import-dependent demand centers, investing in distribution and end-use, with emerging liquid hydrogen (LH_2) networks

With limited domestic production capacity (~40 Ktpa committed capacity) but ambitious decarbonization targets and acute interest in bolstering energy security, Japan and Korea's hydrogen investment is focused largely on distribution and end-use (over 90% of committed investment). Both countries are structurally import-dependent, with demand in Japan centered on low-carbon ammonia for power co-firing, largely sourced from the U.S. Gulf Coast so far, and supported by the Contracts-for-Difference (CfD) mechanism, in addition to an emerging mobility ecosystem.

The Korean Clean Hydrogen Portfolio Standard (CHPS) program's ambitions have been curtailed from the original target of 3,000 GWh from hydrogen (2025, suspended) to the new 500 GWh target (2026)[10] and the outlook for ammonia co-firing has been reduced from prior targets. However, home-grown hydrogen mobility ecosystems are also emerging, with early traction seen in deployment of new vehicles (e.g., Hyundai's buses and NEXO passenger cars).

A renewed focus on sourcing domestic clean hydrogen is also emerging although long-term ecosystem scaling likely depends on a combination of local production with securing imported molecules and building the import and trade infrastructure to land them, including via an emerging liquid hydrogen value chain.

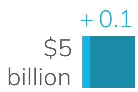
India



Emerging low-cost renewable ammonia for import substitution and potential exports

With around 80% of its ammonia demand[11] met either by imported liquid ammonia or ammonia synthesized from imported natural gas today, India has focused its efforts on reducing import dependence via a central government-supported push to grow domestic renewable ammonia production. Through initiatives like the National Green Hydrogen Mission's (NGHM) Strategic Interventions for Green Hydrogen (SIGHT) auctions (whose first tranche awarded 724 Ktpa of renewable ammonia, expected to displace approximately 25-30% of direct liquid ammonia imports),[12] India is converting government-supported domestic renewable power into low-cost renewable ammonia. India is simultaneously positioning itself as an emerging exporter. Recent long-term offtake agreements between Indian producers such as ACME and Japanese buyers provide early evidence of export demand. These follow AM Green's binding agreement with Uniper for up to 500 Ktpa, one of the first large-scale renewable ammonia contracts between India and Europe, pointing to a widening set of export commitments.[13] This momentum is reflected in CEOs surveyed for this report rating India, alongside China, as one of the two fastest accelerating geographies.

Rest of the World



Fragmented momentum, concentrated in several large export projects

The rest of the world represents broad but fragmented momentum with scale concentrated in a handful of large export projects. Export basins are emerging in Australia, Latin America and several African renewable hydrogen and ammonia corridors. Most of these geographies are earlier-stage, export-led, and contingent on a more established global trade network in order to establish contracted offtake and achieve scale.

10. MCEE, Public Notice of Proposed 2026 Hydrogen Power Generation Bidding Market Volumes (2026)
11. Of the approximately 25 Mtpa of ammonia demand in India, ~6 Mtpa is imported as embedded ammonia in directly imported final products like urea; ~13-14 Mtpa is synthesized from imported natural gas, another 2-2.5 Mtpa is directly imported as ammonia and a further 3-4 Mtpa is synthesized from domestic natural gas; excluding direct imports of finished products, ~15-16 Mtpa of the remaining 19 Mtpa is reliant on imported ammonia or imported gas synthesized in India; see chapter 2 for detailed sources
12. MNRE, SECI's Landmark Green Ammonia tender set to decarbonize India's fertilizer sector 2025; McKinsey Energy Solutions
13. McKinsey Hydrogen Insights Clean Hydrogen Offtake Tracker

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CEO Perspective

As the world's largest CEO-led hydrogen alliance, the Hydrogen Council brings a unique perspective through direct insights from the CEOs building the industry. Through our CEO Perspective, we go beyond the data from our global project pipeline analysis to capture how business and investor leaders across the value chain are navigating the opportunities and challenges of scaling hydrogen.

This year's edition distills the perspectives of nearly 70 leaders from Hydrogen Council members, drawing on a combination of our annual CEO sentiment survey and in-depth CEO interviews.

Participating companies have diversified portfolios that span industries, regions and the broader energy value chain, including industrial gas companies, power utilities, infrastructure players, technology suppliers, project developers, fertilizer producers, oil & gas majors, and automotive OEMs.

Fukushima Hydrogen Energy Research Field (FH2R) | Interior view of renewable hydrogen production facility | image provided by Asahi Kasei

Five distinct themes emerge this year from the survey results and conversations with CEOs:

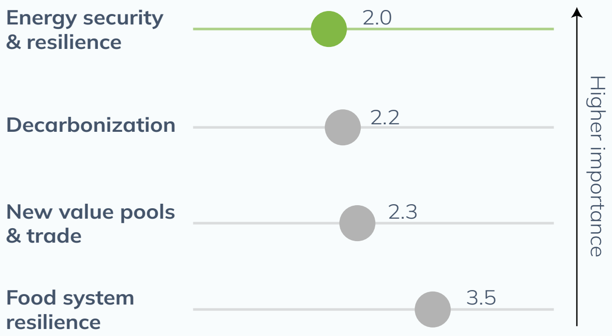
1 | Hydrogen, now more than ever, is a key enabler of global energy security and resilience

CEOs across the value chain emphasize that recent energy crises and rising power demands from rapid electrification and new industrial loads have fundamentally rewritten strategic priorities, elevating the role of clean molecules into a vital geopolitical insurance policy with hydrogen bolstering energy security, resilience, and industrial growth alongside its function as a fundamental decarbonization lever. Furthermore, 64% of CEOs indicated that recent energy shocks accelerated interest in hydrogen.

Leaders see this shift most starkly in heavily energy import-dependent regions like India, Europe, and East Asia where hydrogen is increasingly seen as a necessary pathway to long-term energy diversification and self-reliance. Similarly, European executives highlight how clean molecules address the dual challenge of import reliance and the grid volatility left in the wake of rapid renewable integration, framing hydrogen as a strategic tool to stabilize energy markets.

Looking ahead, energy security and resilience are seen as increasingly important drivers of hydrogen adoption with 74% of CEOs expecting energy security to become an even more prominent motivating factor for clean hydrogen adoption by 2030.

Hydrogen deployment drivers
Mean rank, 1 = highest importance



64% say energy shocks accelerated interest

74% expect energy security to matter more by 2030

> *The conversation has shifted from sustainability targets to immediate industrial resilience – governments now see hydrogen as a strategic solution to protect their industrial base from external shocks.*
> **~ François Jackow, CEO – Air Liquide**

> *Climate remains fundamental, but conversations increasingly focus on energy sovereignty, independence and diversification.*
> **~ Alex Tancock, CEO – InterContinental Energy**

> *Under the current global landscape, energy security and industrial competitiveness have become increasingly critical drivers for the large-scale deployment of hydrogen.*
> **~ Koji Sato, Vice Chairman – Toyota Motor Corporation**

Source: Insights and select quotes derived from interviews and surveys conducted with nearly 70 leaders from a subset of Hydrogen Council member companies from across the hydrogen value chain; analytical findings sourced from Hydrogen Insights Project & Investment Tracker as of June 2026

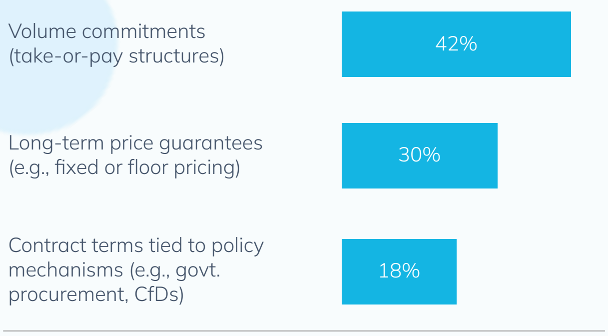
2 | **Hydrogen has shifted from vision to execution** as the project pipeline continues to mature and rationalize

Consistent with last year's findings, industry leaders continue to see an ongoing rationalization of the project pipeline. Uncertain demand signals stemming from prolonged implementation of policies, as well as persistent cost challenges, have led to delays and in some cases cancellations, leading to several major public write-offs, reductions in headcount and industry consolidation.

However, CEOs do not view this rationalization as a sign of overall slowing ambition. While CEOs recognize the real costs associated with project cancellations and shifting hydrogen strategies, over 70% of leaders have either held steady or even increased their investment appetite since last year. Many CEOs ultimately see this phase as a natural, albeit challenging, step in the industry's ongoing maturation, with projects now advancing to final investment decision (FID) increasingly underpinned by strong industrial capabilities and robust business cases. CEOs point out that the projects successfully reaching FID are invariably led by world-class industrial operators with proven track records in deploying hydrogen technologies, building clean energy and trade infrastructure, and navigating complex policy landscapes.

In many cases, the projects moving forward are those that have built a distinct competitive advantage, such as access to a uniquely low-cost power source (e.g., proximity to a hydroelectric asset with excess capacity), an existing infrastructure backbone like the U.S. Gulf Coast domestic transport and export terminals, or reduced cost of capital, sometimes in the form of government-guaranteed financing. The companies leading these projects are characterized by their willingness to form deep, cross-value-chain partnerships, and focus where they have proven core competencies rather than trying to own the entire ecosystem, coupled with a strict 20-to-30-year investment and development horizon focused on long-term asset competitiveness.

What de-risks a hydrogen project
Most critical contract feature (non exhaustive)



70% held steady or increased investment appetite in last 12 months

> *The projects that are moving forward most successfully are those that establish real partnerships across the value chain and find the intersection of interests, rather than doing it alone.*
> ~ **Chris Bohn, CEO – CF Industries**
>
> *We're still in the industrial-cluster phase – connective trade and infrastructure is the missing layer, and likely the key enabler of the next phase of growth.*
> ~ **Maarten Wetselaar, CEO – Moeve**
>
> *The future of hydrogen will be decided by economics. As long as a significant cost gap remains, renewable hydrogen will struggle to scale. Closing this cost gap is essential to creating a sustainable hydrogen market.*
> ~ **Anne-Laure de Chammard, Member of the Executive Board – Siemens Energy**

Source: Insights and select quotes derived from interviews and surveys conducted with nearly 70 leaders from a subset of Hydrogen Council member companies from across the hydrogen value chain; analytical findings sourced from Hydrogen Insights Project & Investment Tracker as of June 2026

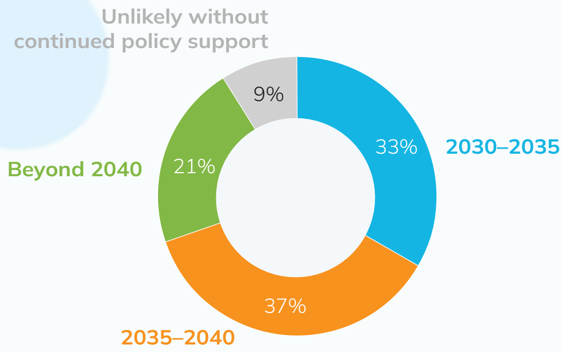
3 | Deploying hydrogen is not a plug-and-play exercise; building an end-to-end value chain requires its own playbook distinct from the deployment model for renewables

Executives widely agree that it would be misleading to compare the deployment of hydrogen to the rapid build out of wind and solar, pointing out that renewable power benefited enormously from plugging into a pre-existing power grid. By contrast, developers stress that for many end-uses, hydrogen requires an entirely new, multi-layered physical value chain including supply, storage, transport, and demand, all in unison, with several drawing more parallels to the early stages of other industries (e.g., LNG). Deployment of clean hydrogen in existing use cases like refining and ammonia can utilize some of the existing infrastructure but still requires several changes to existing value chains.

Two thirds of CEOs are confident that hydrogen can become self-sustaining by 2040 (i.e., functioning with limited to no ongoing subsidies or incentives beyond cost-of-carbon mechanisms like ETS). Still, none expect this before 2030, reflecting the long timelines, long-term investment horizon, and full value chain coordination required. Leaders across the value chain are also maintaining their own long-term ambitions for clean hydrogen, with 68% having maintained their hydrogen strategies over the last 18 months.

Even among those who have altered their near-term hydrogen strategies, 58% say their long-term hydrogen ambitions remain intact. From their perspective, the systemic complexity of building a global clean hydrogen industry requires developers to carefully coordinate massive upstream power and feedstock inputs with complex chemical processing and highly volatile downstream offtake. Industry leaders urge both investors and policymakers to adopt the strategic plans and practical measures needed to deliver industrial-scale ecosystems rather than expecting the plug-and-play immediacy of the power sector.

When the market becomes self-sustaining



68% of respondents retained their existing hydrogen strategies over the last 18 months rather than pivoting away from prior ambitions of the respondents that did shift strategy

58% are retaining their long-term ambitions despite delaying near-term hydrogen ambitions, and no respondents indicated an overall pullback on ambitions

The debate has shifted from whether hydrogen can deliver to how fast countries choose to build. Where countries deploy the whole hydrogen chain suited to their own context and back it with policy, competitive ecosystems are taking hold.
~ Jaehoon Chang, Vice-Chair – Hyundai Motor Group

Hydrogen only scales when the whole value chain moves together – production, conversion, transport, reconversion and demand. Building supply and hoping demand follows doesn't work.
~ Yoshinori Kanehana, Chairman – Kawasaki Heavy Industries

A project only moves forward when everything comes together – a customer willing to sign off-take, mature technology, a competitive energy source and clear risk allocation. Investment decisions are driven by secured customer off-take commitments, not market projections alone.
~ Sanjiv Lamba, CEO – Linde

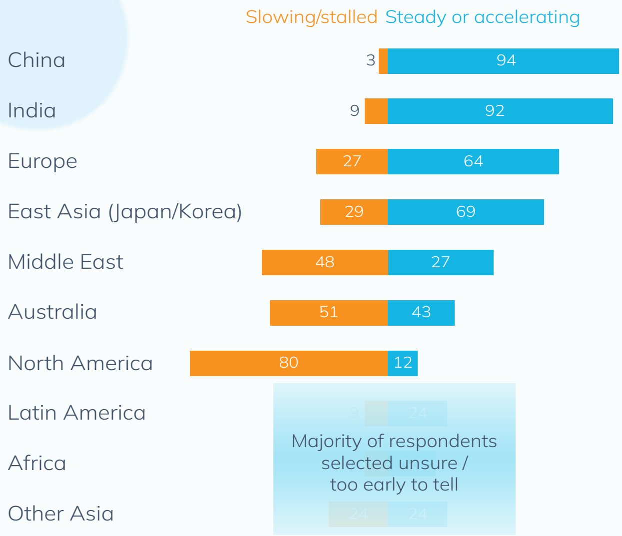
Source: Insights and select quotes derived from interviews and surveys conducted with nearly 70 leaders from a subset of Hydrogen Council member companies from across the hydrogen value chain; analytical findings sourced from Hydrogen Insights Project & Investment Tracker as of June 2026

4 | While perceived industry momentum and investment appetite remain strong, **the field is diverging as some Asian countries run ahead and some Western geographies struggle to translate ambition into execution**

While CEOs maintain a positive overall outlook for clean hydrogen, interviews and survey results reveal a stark geographical gap: CEOs observe that regions with assertive, state-backed demand signals, namely China's rapid build-out and India's domestic security drive, are leaving other countries and regions behind with over 90% of respondents indicating they see either steady or accelerating momentum in these two economies.

European executives, meanwhile, point to positive policy signals, such as the transposition of RED III transport targets, coupled with an established carbon pricing framework via ETS and CBAM (subject to its continued integrity), alongside regional infrastructure planning, they note the overall regulatory outlook remains uncertain. In the U.S., developers report that renewable hydrogen momentum has been slowed by the accelerated phaseout of the 45V tax credit project eligibility, although they highlight that several large-scale low-carbon projects continue to advance based on existing stable supply-side policies, combined with other resource and infrastructure advantages. Meanwhile, leaders see a scale-up in emerging economies contingent on a larger demand pull for exports.

Perceived regional momentum
% of respondents[1]



68% expect China's hydrogen deployment to accelerate global adoption

1. Totals may not add to 100% due to rounding and portion of respondents indicating unsure/too early to tell

> *China is clearly moving full speed ahead, especially in mobility and electrolyzer manufacturing – it's become the global proof point that removes the 'will hydrogen work?' question and builds confidence to scale elsewhere.*
> ~ **Nicholas Loughlan, Managing Director and CTO – Cellcentric**

> *Clean hydrogen has made remarkable progress in a very short period, although it is somewhat less visible. As indicated later in the report, the committed hydrogen projects could already enable almost the same amount of CO_2 emissions abatement as all BEVs in operation worldwide. Deployment even outpaces expectations in several regions, despite the complexities in building new ecosystems from the ground up.*
> ~ **Pierre-Etienne Franc, Chairman – FiveT Hydrogen AG**

> *Advanced projects require two things: stable, diversified demand and true global cost competitiveness.*
> ~ **Lee Young-jun, CEO – Lotte Chemical**

Source: Insights and select quotes derived from interviews and surveys conducted with nearly 70 leaders from a subset of Hydrogen Council member companies from across the hydrogen value chain; analytical findings sourced from Hydrogen Insights Project & Investment Tracker as of June 2026

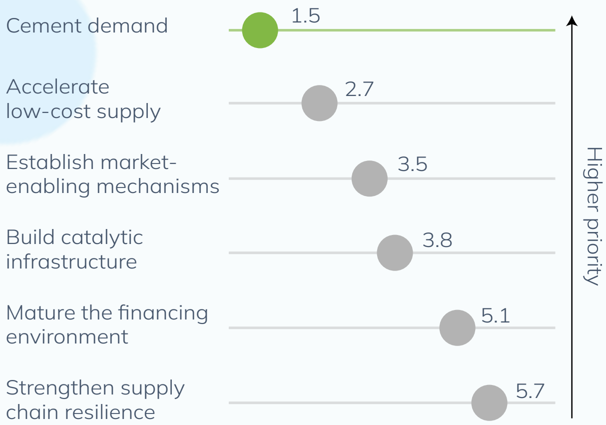
5 | Projects cannot progress to FID without bankable offtake backed by policy; CEOs suggest that **stable execution of existing policy, even more so than new regulatory design, is the highest priority to firm the potential demand**

CEOs note that although capital is available, projects cannot reach FID without bankable, long-term offtake backed by stable rules – making firm demand the industry's top priority (cited by 74% of respondents). CEOs point to actionable and stable supply and demand policy tools like the UK and Japanese CfD mechanisms, the U.S. 45Q credit, and transposed RED III transport targets as examples that deliver the commercial clarity needed to write contracts.

Conversely, they note that high-potential frameworks such as Europe's RED III industrial RFNBO mandates, contract-for-difference schemes for eSAF and maritime fuels, and global International Maritime Organization (IMO) shipping targets face delayed implementation. Consequently, 84% of respondents prioritize finalizing and executing existing policy with the majority emphasizing full implementation of current policies, ahead of designing new incentives, to support the clarity, stability, and pragmatism needed to turn potential demand into bankable offtake.

Industry priorities

Mean rank, 1 = highest priority



74% ranked "Cement demand" as the #1 priority for bolstering industry growth

84% prioritized implementing existing policy frameworks; more than 70% of this group selected enforcing current regulations over drafting new legislation

Hydrogen offers among the lowest climate-impact solutions for aviation. All actors in the hydrogen economy, as well as governments and policymakers, need to work together to create the right conditions today to scale up hydrogen infrastructures and optimize costs. This collaboration is essential to enable short-term growth and support the aviation industry's ambition to reach net-zero CO_2 emissions by 2050.
~ Lars Wagner, CEO of the Commercial Aircraft business – Airbus

Hydrogen does not need a new vision - it needs execution through pragmatic regulatory frameworks that support early-stage deployment, reflect operational realities and enable the market to scale.
~ Wael Sawan, CEO – Shell plc.

A priority is to better connect producers and buyers, from demand enabling mechanisms all the way to physical transport and storage infrastructure, which is essential to create liquidity, improve reliability and give both producers and offtakers the confidence to commit.
~ Philippe Guillemot, CEO – Vallourec

Source: Insights and select quotes derived from interviews and surveys conducted with nearly 70 leaders from a subset of Hydrogen Council member companies from across the hydrogen value chain; analytical findings sourced from Hydrogen Insights Project & Investment Tracker as of June 2026

02

Hydrogen’s renewed strategic value in a volatile energy environment

Persistent global energy market disruptions illustrate and reinforce hydrogen’s role across three complementary and interconnected geopolitical priorities:

— Strengthening energy security and food system resilience

— Enabling industrial growth through value capture in new and growing markets

— Decarbonizing energy-intensive industries

NEOM Green Hydrogen Project | Aerial view of renewable hydrogen production facility | image provided by thyssenkrupp nucera

Hydrogen's strategic value has a renewed relevance in bolstering resilience and enabling industrial growth, alongside deep decarbonization

The global energy system is entering a period of structural transformation. Energy demand, including for power generation, is rising rapidly as new demand centers emerge, economies electrify, and energy-intensive sectors expand. At the same time, recent energy crises have underscored the volatility of global energy markets and exposed the vulnerabilities created by import dependence, concentrated supply chains, and limited system flexibility. In parallel, renewable power penetration is accelerating in some regions, reshaping how energy is produced, transported, stored, and consumed.

Policy is reinforcing this shift in many parts of the world. Electricity made up about 20% of global final energy consumption in 2025 and is projected to reach 24% by 2030 based on IEA figures. The incoming COP31 Presidency proposed a global 35% electrification target by 2035, while the European Commission has proposed the Electrification Action Plan, which sets an indicative 46% electricity share of final energy consumption by 2040.[14]

These shifts are creating a new set of system challenges. Growing energy demand, in part from new industrial-scale loads like data centers serving the rapid adoption of artificial intelligence models and tools, alongside broader electrification, is intensifying competition for clean electrons and placing additional stress on already constrained grid infrastructure, with over 2,500 GW of renewable, large-load and storage projects now stalled in grid queues worldwide.[15] New grid infrastructure can take longer to deliver than the asset waiting to connect, with 5 to 15 years against 1 to 5 years for renewables and 1 to 3 years for data centers, a mismatch the IEA identifies as a critical bottleneck – although there are instances where hydrogen could help alleviate such bottlenecks, for example via adoption of fuel cells for behind-the-meter power configurations.

Disruptions in energy and chemical feedstock supply are increasing the risk of power outages, food security challenges and price spikes, inflationary pressure, and resource scarcity, particularly in regions with high import exposure. The rapid deployment of electric vehicles and batteries, while a strong driver of electrification, also creates concentrated supply chain dependencies. Meanwhile, higher renewable penetration is introducing greater variability in energy supply, requiring significant grid investment, expanded storage capacity, solutions to reduce curtailment, and new pathways to move energy from optimal renewable production regions to major demand centers.

1 | Energy security and food system resilience

Hydrogen can bolster energy resilience, enabling integration and build out of new renewable power to meet rising energy demand – the existing committed renewable hydrogen pipeline alone would already support 50-55 GW of net-new renewable power generation

Hydrogen can strengthen energy security and independence, maximizing the use of domestic resources and diversifying energy sourcing – several regions (e.g., the EU, India, East Asia) with 50-100% energy import reliance are already building home-grown hydrogen programs or shifting sourcing away from disrupted supply centers

Hydrogen can increase agri-food system resilience, delivering reliable, sustainable, and affordable solutions that mitigate exposure to price shocks and supply disruptions for farmers, food companies and consumers – in India, a domestic base of renewable ammonia could mitigate significant crisis-driven price swings in staple foods like rice and minimize the already substantial government support outlays for the agricultural sector

2 | Industrial growth

Hydrogen enables new industrial value pools and export opportunities – for instance, the United States is developing new low-carbon ammonia export markets via strategic trade corridors; China is shifting from fossil energy importer toward electro-state exporter, already accounting for >60% of global electrolyzer manufacturing capacity, the EU is leveraging an existing base of manufacturing to serve domestic and export markets, with other regions like the Middle East, India, Latin America, Oceania and Africa potentially tapping into abundant resources to serve emerging domestic and export demand

3 | Decarbonization

Hydrogen remains a critical decarbonization lever – clean hydrogen is the most cost-efficient or logistically feasible decarbonized alternative for hard to electrify industrial sectors, heavy duty transport, chemical & energy feedstocks

14. UNFCC, COP31 Presidency announces new targets on global electrification, cutting waste, resilient cities, 2026; European Commission, Electrification Action Plan (2026)
15. IEA, Electricity 2026

Hydrogen, when deployed under the right conditions, can play a complementary role alongside electrification and other technologies (e.g., batteries, biofuels) in addressing these challenges, enabling a more secure, diversified, resilient, and competitive clean energy and industrial system. As an energy carrier, industrial feedstock, storage solution, and exportable clean molecule, hydrogen can strengthen energy security and support the integration of renewable power while unlocking home-grown energy and diversifying supply chains. By serving as a long-duration energy buffer and low-emission fertilizer input, hydrogen can bolster energy and food system resilience, allowing countries to proactively insulate against, absorb, and recover from energy price volatility, supply chain shocks, and extreme weather-driven disruptions. Hydrogen can also create pathways for industrial growth, including via clean fuels, low-carbon chemicals and fertilizers, new mobility applications, and cleantech leadership.

Different combinations of energy security, industrial growth, and decarbonization are driving hydrogen deployment across geographies

While individual projects often serve multiple objectives, distinct public initiatives suggest that the strategic rationale for investing in clean hydrogen varies by geography. Hydrogen is distinctive in that it can help address several of today's most prominent geopolitical priorities at once, even as the relative weight of each priority differs by region.

In **Europe,** hydrogen deployment is anchored in decarbonization policy, including RED III requirements for renewable fuels of non-biological origin in transport applications, alongside carbon-pricing mechanisms such as the ETS, coupled with trade measures like CBAM.[16] Europe's energy import dependence and rising power needs also elevate hydrogen's role in diversifying supply, supporting domestic industrial value chains, and adding flexibility to a renewable-heavy grid, as originally outlined in the 2022 REPowerEU strategy.[17] Continued coordinated policy implementation, anchored in the upcoming revised EU Hydrogen Strategy, could support further durable clean hydrogen demand across industries, fuels, and power system flexibility.

In **China,** hydrogen (and hydrogen technologies like fuel cell vehicles) is prominently positioned as a strategic pillar of the 15th Five-Year Plan period, with policy direction emphasizing energy security, technology self-reliance, and the scale-up of clean industrial fuels and feedstocks. The focus is shifting from demonstration toward industrialization, including electrolyzer manufacturing, renewable hydrogen production, hydrogen-based chemicals, and regional clean hydrogen clusters. This reinforces China's broader strategy to build domestic demand, scale equipment manufacturing, and extend clean technology leadership into hydrogen, renewable ammonia, methanol, and other clean molecules.

In **Japan and Korea,** hydrogen deployment is driven by its dual role in strengthening energy security and addressing ambitious decarbonization goals. Given limited domestic renewable and gas resources, both countries are likely to remain structurally reliant on energy imports. Hydrogen offers the potential to diversify future supply across a broader set of partner regions, such as the Americas, China, India, and the Middle East, rather than relying on concentrated energy supply chains. Notably, Japan's draft $2.3 trillion (¥370 trillion) public-private investment roadmap, published in June 2026, anchors this with $38 billion (¥6.2 trillion) to FY2040 for hydrogen and derivatives, framing hydrogen and derivative deployment around economic security and the export of Japanese technologies to global markets.[18]

Japan's 2023 revised Basic Hydrogen Strategy targets up to 3 million tonnes of hydrogen use by 2030, rising to approximately 20 million tonnes by 2050,[19] while Korea's 2019 Hydrogen Economy Roadmap targets 6.2 million fuel-cell vehicles and at least 1,200 refueling stations by 2040.[20] More recently, Korea has also increased its focus on domestic hydrogen production through revisions to the CHPS framework, with the Saemangeum project linking locally produced renewable hydrogen supply to demand from advanced industries including AI, robotics, and future mobility. Both countries also see growth opportunities in hydrogen technologies, infrastructure, mobility supply chains, and liquid hydrogen and carrier systems.

In **India,** hydrogen and clean derivatives are primarily linked to energy and agrifood security and strategic resource positioning. The country currently depends heavily on imports to meet a significant share of its ammonia and fertilizer demand, exposing it to global commodity volatility and supply disruption. Through the NGHM, which targets 5 Mtpa of renewable hydrogen production by 2030 enabled by the SIGHT incentives, policymakers aim to utilize domestic renewable resources, coupled with support mechanisms, to produce hydrogen and downstream derivatives, thereby reducing import dependence while strengthening India's position in emerging clean molecule trade.[21]

16. Proposed reforms under review for both the EU ETS and CBAM may adjust free allowance phase-out schedules, reporting rules, and scope coverage for hydrogen and downstream derivatives, altering these mechanisms' impact on end-user value-in-use
17. European Commission, REPowerEU, 2022
18. Cabinet Office, Government of Japan, Public-Private Investment Roadmap across 17 Strategic Sectors (2026)
19. Ministry of Economy, Trade and Industry (METI), Government of Japan, Basic Hydrogen Strategy (Revised) (2023)
20. Ministry of Trade, Industry and Energy (MOTIE), Government of the Republic of Korea, Hydrogen Economy Roadmap of Korea (2019); International Energy Agency, Korea Hydrogen Economy Roadmap 2040 (2021); IEA Policies Database
21. PIB, Unlocking India's Green Hydrogen Production Potential (2025)

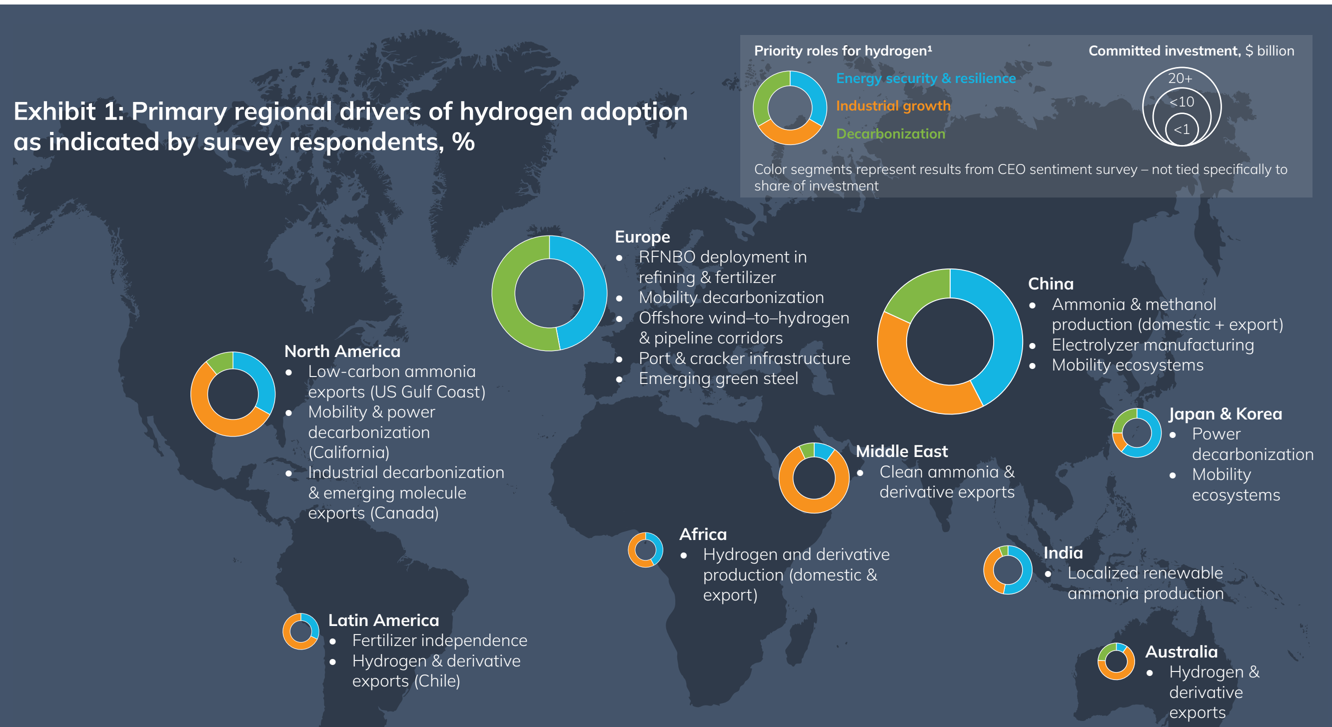
In the **United States,** with its strong energy and geographic resources, alongside significant industrial production and conventional demand, hydrogen offers a new vector for industrial growth and a way to enable food system resilience in several destination end-markets through low-cost ammonia production. Firm supply-side policy in the form of the 45Q tax credit and growing CCUS infrastructure build-out are supporting low-carbon hydrogen and other carbon-managed industrial projects by improving the economics of CO_2 capture and storage and helping projects move toward FID.

In the resource-rich **Middle East,** national strategies such as the UAE National Hydrogen Strategy build on advantaged resources, infrastructure, and export capabilities to position low-emission hydrogen as a future growth platform.[22] Energy supply and transit disruptions driven by current regional volatility are being met with alternative transport build-outs that may have implications for hydrogen as well.

Similar dynamics are emerging in other regions where energy security and industrial growth are driving hydrogen and ammonia deployment. **Australia** is positioning itself as an exporter to global markets through clear government support mechanisms, such as the Hydrogen Production Tax Incentive (HPTI), which pays A$2 per kilogram of eligible renewable hydrogen produced for up to ten years per project.[23] **Africa,** in addition to serving domestic demand, is similarly focused on exports, with more than 80%[24] of the continent's announced ammonia capacity slated to serve demand in other geographies. Here, governments are focusing on attracting foreign investment by reducing the cost of capital, for example through offtake guarantees and concessional financing.

In **Latin America,** approaches differ by country. Brazil, heavily reliant on imported fertilizer, is pushing to reduce that dependence through domestic renewable ammonia production, backed by programs such as PROFER, which sets explicit benchmarks for the domestically-produced share of fertilizers alongside tax incentives for producers.[25] Chile, by contrast, has shifted its focus toward the deployment of hydrogen in hard-to-electrify sectors by leveraging the country's extensive renewable resources.[26]

Exhibit 1: Primary regional drivers of hydrogen adoption as indicated by survey respondents, %



1. % of survey respondents who selected a given leading driver of hydrogen in each market; Insights derived from interviews and surveys conducted with nearly 70 leaders from a subset of Hydrogen Council member companies from across the hydrogen value chain; analytical findings sourced from Hydrogen Insights Project & Investment Tracker as of June 2026

22. UAE, National Hydrogen Strategy (2024)
23. Australian Taxation Office, Hydrogen Production Tax Incentive (2025)
24. IEA, Global Hydrogen Review 2026 - Africa
25. Profert Law, Bill PL 699/2023 (2026)
26. Ministry of Energy, Chile, Green Hydrogen Strategy (2026)
Source: Insights derived from interviews and surveys conducted with nearly 70 leaders from a subset of Hydrogen Council member companies from across the hydrogen value chain; analytical findings sourced from Hydrogen Insights Project & Investment Tracker as of June 2026

The following deep dives showcase how these three drivers reinforce one another in practice: First, hydrogen can address several system-wide challenges in increasingly renewable grids, strengthening resilience while accelerating the decarbonization of the energy system. Second, hydrogen can reduce exposure to concentrated supplies of volatile energy and feedstock imports while building new domestic industries in the case of emerging renewable ammonia production centers. Third, hydrogen can allow countries to tap into substantial energy resources, existing export infrastructure, emerging manufacturing bases, or a combination of these to promote new avenues of industrial growth via clean molecule exports, technology scale-up (e.g., electrolyzers, fuel cells, new vehicle drivetrains, and derivative reconversion) and regional value chain development.

Deep dive: Renewable hydrogen accelerates the shift to a renewable energy system

Rapid renewable deployment creates several energy system challenges that could limit the pace of further deployment – hydrogen can address several of those challenges, accelerating the energy transition. The ongoing shift toward further renewable deployment can be segmented into three conceptual phases:

1 | Initial build-out: Renewables scale through technology improvements and policy support.

The first phase of the energy transition was driven by rapid cost reductions in wind and solar, supported by government incentives and renewable deployment targets. As these technologies matured, renewable electricity became the lowest-cost source of new power (when available) in several countries, accelerating its deployment and enabling the electrification of light transport, buildings, and several industrial sectors

2 | Deployment surge: Electrification accelerates as renewables become the backbone of new power systems. As renewable generation expands, electricity increasingly becomes a preferred energy carrier across a wider range of economic sectors. However, once renewables supply a significant share of generation, the challenge shifts from building capacity to integrating it. Grid congestion and instability, power curtailment, seasonal variability, long-duration storage needs and transmission constraints begin to limit the pace and economics of further renewable deployment.

3 | System integration: Renewable hydrogen could enable deeper electrification and decarbonization. As energy systems move toward higher renewable power penetration and decarbonization of a broader range of energy-intensive industries, renewable hydrogen can act as an important complement to direct electrification by converting surplus renewable electricity (or renewable electricity in cost-optimal production areas) into molecules and feedstocks that can be stored, transported and used when and where electricity is most constrained. Flexible hydrogen production also offers a solution to mitigate curtailment and ease transmission bottlenecks in addition to partially balancing the grid.

Simulations of select future energy systems have indicated that, under the right conditions, highly renewable systems (~95%) that incorporate flexible hydrogen production could benefit from a combination of these mechanisms on the order of 10–20% cost savings[27,28] compared to alternative scenarios with limited hydrogen deployment, even after accounting for several added complexities, including round-trip efficiency losses, electricity price swings, electrolyzer capex and capacity factors, and the added process complexity of converting electrons to molecules. One example that illustrates hydrogen's energy storage potential today is the Advanced Clean Energy Storage (ACES) project in Utah. With a storage capacity of up to 300GWh, stored hydrogen will be used to provide firm power to the California grid, helping the state work toward its 2045 zero-carbon electricity goal as energy is provided from Utah to Southern California via existing power lines and generation infrastructure.

Similar mechanisms are being demonstrated across Europe with several examples illustrating where even smaller scale hydrogen projects can enable energy system integration. On the balancing side, HyBalance operates in sync with grid operators to make efficient use of offshore wind, and Germany's Green H_2 Osterweddingen, a 10 MW proton exchange membrane (PEM) electrolyzer under construction, is expected to produce around 900 tonnes of renewable hydrogen a year in its first expansion phase for local industrial companies. It is planned to run in a grid-supportive manner that balances fluctuations in wind and solar generation and helps relieve strain on the power grid. On the storage side, the Bad Lauchstädt Energy Park pairs renewable hydrogen production with cavern storage to add flexibility to the surrounding system, while in southern Denmark, the Nature Energy Glansager project, operating at its full 9.3 MW capacity since 2024, absorbs surplus renewable electricity into hydrogen that is biologically methanated with CO_2 from an adjacent biogas plant to yield about 3.3 million cubic meters of e-methane a year.

In other instances where existing electricity transmission is not available, and optimal power production sites are over 750 km from demand centers, hydrogen pipelines can carry energy – in some cases up to 15-20% more cost-effectively than moving the equivalent energy via new transmission infrastructure.[29]

27. Shiraishi et al. (2024) estimates that excluding hydrogen storage from Japan's 2050 zero-carbon power system would increase average electricity costs by ~20%, requiring an additional 25 GW of VRE, 15 GW of interregional transmission, and 37 GW of battery capacity vs. the least-cost hydrogen-enabled scenario
28. Yang, Haozhe, et al., "Economic Benefits and Cost Competitiveness of Green Hydrogen in Decarbonizing China's Electricity and Hard-to-Electrify Sectors." (2025)
29. Assumes 36" hydrogen pipeline at 75% utilization, transmission costs based on 500 kV estimated transmission fee over 750+km and increased cost experienced by electrolyzer operator

Hydrogen can also already provide one of the few scalable, deployable decarbonization options for several energy-intensive industries today, including chemicals, fertilizers, shipping, aviation, heavy-duty road transport, and high-temperature industrial heat. While existing end uses like refining and ammonia production have already gained traction, several other end-use sectors are moving from concept to reality. In shipping, European Energy's Kassø plant now supplies Maersk with renewable e-methanol that fuels the world's first methanol-powered container vessel.

Meanwhile in Europe, companies like Norsk e-Fuel and Boeing, as well as OMV Petrom, are advancing synthetic jet fuel deployment to boost resilience and cut emissions in aviation. In parallel, companies such as Airbus are expanding into the development of innovative technologies like new powertrains to bring hydrogen to commercial aviation. In road transport, hydrogen is already in service, for example, in municipal transit fleets in California and around 3,000 of Hyundai's city buses deployed in Korea, while China operates the world's largest hydrogen vehicle fleet at over 32,000 fuel-cell vehicles.[30] Passenger car uptake is also emerging, as in the case of nearly 10,000 units of Hyundai's new-generation NEXO being deployed since its 2025 launch, among other deployments of vehicles in several regions.

By increasing system flexibility, strengthening resilience, creating new demand for renewable power, and offering a feasible pathway to decarbonization, clean hydrogen can enable the next phase of the energy transition while extending decarbonization beyond the power sector. The committed clean hydrogen project pipeline alone is set to pull through an additional 50–55 GW of purpose-built renewable capacity from FID+ projects by 2030.

Advanced Clean Energy Storage Project (Utah, US)

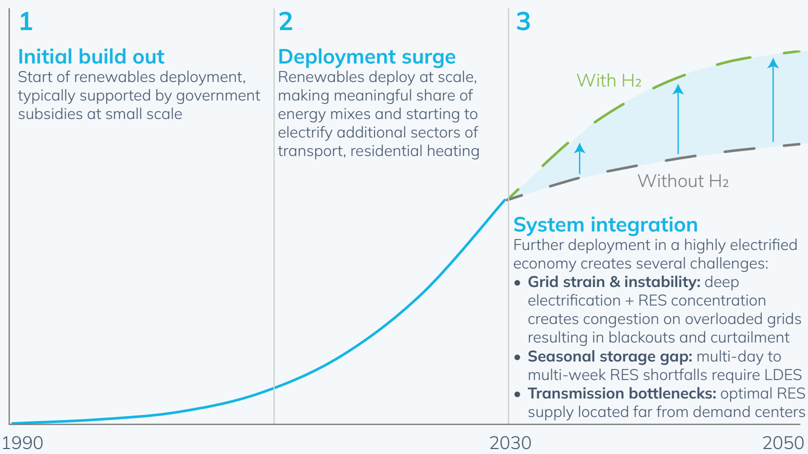
End-use: power | Operational

Project spotlight

A major value of renewable hydrogen is resilience through long-duration storage that supports a renewable grid; the ACES Delta project provides a clear example of that role at scale. Leveraging available renewable energy resources in the western United States, the project is developed as one of the largest renewable hydrogen conversion and storage facilities in the United States. The first phase includes a 220 MW alkaline electrolyzer facility capable of up to 100 TPD of renewable hydrogen at full capacity stored in two salt caverns. The stored hydrogen is initially blended with natural gas and supplied to 840 MW of CCGT using Mitsubishi Power's hydrogen-ready M501JAC gas turbines, with an expected transition to 100% hydrogen operation by 2045. Chevron's New Energies division secured a majority interest through the acquisition of Magnum Development from Haddington Ventures. Together with Mitsubishi Power's technology and long-term service support, the project illustrates how long-duration storage supporting a renewable grid can enable highly renewable systems to remain reliable.

Exhibit 2: Mechanisms for hydrogen to accelerate transition to future energy system

After a phase of rapid renewable power adoption, new challenges could limit the pace of further deployment ...
System-wide share of clean energy, %



... hydrogen addresses those challenges, accelerating the energy transition

Faster • Deploy additional renewable capacity • Alleviate grid constraints	**50-55 GW** additional purpose-built RES from FID+ projects by 2030[1]
Cheaper • Mitigate curtailment • Avoid transmission bottlenecks	**10-20%** potential power system cost savings in select highly renewable grids[2]
More resilient • Build in flexible demand • Enable long-term energy storage • Transport clean energy globally	**15-20%** lower energy transport cost per MWh via H_2 pipelines vs. power lines over long distances (>750km)[3]

1. Illustrative estimate based on 75% electrolyzer utilization, 40% blended RES capacity factor and ~10% headroom for curtailment/losses. Excludes renewable H_2 projects sourcing energy/power from renewable natural gas, biomass, nuclear, hydropower or geothermal
2. Based on a no H_2 storage vs H_2 enabled system and >95% renewables as modeled in Shiraishi et al., LBL
3. H_2 pipeline assumes 36" and 75% utilization, Tx based on 500 kV estimate transmission fee over 750+km and increased cost experienced by electrolyzer operator

30. National Energy Administration of China, 2026
Source: IEA, Electricity 2025; Kenji Shiraishi et al, "The role of hydrogen as long-duration energy storage and as an international energy carrier for electricity sector decarbonization" (2024); Cozzolino et al, "A review of electrolyzer-based systems providing grid ancillary services: current status, market, challenges and future directions" (2024)

Deep dive: Clean hydrogen strengthens energy security via diversification of energy sourcing, particularly in regions highly reliant on energy and chemical feedstock imports

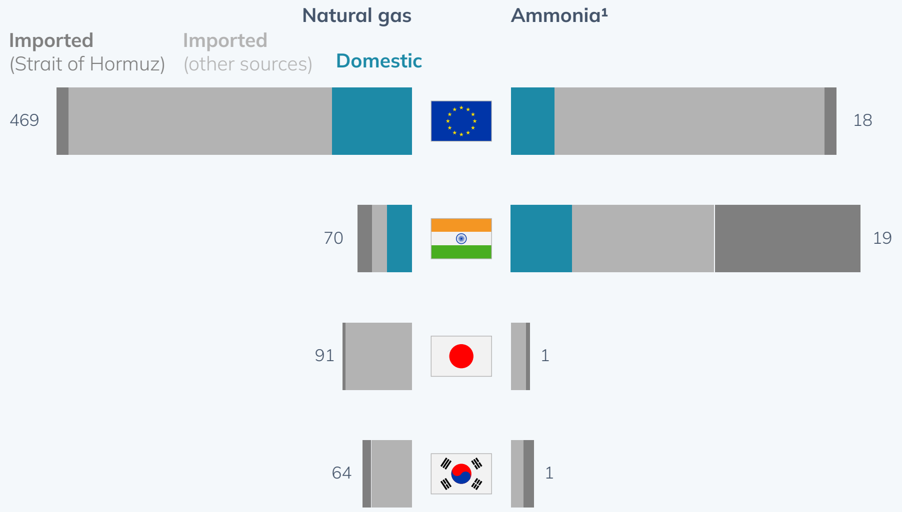
Trade and supply chain disruptions have increased the focus on establishing greater domestic and trade diversification, while the importance of cross-border trade remains a powerful driver of resilience, decarbonization and cost reduction. As the Hydrogen Council documented in 2024, cross-border hydrogen trade is a critical enabler of efficient decarbonization, reducing global hydrogen-related investment requirements by approximately $3.7 trillion through 2050 compared with a localized production model. By matching demand centers with regions possessing lower-cost energy resources, international trade can lower system costs, strengthen energy security, diversify supply, and accelerate deployment of clean hydrogen at global scale.[31] These benefits are even more relevant today than they were in 2024, due in part to the renewed focus on resilience and supply chain diversification as supply chain disruptions have emphasized vulnerabilities in concentrated supply sources. Clean hydrogen can play a role in fostering energy and food system security and resilience by spurring growth and diversification of supply.

Several major economies remain structurally exposed to imported natural gas and fertilizer feedstocks. The EU, India, Japan, and Korea depend on imports for approximately 50–100% of natural gas demand – impacting a range of sectors, namely transport, power generation, and heating, among others. This exposure extends into food systems, since natural gas and ammonia are critical inputs for nitrogen fertilizer production, linking energy security directly to fertilizer availability and food price stability.

The resilience challenge is not purely import dependence, but even more so the concentration risk regarding routing of supply. Several countries reliant on specific suppliers, fuels, or maritime channels can face acute disruption when geopolitical shocks affect narrow trade corridors. Among several key global trade arteries, the Strait of Hormuz is the clearest example, given its role in about one-quarter of global seaborne oil trade and significant LNG and fertilizer-related flows. For regions like India, this creates a direct food system vulnerability, as about 40% of its ammonia consumption, outside of imported final products like urea, relies on either natural gas or direct ammonia imports that pass through the Strait of Hormuz.

Recent disruptions have already shifted sourcing strategies from lowest-cost procurement toward resilience, diversification, and domestic supply options, strengthening the strategic case for clean hydrogen and its derivatives. After Russia's 2022 invasion of Ukraine, the EU reduced Russian pipeline gas imports from more than 40% of its gas supply to less than 10%, expanded alternative LNG supply, and accelerated clean hydrogen policy, for instance through REPowerEU.[32] More recently, disruption risks around the Strait of Hormuz have reinforced the importance of diversified fertilizer sourcing, while highlighting the longer-term value of growing domestic and allied production of clean ammonia, clean hydrogen, and other decarbonized molecules.

Exhibit 3: Import exposure for LNG (bcm) and ammonia (Mtpa), by country, %



80%
of Europe's gas is imported, with over 85% of ammonia dependent on imports

80%
of India's ammonia demand relies on imported ammonia or natural gas, **40% of which passes through the Strait of Hormuz**

>95%
of Japan & Korea's gas and ammonia are imported

1. Excludes ammonia embedded in imported final products (e.g., imported urea)

31. Emerging trade corridors for hydrogen and its derivatives, Hydrogen Council, 2024
32. European Council, Where does the EU's gas come from?, 2026
Source: McKinsey Energy Solutions, Energy Aspect, Reuters, Fertecon 2026, 2025 Statistical Review of the World, CEEW, Woodmac, GTAIC, IEEFA

Deep dive: Increased availability of low-carbon and renewable ammonia sourced from cost-leading markets could reduce exposure to energy price volatility while enabling industrial growth in clean molecule value chains

Global energy price shocks can cascade quickly into cost increases across the economy, impacting costs of energy, goods, and services, while increasing government spending. Global energy disruptions can contribute to a wide range of higher costs, from transportation and electricity to fertilizer and food prices, increasing fiscal pressures in importing economies that have limited domestic production and concentrated import supply sources. The 2022 and 2026 energy supply shocks highlighted the sensitivity of some economies to natural gas supply disruptions.

These impacts have brought into focus the importance of establishing additional sources of supply as well as resilient, diversified and globally flexible supply chains. Expanding clean hydrogen, ammonia production and supply chains could offer greater insulation from supply-side disruptions for a wide range of domestic uses. Among regions with outsized exposure to energy price swings, including parts of Europe, Latin America, Africa and Asia, several countries are establishing mechanisms to bolster energy diversification. For instance, China's growing base of industrial-scale renewable power is shifting the overall energy mix to reduce import exposure.

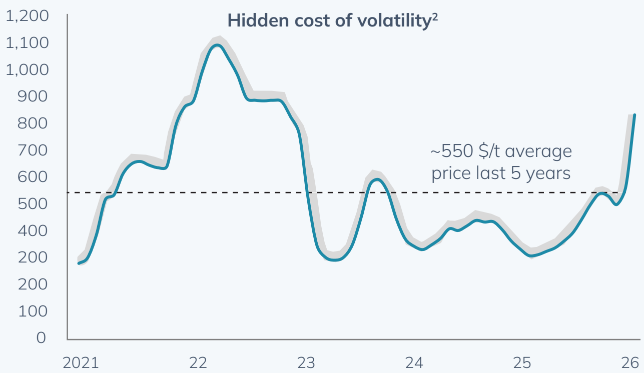
India's domestic renewable ammonia build-out provides another example of how diversification of supply can start to reduce exposure to volatile energy and feedstock markets. Over the last five years, prices for ammonia imports into India have ranged from below 300 $/t to over $1,000/t,[33] even before accounting for the additional agri-food system costs associated with insulating consumers from the full effect of price shocks. There is also a more indirect cost of volatility associated with investments in strategic reserve capacity, government support mechanisms for several parts of the value chain, and the impacts on financing costs under higher risk profiles. To stabilize domestic fertilizer prices through the recent period of volatility, officials and analysts expect the budgeted $17 billion (₹1.71 lakh crore) for fertilizer subsidies in FY2026-27 to be exceeded substantially, with projections ranging from $24 billion to $34 billion (₹2.4–3.4 lakh crore).[34]

One of the ways India is seeking to mitigate disruptions from exposure to such volatility is by supporting additional domestic renewable ammonia supply within a more stable cost range, thereby partially insulating the heavily import-exposed nation. India is doing so in part via supporting upstream renewable power generation via regulatory mandates, manufacturing incentives, inter-state transmission waivers, and several market de-risking mechanisms including competitive reverse auctions anchored by the Solar Energy Corporation of India (SECI). The 724 Ktpa volume of ammonia awarded in the first SIGHT reverse auction as part of the broader National Green Hydrogen Mission[35] accounts for ~30% of India's liquid ammonia imports today (equivalent to about 3% of India's total final ammonia consumption across all end products).[36] Under this first auction round, the 10-year fixed discovered tender value ranged from ~570-740 $/t NH_3,[37] establishing an indicative benchmark for state-supported renewable ammonia offtake in India.

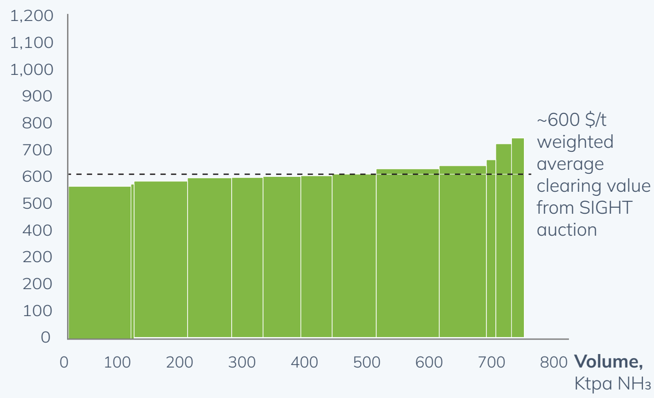
As an alternative (or supplement) to building out a base of insulated domestic production, diversification of sourcing to include decarbonized energy and feedstock supply (low-carbon or renewable) from regions less structurally

Exhibit 4: India renewable ammonia auction results vs historical ammonia prices

Ammonia imports into India have fluctuated from below 300 $/t to over 1,000 $/t in the last five years
India imported ammonia price CFR[1], $/t NH_3



SIGHT auctions in India signal ~600 $/t average clearing values across >700 Ktpa of renewable ammonia
Domestic India renewable ammonia tender values from SIGHT auction, $/ton NH_3



1. Cost and Freight point of delivery
2. Comparable to increase from a forecasted spend of ₹1.71 lakh crore to ₹ 2.4 lakh crore by the Department of Expenditure

33. Fertecon Ammonia Market Report (CFR India Assessments)
34. Agriculture by Economic Times, India Times, India's fertilizer subsidy faces unprecedented surge as global prices climb (2026)
35. The Strategic Interventions for Green Hydrogen Transition (SIGHT) Mode-2A auction is a centralized demand-aggregation mechanism managed by the Solar Energy Corporation of India (SECI) under the National Green Hydrogen Mission, wherein SECI acts as an intermediary procurer awarding 10-year fixed supply contracts to green ammonia producers through cost-based competitive reverse bidding – see Solar Energy Corporation of India (SECI) Request for Selection 2024 for details
36. Council on Energy Environment and Water (CEEW), Economic Feasibility of Green Ammonia Use in India's Fertilizer Sector (2024)
37. Solar Energy Corporation of India Limited (SECI), NGHM (2025)
Source: SECI, Economic Times, Fertecon, S&P Global Commodity Insights, World Bank commodity price data, McKinsey Chemical Insights

impacted by crisis-driven swings in natural gas prices (e.g., North America) can also serve to alleviate supply disruptions and mitigate pressure on governments to fund emergency subsidies or build additional strategic reserves.

Industry partnerships across the value chain remain critical to scale this market. An example of a leading collaboration effort in this space is the LEAF Initiative bringing together first-mover governments, international organizations, and businesses from the food, agriculture, fertilizer, sustainable fuels, and manufacturing sectors to accelerate adoption of low-emission ammonia-based fertilizers (LEAF). Current priorities include working on scaling buyers' alliances, developing product-level carbon footprint standards, and helping secure market-based instruments and disclosure frameworks enabling food companies to demonstrably show emissions reductions achieved with ammonia fertilizers.[38]

Over the coming decades, a diversified mix of production pathways, including renewable ammonia and low-carbon ammonia derived from natural gas with carbon capture and storage, for example, will be important to ensuring scalable, affordable, reliable, and low-emission fertilizer supplies.

Deep dive: Clean hydrogen enables industrial growth, translating natural resources, infrastructure and manufacturing capabilities into clean molecule and clean technology value pools

Hydrogen is creating new industrial growth opportunities in value pools beyond traditional energy commodities. As international markets for clean hydrogen and its derivatives emerge, countries are positioning themselves to capture value through exports of clean molecules, equipment, and project development services. By 2030, annual export opportunities tied to committed investments in the pipeline could reach up to $2.7 billion for the United States through low-carbon ammonia exports, approximately $1.5 billion for the Middle East through combined renewable and low-carbon ammonia exports, and around $1.1 billion combined for India and China through renewable hydrogen derivatives.[39]

Countries are pursuing differentiated strategies to capture value across the hydrogen value chain. Resource-rich regions such as the Middle East are using competitive feedstocks and large-scale projects to establish themselves as clean molecule exporters. Qatar Energy's Ammonia-7 project in Mesaieed Industrial City illustrates the scale involved, with 1.2 million tonnes per year of export-oriented low-carbon ammonia capacity currently under construction. Investment continues to grow and firm in the United States as well with its large domestic market, export infrastructure, energy resources and existing clean energy supply policies, particularly the 45Q tax credit, enabling the launch of low-emissions ammonia exports in 2025.[40]

Meanwhile, India is combining its National Green Hydrogen Mission with centrally-supported low-cost renewable resources to develop a renewable ammonia industry for both import displacement and potentially exports, while China is building leadership across multiple parts of the value chain – including renewable molecule production, electrolyzer and component manufacturing, and international project development.

Early investment is establishing leadership in future hydrogen trade. China already accounts for approximately 37% of committed renewable hydrogen molecule offtake and is involved in the development of around 55% of committed renewable hydrogen production capacity globally, albeit with a different classification and accounting framework for renewable hydrogen than Europe's RFNBO definition. Projects such as Mintal Hydrogen's Baotou plant in Inner Mongolia illustrate the scale behind that lead. As China's first dynamic renewable ammonia facility, its first phase is designed to reach around 1,800 tonnes per day, with captive offtake in chemicals and steel alongside an intent to export. China is also increasingly serving markets abroad, with overseas electrolyzer shipments reaching at least 320 MW in the first half of 2026,[41] up from under 20 MW a year earlier. As global hydrogen trade develops, competitive production costs, manufacturing capabilities, and participation across international projects are several means by which regions can maximize the value they capture.

NEOM Green Hydrogen Project
(Neom, Saudi Arabia)

End-use: Transport and industry | Construction in final completion, commissioning started | COD: 2027 | 237 Ktpa; 2000 MW capacity | $8400 million investment (includes RES investments)

Project spotlight

Renewable hydrogen is creating new traded commodities and export value pools. The world's largest renewable hydrogen plant (300km²), being built by NEOM Green Hydrogen Company (NGHC) exemplifies this development as a gigascale export project (FID $8.4 bn) with a 2.2 GW electrolyzer package powered by 4 GW of wind and solar, to produce up to 600 tonnes of hydrogen daily when operational.

NGHC is an equal joint venture between Air Products, Acwa and NEOM, it is underpinned by an exclusive 30-year global offtake agreement with Air Products, which intends to ship the renewable ammonia worldwide (1.2 Mtpa). This exclusive global offtake arrangement illustrates how a production asset can become a new tradable export commodity, supporting the creation of new export value pools.

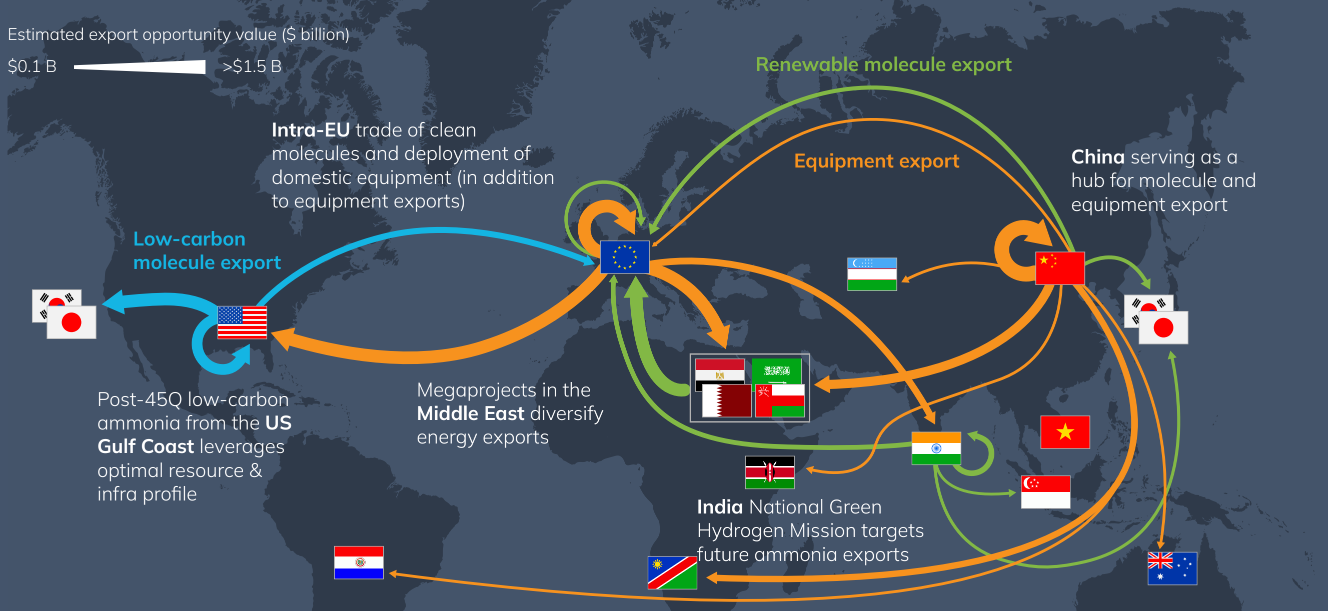
38. Global alliance launches LEAF initiative at COP 30, Hydrogen Council (2025)
39. Based on projects online by 2030, with intent to export all or partial volumes of the project capacity and an average ammonia value of $550/t NH_3
40. In October and November 2025, CF Industries exported low-emissions ammonia (NH_3), produced from natural gas with CCUS from Louisiana, United States, certified under the Verified Ammonia Carbon Intensity program. These shipments included 23.5 kt NH_3 (4 kt H_2 eq) delivered to the port of Antwerp, Belgium, to be used by Envalior in caprolactam production, and 5 kt NH_3 (1 kt H_2 eq) delivered to the port of Varna, Bulgaria, for Agropolychim's nitrogen fertilizer production
41. FCW, Chinese Electrolyzer Exports Surge 17-Fold as Global Hydrogen Projects Accelerate (2026)

Europe already has a track record of deploying electrolyzer equipment, with European companies supplying not only the majority of domestic projects but also large-scale projects in other markets such as the NEOM Green Hydrogen Company (NGHC) project in Saudi Arabia leveraging thyssenkrupp Nucera's electrolyzers and the ACES Delta project in the United States using electrolyzers built by HydrogenPro. Some of the largest low-carbon projects also rely on European technology, with Topsoe's SynCOR autothermal reformers being constructed for the Blue Point One and Beaumont New Ammonia projects in the United States.

European governments are proactively supporting domestic manufacturing capacity to enable industrial growth in the region. In the EU, the Net-Zero Industry Act sets a target for domestic manufacturing to meet 40% of the EU's net-zero technology needs by 2030, complemented by the Innovation Fund, a program designed to help scale up first-of-a-kind manufacturing facilities.[42] In the UK, the Green Industries Growth Accelerator, a fund designed to expand clean energy supply chains, includes a dedicated allocation for hydrogen and carbon capture technologies.[43]

For Europe, and other regions with relatively high power costs, integrating a portion of lower-cost clean molecule imports alongside domestic production can also enable industrial growth by freeing up capital to scale higher-value downstream applications and clean-tech manufacturing, such as electrolyzers, rather than bearing the full expense of a purely domestic upstream build-out.

Exhibit 5: Indicative value capture in hydrogen-related exports and trade across select regions (not exhaustive)



Based on projects online by 2030, with intent to export all or partial volumes of the project capacity and an average ammonia value of $550/t NH_3
Based on equipment deployed in projects online by 2030 and valued using the McKinsey Global Hydrogen Trade Model, including electrolyzer CAPEX of $350-750/kW
Values reflect annual export revenues; for equipment exports, values reflect one-time equipment sales revenues

Alongside energy security, resilience, and industrial growth, hydrogen remains a critical decarbonization lever, particularly in energy-intensive heavy industries

Even as energy security and industrial growth have become the more visible drivers of hydrogen deployment, decarbonization remains the enduring case beneath them and a core benefit of addressing the former priorities with clean hydrogen. In a set of hard-to-abate sectors, clean hydrogen is one of the few scalable routes to deep decarbonization – and for sectors like steel, maritime and aviation, one of the only viable at-scale options. For feedstock uses such as ammonia, refining and methanol, it directly replaces the unabated hydrogen embedded in products. In sectors less suited to direct electrification, it provides the reductant, high-temperature heat, or drop-in fuels that batteries cannot – complementing electrification rather than competing with it. This is the foundation on which the energy-security and industrial-growth narratives ultimately rest.

Momentum is real – investment, capacity and enabling policy are all showing signs of progress. The committed pipeline of projects at final investment decision has grown to approximately $130 billion of investment behind about 6.9 Mtpa of clean hydrogen capacity – which would equate to about 7% of all hydrogen used today, up from

42. European Commission, Net-zero Industry Act (2024)
43. Department for Energy Security and Net Zero, Green Industries Growth Accelerator (2024)
Source: Hydrogen Insights Project & Investment Tracker 2026; McKinsey Hydrogen Insights Clean Hydrogen Offtake Tracker; McKinsey Global Hydrogen Trade Model

less than 1%[44] supplied from clean sources historically. As this capacity comes online it translates directly into emissions abated. The committed clean hydrogen project pipeline alone could abate 55–60 $MtCO_2$ per year – roughly equal to the abatement impact of the 50 million battery electric vehicles (BEVs) on the road today.[45]

Even as the broader project pipeline continues to mature, concrete progress is now visible across clean hydrogen and derivatives alike – from larger scale renewable hydrogen project deployments in several markets to low-carbon ammonia projects coming online on the U.S. Gulf Coast. Enabling policy has moved from design to implementation, with CBAM enacted, RED III transport targets transposed and the EU Emissions Trading System in force.[46]

However, a gap remains relative to earlier ambitions, and closing it is now more a question of execution than design. While meaningful progress has been made and clean hydrogen projects are starting operations, several challenges would need to be addressed to advance deployment at the scale needed to drive down technology and production costs. Policy frameworks in some markets have struggled to convert ambition into bankable demand, including RED III's industrial quotas which have not been transposed and are slated to be re-designed; uncertainty regarding final implementation of CBAM, delays in rolling out contracts-for-difference for eSAF and maritime fuels, implementation delays of IMO shipping targets; shifts in U.S. 45V policy that have slowed renewable hydrogen momentum in the U.S.; and in some sectors, such as steel, near-term deployment has begun to favor routes other than hydrogen. The gap is therefore less about new policies than about executing existing policy consistently and building firm, bankable demand to drive the deployment needed for hydrogen to move down the cost curve and achieve its full potential.

44. IEA, Global Hydrogen Review 2024

45. Assuming 8-9 $kgCO_2/kgH_2$ replaced; 6.9 Mtpa × 8-9 = ~55-60 $MtCO_2$/yr, with benchmark intensities of 10-19 $kgCO_2/kgH_2$ for unabated and 1-4 for low-carbon hydrogen (De Blasio, The Colors of Hydrogen, Belfer Center, 2024). BEV comparison based on ~50m battery-electric cars, ~two thirds of the 74.3m electric cars in use at end-2025 (ZSW, 2026), excluding plug-in hybrids and range extenders: 7.8 Lge/100 km × 2.35 $kgCO_2$/L = ~183 gCO_2/km, less 20.1 kWh/100 km × 458 gCO_2/kWh = ~92 gCO_2/km, × 12,500 km/yr = ~1.1 tCO_2/vehicle, × ~50m = ~56 $MtCO_2$/yr (IEA, Global EV Outlook 2026; U.S. EPA, 2025; TNO, 2022; Ember, 2026). Petrol on a tailpipe basis, electricity on a lifecycle basis; vehicle manufacturing excluded

46. Although ETS and CBAM are in force as of the writing of this piece (July 2026), ongoing discussions in the EU suggest possible revisions may be put forward

03

The state of the clean hydrogen industry

The hydrogen industry's foundation is in place with committed investment at ~$130 billion, up 18% since last year, with ~7 Mtpa of committed capacity

11 Mtpa of potential clean hydrogen demand could materialize by 2030, of which 6 Mtpa has either confirmed offtake or fully enacted policy support behind it

Those 6 Mtpa are largely already matched to confirmed supply (4.2 Mtpa of which via binding offtake). Additional FID and FEED supply could feasibly serve the remaining 5 Mtpa of potential demand, but additional policy certainty is required to firm that demand and several applications would require additional infrastructure to connect

NEOM Green Hydrogen Project | Aerial view of renewable hydrogen production facility | image provided by thyssenkrupp nucera

Section 3a - Industry growth

The foundation of the hydrogen industry is in place and growing; momentum is most visible in regions where energy resilience priorities complement either decarbonization ambitions or expansion into new hydrogen value pools and trade

$130 billion committed

investment in clean hydrogen projects globally, with $30 billion added in last 12 months and $6 billion delayed or canceled[1]

6.9 Mtpa committed

Clean hydrogen capacity that has taken FID, is under construction, or already operational (1.7 Mtpa)

579 projects committed

out of a total global project pipeline of 1,948 projects

1. ~$5 billion in value has been adjusted due to updated data on project sizes and phasing

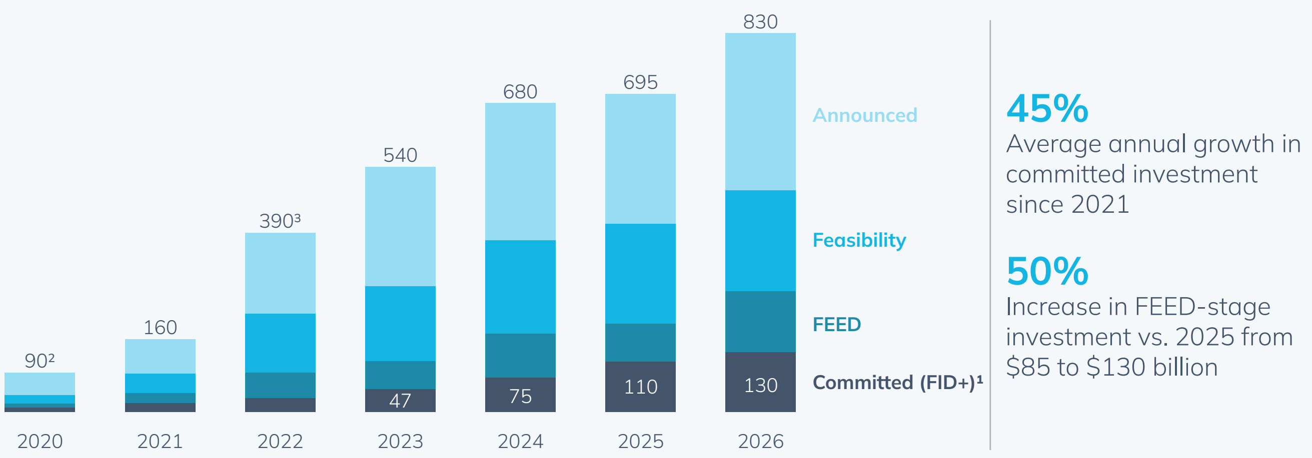
Committed investment in clean hydrogen continues to rise as the project pipeline matures

Cumulative committed clean hydrogen investment has reached $130 billion, up from $110 billion last year. An additional $5 billion in committed investment is tied to projects with commercial operation dates (CODs) beyond 2030. While year-over-year growth in committed investment in projects with CODs by 2030 has moderated to about 20% (compared to about 45% on average since 2021), earlier-stage project activity is accelerating again after the 2024-2025 reset. Front-end engineering and design (FEED)-stage investment has grown 50% versus 2025, led in large part by the Middle East through projects such as the Yanbu Green Hydrogen & Ammonia Mega Project, which alone accounts for over $3 billion in new investment currently at FEED stage.

Project scale is increasing as the pipeline matures. Average investment per committed project has grown to approximately $225 million, while FEED-stage projects average $1 billion. This points to a shift from smaller early projects toward at-scale developments in the next wave.

Supply readiness is ahead of demand, indicating cost competitiveness of supply remains key. The growing bench of FEED-stage supply signals available capacity, but for these projects to take FID, further firm demand is necessary, which in turn depends on government policy giving investors and developers the certainty to commit. Many projects in FEED would also rely on the establishment of strategic trade corridors, and the necessary infrastructure therein, to fall into place to reach offtakers even once policy is in place. In addition, particularly in a demand-constrained environment, only the most cost-competitive projects may reach FID, indicating a continued need for the industry to make further progress in optimizing production and distribution costs.

Exhibit 6: Investment pipeline in clean hydrogen projects by 2030, $ billion[4]



1. FID, Under construction, Commissioned, Operational
2. Data from report normalized based on updated capex numbers used from the December 2023 Hydrogen Insights report onwards as well as investments in deployments removed
3. Data from report normalized based on updated capex numbers used from the December 2023 Hydrogen Insights report onwards
4. Includes investment across all value chain steps from production through end use

The rationalization of the project pipeline continues. Several large-scale project developments have been canceled in the last year, including a handful of projects that had taken FID, and a number of projects in the pipeline are delayed or have not made significant progress in the last 12 months. Attrition in any project development pipeline is natural, but it also reflects the difficulty in bringing projects to FID in an environment with uncertainties around the development of offtake, costs, and prices.

Source: Hydrogen Project & Investment Tracker, as of December 2020, May 2021, May 2022, October 2023, May 2024, July 2025, and June 2026

China and Europe account for nearly 60% of committed investment today, and 80% of the growth since last year, with each region's investment mix reflecting its role in the value chain

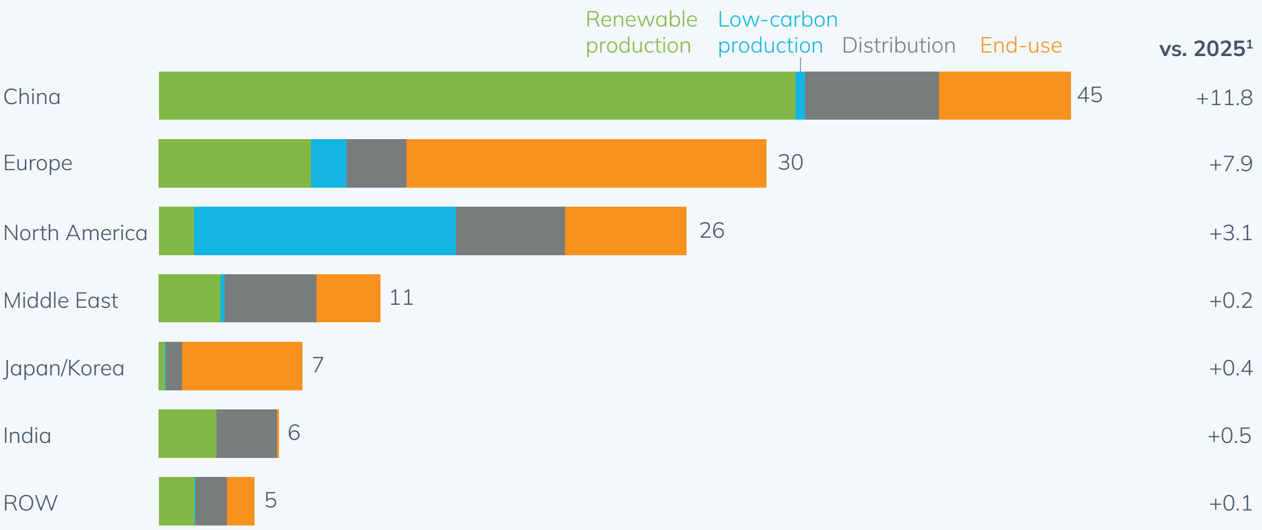
Investment composition differs sharply by region, reflecting each market's role rather than differences in ambition. In China, hydrogen is treated as an extension of the renewable power system, and roughly 70% of committed investment sits in renewable production. In North America, a structural natural gas and CCUS cost advantage combined with the 45Q credit places close to half of committed investment in low-carbon production.

India and the Middle East have the highest relative concentrations of committed distribution investment, at roughly 50% and 42% of committed investment respectively, reflecting the ammonia conversion and port capacity required for export. Distribution has also gained the most share of any step over the past year, rising from about 16% to 19% of global committed investment. Several larger markets have comparable overall absolute investment allocated to distribution, but lower relative shares, for instance, North America (21%), China (15%) and Europe (roughly 10%). In China, investment in distribution extends well beyond derivative production into dedicated transport infrastructure, with the Zhangjiakou Kangbao–Caofeidian pipeline, set to be the world's longest hydrogen pipeline, accounting for about $1.9 billion of the total.

Europe and the import-dependent markets of Japan and Korea sit at the opposite end of the value chain, directing about 65% and 95% of committed investment, respectively, to distribution and end-use. Limited domestic renewable and natural gas resources constrain production in both, so investment flows in large part to the applications that underpin demand supported by RED III transport targets in Europe and power sector co-firing in Japan and Korea. Europe's end-use investment is the largest of any region at about $18 billion, of which Stegra's Boden green steel plant in Sweden accounts for about $8.2 billion.

Growth this year was concentrated largely in two regions, with China adding $11.8 billion and Europe $7.9 billion, together more than 80% of the total net investment increase. Europe's addition has positioned it as the second-largest region by committed investment.

Exhibit 7: 2030 Committed (FID+) clean hydrogen investment by region, by value-chain step, by pathway, $ billion



1. Accounting for value adjustments to 2025 estimates based on new data for project phasing

$30 billion in newly committed hydrogen investment is partly offset by several large project cancellations

$30 billion of newly committed investment was added over the past year, although this growth was tempered somewhat by cancellations and project delays worth approximately $3 billion each, concentrated in a few large-scale projects in North America, South America, and Europe. In total, the $30 billion that advanced to FID+ was roughly five times the $6 billion that was discontinued or delayed. A net $5 billion value adjustment (reflecting announced changes to project phasing, capacities, and estimated investment) further reshaped the committed investment base.

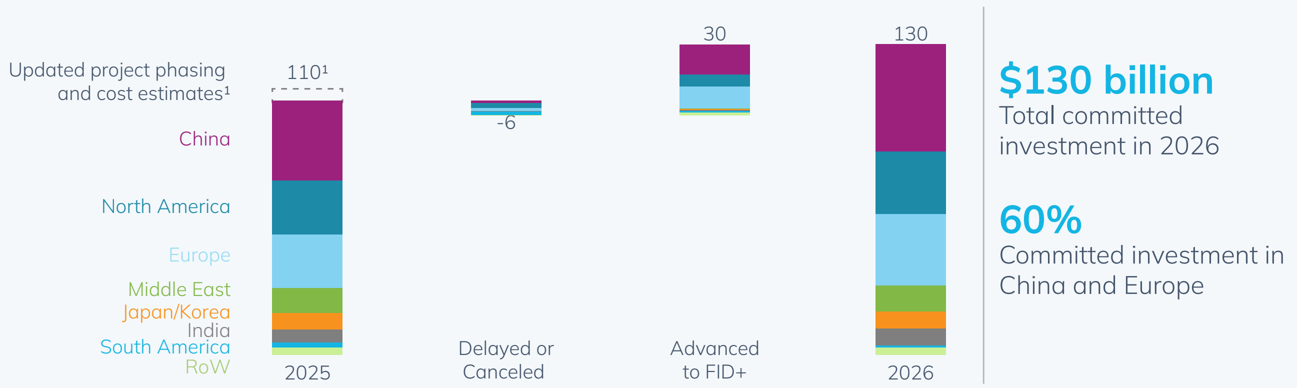
Source: Hydrogen Project & Investment Tracker 2026

Beyond legislative and economic uncertainty, even advanced projects can face challenges getting from FID to starting operations, although in many cases this is for project-specific reasons. For instance, the Recyclage Carbone Varennes biomethanol project in Quebec broke ground before financial and execution setbacks forced it into restructuring, removing approximately $730 million in previously committed investment from the project pipeline. In a separate case, Plug Power's Limestone project was suspended as capital was reallocated toward higher-return opportunities, leading to a reduction of $850 million of previously committed investment. AES Andes' Inna project in Chile meanwhile faced sustained opposition from the scientific community over light pollution concerns near the Paranal Observatory and was later canceled due to a portfolio review decision, representing about $1.5 billion in canceled committed investment.

Newly committed investment remains concentrated in a small set of regions. Although China grew the most in absolute terms, Europe recorded similarly strong growth, with the two regions combined now accounting for nearly 60% of committed investment today. While all other regions advanced, South America was the only one to contract, the result of a single large project cancellation rather than a broad-based decline.

Large projects continue to drive year-on-year swings. A limited number of at-scale projects account for much of the movement in committed investment, both as they advance to FID+ and as others are discontinued or delayed. As a result, overall industry growth is largely tied to the trajectory of a small number of large-scale projects.

Exhibit 8: Committed (FID+) investment in clean hydrogen projects by 2030, $ billion



1. ~$5 billion 2025 value adjustment accounts for value adjustments based on announced changes re. project phasing, production capacities, and project timelines

Committed clean hydrogen capacity also continues to grow, with operational capacity increasing 70% in the last 12 months

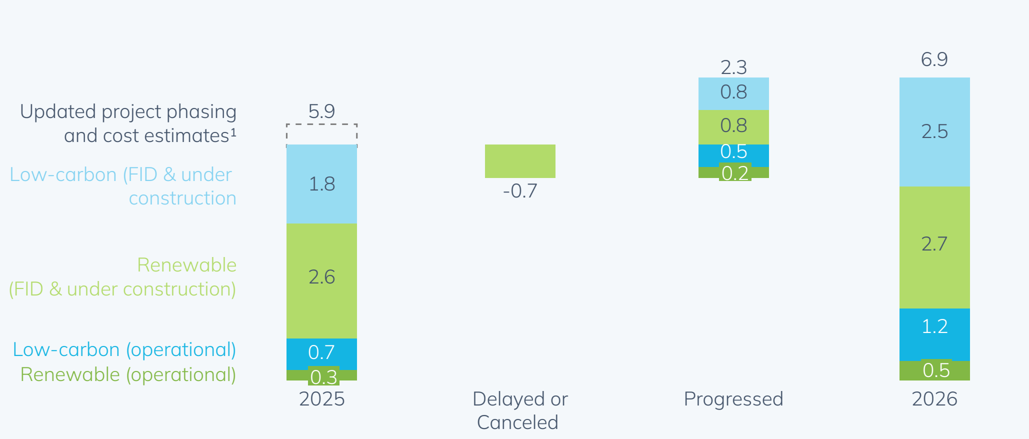
Committed clean hydrogen capacity grew by 1.0 Mtpa over the last 12 months, reaching 6.9 Mtpa. This represents 17% growth, with newly committed capacity split approximately evenly between low-carbon and renewable pathways. In capacity terms, after accounting for about 0.6 Mtpa in capacity adjustments, about 2.3 Mtpa of clean hydrogen capacity progressed – approximately three times as much as was delayed or canceled (roughly 0.7 Mtpa). To contextualize the scale of the committed clean hydrogen project pipeline in energy terms, 6.9 Mtpa represents roughly 270 TWh (HHV), over half of France's current annual electricity consumption.[47]

Operational clean hydrogen capacity is scaling even faster than the overall committed pipeline, increasing from 1.0 Mtpa to 1.7 Mtpa – 70% growth over the past year. While low-carbon hydrogen still accounts for most operational capacity today, renewable capacity online grew by over 85%, and could continue to outpace low-carbon growth in the near term given the larger share of capacity under construction today.

Nonetheless, the delivery risk for clean hydrogen capacity moving into operation remains material. Around 25% of committed clean hydrogen capacity is now operational, with the remaining 5.2 Mtpa still in FID or under construction after an estimated 700 Ktpa of capacity was either delayed or canceled. Although 80% of this capacity adjustment was tied to three large-scale projects, it illustrates how converting post-FID projects into operational projects remains a key delivery challenge through 2030.

47. Converted at the conventional higher heating value (HHV) of 39.4 kWh/kg H_2, compared against French electricity consumption of 451 TWh in 2025. Source: IEA, Global Hydrogen Review (2025); RTE, Bilan électrique (2025)
Source: Hydrogen Project & Investment Tracker 2026

Exhibit 9: Global committed clean hydrogen capacity by 2030 by pathway and status, Mtpa



+1 Mtpa

Increase in committed capacity globally in last 12 months

70%

Increase in operational clean capacity in last 12 months, nearing ~2 Mtpa of capacity online

1. Accounts for value adjustments based on announced changes re. project phasing, production capacities, and project timelines

Committed capacity is concentrated in North America and China

North America and China now account for 72% of committed capacity, up from about 70% a year ago, and are responsible for the bulk of net additional committed capacity. The two are anchored by different pathways. China accounts for around 55% of committed renewable capacity, driven by domestic supply projects and larger average project size than most other regions, and has set a target of at least 2 Mtpa of renewable hydrogen production by 2030.[48]

North America accounts for 80% of committed low-carbon capacity and has led overall committed capacity growth since 2025, expanding from 2.2 to 2.9 Mtpa. About 20% of the total low-carbon capacity in North America is linked to legacy projects from before 2021, including CF Industries' addition of CCUS at its Donaldsonville, Louisiana, ammonia complex. Recent additions there have come primarily from purpose-built low-carbon ammonia projects such as Beaumont New Ammonia in Texas, scheduled to start low-carbon operations next year. Renewable capacity in smaller markets such as Southern Asia and South America contracted over the same period as several large projects dropped out, leaving the global pipeline larger overall but more geographically concentrated.

Globally, projects under construction average 10x larger than today's operational projects

The next wave of projects is materially larger than today's operating base. FID and under-construction projects are on average 10 times larger than currently operational projects across regions and pathways. In the United States, the CF Industries, JERA, and Mitsui 1.4 Mtpa Blue Point One project will be the largest new ammonia facility in the world when it comes online in 2029 and will have an estimated 95% reduction in carbon emissions compared to conventional natural gas-based ammonia production.

US Wabash Low-Carbon Ammonia Project (West Terre Haute, Indiana, US)

End-use: Chemicals | Status: Under construction | COD: 2029 | Capacity: 500 Ktpa NH_3 | Investment: USD 2.6 billion

Project spotlight

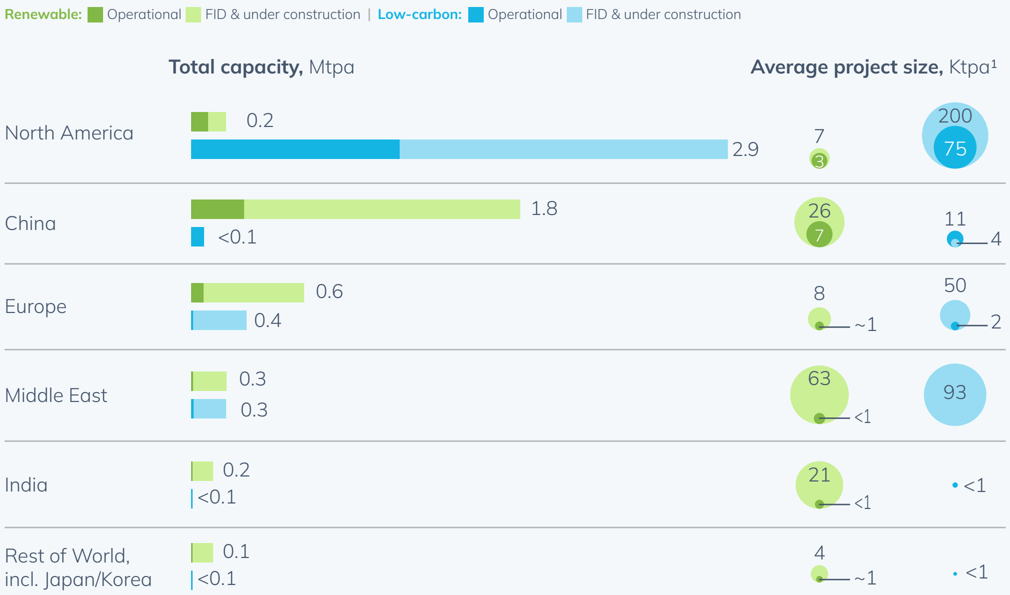
The Wabash Low-Carbon Ammonia Project illustrates how targeted policy support can unlock investment in large-scale low-carbon ammonia production. Following approval of a USD 1.5 billion loan from the U.S. Department of Energy, the project advanced into construction, demonstrating how public financing can accelerate the deployment of industrial decarbonization projects.

The plant will produce 500,000 tonnes per year of low-carbon ammonia while capturing approximately 1.67 Mtpa of CO_2 for permanent geological storage. Casale has been selected as technology provider for the ammonia synthesis loop, while Samsung E&A serves as EPC contractor. Scheduled for commissioning in 2029, the project represents a practical example of public-private collaboration enabling the scale-up of low-carbon ammonia production.

Meanwhile AM Green's renewable ammonia complex in Kakinada, India also illustrates the scale of this shift. Currently under construction, its first phase is expected to produce 0.5 Mtpa of renewable ammonia (~88 Ktpa H_2 equivalent) by 2027, backed by ~640 MW of electrolyzer capacity, with the full complex planned to scale to 1.5 Mtpa of ammonia by 2030. Projects like these point to a step-change in scale but also increases in execution risk as larger projects move from FID and construction into commissioning and operation.

48. While China's NDRC/NEA energy guidelines set a national baseline target of 2 Mtpa of renewable hydrogen production by 2030, bottom-up aggregations of provincial-level Five-Year Plans (e.g., BloombergNEF, RMI, China Hydrogen Alliance) indicate that combined subnational targets reach 3.5 to 5.0 Mtpa by 2030
Source: Hydrogen Project & Investment Tracker 2026

Exhibit 10: Global committed clean hydrogen capacity by 2030 by pathway and status vs average project size



72%

Share of committed clean capacity concentrated in North America, China

10x

Average size difference between renewable operational projects and renewable committed projects slated to come online by 2030

1. Scales are independent for renewable and low-carbon projects

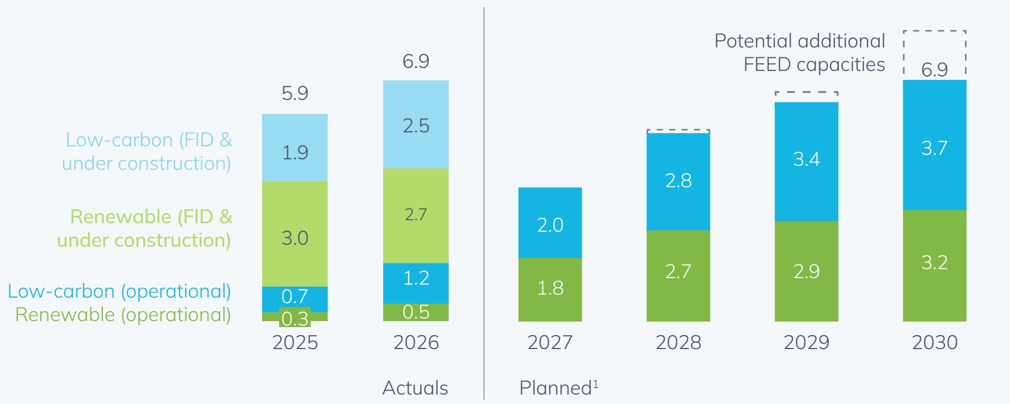
Operational capacity is set to more than double in the coming year

Based on announced start-up dates, operational clean hydrogen capacity could rise from 1.7 Mtpa in 2026 to 3.8 Mtpa in 2027. Much of this reflects projects that reached FID around 2023 and are now coming online – a reminder that commitments translate into operating capacity with a three-to-four-year lag, so today's momentum will not show up in delivered supply until later this decade.

The near-term spike is driven by renewable hydrogen. Renewable operational capacity is expected to more than triple in 2027, rising from 0.5 to 1.8 Mtpa, the single largest jump, as the first large renewable projects reach start-up. Examples include the NEOM Green Hydrogen Company (NGHC) project in Saudi Arabia and AM Green's Kakinada, India ammonia plant. By 2030 renewable capacity could reach 3.2 Mtpa, roughly on par with low-carbon at 3.7 Mtpa.

FEED conversion could materially expand committed supply by 2030. Around 7.5 Mtpa of additional capacity currently in FEED is targeting operation by 2030. A prominent example is the HIF Global and Electric Hydrogen Matagorda project aiming to produce approximately 750 million liters annually of carbon-neutral fuel using electrolysis by 2027. If all 7.5 Mtpa of FEED supply were to convert to FID+, total supply could rise from 6.9 Mtpa to as much as 15 Mtpa, although the timeline is becoming increasingly tight and historically only projects with confirmed offtake reach and pass the final investment decision milestone.

Exhibit 11: Global committed clean hydrogen capacity by 2030 by pathway and status, Mtpa



4x

Increase in operational clean capacity today until 2030

7.5 Mtpa

Of additional capacity currently in FEED targeting start of operation by 2030

1. Based on announced CODs, some delays are to be expected

Source: Hydrogen Project & Investment Tracker 2026

Installed electrolysis capacity continues to scale, reaching 4.5 GW globally

Cumulative installed capacity has grown by more than 50% year-on-year for five consecutive years, reaching 4.5 GW, with the largest addition, the Songyuan Hydrogen Industrial Park, alone adding 0.64 GW. The 468 Ktpa of hydrogen production capacity online today is equivalent to about 40% of the RFNBO demand that RED III's transport sub-targets alone are set to create in Europe by 2030. Growth remains rapid, but from a comparatively small base relative to the announced project pipeline.

China is the main driver of recent capacity additions. China accounted for the majority of new installed capacity this year and now represents over 70% of global installed electrolysis capacity. Europe, North America, and other markets continue to add capacity, but at a smaller scale and slower pace. Europe's largest currently operational electrolysis projects sit in the 20 to 50 MW range, while China's largest reach over 500 MW. Nonetheless, Europe's pipeline is materially larger than its current installed base, with several large-scale plants slated to come online soon, including Stegra's 740 MW plant at Boden in Sweden and the two 200 MW Holland Hydrogen and Normand'Hy projects.

The global technology mix is partly driven by China's alkaline build-out. Globally, alkaline technology accounts for 74% of installed capacity, with proton-exchange membrane (PEM) systems at 24% and other technologies at 2%. Excluding China, the split is more balanced, with alkaline at 48%, PEM at 46%, and other technologies at 6%, reflecting region-specific use-cases and market-driven technology selections. China holds about 60% of global electrolyzer manufacturing capacity,[49] and competition among more than 100 domestic manufacturers has cut alkaline system costs by roughly 45% in five years to below $350/kW, delivering strong cost-competitiveness. Outside China, alkaline and PEM sit closer to parity with one another, with technology selection driven more by project-level operating requirements than by equipment cost alone.

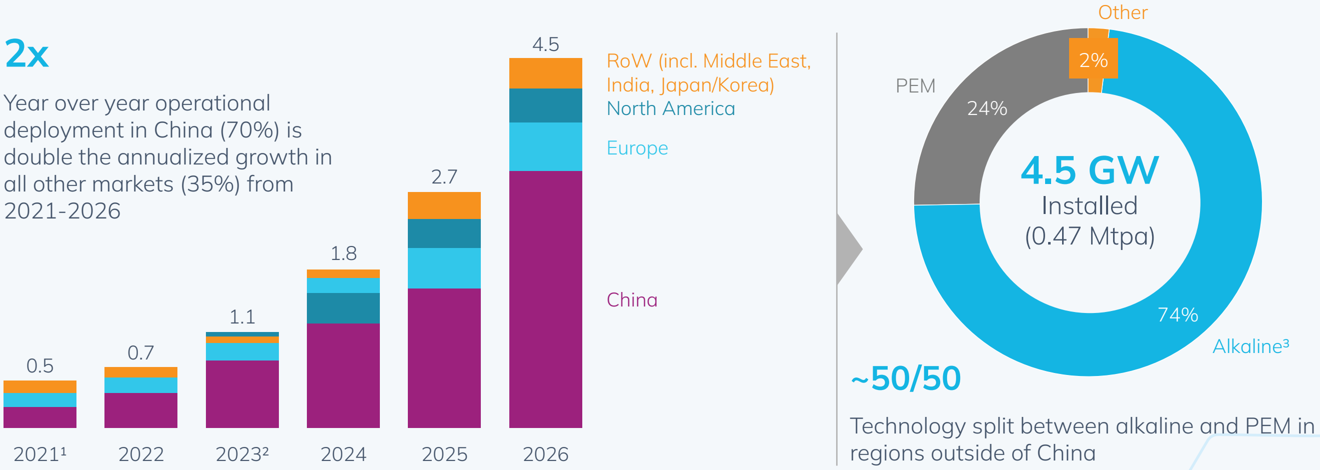
ELYgator (Rotterdam, Netherlands)

End-use: refining/mobility | Under construction | COD: 2027 | 23 Ktpa; 200 MW capacity

Project spotlight

Installed electrolysis capacity has been growing by more than 50% year-on-year. The ELYgator project reflects this increase in scale through Air Liquide's 200 MW electrolyzer, supported by an investment of more than €500 million and selected under the first call of the EU Innovation Fund, with electrolyzers already delivered to site. In addition to combining both PEM and alkaline electrolyzers, another distinguishing feature of the project is its system integration: the renewable hydrogen will feed directly into Air Liquide's industrial hydrogen pipeline. The project provides an example of the large-scale, grid-connected electrolysis underpinning this growth curve.

Exhibit 12: Global cumulative installed electrolysis capacity by technology by region, GW



1. Growth from 2020 to 2021 driven by 150 MW Ningxia Project
2. Growth from 2022 to 2023 driven by 260 MW Kuqa Green Hydrogen Project, currently the largest operational electrolyzer
3. Includes ~530 MW in 2024 and ~920 MW in 2025 of capacity in China with no publicly announced electrolyzer technology – assumed to leverage alkaline technology given prevalence in China

49. IEA, Global Hydrogen Review 2025

Source: IEA Global Hydrogen Review 2021 & 2022; Hydrogen Project & Investment Tracker, as of December 2020, May 2021, May 2022, October 2023, May 2024, July 2025, and June 2026

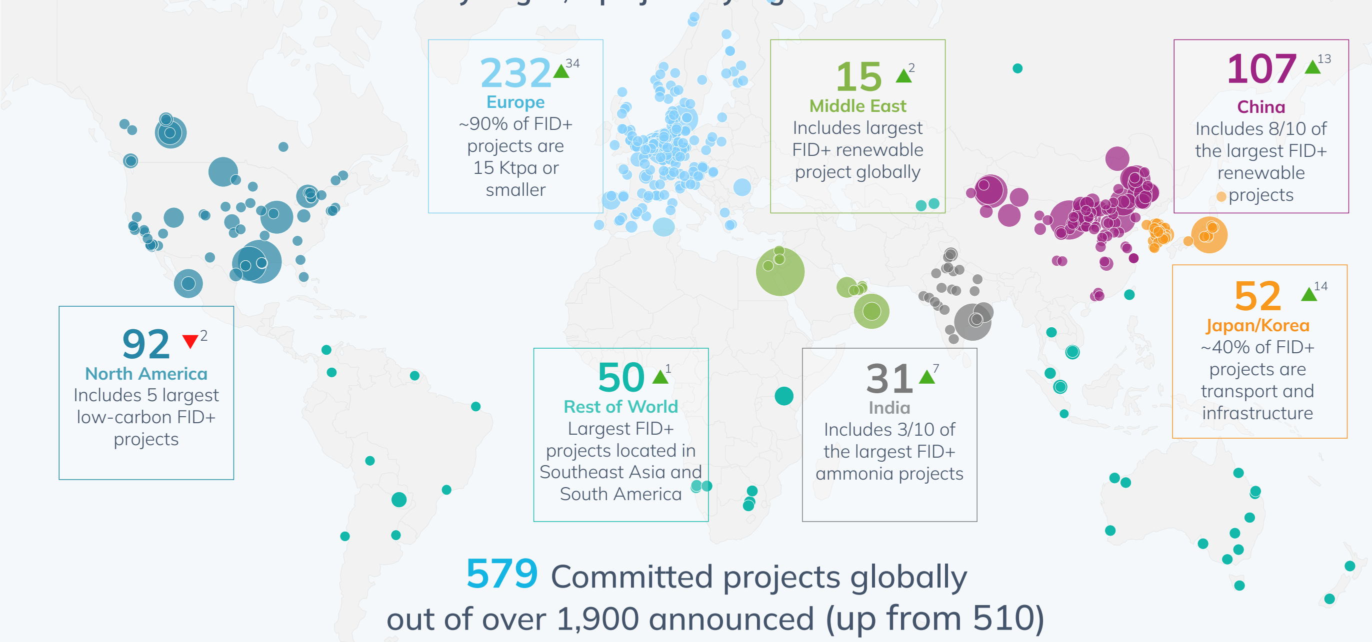
Of the total clean hydrogen project pipeline, 579 projects are committed with more than 60 added in the last 12 months

Of more than 1,900 projects announced globally, 579 have reached FID, with 540 already under construction or operational. Projects refer to announced clean hydrogen developments across the value chain, including production projects (above 1 MW equivalent), infrastructure, and end-use applications.

Europe leads in the number of committed projects, while regional deployment models are diverging. Europe accounts for 232 committed projects, adding the most over the past year (+34 net new), although its pipeline remains weighted toward smaller-scale projects with 90% of FID+ projects being smaller than 15 Ktpa. China has reached 107 committed projects and leads in large-scale renewable hydrogen deployment (being home to 8 out of 10 of the largest renewable FID+ projects), whereas Japan and Korea, constrained by limited domestic renewable and natural gas resources, have instead first prioritized infrastructure build-out and end-use applications such as mobility networks.

While there is positive momentum in several markets, at-scale deployment remains concentrated in a few. Although committed projects are distributed across key regions globally, the largest developments remain concentrated in several markets: North America leads for low-carbon projects, while China, the Middle East, and India account for more than 70% of committed renewable capacity by 2030.

Exhibit 13: Global committed clean hydrogen, # projects by region



Includes projects above 1 MW; Projects with multiple phases, including expansions, are counted once

Source: Hydrogen Project & Investment Tracker 2026

Section 3b - Demand

Demand is emerging, supported by the right combination of energy policies and underlying economics; however, bankability still requires enforcement of proposed policies

6 Mtpa firm demand by 2030

Clean hydrogen demand with existing offtake or enacted policy backing

Up to 11 Mtpa by 2030

Potential demand for clean hydrogen either already off-taken or with indicative policy support (6 Mtpa firm + additional 5 Mtpa yet to be enabled)

Up to 18 Mtpa by 2035

Potential demand for clean hydrogen, majority of which yet to be enabled by policy enactment

Demand for clean hydrogen is emerging where it is supported by the right combination of enacted energy policies and underlying economics

Whether a potential hydrogen end user adopts clean hydrogen or not is contingent on there being a positive business case for using clean hydrogen relative to both conventional and other decarbonized alternatives. To estimate total demand for clean hydrogen, the "competitiveness" of clean hydrogen adoption is assessed for each potential hydrogen end-use sector in each major geography.

Competitiveness is calculated by comparing each sector's policy-adjusted "value-in-use" with the likely delivered cost of supplying clean hydrogen or its derivative. The resulting metric represents the gap between value and cost. Segments where value-in-use exceeds cost to serve are considered to have a "positive business case," while negative-gap segments require further cost reductions, stronger policy support, or additional willingness to pay for low-emissions products. A positive competitiveness value is a sign that a given end use in a given geography could have a viable business case – it is not indicative of a producer's potential margin; actual hydrogen pricing will depend on local market economics, supply availability, and offtake contract structures.

Value-in-use reflects the economic benefit of adopting clean hydrogen relative to incumbent technologies. It includes the underlying economic break-even value versus conventional alternatives, combined with avoided carbon costs, compliance with regulatory requirements, and other policy-driven value. Results are assessed at the sector-by-geography level to capture differences in market structure, energy systems, and policy environments.

Policy mechanisms can improve competitiveness either by increasing value-in-use or lowering effective cost to serve. The analysis incorporates the most impactful hydrogen-related policies globally as of May 2026, including existing carbon pricing and emissions trading systems (e.g., the EU's ETS), the EU's CBAM, clean fuel standards (e.g., California's Low-Carbon Fuel Standard (LCFS)), renewable fuel mandates (e.g., RED III), production incentives (e.g., 45Q), contracts-for-difference (e.g., Japan's CfD), and clean hydrogen procurement schemes (e.g., Korea's CHPS).

Policy effects are translated into \$/kg H_2-equivalent adjustments. For example, an illustrative EU ETS price of \$130/tCO_2 would potentially increase conventional hydrogen costs by approximately \$1.1/kg H_2,[50] assuming emissions of about 8-9 kgCO_2/kg H_2. This raises clean hydrogen's relative value in sectors where conventional alternatives face carbon costs.

Production incentives are treated as cost reductions. In the United States, 45Q provides up to \$85/tCO_2 for captured and stored CO_2 for the first 12 years of a facility; under modeled plant economics, this reduces the effective cost of low-carbon hydrogen by approximately \$0.5/kg H_2 over the plant lifetime.[51] Other mandates, penalties, auctions and procurement schemes are treated similarly based on whether they increase end-user value or reduce cost-to-serve.

Kassø e-Methanol Plant
(Kassø, Denmark)

End-use: maritime fuels, road transportation fuels, chemicals | Operational | COD: 2025 | 8 Ktpa; 53 MW capacity

Project spotlight

Emerging end-use demand not only in chemicals but also in maritime fuel and road transportation fuel is exemplified by the Kassø e-Methanol Project in Denmark, jointly owned by European Energy (51%) and Mitsui & Co., Ltd. (49%). The project demonstrates the transition from concept to operation as an operational e-methanol plant set to produce 42,000 tonnes a year, with 52.5 MW of electrolyzer capacity powered by the adjacent 304 MWp Solar Park Kassø. As an operating renewable methanol asset in a new derivative market, the project provides tangible early evidence that demand is beginning to scale beyond traditional hydrogen end-uses.

~10% of 2030 global hydrogen demand could carry a policy-supported business case for clean hydrogen if all current policies are implemented, up from ~1% today

When we apply this approach to the total expected hydrogen consumption by 2030, we find that 11 Mtpa could potentially carry a policy-supported positive business case for clean hydrogen, although only the subset of that demand tied to fully implemented policies would be considered bankable.

Approximately 100 Mtpa of hydrogen is consumed today, of which only about 1% is sourced from decarbonized pathways. Current demand is concentrated in refining, ammonia production, and methanol synthesis, with additional demand in several other industrial and specialty chemical applications. By 2030, total hydrogen demand (sourced from all hydrogen pathways) could exceed 110 Mtpa,[52] still largely concentrated in existing end uses but including additional segments like transport and emerging industrial applications.

Under today's policy and cost outlook, approximately 11 Mtpa – about 10% of global hydrogen use across all

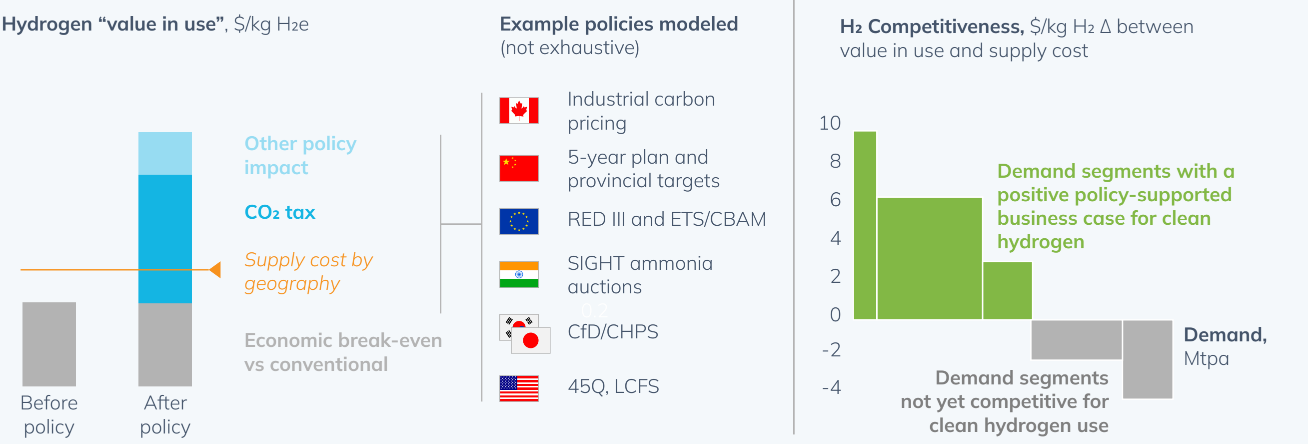
50. \$130/tCO_2 × 8.5 kgCO_2/kg H_2 ÷ 1,000 = ~\$1.1/kg H_2; latest EU ETS review proposal assumes EUA price of €150/ tCO_2 in 2040
51. NPV of credit over 30 year plant lifetime
52. Global increase of about 10 Mtpa total hydrogen demand (across all pathways) driven in large part by expected increase in existing end uses: +1 Mtpa refining, +3 Mtpa ammonia, +3 Mtpa methanol, in addition to incremental demand in new end-use sectors

Exhibit 14: Clean hydrogen "competitiveness" calculation overview

Hydrogen "value in use" is assessed across 10+ sectors in 11 regions. Policies in select markets serve to either raise the value in use or lower the cost to serve that demand segment

Segments where value in use is greater than cost to serve carry a "positive business case"

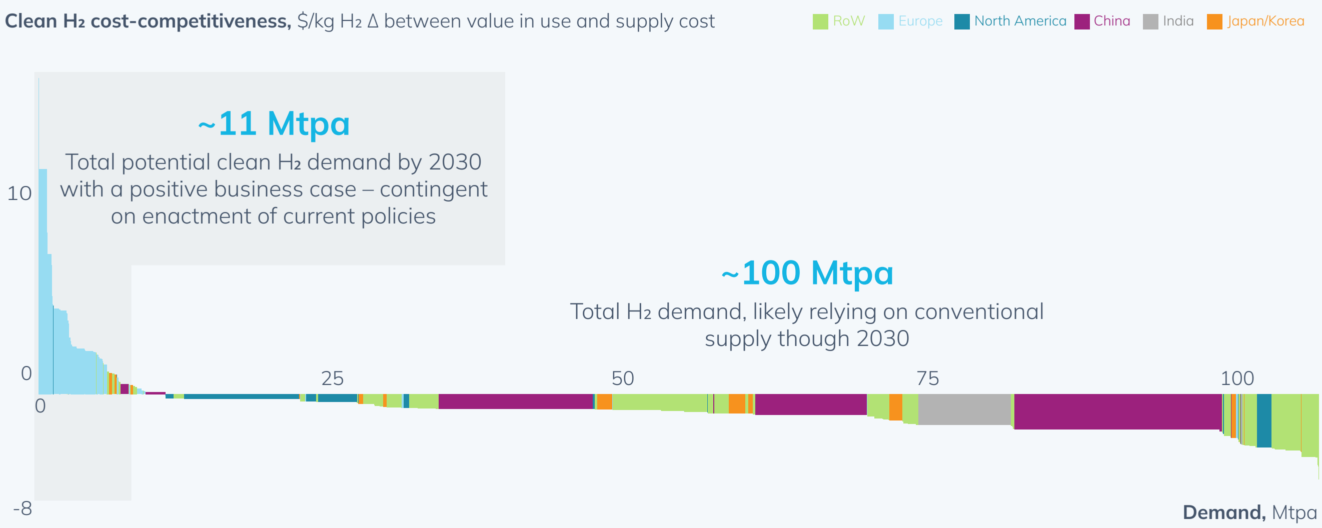
ILLUSTRATIVE



pathways – could potentially carry a positive business case for clean hydrogen by 2030, assuming all existing hydrogen-related policies are fully implemented and enforced. These 11 Mtpa are the sum of all sector-by-geography segments for which calculated value-in-use exceeds the likely cost of clean hydrogen supply by 2030 after accounting for the impact of existing policies on the underlying economics in each segment. The 11 Mtpa is agnostic to the implementation status of each individual policy. Later in this section, this is broken down by the degree to which enactment of these policies has or has not yet "firmed" each individual demand segment.

A much larger pool of demand sits close to competitiveness but would require an acceleration of supply cost reductions, additional policy action, and extensive build out of connective trade infrastructure to unlock. The next roughly 50 Mtpa of 2030 hydrogen demand, primarily in existing use cases such as refining and ammonia production, although theoretically within about $1/kg of a positive business case by then, would require substantial effort to unlock. In addition to requiring net-new trade and transmission infrastructure to access, much of this demand, even in markets like China which could potentially achieve 2-2.5 $/kg clean hydrogen production costs,[53] would still carry value-in-use tied to the value of unabated hydrogen at less than half the cost of clean hydrogen, barring the development of additional policies or cost improvements that could bridge that gap.

Exhibit 15: 2030 global hydrogen TAM[1] ranked by cost-competitiveness for clean hydrogen[2], Mtpa



1. Total addressable market
2. Competitiveness calculated as difference between end user's estimated value in use and the specific cost of clean hydrogen for each respective application in each geography

53. McKinsey Hydrogen Insights Global Hydrogen Trade Model
Source: McKinsey Hydrogen Insights Total Cost of Ownership and Clean Hydrogen Willingness to Pay Models

An examination of the potential demand by 2030 reveals that several combinations of today's existing policies could support the business case for clean hydrogen

Policy support continues to shape the first wave of competitive clean hydrogen demand. Across most regions, carbon pricing mechanisms, low-emissions fuel mandates, contract-for-difference schemes, and production incentives could either increase the value of clean hydrogen adoption or reduce the effective cost of supply.

The EU accounts for the largest share of potential demand, supported by RED III, ETS and CBAM. Europe represents the largest pool of potentially cost-competitive demand, with RED III renewable fuel quotas, should they be fully transposed, creating substantial value for industrial and transport applications. This demand would be reinforced by the EU ETS and CBAM mechanisms as they exist today, which increase the cost of carbon-intensive alternatives, strengthening the business case for clean hydrogen and its derivatives.

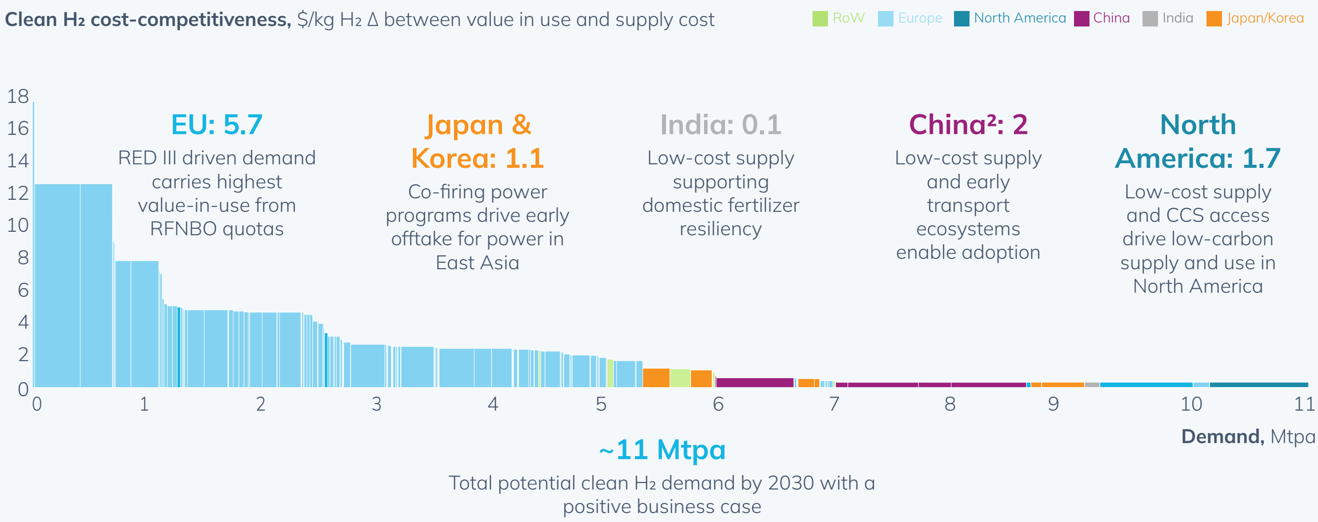
However, the timeliness, certainty, and effectiveness of policy implementation and enforcement will ultimately dictate whether this demand becomes bankable. Elements of RED III, for instance, may be revised to align with the EU's new 2040 climate targets and the results of the ETS review could alter the application of and timeline for phase out of free allowances. Likewise, final guidance on proposed elements of CBAM (e.g., Article 27a[54]) may impact the underlying business case for producing decarbonized products like ammonia and fertilizer.

Across Japan and Korea, China, and North America, several distinct mechanisms offer pathways to competitiveness. Although power-sector co-firing programs underpinned early hydrogen and ammonia demand in Japan and Korea, deployment has progressed more gradually than initially anticipated, including the postponement and revision of Korea's original CHPS targets, and Japan's ammonia co-firing rollout falling behind its 20% target for 2030.[55]

Meanwhile, China is rapidly expanding domestic clean hydrogen supply and infrastructure, with adoption across industrial and transport sectors supported by centrally-driven and province-level mandates alongside several government-backed support mechanisms. In North America, policies like the 45Q tax credit for carbon sequestration, combined with abundant low-cost natural gas, some existing CO_2 pipeline infrastructure and growing CO_2 sequestration infrastructure have enabled early low-carbon hydrogen deployment, serving export markets in particular. Ongoing North American scale up will hinge on the further advancement of both CO_2 pipelines and sequestration wells.

New export-oriented supply hubs are beginning to emerge. India is seeking to position itself as both a domestic demand center and a low-cost export hub. Government-supported low-cost renewable power, alongside other industrial policy and financial support, coupled with growing domestic consumption are fostering investment across several end-use segments with projects seeking to supply international markets with clean hydrogen and ammonia.

Exhibit 16: 2030 global clean hydrogen TAM ranked by cost-competitiveness[1], Mtpa



1. Competitiveness calculated as difference between end user's estimated value in use and the specific cost of clean hydrogen for each respective application in each geography; competitiveness score is not indicative of a margin for supplying clean hydrogen to a given end use sector – it is an indicator that an end-use sector could have sufficient value in use to adopt clean hydrogen. Actual clean hydrogen pricing is driven by availability of supply, region-specific market conditions, and offtake contract terms
2. China's NDRC/NEA energy guidelines set a national baseline target of 2 Mtpa of renewable hydrogen production by 2030, bottom-up aggregations and modeling of provincial-level targets indicate at least 2.3 Mtpa of demand by 2030 with external sources indicating as much as 3.5-5 Mtpa

54. Article 27a, if enacted, allows for the temporary removal of specific goods from the scope of CBAM if their inclusion causes severe unforeseen economic disruption in the EU
55. James Walter, "Japan's Ammonia Co-Firing Strategy Constrained by Cost, Supply, and Timing." (2026)
Source: McKinsey Global Energy Perspective 2026 (Sustainable Transformation Scenario); McKinsey Hydrogen Insights Total Cost of Ownership; McKinsey Hydrogen Insights Global Hydrogen Trade Model

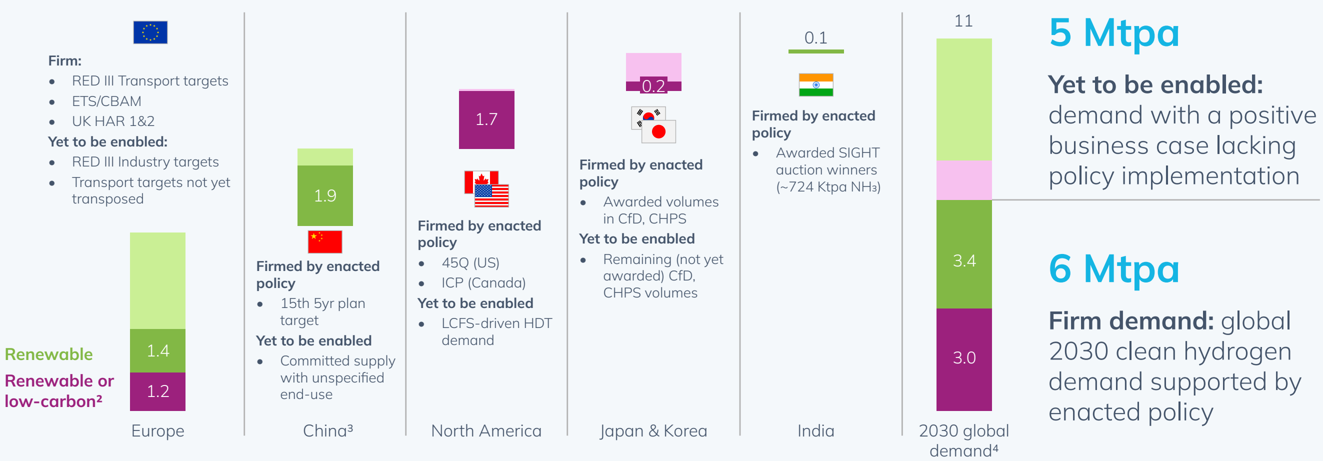
Implemented policies firm 6 Mtpa of the potential demand by 2030; the next 5 Mtpa requires further policy implementation to become bankable

Not all potential demand carries the same level of policy certainty today. The potentially competitive clean hydrogen demand identified by 2030 reflects sectors where policy-adjusted value-in-use exceeds the cost of supply. However, realizing this demand depends not only on competitiveness, but also on the degree to which supporting policies are enacted, implemented, and translated into market activity. As a result, demand can be categorized based on the "firmness" of current policy support underpinning adoption. "Firm demand" is defined by geography-by-sector segments where the policies that support the business case have been formally implemented or otherwise operationalized. Demand that could carry a positive business case but for which the supporting policies are not yet implemented is defined as "yet to be enabled" in the following analyses.

6 Mtpa of 2030 demand is firmed by policies already in force, increasing its bankability. The firmest demand segments are supported by policies that have already been implemented and are generating market activity today. Demand in Europe supported by ETS, CBAM and the transposition of RED III transport targets in 11 of 27 Member States[56] is considered "firm," as are the limited portions awarded from Japan's CfD and Long-term Decarbonized Power Auction (LTDA) as well as the sole 750 GWh portion of Korea's CHPS mechanism originally awarded to KOSPO as part of the inaugural 2024 auction.[57] Firm demand also includes several mobility and industrial ecosystems in China. In these markets, clear policy signals have largely moved beyond planning and into execution.

Another 5 Mtpa of potential demand is yet to be enabled and requires additional policy implementation to progress. Other potential demand segments depend on policies that have been announced but are not yet fully realized. In Europe, a significant portion of demand is contingent on member states transposing RED III industry targets into national legislation. In Japan and Korea, hydrogen and ammonia power-sector programs have established a pathway for future demand, but implementation has progressed more gradually than initially expected, and unawarded volumes of Japan's CfD and Korea's recently curtailed CHPS programs are considered not yet firm.

Exhibit 17: Potential 2030 global clean hydrogen demand by region by firmness of policy support¹, Mtpa



1. Policies listed not exhaustive, to see a list of policies considered refer to the appendix
2. Includes non-specific pathway demand, where a demand is not specified by user or regulator
3. China's NDRC/NEA energy guidelines set a national baseline target of 2 Mtpa of renewable hydrogen production by 2030, bottom-up aggregations and modeling of provincial-level targets indicate at least 2.3 Mtpa of demand by 2030 with external sources indicating as much as 3.5-5 Mtpa
4. RoW: 0.02 Mtpa consisting of Australia, New Zealand and Singapore

56. Transposition of RED III targets is ongoing and figures are expected to change as additional member states continue to implement legislation; public references to transposition status range from 9 to 14 at time of publication depending on timestamp and transposition definition; for purposes of modeling in this report, transposition includes full implementation into law and/or highly advanced legislation with announced non-compliance penalties
57. Ammonia Energy Association, Korea Southern Power selected as final bidder in national clean power auction (2024)
Source: McKinsey Global Energy Perspective 2026 (Sustainable Transformation Scenario); McKinsey Hydrogen Insights Total Cost of Ownership; McKinsey Hydrogen Insights Global Hydrogen Trade Model

By 2035, clean hydrogen demand could reach about 18 Mtpa, but the majority still hinges on policy implementation and market scale-up

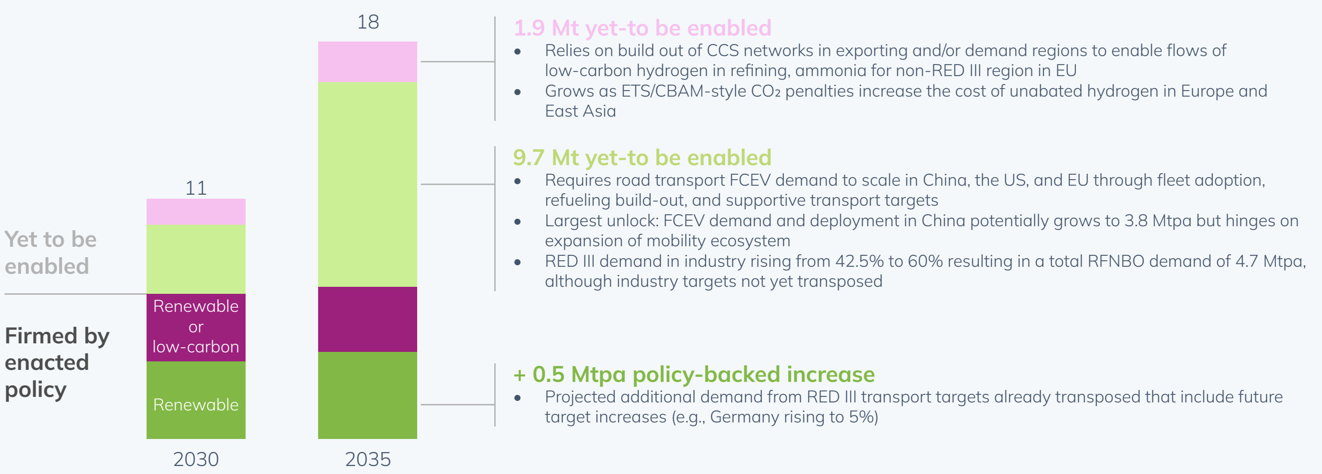
Applying the same analysis for 2035 suggests up to 18 Mtpa of potential demand in the next decade. However, almost the entire incremental increase from 2030 to 2035 remains yet to be enabled, meaning demand that appears economic would still require policy implementation, infrastructure delivery, supply-chain coordination, supply cost reductions, and increased end-user adoption to materialize.

Europe is a major 2035 swing factor depending on how currently discussed policy ambition translates into demand. A large share of additional demand depends on 2040 climate target-adjusted review of RED III, ETS, and CBAM being fully embedded into national regulation and industrial decisions. RED III is especially important as industrial RFNBO targets rise from 42.5% to 60% by 2035, while transport obligations still need to translate into signed offtake. ETS/CBAM penalties and CCS network deployment will also shape whether low-carbon hydrogen scales in refining, ammonia and other industrial applications.

One of the largest potential growth drivers would be broader renewable hydrogen deployment in China, particularly if additional fuel cell electric vehicle (FCEV) demand materializes. China could become one of the largest sources of additional 2035 demand if its clean hydrogen supply build-out translates into scaled uptake across transport and industry. Road transport is the largest unlock, but requires fuel-cell vehicle adoption, refueling infrastructure and supportive local procurement to move from early deployment to mass-market demand. If realized, this would materially expand clean hydrogen use beyond today's industrial applications.

The 2035 opportunity will be informed by near-term policy and investment decisions. The key question for 2035 is not whether clean hydrogen can become competitive, but whether competitive demand can be realized at scale. Without the implementation of existing policy, infrastructure build-out and coordinated market formation, especially in Europe and China, a significant share of the 2035 opportunity would likely be unrealized.

Exhibit 18: 2030 vs 2035 global clean hydrogen demand ranked by firmness of policy support[1], Mtpa



1. Policies listed not exhaustive, to see a list of policies considered refer to the appendix

Source: McKinsey Hydrogen Insights Total Cost of Ownership; McKinsey Hydrogen Insights Global Hydrogen Trade Model; Government websites; IEA

Section 3c - The supply/demand balance

55% of potential demand (6 Mtpa) is likely matched to supply; remainder requires firming demand-side policies, accelerating local supply projects and tapping into strategic trade corridors

6 Mtpa matched demand

clean hydrogen demand that already has offtake agreements or is otherwise matched to FID supply

4.2 Mtpa binding offtake

Secured either through captive or binding sales and purchase agreements

5 Mtpa supply gap

Potentially competitive demand without either binding offtake or a likely supply match, largely driven by limited policy backing

Contracted clean hydrogen offtake continues to grow, reaching 4.2 Mtpa globally

Binding offtake, including signed purchase agreements and captive offtake into FID+ projects, rose about 16% over the past 12 months to 4.2 Mtpa H_2 equivalent. New additions include large-scale hub projects such as Gulf Coast Hydrogen/JERA/Conoco at ~352 Ktpa, alongside export-oriented ammonia projects such as Itochu/L&T at approximately 53 Ktpa. North America remains the largest offtake center (sourced from domestic production) at 1.7 Mtpa, followed by Europe at 1.0 Mtpa; publicly available data indicates at least 0.7 Mtpa of offtake in China, though committed capacity suggests this may be undercounted.

Demand remains concentrated in existing hydrogen use cases, but recent offtake additions show a broader set of project archetypes emerging. Ammonia and refining still account for 71% of binding offtake and drove nearly all recent growth. Within that, clean ammonia is increasingly being channeled into fertilizer production at scale. This is illustrated by agreements such as PepsiCo's agricultural offtake of approximately 30 Ktpa, and Atome's 145 MW project in Villeta, Paraguay, set to produce 260,000 tonnes a year of renewable ammonia-based fertilizer under a binding ten-year offtake agreement with Yara.

However, new offtake examples point to demand forming across a wider spread of end-use sectors. Commitments such as Stavian Industry Metal and Stegra illustrate growing industrial offtake, while Moses Lake E-Jet Fuel and Project Roadrunner in Reeves County, Texas, where a 100 MW electrolyzer feeds Infinium's e-fuels facility to produce eSAF, eDiesel, and eNaphtha from renewable hydrogen and waste CO_2, indicate demand for fuels. Similarly, China-based methanol and alcohol projects such as CGN's Xing'an Project and Mingyang Green Chemical Chifeng have secured offtake in chemicals.

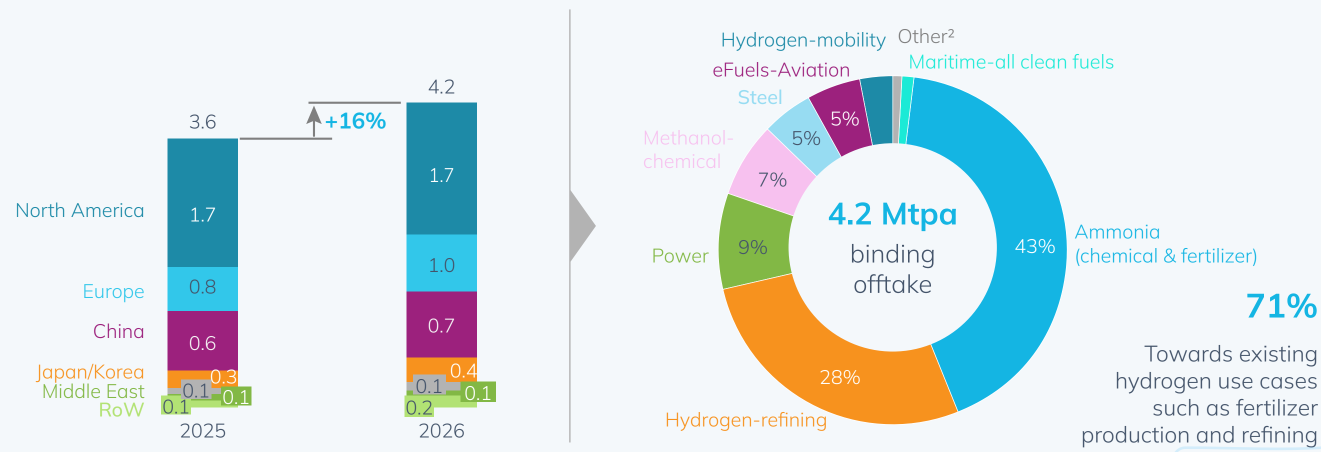
The last 12 months also show a growing long tail of smaller regional projects, including Ningxia Solar Hydrogen, that connect clean hydrogen to specific industrial users, chemicals demand, and localized mobility or fuel applications.

Project Roadrunner
(Reeves County, TX, US)

End-use: aviation | Under construction | COD: 2027 | 23 Ktpa efuels | 100 MW electrolyzer capacity

A defining challenge is expanding hydrogen demand beyond legacy applications into new fuel markets. The Roadrunner project provides an example of this transition: a project under construction deploying Electric Hydrogen's 100 MW modularized electrolyzer plant within Infinium's e-fuels facility to produce eSAF and eNaphtha from waste CO_2 and renewable hydrogen. The project demonstrates demand forming in e-fuels for aviation and in low-carbon plastics feedstocks, beyond legacy hydrogen uses. Financial backing from Breakthrough Energy Catalyst ($75M project equity) and Brookfield illustrates that offtake into these new fuels is now attracting serious project finance. Modular skidded pre-fabrication and self-performance of EPC by electrolyzer OEM (Electric Hydrogen) minimizes installed cost and enables rapid electrolyzer installation. Project Roadrunner is expected to be completed in 2027.

Exhibit 19: Clean hydrogen offtake by destination geography by end use sector[1], Mtpa H_2e



1. Sector reflects the chemical used at end use, not the distribution form (e.g., ammonia cracked back to H_2 for use in refining is attributed to hydrogen-refining)
2. Includes chemical intermediates as well such as offtake from the Path2Zero ethylene and derivatives plant

Source: Hydrogen Project & Investment Tracker 2026; McKinsey Hydrogen Insights Clean Hydrogen Offtake Tracker

Granular supply-demand matching suggests the 6 Mtpa of firm 2030 demand is largely matched to supply, leaving a 5 Mtpa gap to fill

By 2030, about 6 Mtpa of demand firmed by enacted policy is already aligned to supply, with most supported by binding offtake. This includes 4.2 Mtpa of contracted offtake and about 2 Mtpa of FEED+ supply matched to firm demand. Examples include supply that serves enacted policy-backed demand pools such as RED III-supported transport in Europe (in many cases where renewable hydrogen displaces conventional hydrogen in refining), existing industrial demand in China, and offtake linked to committed supply in North America, the Middle East, and the Rest of World.

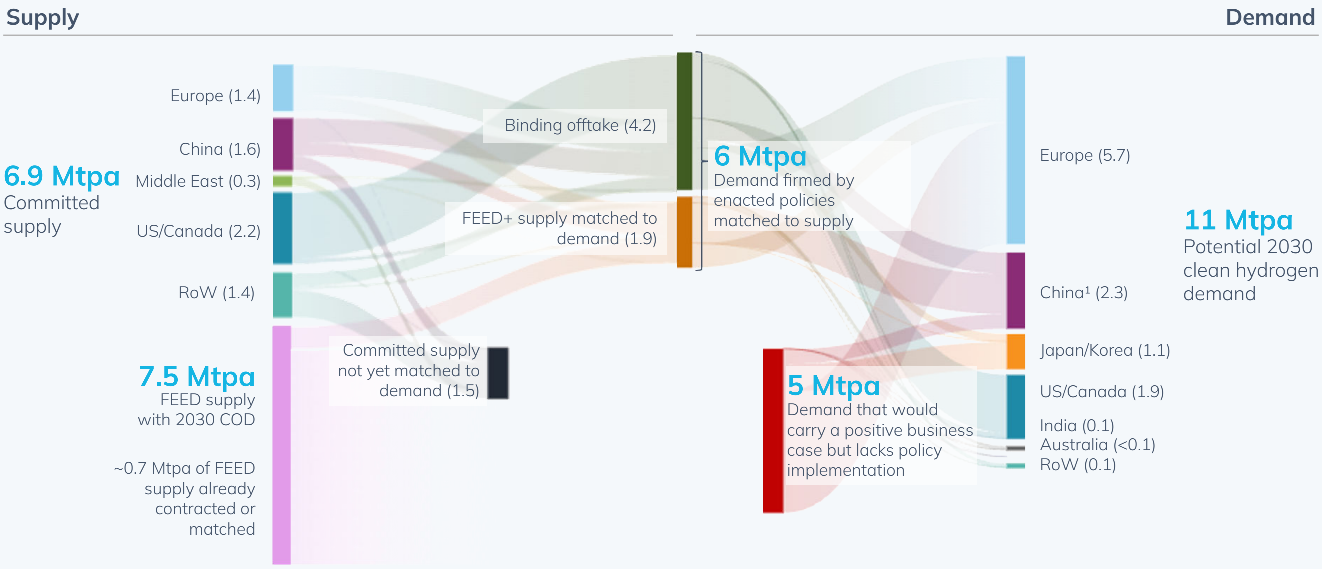
Closing the remaining ~5 Mtpa demand gap would depend primarily on the degree of additional policy implementation. This demand could carry a positive business case by 2030 but remains unmatched because the required enabling policies are not yet fully implemented or subscribed to. Key examples include RED III industry targets (under review alongside EU ETS and CBAM elements), additional allocation of Japan's CfD, additional CHPS auction volumes (pending review completion and auction roll out), and other segments awaiting enactment of proposed or stalled support mechanisms.

Committed supply is available to meet part of the upside but lacks demand certainty today. At least 1 Mtpa of committed supply is not yet concretely matched to demand. This represents a combination of supply projects that have reached FID but do not yet have a public offtaker in place or the merchant portions of larger projects for which part of the production capacity has already been contracted.

Another approximately 7.5 Mtpa of mature pre-FID supply stands ready to meet newly firm demand as well, but could face significant cost competition given the supply/demand mismatch. Approximately 0.7 Mtpa of this FEED-stage supply is also either already contracted or very likely matched to demand (e.g., several large-scale projects in China appear to have captive offtake without public announcements).

If proposed policies are enacted and converted into procurement, offtake, and infrastructure build-out, committed and FEED-stage supply could absorb most, if not all, of the 5 Mtpa gap; without additional policy certainty, some of this supply could remain stranded while demand remains unrealized.

Exhibit 20: 2030 Global clean hydrogen supply/demand balance



1. China's NDRC/NEA energy guidelines set a national baseline target of 2 Mtpa of renewable hydrogen production by 2030, bottom-up aggregations and modeling of provincial-level targets indicate at least 2.3 Mtpa of demand by 2030 with external sources indicating as much as 3.5-5 Mtpa

Source: McKinsey Hydrogen Insights Willingness-to-pay Model; Hydrogen Project & Investment Tracker 2026; Government websites

04

Emerging hydrogen ecosystems

Progress is not universal, but competitive ecosystems are emerging where demand is meeting cost-optimal supply under the right market-enabling conditions:

— EU RED III transport target transposition is driving both local and international FIDs, with majority of global RFNBO trade heading to Europe

— China's 15th five year plan positions hydrogen as a strategic lever for energy security and industrial growth, with a centrally-driven push to complementary end-to-end industrial and mobility ecosystems

— India's National Green Hydrogen Mission and the support measures therein catalyze early deployment of one of the lowest cost renewable ammonia ecosystems globally, targeting both import replacement and eventually exports

— In the US, optimal production conditions meet existing export infrastructure and the 45Q CCUS tax credit to enable low-carbon ammonia from the Gulf Coast to reach parity with unabated ammonia in demand centers like the EU, as well as serve as a leading option for power decarbonization in East Asia

Kassø e-Methanol Plant | Aerial view of e-methanol production facility and adjacent solar park | image provided by Siemens and Mitsui

Hydrogen ecosystems develop when bankable demand is effectively linked to cost-competitive supply by the right infrastructure, with market activation tying the value chain together to enable scale

Each of these elements plays a distinct role, and their interaction, rather than any one pillar in isolation, is what allows an ecosystem to take hold.

Cost-competitive supply is integral to economically serve end-use sectors – supply costs typically need to fall below value-in-use to solidify the business case for clean hydrogen. In many cases, this requires tapping into optimal natural resources (renewable power or natural gas feedstocks) but can also be supported via supply-side policy mechanisms like production tax credits. In India, for example, solar-wind hybrids achieve high-capacity utilization and drive some of the lowest global tender prices, allowing centrally-supported renewable ammonia to compete with conventional imports.

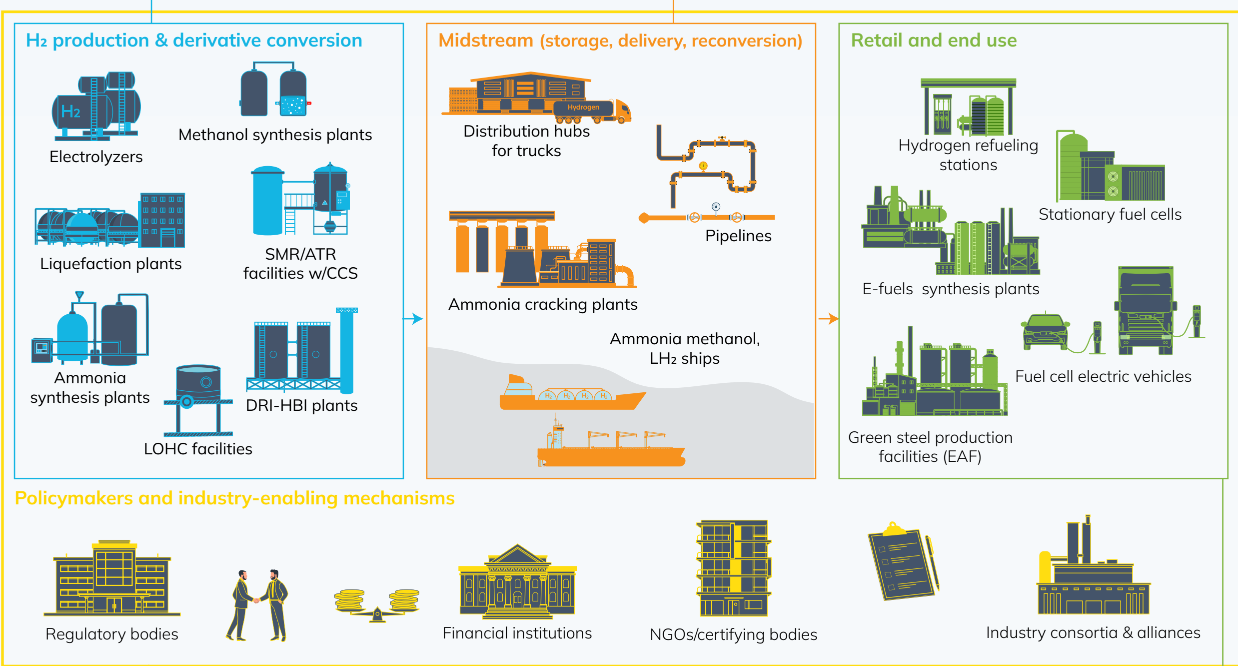
Infrastructure then connects supply to demand, both physically and commercially: hard assets such as pipelines and ports work alongside soft infrastructure such as carbon-intensity certificates and trading frameworks. The U.S. Gulf Coast illustrates this, where world-class operating ammonia plants, an established Gulf pipeline network, existing CO_2 transport and storage network, and deepwater ports provide an optimal infrastructure landscape that enables fast scaling.

On the other side of the value chain, **bankable demand,** whether captive industrial demand or demand backed by regulatory mandate, enables the offtake necessary to support project investment. In Europe, RED III transport sub-quotas mandate the use of RFNBO across several mobility sectors, converting policy into firm demand. Finally, **market activation** supplies the financing and coordination that tie the value chain together and enable scale. China demonstrates this dynamic. Hydrogen is seen as a potential new growth driver, with government entities identifying several demonstration cities and enabling deployment via a range of support mechanisms and cost reduction levers.

Exhibit 21: Core building blocks of emerging hydrogen ecosystems

1 | Cost-competitive supply. Production resources (e.g., low-cost renewable power, access to natural gas fields), financing structures and optimized equipment access that enable cost-optimized hydrogen production

2 | Catalytic infrastructure & enabling technology. Connective trade and transport infrastructure that physically links supply and demand (e.g., pipelines, ports, refueling stations, reconversion technology) or enables production (e.g., CCUS networks)



4 | Market-activating mechanisms. Ecosystem-specific policy mechanisms, financing support, and value chain coordination measures that tie together supply, demand and infrastructure to enable scale (e.g., binding quotas, central mandates, public/private financing measures, CI certificates, trading frameworks, cross-border standards, custody mechanisms)

3 | Bankable demand in granular pockets of policy-backed offtake. Offtake into captive industrial demand sectors (e.g., direct refining or ammonia offtake) or otherwise policy-backed demand in emerging end uses (e.g., mobility)

Four emerging ecosystems illustrate how matching supply and demand underpins pockets of competitiveness

Each of the four case studies that follow shows a different element acting as the primary catalyst: bankable demand in Europe, market activation in China, physical infrastructure on the U.S. Gulf Coast, and cost-competitive supply in India, though sustaining any of these ecosystems still requires all four working together.

In the EU, a renewable hydrogen ecosystem is supported by bankable demand in the transport sector underpinned by transposition of RED III transport targets. RED III's transport sub-targets mandate RFNBO uptake, and penalty enforcement that exceeds supply cost converts the mandate into firm demand, although only about a quarter of all EU refineries have already connected to FEED+ renewable hydrogen supply. That pull is met by both domestic supply (co-located or delivered via new and/or retrofitted pipeline networks) and potential imports carried through repurposed gas pipelines connecting import terminals to refineries and activated by ongoing member-state transposition of the transport targets.

China's strategic market activation efforts, including significant government financial support and targeted industrial policy, enable industrial ecosystem development complemented by growing road mobility build out. In addition to the strategic government support tied to the elevation of hydrogen, China draws on the largest global electrolyzer manufacturing base (60% of global capacity)[58] and low-cost equipment that allows ammonia production costs potentially below $500/t, state-built transport corridors, and 700+ Ktpa of binding offtake from integrated value chains spanning chemicals and mobility.

The United States Gulf Coast is home to an emerging low-carbon production and export ecosystem supported by a unique resource-infrastructure-policy landscape combination. Operating ammonia plants with retrofit and new-build CO_2-capture, existing hydrogen and CO_2 networks, domestic transportation and deepwater export terminals sit on a structural natural-gas and CCUS cost advantage. Export pull from Japan, Korea and the EU, along with strong U.S. agricultural demand, supports part of the region's 1,400+ Ktpa of low-carbon offtake, made bankable by the 45Q carbon capture tax credit closing the cost gap.

India's renewable ammonia ecosystem is enabled by government-supported low-cost supply, primarily for import displacement. Several government support mechanisms enable solar-wind hybrids to deliver low PPA prices and high-capacity utilization. These support mechanisms seek to put renewable ammonia near or below conventional import parity. That supply feeds an integrated renewables-to-ammonia-to-port chain and is already supporting over 130 Ktpa of binding offtake secured through SIGHT auctions and NGHM transmission-fee waivers.

Exhibit 22: Emerging clean hydrogen ecosystems

	Europe **Transport** ***RED III transport target transposition drives RFNBO uptake in refining, mobility applications***	China **Industrial chemicals & mobility** ***End to end complementary industrial and mobility ecosystems deploy in parallel under central mandate***	United States **Low Carbon exports** ***Optimal resource & infrastructure profile enables lowest-cost low-carbon ammonia exports***	India **Renewable ammonia** ***Low-cost, centrally-supported domestic renewable ammonia to displace imports, enable future export***
1 **Cost-competitive supply**	Co-located electrolysis + potential RFNBO imports from low-cost regions	Lowest cost electrolyzers + curtailed renewable power lowers cost to ~$2-3.5/kg by 2030	Structurally low-cost natural gas feedstock	Low-cost renewables enable renewable ammonia to near parity with imports
2 **Infrastructure**	Retrofitted + purpose-built pipelines connecting port terminals and H_2 valleys to demand centers (e.g., refineries)	State-built pipeline corridors from core supply regions to demand centers	Existing ammonia plants + CCUS networks + deepwater export terminals	Integrated renewables-to-ammonia-to-port chain
3 **Bankable demand**	Fuel supplier value-in-use for RFNBO hydrogen exceeds cost to serve	Integrated value chains across sectors, with 2.3 Mtpa of emerging demand & 700+ Ktpa binding offtake	Export pull – EU CBAM-driven ammonia displacement + JP/KR decarbonization policies	Fertilizer import substitution to enable agri-food system resilience; 80% of ammonia consumption relies on imports or imported feedstock
4 **Market Activation**	RED III transport transposition & penalty enforcement combined with ETS/CBAM implementation	15th Five-Year Plan + centrally supported financing	45Q makes NH_3 export economics bankable	SIGHT auctions secure domestic green NH_3 offtake

58. IEA, Global Hydrogen Review 2024

Several earlier-stage hydrogen ecosystems show signs of credible momentum but would largely rely on better-established global trade corridors and infrastructure falling into place. Although most are less well established than today's leading hydrogen hubs detailed in this section, each has a plausible scaling logic: advantaged resources, existing export infrastructure, policy-backed demand, or cross-border offtake formation.

One such example where several ecosystem building blocks are starting to fall in place is in Japan and Korea, where emerging import-led demand ecosystems comprised of several end-use sectors are growing in parallel. Japan is advancing ammonia co-firing to decarbonize coal power and developing liquid hydrogen import chains for industrial and urban energy demand, supported by procurement mechanisms and dedicated receiving infrastructure. Korea's emerging ecosystem is more centered on hydrogen mobility, liquefaction, and fuel cells, with demand supported by the Clean Hydrogen Portfolio Standard.

Japan is also establishing a government-backed, mobility-led "hydrogen backbone". Led by METI alongside partners like Toyota Motor Corporation and Kawasaki Heavy Industries, the initiative features a 1,300 km truck network (Fukushima to Fukuoka) supporting about 1,500 heavy-duty fuel cell trucks (around 7,500 t/yr) across about 30 stations. Supported by price support and a joint demand aggregation declaration, this transport ecosystem is intended to eventually expand to power, steel, and chemicals.[59]

However, limited domestic resources coupled with ambitious decarbonization targets create structural import needs for clean molecules in both markets, making import and reconversion infrastructure two critical enablers for establishing fully operational ecosystems. In this context, both Japan and Korea have advanced liquefied hydrogen carrier technologies toward commercial readiness through technology validation projects and increasingly large-scale supply chain demonstrations.

Globally, the maritime sector is also emerging as a cross-cutting hydrogen derivatives ecosystem across several geographies. Shipping decarbonization could create demand for ammonia, methanol and liquid hydrogen as marine fuels, with port-based aggregation points such as Rotterdam, Antwerp-Bruges, Singapore and several Chinese ports advancing bunkering capabilities. The ecosystem remains policy-dependent, particularly given ongoing debate around the IMO Net-Zero Framework, but could become an important demand-pull mechanism linking clean molecule supply regions with global shipping corridors.

Waste-to-Hydrogen: A Local Circular Economy Model (Cheongju, South Korea)

End-use: Mobility, Operational | COD: 2026

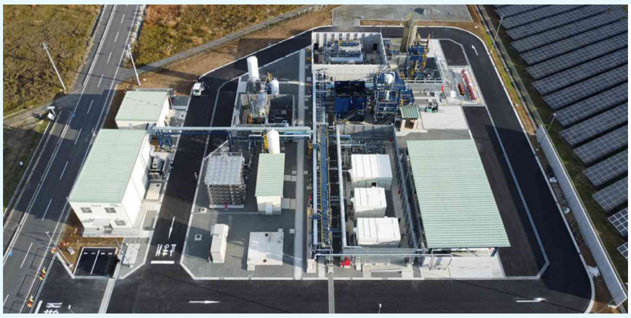
Project spotlight

Korea is also building up domestic production capacity alongside the expansion of hydrogen mobility. The Cheongju Waste-to-Hydrogen facility, operated by Hyundai Motor Group, is a representative example. The facility applies a produce-locally, consume-locally approach to lower delivered prices, a key condition for wider hydrogen adoption. It produces hydrogen at 99.97% purity by purifying and reforming biogas recovered from local food waste and sewage sludge. This approach improves price competitiveness by avoiding the cost of trucking in hydrogen produced at coastal industrial hubs, while also cutting the methane emissions this waste would otherwise release and strengthening the region's energy self-sufficiency.

The facility can produce 500 kg of hydrogen per day and began commercial operation in May 2026. The hydrogen produced is supplied to hydrogen stations across North Chungcheong Province. Output is planned to scale to 2 tonnes per day by 2030. In step with this, Cheongju plans to deploy 225 hydrogen passenger vehicles and buses citywide in 2026 alone, and to continue converting its city bus fleet to hydrogen going forward. Hyundai Motor Group plans to extend this approach to markets such as Indonesia and Hong Kong, adapting it to each region's local waste profile.

Demonstrating an Integrated Hydrogen Value Chain from Production to Application (Namie, Japan)

End-use: Mobility, Ammonia production | Operational | COD: 2026



Project spotlight

Japan's focus is technology readiness, proving the pathway works ahead of scale. The Fukushima Hydrogen Energy Research Field (FH2R) serves as a demonstration platform for the production, transportation, and end-use of hydrogen, supporting the development and validation of an integrated hydrogen value chain. Constructed in 2020 with support from New Energy and Industrial Technology Development Organization (NEDO), FH2R is equipped with a 20 MW PV system, a 10 MW alkaline electrolyzer, storage and supply system. For more than six years, the project has stably provided hydrogen to various applications, including stationary fuel cells, FCVs, and fuel cell buses, while accumulating valuable operational experience in large-scale hydrogen production under renewable energy conditions.

Building on this operational experience, Asahi Kasei and JGC launched a renewable ammonia production demonstration project in 2026 under NEDO Green Innovation fund. JGC's 4 metric ton per day (MTPD) demonstration plant, basic design and licensed by KBR, produces renewable ammonia from renewable-powered hydrogen, drawing on the nearby FH2R field through pipeline, and supplies it, via an off-taker, to thermal power stations as a De-NOx agent. The project provides a working demonstration of production technology for renewable ammonia. The project validates the technical feasibility of producing ammonia from renewable energy and serves as an important stepping stone toward commercial-scale deployment.

59. Japan Hydrogen Association (2026)

The following four deep dives illustrate how regional and sector-specific variations of clean hydrogen ecosystems are emerging. Each ecosystem exhibits the four key elements, but the mechanism by which each ecosystem is unlocked and the conditions within which each has developed are unique to each sector-by-geography combination.

EU TRANSPORT

Transposition of EU RED III transport targets is fostering the first demand ecosystem for RFNBO hydrogen although an 800 Ktpa supply gap remains to be filled

What makes the ecosystem work:

Demand for clean hydrogen in the transport sector in Europe is materializing behind RED III transport target transposition. RED III's binding RFNBO transport sub-targets create approximately 1.2 Mtpa of potential renewable hydrogen demand. So far, 11 of 27 member states have transposed targets into law or have advanced drafts, some of which include specific penalty guidance (e.g., Germany).

While RFNBO hydrogen can be fed directly into hydrogen vehicles to address the quota, in many cases, initial compliance is being achieved via the "refinery route." RFNBO hydrogen is fed into refinery hydrotreating and hydrocracking to make road, maritime and aviation fuels. However, the mandate only applies to dedicated (non-byproduct) hydrogen eligible under RFNBO accounting, which eventually puts an upper limit on the refinery route (in addition to several Member States setting their own limits), potentially pushing future volumes directly into vehicles via refueling infrastructure.

Supply is falling into place, anchored by refinery early-movers. North-Western Europe refiners are integrating clean hydrogen on existing industrial bases; about 25% of EU refineries have secured FEED+ supply. Project scale is stepping up sharply (projects under construction are 2-24 times larger than those already operational), but the largest plants (100+ Ktpa, clustered in Rotterdam) start up only in 2026–2028. Imports into Europe may need to land at around 5–9 $/kg, to remain cost-competitive with domestic projects.

However, a supply–demand gap remains. Most large domestic projects are pre-operational, and the approximately 0.7 Mtpa of remaining potential 2030 demand only becomes bankable when the policy signal is firmed further via continued transposition across member states.

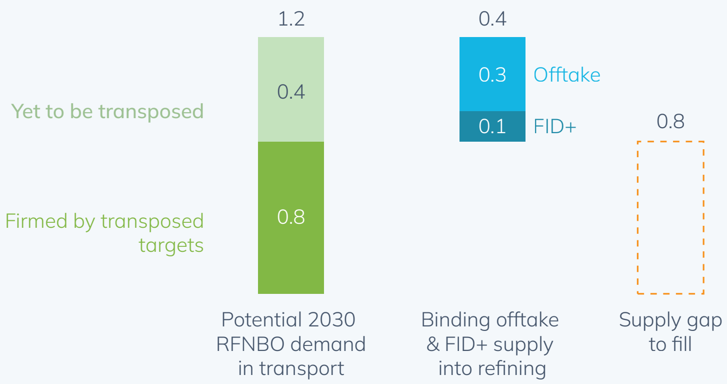
Hamburg Green Hydrogen Hub (Hamburg, Germany)

End-use: transport, industry, port | Under construction | COD: 2027 | 10 Ktpa, 100 MW capacity | $175.6 million IPCEI funding; Total investment in mid-hundreds of millions

Project spotlight

This chapter highlights how Europe's momentum is being sustained. The Hamburg project illustrates this through its location: Luxcara and Hamburger Energiewerke are constructing a 100 MW electrolyzer on the grounds of the former Moorburg coal power plant, supplying industry, the port and transport. By transforming a decommissioned coal site into a hub for renewable hydrogen production, the project demonstrates how existing energy infrastructure can be repurposed to support Europe's industrial decarbonization and hydrogen scale-up.

Exhibit 23: European supply/demand balance for RED III transport-driven demand, Mtpa



11/27 member states[1]
EU member states transposed RED III transport targets

1.2 Mtpa
Potential RFNBO demand in transport fuels (road, maritime + aviation)

0.3 Mtpa
Supply with binding offtake so far

1. Transposition of RED III targets is ongoing and figures are expected to change as additional member states continue to implement legislation

Source: McKinsey Hydrogen Insights, McKinsey Energy Solutions H_2 Cost Optimization Model (H_2-COM), Ammonia Energy Association (2026)

Transposed RED III transport targets coupled with penalties typically drive sufficient value-in-use to support the RFNBO business case

RED III transport target transposition demonstrates how policy action translates to firm hydrogen demand. The directive sets a binding 1% minimum share of RFNBOs in transport energy by 2030 (the first hydrogen-specific mandate). The obligation falls on fuel suppliers, but several key value chain stakeholders – hydrogen producers, refinery operators, end users in road mobility, aviation and maritime – rely on the mandate to enable their respective business cases.

Fuel suppliers have several potential routes to comply. They can, for example, supply hydrogen directly to road and rail vehicles, or sell e-fuels into aviation and maritime markets, where operators face their own, separate mandates (ReFuelEU's 1.2% e-SAF sub-target and FuelEU Maritime's future 2% sub-target). Alternatively, they can substitute renewable hydrogen for unabated hydrogen in refineries. At low incremental cost to downstream vehicle operators, this drop-in option is often the cheapest, lowest-infrastructure option to build an initial base of RFNBO hydrogen demand. However, several states have already capped or discounted this mechanism (e.g., the Netherlands' correction factor, Finland's hard cap) to stop it from crowding out direct use and e-fuels.

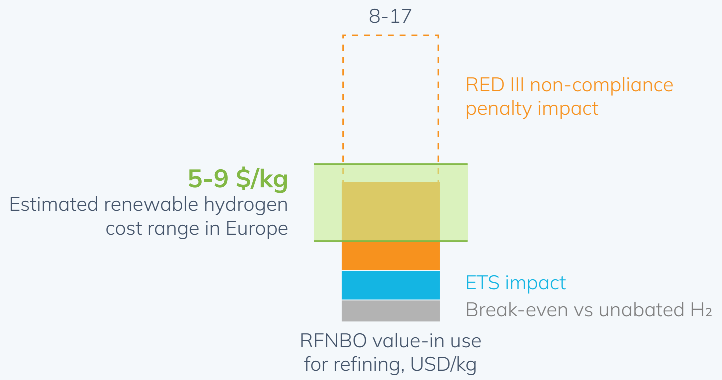
Penalties support the business case by closing the cost gap. Non-compliance penalties enacted or proposed by Member States (up to €14/kg),[60] stacked with ETS costs and the break-even against unabated hydrogen, lift RFNBO value-in-use to 8-17 $/kg for refineries – in most cases above the cost of renewable hydrogen in Europe. Where transposition is advanced, value-in-use already typically exceeds supply cost, closing the gap that has previously held back RFNBO investment.

Exhibit 24: Mechanisms to address and economics of meeting RED III transport targets

Three potential ways for a fuel supplier to comply

- **Direct-use hydrogen in road and rail (e.g., FCEVs, H_2 ICE)**
  Significant infrastructure cost and complexity, but direct mitigation of downstream emissions and supports shift toward low-emission vehicles
- **Sell e-fuels into aviation & maritime**
  Serves operators' own mandates (ReFuelEU 1.2% e-SAF, FuelEU); potentially high willingness to pay but limited market
- **"Refinery route"**-substitute renewable for unabated H_2 in existing refinery processes
  No new fuel production or distribution infrastructure, lowest cost impact on downstream user, but limited to no vehicle drivetrain switch-over incentivized

RFNBO value-in-use vs estimated supply cost, $/kg H_2



Value-in-use exceeds supply cost
In most instances, penalties enacted or proposed by Member States (5-10+ €/kg) with advanced transposition drafts effectively bridge the cost gap

Scaling the EU's emerging clean hydrogen ecosystem will require progress on three fronts: firming demand, accelerating domestic supply, and building the infrastructure needed to move molecules across borders and into end-use markets

Firming demand. Europe can firm the remaining demand base created by RED III transport transposition and adjacent policy mechanisms. Transposition across the remaining Member States could solidify the bankability of approximately 700 Ktpa of additional demand, creating clearer offtake signals for suppliers and financiers. Beyond RED III transport, further implementation of RED III industry targets, FuelEU Maritime, and ReFuelEU Aviation could expand the pool of bankable demand across industrial, maritime, aviation, and refining applications.

Accelerating domestic supply. Europe could convert more pre-FID domestic supply into operational projects. A meaningful pipeline of renewable hydrogen capacity remains in FEED and could still come online by 2030 if projects can secure offtake, grid access, permitting, and financing. Streamlining measures such as Germany's H_2 Acceleration Act illustrate the levers that can reduce development timelines and support conversion to FID.

Building the infrastructure. Establishing intra-EU and extra-EU import infrastructure could connect low-cost supply with demand centers. The European Hydrogen Backbone would move dedicated hydrogen infrastructure beyond local clusters, with corridors that could link major production hubs to demand centers across Europe. These corridors can carry renewable and low-carbon hydrogen

60. Hydrogen Council, Why RED III implementation matters, 2026
Source: McKinsey 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

from both intra-EU and neighboring supply regions to consumers across multiple end uses.

Early links are emerging at the cluster level, such as HyTransPort.RTM in Rotterdam and the Vlieghuis–Ochtrup cross-border converted gas line linking Dutch import hubs with Germany's hydrogen core network. At corridor scale, Enagás' planned approximately 2,800 km Spanish Hydrogen Backbone and the BarMar and CelZa interconnections of the H2Med corridor could enable Iberian renewable hydrogen to reach northwest European demand, supported by production anchors such as Moeve's Andalusian Green Hydrogen Valley in Huelva. The approximately 3,300 km SoutH2 Corridor could connect low-cost North African production with European demand centers and enhance supply diversification.

At-scale imports will require additional infrastructure at ports and industrial entry points. This includes import terminals, storage, last-mile links to refineries and industrial valleys, and reconversion capacity for imported carriers such as ammonia. European ammonia cracking remains in large part pre-commercial but relevant projects are advancing: Air Liquide's Antwerp cracker is operational at approximately 30 t/day of ammonia, Uniper and thyssenkrupp Uhde's Gelsenkirchen-Scholven demonstration plant is under construction at about 28 t/day with commissioning planned for the end of 2026, and AMMONEX in Rotterdam has reached FID with testing expected in 2027. Liquid hydrogen import corridors are at an earlier stage, with agreements covering seaborne delivery (e.g., from Oman to Amsterdam signed in 2025) emerging but not yet operationalized. Together, these infrastructure elements will be critical to linking low-cost domestic and imported supply with RED III-driven demand across Europe.

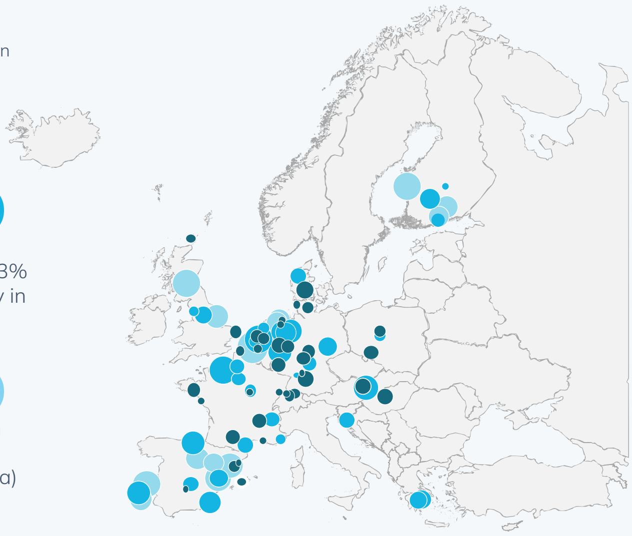
Ammonia Cracking Pilot Unit (Antwerp, Belgium)

End-use: Industry | Operational | COD: 2025 | 30 tpd cracking capacity

Project spotlight

Ammonia cracking technology will increasingly be needed to connect global hydrogen markets through ammonia as a cost-effective hydrogen carrier, leveraging existing ammonia supply chains during the market activation phase. In 2025, Air Liquide commissioned the world's first industrial scale ammonia cracking pilot unit, with 30 tpd of conversion capacity. Reliable long-term operation of all components was proven at the Antwerp site while demonstrating maximum energy efficiency and highest possible hydrogen yield. The project illustrates how technologies and facilities can be developed and adapted to pioneer the low carbon and renewable hydrogen market and unlock large scale clean hydrogen international energy supply chains. This approach will serve as a template to enhance time to market with the project's results to be leveraged into larger scale projects that are currently in development.

Exhibit 25: European renewable hydrogen projects, by maturity



1.6 GW (210 Ktpa)

Committed (FID+) renewable hydrogen capacity for refining (13% of committed renewable capacity in Europe)

2.0 GW (230 Ktpa)

Additional capacity for refining in FEED. All other FEED-capacity amounts to ~10.6 GW (1270 Ktpa)

5–9 $/kg

Estimated domestic European supply costs

Schwechat refinery & UpHy I/II (Austria)

End-use: refining | Under construction | COD: 2027 | 23 Ktpa; 140 MW capacity | 600 MEUR investment

Project spotlight

On the renewable side, OMV's 140 MW electrolyzer, set to be Austria's largest renewable hydrogen plant when it enters operation, supported by €123 mn in secured government funding, a €450 mn loan from the European Investment Bank (EIB) and a partnership with Masdar, will replace fossil-based hydrogen at the Schwechat refinery with renewable hydrogen, contributing to the decarbonization of refinery operations. A distinguishing feature of the project is demand diversification across a single site, supporting the production of more sustainable fuels and chemical feedstocks.

Air Products Hydrogen Liquefier in Rotterdam (Rotterdam, Netherlands)

End-use: Transport and industry | Under construction | COD: 2027 |

Project spotlight

Connective infrastructure is a top priority for future hydrogen scaling. Air Products' second Rotterdam liquefaction plant, now more than 65% complete and with commercial operation scheduled for 2027, is set to become the largest liquid hydrogen production facility in Europe, expanding liquid hydrogen availability for a wide range of existing and emerging industries. It reflects a major step in reinforcing and modernizing Air Products' current hydrogen footprint in the Netherlands and further strengthens Rotterdam's position as one of Europe's key hydrogen and energy hubs, supported by government policy, existing infrastructure, logistics and industrial demand. The project provides an example of catalytic midstream infrastructure supporting distribution and unlocking downstream demand rather than production capacity itself.

Source: McKinsey Hydrogen Insights, McKinsey Energy Solutions H_2 Cost Optimization Model (H_2-COM), Ammonia Energy Association (2026)

CHINA INDUSTRIAL CHEMICALS & MOBILITY

China is establishing an end-to-end hydrogen value chain to build complementary industrial and mobility ecosystems

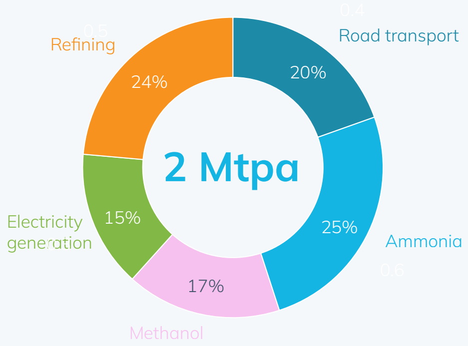
What makes the ecosystem work:

China's model is enabled by low-cost supply and renewable power being built in parallel, connected across regions and anchored first by large industrial offtake, with distributed mobility demand emerging alongside core industrial offtake corridors. Low-cost equipment (allowing plants to run at more variable or lower utilization), access to cheap or curtailed renewable power, and state-backed capital are pushing China toward some of the lowest projected renewable hydrogen costs globally. Government efforts reinforce this shift from pilot power-to-hydrogen projects toward scaled renewable hydrogen, ammonia, and methanol value chains, with hydrogen positioned to absorb renewables and convert them into industrial feedstocks and fuels or transport the energy over long distances.

Chemicals provide the baseload demand anchor. Refining, ammonia, methanol and chemicals can justify large-scale production and infrastructure investment, while an emerging mobility ecosystem consisting of hydrogen refueling station (HRS) networks, port trucks and urban FCEV clusters creates additional endpoint demand. This combination supports at least 2 Mtpa of potential clean hydrogen demand in China by 2030,[61] including 700+ Ktpa of binding offtake today, alongside over 32,000 FCEVs and over 500 refueling stations.[62]

China's policy framework also points to a full supply chain build-out, including storage and transport systems, clean fuel bunkering and hydrogen refueling infrastructure. By connecting value chains through one shared backbone, China is using large industrial offtake, especially chemicals, to anchor hydrogen production and justify pipeline investment. The same northern/western renewable hydrogen supply base and pipeline corridors can then serve distributed mobility demand, linking production, manufacturing, chemicals and mobility into a single infrastructure system rather than separate project-by-project value chains.

Exhibit 26: 2030 clean hydrogen demand in China by end use sector, Mtpa



2 Mtpa

Potential clean hydrogen demand by 2030
for industry and FCEV/transport

~1 trillion ¥

Projected China hydrogen market size

Envision Green Hydrogen and Ammonia Project (Chifeng City, China)

End-use: industry | Operational | COD: 2025 | 64 Ktpa; 530 MW capacity | 1770 MUSD investment

Project spotlight

China is credited with roughly 70% of new electrolysis capacity this year, with China scaling supply and export offtake together. The Envision Chifeng project, the world's largest renewable hydrogen and ammonia plant, demonstrates both developments: operational since July 2025 and producing 320,000 tonnes of renewable ammonia a year, it completed a first RFNBO-compliant shipment to LOTTE Fine Chemical in Ulsan, Korea, creating an end-to-end supply chain from production through maritime export. The combination of at-scale operational supply and a certified international offtake shipment provides an example of supply and offtake scaling together.

61. China's NDRC/NEA energy guidelines set a national baseline target of 2 Mtpa of renewable hydrogen production by 2030, bottom-up aggregations and modeling of provincial-level targets indicate at least 2.3 Mtpa of demand by 2030 with external sources indicating as much as 3.5-5 Mtpa
62. National Energy Administration of China, 2026
Source: McKinsey Hydrogen Insights, McKinsey Energy Solutions H_2 Cost Optimization Model (H_2-COM), Ammonia Energy Association (2026)

State activation, in part via state-owned enterprises, is linking supply, demand and infrastructure into regional clusters. Demonstration cities, zero-carbon industrial parks and policy bank financing are moving deployment beyond pilots. There are differentiated regional roles, with Northeast China positioned for outbound renewable hydrogen-ammonia-methanol supply, while the Yellow River bend, North China and northern Tianshan foothills are oriented more toward nearby consumption. Weak-grid and off-grid wind/solar-to-hydrogen models also support production around remote renewable resources without relying entirely on long-distance power transmission.

Domestic scale-up is paired with global export ambition. Increasing evidence of molecule and equipment exports from China suggest an opportunity for the industrial growth playbook to enable decarbonization efforts both domestically and abroad. This playbook, using coordinated industrial policy and capital support to build domestic scale and competition to reduce costs, followed by export expansion, has already proven successful in electric vehicles, batteries, and solar, where it underpinned significant global market share. That same ambition and approach is now showing up commercially: SPIC Green Energy's shipment of 3,750 tonnes of renewable ammonia produced in Jilin province to South Korea via Lianyungang Port is described as the world's largest single-batch renewable ammonia delivery, marking a shift from technical demonstration toward large-scale international commercial export.[63]

To enable a self-sustaining ecosystem, further progress is needed to scale infrastructure, improve market mechanisms and close the cost gap with conventional hydrogen

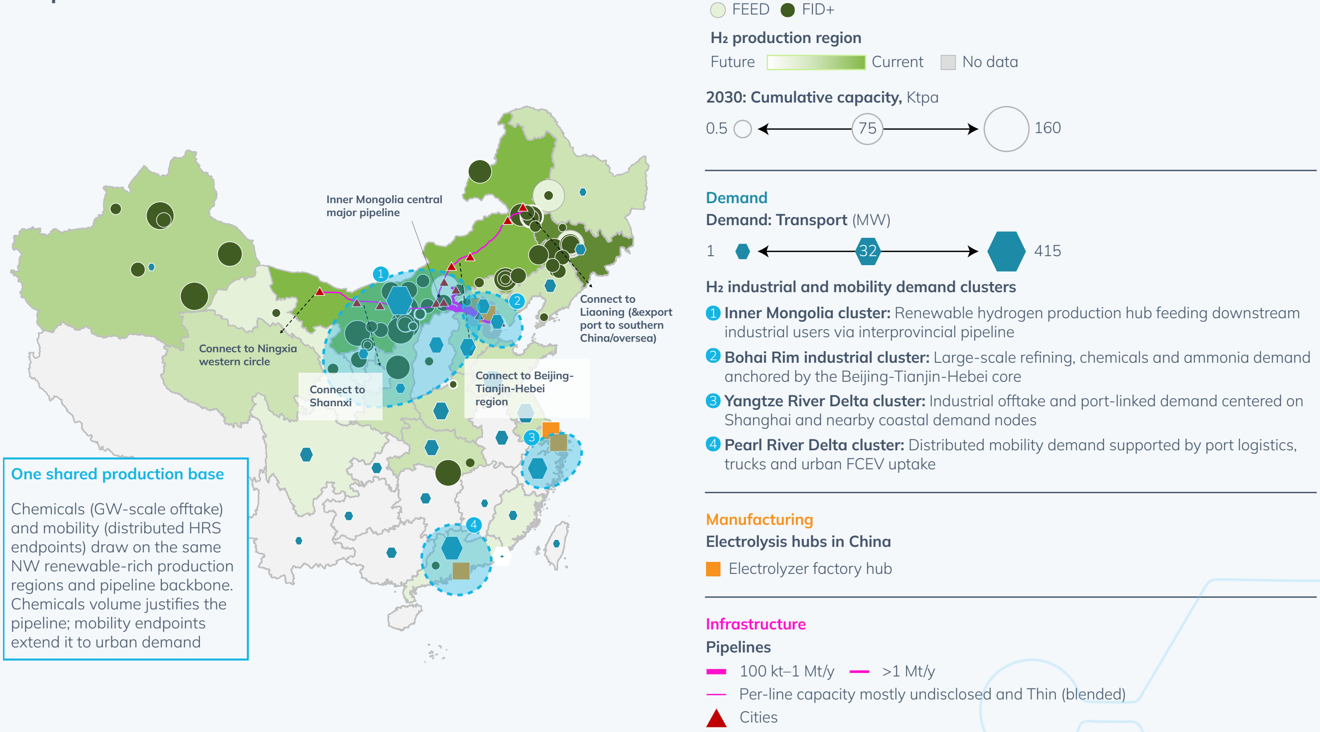
Dedicated hydrogen pipelines and regional corridors could expand into an inter-provincial backbone connecting western and northern supply with eastern demand. Long-term offtake pricing, standardized trading, price transparency, certification alignment and clearer carbon penalties could also make demand more bankable. Renewable hydrogen costs are falling, but further CAPEX reduction, cheap power access and/or higher utilization are still required to close the gap versus conventional hydrogen.

Turning corridor ambition into line-of-sight infrastructure: China is planning more than 5,500 km of long-distance pure-hydrogen pipeline across over 20 projects, of which around 350 km is built and operational today. Projects illustrating the scale of the ambition include Sinopec's "West Hydrogen to East" corridor, a ~400 km line from Ulanqab, Inner Mongolia, to the Beijing-Tianjin-Hebei demand center. The National Energy Administration described the project as China's first cross-provincial, large-scale, long-distance hydrogen pipeline, with an initial capacity of 100 Ktpa scalable to 500 Ktpa.

A second major corridor is Haitai Solar's ~1,000 km Hebei pipeline, which would further connect northern renewable hubs directly to eastern industrial demand clusters. By connecting low-cost northern supply with eastern refining and industrial demand, these corridors help address supply-demand mismatches and create access points for future hydrogen sources to connect into the system.

This integration, along with key projects such as Ulanqab's 100 Ktpa wind-solar-to-hydrogen project, backed by 1.7 GW of wind and 804 MW of solar, further strengthens Inner Mongolia's role as a hydrogen production hub. The province is moving toward a wider network described as "one trunk, two rings and four outlets," with links such as Damao Banner–Baotou now under construction and others, such as Shanghaimiao–Shuiquan, still pending approval.

Exhibit 27: China's clean hydrogen value chain components



63. FCW, World's Largest Green Ammonia Shipment Sails From China to South Korea (2026)
Source Ministry of Natural Resources of the People's Republic of China, Standard Map Service

Scale and domestic competition have driven Chinese alkaline electrolyzer system costs down approximately 45% between 2020 and 2025, contributing to China accounting for almost 60%[64] of global electrolyzer manufacturing capacity today.

Several distinct factors explain why system costs fell so sharply. In some cases, state-owned enterprises keep building regardless of near-term economics, with projects proceeding on mandate even when renewable hydrogen remains more expensive than conventional supply. More than 100 manufacturers compete, creating an unmatched density of electrolyzer OEM competition that drives prices down.

A dual certification strategy lets China run its domestic market under its own standards while seeking to obtain RFNBO/ISCC certification for exports, potentially capturing both the deployment volume needed to come down the cost curve and a higher premium simultaneously. Central planning also assigns regional roles, with production concentrated in northern regions (90%+), R&D in the Yangtze River Delta (90% localization), and end-use applications in the Greater Bay Area, a level of coordination distinct to centrally-planned systems.

The combination of these drivers has enabled some of the lowest renewable hydrogen production costs globally in parts of China – in some cases as low as ~$3.5/kg (~25 CNY/kg) today.[65] As manufacturing scale deepens, certification pathways mature, and the northern production hubs benefit from increasingly optimized wind-solar configurations, China's cost-down trajectory could enable production costs closer to ~$2/kg (~15 CNY/kg) by 2030, about 40% lower than today's costs.[66]

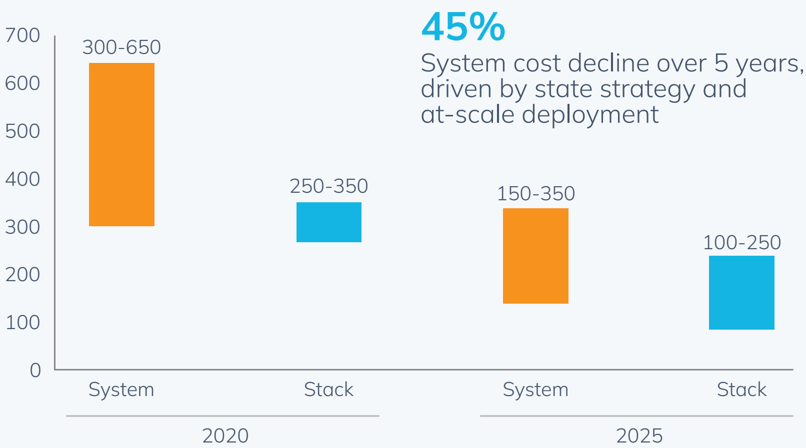
Sinopec Kuqa Renewable Hydrogen Project (Kuqa, Xinjiang, China)

End-use: refining | Operational | COD: 2023 | 20 Ktpa capacity; 300 MW solar PV

Project spotlight

The Sinopec Kuqa Renewable Hydrogen Project in Xinjiang uses a roughly 300 MW solar PV array to power an electrolysis plant with 52 electrolyzers, commissioned in Aug 2023 as the world's largest solar-to-hydrogen facility at that time. It has been operating safely and steadily for three years, ranking first among Chinese enterprises in renewable hydrogen output. The site includes 270,000 cubic meters of on-site hydrogen storage and a pipeline transporting up to 28,000 cubic meters per hour to Sinopec's downstream Tahe Refining & Chemical plant, where the hydrogen replaces fossil-based hydrogen in refining. Sinopec has since begun building a 30 Ktpa renewable hydrogen project in Ordos, Inner Mongolia, and is developing an even larger renewable hydrogen project in Ulanqab. Accordingly, the Kuqa project serves as the core proof-of-concept demonstration underpinning Sinopec's extensive renewable hydrogen rollout strategy across Northwest China.

Exhibit 28: AWE electrolyzer technology cost, $/kW



~2 $/kg

Projected renewable hydrogen production cost by 2030, down from ~$3.5/kg estimated costs today

Lower CAPEX allows projects to operate electrolyzers on fewer hours of low-cost electricity, compounding cost savings

64. IEA, Global Hydrogen Review 2025
65. NEA, China Hydrogen Energy Development Report (2026)
66. IEA Global Hydrogen Review 2026

Source: China 15th 5-year plan, China H_2 development 2025 by National energy department, Expert interview, Hydrogen Insights, team analysis. S&P Global Commodity Insights. S&P Global Commodity Insights, "China's hydrogen electrolyzer industry facing technology..." (2025); China Renewable Energy Engineering Institute (CREEI)-linked data as reported by Hydrogen Insight, "Cost of Chinese alkaline electrolysers falls by 33% in two years, with PEM prices dropping even faster" (2025); BloombergNEF Electrolyzer Price Survey (2022, 2024), as cited via FuelCellChina, "Cost of electrolysers for green hydrogen production is rising..." (2025); CRU Group, "Chinese green hydrogen has cost benefits, but challenges are emerging" (2025); World Bank ESMAP, "Electrolyzers for Hydrogen Production: Technical and Economic Characteristics" (2026); Energy China/CEEC 2023 tender results, as reported by Hydrogen Insight, FuelCellChina, and China Hydrogen; Wood Mackenzie, "The Competitive Edge of China's Electrolysers" (2024); Shanghai Metal Market (SMM), Hydrogen Energy Weekly Electrolyzer Industry Review (2025); and IRENA, "Green Hydrogen Cost Reduction: Scaling Up Electrolysers to Meet the 1.5°C Climate Goal" (2020)

U.S. GULF COAST LOW-CARBON AMMONIA EXPORTS

The U.S. Gulf Coast combines existing infrastructure with the 45Q tax credit to enable export of the lowest cost low-carbon ammonia globally

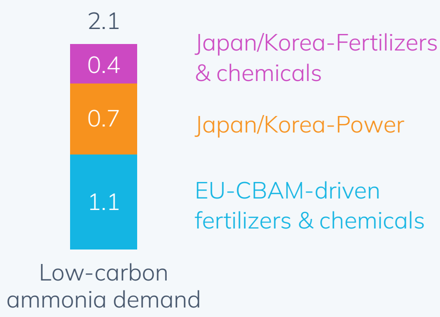
What makes this ecosystem work

The Gulf Coast's world-class base of operating ammonia plants, hydrogen pipelines, storage and domestic transportation and deepwater ports lets new low-carbon projects reuse proven assets rather than build entirely from scratch, in some cases lowering capital cost and execution risk, and enabling rapid scaling. Gas-basin supply feeds the Corpus Christi–Houston–Beaumont–South Louisiana corridor, where low-carbon hydrogen and ammonia projects are already advancing through FEED, FID, construction and operation – including Beaumont New Ammonia (Texas) and Blue Point One (Louisiana).

Existing hydrogen infrastructure is anchored by over 1,500 miles of hydrogen pipelines along the Gulf Coast – the densest such network in the world – letting new projects reach scale faster and cheaper than regions building from scratch. Beyond this infrastructure advantage, abundant low-cost natural gas sits alongside growing industrial CO_2 networks and nearby saline storage formations, giving the region a structural cost advantage in low-carbon ammonia, although these networks would need to continue to grow to enable further build out of low-carbon supply.

Policy further strengthens this, as the 45Q tax credit – an existing, readily monetizable CCS credit – gives developers a durable, bankable incentive. On top of this, state-level incentives and remaining DOE-backed hydrogen hub funding have the potential to improve project economics – although hub funding remains uncertain and depends on ongoing budget decisions. Demand is emerging in key economies, as import-dependent buyers in Japan, Korea and Europe may look to use low-carbon ammonia for both power and industry – and, for Europe, to replace supply from aging domestic plants – providing durable demand pull for Gulf Coast exports. Deepwater export terminals and ports capable of handling VLAC/VLGC vessels connect USGC low-carbon ammonia to import-dependent demand centers in Europe and East Asia, alongside over 1 Mtpa of conventional ammonia already exported from the region today.[67] Underpinning it all is an abundance of low-cost natural gas, exemplified by the cluster of LNG projects operating and under construction across the coast.

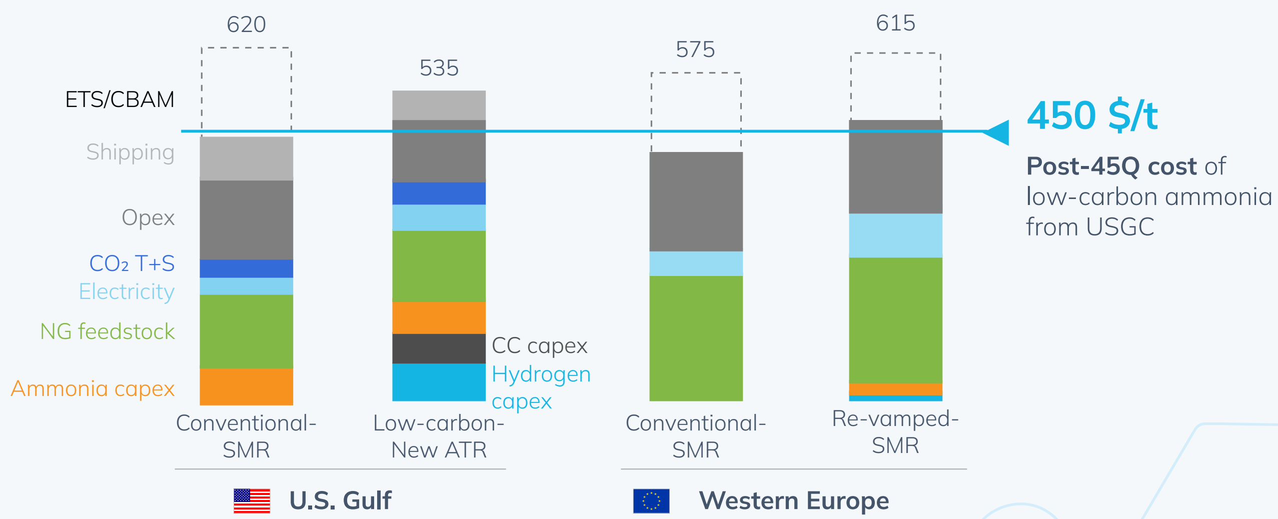
Exhibit 29: Potential 2030 demand for low-carbon ammonia, Mtpa H_2e



2.1 Mtpa

Potential clean hydrogen equivalent demand by 2030 for export to Europe and East-Asia (~12 Mtpa NH_3)

Exhibit 30: Landed costs of ammonia in Europe, 2030 $/t$NH_3$



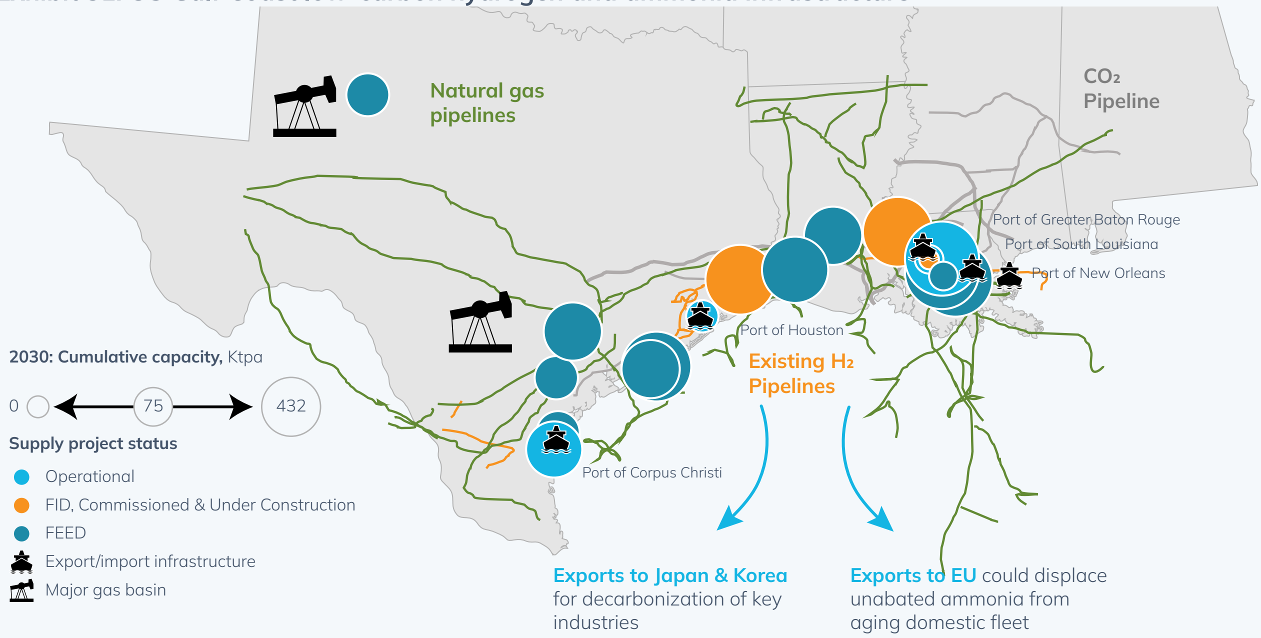
67. U.S. Geological Survey (USGS), Mineral Commodity Summaries 2026: Nitrogen (Ammonia)
Source: McKinsey Hydrogen Insights, McKinsey Energy Solutions H_2 Cost Optimization Model (H_2-COM), Ammonia Energy Association (2026)

What is still needed to expand the ecosystem

The majority of Gulf ammonia exports today are from conventional pathways, so scaling low-carbon production and export trade requires deepening demand across fertilizer, power generation, marine fuel and ultimately industrial hydrogen clusters so growth is not constrained to a few flagship megaprojects. Long-term offtake commitments remain critical, as buyers require clarity on premium pricing and regulatory standards for decarbonized versus conventional ammonia to sign offtake contracts.

With respect to the policy landscape, the baseline framework for the 45Q tax credit is well-established; the primary challenge has shifted from statutory ambiguity to execution risks such as managing construction timelines, tax transferability structuring, and supply chain/content compliance. The true regulatory and operational bottleneck lies in CO_2 infrastructure and storage: while state Class VI well primacy in key Gulf Coast jurisdictions (like Louisiana and Texas) has reduced the federal permitting backlog, CCS project developers still face regulatory scrutiny with critical-path friction around pore space acquisition, some limited local opposition, and the physical scaling of shared sequestration infrastructure. Ultimately, combining continued project-level cost reductions with permitting and carbon management infrastructure build-up will be vital to unlock the next wave of FIDs and build deeper, more liquid export opportunities.

Exhibit 31: US Gulf Coast low-carbon hydrogen and ammonia infrastructure



Blue Point One (Louisiana, US)

End-use: Low carbon ammonia, domestic and export | Under construction | COD: 2029 | 250 Ktpa capacity | $4650 million investment

Project spotlight

Blue Point One illustrates world-scale, low-carbon ammonia production reaching final investment decision. The CF Industries/JERA/Mitsui joint venture (40%/35%/25%) has taken a final investment decision on a greenfield ATR-with-CCS ammonia plant, comprising a $3.7B facility together with CF Industries' $0.55B scalable infrastructure and Linde's $0.4B ASU (approximately $4.65B in total). The project has a nameplate capacity of 1.4 Mtpa of low-carbon ammonia (approximately 250 Ktpa H_2), will capture 95% of its CO_2 and reduce well-to-gate emissions by more than 70% compared with conventional production. The project provides a clear example of the U.S. Gulf converting its feedstock and infrastructure advantage into bankable low-carbon capacity to serve both the American heartland and export markets, including emerging Japanese energy demand. Construction has begun as of August 2026.

Source: McKinsey Hydrogen Insights Project & Investment Tracker 2026, ArcGIS REST Services Directory, RBN Energy

INDIA DOMESTIC RENEWABLE AMMONIA

India translates low-cost renewables into bankable domestic ammonia, reducing import dependence and enabling new exports

What makes this ecosystem work:

Strong domestic demand pull: As the world's second-largest fertilizer consumer, today heavily reliant on imported ammonia,[68] India has a durable domestic substitution opportunity with bankable early offtakers – the anchor for its renewable ammonia build-out.

Globally competitive, government-supported renewable power: High solar irradiation and strong wind corridors deliver some of the world's lowest tariffs – recent SECI round-the-clock awards cleared at ~$57/MWh (₹5.06/kWh, RTC-IV, May 2025)[69] – giving renewable ammonia the low-cost, high-utilization power its economics depend on.

Industrial policy support: Competitive reverse auctions, ten-year purchase agreements and front-loaded production incentives all help make India's markets more competitive. Add to this a 25-year waiver of interstate transmission charges, energy banking and open access, and Indian projects feature strong bankability, with long-term offtake for revenue certainty, incentives for early cash flows, and cheaper power for competitive unit costs.

Export optionality and infrastructure: Coastal bulk-handling ports and shipping links give India export optionality – trade infrastructure, not proximity, is what matters. Although awarded volumes are domestic today, the next auction phases may include support for exports.

AM Green's green ammonia project (Kakinada, Andhra Pradesh, India)

End-use: Ammonia production | Status: Under construction | COD: 2028 | Capacity: 1 Mtpa; 1.3 GW electrolysis

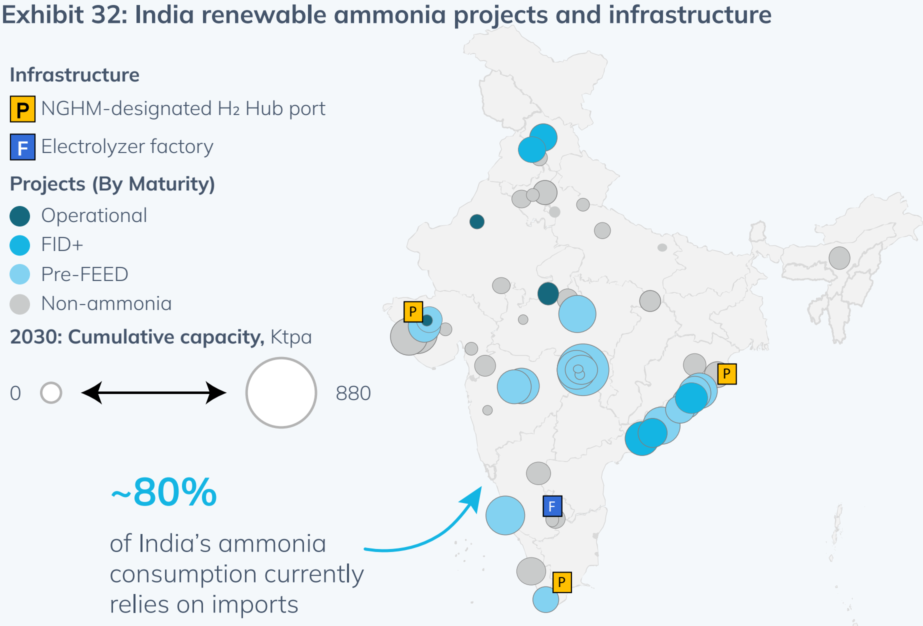
Project spotlight

India demonstrates how integrated renewable energy ecosystems can enable commercially scalable renewable ammonia production.

The AM Green Kakinada project is being developed as India's first and largest integrated green ammonia and renewable hydrogen complex, representing a significant milestone in the country's clean energy transition. Designed as a world-scale integrated renewable ammonia ecosystem, the project combines renewable power generation, power storage, electrolysis and renewable ammonia production to enable commercially competitive RFNBO-compliant renewable ammonia. The project leverages Casale's FLEXIGREEN® renewable ammonia technology, combining advanced ammonia synthesis and revamping expertise to support large-scale renewable ammonia production.

Phase 1 comprises 500 thousand tonnes per annum (Ktpa) of renewable ammonia production capacity, supported by 640 MW of renewable ammonia production capacity, supported by 1.3 GW of John Cockerill electrolyzers and enabled by AM Green's unique renewable electricity architecture, combining wind, solar and pumped-hydro storage to provide firm and dispatchable clean power and creating a commercially scalable industrial ecosystem. Its commercial viability is reinforced by a long-term binding offtake agreement with Uniper for up to 500,000 tonnes per year of renewable ammonia, establishing one of the first large-scale renewable ammonia supply corridors between India and Europe. Backed by Petronas, GIC and ADIA, the project is scheduled for commissioning in 2028.

Exhibit 32: India renewable ammonia projects and infrastructure



724 Ktpa

Tranche 1 of SIGHT auctions awarded for import displacement (~25-30% of direct liquid ammonia imports)

$2.5 billion

Projected 10-year savings from replacing imported unabated ammonia[1]

1. Under India's SIGHT program, the initial awarded tranche of green ammonia auctions is expected to generate foreign exchange savings of approximately $2.5 billion over 10 years by substituting imported grey ammonia in non-urea fertilizer units

68. Council on Energy, Environment and Water (CEEW), Transforming India's Fertilizer Production with Green Ammonia (2025)
69. Central Electricity Regulatory Commission, Petition under Section 63 of Electricity Act (2025)
Source: McKinsey Hydrogen Insights, McKinsey Energy Solutions H_2 Cost Optimization Model (H_2-COM), Ammonia Energy Association (2026), India Ministry of New and Renewable Energy (MNRE), press release

Large integrated developers: Reliance, Adani, ACME, AM Green and NTPC, among others, bring balance-sheet strength and execution across renewables, hydrogen and ammonia; ACME alone has won multiple SIGHT auctions.

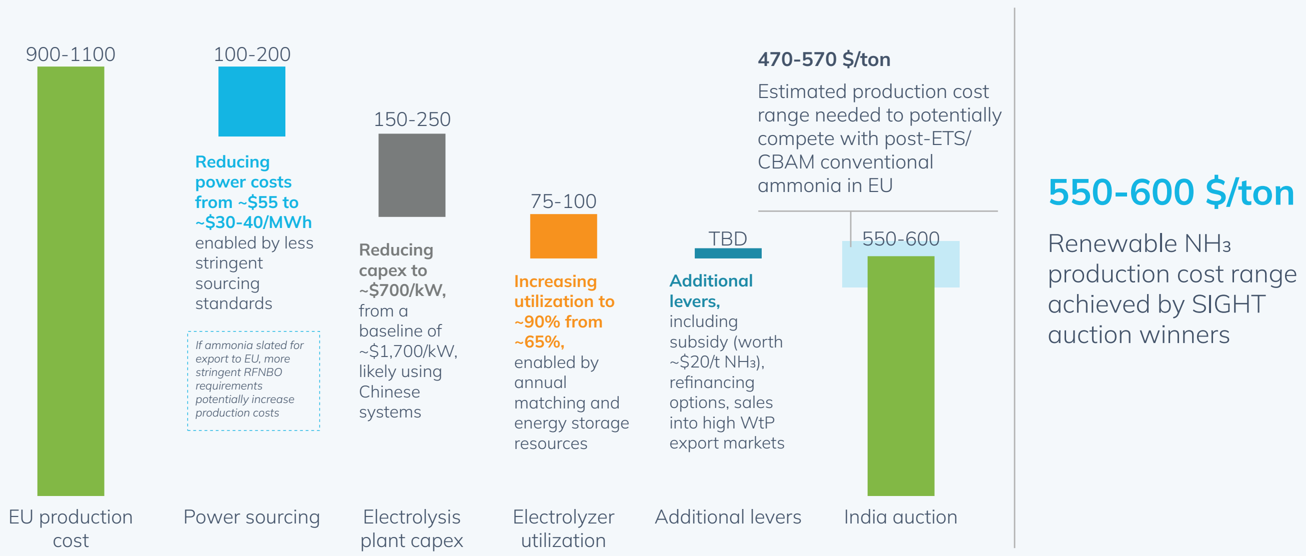
India leverages a combination of flexible sourcing of renewable power, with low-cost electrolyzers to bring ammonia production cost to at or below $600/t

Low-cost power and stacks with high utilization create a structural cost advantage. Less stringent sourcing standards (e.g., compared to RFNBO requirements) allow hybrid solar-wind supply at $0.02-0.03/kWh with greater than 65% capacity factors, while Chinese electrolyzer systems cut installed capex to about $700/kW from the approximately $1,700/kW EU baseline. Energy storage and annual matching turn intermittent output into near-continuous operation, lifting utilization from around 65% to 90% and spreading capex over increased annual production volumes, bringing production costs to at or below $600/t in some cases.

In contrast to RFNBO, which prescribes how renewable power is procured, India pursues a less stringent strategy backed by direct state support. India uses a centralized national accounting mechanism that certifies against an emissions threshold rather than specifying where and when the electricity is generated, allowing flexible grid sourcing and annual banking of renewable output. This is reinforced by SIGHT production incentives of $0.60-1.10/kg, waived inter-state transmission charges for projects commissioned through 2030,[70] and concessional access to land and port infrastructure in dedicated hydrogen hubs.

Despite the reduction achieved, further cuts, to $470-570/t, could bring costs near parity with ETS/CBAM-impacted ammonia in the EU. For volumes to qualify as RFNBO in the EU, they must be produced in line with EU standards, adding matching and certification costs on top of freight. Exported volumes that don't qualify as RFNBO could still compete in ETS/CBAM-driven demand segments, based on cost to serve and carbon incidence. Closing this gap depends on additional cost-down efforts from lower electrolyzer capex, firmed renewable supply and increased conversion efficiency.

Exhibit 33: Comparison between European and India renewable NH_3 production cost, $/ton NH_3



What is still needed to expand the ecosystem:

Conversion of low costs into durable offtake: SIGHT incentives are front-loaded and taper over the first years, so longer-term offtake will increasingly need to stand on market economics rather than incentives.

Certification alignment for export: EU RFNBO compliance (additionality, temporal matching, guarantees-of-origin) would be required to turn export ambitions into bankable offtake in Europe, although CI scoring mechanisms in other regions may not require these attributes and non-RFNBO renewable ammonia may still be near parity with post-ETS/CBAM domestic EU conventional supply.

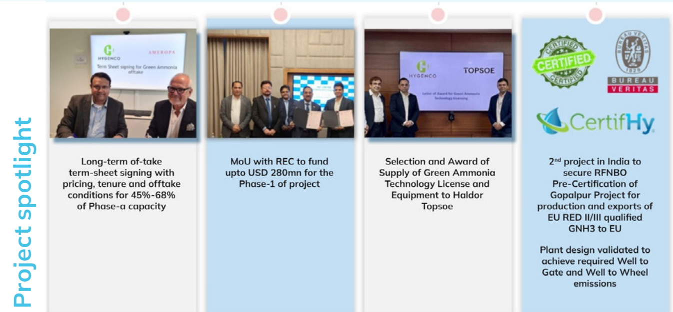
Scale-up of export infrastructure: Export-scale volumes will require expanding export capacity at existing (or new) ammonia terminals, storage and shipping – though CEOs rank infrastructure a lower-order constraint than the price gap and offtake mandates.

Sustained policy clarity beyond 2030: NGHM is centered on 2030 (e.g., the 5 Mtpa target; ISTS waivers applying only to projects commissioned by end-2030),[71] so long-term signals like carbon pricing and sectoral mandates remain less defined today.

70. IEA, Waiver of inter-state transmission charges (2025)
71. Government of India, Press Information Bureau, Cabinet approves National Green Hydrogen Mission (2023)
Source: McKinsey Global Hydrogen Trade Model, SECI

Hygenco & Ameropa Ammonia Project (Gopalpur, Odisha, India)

End-use: Ammonia production | FID is expected in Q1 2027| COD: 2030 | 48 Ktpa; 430 MW capacity | $990 million investment



India's ecosystem is maturing into a more competitive market rather than relying on a single flagship project: Hygenco's financed renewable ammonia plant at Gopalpur port, with Topsoe as technology provider and a first phase of approximately 220 Ktpa targeted for 2030 represents a second bankable Indian renewable ammonia project, distinct from the Kakinada flagship. Its significance lies less in its scale than in its existence: a competing, financed plant at a different port demonstrates depth forming across the Indian ecosystem.

Although every ecosystem will be shaped by its unique geographic footprint and market-specific nuances, and the mechanisms by which each ecosystem is founded will vary, the four key building blocks are required for any ecosystem to grow:

Firm demand is typically the highest priority for establishing an ecosystem, and largely relies on a stable landscape of enforced policy mechanisms, as well as a clear downstream demand pull for end-consumer products in lead markets (e.g., industrial products, fertilizers). Alongside the existing design of the EU's ETS and CBAM measures, transposition of RED III's transport sub-targets with penalties outlined in a growing number of member states illustrates how to convert an obligation into bankable offtake. In Japan and Korea, awarded CfD and CHPS volumes do the same. Ecosystems that rely on cross-border trade can encounter challenges if policy landscapes and measurement standards are not harmonized, but future landscapes where more liquid credit trading and carbon intensity accounting mechanisms are established and aligned can alleviate these challenges. The publication of ISO 19870-1, the first international standard for life-cycle hydrogen GHG emissions accounting, provides a model for such cross-border alignment, and can contribute to de-risking international offtake agreements.

Catalytic infrastructure is crucial for connecting supply with growing demand centers at scale, as the associated costs of moving clean hydrogen and derivatives can erase any apparent production-cost advantage. Strategic trade corridors and advancements in reconversion technology can connect potential ecosystems (particularly in resource-constrained regions) to low-cost imported supply rather than developing more costly home-grown production assets. Existing LNG corridors offer valuable lessons here, having matured from point-to-point fixed routes to today's destination-flexible trade routes and modular import capacity that match low-cost supply centers to importing regions.

Cost-competitive supply, particularly in the lowest decile of the cost curve, enables access to a broader range of end-use sectors, even those with lower average value-in-use. Otherwise cost-competitive supply in several regions is sometimes constrained by long grid connection queues or complex permitting processes, pushing construction timelines (and sometimes CODs) out far enough that project economics are impacted. Several measures exist across industries to alleviate such constraints; for instance, Germany's 2022 LNG Acceleration Act[72] illustrates what expedited project approval can achieve, having delivered the Wilhelmshaven import terminal in under 200 days,[73] and its Hydrogen Acceleration Act extends the same "overriding public interest" designation to hydrogen infrastructure.[74] Where favorable economics and supportive permitting already coincide, projects advance, as seen in several large-scale projects on the U.S. Gulf Coast as well.

Market-enabling mechanisms then weave together and smooth the interactions along the value chain, underpinning self-sustaining ecosystems. Several other sectors provide precedents for how such mechanisms can enable a shift from project-by-project deals toward a more self-sustaining industry. Where buyers and sellers cannot yet meet at scale and no reference price exists, trading platforms such as H2Global and buyers' alliances like SABA (Sustainable Aviation Buyer's Alliance) and ZEMBA (Zero Emission Maritime Buyer's Alliance) create transparency and bundle fragmented purchasers into a bankable signal. Once volumes move across jurisdictions, tracking and accounting for them becomes equally important, and mechanisms like book-and-claim accounting, already established in electricity markets and now scaling for aviation fuel, offer precedents for separating attributes from physical delivery.

Enabling supply chain coordination is also critical, since independent producers, shippers, crackers and offtakers only interoperate efficiently against common standards. For instance, in the semiconductor industry, another globally dispersed, technology-centered value chain, SEMI[75] and JEDEC[76] play this role by unifying global standards, ensuring interoperability across regions, and establishing clear supply chain visibility and resilience.

72. Federal Republic of Germany, LNG-Beschleunigungsgesetz (LNGG) (2022)
73. German Federal Chancellor's Office, "LNG-Terminal in Wilhelmshaven eröffnet" (2022)
74. Federal Republic of Germany, Hydrogen Acceleration Act (2026)
75. Semiconductor Equipment and Materials International
76. Joint Electron Device Engineering Council

Appendix

Clean hydrogen policies considered

Region	Policy	Policy firmness	Overview	Implementation	Resulting 2030 demand, Mtpa	Source
Australia	Hydrogen Production Tax Incentive	Firm	Refundable production tax offset of A$2/kg for eligible renewable hydrogen produced between 2027-28 and 2039-40, for up to 10 years per project	Lowers renewable production cost by 0.8/kg	<0.1	Link
Brazil	Low-Carbon Hydrogen Development Program (PHBC)	Yet-to-be enabled	Tax-credit program with a BRL 18.3B cap for 2028-2032 that can cover up to 100% of the price gap between low-carbon hydrogen and conventional alternatives	Limited uptake detected	~0	Link
Canada	Clean Hydrogen Investment Tax Credit	Firm	ITC between 15-40% based on carbon intensity of final hydrogen production plant	Credit ranging from 0.1 - 0.9/kg based on production pathway	Total country: 0.85	Link
Canada	Industrial Carbon Pricing/OBPS	Firm	Federal and provincial industrial carbon pricing systems continue to apply to large emitters even after the consumer fuel charge was removed	CO_2 penalty of $115 CAD in 2030, $130 CAD in 2035	Total country: 0.85	Link
Chile	National Green Hydrogen Strategy/ Action Plan	Yet-to-be enabled	National strategy and 2023-2030 action plan position Chile as a low-cost green hydrogen and derivatives producer and exporter, with electrolyzer and export ambitions.	Limited uptake of public support for favorable financing	~0	Link
China	Medium and Long-Term Plan for Hydrogen Industry	Firm	National plan sets early renewable hydrogen and fuel-cell-vehicle deployment targets and establishes hydrogen as a strategic emerging industry	Sets clean demand to meet target of at least 2 Mtpa by 2030; bottom-up aggregated provincial targets indicate at least 2.3 Mtpa by 2030 (with external estimates potentially closer to 3.5-5 Mtpa)	2 (stated as demand floor); 2.3 (modeled as likely demand)	Link 1 Link 2
Egypt	National Low-Carbon Hydrogen Strategy	Yet-to-be enabled	Strategy targets 1.5 Mtpa renewable hydrogen by 2030 and positions Egypt for low-carbon hydrogen and derivatives exports by 2040	No direct support modeled	~0	Link
EU	ETS/CBAM	Firm	Aims to set a fair price on emissions in industry	$130/t CO_2 in 2030 and $150/t CO_2 in 2035	Total region: 5.4	Link

Region	Policy	Policy firmness	Overview	Implementation	Resulting 2030 demand, Mtpa	Source
EU	RED III RFNBO Industrial Target	Varies by member state	Requires RFNBOs to reach at least 42% of industrial hydrogen use by 2030 and 60% by 2035, subject to detailed implementation rules.	Varies by country using national penalties for non-compliance; not yet transposed in most member states	Total region: 2.7	Link
EU	RED III RFNBO Transport Target	Varies by member state	Requires RFNBO use in final transport energy consumption; requires member state implementation	Varies by country using published penalties for non-compliance where transposed	Total region: 1.2	Link
EU	FuelEU Maritime	Varies by member state	EU maritime regulation limits the GHG intensity of energy used on ships calling at EU ports and promotes renewable and low-carbon marine fuels. A 2% RFNBO sub-target applies from 2034 if RFNBO use in covered maritime bunker fuel is below 1% by 2031.	Varies by country using published penalties for non-compliance where transposed	Total region: <0.1	Link
EU	ReFuelEU Aviation	Varies by member state	EU aviation fuel suppliers must blend increasing shares of SAF at EU airports, starting at 2% in 2025 and rising to 6% in 2030. The regulation also creates a synthetic aviation fuel/eSAF sub-quota, including 1.2% by 2030, and allows renewable hydrogen or qualifying low-carbon hydrogen for aviation compliance in defined cases	Varies by country using published penalties for non-compliance where transposed	Total region: <0.1	Link
India	SIGHT Auction	Firm	A targeted bid for domestic fertilizers to adopt green ammonia as a feedstock	Sets a demand floor for India ammonia demand	0.1	Link
India	Green Hydrogen Mission	Firm	Waives transmission fees for electrolysis projects	Allows for lowest cost renewable to be used for H_2 production, using recent auction PPAs for power costs	<0.1	Link
Japan	Hydrogen Society Promotion Act/ CfD	Firm (awarded portions)	Legal framework for low-carbon hydrogen and derivatives, including support focused on the price gap versus conventional fuels and hub development. Sets aside ~$19B for CfD program	Sets minimum demand for power sector in 2030; assumes all CfD budget goes to power	0.7	Link

Region	Policy	Policy firmness	Overview	Implementation	Resulting 2030 demand, Mtpa	Source
Mexico	Hydrogen Guidelines	Yet-to-be enabled	National guidelines establish a policy framework for low-emission hydrogen adoption in energy, industry and mobility and call for a future national strategy.	No direct support available	~0	Link
Morocco	Morocco Green Hydrogen Offer	Yet-to-be enabled	Integrated green hydrogen investment offer covering renewable power, electrolysis, downstream conversion, land access, infrastructure and incentives.	No direct support modeled	~0	Link
Singapore	Ammonia Power and Bunkering Pathfinder	Yet-to-be enabled	Jurong Island low/zero-carbon ammonia project under development seeks 55-65 MW of power generation and at least 0.1 Mtpa ammonia bunkering capacity, subject to FID.	No direct support modeled (project has not reached FID)	~0	Link
South Korea	Clean Hydrogen Portfolio Standard/Power Auctions	Firm (awarded portions)	Clean hydrogen power bidding market procures clean-hydrogen-based power under long-term contracts; originally included 3,000 GWh/year bidding volume which has since been reduced to 500 GWh/year	Sets minimum demand for power sector in 2030	0.4	Link 1 Link 2
United Kingdom	Hydrogen Allocation Rounds (HAR)	Awarded rounds firm	National strategy and roadmap set an ambition of up to 10 GW of low-carbon hydrogen production capacity by 2030, with allocation rounds supporting early projects.	Sets a floor of clean domestic demand for approved HAR projects of 0.3 Mtpa	0.1	Link 1 Link 2
United States	45Q CCS Credit	Firm	Pays up to $85/t for first 12 years of operation for CO_2 capture and storage	Lowers low-carbon production cost by $0.5/kg	0.9	Link
United States	LCFS	Firm	State-specific credits in CA, WA, OR, NM that incentivize the uptake of clean fuels	Raises value in use of H_2 FCEV by $1.5/kg	<0.1	Link
United States	45V Credit	Firm (shortened qualification period)	Pays up to $3/kg for clean H_2 production for first 10 years of project lifetime	Limited renewable volumes on market; PTC not applied across green costs	<0.1	Link

Glossary of terms

Term	Definition
Captive offtake	Hydrogen is used for an existing purpose (e.g., existing refinery) or it is inferred that there is a captive offtake from the same parent company (e.g., a company is building refueling stations as a part of the project).
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.
Clean hydrogen	Combined term referring collectively to hydrogen derived from either renewable or low-carbon pathways.
Distribution/infrastructure investment	Distribution/infrastructure relates to storage and transport activities, including certain derivative production (e.g., ammonification) - in cases where a single project produces hydrogen that is then converted into a derivative, the investment for hydrogen production (e.g., electrolysis, methane reformation) is allocated to "production" and the investment for derivative production is allocated to "distribution/infrastructure".
End-use investment	End-use corresponds to the ultimate application of hydrogen, for example, the manufacturing of fuel cell electric vehicles (FCEV) or the construction of HRS.
ETS/CBAM	Emissions Trading Scheme/Carbon Border Adjustment Mechanism in the European Union 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. https://taxation-customs.ec.europa.eu/carbon-border-adjustment-mechanism_en; https://eur-lex.europa.eu/eli/C/2025/2983/oj/eng
IRA	Inflation Reduction Act in the USA that created the 45V clean hydrogen production tax credit along with the expanded 45Q credit for carbon sequestration.
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 greenhouse gas (GHG) emissions assessment, including i) hydrogen produced using natural gas feedstock with steam methane reforming (SMR) or autothermal reforming (ATR) coupled with carbon capture and storage (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.
Production investment	Production corresponds to the production of hydrogen, such as electrolysis or autothermal reforming (ATR).
Project	A hydrogen project is a defined initiative to plan, finance, build, and operate infrastructure or facilities for the production, distribution, storage, or use of hydrogen. A project represents the physical deployment of assets and activities. Announcements of a government or industry alliance to develop an aggregation of projects is tracked based on the individual projects while the overarching initiative is considered a deployment and not analyzed in this report.

Glossary of terms

Term	Definition
RED III	Renewable Energy Directive III is the third piece of legislation aimed at promoting renewables within the EU. Among other factors, it sets volume targets for RFNBO based hydrogen and hydrogen derivatives (42.5% by 2030, 60% by 2035). https://energy.ec.europa.eu/topics/renewable-energy/renewable-energy-directive-targets-and-rules/renewable-energy-directive_en
Renewable hydrogen	Electrolytic-derived clean hydrogen produced from renewable energy.
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 RFNBO.
Sales & purchase agreement	A new binding offtake agreement for hydrogen (or the hydrogen derivative produced by the plant) has been signed between two separate companies (i.e., not a subsidiary).
Unabated hydrogen	Hydrogen produced from unabated fossil fuels.

Select methodology details

Hydrogen Council & McKinsey Project & Investment Tracker

The underlying database provides an overview of all large-scale hydrogen projects (excluding renewable hydrogen projects below 1 MW) that have been announced globally. It covers projects along the entire value chain, including: Hydrogen production, transport, distribution and retail, and end-use projects. Manufacturing projects are not included. The dataset only contains public information that was enriched by internal estimations where public data was not available and has been reviewed by Hydrogen Council members. Cancellation announcements and reasons are tracked via public press releases.

McKinsey Hydrogen Insights Clean Hydrogen Offtake Tracker

The underlying database captures information on confirmed or indicated offtake for hydrogen projects that have been announced globally. It covers the type and structure of offtake agreements, the companies involved and geographic regions, share of offtake, and distribution of volumes across end-use sectors. The dataset only contains public information that was enriched by internal estimations where public data was not available and has been reviewed by Hydrogen Council members.

Difference between estimated value-in-use and 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. 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.

After subtracting supply costs from value-in-use for each segment, ~11 Mtpa of demand, appears to carry a positive business case.

However, a positive business case that relies on policy impact (either on the value-in-use or cost-to-serve) would only translate to a bankable demand segment if the relevant policies are enacted as currently written. Amendments, delays, or revisions to existing policies could change the economic impact on each demand segment, and lack of implementation could prevent a demand segment from materializing into bankable offtake.

A positive business case (i.e., a value above the x-axis) also 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.