Unlocking India's Green Hydrogen Exports

Pathways, Markets, and Trade Catalysts

Report / October 2025

Rocky Mountain Institute, or RMI, is an independent, nonpartisan nonprofit founded in 1982 that transforms global energy systems through market-driven solutions to secure a prosperous, resilient, clean energy future for all. In collaboration with businesses, policymakers, funders, communities, and other partners, RMI drives investment to scale clean energy solutions, reduce energy waste, and boost access to affordable clean energy to enhance security, economics and improve people's livelihoods. RMI is active in over 50 countries. In India, we have been active since 2016 supporting the energy transition and advancement of electric mobility.

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पत्तन, पोत परिवहन और जलमार्ग मंत्री
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Foreword

India stands at the threshold of a historic transformation in its energy and economic journey. As the world accelerates toward a low-carbon future, green hydrogen and its derivatives are emerging as the foundation of tomorrow's energy economy. For India, this is not merely a story of technology—it is an *Amrit Kaal* opportunity to redefine our global standing, secure energy independence, and lead clean-energy trade across Europe, East Asia, and Southeast Asia.

Even as global momentum has moderated due to investment delays and evolving standards, India views these as opportunities. With an unmatched renewable base and decisive policy instruments under the National Green Hydrogen Mission, India is advancing where others hesitate.

India's maritime ecosystem is strengthening at pace. The Union Cabinet's ₹69,725-crore development package is set to unlock shipbuilding, clean-energy logistics, bunkering, and green shipping corridors. These will be the fundamental enablers for hydrogen and ammonia trade. Paradip, Deendayal, and V.O. Chidambaranar are taking shape as dedicated hubs, operationalising the "Ports to Green Hydrogen Hubs" vision.

Through strategic partnerships with Europe, Japan, and Singapore, and by aligning certification frameworks and deploying innovative de-risking finance mechanisms, India is converting intent into bankable projects and long-term offtake agreements.

India is not preparing to participate in the green hydrogen economy—we are preparing to lead it. By coupling cost leadership with port-led infrastructure, transparent certification, and innovative financing, India will become a reliable, indispensable supplier of clean molecules—powering *Viksit Bharat* and shaping global clean-energy trade through the *Amrit Kaal*.

(Sarbananda Sonowal)

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Executive Summary

India is at a critical juncture in its clean energy transition, with green hydrogen offering a transformative opportunity to diversify the country's energy mix and participate in the future of global energy trade. Recognising this opportunity, Indian industry players have announced projects for a production capacity of up to 12 million tons per annum (Mtpa) of green hydrogen and its derivatives by 2030, aimed at both domestic use and exports. Notably, nearly 30% of this capacity is directed internationally, positioning India to become a key supplier to European and East Asian markets.

However, over the past two to three years, global momentum around green hydrogen has slowed, marked by delayed final investment decisions, softening price signals, and underwhelming offtake commitments. This emerging uncertainty, combined with evolving international standards and subsidy regimes, underscores the need for Indian public and private stakeholders to closely track the latest market developments, risks, and enablers shaping the global hydrogen economy. To become a competitive supplier of green hydrogen and its derivatives, India will need to address key challenges: cost competitiveness, demand uncertainty, and regulatory and infrastructure gaps.

This report identifies key challenges and strategic drivers in India's export ecosystem of green hydrogen and its derivatives, analysing market demand trends, cost dynamics, and four critical trade enablers: infrastructure preparedness, standards and certifications, strategic partnerships and global agreements, and trade and financial de-risking mechanisms. Drawing on global developments, it provides actionable recommendations to position India as a cost-competitive exporter of green hydrogen and its derivatives.

Amidst market headwinds, a realistic near-term demand for green hydrogen is emerging.

Most recent projections indicate a smaller-than-expected green hydrogen import market,[1] with the European Union (EU) and East Asia together now estimated to import 3.4–6 Mtpa by 2030, down from approximately 13.5 Mtpa, as per RMI analysis. This decline is attributed to slow policy rollout, permitting challenges, and competing energy priorities.[2] The EU's green hydrogen demand is projected to be 1.7–2.8 Mtpa, with voluntary demand potentially adding 1.5–4.2 Mtpa by 2030.[3] Japan and South Korea anticipate 1.96–3 Mtpa by 2030.[4]

For India, these revised projections offer a pragmatic perspective on global hydrogen trade. India can adopt a strategic approach, focusing on cost competitiveness, infrastructure readiness, and trade enablers to secure long-term offtake agreements. India has the opportunity to position itself as a credible supplier, aligning its investments with actual and evolving market needs.

India can become an early cost-competitive supplier to European and East Asian markets.

India's comparative advantage lies in its low-cost renewable energy and cost-effective ammonia production, which can offset longer shipping distances to Europe and ensure competitive landed prices.

Early exporters like Australia, Egypt, and Namibia have scaled hydrogen using incentives over mandates, a path India mirrors through the Strategic Interventions for Green Hydrogen Transition (SIGHT) scheme. It can continue to build on this foundation while complementing it with efforts to develop domestic demand for long-term market resilience.

At the time of writing, India was one of only three countries, along with Saudi Arabia and Oman, to secure a final investment decision on a major electrolysis-based hydrogen project. Despite this milestone, most of India's announced 12 Mtpa green hydrogen and derivative production capacity remains in the planning stage. To gain a competitive position in the green hydrogen market, India can prioritise infrastructure, standards, partnerships, and risk mitigation strategies to translate these announcements into actual investments.

Realising India's green hydrogen export potential depends on effectively executing four critical trade enablers.

Strengthening port infrastructure for driving exports

Globally, ports are advancing the trade of ammonia and hydrogen through dedicated terminals, green corridors, and demand aggregation. India is strengthening the role of its ports through export-oriented projects at Paradip, Deendayal, and V. O. Chidambaranar. Deendayal plans to house 6.5 Mtpa of green ammonia capacity, while Paradip and Gopalpur have set a target of hosting a combined 5.2 Mtpa by 2030.

With strategic locations, proximity to domestic industrial clusters, and existing infrastructure, Indian ports can become major hubs for both domestic hydrogen use and exports. However, challenges remain in infrastructure readiness, scalability, and financial risks. Significant upgrades in port handling capacity and regulatory frameworks are required to meet international trade standards. Addressing these issues can enable Indian ports to play a crucial role in the global green hydrogen trade.

Harmonising standards and certifications for global market access

Certification of carbon intensity is a critical enabler for market access, as varying hydrogen standards across countries have created bottlenecks for global trade. India's Green Hydrogen Standard aligns with Japan's and South Korea's guidelines but lacks requirements for life-cycle emissions accounting and additionality criteria, making it difficult for India's green hydrogen to qualify under the EU's renewable fuels of non-biological origin standard. Establishing mutual recognition agreements with key markets such as the EU, Japan, and South Korea can streamline exports, reduce compliance costs, and improve market access. Expanding India's certification framework to include hydrogen derivatives like ammonia and methanol would further enhance trade opportunities, particularly in shipping, chemicals, and power generation. Ensuring internationally recognised certification will be essential for India's hydrogen exports to remain competitive and integrate smoothly into global supply chains.

Expanding strategic partnerships to secure long-term agreements

International partnerships are emerging as a crucial enabler for unlocking the global green hydrogen trade by reducing investment risks, facilitating technology transfer, and harmonising regulatory frameworks. India has made significant progress through key collaborations, such as the India-Germany Green Hydrogen Task Force, the India-Australia Green Hydrogen Task Force, and the India-Japan Clean Energy Partnership. These agreements focus on developing hydrogen hubs, securing long-term offtake agreements, and advancing research in electrolyser manufacturing and hydrogen-based power generation. While India has begun securing early export agreements, large-scale, binding offtake deals remain limited. Aligning regulations with international standards, strengthening trade alliances, and securing long-term offtake agreements will be essential for India to establish itself as a reliable supplier in the global hydrogen economy.

Implementing financial mechanisms to de-risk investment

Developing large-scale green hydrogen projects requires innovative financing solutions to mitigate risks and attract investments. Instruments such as blended finance, export credit agencies, and contract-for-difference schemes can play a key role in scaling hydrogen exports globally.

India has allocated US$2.4 billion under the National Green Hydrogen Mission, while the Solar Energy Corporation of India Limited (SECI) has aggregated 7.24 lakh tons per annum (0.724 Mtpa) of green ammonia demand to create a more predictable market. However, challenges persist: globally, schemes like H2Global have seen delayed funding rollout; domestically, high production costs relative to grey hydrogen and ammonia, and concerns over project viability beyond the current subsidy period, continue to constrain project bankability.

Auction-based models, a hydrogen price index, and the leveraging of global funding mechanisms can help India attract investment and strengthen its position in the global hydrogen trade. Establishing transparent pricing mechanisms and balancing domestic and export priorities will be critical for meeting long-term financing needs of the sector.

Recommendations to scale green hydrogen exports from India

The enablers discussed earlier can provide a strong foundation for India's participation in the global green hydrogen trade. However, unlocking India's full export potential and positioning it as a competitive global supplier will require targeted interventions.

Build and deepen mutual trade partnerships with key importing markets like Europe, Japan, and South Korea to facilitate long-term supply agreements

India could deepen trade relationships with major hydrogen-importing markets such as the EU, Japan, and South Korea by building government-to-government partnerships that enable long-term offtake agreements between private entities. Establishing an India–Europe hydrogen corridor and leveraging free trade agreements can help diversify markets and strengthen supply security. These agreements can enable tariff reductions, improve market access, protect investments, and support regulatory harmonisation, drawing on models like the Australia–Japan Hydrogen Energy Supply Chain.

Strengthen regional hydrogen market integration and mutual recognition of certification

Harmonising India's certification framework with global standards, such as the EU's CertifHy and Japan's Hydrogen Quality Assessment, will ensure smooth cross-border trade. Establishing mutual recognition agreements with key partners can streamline compliance, reduce trade barriers, and improve market access, leveraging India's participation in the International Partnership for Hydrogen and Fuel Cells in the Economy.

Develop hydrogen-ready export infrastructure at major ports within India and partner importing regions

Strategic cross-border investments with Japan, South Korea, Germany, and Singapore can accelerate the development of hydrogen-ready port terminals. India can build on successful models like DP World's investments in Indian ports and Singapore's hydrogen trade corridor initiatives to create a seamless and cost-effective hydrogen export ecosystem.

Expand India’s demand aggregation model for global hydrogen trade

Expanding India’s demand aggregation framework, like SECI’s auctions, to the hydrogen market can secure long-term offtake agreements, stabilise prices, and enhance investor confidence. Drawing from the H2Global initiative, India can implement reverse auction mechanisms to attract international buyers and de-risk large-scale hydrogen projects.

Establish green shipping corridors to promote hydrogen-based fuels

Collaborating with key ports like those in Singapore, Rotterdam, and Busan to develop green shipping corridors for ammonia and methanol can position India as a leading supplier of clean maritime fuels. Learning from Norway’s Green Shipping Programme and the Clydebank Declaration, India can create supportive infrastructure and policies to facilitate the decarbonisation of global shipping.

Establish dedicated financing mechanisms to de-risk green hydrogen investments

India could partner with export credit agencies such as Japan’s JBIC and Germany’s Euler Hermes to access low-cost financing. Establishing a green hydrogen infrastructure fund modelled after the European Hydrogen Bank and engaging multilateral institutions like the World Bank can mobilise investments for hydrogen production, storage, and export infrastructure.

1. Introduction

India has the opportunity to redefine its role in the global energy landscape by building a thriving hydrogen economy. With abundant renewable energy resources and a growing push for industrial decarbonisation, it is well positioned to become a cost-competitive supplier of green hydrogen and its derivatives. Export ambitions targeting key markets such as Japan, South Korea, and the European Union (EU) offer a strategic pathway to diversify India's energy trade and enhance economic resilience.[5]

The National Green Hydrogen Mission has laid a strong foundation, committing US$2.4 billion to foster a green hydrogen industry.[6] Complementing this public sector push, private players have also announced plans for nearly 12 million tons per annum (Mtpa) of green hydrogen and derivative production capacity by 2030.[7] Around 30% of this capacity (~3.8 Mtpa)[i] is directly aimed at exports, and several other projects are located near ports, though the end use has not been confirmed.

The export orientation of many announced projects aligns with growing near-term opportunities in global markets. These markets are expected to demonstrate greater willingness to pay the cost premium, enabling Indian green hydrogen and derivative production projects to reach final investment decisions (FIDs). Southeast Asian economies are projected to create a green hydrogen market worth nearly US$10 billion by 2030,[8] while European economies are expected to generate a market valued at nearly US$60 billion by 2034, driven by energy security and decarbonisation goals.[9]

India is actively pursuing both domestic and international offtake agreements to accelerate the deployment of green hydrogen and its derivatives. By adopting a dual-pronged approach, India is leveraging near-term export opportunities to de-risk investments and build early infrastructure and operational expertise while simultaneously laying the groundwork for wider domestic adoption. This can support long-term cost reduction and enhance overall competitiveness.

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i. This is based on RMI analysis of the green hydrogen project database, mapping, and analysing individual projects to determine their domestic or export focus.

This strategy is further reinforced by India's growing engagement in international partnerships — with key examples including Germany, Japan, and South Korea — aimed at facilitating cross-border hydrogen trade and technology collaboration.[10] For instance, the Solar Energy Corporation of India Limited (SECI), the implementing agency appointed by the Ministry of New and Renewable Energy (MNRE) to execute the Strategic Interventions for Green Hydrogen Transition (SIGHT) programme,[ii] signed a memorandum of understanding (MoU) with Hamburg-based H2Global to establish a framework for cross-border hydrogen collaboration.[11] In the private sector, companies like ACME, AM Green, and Sembcorp are securing offtake agreements with Japanese and European buyers.[12]

However, despite these advancements, Indian project developers struggle to secure domestic offtakers and not all export-oriented projects may reach FID amidst growing uncertainty in the global hydrogen market. Pilot projects have emerged, but large-scale adoption requires further cost reductions and policy support to create sustainable demand across sectors.

Addressing gaps in cost competitiveness, along with having greater clarity on international buyers' demand and willingness to pay the green premium, could enhance India's export ambitions. Infrastructure and policy gaps add further complexity because India has limited ammonia-ready ports, and its national standard for green hydrogen differs from global standards.

Amidst these uncertainties, this report aims to identify key barriers and enablers in India's green hydrogen export ecosystem. It analyses market demand trends, cost competitiveness, and four critical trade enablers: infrastructure preparedness, standards and certifications, strategic partnerships and global agreements, and trade and financial de-risking mechanisms. By unpacking global trends and lessons, the report offers actionable recommendations for stakeholders to help India chart a strategic and competitive pathway in the global green hydrogen trade economy.

> **"By coupling export demand with domestic offtake, India is de-risking investments, accelerating the deployment of green hydrogen, and building scale to emerge as a cost-competitive and globally trusted supplier."**

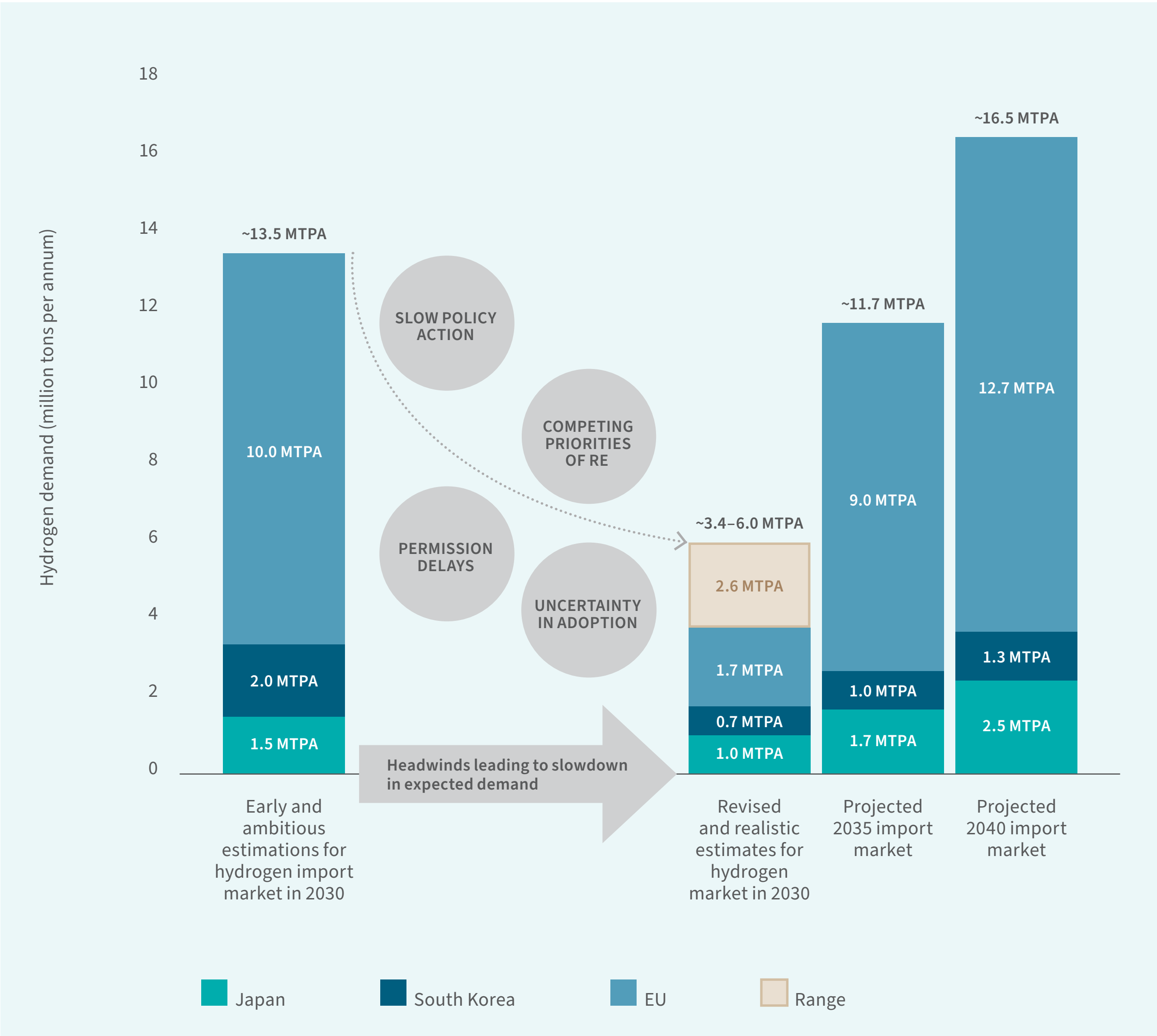
ii. SIGHT is an incentive programme under the National Green Hydrogen Mission, with an outlay of ₹17,490 crore, to support domestic manufacturing of electrolysers and the production of green hydrogen, facilitating the growth of the green hydrogen industry value chain in India.

2. Global Market Opportunities for Green Hydrogen and Its Derivatives

The EU, Japan, and South Korea are emerging as key players in clean hydrogen offtake,[13] driven by energy security concerns and ambitious decarbonisation targets. However, land constraints and permitting bottlenecks limit their ability to scale renewable energy production domestically, making them reliant on imports to meet their clean hydrogen demand.[14] Though demand markets such as Japan and South Korea will be importing both green and blue hydrogen under their technology-agnostic clean hydrogen standards, the EU is signalling a push for renewable hydrogen through its mandates under the Renewable Energy Directive (RED III). To diversify supply chains and mitigate geopolitical risks, these economies are turning to places with abundant renewable energy resources like India and Australia, creating a strong market pull for exporters.

Although the initially projected 13.5 million ton import market in the EU and East Asia may not materialise as expected,[15] a substantial and realistic opportunity still exists for exporters. As shown in **Exhibit 1**, new estimated demand by 2030 is expected to be lower than previous estimates, ranging between 3.4 and 6 Mtpa. This revision is driven by several factors: slow policy implementation, permitting delays, and uncertainty around the adoption of green hydrogen at scale in various end-use sectors. Additionally, competing priorities for renewable energy, the green premium between grey and green hydrogen, and a mismatch in contract expectations contribute to the challenge. Producers seek long-term commitments, while buyers prefer short-term flexibility.[16] With a smaller global import market, competition among exporters is likely to intensify, making cost competitiveness, reliability, and strategic partnerships even more critical for securing offtake.

Exhibit 1 Headwinds are slowing the momentum, leading to revised demand estimates for the EU, Japan, and South Korea



Note: The expected import targets for 2030 in the EU are based on RMI analysis and on International Energy Agency (IEA) projections for Japan and South Korea. Estimates for 2035 and 2045 for all three locations are based on RMI analysis derived from IEA projections.
RMI Graphic. **Source:** RMI analysis and IEA, **https://www.iea.org/reports/global-hydrogen-review-2024**.

The EU's hydrogen demand is now estimated at 1.7–2.8 Mtpa of hydrogen-equivalent by 2030,[17] significantly lower than the earlier 10 Mtpa projection. This demand is largely driven by policy mandates such as RED III and ReFuelEU. RED III, updated in 2023, requires member states to ensure that at least 42% of their hydrogen consumption comes from renewable fuels of non-biological origin (RFNBOs) and that RFNBOs account for 1% of total transportation energy by 2030.[18]

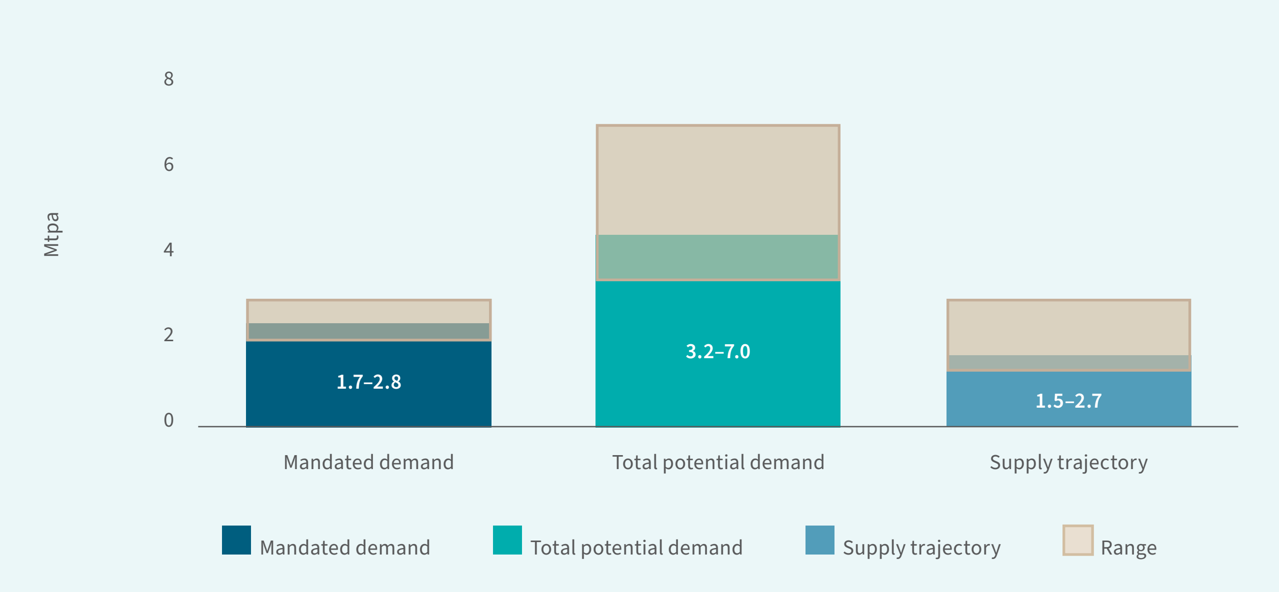
However, implementation remains uncertain because no EU member state met the May 2025 deadline to put the RED III guidelines into national law, further increasing regulatory ambiguity.[19]

Additional regulations will also explicitly increase demand for RFNBOs. ReFuelEU, the regulation pertaining to sustainable aviation fuels (SAFs), requires 1.2% of fuel to be synthetic (produced with RFNBO hydrogen, as defined by the European Commission [EC]). FuelEU, the regulation pertaining to the carbon intensity of maritime fuels, sets a subtarget of 1% of energy to come from RFNBOs by the reporting period of 2031.

Outside of EU mandates, RMI analysis shows that the potential demand for RFNBO hydrogen within the EU could add an additional 1.5–4.2 Mtpa of demand by 2030. Additional demand will be driven by a variety of factors, including future International Maritime Organization (IMO) regulations, voluntary industry uptake among the steel, fertiliser, and aviation sectors, and indirect incentives for the use of RFNBOs through carbon pricing under the emissions trading system and its new, complementary regulation, the carbon border adjustment mechanism. As the price of carbon under these mechanisms rises, low- and zero-carbon fuels will become more competitive with fossil incumbents.

Europe's supply pipeline is unlikely to meet this demand. Given the current trajectory of projects, RMI estimates that 1.5–2.7 Mtpa of European hydrogen production could materialise by 2030, shown in comparison to demand in **Exhibit 2**. Although it is possible that supply will cover the lower end of demand, many challenges exist, including volatile electricity prices and a need for intercontinental pipelines. This provides an opportunity for India to supply RFNBO-certified hydrogen to fill the potential gap in European markets.

Exhibit 2 Total EU hydrogen supply and demand, in Mtpa of hydrogen, 2030



Note: Range of estimation shown in shaded areas. Total potential demand includes mandated demand. RMI Graphic. **Source:** European Hydrogen Observatory, Eurostat, IEA, RMI analysis.

India has additional incentive to engage with exports of hydrogen to Europe because the EU has developed funding mechanisms to encourage it. H2Global, a double-sided auction platform open to any country, awards long-term offtake contracts to subsidise international hydrogen and hydrogen-derivative producers. An intermediary, Hintco, purchases hydrogen, and then resells it domestically via auction. At the supernational level, the EU has set up the European Hydrogen Bank (EHB), which provides a fixed subsidy per kilogram of hydrogen produced for a period of 10 years. The EU has announced an interest in using H2Global as an international component of the EHB.

East Asian markets are also ramping up efforts to secure imports of both green and blue low-carbon hydrogen to meet their energy transition goals. Japan and South Korea, being heavily reliant on energy imports, have prioritised hydrogen adoption across different end-use sectors to enhance energy security and decarbonisation efforts. However, the pace of demand growth could be influenced by factors such as policy implementation delays, cost competitiveness, and infrastructure readiness.

Japan's revised Basic Hydrogen Strategy aims to achieve a demand of 3 Mtpa clean hydrogen by 2030, which is a technology-agnostic target so long as the molecules comply with Japan's low-carbon standard.[20] Although specific import targets are unspecified, significant volumes are anticipated to be imported.

Key sectors driving hydrogen demand in Japan include power generation through co-firing technologies, with a goal of reaching 30% hydrogen and 20% ammonia co-firing by 2030. Additionally, Japan plans to expand the adoption of fuel cell electric vehicles (FCEVs) to 800,000 units by 2030.[21] However, FCEV sales in Japan have plummeted by approximately 73% over the past three years due to high costs, limited refuelling infrastructure, and growing competition from battery electric vehicles.[22]

South Korea's hydrogen strategy aims for clean hydrogen to supply one-third of its energy mix by 2050.[23] Hydrogen demand is expected to rise from 3.9 Mtpa in 2030 to 27.9 Mtpa by 2050, with imports reaching 1.96 and 22.9 Mtpa, respectively. However, current trends indicate that actual hydrogen imports will likely be significantly lower (see **Exhibit 1**). The country is also expanding its FCEV market, targeting 6.2 million hydrogen-powered vehicles and 1,200 refuelling stations by 2040.[24]

To accelerate hydrogen adoption in power generation, South Korea introduced the world's first clean hydrogen power generation bidding market in 2024, emphasising hydrogen or ammonia co-firing with coal.[25] However, the first auction faced setbacks due to low price ceilings, with only one developer, Korea Southern Power Co., securing 750 gigawatt-hours (GWh)/year of the 6,500 GWh tender.[26] The second auction was launched in May 2025 and is open for bid submissions until October 2025.[27] Learning from the outcomes of the first auction, the Ministry of Trade, Industry and Energy has changed some rules, including adding an exchange-rate-linked settlement system to reduce currency risks.[28] Although these changes could offer new opportunities for emerging exporters, it remains to be seen whether they will boost participation.

Despite these near-term hurdles, the long-term outlook remains promising. This underscores the need for project developers, policymakers, and investors to align their strategies with evolving market conditions, focussing on infrastructure development, cost competitiveness, and policy coordination to capture future growth opportunities.

3. India's Competitive Advantage in the Global Hydrogen Economy

India is strategically positioning itself to be a leading exporter of hydrogen and its derivatives, competing with other potential suppliers such as Australia, Brazil, Chile, Saudi Arabia, and the United States in the long run. Abundant renewables, land availability, and ongoing infrastructure development give India a strong base for scaling hydrogen exports. Supported by MNRE and other national and subnational government agencies, India's progress is reinforced by funding initiatives like the SIGHT programme under India's National Green Hydrogen Mission and central waivers on Inter-State Transmission System charges. At the state level, several governments have announced additional incentives, including exemptions for state transmission utility charges, wheeling charges, cross-subsidy surcharges, additional surcharges, and electricity duties.

3.1. Global policy approaches to scaling green hydrogen exports

Across export-oriented countries globally, there have been a variety of policies released targeting the exports value chain (see **Exhibit 3**). In comparing these approaches, several common themes emerge that are driving progress to scale trade of hydrogen and its derivatives.

The first-mover exporting countries highlighted in **Exhibit 3** share key characteristics, including abundant renewable energy resources, supportive regulatory environments (either completed or in development), and well-established trade routes to major markets like the EU and Japan.

Production incentives and direct investments have been the primary drivers of hydrogen capacity expansion, rather than regulations or compliance mechanisms across these countries (see **Exhibit 3**). A common strategy among them is the development of hydrogen hubs, valleys, or special economic zones (SEZs), which offer streamlined permitting, infrastructure development, and proximity to ports and industrial end-users, fostering the growth of integrated hydrogen ecosystems.

Although nations and regions with strong export ambitions, such as Australia and the Middle East, have introduced incentives to support hydrogen export, direct public funding for port infrastructure and trade facilitation remains limited globally. India's policy framework, like those of many emerging exporters, has prioritised upstream production with a growing focus on infrastructure readiness. As global hydrogen trade mechanisms evolve, India has the opportunity to strengthen its position by expanding support for infrastructure and enabling seamless cross-border trade.

Exhibit 3 Policies in exporting countries have differentiated efforts across the green hydrogen value chain to scale project development and trade

Key country policies along export value chain at national level

		UPSTREAM: Component and equipment	UPSTREAM: Renewable electricity generation and transmission	PRODUCTION: Green hydrogen and ammonia production	TRANSPORTATION AND PORTS: Transport and distribution	TRANSPORTATION AND PORTS: Ports: storage and loading	TRADE: Exports
INDIA	Incentive	• SIGHT: Domestic electrolyser manufacturing	• Renewable energy investment for SECI & IREDA • Waived ISTS fees	• SIGHT: Green H_2 production • Green Hydrogen Hubs • Land in renewable energy parks and manufacturing zones for green H_2/NH_3		• Green hydrogen hubs • Bunker near ports for manufacturers of green H_2/NH_3	
INDIA	Regulation						
AUSTRALIA	Incentive	• Resourcing Australia's Prosperity	• Solar Sunshot Program	• Hydrogen Headstart Program			• Australia Clean Hydrogen Trade Program
AUSTRALIA	Incentive		• ARENA funding* (spans renewable electricity and production)				
AUSTRALIA	Incentive		• Regional Hydrogen Hubs Program (spans renewable electricity and production)				
AUSTRALIA	Incentive		• HPTI (spans renewable electricity and production)				
AUSTRALIA	Regulation		• Hydrogen and Renewable Energy Act* (spans renewable electricity, production, and transport and distribution)				
AUSTRALIA	Regulation			• National Gas Law and NERL			
BRAZIL	Incentive		• REIDI: Electricity generation and transmission	• PHBC • Rehidro • FNMC for H_2 from renewable sources • Low-carbon hydrogen hubs			
BRAZIL	Regulation						
EGYPT	Incentive	• Law No. 2 of 2024: VAT exemption		• Special Economic/Free Zones • Green H_2 incentives • Green Hydrogen Incentives Law		• Reduction in port usage, handling, and depo land fees	• VAT exemptions
EGYPT	Regulation						
NAMIBIA	Incentive	• Namibia-EU Strategic Partnership on Raw Materials*		• Namibian Hydrogen Valleys • EU investments including Namibia Green Hydrogen Program			
NAMIBIA	Regulation	• African Growth and Opportunity Act		• Synthetic Fuels Act			
UNITED STATES	Incentive	• IRA 45X • IRA 48C	• IRA 45Y/48E	• IRA 45V • IIJA H2Hubs Program	• IIJA DOT/MARAD — Port Infrastructure Development Program		
UNITED STATES	Regulation						

Incentive Regulation

Note: *Policy spans multiple categories along the value chain. Policies are at the national level. More policies (incentives and regulations) may exist at the subnational level for each country. US policies along the value chain are illustrative as of May 2025. **ARENA:** Australian Renewable Energy Agency; **DOT/MARAD:** Department of Transportation/ US Maritime Administration; **FNMC:** Brazil's National Climate Change Fund; **HPTI:** Hydrogen Production Tax Incentive; **IIJA:** Investment in Infrastructure and Jobs Act; **IRA:** Inflation Reduction Act; **IREDA:** India Renewable Energy Development Agency; **ISTS:** Inter-State Transmission System; **NERL:** National Energy Retail Law; **PHBC:** Brazil's Low-Carbon Hydrogen Development Program; **Rehidro:** Brazil's Special Incentive Regime for Low Carbon Hydrogen Production; **REIDI:** Brazil's Special Incentives Regime for Infrastructure Development.

RMI Graphic. **Sources:** RMI compilation based on Green Hydrogen Organization (GH2), Baker McKenzie Global Hydrogen Policy Tracker, IEA policies database, Ashurst Investing in Hydrogen Guide, Commonwealth Scientific and Industrial Research Organisation-HyResource, RMI analysis.

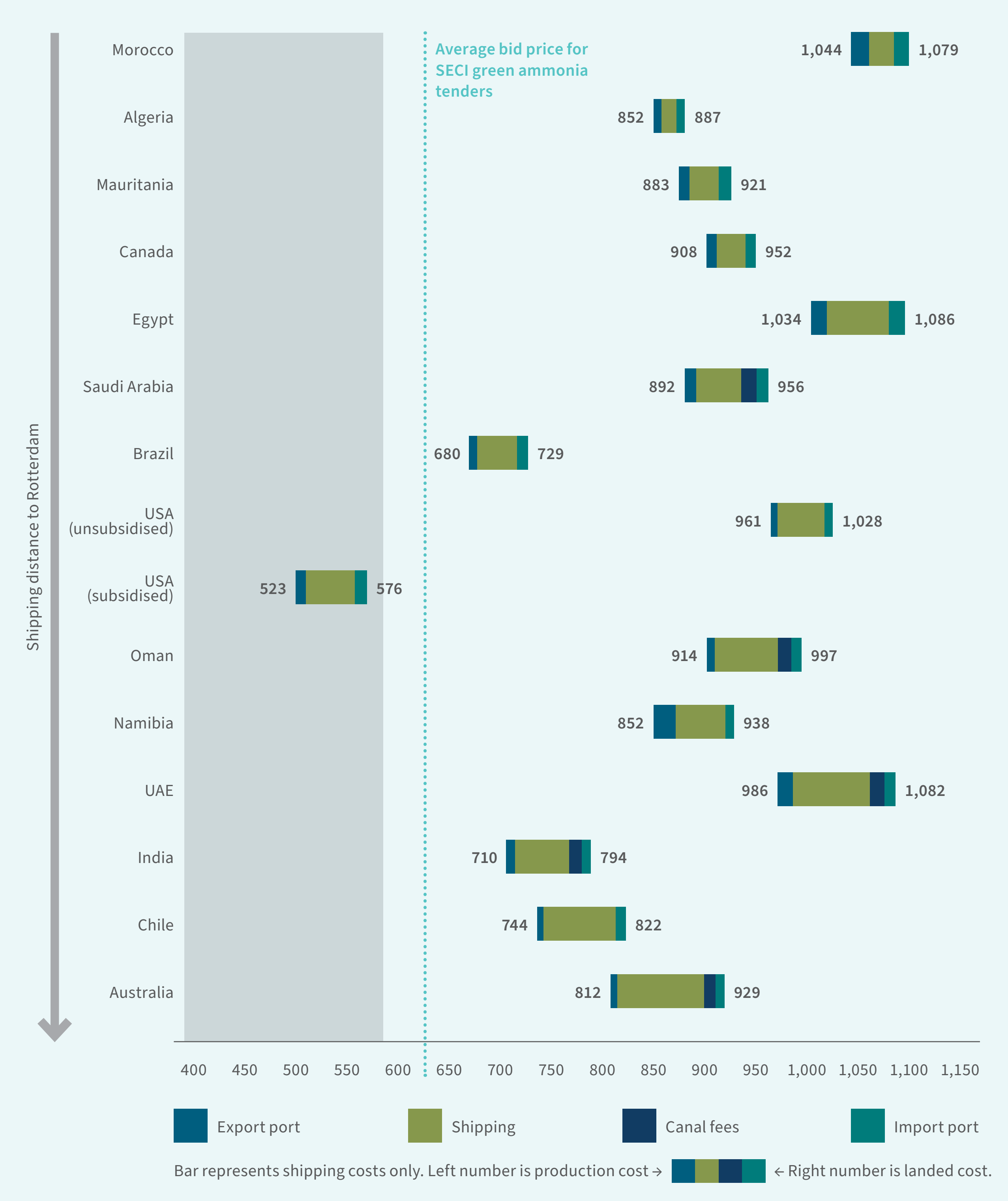
3.2. Cost competitiveness and market readiness among early movers

By 2030, global shipments of green hydrogen and its derivatives are expected to play a crucial role in meeting hydrogen demand across key markets. Among these derivatives, ammonia is examined as a case study across the report. This focus does not imply that other hydrogen carriers will not scale, but rather reflects the current project landscape, where ammonia has emerged as a dominant fuel. However, the insights drawn from ammonia should be viewed as indicative of broader trade opportunities for hydrogen derivatives, rather than being limited to this molecule itself.

Current RMI modelling suggests that India has the potential to be amongst the most competitive suppliers of green ammonia, comparable to other countries such as Chile and Brazil. Over time, technological advancements and economies of scale will narrow the gap between green and grey ammonia globally, but this will require significant investment in innovation and policy mechanisms to drive down the cost further, making early movers a key component of kick-starting the renewable hydrogen industry.

Determining the delivered cost of ammonia to importing countries like the Netherlands involves factors beyond production costs alone. Additional expenses such as shipment costs, canal fees, and port charges raise the final landed cost (see **Exhibit 4**). Although shipment costs are generally a smaller proportion of the total cost, long distances can raise fuel and charter costs. The ammonia trade was modelled from multiple countries targeting ammonia exports, with Rotterdam, in the Netherlands, as the final destination. Rotterdam was chosen because it is a major shipping hub interested in expanding hydrogen and ammonia imports. To represent a clean supply chain, shipping was modelled using part of the ammonia cargo as fuel. Ammonia-fuelled vessels are a nascent technology but have the potential to provide zero- or near-zero-carbon emissions.

Exhibit 4 Shipping cost impact on landed cost, US$/ton ammonia, 2030



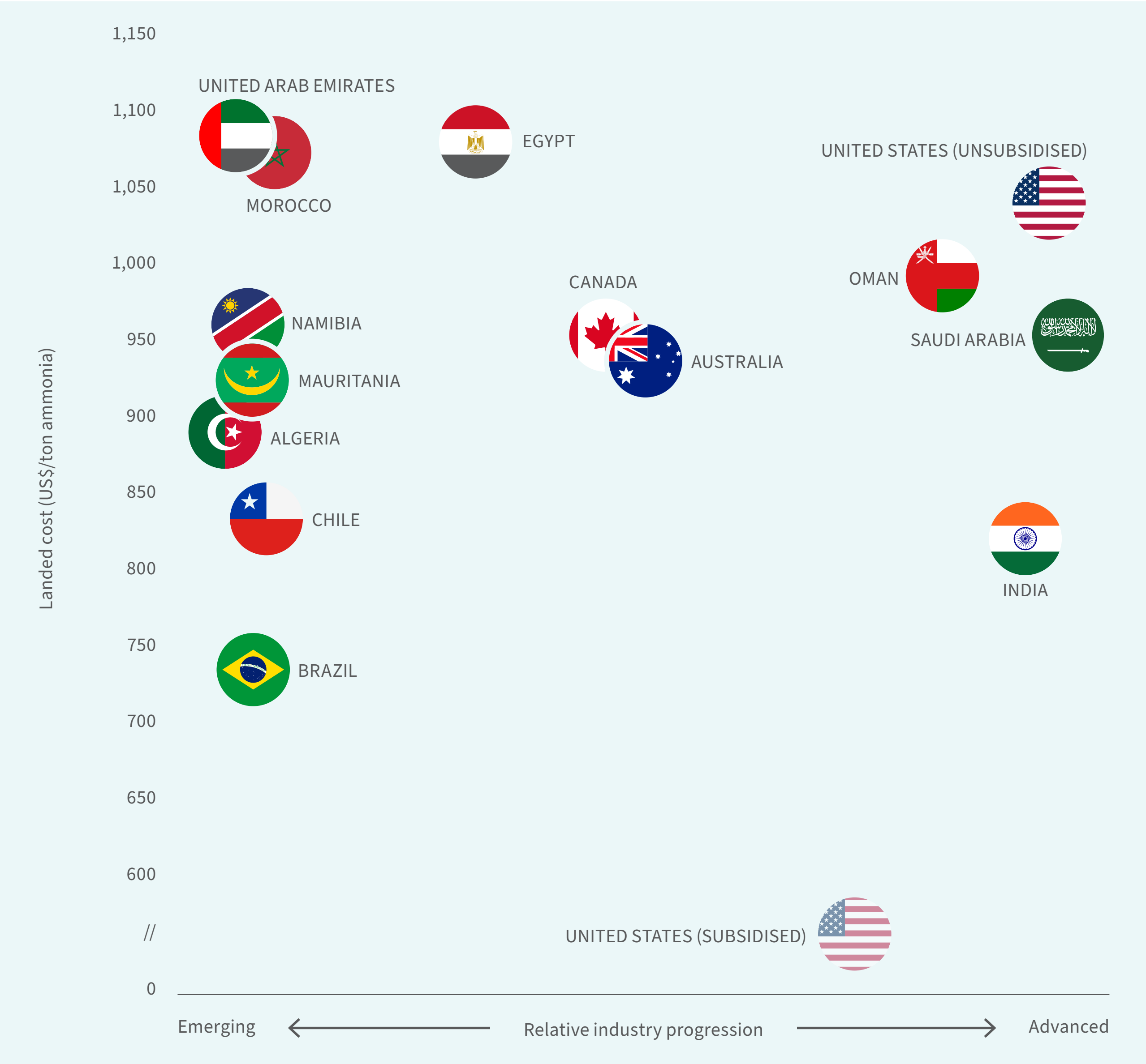
Note: Route is from major export projects in their relevant countries to Rotterdam. Shipping was modelled using ammonia as fuel. Fuel consumed was factored into the final landed cost to recover value from lost cargo. US subsidised cost includes 45V and 45Y tax credits.
RMI Graphic. **Source:** IEA, RMI analysis.

Consuming part of the ammonia cargo as fuel means that countries with higher ammonia prices will face an added cost burden if using ammonia as fuel because they must account for both fuel consumption and travel distance. In India's case, its low ammonia production cost helps minimise the impact of shipping expenses, despite being one of the farthest export locations from Europe (see **Exhibit 4**). Another key factor is canal fees: transiting through the Suez Canal alone accounts for nearly 20% of India's total shipping costs.

Green ammonia production costs and landed prices in import markets are not the only measures of a well-developed global market of hydrogen and its derivatives. To assess market readiness for export projects, the analysis examines the progress of initiatives in countries with strong hydrogen and ammonia export ambitions (see **Exhibit 5**).

Given the varying market complexities, the evaluation — referred to as relative industry progression — prioritises projects that are either in advanced discussions or have reached FID, with a stronger focus on export-oriented and electrolysis-based projects than those catering primarily to domestic markets or relying on fossil fuels with carbon capture. The metric aims to capture the advancement of each country's respective renewable ammonia export industry in relation to others'.

Exhibit 5 Export countries' landed green ammonia costs in European ports compared with advancement of green ammonia export industry, 2030



Note: Landed cost was found using an RMI electrolytic renewable hydrogen and ammonia production cost model and an RMI hydrogen trade model. Modelled values assume dedicated renewable energy systems for production, except for Brazil, which was modelled using an assumed power purchase agreement for hydropower priced at US$45/megawatt-hour to reflect the likely electricity sourcing strategy in the Northeast region. Relative industry progression is measured by evaluating the overall volume and number of projects having reached FID, and the volume and number of projects having reached FID that are export-oriented. Using this data, countries that have reached FID or are closer to FID are scored higher. Specific details on data can be found in **Appendix B**. Costs are modelled as unsubsidised for all countries, except in the United States (45V and 45Y tax credits under the Inflation Reduction Act) and India (waiver of Inter-State Transmission System charges) (Ministry of Power, "In a Big Boost to Off-Shore Wind Energy Projects, Government Gives Complete Waiver of ISTS Charges for 25 Years to Projects Commissioned on or before 31st Dec, 2032," accessed April 21, 2025, **https://pib.gov.in/pib.gov.in/Pressreleaseshare.aspx?PRID=1928128)**. State-level policy incentives have not been accounted for in the analysis for any country.
RMI Graphic. **Source:** IEA, RMI analysis.

Modelling shows that India's ammonia exports to Rotterdam would be competitive with those of other hydrogen-exporting nations (see **Exhibit 4**). India is also amongst the front-runners in clean ammonia exports, backed by its strong commitment to large-scale projects.

As of 2024, 30% of India's announced green hydrogen and its derivatives capacity is export-oriented,[iii] many projects are in the early stages of development, demonstrating India's ongoing efforts to scale up its hydrogen capabilities. An analysis of announced initiatives shows that as of July 2025, India is one of only three export nations to have secured an FID on a major electrolysis-based hydrogen project, alongside Saudi Arabia and Oman.[29] An additional project in Egypt is likely to reach FID by 2026 because it was the sole winner of the first H2Global auction round.[30]

Currently, the United States leads in clean ammonia export projects (by volume and number of projects) having reached FID. However, the US hydrogen export market remains largely dominated by natural gas reforming with carbon capture (blue ammonia), with two large-scale blue ammonia export projects having taken FID. But with EU mandates such as RED III focusing on RFNBOs, European markets are expected to prioritise trade with countries focussing on RFNBO-compliant ammonia, such as India.

Early trade ties between the EU and these nations are already taking shape, with projects securing binding offtake agreements and obtaining precertification for RFNBO compliance. Notably, India's AM Green project has received precertification from CertifHy,[31] one of the three voluntary RFNBO certification schemes to have passed a positive technical assessment as of July 2025.[32]

With their current project pipelines, India, Saudi Arabia, and Oman are well positioned to establish early green hydrogen and ammonia trade routes, capitalising on first-mover advantages. However, building India's leadership in this emerging market will require continuous adaptation and strategic advancements, especially as global competition intensifies with the emergence of additional cost-competitive exporters.

With AM Green, India has successfully designed and financed one of the world's first clean ammonia export projects. To gain a long-term competitive edge, India should continue scaling its hydrogen export ecosystem by leveraging infrastructure, operational expertise, and trade partnerships to strengthen its position in the global market.

iii. Based on RMI analysis of the National Green Hydrogen Mission project database.

4. Key Trade Enablers for India's Green Hydrogen and Its Derivatives

India's cost competitiveness and market readiness could position the country as one of the leading exporters of green hydrogen and its derivatives. However, realising this opportunity requires addressing key challenges around creating robust export infrastructure, aligning with global certification frameworks, creating bilateral offtake agreements, and securing long-term demand. Strategic enablers (see **Exhibit 6**) will be critical in navigating global ecosystem uncertainty, mitigating risks, and mobilising investments for India.

Exhibit 6 Key enablers for India's positioning in global green hydrogen market

Infrastructure preparedness

India can develop port infrastructure, hydrogen pipelines, and storage facilities to support production and export of green hydrogen and its derivatives. Ports serve as critical gateways for trade, and investments in common infrastructure can reduce logistical costs and improve supply chain efficiency.

Standards and certifications

Standards and certifications of green hydrogen and its derivatives are essential to unlock global trade opportunities by ensuring that products comply with hydrogen import country standards. Harmonised standards will bolster India's position as a reliable green hydrogen exporter in global markets.

Strategic partnerships and global agreements

Strategic partnerships play a vital role in fostering technology exchange, securing long-term offtake agreements, and promoting joint investments. Collaborations with key markets can accelerate project development and strengthen India's position in the global green hydrogen market.

Trade and financial de-risking mechanisms

Structured trading mechanisms and financial instruments are critical to mitigate risks and improve the bankability of green hydrogen projects. Trade mechanisms and financial instruments such as contracts for difference and sovereign guarantees can help address price volatility and market risks, enabling scalable hydrogen exports.

RMI Graphic.

The following sections delve into each trade enabler in detail, exploring the global landscape, India's status and developments, and the challenges and opportunities that lie ahead.

4.1. Infrastructure preparedness

Infrastructure to handle hydrogen derivatives like ammonia or methanol will be essential at ports to enable cost-efficient trade. This infrastructure, often referred to as common-user infrastructure (CUI), comprises various components, including electricity substations, transmission lines, pipelines, storage tanks, and other facilities across the value chain.[33] Given that ports serve as critical gateways for trade, the development of common infrastructure could position them as pivotal green hydrogen hubs for both exporting and importing countries.[34]

Global landscape

Getting ports ready for the ammonia trade is no longer just a concept, but a widely accepted need worldwide. The Global Ports Hydrogen Coalition signals ports' interest in building hydrogen infrastructure, handling, safety capabilities, and bringing representatives from ports together with government decision makers as well as industry with the goal of accelerating low-carbon hydrogen deployment.[35] It is part of the Hydrogen Initiative, originating from the Clean Energy Ministerial (CEM), which is dedicated to supporting the scale-up of clean hydrogen in the global economy.[36] Lately, Clean Energy Marine Hubs (or CEM-Hubs), administered by CEM, have been leading the conversation. The CEM-Hubs initiative is a first-of-its-kind partnership between the private sector and governments across the energy–maritime value chain, intended to de-risk investments needed to produce low- and zero-emissions fuels for maritime sector transportation.[37]

Globally, ports are advancing green hydrogen trade by developing dedicated terminals for both import and export (see **Exhibit 7**). Exporting ports, like Walvis Bay in Namibia and Duqm and Salalah in Oman, are investing in CUI, while importing ports, such as Rotterdam, focus on inland transport networks.[38] A key trend is the hub-based model, which helps facilitate the production and trade of ammonia, methanol, and commodities like green steel and fertilisers. Additionally, ports are driving green corridor initiatives and demand aggregation through bilateral agreements, as seen with Hamburg's partnerships with South American nations like Chile.[39]

Exhibit 7 Global examples of port initiatives to facilitate green hydrogen trade

Country and port	Infrastructure-related port activities to enable a green hydrogen economy
Belgium Port of Antwerp-Bruges	• The port is developing infrastructure such as terminals, quays, and pipelines for receiving and further distributing hydrogen.* • It is committed to the global supply or importing of hydrogen and its carriers from major exporters worldwide with the Hydrogen Import Coalition and bilateral agreements with exporters. • The port is working on facilitating local production with initiatives such as HyoffWind and Plug while congregating local offtake.
Brazil Port of Açu	• The Low-Carbon Hydrogen and Derivatives Hub, located at the port, was established to ensure environmental and social sustainability for an area of 1 million km² with a 3.7 gigawatt capacity, seamlessly integrated into port infrastructure and industrial zones.† • The port provides water supply from various sources (including industrial reuse), deepwater export infrastructure, and connectivity to the Brazilian grid (SIN), and it supports both on-grid and off-grid renewable energy projects.‡
Germany Port of Hamburg	• The Hamburg Port Authority and the Port of Argentia, in Newfoundland, Canada, signed a letter of intent in March 2024 to collaborate on the export of green hydrogen from Canada and its import to Germany.§ • International agreements have also been signed with Chile, Argentina, and Uruguay for the import of green hydrogen.‖ • A new ammonia import terminal has been planned by Hamburg-based energy company Mabanaft at the port of Hamburg.#
Morocco Tan Tan Port	• The National Ports Agency has initiated a technical feasibility study to enhance the Tan Tan Port for green hydrogen and derivatives exports.**
Namibia Port of Walvis Bay	• A €250 million project is in development by private investors along with the Port of Antwerp-Bruges for the construction of an ammonia and hydrogen export terminal.††
The Netherlands Port of Rotterdam	• The port is exploring green hydrogen import opportunities through over 150 global projects and has established agreements with 25 countries such as Singapore and Australia.‡‡ • It aims to build a hydrogen pipeline network connecting the port to other European pipeline systems with multiple projects such as HyNetwork and hyTransPort.RTM.§§ • Multiple consortiums are in the process of developing import terminals for hydrogen and derivatives such as OCI, Air Products, and Gasunie.‖‖
South Africa Boegoebaai Port	• A new deep port is under development to serve green hydrogen exports in western South Africa.##
South Korea Port of Ulsan	• In July 2023, the Port of Ulsan became the world's first to successfully bunker green methanol and biodiesel to the Maersk Solstice container vessel, supporting its energy transition strategy and carbon neutrality goals.*** • The port plans to build a clean hydrogen and ammonia terminal at Ulsan New Port by 2030. ††† • In August 2024, the Ulsan Port Authority signed a US$17.6 million equity investment agreement with Hyundai Oil Terminal Corporation to develop an alternative marine fuel supply chain at the Port of Ulsan. ‡‡‡

RMI Graphic. **Sources:** *"Hydrogen," Port of Antwerp-Bruges, accessed March 17, 2025, **https://www.portofantwerpbruges.com/en/our-port/climate-and-energy-transition/hydrogen**. † "Port of Açu — Low-Carbon Hydrogen and Derivatives Hub," World Port Sustainability Program, 2024, **https://sustainableworldports.org/project/port-of-acu-low-carbon-hydrogen-and-derivatives-hub/**. ‡ "Renewable Projects," Port of Açu, accessed March 17, 2025, **https://portodoacu.com.br/en/renewable-projects/**. § "Port of Hamburg and Canada Forge Closer Ties on Hydrogen," Hamburg News, March 21, 2024, **https://hamburg-business.com/en/news/hpa-and-port-of-argentia-decide-to-increase-hydrogen-transports**. ‖ "Hamburg, Chile, Argentina and Uruguay Agree on Hydrogen Imports,"2022.
#Ajsa Habibic,"Plans for Ammonia Import Terminal in Hamburg Port Gain Ground," Offshore Energy, February 8, 2024, **https://www.offshore-energy.biz/plans-for-ammonia-import-terminal-in-hamburg-port-gain-ground/**.

Anela Dokso,"Green Hydrogen Technical Feasibility Study Starts in Tan-Tan Port," November 11, 2024, **https://energynews.biz/green-hydrogen-technical-feasibility-study-starts-in-tan-tan-port/. ††Polly Martin,"Belgian Port Plans to Build €250m Hydrogen and Ammonia Export Terminal in Namibia," Hydrogeninsight, May 3, 2024, **https://www.hydrogeninsight.com/production/belgian-port-plans-to-build-250m-hydrogen-and-ammonia-export-terminal-in-namibia/2-1-1637210**. ‡‡ "Import of Hydrogen," Port of Rotterdam, accessed March 21, 2025, **https://www.portofrotterdam.com/en/port-future/energy-transition/ongoing-projects/hydrogen-rotterdam/import-of-hydrogen**. §§ "Hydrogen in Rotterdam," 2025. |||| "OCI Expands Import Terminal for (Green) Ammonia," Port of Rotterdam, June 15, 2022, **https://www.portofrotterdam.com/en/news-and-press-releases/oci-expands-import-terminal-for-green-ammonia**; Michele Labrut, "Vopak, Gasunie and HES to Build Rotterdam Green Ammonia Terminal," Seatrade Maritime News, April 13, 2022, **https://www.seatrade-maritime.com/green-shipping/vopak-gasunie-and-hes-to-build-rotterdam-green-ammonia-terminal**. ## "The Boegoebaai Port and Green Hydrogen Cluster," Global Africa Network, March 24, 2024, **https://www.globalafricanetwork.com/featured/boegoebaai-port-and-green-hydrogen-cluster/**. *** "Maersk Ship Completes First Green Methanol Bunkering in Ulsan Ahead of MV," The Maritime Executive, February 2024, **https://maritime-executive.com/article/maersk-ship-completes-first-green-methanol-bunkering-in-ulsan-ahead-of-mv**. ††† Jung Hoon, "Esbjerg and Ulsan Collaborate on Hydrogen and Ammonia for Renewable Energy," September 2024, **https://www.chemanalyst.com/NewsAndDeals/NewsDetails/esbjerg-and-ulsan-collaborate-on-hydrogen-and-ammonia-for-renewable-energy-30148**. ‡‡‡ Ioanna Kontos, "Ulsan Port Authority and Hyundai Oil Terminal Sign USD17.6 Million Investment Deal." Container News, August 8, 2024, **https://container-news.com/ulsan-port-authority-and-hyundai-oil-terminal-sign-us17-6-million-investment-deal/**.

Competitive export-driven countries like Egypt and South Africa have established Special Economic Zones (SEZ) to position their ports as green hydrogen hubs, attracting investment and enhancing export opportunities for production projects. The Suez Canal Economic Zone (SCEZ) is a prime example of successful investment in port infrastructure preparedness.

The SCEZ, which includes six ports in Egypt, offers tax exemptions for custom duties, income taxes, and stamp duties for five years;[40] access to infrastructure and utilities; and land allocation, among other incentives. Similarly, Freeport Saldanha's SEZ in South Africa provides tax incentives, value-added tax exemptions, and strategically located land near the port, along with clustering benefits for industrial customers.[41]

Designating ports as SEZs or hydrogen hubs can drive local and state-level incentives while ensuring export-oriented projects have proximity to departure points, permitted land, and leasing advantages, strengthening their global competitiveness.

India's status and developments

As global ports progress in the hydrogen trade, India is also working to strengthen the role of its ports in the international market. Harit Sagar guidelines by the Ministry of Ports, Shipping, and Waterways (MoPSW) launched in May 2023 set the goal for India to be a global bunkering hub,[42] opening avenues for green corridors with global importers. MoPSW and MNRE are also driving efforts to enhance export capabilities at ports for green ammonia and methanol.[43] Developing ports of Paradip (in Odisha), Deendayal (in Gujarat), and V. O. Chidambaranar (VOC) (in Tamil Nadu) as green hydrogen hubs marks the inception of green hydrogen hubs development around ports to cater to export and domestic demand.[44]

Several exports-oriented projects have been initiated by major ports like Paradip, Deendayal, and VOC. The Deendayal port intends to house projects with a combined capacity of 6.5 Mtpa of green ammonia, while Paradip and Gopalpur together are aiming to host 5.2 Mtpa of green ammonia projects by 2030.[45] These projects aim to take advantage of the ports' conventional role of being enablers of trade and their expertise in handling energy molecules such as ammonia to export green molecules globally. Paradip is also developing CUI, including desalination plants, pipelines, and specialised hydrogen berths, with an investment of US$390 million.[46] Additionally, VOC has allocated 500 acres and Deendayal 3,400 acres for green hydrogen production and derivatives.[47]

Challenges and opportunities for India

With their strategic locations, proximity to industrial clusters, and existing infrastructure, ports are uniquely positioned to drive green hydrogen exports in India. Ports in India also have extensive experience in handling hydrogen derivatives with ammonia imports totalling 2.43 Mtpa and methanol imports totalling 3.11 Mtpa in 2022.[48] Key Indian ports that have seen a rise in green hydrogen project announcements such as Paradip (0.05 MMT) and VOC (0.03 MMT) have ammonia storage in their vicinity. This experience forms the basis for managing derivatives such as ammonia and methanol, encompassing essential safety protocols, regulatory compliance, and operational expertise.

Key opportunities in developing Indian ports as export hubs for green hydrogen and its derivatives are outlined below:

Geographical location suited for export to demand centres

India is geographically well positioned to cater to the demands of Europe and East Asia (e.g., Japan, South Korea) based on proximity and existing shipping lanes. With western coast ports such as Deendayal and Jawaharlal Nehru Port Authority offering easy access via the Suez Canal to Europe and eastern coast ports such as Paradip and VOC utilising their short direct routes to East Asia, India's vast spread of major ports is an added advantage to optimise logistics based on the target demand market. Apart from green hydrogen and its derivatives, ports can also become a gateway for the export of green hydrogen–based products such as green urea and green hydrogen–based steel by utilising the natural formation of industrial clusters around them.[49]

Ability to leverage existing and new infrastructure for future scale-up

Leveraging existing infrastructure, including ammonia storage facilities and liquefied natural gas (LNG) terminals, can provide a foundation for initial decarbonised hydrogen and ammonia operations.[50] Indian ports can also size new infrastructure to accommodate increasing green hydrogen and ammonia fuel both for export and for bunkering on global green shipping corridors. As demand increases, especially as green shipping becomes a leading end-use sector for hydrogen and its derivatives due to IMO regulations, infrastructure can be scaled according to the projected production and bunkering estimates.

Some challenges persist for India in terms of infrastructure readiness, which ultimately boil down to the nascency of the industry. Even though some Indian ports have experience in handling hydrogen and its derivatives, these ports would need to upgrade storage facilities as reliable demand for green hydrogen and its derivatives increases. Major hubs such as Deendayal and Paradip-Gopalpur have announced 11.7 Mtpa worth of green ammonia projects already, which eclipses the country's total handling capacity of 3.11 Mtpa.

Additional challenges include:

Scalability and financial risks

The lack of reliable demand also hampers the scalability of infrastructure to cater to the market. The lack of binding offtake compounds the financial risks associated with these high infrastructure investments, thereby slowing the rollout of infrastructure additions.[51]

Infrastructure and port readiness

While ammonia might be a common commodity for Indian ports, the ports would need to fit methanol and other hydrogen derivatives into their handling and regulatory frameworks given the quantities expected to be transported. India's ports need significant upgrades to handle green ammonia, methanol, and other derivatives at scale, requiring large infrastructure investments and regulatory adaptations. Developers are also cautious about potential timeline delays that infrastructure projects may cause.[52]

4.2. Standards and certifications

Standards and certification of green hydrogen and its derivatives are essential to unlock global trade opportunities by (1) ensuring that products comply with the green hydrogen standards of the importing country and (2) enabling access to government support mechanisms and funding.

Methodologically, standards lead to certifications (see **Exhibit 8**). A hydrogen standard outlines the methodology to calculate the emissions intensity (per kg of hydrogen) of hydrogen and its derivatives, while the emissions threshold sets the upper limit for the intensity.

Exhibit 8 Different aspects of hydrogen standards and certifications

Standards

Methodology

- Outlines a methodological criteria for hydrogen/hydrogen-derivatives to qualify for emissions threshold regulations
- Used to measure product emissions intensities to comply with voluntary emissions thresholds or regulations
- May differ in scope (i.e., only point of production, well-to-gate, well-to-end-use)
- Set at the local, country, regional, or international level based on the governing body's decarbonisation and industrialization ambitions

LEADS TO

Certifications

Implementation of methodology

- Verifies hydrogen/hydrogen-derivative molecules are created in compliance with specified emissions regulation
- Best practices are for certifications to be third-party verified from an independent certification body
- Can vary by system boundaries (i.e., can be created for only point of production emissions, well-to-gate emissions, or lifecycle [well-to-end-use] emissions)

RMI Graphic. **Source:** RMI compilation

While there is a global push to have aligned standards across borders, emissions thresholds are set at the national level based on a country's decarbonisation objectives.

Nongovernmental bodies such as the International Organization for Standardization are attempting to establish guidelines globally for hydrogen standards.[53] Building on the momentum from the 2024 United Nations Climate Change Conference (COP29) to have mutual recognition of certification schemes,[54] first-mover markets have spurred the development of standards and certifications to ease the global trade of hydrogen, with a focus on harmonising certification schemes and mutual recognition of hydrogen certification schemes at the national level.

Global landscape

First-mover countries such as India, Australia, Brazil, Japan, South Korea, and the United States are establishing benchmarks aligned with their hydrogen strategies and roadmaps (see **Exhibit 9**). These efforts balance decarbonisation goals outlined in their Paris Agreement Nationally Determined Contributions (NDCs) with objectives related to industrialisation and energy security.

For trade to take place, molecules produced in exporter countries need to qualify in importing countries based on the standards set by the importer. Unharmonised standards have created bottlenecks in the global hydrogen trade economy, stifling offtake agreements and projects taking FID.[55]

Exhibit 9 National hydrogen standards across key hydrogen importers and exporters

Country	Designation	Emissions threshold (kg CO_2e/kg H_2)	System boundary	Status	Tied government scheme
Australia	Exporter	0.6	WtG	✓	Hydrogen Production Tax Incentive (HTPI)
Brazil	Exporter	7.0	WtG	✓	Low-Hydrogen Carbon Development Program (PHBC)
Canada*	Exporter	0.75–4.0	WtG	✓	Clean Hydrogen Investment Tax Credit
India**	Exporter	2.0	WtG	✓	SIGHT: Green H_2 production auction
United Kingdom	Exporter	2.4	WtG	✓	HAR1 CfD (Contract for Difference) Scheme
United States*	Exporter	0.45–4.0	WtG	✓	Clean Hydrogen Production Tax Credit (45V)
EU RFNBO	Importer	3.38	WtU	✓	H2Global, EU Hydrogen Bank
EU Low-Carbon H2^{+}	Importer	3.38	WtU	—	H2Global, EU Hydrogen Bank
Japan	Importer	3.4	WtG	✓	CfD (Contract for Difference) Scheme
South Korea	Importer	4.0	WtG	✓	Clean Hydrogen Power Auction

WtG = Well-to-gate WtU = Well-to-end-use ✓ = In effect — = Under development

Note: 2 kg CO_2e/kg hydrogen averaged over a 12-month period. * The US Clean Hydrogen Production Standard emissions threshold is 4 kg CO_2e/kg hydrogen. The US and Canadian clean hydrogen production tax credits are tiered, where the threshold is between 0.45 and 4 kg CO_2e/kg hydrogen and 0.75 and 4 kg CO_2e/kg hydrogen, respectively, to qualify under current governmental regulations. $^{+}$ Methodology for low-carbon hydrogen has not been codified by the EC yet. Draft guidance has been released, and it is expected that final guidance will be harmonised with methodology for RFNBO.
RMI Graphic. **Source:** RMI compilation

Not all countries with great renewable resources and incentives for hydrogen production from **Exhibit 3** have implemented a green or clean hydrogen standard. Import-oriented regions and nations, including the EU, Japan, and South Korea, have standards that range from life-cycle system boundaries and strict requirements for renewable energy capacity additionality, to temporal and geographic matching (EU), to well-to-gate system boundaries with no stipulations for power configuration of hydrogen production facilities (Japan, South Korea).

Export-oriented nations such as Australia, India, the United Kingdom, the United States, Canada, and Brazil have hydrogen standards that encompass well-to-gate system boundaries and are tied to national funding mechanisms but vary by emissions threshold.

India's status and developments

Box 1. Green hydrogen and its derivatives from India can differentiate in the import market based on carbon intensity of products

As national regulatory bodies continue to tighten hydrogen standards to align with planetary carbon budgets, the carbon intensity of traded hydrogen and its derivatives will need to comply. This can be seen in regions such as the EU, where the regulations on required renewable energy consumption increased from 32% (RED II) to 42.5% (RED III) by 2030.[iv]

India's national hydrogen strategy under the National Green Hydrogen Mission focuses on green hydrogen and its derivatives. Conversely, some exporting countries such as the United States are doubling down on blue hydrogen production that could be imported by Japan and South Korea based on their technology-agnostic standards. When it comes to emissions reductions, India can differentiate its export product with lower carbon intensities under the Green Hydrogen Standard from the blue molecules from other exporting markets. This differentiation will be especially important as importing countries count emissions towards their voluntary NDC targets under the Paris Agreement.

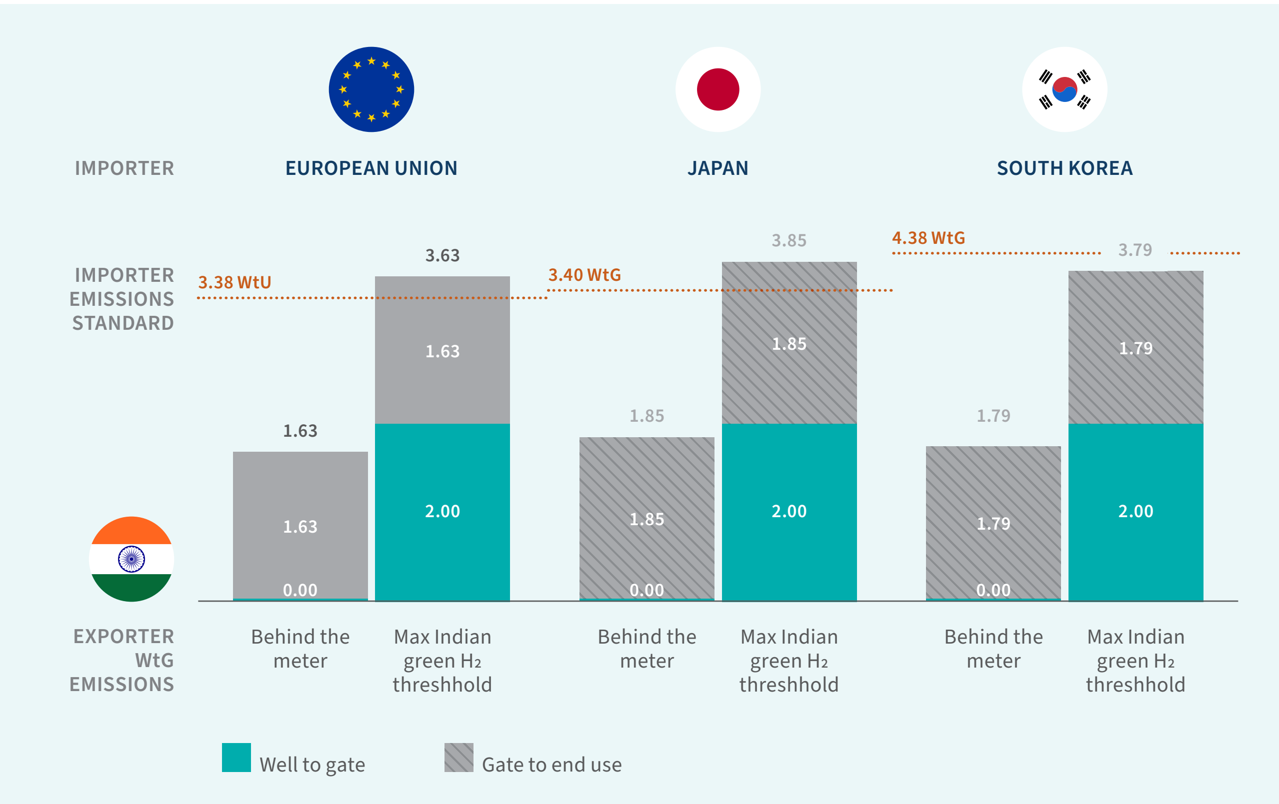
The Green Hydrogen Standard in India currently covers well-to-gate emissions in scope with an emissions threshold of 2 kgCO_2e/kg hydrogen (see **Exhibit 9**). Technology covered under the standard includes hydrogen produced by renewable electricity or biomass. Emissions are measured as an average over a 12-month period with no stipulations for additionality or temporal or geographic matching of renewable electricity.

iv. The Renewable Energy Directive (RED) is a regulation by the EC to set targets for renewable energy use in all sectors of the EU economy. The 2030 target from RED III is to have 42.5% of the EU-wide economy incorporate renewable energy, including for hydrogen used in industry. The definition of renewable hydrogen is outlined by the EC in two delegated acts on RNFBO including the methodology for calculating life-cycle emissions of hydrogen products and requirements for additionality, temporal, and geographic matching for the production of green hydrogen molecules (**https://energy.ec.europa.eu/topics/eus-energy-system/hydrogen/renewable-hydrogen_en**).

With India poised to be a lead producer and exporter of green hydrogen and its derivatives, its standard will be crucial to enable trade. The Green Hydrogen Standard has been finalised, and the corresponding Green Hydrogen Certification Scheme of India (GHCI) has been officially announced by MNRE, with operationalisation underway.[56]

The current Green Hydrogen Standard in India complies with Japan's and South Korea's standard definitions and emissions thresholds (see **Exhibit 10**). Because there are no requirements for measuring life-cycle emissions or additionality and temporal matching requirements for the Indian Green Hydrogen Standard, producers will need to take extra steps to comply with the EU's definition for green hydrogen through the RFNBO Delegated Act.

Exhibit 10 **Emissions intensity of exported green ammonia from India and imported to three key demand markets including the European Union, Japan, and South Korea ($kgCO_2e/kgH_2$)**



Note: Behind the meter assumes renewables for electricity usage for both hydrogen and ammonia production. Grid electricity represented by maximum allowance of emissions under India's Green Hydrogen Standard. The EU, Japanese, and South Korean cases show imported ammonia consumed as the end product, with no intermediary step of cracking ammonia back into hydrogen. The 'gate to end use' blocks for Japan and South Korea are shaded because their standards use a 'well to gate' boundary, excluding emissions beyond the plant gate from accounting. For assumptions, see **Exhibit A6**.
RMI Graphic. RMI analysis.

The alignment of India's Green Hydrogen Standard with end-use markets is illustrated in **Exhibit 10**. In the scenario where 100% on-site behind-the-meter renewables are modelled, the exported green hydrogen qualifies under the emissions thresholds of key demand countries. However, beyond just the emissions threshold, Indian-produced ammonia will need to qualify with additional measures such as additionality and temporal matching requirements to qualify for RFNBO in the EU. Whereas hydrogen produced with well-to-gate emissions at the maximum threshold of India's green hydrogen standard (2 kg CO_2e/kg hydrogen) would qualify as green domestically, hydrogen traded to the EU would not qualify under the EU's RFNBO delegated act.

Additionally, three certification bodies have voluntary schemes approved by the EC to certify that hydrogen is RFNBO-compliant, including CertifHy, International Sustainability and Carbon Certification EU, and REDcert, while the Roundtable on Sustainable Biomaterials Association and KZR INiG system are under review by the EC. Hydrogen and derivatives exported from India would need to use these certifications approved by the EC to qualify as RFNBO in the EU.

In contrast, hydrogen produced with the maximum emissions allowance under the Indian Green Hydrogen Standard would qualify in Japan and South Korea due to the countries' standards having well-to-gate system boundaries that exceed the Indian Green Hydrogen Standard's emissions threshold. To continue to strengthen trade relations and streamline certification processing, the governments of Japan and South Korea could recognise the GHCI scheme as compliant with each country's hydrogen standards.

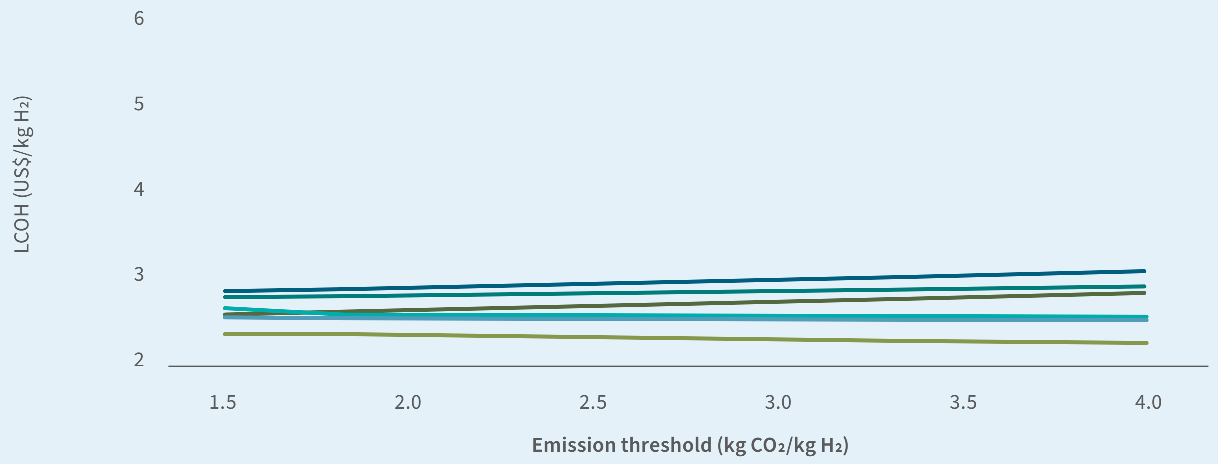
Box 1. Impact of varying emissions standards on project economics

India's Green Hydrogen Standard imposes a CO_2 emissions limit of 2 kg CO_2e/kg hydrogen, which is significantly more stringent than Japan's 3.4 kg CO_2e/kg hydrogen and South Korea's 4 kg CO_2e/kg hydrogen thresholds. This variation in emissions standards may encourage Indian developers to rely more on grid electricity for hydrogen production, an approach that does not meet India's domestic standard but would qualify under the more lenient thresholds of key export markets. However, such reliance raises both cost and credibility concerns, particularly as India seeks to establish itself as a supplier of green hydrogen globally.

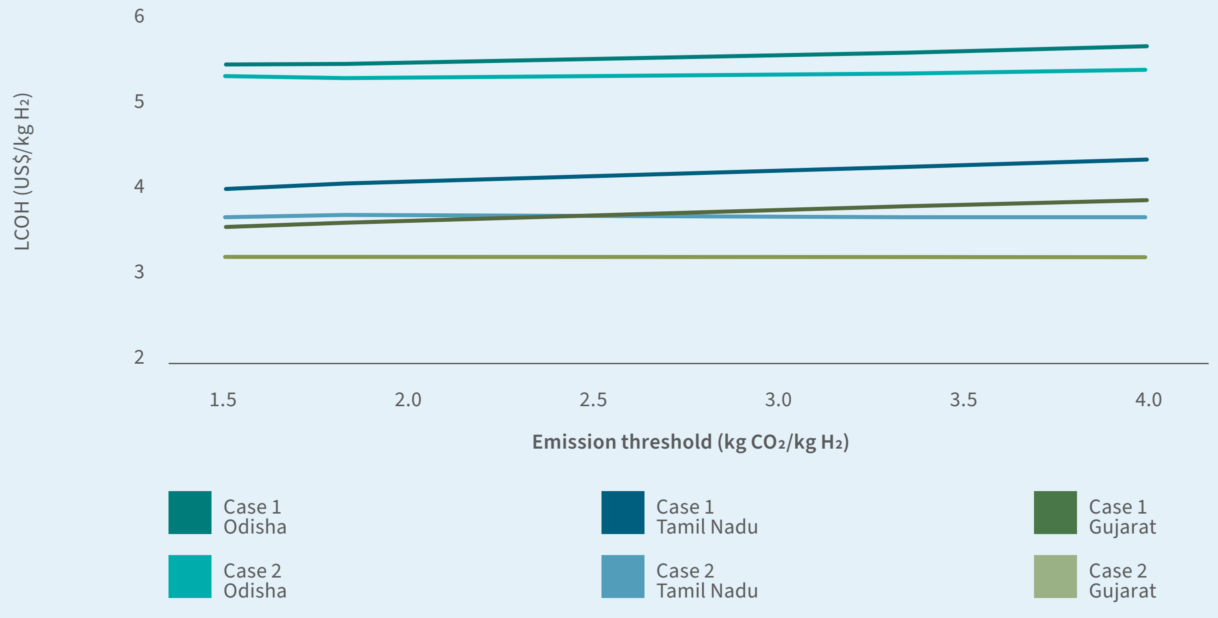
Exhibit 11 illustrates how different CO_2e emissions thresholds influence the levelised cost of hydrogen (LCOH) across India's key hydrogen export hubs: Kandla (Gujarat), Paradip (Odisha), and Tuticorin (Tamil Nadu) (for detailed assumptions and LCOH breakdown, refer to **Exhibits A7–A13**). The solid lines in **Exhibit 11** represent LCOH under prevailing industrial grid tariffs, whereas the dotted lines indicate potential LCOH if grid electricity prices matched renewable energy costs.

Exhibit 11 Implications of different CO_2 emissions allowances on hydrogen production costs in India

A. Behind-the-meter



B. Off-site hybrid renewable electricity



Note: Case 1 considers actual industrial grid electricity prices within the respective state, while Case 2 assumes electricity costs equal to the average renewable generation cost in the same state. Behind-the-meter setups considered for this analysis are not purely renewable and include grid connectivity to support baseload requirements.
RMI Graphic. **Source:** RMI analysis

Theoretically, a higher reliance on grid electricity can improve system utilisation, reduce the need for dedicated renewable energy capacity, and lower up-front capital expenditure. Despite the benefits of increased utilisation, industrial grid electricity in India remains costly due to cross-subsidy charges, wheeling fees, transmission levies, and additional surcharges, ultimately keeping LCOH elevated, even with improved system efficiency. Only if grid electricity prices decline to levels comparable with renewable energy would this strategy become financially viable.

Moreover, depending on lenient emissions standards to access export markets presents long-term risks:

1. **Regulatory uncertainty:** Countries such as Japan and South Korea may tighten their emissions thresholds over time, affecting project bankability.

2. **Reputational and market risks:** Aligning with relaxed standards could undermine climate credibility, affecting access to future green financing and premium markets.

Challenges and opportunities for India

India's early efforts in developing a green hydrogen certification framework present a strategic opportunity to align proactively with evolving global standards. By strengthening cooperation with key trading partners and engaging in international standardisation efforts, India can position itself as a leader in shaping a globally recognised certification system.

Establishing mutual recognition agreements with major import markets — such as the EU, Japan, and South Korea — can enhance market access, reduce compliance costs, and create a streamlined pathway for hydrogen exports. Additionally, expanding the certification framework to include hydrogen derivatives such as ammonia and methanol would help capture emerging demand in international markets, particularly in shipping, chemicals, and power generation.

However, certain gaps in India's GHCI could impede export ambitions if not addressed:

- **Limited cross-border recognition:** The GHCI is still in its early stages, and lack of formal recognition in key markets could require additional verification steps, adding costs and complexity for exporters.

- **Misalignment in emissions accounting approach:** India calculates emissions on a well-to-gate basis, whereas the EU's RFNBO rules require a well-to-use approach, which includes transportation and end-use emissions. This discrepancy may affect the eligibility of Indian hydrogen under EU import regulations.

- **Lack of coverage for hydrogen derivatives:** The current framework does not yet include green ammonia, methanol, or synthetic fuels, despite their expected role in driving future hydrogen trade. Uncertainty around their qualification under green hydrogen standards could limit India's ability to capitalise on growing export demand in shipping, fertilisers, and industrial applications.

4.3. Strategic partnerships and global agreements

International partnerships are emerging as a critical enabler for unlocking global green hydrogen trade. Cross-border collaborations are essential in mitigating supply chain vulnerabilities, harmonising certification systems, securing long-term offtake agreements, and fostering technology transfer and regulatory alignment. By leveraging multilateral platforms and targeted bilateral collaborations, India can strengthen its export strategy while addressing domestic infrastructure and policy gaps.

Global landscape

A well-integrated global hydrogen market requires the development of cross-border trade corridors, standardised certification frameworks, and shared infrastructure. Recognising this, international initiatives such as the International Hydrogen Trade Forum (launched at COP28 in 2023) and the Hydrogen Council, a CEO-led alliance of 132 companies, are working to identify viable trade corridors and harmonise certification standards.[57] India's active engagement in such frameworks is essential to ensuring its hydrogen exports remain competitive and compliant with international regulations.

Securing resilient supply chains is also crucial for large-scale hydrogen deployment. The Quad Clean Energy Supply Chain Diversification Program,[58] initiated by Australia, India, Japan, and the United States, aims to enhance the production and distribution of critical clean energy technologies across the Indo-Pacific. By reducing dependency on a single geography for key components, this initiative helps mitigate risks that could disrupt hydrogen production. India must build on such collaborative efforts to de-risk its supply chain and scale up domestic manufacturing of electrolysers and other enabling technologies.

International hydrogen cooperation has primarily been driven by bilateral agreements, focusing on exploring joint funding opportunities, facilitating technology transfer, and aligning regulatory frameworks. These agreements provide market certainty, reduce investment risks, and accelerate the development of necessary export infrastructure.

Exhibit 12 provides an overview of key bilateral agreements and their impact, illustrating how nations are leveraging these partnerships to scale hydrogen trade and innovation. By participating in both multilateral trade frameworks and targeted bilateral agreements, India can ensure market access while attracting investment and technology to scale its domestic hydrogen ecosystem.

Exhibit 12 Examples of global partnerships shaping the hydrogen trade

Initiative/partnership	Impact/plans
Australia–Germany Hydrogen Accord	Australia and Germany signed an agreement to enhance cooperation in green hydrogen supply chains through a US$660 million (€400 million) H2Global funding window.* Additional funding from both governments supports the HyGATE programme, facilitating hydrogen supply chain development.†
Japan–Australia Partnership	Australia and Japan invested AU$500 million in the Hydrogen Energy Supply Chain project,‡ achieving the world's first liquid hydrogen shipment in 2022. Australia also launched the AU$150 million Clean Hydrogen Trade Program to export clean hydrogen to Japan.§
Australia–Netherlands Collaboration	The two nations are working together on hydrogen trade policy, certification, port infrastructure, supply chain development, and regulatory harmonisation.‖
Hydrogen Europe and H2Chile	This joint industry–government initiative between the EU and Chile, focuses on regulatory cooperation, financing mechanisms, research and innovation, and skill development.#
Chile–Germany Cooperation	Chile signed an MoU with the Port of Hamburg for green hydrogen exports.** Germany's KfW Bank approved a €100 million loan to support hydrogen projects in Chile.††

Note: The presented list is not exhaustive but representative.
Sources: *"Joint Media Release: $660m to Advance Australia and Germany's Cooperation on Energy and Climate," Department of Climate Change, Energy, the Environment and Water, September 2024, **https://minister.dcceew.gov.au/bowen/media-releases/joint-media-release-660m-advance-australia-and-germanys-cooperation-energy-and-climate**. † "German-Australian Hydrogen Innovation and Technology Incubator (HyGATE)," Australian Renewable Energy Agency, accessed March 11, 2025, **https://arena.gov.au/funding/german-australian-hydrogen-innovation-and-technology-incubator-hygate/**. ‡ "Australian Clean Hydrogen Trade Program (ACHTP) — Policies," International Energy Agency, accessed March 11, 2025, **https://www.iea.org/policies/14738-australian-clean-hydrogen-trade-program-achtp**. § "Australia Japan Clean Hydrogen Trade Partnership," Ministers for the Department of Industry, Science and Resources, January 7, 2022, **https://www.minister.industry.gov.au/ministers/taylor/media-releases/australia-japan-clean-hydrogen-trade-partnership**. ‖ "Australia and the Netherlands Sign Milestone Renewable Hydrogen Agreement," Department of Climate Change, Energy, the Environment and Water, January 31, 2023, **https://www.dcceew.gov.au/about/news/australia-netherlands-sign-milestone-renewable-hydrogen-agreement**. # "Hydrogen Europe and H2 Chile Agree to Strengthen Industry Cooperation on Clean Hydrogen Deployment and Trade," EEAS, November 21, 2024, **https://www.eeas.europa.eu/delegations/chile/hydrogen-europe-and-h2-chile-agree-strengthen-industry-cooperation-clean-hydrogen-deployment-and_en?s=192**. ** "Chile Signs Agreement with Germany's Largest Port for Green Hydrogen Exports," Minrel, accessed March 11, 2025, **https://minrel.gob.cl/news/chile-signs-agreement-with-germany-s-largest-port-for-green-hydrogen**. †† Tanya Ivanova, "Germany Grants EUR 100m for Green Hydrogen in Chile," *Renewables Now,* January 2025, **https://renewablesnow.com/news/germany-grants-eur-100m-for-green-hydrogen-in-chile-1268926/**.
RMI Graphic. **Source:** RMI compilation

India's status and developments

India is also actively forming strategic international partnerships to bolster its green hydrogen ambitions. Notable collaborations include:

- **India–Germany Green Hydrogen Task Force**
  This task force, established in 2022, has now evolved into a permanent working group under the Indo-German Energy Forum.[59] The Indo-German Green Hydrogen Roadmap, released in October 2024, focuses on developing export-oriented hydrogen hubs and promoting global trade through bilateral offtake agreements and platforms like H2Global.[60]

- **India–Australia Green Hydrogen Taskforce**
  Formed in 2023, this task force explores trade, commercial, and research opportunities in green hydrogen, with a focus on electrolyser manufacturing, fuel cell production, infrastructure, and regulatory frameworks.[61]

- **India–Japan Clean Energy Partnership**
  Established in 2022,[62] this partnership builds on the India-Japan Energy Dialogue to enhance cooperation on energy security, clean energy transition, and supply chain resilience. Key developments include:

    - **ACME-IHI Agreement:** A long-term supply agreement for 0.4 Mtpa of green ammonia from India to Japan.[63]

    - **JICA-Mitsubishi-Hygenco Partnership:** Collaboration on hydrogen/ammonia-fired gas turbine combined cycle power plants in India.[64]

    - **Sembcorp-Sojitz-Kyushu Electric Offtake Agreement:** Establishment of a cross-border green ammonia supply chain.[65]

Challenges and opportunities for India

India has significant opportunities to deepen its bilateral and multilateral relationships in the global hydrogen trade. These relationships can help scale the export market as described below:

Expanding market demand

The EU and East Asia are accelerating their hydrogen imports to meet decarbonisation targets, providing India with the chance to secure long-term offtake agreements and establish itself as a reliable supplier.

Creating strategic collaborations

Countries like Japan, which aims for 15 gigawatts (GW) of global electrolyser capacity by 2030, offer avenues for India to form supply partnerships, codevelop cutting-edge hydrogen technologies, and integrate into global hydrogen value chains.

Enabling new market entry

South Korea's clean hydrogen power generation bidding market presents a structured mechanism for long-term hydrogen supply contracts, allowing Indian producers to tap into Korea's growing clean energy sector. Similarly, India can capitalise on Japan's low-carbon hydrogen supply chain subsidy by forging strategic partnerships with Japanese importers or setting up subsidiary entities in Japan, ensuring access to financial incentives.

However, to harness these opportunities, India must overcome the following challenges:

Limited bilateral offtake agreements

While India has begun securing early export agreements, it has yet to lock in multiple large-scale, binding offtake deals, limiting its ability to ensure stable demand and long-term revenue certainty.

Infrastructure gaps

While India has ambitious hydrogen production targets, the absence of dedicated hydrogen pipelines, refuelling stations, and ammonia export facilities poses logistical hurdles in achieving seamless trade with global markets.

Regulatory and certification uncertainty

Global hydrogen buyers require stringent carbon footprint certification and guarantees of origin. India must align its regulatory framework with international standards to ensure smooth market entry.

By proactively addressing these challenges and strengthening its participation in multilateral trade frameworks, India can position itself as a global green hydrogen leader while fostering investment, technology development, and long-term energy partnerships.

4.4. Trade and financial de-risking mechanisms

The global green hydrogen market is still in its early stages, facing uncertainties around pricing, long-term demand, and policy frameworks. Projects struggle to secure financing and offtake agreements, slowing overall market development. For pioneering export-oriented green hydrogen and derivative projects, innovative financing solutions are essential to balance the risk–reward equation for investors, developers, and offtakers. Instruments such as blended finance, export credit agencies (ECAs), and contract-for-difference (CFD) schemes can help lower costs and enhance the competitiveness of export projects.

Global landscape

Various instruments are being adopted globally to mitigate trade and financial risks. While not all are universally applicable, analysing successful case studies and key learnings from blended finance, ECAs, and CFD schemes can help shape effective risk mitigation strategies.

A. Blended finance

Blended finance funds can play a crucial role in securing investment for large infrastructure projects in emerging economies, helping projects reach FID while distributing risk and returns among multiple stakeholders. These funds typically follow a public–private partnership model, leveraging public capital to attract private investment and accelerate project development.

BLENDED FINANCE: CASE STUDY

Namibia's SDG Namibia One Fund — US$1 billion fund for a green hydrogen ecosystem

One example of a blended finance mechanism at the national level is SDG Namibia One, a US$1 billion fund designed to support Namibia's green hydrogen ecosystem.[66] It is a joint initiative between Namibia's Environmental Investment Fund, the EU's Climate Fund Managers, and the Netherlands' Investment International, and has attracted private investment in Namibia for green hydrogen production, such as the Hyphen Hydrogen Energy export project. Establishing this type of fund at the national level in India could reduce capital expenses for new projects and bring in financial partners from potential import markets, such as the EU.

B. ECAs

Exporting hydrogen is distinct from other energy commodities because it requires coordination between two regions: one for production and another for offtake. This unique structure allows projects to access financing from both locations.

ECAs differ from traditional credit institutions because they are typically government-owned and specialise in financing export-driven projects. For hydrogen production projects planning to export, ECAs can provide loan guarantees or direct loans at low interest rates, reducing financial risk and making projects more bankable. By absorbing political risk in emerging economies, ECAs can unlock capital for projects that traditional banks might otherwise avoid.

ECAs: CASE STUDY

UK's £5 billion support for Chilean hydrogen projects

ECAs have already played a key role in facilitating the global green hydrogen trade. In 2024, UK Export Finance committed £5 billion to support hydrogen production projects in Chile, offering financing in Chilean pesos rather than foreign currency.[67]

This approach creates a win-win scenario:

- **For Chile**, local currency financing reduces exchange rate risks, making investments more attractive and accelerating project development.
- **For the UK**, the agreement ensures that Chilean projects procure UK-made goods and services, fostering technology transfer and strengthening bilateral trade ties.

C. CFD schemes via auction mechanisms

In the early stages of the green hydrogen market, buyers and sellers often have misaligned expectations regarding price, volume, and contract terms. A CFD is a financial instrument that allows two parties to exchange the difference in an asset's price over time. As a leveraged product, CFDs enable investors to engage in market movements without directly owning the asset, helping stabilise volatile markets.[68]

CASE STUDY

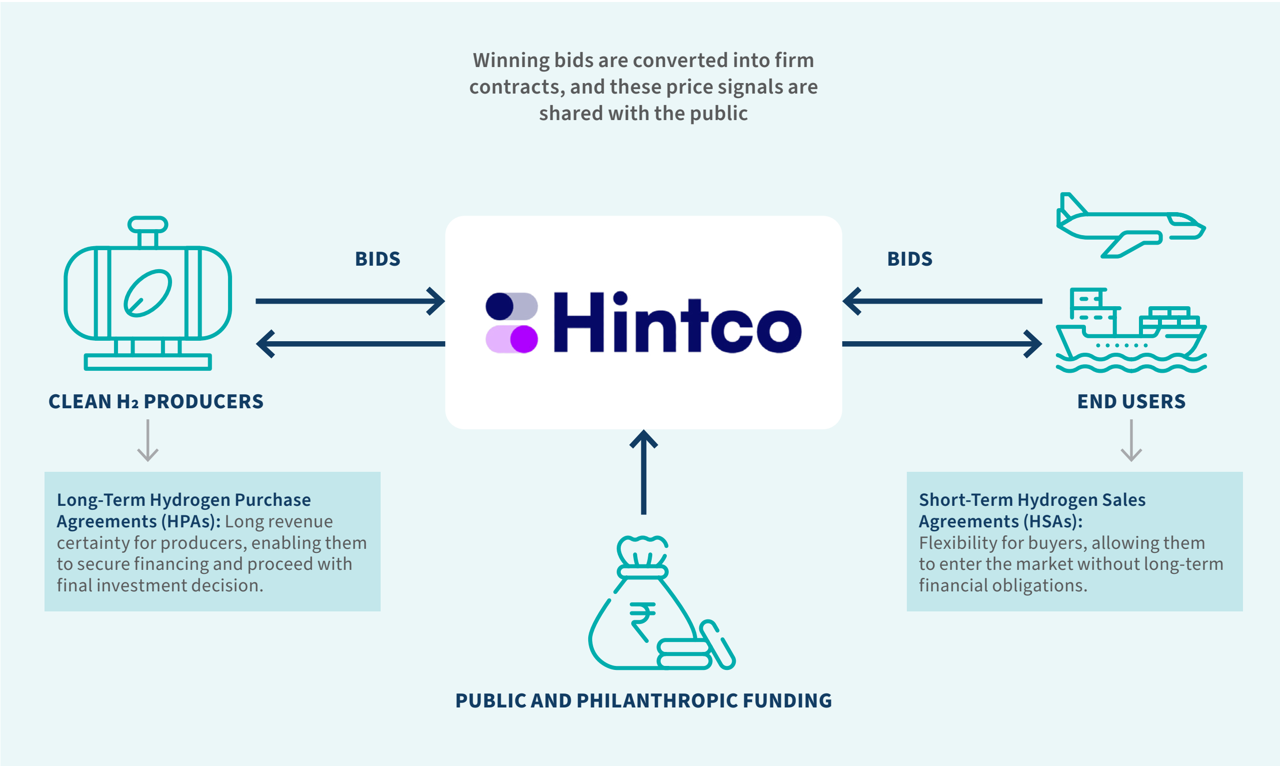
H2Global Foundation's double-sided auction

To address market uncertainties, Hintco, a subsidiary of the H2Global Foundation, has introduced a double-auction mechanism based on the concept of CFDs (see **Exhibit 13**).[69] This model mimics a functioning hydrogen market by securing:

- **Long-term** hydrogen purchase agreements (HPAs) for suppliers through competitive bidding, ensuring revenue certainty for producers
- **Short-term** hydrogen sales agreements for buyers, allowing flexibility in procurement without long-term financial commitments

Because green hydrogen projects require substantial up-front investments, developers need long-term revenue certainty to secure financing and make an FID. HPAs help mitigate this risk by guaranteeing stable revenue streams.

Exhibit 13 Hintco's double-auction mechanism



RMI Graphic. **Source:** Hintco.

Although buyers are selected through competitive bidding, a price gap between purchase and sales is expected in the short to medium term. To bridge this gap and support market maturation, Hintco leverages public and philanthropic grants. As of 2024, this initiative has attracted more than €5.5 billion in international funding.[70]

H2Global's first pilot auction in 2024 awarded Fertiglobe — a joint venture between Abu Dhabi National Oil Company and OCI — a contract to supply 397,000 tons of renewable ammonia from Egypt to the Port of Rotterdam at €1,000 per ton.[71] Launched in February 2025 with an outlay of up to €2.5 billion, the second auction is set to supply renewable hydrogen and its derivatives to Germany and the Netherlands.[72]

India's status and developments

India's National Green Hydrogen Mission (summarised in **Exhibit 14**) aims to attract more than approximately US$100 billion in investment by 2030.[73] While efforts are visible across multiple initiatives, incentives through the SIGHT programme and SECI's demand aggregation can help mitigate trade and financial risks for projects.

Exhibit 14 Highlights of India's efforts under the National Green Hydrogen Mission

Key initiatives	SIGHT program	Pilot projects	GH_2 hubs
Outlay	INR 17,490 crore (US$2.1 billion)	INR 1066 crore (US$0.13 billion)	INR 400 crore (US$0.05 billion)
Timeline	2029–30	2025–26*	2025–26
Support	Incentives for manufacturing of electrolyzers and production of green hydrogen	Support for low carbon steel projects, mobility pilot projects, and shipping pilot projects	To set up at least two green hydrogen hubs
Key updates	3 GW electrolyzer manufacturing capacity and 41,200 Mt GH_2 production capacity awarded	Three pilot projects sanctioned by MNRE in the steel sector, Scheme Guidelines published for implementing pilots in shipping and transportation sector	Call for Proposals released for Setting up of Green Hydrogen Hubs in India under National Green Hydrogen Mission

Other focus areas	Expected outcomes	
• Demand creation • Enabling policy framework • Infrastructure development • Regulations and standards • Skill development • Research and development	5 Mt of annual GH_2 production by 2030	60–100 GW electrolyzer installation
	50 Mt of cumulative carbon abatement	125 GW of RE for GH_2 production
	6 Lakh (0.6 million) new green jobs	Over INR 8 lakh crore (US$96 billion) investments

Note: * The timeline for low-carbon steel pilots is until 2029–30. RMI Graphic. **Source:** Hintco.

Under the SIGHT programme, two auction rounds have advanced domestic electrolyser manufacturing and reduced green hydrogen production costs.[74] In round one, winners like ACME secured production incentives for an export-oriented project in Odisha.[75] The second electrolyser auction was oversubscribed, with bids for 2.8 GW, highlighting strong demand for government-backed cost reduction measures.

The second auction for green hydrogen production subsidies is ongoing, starting with ₹50/kg, decreasing to ₹40/kg in year two and ₹30/kg in year three. This round saw 0.623 million tons bid — 0.173 million tons over the 0.450 million tons limit — demonstrating strong demand from Indian producers to lower production costs.[76]

Box 3. Learnings from SECI's green ammonia demand aggregation for export-oriented efforts

SECI has implemented a demand aggregation approach to accelerate green ammonia production and supply in India.[77] This strategy consolidates fragmented demand from multiple buyers and regions, creating a large-scale, reliable offtake market (see **Exhibit 15**). Ensuring demand certainty facilitates investment in large-scale production facilities.

Through competitive bidding, SECI has selected nationwide green ammonia producers and is establishing long-term supply agreements. By aggregating demand from nine states, totalling 7.24 lakh Mtpa, this initiative represents the largest green ammonia procurement tender to date. The tender follows a back-to-back supply model, where SECI procures green ammonia from successful bidders and supplies it to procurers over a 10-year period.

Exhibit 15 Volumes and fertiliser units targeted under SECI's demand aggregation request for selection

Name of procurer	Location of procurer's plant	Volume (tons)	Winner	Bid price (₹/kg)	Bid price (US$/ton)*
Indian Farmers Fertiliser Cooperative Limited	Kandla, Gujarat	100,000	ACME Cleantech Solutions Private Limited	54.73	629.08
Indian Farmers Fertiliser Cooperative Limited	Paradip, Odisha	100,000	ACME Cleantech Solutions Private Limited	49.75	571.84
Madras Fertilizers Limited	Manali, Tamil Nadu	4,000	Suryam International Private Limited	50	574.71
Gujarat Narmada Valley Fertilizers & Chemicals Limited	Bharuch, Gujarat	50,000	Onix Renewable Limited	52.5	603.45
Paradeep Phosphates Limited	Paradeep, Odisha	75,000	ACME Cleantech Solutions Private Limited	55.75	640.80
Paradeep Phosphates Limited	Zuarinagar, Goa	25,000	ACME Cleantech Solutions Private Limited	62.84	722.30
Indorama India Private Limited	Haldia, West Bengal	20,000	ACME Cleantech Solutions Private Limited	64.74	744.14
Mangalore Chemicals & Fertilizers Ltd.	Panambur, Karnataka	15,000	SCC infrastructure Private Limited in consortium with M/s InSolare Energy Limited	57.65	662.64
Coromandel International Limited	Vishakhapatnam, Andhra Pradesh	50,000	ACME Cleantech Solutions Private Limited	51.89	596.44

Exhibit 15 Volumes and fertiliser units targeted under SECI's demand aggregation request for selection (continued)

Name of procurer	Location of procurer's plant	Volume (tons)	Winner	Bid price (₹/kg)	Bid price (US$/ton)*
Coromandel International Limited	Kakinada, Andhra Pradesh	85,000	Jakson Green Limited in consortium with Ocior Energy India Private Limited, First Element Private Limited & JGGJ Renewable One Private Limited	50.75	583.33
Krishana Phoschem Limited	Meghnagar, Madhya Pradesh	70,000	NTPC Renewable Energy Limited	51.8	595.40
Madhya Bharat Agro Products Limited-II	Sagar, Madhya Pradesh	60,000	Oriana Power Limited	52.25	600.57
Madhya Bharat Agro Products Limited-III	Dhule, Maharashtra	70,000	SCC infrastructure Private Limited, in consortium with InSolare Energy Limited	53.05	609.77

Note: *Bid prices in US$/ton calculated with an exchange rate of 87 INR/US$
RMI Graphic. **Source:** SECI **https://www.seci.co.in/uploads/news/1757001950_Website_result_for_GA_M2AT1.pdf**.

The structured incentive mechanism starts at ₹8.82/kg in the first year, decreasing to ₹7.06/kg in the second year, and further declining to ₹5.30/kg in the third year.

By consolidating significant demand, this initiative has established a global benchmark for green ammonia trading, creating a scalable and de-risked market for both domestic consumption and exports. Additionally, demand aggregation can drive the development of shared infrastructure, benefiting both domestic use and international trade.

With the reverse-auction rounds now concluded under SECI's SIGHT Scheme, price discovery places domestic renewable-ammonia tariffs in the US$570–US$625/ton range (see **Exhibit 15**). The prices are rapidly approaching parity with grey hydrogen, marking a significant milestone for India's green hydrogen transition and decarbonisation of the fertiliser sector. Relative to H2Global's historic renewable-ammonia award, India's discoveries are roughly 35%–50% lower, underscoring India's emerging cost leadership in green ammonia production, use, and trade. This achievement lays the foundation for a global shift, positioning India as a competitive player in the global green ammonia market.

Challenges and opportunities for India

Although financial and trade mechanisms have played a crucial role in accelerating global green hydrogen deployment, India has significant opportunities to leverage these mechanisms to strengthen its ecosystem including:

Strategic partnerships to enhance market mechanisms

The MoU between SECI and H2Global presents an opportunity to codevelop auction-based models, fostering international trade and improving price transparency.[78]

Development of a hydrogen price index

Initiatives by the Indian Gas Exchange and Gujarat State Petroleum Corporation to establish a global hydrogen trading mechanism could create a standardised hydrogen price index, enhancing market stability and investor confidence.[79]

Adopting global funding models

India can learn from Namibia's SDG Namibia One fund and explore blended finance structures to attract investment, ensuring risk sharing between public and private stakeholders.

To harness these opportunities, it is critical to overcome described challenges associated with trade and finance such as:

Delayed rollout of funding schemes

Mechanisms such as H2Global have faced delays due to political risks and challenges in auction design refinement (e.g., Germany's e-SAF tender).[80] Similar hurdles exist for Japan's CFD scheme and South Korea's clean power auction, which only selected one company in its first round.

High production costs and need for subsidies

Green ammonia remains more expensive than fossil-based alternatives, requiring financial support to reach FID. Ensuring a balanced allocation of funds between domestic market growth and export-oriented projects is essential.

Balancing domestic and export priorities

Establishing a blended finance vehicle, similar to Namibia's SDG Namibia One, could help shift the financial burden of export projects to importing nations. However, aligning such mechanisms with India's domestic growth strategy requires careful planning.

Lack of transparency in hydrogen pricing

A functioning trading market for hydrogen and its derivatives depends on transparent price discovery. While global initiatives like HYDRIX by the European Energy Exchange provide price signals, India needs its own mechanisms to enhance market efficiency and investor trust.[81]

5. Pathway to Scale: Recommendations and Strategic Priorities

The enablers discussed earlier set the stage for India's active engagement in the global green hydrogen trade. However, to fully realise India's export potential and establish it as a competitive global supplier, strategic interventions will be essential.

The following six strategic recommendations can help India position itself as a key player in the global green hydrogen market:

1. **Build and deepen mutual trade partnerships with key importers like the EU, Japan, and South Korea, creating an enabling environment for long-term hydrogen trade**

   Strengthen trade relationships with major hydrogen-importing nations such as Germany, Japan, and South Korea by creating an enabling environment for long-term offtake agreements between private entities. This could involve advancing free trade agreement (FTA) discussions, leading to tariff reductions and elimination, market access and facilitation, investment protection and market stability, regulatory harmonisation, and strategic partnerships. Developing a dedicated India-Europe hydrogen corridor leveraging existing trade routes via the Suez Canal may also help diversify markets. Global examples provide valuable insights. Australia and Japan's Hydrogen Energy Supply Chain is a pioneering hydrogen trade agreement.[82] Germany, alongside broader EU efforts, is also securing independent long-term offtake deals from North African nations. Similarly, the UAE's ADNOC has signed low-carbon blue ammonia supply agreements with Japan's Mitsui and South Korea's GS Energy, demonstrating successful cross-border collaborations.[83]

2. **Strengthen regional hydrogen market integration and mutual recognition of certification**

   Explore regional collaboration on trade regulations, certification frameworks, and logistics coordination by establishing an India-led Asian hydrogen trade consortium. Aligning with global certification systems such as CertifHy (EU), the Hydrogen Quality Assessment (Japan), and RED II (EU renewable energy directive) could facilitate seamless hydrogen exports. Additionally, mutual recognition agreements on certification with key trade partners may help streamline verification processes, reduce compliance costs, and enhance cross-border hydrogen trade. Learnings from the International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE) on global standardisation efforts could be useful.[84] IPHE is developing global hydrogen sustainability and emissions standards, enabling countries to mutually recognise each other's certification schemes. The United States and EU are already engaged in discussions for standard harmonisation through IPHE. India could leverage its participation in IPHE to ensure compatibility of its certification framework with global markets.

3. Develop hydrogen-ready export infrastructure at major ports within India and partner importing regions

Explore cross-border investments, where both India and key importing nations (Japan, South Korea, Germany, the UAE, and Singapore) collaborate to codevelop port infrastructure, ensuring seamless and cost-efficient hydrogen trade. India has a strong precedent for cross-border investments in port infrastructure, particularly in LNG terminals, container hubs, and strategic expansions. For example, DP World (Dubai) has invested more than US$1 billion in Indian ports,[85] setting a model for similar hydrogen-ready terminals. Japanese firms (JERA, Sojitz) have invested in LNG terminals in India,[86] which could be retrofitted for hydrogen exports. Additionally, Singapore's PSA International, a key port operator in India, is exploring hydrogen trade corridors between India and Southeast Asia,[87] reinforcing India's role in global hydrogen logistics.

4. Expand India's demand aggregation model for global hydrogen trade

Evolve demand aggregation frameworks to secure bulk green hydrogen offtake agreements with international buyers, ensuring long-term price stability and boosting investor confidence. Expanding SECI's demand aggregation model to hydrogen markets could help consolidate demand from multiple sectors, including refining, fertilisers, chemicals, and shipping, creating economies of scale for large-scale production. Learning from Germany's H2Global initiative, which facilitates competitive auctions for hydrogen imports, India could consider implementing reverse auction mechanisms to secure global buyers at predetermined prices.

5. Establish green shipping corridors to promote hydrogen-based fuels

Develop green shipping corridors with major global ports such as those in Singapore, Rotterdam, and Busan to strengthen India's position as a key supplier of green ammonia and methanol for the maritime sector. This can be facilitated through blending mandates for shipping fuel and active participation in global initiatives like the Clydebank Declaration.[88] Learning from Norway's Green Shipping Programme, India could create infrastructure and policy frameworks to support clean shipping. Globally, Singapore and the Port of Rotterdam are already working on a green corridor, while Los Angeles and Shanghai are collaborating on decarbonising transpacific shipping routes.

6. Establish dedicated financing mechanisms to de-risk green hydrogen investments

Facilitate ECA collaborations with institutions like Japan's JBIC, Germany's Euler Hermes, and South Korea's KEXIM to secure low-cost financing for green hydrogen infrastructure. Implementing sovereign-backed guarantees and risk-sharing mechanisms may help attract large-scale investments, following the example of JBIC-backed hydrogen projects in Australia.[89] Additionally, India may consider launching a green hydrogen infrastructure fund, modelled after the EHB, to support storage, transportation, and export infrastructure. Engaging multilateral financing institutions like the World Bank, the Asian Development Bank, and the International Finance Corporation could further mobilise funding. Global initiatives like H2Global highlight how strategic public financing can accelerate green hydrogen adoption and trade.

6. Conclusion

India can leverage green hydrogen exports as a cornerstone of its future energy and trade strategy. Despite evolving market conditions and uncertainties surrounding global demand, India's strategic advantages — including cost-competitive production, favourable geography, and growing policy support — offer a clear pathway to securing a leadership role in the global hydrogen economy. However, unlocking this potential requires measured policy actions that align export ambitions with evolving market needs while ensuring long-term competitiveness.

Scaling India's green hydrogen exports requires strengthening four key enablers: infrastructure preparedness, standards and certifications, strategic partnerships and global agreements, and trade and financial de-risking.

Investments in hydrogen-ready port infrastructure, supported by collaborations with countries like Germany, Japan, and Singapore, could reinforce India's role in the global supply chain. Engaging with major ports such as Singapore and Rotterdam to develop green shipping corridors presents an opportunity to advance India's position as a supplier of clean maritime fuels.

Ensuring seamless market access will also require aligning India's certification framework with international standards like CertifHy and Japan's Hydrogen Quality Assessment. This alignment could ease compliance requirements and facilitate cross-border trade. Expanding trade relationships through long-term offtake agreements and leveraging FTAs may further strengthen India's foothold in global hydrogen markets.

Building investor confidence will be essential to scale green hydrogen projects. Demand aggregation models, inspired by Germany's H2Global initiative, could help stabilise prices and attract international buyers. Meanwhile, exploring financing mechanisms — such as a green hydrogen infrastructure fund and partnerships with ECAs — could help de-risk investments and accelerate project development.

By taking these strategic actions, India can position itself as a key player in the global hydrogen trade, strengthening its export potential while reinforcing its role in future energy markets.

7. Appendices

Appendix A. Assumptions for landed cost-based modelling

Landed costs were calculated by breaking the transportation process down into the supply chain components of production, port costs (for both import and export), and shipping. RMI in-house models were used for each stage. Ammonia was assumed to be transported on ammonia-fuelled vessels that used cargo as fuel.

While the analysis was conducted using the same in-house model, the assumptions for India were updated based on multiple sources and inputs from stakeholders. The assumptions for India are shown in **Exhibit A1**, while for the remaining countries the assumptions remain unchanged and are based on global averages as per RMI assumptions and analysis (see **Exhibit A2**).

Exhibit A1 Ammonia production assumptions for India

Renewables		
Wind capex	US$/kilowatt	752
Solar capex	US$/kilowatt	470
Total renewable capacity	GW	2.1
Hydrogen		
Electrolyser		Alkaline
Capacity	megawatt	564
Energy requirement	kilowatt-hour/kg	47
Electrolyser capex (stack, balance of plant)	US$/kilowatt	248
Indirect capex (land and engineering, procurement, and construction)	US$/kilowatt	148
Ammonia		
Capacity	ktpa ammonia	280
Capex air separation unit or pressure swing absorption	US$/ton nitrogen	298
Nitrogen storage capex	US$/ton nitrogen	160
Haber-Bosch capex	US$/ton ammonia	1,143

RMI Graphic. **Source:** Hintco.

Exhibit A2 Ammonia production assumptions for the considered countries (except India)

Renewables		
Wind capex	US$/kilowatt	1,150
Solar capex	US$/kilowatt	1,038
Total renewable capacity	gigawatt (GW)	Varies by location, generally 5–10
Hydrogen		
Electrolyser		Alkaline
Capacity	GW	Varies by location, generally 1.4–2
Energy requirement	kilowatt-hour/kg	54
Electrolyser capex (stack, balance of plant)	US$/kilowatt	554
Indirect capex (land and engineering, procurement, and construction)	US$/kilowatt	324
Ammonia		
Capacity	kilotons per annum (ktpa) ammonia	1,200
Nitrogen storage capex	US$/ton nitrogen	109
Haber-Bosch capex	US$/ton ammonia	507

Note: Ammonia production costs were evaluated using an in-house RMI hydrogen-ammonia integrated model.
RMI Graphic.

Port costs and shipping costs were evaluated using an in-house RMI port fuel supply model and an in-house shipping calculator. Refer to **Exhibit A3** and **Exhibit A4** for respective assumptions.

Exhibit A3 Ports

Storage		
Capex	US$/ton	1,156–1,418
Opex	% of capex	3
Bunker vessel		
Capex	US$	25,000,000
Labour and operational expenses	US$/day	8,000
Size	tons ammonia	12,000
Vessel utilisation	%	60

RMI Graphic.

Exhibit A4 Shipping

Shipping fuel		Ammonia
Speed	knots	15
Ship volume	m3	93,000
Capacity utilisation	%	98
Charter cost	US$/day	35,000
Insurance	US$/day	2,600
Laden fuel consumption	tons/day	71.1
Ballast fuel consumption	tons/day	63.3
Idle fuel consumption	tons/day	17.8
Load time	days	2
Unload time	days	2
Canal fees, Suez, laden	US$	390,824
Canal fees, Suez, ballast	US$	333,934

RMI Graphic.

Appendix B. Industry progression analysis

Industry progression was evaluated based on the advancement of hydrogen projects in each country. Data from the International Energy Agency (IEA) Hydrogen Production Projects Database (2024) was used. Project volumes consider capacity factors. Relative scores were generated for each country based on two main metrics — hydrogen export project progression and overall clean hydrogen industry progression — compared with other countries evaluated. Details on metrics evaluated for industry progression assessment and final scores obtained can be found in **Exhibit A5**.

Exhibit A5 Industry progression assessment

Details on metrics evaluated for industry progression assessment					
Metric assessment	Industry interest in hydrogen export	Industry success in finalising hydrogen export; green	Industry success in finalising hydrogen export; blue	Countrywide success in enabling and scaling hydrogen projects; green	Countrywide success in enabling and scaling hydrogen projects; blue
Metric rationale	Reflects future growth of hydrogen export	Reflects current stage of hydrogen export	Reflects current stage of hydrogen export	Reflects country's overall green hydrogen industry and average size	Reflects country's overall blue hydrogen industry and average size
Use	Export	Export	Export	Export and domestic	Export and domestic
Project status	Feasibility study	FID/construction	FID/construction	FID/construction	FID/construction
Sampled data	All export candidate countries	All export candidate countries	All export candidate countries	Top 15 large-scale projects at FID in candidate countries	Top 15 large-scale projects at FID in candidate countries
Units evaluated	Total project volume	Total project volume	Total project volume	Average project size	Average project size
Technology	Electrolysis and fossil + CCS	Electrolysis	Fossil + CCS	Electrolysis	Fossil + CCS
Weight	0.1	1	1	1	0.25
Weight rationale	Weighted lower to reflect the chance of these projects reaching FID and emphasise the current state of the market over the future	—	Weighted the same as electrolysis to emphasise the impact of establishing hydrogen trade (infrastructure, contracts, other processes)	—	Weighted lower than electrolysis to emphasise the country's overall electrolysis progression

Exhibit A5 Industry progression assessment (continued)

Metric values: final scores obtained using reverse ranks and applying weights					
Country	**kt hydrogen**	**kt hydrogen**	**kt hydrogen**	**kt hydrogen/ project**	**kt hydrogen/project**
Algeria	0.0	0.0	0.0	0.0	0.0
Australia	1,316.8	0.0	0.0	21.7	0.0
Brazil	862.0	0.0	0.0	0.0	0.0
Canada	593.3	0.0	0.0	6.7	126.0
Chile	1,289.6	0.0	0.0	0.0	0.0
Egypt*	58.9	0.0	0.0	0.0	0.0
India	78.0	154.2	0.0	154.2	0.0
Mauritania	230.4	0.0	0.0	0.0	0.0
Morocco	758.7	0.0	0.0	0.0	0.0
Namibia	260.1	0.0	0.0	0.0	0.0
Oman	701.4	16.6	0.0	16.6	0.0
Saudi Arabia	0.0	237.3	0.0	237.3	0.0
UAE	36.0	0.0	0.0	0.0	0.0
United States	0.0	0.0	561.7	15.8	280.8

Note: *As of writing, Fertiglobe had not taken a final investment decision (FID) on its Egypt-based ammonia export project, but it is expected to do so in the second half of 2025. To reflect this, the volume was considered as FID but discounted for uncertainty. CCS = carbon capture and storage; kt = kilotons.

RMI Graphic. **Source:** RMI analysis of International Energy Agency data, **https://www.iea.org/data-and-statistics/data-product/hydrogen-production-and-infrastructure-projects-database**.

Appendix C. Emissions intensity analysis of traded ammonia under different project arrangements

Exhibit A6 Assumptions in emissions intensity analysis of traded products

Country/region	Assumptions
Export-oriented countries modelled	
India	• **Behind the meter:** Zero emissions from electrical T&D, H_2 production (electrolysis with BTM renewables), and ammonia production (N_2O scrubbers with BTM renewables) • **Max Indian green H_2 threshold:** Well-to-gate (upstream to hydrogen production) emissions equal 2 kg CO_2e/kg H_2 in line with maximum allowance for emissions for the Green H_2 Standard in India • **Ignore H_2 leakage:** Compress H_2 to 100 bar for transport, assume distance of 100 km from hydrogen production to ammonia production facility and port of departure for export • **Storage and handling:** Includes energy needed to store ammonia (refrigeration) + loading ship (bunkering); assume 2023 India grid electricity (Ember 2025) • **Assume fuel emissions upstream for shipping:** Use 100% green ammonia as fuel; N_2O scrubbers assumed
Import-oriented countries modelled	
EU (NL)	• Ammonia storage and handling uses 2023 Netherlands (NL) grid electricity (Ember 2025) • No cracking ammonia back to hydrogen • For ammonia transportation, assume 15 km from port to end-use facility (compress to 100 bar), assume electricity needed based on 2023 NL grid intensity (Ember 2025) • Assume zero emissions from ammonia combustion, N_2O scrubbers assumed; electrical energy to run facility based on 2023 NL grid intensity (Ember 2025)
Japan	• Ammonia storage and handling uses 2023 Japanese (JP) grid electricity (Ember 2025) • No cracking ammonia back to hydrogen • For ammonia transportation, assume 15 km from port to end-use facility (compress to 100 bar), assume electricity needed based on 2023 JP grid intensity (Ember 2025) • Assume zero emissions from ammonia combustion, N_2O scrubbers assumed; electrical energy to run facility based on 2023 JP grid intensity (Ember 2025)
South Korea	• Ammonia storage and handling uses 2023 South Korea (SK) grid electricity (Ember 2025) • No cracking ammonia back to hydrogen • For ammonia transportation, assume 15 km from port to end-use facility (compress to 100 bar), assume electricity needed based on 2023 SK grid (Ember 2025) • Assume zero emissions from ammonia combustion, N_2O scrubbers assumed; electrical energy to run facility based on 2023 SK grid intensity (Ember 2025)

RMI Graphic. **Source:** Ember (2025).

The impact of emissions thresholds and electricity cost assumptions on levelised cost of hydrogen (LCOH) was analysed for three key ports, considering two scenarios: (1) behind-the-meter (BTM) (grid-connected) and (2) off-site hybrid solar and wind within the same state. For the first scenario, the actual grid electricity price for industrial customers, inclusive of all tariffs and charges specific to each state, was used. In the second scenario, the grid electricity cost was assumed to be equal to the average price of renewable energy generation.

These cost assumptions were incorporated into RMI's LCOH optimisation model to evaluate the impact of varying emissions thresholds on hydrogen production costs. The assumptions used in the analysis are mentioned in **Exhibit A7**, along with a detailed breakdown of LCOH for each state.

Exhibit A7 Grid electricity price assumptions for Case 2

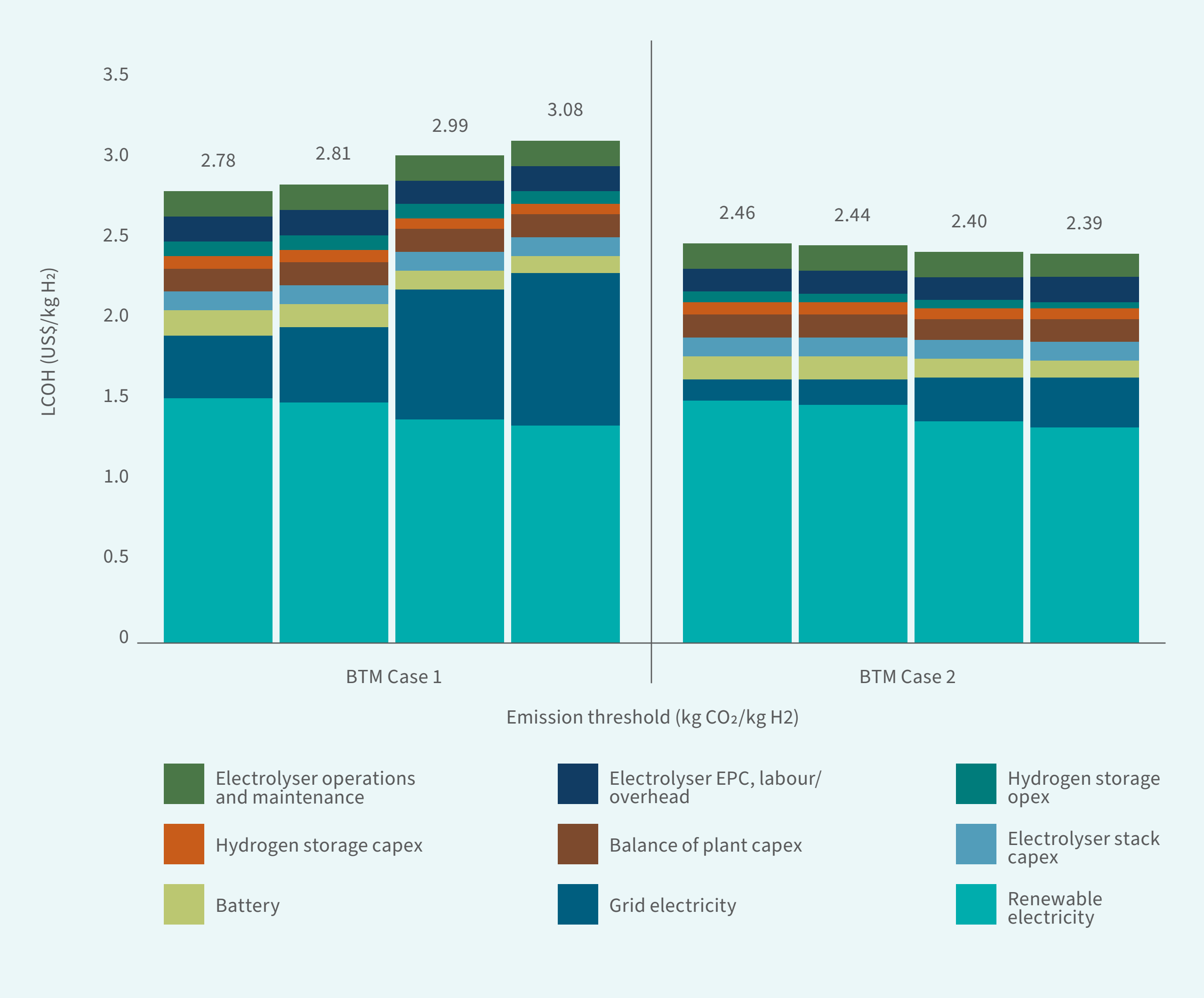
No.	Scenario	Grid electricity price (US$/megawatt-hour)
1	Odisha behind-the-meter	25.56
2	Odisha off-site hybrid	50.08
3	Tamil Nadu behind-the-meter	25.60
4	Tamil Nadu off-site hybrid	31.17
5	Gujarat behind-the-meter	20.95
6	Gujarat off-site hybrid	27.90

RMI Graphic. **Source:** CEA, https://cea.nic.in/wp-content/uploads/baseline/2024/01/User_Guide__Version_19.0.pdf.

The detailed breakdown of the LCOH illustrates the impact of varying CO_2 emissions allowances on production costs in Tamil Nadu under two scenarios: BTM Case 1 and BTM Case 2, as shown in **Exhibit A8**.

For BTM Case 1 (see **Exhibit A8**), as the CO_2 emissions threshold increases from 1.7 to 4 kg CO_2/kg hydrogen, the share of grid electricity in the cost structure increases. Although a higher emissions allowance theoretically provides more flexibility to developers by allowing greater grid electricity usage, this advantage is offset by high industrial electricity tariffs in India. Consequently, instead of reducing costs, the LCOH increases from US$2.78/kg hydrogen at 1.7 kg CO_2/kg hydrogen to US$3.08/kg hydrogen at 4 kg CO_2/kg hydrogen.

Exhibit A8 LCOH breakdown for Tamil Nadu BTM scenarios

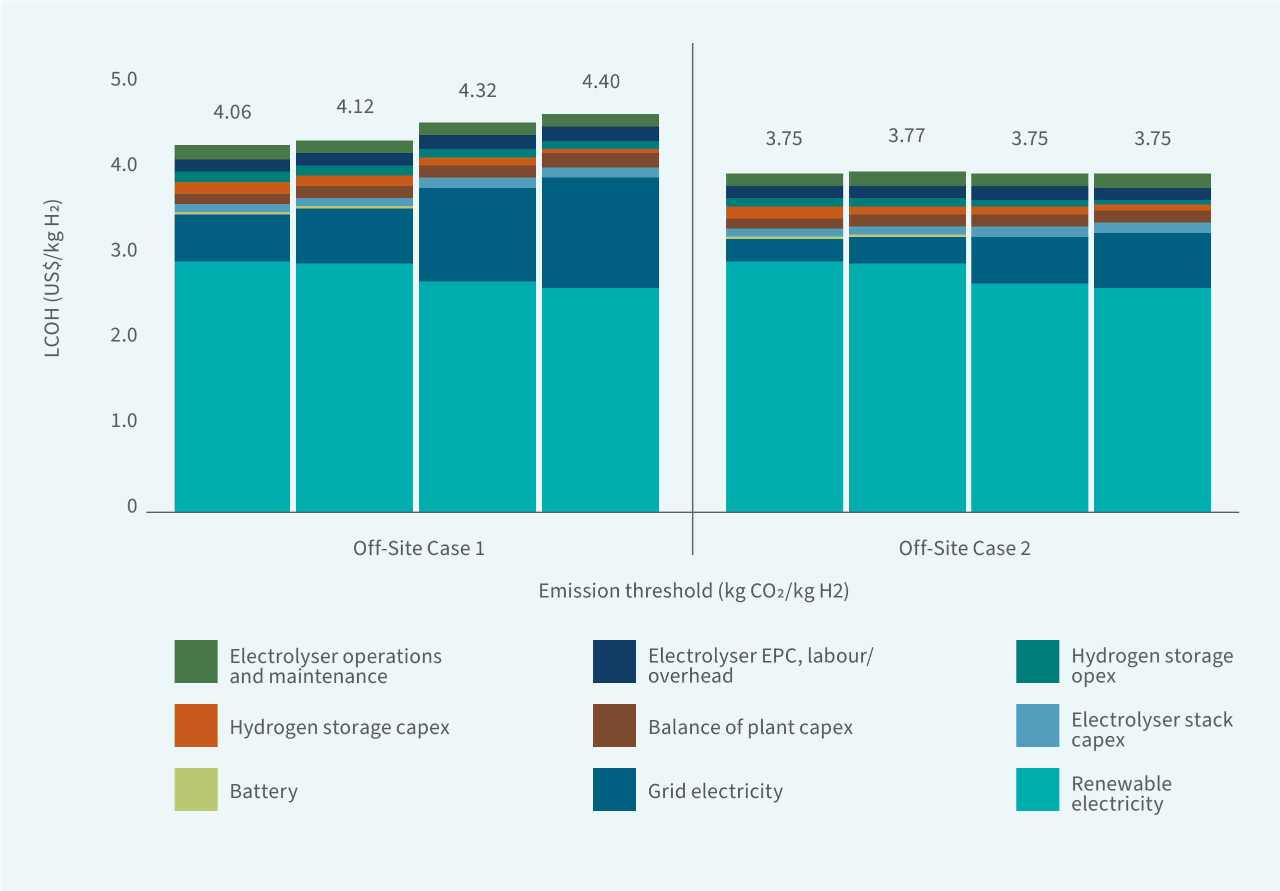


RMI Graphic. **Source:** RMI analyisis

In BTM Case 2, where the cost of grid electricity is assumed to be equal to renewable energy costs, the LCOH remains somewhat stable, ranging from US$2.46/kg hydrogen at 1.7 kg CO_2/kg hydrogen to US$2.39/kg hydrogen at 4 kg CO_2/kg hydrogen. This suggests that allowing relaxed CO_2 emissions standards will only be viable if industrial grid electricity prices are drastically reduced to levels comparable to those of renewable energy costs.

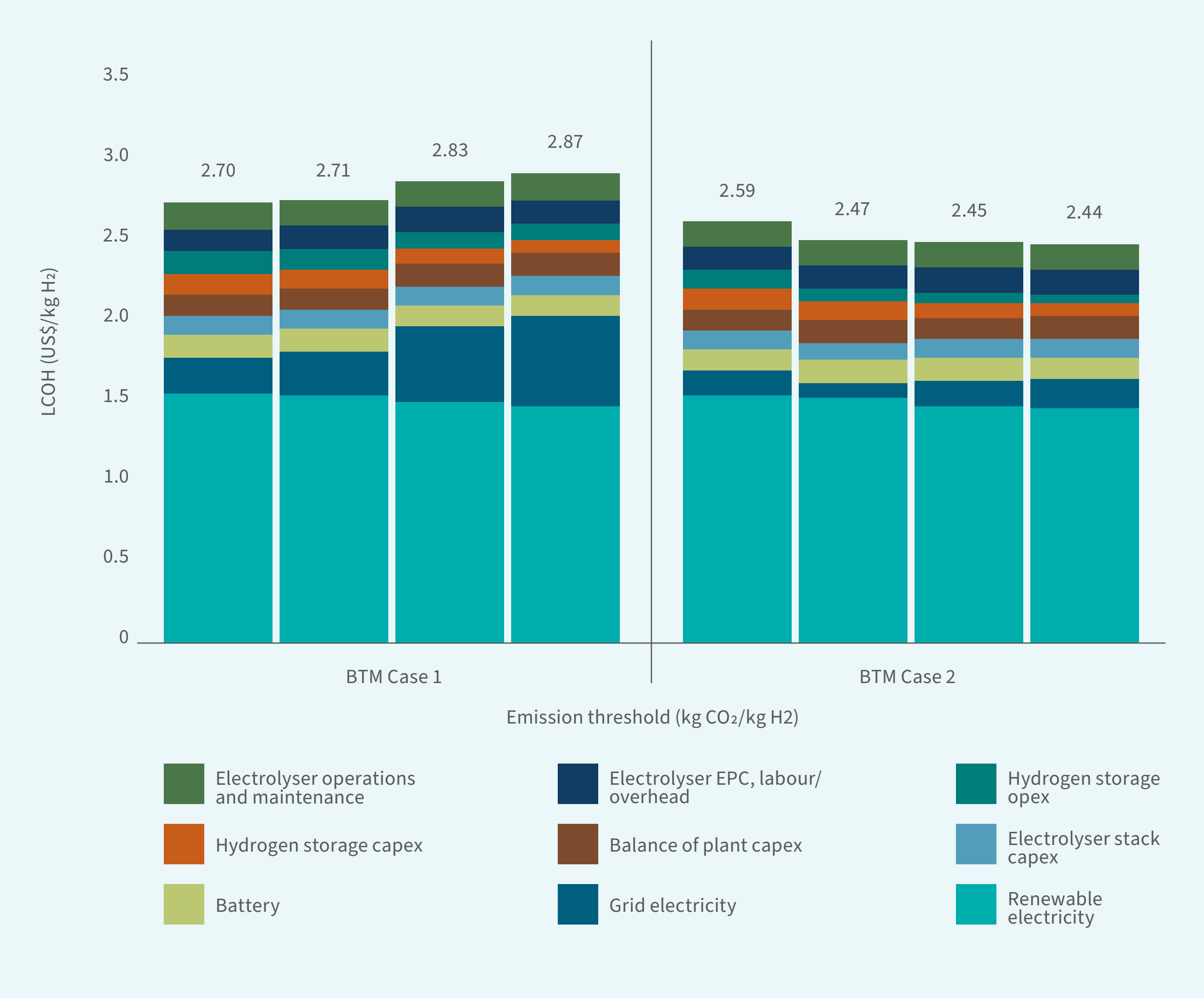
The same trend is observed in the off-site hybrid renewable energy scenario and across other states, though LCOH values may vary depending on regional renewable energy potential and industrial electricity tariffs. The detailed breakdown of the remaining cases is presented in **Exhibits A9** through **A13**.

Exhibit A9 LCOH breakdown for Tamil Nadu off-site hybrid renewable energy scenarios



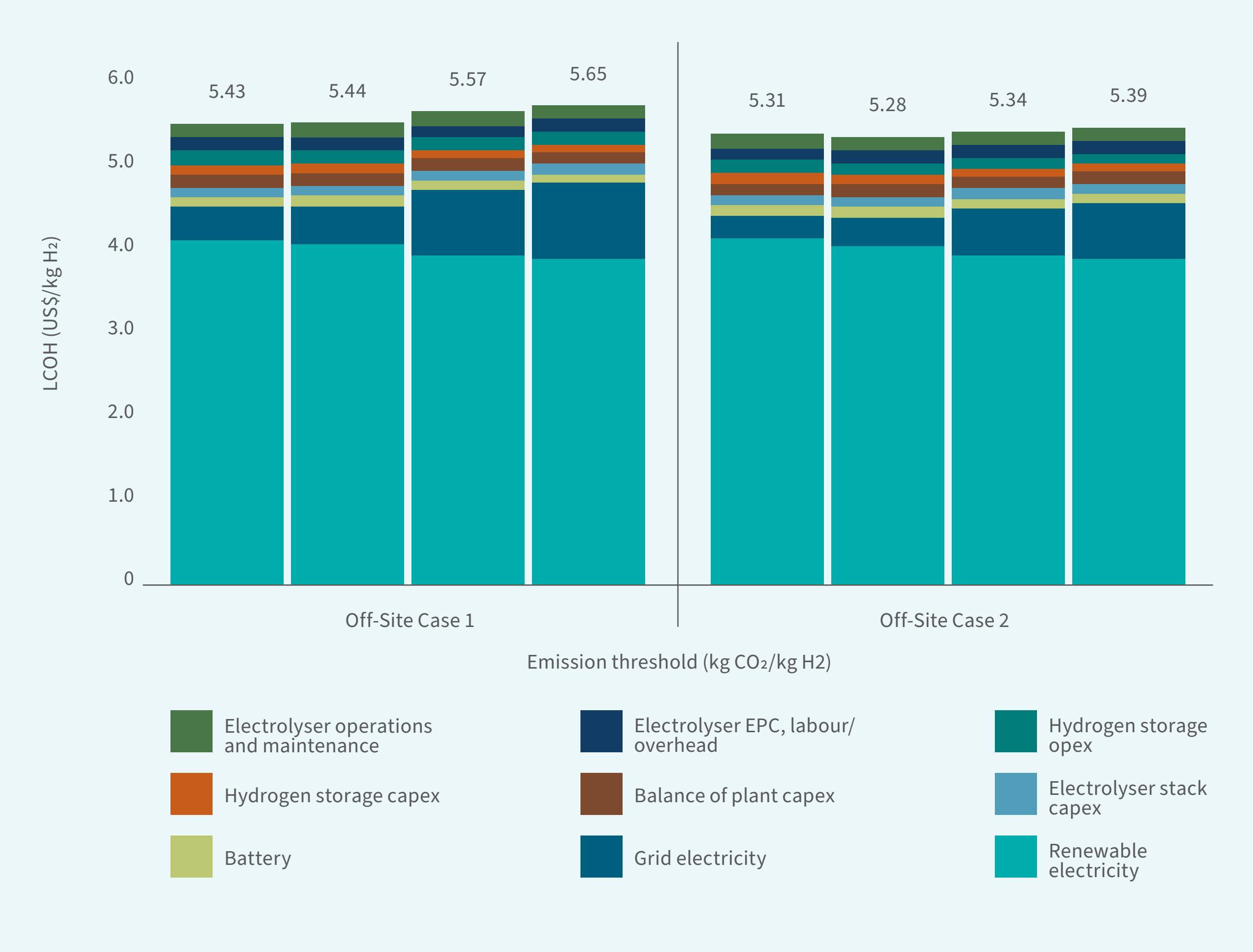
RMI Graphic. **Source:** RMI analyisis

Exhibit A10 LCOH breakdown for Odisha BTM scenarios



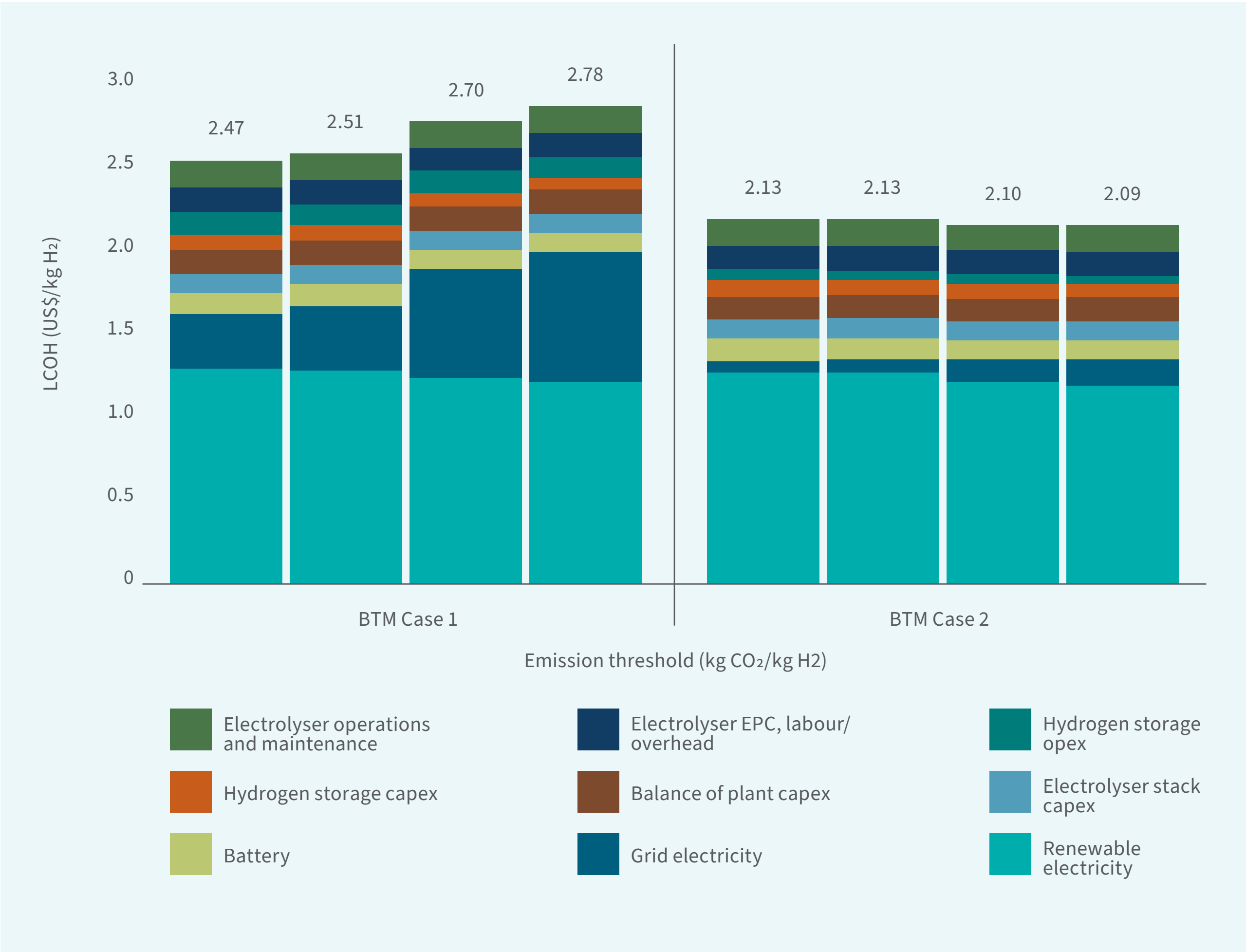
RMI Graphic. **Source:** RMI analyisis

Exhibit A11 LCOH breakdown for Odisha off-site hybrid renewable energy scenarios



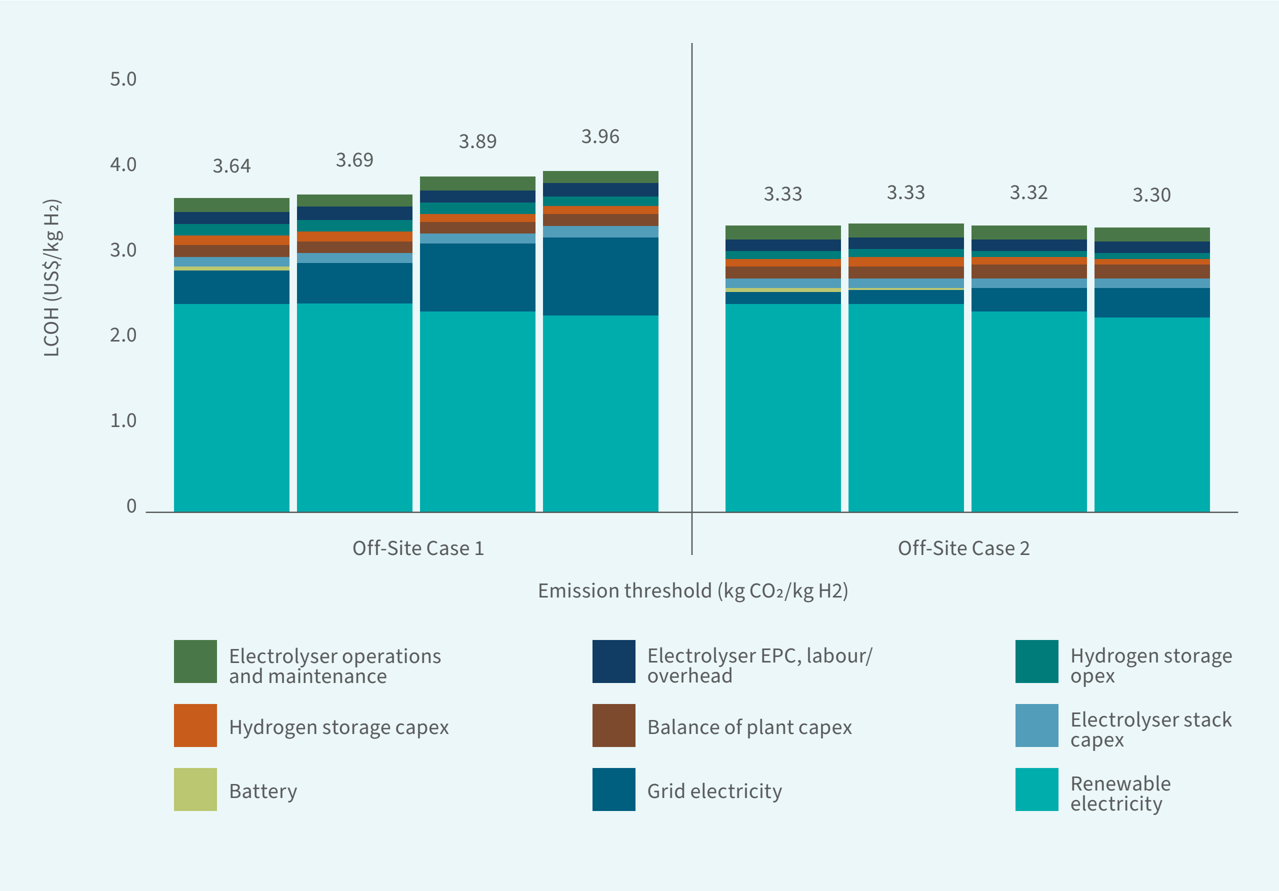
RMI Graphic. **Source:** RMI analyisis

Exhibit A12 LCOH breakdown for Gujarat BTM scenarios



RMI Graphic. **Source:** RMI analyisis

Exhibit A13 LCOH breakdown for Gujarat off-site hybrid renewable energy scenarios



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