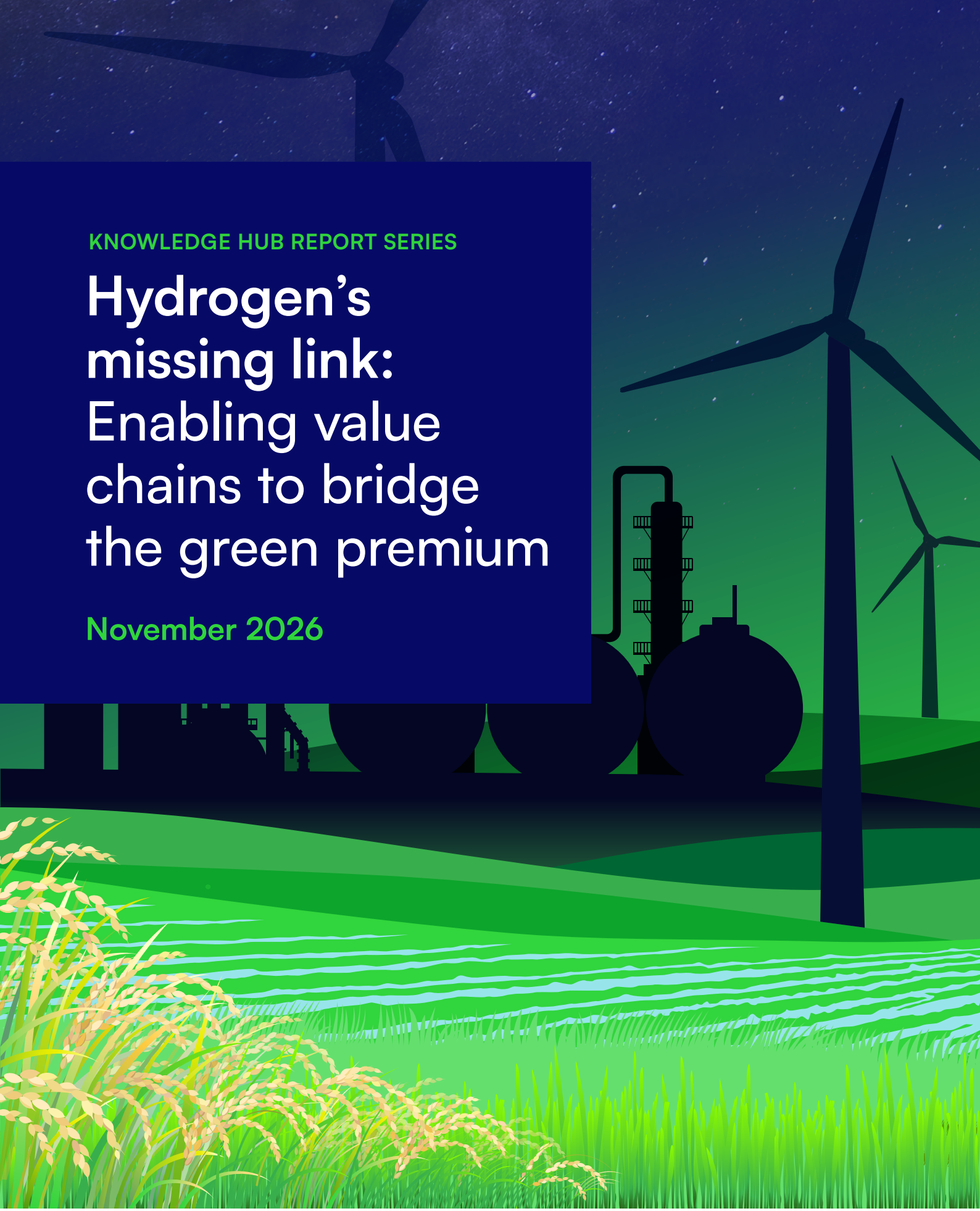


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Hydrogen's missing link: Enabling value chains to bridge the green premium

November 2026

H2Global Foundation

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Publisher

Department—Analysis and Research
Trostbrücke 1
20457 Hamburg

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H2Global Knowledge Hub Report Series

ISSN: 2944-7801

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Glossary

Term	Definition
ATR	Autothermal reforming
BF-BOF	Blast furnace-basic oxygen steelmaking
CAPEX	Capital expenditure, i.e., funds used by a company to acquire, upgrade, and maintain physical assets
CBAM	Carbon border adjustment mechanism
CCTS	Carbon credit trading scheme
CCfD	Carbon-contract-for-difference
CCUS	Carbon capture, utilisation, and storage
CfD	Contract-for-difference: subsidy model in which both positive and negative deviations from a fixed reference price are paid out to the contractual partner
CO_2e	Carbon dioxide equivalent, a measure used to compare emissions from various greenhouse gases based upon their global warming potential
DSA	Double-sided auction
DRI	Direct reduction of iron
EAF	Electric arc furnace
E-fuels	Synthetic fuels produced by the conversion of electrical energy into chemical energy, often produced using clean energy sources
ETS	Emissions Trading System
EMDC	Emerging markets and developing countries: nations characterised by lower income levels and industrialisation stages, with potential for rapid economic growth
EPC	Engineering, procurement, and construction
FID	Final investment decision: a decision by the board of directors that officially sanctions and allows for the commitment of funds to a project or investment

Term	Definition
GDP	Gross domestic product
GHG	Greenhouse gas
GI	Geographical Indication
GoI	Government of India
H2	Hydrogen
IPCEI	Important Projects of Common European Interest
IAA	Industrial Acceleration Act
LESS	Low-Emission Steel Standard
LH2	Liquid hydrogen
LCOH	Levelised cost of hydrogen
LNG	Liquefied natural gas
MoEFCC	Ministry of Environment, Forest and Climate Change
MRP	Maximum retail price
NBS	Nutrient-based subsidy
NPKs	Nitrogen, phosphorus, and potassium
OEM	Original equipment manufacturer
OPEX	Operational expenditure
PLI	Production-linked incentive
RED III	Third Renewable Energy Directive in the EU
RFNBO	Renewable fuels of non-biological origin
SECI	Solar Energy Corporation of India
SAFc	Sustainable aviation fuel certificates
SMR	Steam methane reforming
SNG	Synthetic natural gas.
WtP	Willingness-to-pay
ZEMBA	Zero Emission Maritime Buyers Alliance

Acknowledgements

This report was developed by the research team of the H2Global Foundation. It is part of the H2Global Knowledge Hub, a research programme sponsored under the 7th Energy Research Programme by the German Federal Ministry of Research, Technology and Space. The authors were Jan Klenke and Macarena Fuentes Mendoza. Victor Ponsford and Julia Cave Smith provided editing and communications support, and Anne Sokarmo contributed design expertise.

Sincere thanks are extended to Jakob Frerichs, whose contribution has significantly enriched the model calculations in this report. His expertise, insight, and diligent efforts have greatly improved the quality of the work.

Gratitude is also extended to H2Global Foundation's knowledge partners and peer reviewers Anne-Sophie Corbeau (CGEP), Eleonora Moro (OECD), Deger Saygin (OECD), Nalabolu Dharanidhar (Boston Consulting Group), Stephen Crolius (Ammonia Energy Association), Grzegorz Pawelec (Hydrogen Europe) and Joe Boyland (Global Maritime Forum) for their important feedback, which greatly helped enhance the quality of this report.

The H2Global Foundation gratefully acknowledges the donors who so graciously provided feedback throughout the "Hydrogen's missing link: Enabling value chains to bridge the green premium" working group meetings. It is through their comments that H2Global has been able to make the report speak to practitioners in the field.

H2Global Foundation

Research
An H2Global Foundation Program

With funding from the:

Federal Ministry
of Research, Technology
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Foreword

2026 has been a year of progress for clean hydrogen projects after almost two years of bad news. This year, companies focused on fewer projects that have better chances of succeeding. Major projects in China, Latin America, and Europe went online or started construction. H2Global also delivered on its second round of tenders with new winning projects across regional lots, mobilising significant volumes for imports to Europe. H2Global's unique double-sided auction mechanism thus contributes to the creation of hydrogen markets alongside its global engagement with governments and industry leaders, and its in-depth research. H2Global's work is increasingly gaining trust as demonstrated by the funds committed to the double-sided auctions designed and conducted by its trading intermediary Hintco, which are worth up to EUR 9bn in total at this point.

In 2024 and 2025, H2Global published the first two rounds of research reports as part of the H2Global Knowledge Hub Programme, which is financially supported by a research fund issued by the German Federal Ministry of Research, Technology and Space. We are proud to continue this series in 2026 by tackling three of the biggest challenges facing the clean hydrogen economy: catalysing investment in export infrastructure, enabling value chains to bridge the green premium, and activating lead markets for clean hydrogen. These reports were created with the valuable insights of our 77 private sector supporters.

Attendees at clean hydrogen conferences and trade fairs will recognise that discussions often centre on three common complaints: the cost of clean hydrogen is too high, offtakers are not ready to sign contracts, and regulation in key markets is not fit for purpose. Yet these elements are connected, and developing value chains still lack a comprehensive approach to allocating the green premium so as to overcomes barriers and align value chains effectively. Most analyses stop at the primary users of hydrogen, but these users in turn need to find customers for their clean products.

This report, "Hydrogen's missing link: Enabling value chains to bridge the green premium", starts where others finish. For two value chains — fertilisers-to-plate and steel-to-wind-turbines — it analyses the cost impact of clean hydrogen on each segment of the chain, and how well these actors are prepared to absorb the green premium based on cost structure and competition.

Beyond this analysis, we also examine which instruments can be used to enable value-chain formation.

Our third report for 2026, "Activating lead markets: Pathways to scale for clean hydrogen", delves further into comprehensive and integrated approaches to co-develop lead sectors and regions for clean hydrogen. Besides cost and support challenges, hydrogen users also require supply security. As international supplies have an important role to play to this end, the first report in 2026: "Hydrogen's trade gateway: Catalysing investment in export infrastructure" examines the infrastructure conditions that make international trade possible.

"The analysis in this report shows that clean hydrogen adoption is not a cost issue for end-users, but a value chain coordination problem. As high initial costs stall early steps across the value chain, policymakers have a critical role to play in supporting coordination with a comprehensive tool set."

Anne-Sophie Corbeau
Global Research Scholar
Center on Global Energy Policy at Columbia University

The three reports in 2026 are the latest additions to H2Global's growing, internationally recognised knowledge base, and conclude the current cycle of Knowledge Hub reports. By providing clear solutions to the challenges of the clean hydrogen economy, these publications aim to improve shared understanding of global clean fuels markets. Our research remains dedicated to decarbonising energy markets and creating a more resilient energy system globally.

Executive summary

Clean hydrogen deployment is constrained by weak demand commitments as well as high production costs: fewer than 6% of announced projects have secured firm offtake agreements. Steelmakers and fertiliser producers face a green premium when switching to cleaner inputs, but their ability to recover it depends on buyers further down the value chain. This report examines how the premium changes from production to final consumption, tracing the fertiliser-to-rice and steel-to-wind-turbine value chains in India and Germany. It combines cost modelling with an assessment of competition and policy instruments to identify where support can unlock demand for clean hydrogen.

The green premium is highest where clean hydrogen enters production, but the greatest capacity to pay often lies further down the value chain.

The analysis points to five key findings:

— **Cost premiums shrink sharply along both value chains.** In the report's model, clean hydrogen raises Indian urea production costs by 136%, but the resulting basmati rice retail price by 13% in India and 3% in Germany. Similarly, clean-hydrogen-based steel increases steelmaking costs by 22% in India and 45% in Germany, while the cost increase for a wind project is 5% and 15%, respectively. These differences reflect the declining share of clean inputs in downstream products; they do not guarantee that higher costs can be passed on.

— **Fertiliser subsidies protect farmers but constrain the market signal.** India's maximum retail price for urea shields farmers from higher fertiliser costs and shifts the premium to public expenditure; the modelled rice price increases assume this subsidy is absent. The current scheme covers around 85% of urea production costs. Under a complete shift to renewable urea, the report estimates annual subsidy requirements of USD 30.4bn (EUR 28bn), against roughly USD 12.2bn (EUR 11.2bn) today. Fragmented farming and milling also complicate the traceability needed to connect consumer demand to cleaner fertiliser production.

— **Competitive pressure concentrates the burden upstream in wind power.** Steelmakers have limited pricing power in global markets, while steel accounts for around 90% of wind-tower manufacturing costs. Tower manufacturers risk losing orders to cheaper suppliers if they raise prices. The relative premium diminishes for turbine manufacturers and power companies, where procurement requirements could generate demand for cleaner steel. However, requirements confined to wind turbines would increase the cost of an already low-carbon technology; broader clean-steel lead markets are needed.

— **Quotas create demand, but carbon pricing alone is insufficient.** Modelled clean-hydrogen quotas of 11.2—42% in India's urea sector could mobilise 0.30—1.14mn tonnes of hydrogen a year, with substantial costs potentially falling on the subsidy budget. The same quota levels applied to wind-turbine steel would mobilise 16,000—60,000 tonnes annually. Carbon prices needed for cost parity remain high: around USD 555 per tonne of CO_2 for renewable urea using industrial carbon, and USD 104 and USD 213 per tonne for green steel in India and Germany, respectively.

— **Competitive support goes further as buyers take on the premium.** In the report's ten-year double-sided auction scenarios, USD 1bn in public funding could contract around 86,000 tonnes of clean hydrogen for German steel and 206,000 tonnes for Indian fertilisers when buyers pay only the conventional product price. Greater willingness to pay and optional supply volumes allow the same funding to mobilise substantially more clean hydrogen. Auctions and other demand instruments also depend on credible, internationally compatible standards and chain-of-custody systems that allow buyers to recognise lower-emission products.

Five priorities follow for policymakers: establish interoperable standards and traceability across entire value chains; use predictable carbon pricing as a long-term signal without expecting it to eliminate the premium on its own; introduce gradually increasing, sector-specific quotas and mandates; deploy competitive auctions and contracts-for-difference to bridge residual cost gaps; and focus direct capital support on first movers and value-chain bottlenecks. Where investment takes place in producer countries, but end-user purchasing power lies in export markets, international cost-sharing can also help. Ultimately, a coordinated policy mix is needed to translate end-user willingness to pay into bankable clean-hydrogen investments.

Table 1: Key recommendations

Key area	Recommendation
Establish internationally interoperable standards and traceability across entire value chains	• Develop internationally compatible definitions for clean hydrogen, its derivatives, and relevant final products. • Ensure full value-chain coverage of certification. • Adapt monitoring and chain-of-custody requirements to the structure of individual sectors.
Use carbon pricing as the long-term backbone	• Pursue a broad and predictable carbon price. • Maintain a level playing field through complementary measures and regulations. • Do not rely on carbon pricing alone.
Create predictable market conditions through gradually increasing quotas and mandates	• Use gradually increasing quotas to create predictable demand. • Focus quotas on the limited number of large fertiliser producers. • Account for how quotas interact with India's MRP. • Apply green steel quotas to wind-turbine OEMs. • Apply quotas across multiple steel offtakers simultaneously.
Bridge the remaining cost gap with competitive, market-based instruments	• Use double-sided auctions, contracts-for-difference, and other competitive supply tenders to bridge residual cost gaps. • Design these instruments to scale down as private willingness to pay increases. • Tailor instrument choice to specific product. • Favour competitive allocation mechanisms over administratively negotiated support.
Target scarce public funding at first movers and value-chain bottlenecks that cannot pass on the premium	• Prioritise steelmakers, tower manufacturers, and fertiliser producers for payment-based support. • Avoid passing costs onto farmers through policy design. • Focus CAPEX support on large upfront investments, and plan a clear phase-out from the start. • Explore mechanisms through which part of the premium can be transferred back to the producing country.



IMAGE CREDIT: ADOBE STOCK / TRONG



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1

The relevance of end-users

In the early 2020s, clean hydrogen was celebrated as a breakthrough in the fight against climate change, promising to decarbonise hard-to-abate industries without alternative decarbonisation pathways. Recently, policymakers have also recognised the potential of clean hydrogen to improve the resilience of energy supplies. Despite the primary role of potential offtakers, clean hydrogen support has focused first and foremost on supply projects and their associated opportunities and challenges.

The supply side saw a steadily growing pipeline of projects until a sobering 2025, when many projects stalled or were cancelled. Project developers around the world and market observers identified regulatory uncertainties and a lack of demand commitments as the primary challenges blocking projects from reaching final investment decisions (FIDs).[1]

Indeed, fewer than 6% of announced clean-hydrogen projects have achieved firm offtake agreements. If the pipeline of potential supply projects is full, the question is: what is keeping offtakers from committing?[2]

The H2Global report "Shoring up demand: The key instruments supporting clean hydrogen demand build-up" assessed the risks that offtakers across different sectors face when introducing technologies based on clean hydrogen into their business models.

Fewer than 6% of announced clean-hydrogen projects have achieved firm offtake agreements.

While the report finds some differences between sectors (such as steel, chemicals, or shipping) and business models (hydrogen-based fuel of choice, captive and merchant setups), it highlights **price, regulation, supply, and offtake** as the most pressing challenges.[3]

Of these four key risks, supply and regulatory risks, on the one hand, mirror the assessment of potential suppliers.

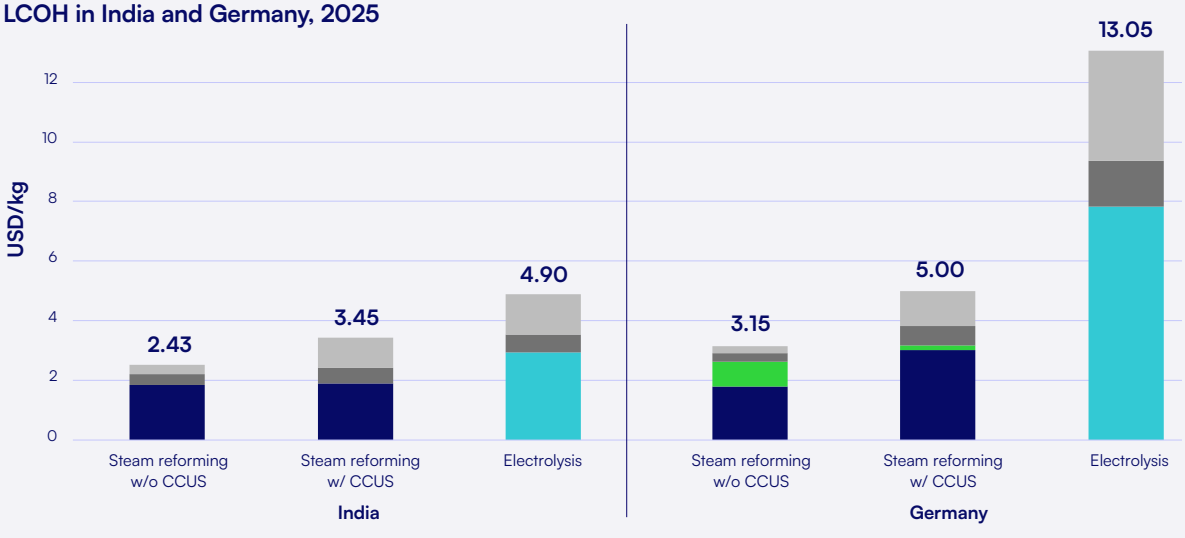
Box 1: The cost of clean hydrogen

The figure below shows the cost breakdown of hydrogen production in India and Germany. In technical terms, the report covers hydrogen produced:

- conventionally from natural gas via steam reforming;
- with 80% CO_2 capture via carbon capture, utilisation, and storage (CCUS); and
- via water electrolysis using renewable power.

For conventional and low-emission hydrogen production, costs are mainly driven by natural gas (55—73%), while for renewable hydrogen production, the primary driver is electricity, which accounts for around 60% of total costs.

LCOH in India and Germany, 2025



Sources: Cost breakdown from the IEA's Hydrogen Tracker (2026), based on cost shares from Souissi (2025) — *Fuelling the future.* For India, hydrogen costs were selected from the lower end of the range, in line with SECI auctions. For Germany, the calculation uses the European average, as lower-end values apply to Iberian or Nordic countries. The analysis assumes an EU carbon price of 80 USD/tCO_2 and costs of 97.5 USD/tCO_2 for carbon capture, liquefaction, transport, and storage.

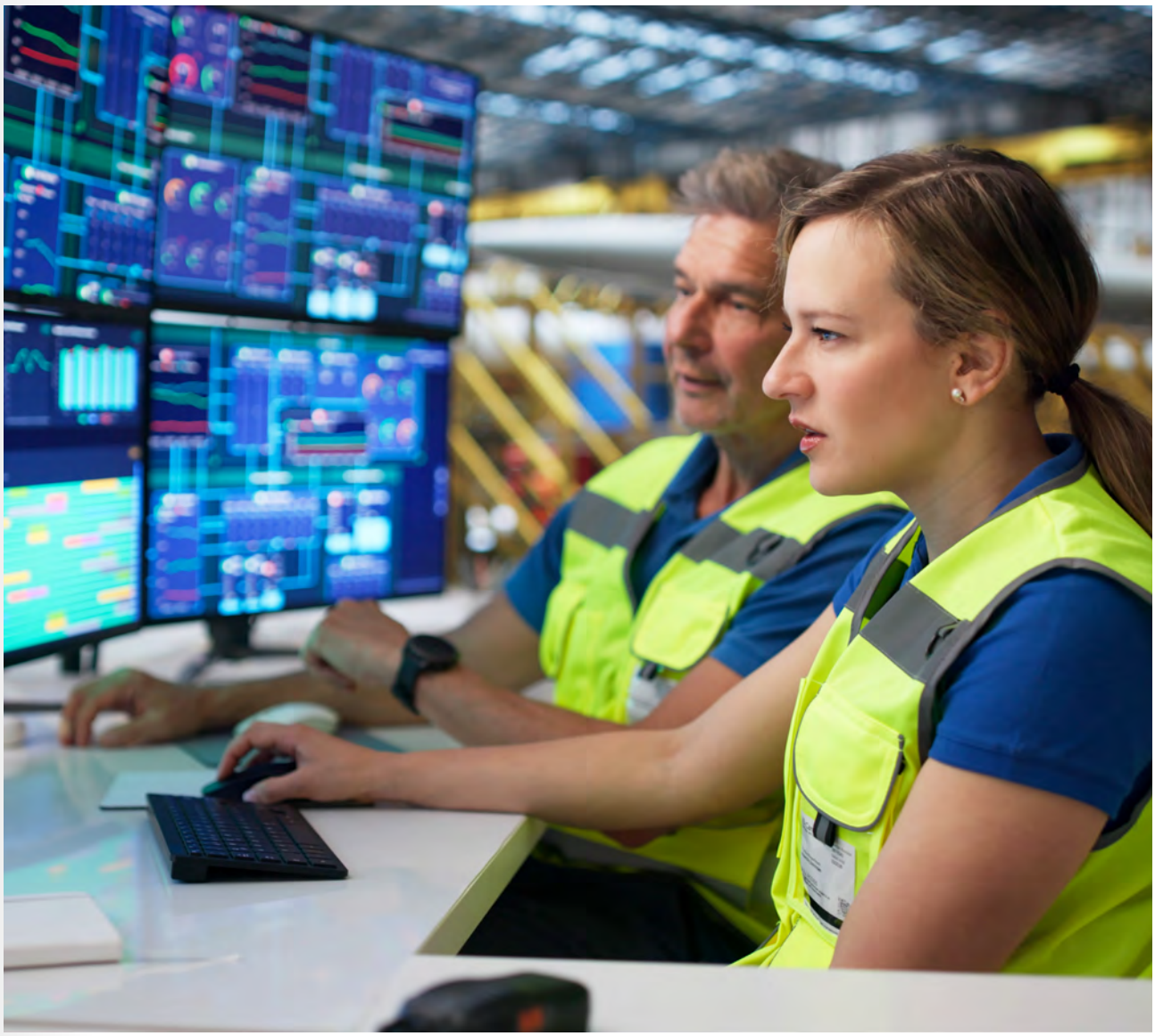


IMAGE CREDIT: ADOBE STOCK / ANDREY POPOV

The shared challenge of balancing supply and demand must be addressed through effective coordination via quotas, mandates, tender-based approaches such as H2Global or ZEMBA, guarantees, and matchmaking platforms. All coordination approaches also depend partly on sound regulatory frameworks and require long-term political commitment to clear and actionable policy design.

Price risks, on the other hand, stem not only from the persistently high cost of clean hydrogen and uncertain prospects for falling prices over the next decade, but also from the limited ability of offtakers to sell their products at higher prices, i.e., their own offtake risk.

As long as end-users will not buy food, appliances, clean-hydrogen-based power, and other products at a premium, competitive pressures will prevent a market ramp-up for clean hydrogen at scale.

Even if end-users are willing to pay a green premium, the **cost structures and competitive environments** of the companies linking primary clean-hydrogen users to end-users may prevent that premium from passing through the value chain. A holistic understanding of clean-hydrogen value chains is therefore crucial.

This report provides an in-depth assessment of two value chains. The first analysis focuses on the **fertiliser-to-plate** value chain for rice. Rice is a global staple food, purchased daily by millions of households. For basic goods consumed regularly, consumers are typically price-sensitive because these products represent essential expenditure, while governments seek to ensure food security at affordable prices. Fertilisers are crucial to that food security and can be decarbonised by using ammonia derived from clean hydrogen to produce nitrogen fertilisers, such as urea. Ensuring the affordability of these low-emission alternatives remains a challenge, however. In addition, the closure of the Strait of Hormuz in 2026 demonstrated that diversifying ammonia sourcing away from traditional fossil-fuel-producing countries can substantially improve food security.[4]

Table 2: Overview case selection

Product	Key component	End-consumer	Case selection rationale
Rice	Fertiliser (urea)	Private households	• Major staple food commodity • Low consumer price elasticity • Consistent global consumption
(Onshore) wind turbines	Steel in towers	Private developers	• Substantial, recurring steel demand • High policy control via standards and tender design • High relevance for the energy transition across the globe

The second analysis focuses on the **steel-to-wind-turbine** value chain, in which power companies act as end-users. The towers of wind turbines are particularly steel-intensive and require high-grade steel. Primary steel production, in turn, depends heavily on clean hydrogen to decarbonise its processes and help mitigate the 8—10% of global greenhouse-gas (GHG) emissions arising across steel offtake sectors. Investments in wind power capacity proceed continuously and at scale in a fast-growing market, with average annual capacity growth of 8.5%, amounting for around 4% of EU steel demand in 2025. While other sectors, such as construction (38%) and vehicles (18%), account for higher shares, wind turbines combine substantial steel requirements per unit with demand for high-quality flat steel that is likely to be decarbonised via the direct reduced iron (DRI) route. The public sector also exerts strong influence through regulation, incentives, and public procurement, opening up different avenues compared with the food market.[5]

The capacity and influence of governments, alongside market conditions, differ across geographies. Advanced economies typically possess greater financial and administrative capacity than emerging markets and developing countries (EMDCs), allowing them to implement larger programmes to support market ramp-up. Simultaneously, most EMDCs place energy availability and affordability ahead of decarbonisation as primary development goals, reflecting the immediate needs of their populations.

This report focuses on Germany and India as two countries with ambitious energy policies and relevant markets for both rice and wind turbines. Globally, India is the second-largest producer of both rice and steel, the largest exporter and third-largest consumer of rice, and a major trader of steel in both directions. Germany, by contrast, is the world's fifth-largest steel importer and exporter, and ranks seventh in production.[6]

Advanced economies typically possess greater capacity to implement large support programmes. Simultaneously, EMDCs place energy availability and affordability ahead of decarbonisation as primary development goals.

Against this background, this report aims to:

1. develop a deeper understanding of clean-hydrogen value chains for steel- and fertiliser-based products;
2. conduct a cost analysis of using clean hydrogen throughout these value chains;
3. assess the competitive environment facing companies active along these value chains in Germany and India, identifying the segment best placed to absorb a green premium; and
4. identify policy instruments governments can deploy to provide targeted support for clean hydrogen at each stage of the value chain.



IMAGE CREDIT: PEXELS.COM/ RAVI ROSHAN



IMAGE CREDIT: ADOBE STOCK / NIKS ADS



2

Fertiliser-to-plate: The case of rice

Rice is the most common staple food in the world and the third most harvested crop, after wheat and maize. While essential for food security, conventional fertiliser production is highly emissions-intensive — accounting for an estimated 1.3% of global CO_2 emissions.[7] Ammonia, the indispensable feedstock for nitrogen fertilisers such as urea, accounts for roughly 90% of the fertiliser industry's total energy consumption.[8]

Understanding the fertiliser-to-plate value chain

Global rice production in 2025—2026 stood at 541 Mt, led by India (28%) and China (27%).[9] Consumption is heavily concentrated in Asia and Africa, which together account for nearly 80% of global rice trade, whereas Europe represents only a marginal share.[10] Yet the higher purchasing power of European consumers could exert substantial pull on rice markets, steering value chains towards more sustainable production pathways.

India stands apart as the dominant force in the global rice trade. It is the world's largest exporter of both common rice (accounting for 36% of global exports) and basmati rice, supplying 74% of global volumes around 6.5 Mt/a.[11] Beyond its role in international trade, rice is the cornerstone of India's domestic food security. Fertiliser is a critical input underpinning this production—and, by extension, that security—making it a central concern for public policy.

India is the world's third-largest producer and second-largest consumer of fertilisers.[12] Fertilisers are vital to domestic food security because they increase agricultural productivity.[13] The government of India (GoI) thus provides substantial subsidies to shield farmers from price volatility and prohibitively high costs. These subsidies fall into two categories:

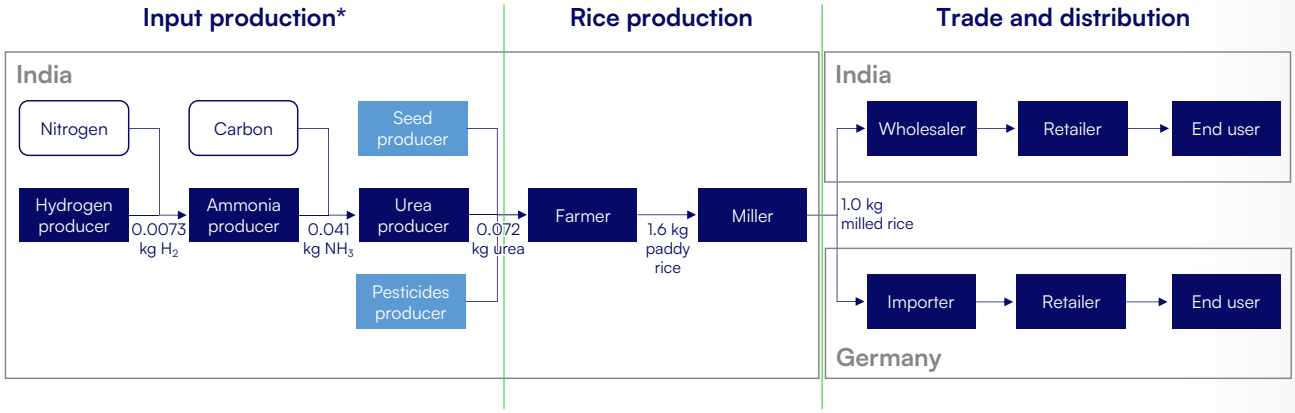
- a maximum retail price (MRP) for urea; and
- nutrient-based subsidies (NBS) for non-urea fertilisers containing nutrients such as nitrogen (N), phosphorus (P), potassium (K), and sulphur (S).

The MRP applies to urea — the country's most widely used fertiliser, accounting for 54.6% of total fertiliser consumption in India.[14] The GoI reimburses fertiliser manufacturers and importers for the difference between production costs and the MRP. The NBS, by contrast, provides a fixed per-kilogram subsidy, while allowing manufacturers to determine retail prices freely within reasonable margins.[15]

This difference in subsidy design — with the government fixing fertiliser prices under one scheme while producers can set prices subject to oversight under the other — has led most farmers to rely heavily on urea.[16] Farmers also prefer solid urea to liquid alternatives because dry bulk is easier to handle and store.[17] The report therefore focuses on urea.

Ammonia is a key feedstock for urea production, synthesised industrially via the Haber-Bosch process from nitrogen and hydrogen. Nitrogen is typically sourced from an air-separation unit, which runs on electricity and can be decarbonised by procuring renewable energy. On the other hand, hydrogen is conventionally obtained from fossil-based processes—steam methane reforming (using natural gas) or coal gasification—that emit 7-10 kg_{CO2}/kg_{H2}. Because urea also contains carbon, the production of hydrogen, ammonia, and urea is conventionally co-located, allowing producers to recycle carbon from the syngas stream of the steam reforming process. For illustrative purposes, hydrogen, ammonia, and urea production are presented as separate stages of the value chain shown in Figure 1.[18]

Figure 1: The fertiliser-to-plate value chain[19]



The analysis focuses on the value-chain segments highlighted in dark blue.

* Hydrogen, ammonia and urea production can be integrated in one plant, depending on the production technology and business model of the producer(s).

Urea application rates and yields in India are based on data collected by APEDA in Punjab, Uttar Pradesh, Uttarakhand, and Haryana, averaging 230 kg of urea per hectare and 4.5 tonnes of paddy rice per hectare respectively. The milling conversion rate is 1.6 kg of paddy rice for each kg of milled rice. Each kg of ammonia requires 0.178 kg of hydrogen, while each kg of urea requires 0.569 kg of ammonia.

Decarbonising nitrogen-based fertilisers consequently requires a climate-neutral pathway to source both hydrogen and carbon. The renewable-hydrogen route offers an additional dual benefit by avoiding reliance on natural gas: it increases resilience while reducing dependence on natural gas imports. This is particularly significant for countries with high renewable energy potential.

The renewable-hydrogen route offers an additional dual benefit by avoiding reliance on natural gas: it increases resilience while reducing dependence on natural gas imports.

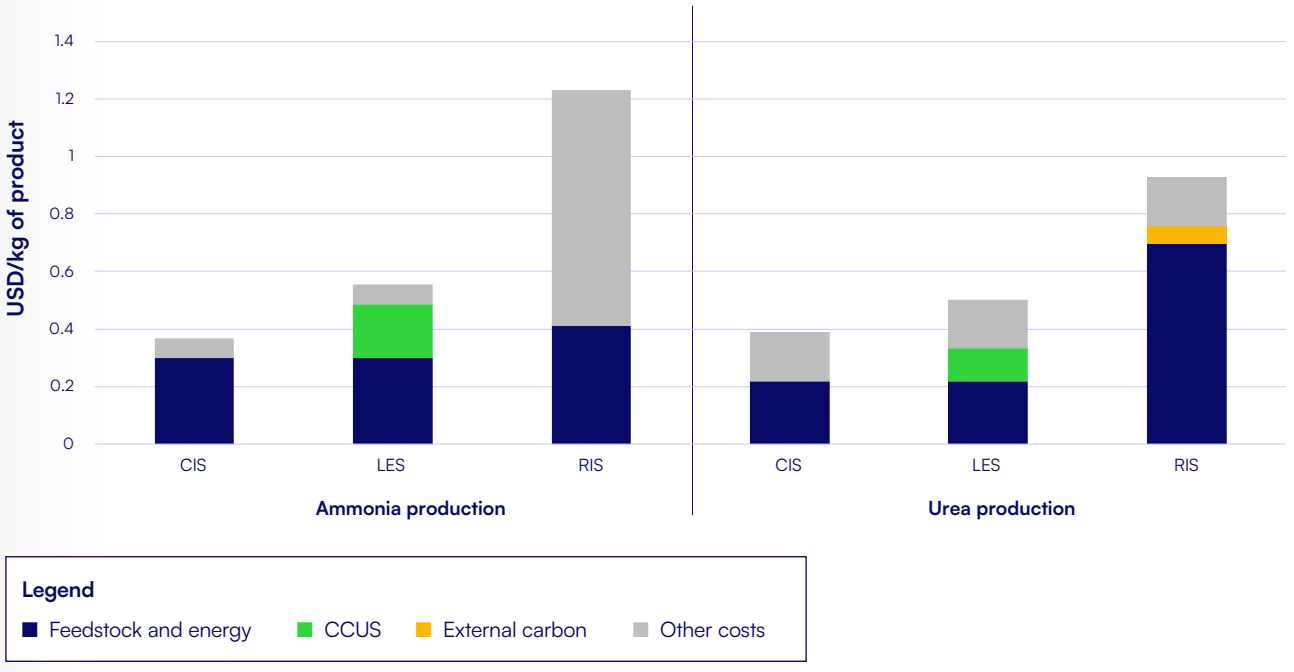
Rice production begins with the sowing of paddy, followed by a cultivation and harvesting cycle of approximately three months. Once harvested, the paddy is sun-dried and milled to remove the outer husk, yielding white rice. The milled rice is then bagged and sold to wholesalers, who repackage it into consumer-ready units and supply it to retailers — the final point of sale for consumers.

The value-chain structure differs between the two market contexts analysed in this report. This analysis focuses on basmati rice, which allows for a meaningful comparison across both countries: it is the rice most commonly consumed in Germany, making it the natural reference point for both markets. For India, the full chain — from rice cultivation and milling through to wholesaling and retailing — takes place domestically. For Germany, rice sold to consumers is assumed to be cultivated and milled in India, as basmati rice is subject to Geographical Indication (GI) protection. The export route assumes shipment from Mundra Port (Gujarat) to Hamburg and is subject to applicable European Union import tariffs on rice.

The impact of hydrogen on rice prices

Based on the value-chain structure above, the report uses a first-pass parametric model to estimate the impact of using clean hydrogen to produce fertilisers and, ultimately, rice. For the upstream chain—from hydrogen production through ammonia to urea—the model relies on production-cost data from the IEA[20] and GIZ,[21] alongside stoichiometric conversion factors linking each stage. Publicly reported expenditures of basmati rice farmers in India inform the cost per kilogram of rice in the subsequent steps.[22]

Figure 2: Cost breakdown per kilogram of product in the ammonia-urea production process[23]



Source: Authors' calculations based on hydrogen costs shown in Box 1 and ammonia cost modelling for India by GIZ. CIS, and LES assume a natural gas price of 2.93 USD/MWh. For renewable urea, external CO_2 is sourced from a nearby steel or cement plant at a CO_2 price of 80 USD/tCO_2. Each kilogram of urea requires 0.56 kg of ammonia and 0.74 kg of CO_2.

The analysis distinguishes three scenarios:

- the conventional-input scenario (CIS), based on unabated steam-reforming processes;
- the low-emission scenario (LES), retrofitting existing hydrogen production with carbon capture, utilisation and storage (CCUS) to cut emissions by 60-80%; and
- the renewable-input scenario (RIS), producing hydrogen via renewably powered water electrolysis to achieve near-zero emissions (renewable hydrogen), while sourcing external carbon, in this case, from steel and cement plants.

Both alternatives require significant capital investments and increase operating expenditure under current technological and market conditions. Figure 2 breaks down production costs for ammonia and urea in India across the three scenarios.

Hydrogen costs constitutes 70-80% of the cost of ammonia and urea, and are themselves determined largely by the price of natural gas or electricity, depending on the production technology.[24] The calculation indicates a conventional urea production cost of 0.39 USD/kg, compared with 0.50 USD/kg for low-emission and 0.92 USD/kg for renewable urea, representing increases of

At an average SECI price of 618 USD/t, the green premium for ammonia falls from 234% to 68%. This trend holds at the urea producer level as well, where the premium decreases from 136% to 47%.

27% and 136%, respectively. For renewable urea, this higher premium reflects both the higher cost of renewable ammonia and the additional expense of procuring an external CO_2 source.

Tenders conducted in 2025 by the Solar Energy Corporation of India (SECI) reveal a discovered price for renewable ammonia of around 565—735 USD/t,[25] lower than the 1,230 USD/t figure from GIZ used in this analysis, as well as the estimate from the International Energy Agency's Hydrogen Tracker.[26] Notably, the SECI values already incorporate government financial incentives, such as the Production Linked Incentive (PLI) scheme, which provides 98 USD/t, 78.4 USD/t, and 58.8 USD/t over the first three years, respectively.[27] This suggests that real-world values can be expected to be even lower still.



IMAGE CREDIT: ADOBE STOCK / ABC FOTO

At an average SECI price of 618 USD/t, the green premium for ammonia falls from 234% to 68%. This trend holds at the urea producer level as well, where the premium decreases from 136% to 47%. H2Global's analysis uses the higher price estimates from GIZ and the IEA to assess the potential impact on consumers.

However, lower price signals are already emerging and may decline further as the market matures.

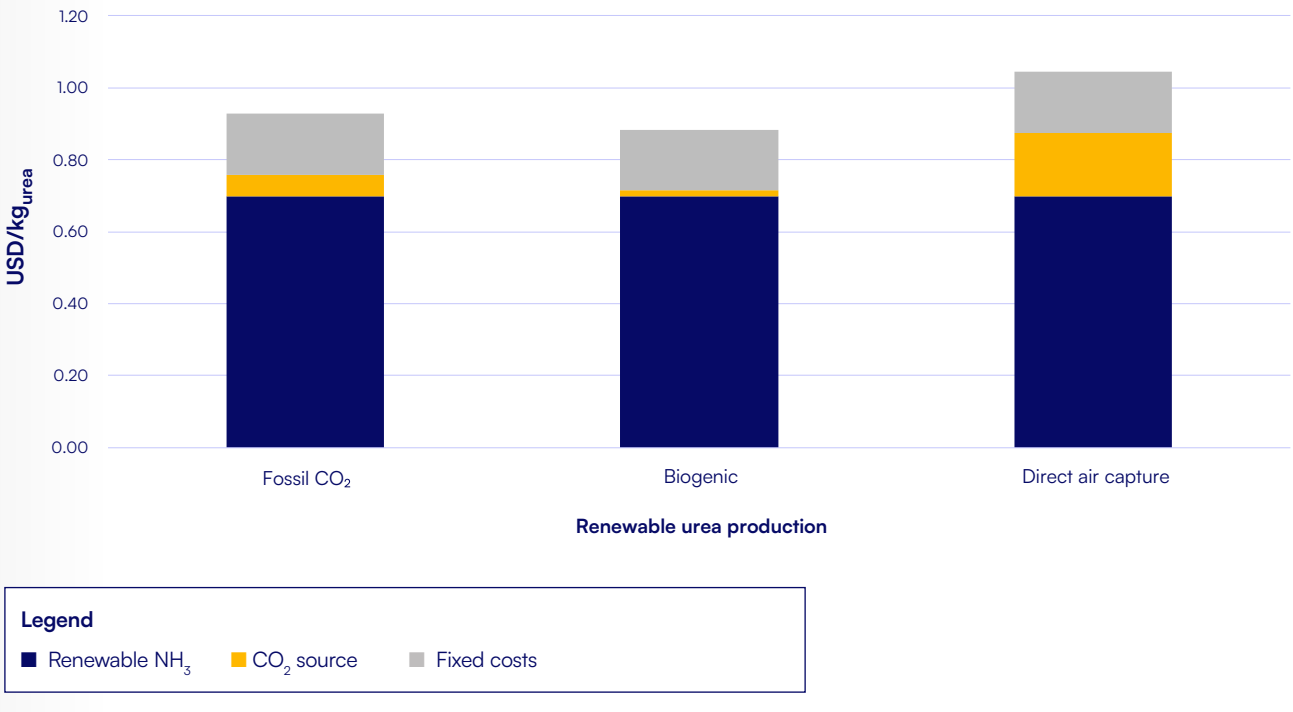
Besides direct cost increases under the RIS, heavy reliance on natural gas exposes conventionally produced hydrogen and its downstream products to price volatility triggered by market shifts and geopolitical tensions. A recent example is the price increase caused by disruptions in the Strait of Hormuz, through which approximately 20% of the world's liquefied natural gas (LNG) passes.[28] As a result of the associated risk premium, urea prices in India nearly doubled compared with levels recorded two months before the conflict.[29]

Given the carbon content in urea, renewable fertiliser projects must evaluate carbon sources carefully. Figure 3 compares the cost of renewable urea production across three alternative external CO_2 sources: direct air capture, biogenic CO_2, and CO_2 captured from nearby steel and cement plants. Renewable urea produced using biogenic CO_2 achieves the lowest cost, whereas direct air capture remains the most expensive option, driven primarily by the lower concentration of atmospheric CO_2 compared with industrial streams.[30]

For the rest of the value chain, it is important to note that the model assumes the absence of the MRP. In 2026, the MRP stands at INR 266.5 per 45 kg bag (USD 2.96 per bag, equivalent to USD 0.07 per kg),[31] against estimated production costs in 2023 of around INR 2,200 per 45 kg bag (USD 24.40 per bag, equivalent to USD 0.54 per kg),[32] meaning the government subsidy covers nearly 88% of production costs. Subsequently, these subsidies affect the costs of farmers, millers, and retailers—and therefore rice buyers in both India and importing markets such as Germany.

As long as the MRP remains in place, actors along the value chain will not bear additional costs, as these are absorbed by the government. Given the expected expansion of renewable ammonia production, this could significantly strain the Indian government's budget over time and drive the search for alternative support instruments. Omitting the MRP from the analysis allows policymakers to understand both the effects of lifting the MRP and the alternative policy options available. If the MRP is maintained, Indian policymakers may still consider ways to secure buy-in from rice-importing advanced economies that benefit indirectly from the MRP.

Figure 3: Cost breakdown of renewable urea in India by CO_2 source[33]



Notes: Renewable NH3 is 1.23 USD/kg. Biogenic CO_2 is 22.5 USD/tCO_2, direct air capture CO_2 is 240 USD/tCO_2, and fossil CO_2 is assumed to be externally sourced from cement and steel plants in India at 80 USD/tCO_2.

Figure 4 shows the costs and profits associated with the production and sale of basmati rice along the Indian value chain for conventional, low-emission, and renewable pathways. Without the MRP, urea prices would increase by 136%.

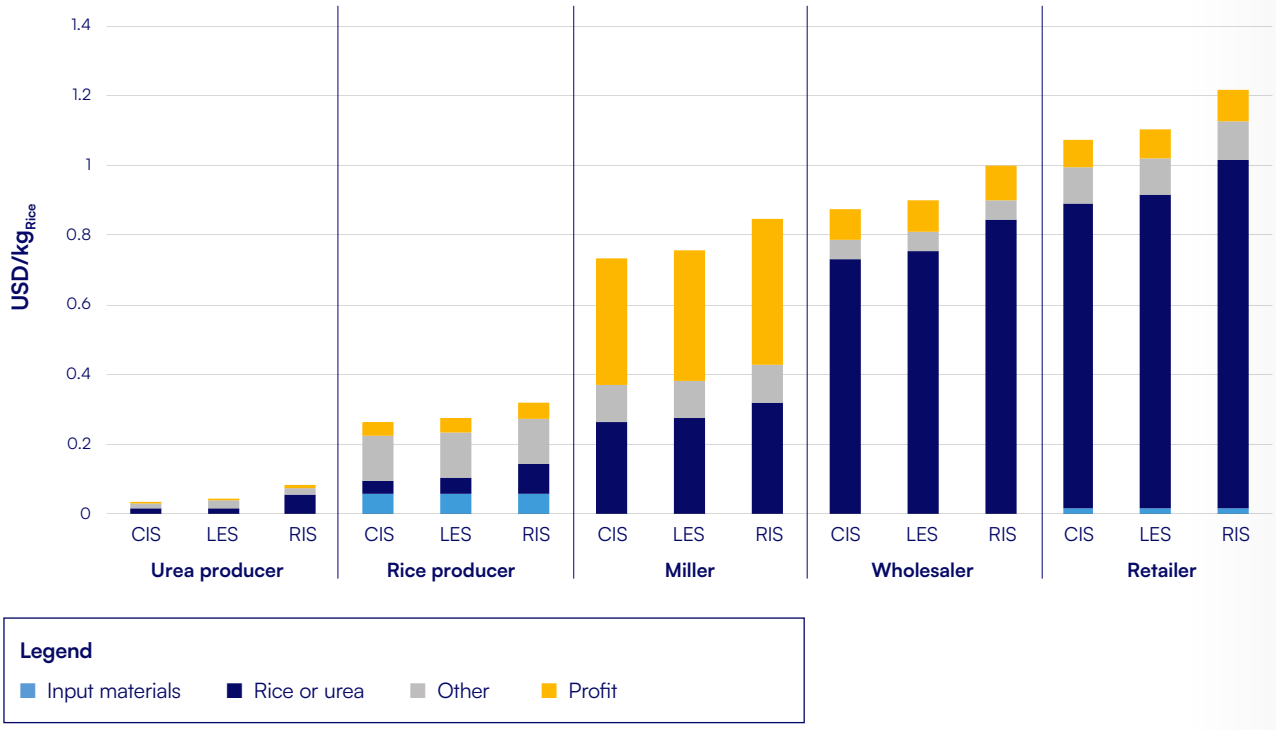
Urea accounts for approximately 14% of total paddy rice production costs, making it one of the larger individual cost components.

Costs incurred by paddy rice farmers include material inputs such as seeds, fertilisers, herbicides, and insecticides; machinery and the cost for urea; and other costs such as refinancing, energy, administration, levies, taxes, and labour from pre-harvest to post-harvest activities. Urea accounts for approximately 14% of total paddy rice production costs, making it one of the larger individual cost components. However, the vast majority of the overall cost structure remains independent of the chosen decarbonisation pathway.



IMAGE CREDIT: ADOBE STOCK / SAWAT

Figure 4: Total cost and profit per kg of basmati rice along the Indian value chain: CIS, LES, RIS[34]



Notes: "Rice or urea" denotes the primary inputs tracked throughout the value chain and the component expected to vary across the different hydrogen production pathways. "Input materials" includes secondary inputs that are not the focus of the analysis, such as seeds, herbicides, fungicides, zinc (for farmers), and packaging materials (for retailers). "Other" comprises all remaining cost components not included in the previous categories, including storage, transport, rice processing, harvesting, transplanting, nursery operations, and miscellaneous expenses. Profit margins are based on a study conducted in Haryana involving a sample of 30 farmers, 5 millers, 10 wholesalers, and 20 retailers.

Millers only process paddy rice and thus do not incur costs for additional material inputs. In their case, other costs include labour, storage, transport, marketing, energy and administrative expenses. While significant, these costs remain considerably lower than the cost of acquiring paddy rice, which constitutes the largest share of millers' expenditures. Millers also capture a substantial share of the profits generated along the value chain.

Both wholesalers and retailers act primarily as intermediaries with limited additional costs deriving from storage, transportation, packaging, administration, and taxes. Consequently, purchasing the product from the previous trader is their most significant cost component.

For India, the resulting data show a 3% increase in retail prices per kilogram of basmati rice.

For India, the resulting data show a 3% increase in retail prices per kilogram of basmati rice, bringing the estimated retail price from 1.07 to 1.10 USD/kg.

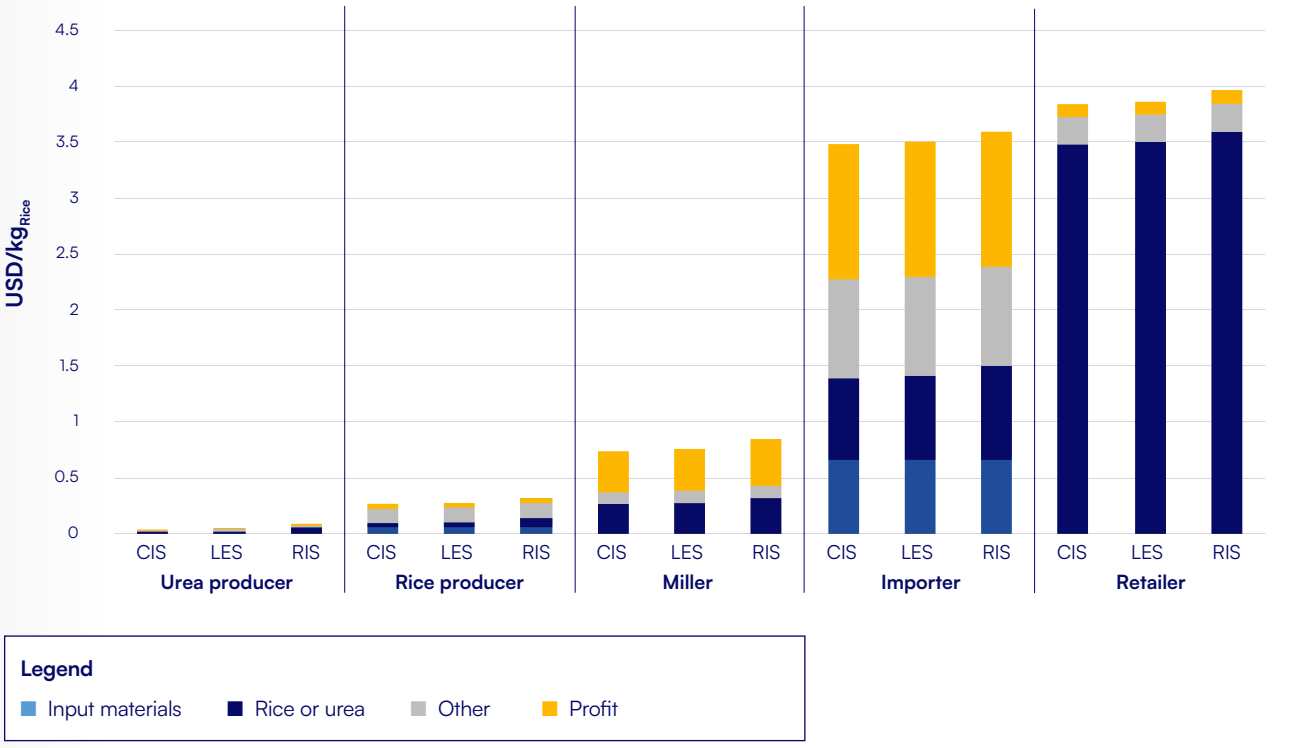
If renewable hydrogen is used instead, the retail price would rise by approximately 13% to 1.22 USD/kg.

Figure 5 shows the corresponding costs and profits for basmati rice grown in India and sold in Germany. In the model, the figures remain identical until the milled rice leaves the mill. The major difference from the domestic Indian value chain arises from longer transport distances, customs duties, and other import-related expenses; German intermediaries also capture a significant share of overall profits. For retailers, this translates into higher overall costs, though the underlying cost structure remains similar to that of the Indian market.

As a result, substituting conventional hydrogen with low-emission hydrogen would increase the retail price of basmati rice in Germany by less than 1%, from a baseline of 3.84 to 3.86 USD/kg. Under the renewable hydrogen scenario, the premium would rise to 3%, bringing the German retail price to 3.96 USD/kg.

Across both India and Germany, the analysis shows that switching to renewable hydrogen results in a higher downstream cost increase than transitioning to low-emission hydrogen—a pattern that holds consistently along the entire value chain through to retail.

Figure 5: Total cost and profit per kg of basmati rice along the German value chain: CIS, LES, RIS[35]



Notes: "Rice or urea" denotes the primary inputs tracked throughout the value chain and the component expected to vary across the different hydrogen production pathways. "Input materials" includes secondary inputs that are not the focus of the analysis, such as seeds, herbicides, fungicides, zinc (for farmers), and packaging materials (for retailers). "Other" comprises all remaining cost components not included in the previous categories, including storage, transport, rice processing, harvesting, transplanting, nursery operations, and miscellaneous expenses. Profit margins are based on a study conducted in Haryana involving a sample of 30 farmers, 5 millers, 10 wholesalers, and 20 retailers. Trade is assumed to occur between Mundra Port in India and Hamburg Port in Germany.

Substituting conventional hydrogen with low-emission hydrogen would increase the retail price of basmati rice in Germany by less than 1%.

As shown in Figure 3, Figure 4, and Figure 5, this cost gap is largest at the ammonia production stage (234%), narrowing to 136% at the urea production stage and to 22% at the farm level. This sharp narrowing reflects the fact that urea accounts for only 14% of the production costs of basmati paddy rice, which limits the pass-through effect and keeps the cost differential comparatively modest further down the value chain in both countries.

These results indicate that even substantial increases in hydrogen and urea production costs translate into only modest increases in final consumer prices, particularly in markets like Germany, where downstream logistics, distribution, and retail margins account for a large share of total value-chain costs.

The increase in the final price of rice falls well within the range of normal price competition already observed in the packaged basmati rice market in both countries: 2.49-4.59 EUR/kg (2.92-5.38 USD/kg)[36] in Germany, and 60-100 INR/kg (0.63-1.05 USD/kg)[37] in India, representing spreads of approximately 80% and 63%, respectively, compared with the cheapest price.

Despite this modest increase, its impact should be assessed in relation to purchasing power and consumption patterns in each country. In Delhi, India, the monthly minimum wage for unskilled workers is INR 18,456 (USD 205),[38] compared with EUR 2,410 (USD 2,795) in Germany. Rice also represents a substantially larger share of food consumption in India, with annual per-capita consumption of approximately 51.36 kg,[39] compared with 7.06 kg in Germany.[40] Together, these differences suggest that the green premium would represent a smaller relative burden for consumers in Germany, reflecting both higher purchasing power and lower rice consumption.

The greater upstream cost gap, particularly in the hydrogen-ammonia-urea segment, highlights the need for stronger support mechanisms in this part of the value chain. Farmers also continue to face a substantial cost premium. Given their critical role in ensuring food security and the government's longstanding efforts to keep fertilisers affordable, additional support measures for this group remain essential.



IMAGE CREDIT: ADOBE STOCK / ALEKSEI

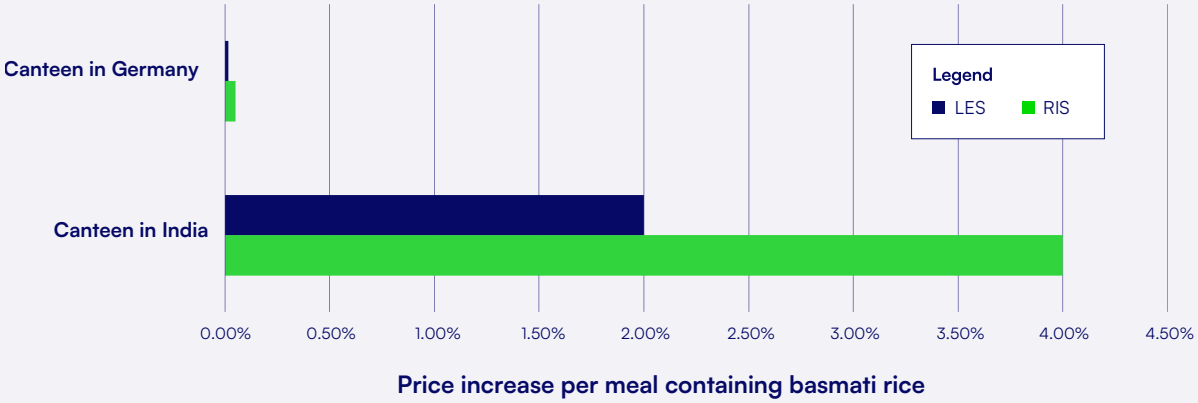
Box 2: Effect on public canteens[41]

Rice is consumed not only in private households, but also in workplace and public canteens. In India, subsidised canteens are widespread, providing freshly cooked meals to support people struggling to meet their daily nutritional needs. In this context, any potential price increases from more costly fertilisers is particularly significant.

In Delhi, for example, the local government launched the Atal Canteen Scheme in December 2025, offering nutritious meals for INR 5 (USD 0.052). The meals typically include rice, chapati, vegetables, and achar. Each portion includes approximately 0.2 kg of cooked rice (equivalent to 0.1 kg of raw rice). Assuming the use of basmati rice produced with low-emission or renewable urea, the final meal price would increase to approximately USD 0.053 and USD 0.054, respectively — representing increases of around 2% and 4% compared with the conventional production pathway. In Germany, workplace canteens serve primarily to give employees access to reasonably priced food during lunch breaks, with meals costing an average of EUR 5 (USD 5.85). Applying an analogous calculation, basmati rice produced with low-emission or renewable urea would increase the final meal price to approximately USD 5.851 and USD 5.853, respectively. This represents an increase of approximately 0.017% and 0.051% compared to the conventional pathway.

The figure below provides an overview of how different hydrogen production pathways affect public canteen meal prices in Germany and India. Overall, public canteens in India experience a larger relative impact than their counterparts in Germany. This is largely due to the substantially lower price of canteen meals in India, which is around 110 times less than the average German meal. Consequently, higher urea production costs result in a larger percentage increase in the final meal price in India. However, this estimate should be interpreted with caution, as Indian public canteens are likely to use lower-cost, non-basmati rice variants.

Impact of different hydrogen production pathways on public canteen meal prices in Germany and India



Competition in the rice value chain

Understanding the competitive environment in which actors along the fertiliser value chain operate is essential to assessing their capacity to absorb a green premium. Companies facing intense competition and operating with narrow profit margins have limited flexibility to absorb additional costs and are therefore highly dependent on maintaining a level playing field. Even companies with higher profit margins may struggle to absorb substantial green premiums unless these are offset by additional revenues, for example through improved market access.

Hydrogen—ammonia—urea

The extent to which price increases along the value chain matter depends largely on how competition is structured within the relevant segment. India is the world's second-largest consumer and third-largest producer of fertiliser.[42] Urea is the most widely used fertiliser in the country, accounting for 54.6% of total consumption and reaching 38.7 Mt in 2024-25. It is followed by NPKS (21.1%), DAP (13.5%), SSP (6.9%), and MOP (3.1%).[43]

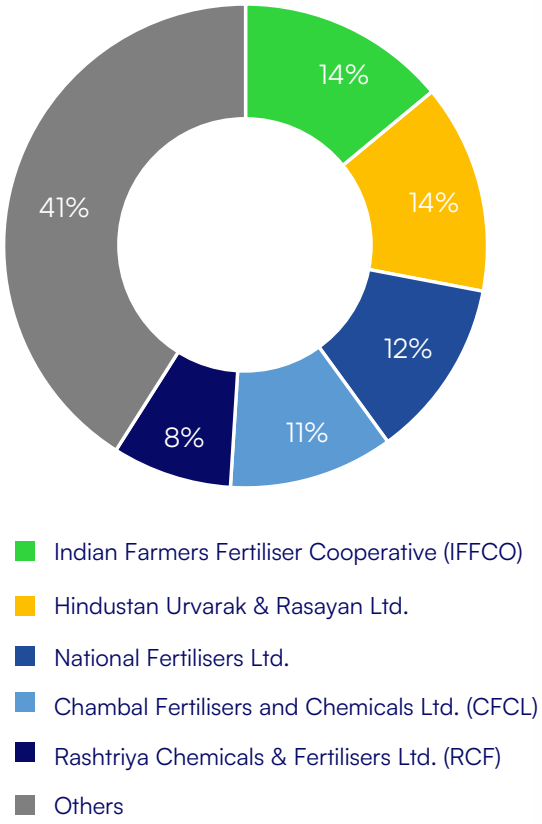


IMAGE CREDIT: ADOBE STOCK / PVINCE73

Urea is produced mainly in integrated ammonia—urea plants, where ammonia is produced on site from natural gas or coal. India consumes around 19 Mt/a of ammonia as feedstock for urea production, with domestic production supplying almost 89% of this requirement. The remaining ammonia is imported from Oman, Saudi Arabia, Indonesia, Qatar, and Malaysia.[44] To produce ammonia domestically, India remains dependent on imported liquefied natural gas (LNG);[45] in 2025 it was the world's fourth-largest natural gas importer,[46] sourcing around 60% of its imports from Qatar and the UAE.[47] This dependence exposes urea producers to geopolitical disruptions in their feedstock supply. In March 2026, the Government of India responded with the Natural Gas (Supply Regulation) Order, which prioritises the fertiliser sector and guarantees plants at least 70% of their average natural gas consumption.[48]

India has 33 urea production units, operated by 20 companies, with a current combined installed capacity of 26.94 Mt/a (see Figure 6). These units span four ownership categories: 14 private-sector plants (capacity: 10.37 Mt/a), 9 public sector undertakings (6.07 Mt/a), 6 cooperatives (5.42 Mt/a), and 4 joint ventures (5.08 Mt/a). The fertiliser market is moderately concentrated, with four major producers accounting for more than half of national production capacity: the joint venture Hindustan Urvarak & Rasayan Ltd (HURL, 14%), the cooperative Indian Farmers Fertiliser Cooperative (IFFCO, 14%), the public company National Fertilizers Limited (NFL, 12%), and the private company Chambal Fertilisers & Chemicals Limited (CFCL, 11%). The remaining 16 companies each hold an average market share of approximately 3%.[49] This concentration could facilitate the introduction of a decarbonisation scheme by limiting the number of companies required to participate.

Figure 6: Urea production in India by company in 2024—2025[50]



The challenge is compounded by the design of India's urea subsidy scheme. Because producers and importers are required to sell urea at the MRP set by the Government of India, they have limited scope to pass higher production costs on to consumers. The resulting cost gap would therefore need to be absorbed through the government's subsidy system, which already requires around USD 12.2bn

in annual public expenditure (68% of the Department of Fertilizers' budget) and could more than triple if all domestic production were to transition to renewable urea.[51] Without adequate support, this segment of the value chain would be unable to absorb the cost increase unaided, underscoring the importance of targeted policy instruments to support the uptake of renewable hydrogen and limit the additional fiscal burden on the government.

Without adequate support to bridge this cost gap, higher fertiliser costs could place additional pressure on farm margins and, if sustained, depress production and compromise food security.

Farming

India is the world's leading producer and exporter of basmati rice, supplying around 74% of the global market. Despite being exported in far smaller volumes than non-basmati rice — 4.6 Mt/a compared with 13.8 Mt/a — basmati generates nearly twice the export value, at USD 6.5bn per year.[52] Its superior aroma and grain quality command higher prices in both domestic and international markets.[53] The value of basmati is further protected by a geographical indication (GI) designation, restricting use of the name to rice cultivated in a defined region spanning seven states and union territories: Punjab, Haryana, Uttar Pradesh, Uttarakhand, Himachal Pradesh, Delhi, and Jammu & Kashmir,[54] with more than 90% of production concentrated in Punjab, Haryana, and Uttar Pradesh.[55]

Agriculture in India is highly decentralised, with basmati rice cultivated across a wide range of farm sizes. Haryana, for example, has over 1.6mn registered farmers, the majority operating marginal holdings (less than 1 ha), followed by smallholders, whereas Punjab's 1.8mn farmers predominantly cultivate semi-medium (2-4 ha) and medium-sized farms (4-10 ha).[56] This fragmentation means no single producer or producer group commands significant market power, keeping the basmati supply side structurally competitive.

Contract farming is a common model for cultivating basmati rice in India, whereby large food companies partner directly with farmers, guaranteeing procurement and providing greater demand certainty. Through these arrangements, contracting firms promote improved, cost-effective farming practices and provide technical guidance on cultivation methods. In return, contract farmers typically receive a premium price compared with other basmati growers.[57] Companies engaged in contract farming, such as KRBL Limited, promote sustainable farming practices through their sustainable procurement policies.[58] Although these policies could in future incorporate requirements for low-emission fertilisers, there is currently little evidence of a concerted effort to advance this pathway.

The potential uptake of low-emission fertilisers also depends on how farmers respond to changes in fertiliser and crop prices. In general, demand for ammonia-based fertilisers is relatively inelastic due to their fundamental role in farming, meaning that a 10% increase in fertiliser prices is associated with an estimated 2—5% reduction in the quantity demanded.[59] Given the relatively narrow profit margins of farmers and their already high debt levels,[60] there is limited room to absorb higher fertiliser costs without undermining profitability, while reducing fertiliser application rates risks reducing crop yields. Without adequate support to bridge this cost gap, higher fertiliser costs could place additional pressure on farm margins and, if sustained, depress production and compromise food security.

Milling

Milling converts harvested paddy into rice and is the stage where basmati is processed, graded, and prepared for sale. In India, this segment is highly fragmented. The country possesses more than 100,000 mills, comprising 82,000 registered single-huller units, 2,600 double-huller units, 5,000 disc sheller-cum-polisher units, and 10,000 rubber roll sheller units—the vast majority of which operate on a small scale.[61]



IMAGE CREDIT: ADOBE STOCK / YUDI KURNIADI



IMAGE CREDIT: ADOBE STOCK / CAFTOR

Despite a large number of relatively small-capacity millers, major exporting companies such as LT Foods Limited, Kohinoor Foods Limited, and KRBL Limited source paddy through contract farming with growers, with plants processing between 50 and 207 tonnes of paddy per hour.[62] Owning the mills gives these companies control over product quality and allows them to meet international food-processing standards. Large exporters are better placed to pass costs forward: they hold longer contracts with export buyers and control their own milling, helping them recover costs provided buyers recognise the added value of the product.

Large exporters have started to address their emissions, but mostly within their own operations. KRBL Limited is increasing the share of renewable electricity in its milling, processing, and packaging facilities.[63] LT Foods Limited goes further, aiming for carbon neutrality in its indirect emissions (Scope 3) by FY2045 — a boundary that includes the fertiliser used by its contracted growers.

The company, however, provides limited information on how it approaches fertiliser use and sourcing.[64] Companies with Scope 3 targets and direct contact with growers are therefore well placed to create demand for low-emission fertilisers, but this role is not yet visible in their strategies.

Retail

In India, basmati rice accounts for only around 4% of total national rice consumption,[65] rising to approximately 42% among urban households.[66] Even within this urban segment, only 19.2% of consumers purchase packaged basmati rice,[67] reflecting the continued dominance of loose, unbranded rice in local markets — a share that is nonetheless expected to shift as urbanisation accelerates.

Currently, Indian retail is dominated by traditional *kirana* stores ("mom-and-pop" shops), which account for around 74% of sales, while modern supermarkets and online platforms are expanding quickly.[68] The roughly 13mn *kirana* stores[69] still draw their relevance from familiarity and proximity.[70] The decentralised nature of *kirana* stores poses an implementation challenge for certification schemes that would allow a green premium to be passed on to consumers, especially because loose rice predominates in these stores.

The German food-retail market has a medium to high concentration, with four main groups controlling over 85% of sales.

In Germany, basmati rice can be purchased in different types of retail outlets, such as supermarkets, discounters, organic food shops, and pharmacies, typically in 0.5 kg or 1 kg plastic packets. Germans purchase their food mainly in discounters (45.4%), followed by supermarkets (42.4%); hypermarkets and specialised food shops account for the remainder.[71] The German food-retail market has a medium to high concentration, with four main groups controlling over 85% of sales directly or via franchising: Edeka Group, Rewe Group, Aldi Group, and Schwarz Group. Within

these groups, three major chains account for more than half of food revenues: Edeka, Rewe, and Lidl.[72] This market power gives them substantial bargaining power over suppliers, potentially compressing wholesalers' margins and creating ripple effects throughout the value chain, including for upstream stakeholders such as millers and farmers. However, as in India, German retailers depend on the upstream value chain to track the low-emission qualities of the rice so that consumers are informed and a green premium can be justified on the shelf.

Consumers

A survey conducted across 12 European countries found that 69% of respondents would choose a climate-friendlier food item over a cheaper alternative, and 51% stated a willingness to pay more for food produced without fossil fuel inputs.[73] However, a more recent study from 2025 found that only 17% of European consumers are in practice willing to pay a green premium for grocery products — a figure that has declined compared to 2024, driven by budget constraints under conditions of economic and political uncertainty.[74]

Even among those willing to pay a premium, the magnitude is limited. PwC's *Voice of the Consumer Survey* found that consumers cite a willingness to pay, on average, 9.7% more for sustainably produced goods — even as cost-of-living pressures weigh on household budgets.[75] The prices discovered in the present analysis show that end-prices for consumers in Germany would vary between 1% and 3% for basmati rice when using low-emission and renewable hydrogen, respectively, far below the 9.7% threshold in the survey. Since switching hydrogen production pathways has only a marginal impact on the price of basmati rice, the survey results indicate a potential willingness among respondents to pay the associated green premium, although this may not necessarily translate into actual purchasing behavior.

Similarly, a survey analysing Indian consumers' willingness to pay a sustainability premium for rice found that 88% of respondents were willing to pay a green premium for sustainably produced rice, with most respondents willing to pay a premium of 5% or more.[76] Our analysis shows that the price increase associated with low-emission and renewable production routes in India would range between 3% and 13%. These results indicate that most Indian consumers would be willing to pay the premium associated with a low-emission production pathway. The higher premium of a renewable pathway, however, may limit acceptance among price-sensitive consumers.

These differences are also in line with assessments of real market reactions to price increases for rice, which identify a similar elasticity for German and at least higher-income Indian households. As a high-quality rice variety, basmati likely has more elastic demand, as consumers may switch to less expensive varieties of rice.[77]

Although this represents a positive sign for decarbonisation efforts, it would require effective tools capable of tracing the low-emission attributes of the rice throughout the value chain, as well as appropriate marketing strategies that effectively communicate these characteristics to consumers. At the same time, the analysis presented here suggests that rice consumption levels are likely to be affected only minimally by the introduction of renewable hydrogen into the fertiliser supply chain, given the combination of inelastic demand and limited increases in consumer prices.

Key takeaways

Farmers appear to have the most limited capacity to bear additional costs associated with the green premium, given their limited market power, dependence on external financing, and narrow profit margins. Under India's current MRP system, however, farmers are largely shielded from these costs, as government subsidies cover approximately 85% of urea production costs. Maintaining this mechanism as urea becomes 136% more expensive due to the use of renewable hydrogen would place considerable pressure on public finances. Assuming the full decarbonisation of India's 26 Mt/a of domestic urea production, the government would need to allocate approximately USD 30.43bn — almost three times the current budget of around USD 12.2bn for both domestic and imported urea.[78] This underscores the importance of identifying complementary instruments — across both the public and private segments of the value chain — to distribute the green premium associated with low-emission fertiliser pathways more broadly and sustainably.

Additionally, the Indian rice value chain is highly decentralised. Each step of the value chain is highly competitive resilient against the default of individual market participants, but such granular market structures pose a substantial challenge for coordination and for tracing sustainability criteria without extensive use of digital tracking systems. Such tracing is essential to allow consumers to make informed purchasing decisions based on reliable labels.

The downstream value chain in Germany may be better positioned to accommodate the green premium, given greater retail concentration and consumers' relatively higher purchasing power. Survey findings also suggest a potential willingness among consumers to pay a premium for sustainably produced products. However, the ability to pass on these costs depends on maintaining a reliable chain of custody upstream, particularly in India, to ensure that the low-emission attributes of basmati rice can be credibly traced.



IMAGE CREDIT: ADOBE STOCK / CHANAKON



3

Steel-to-wind-turbines: The case of towers

Wind turbines are an essential part of the energy transition, and their towers are a major application of high-quality steel. Using hydrogen-based steel production to decarbonise turbine manufacturing offers the dual benefit of reducing Scope 3 emissions and improving the resilience of power generation and its value chains against fossil-fuel dependence.

Understanding the steel-to-wind-turbine value chain

Steel is one of the most-produced and most-traded commodities in the world. Its applications can be found in every aspect of life, from cutlery to cars, heavy machinery, and buildings. In 2025, the steel sector produced 1,885 Mt of crude steel and recycled 630 Mt. China produces more crude steel than all other countries combined and consumes almost half of all finished steel products. India and Germany nevertheless assume an important position in global steel markets, as they are, respectively, the second- and seventh-largest producers of crude steel, as well as the second- and ninth-largest consumers of finished steel products.[79]

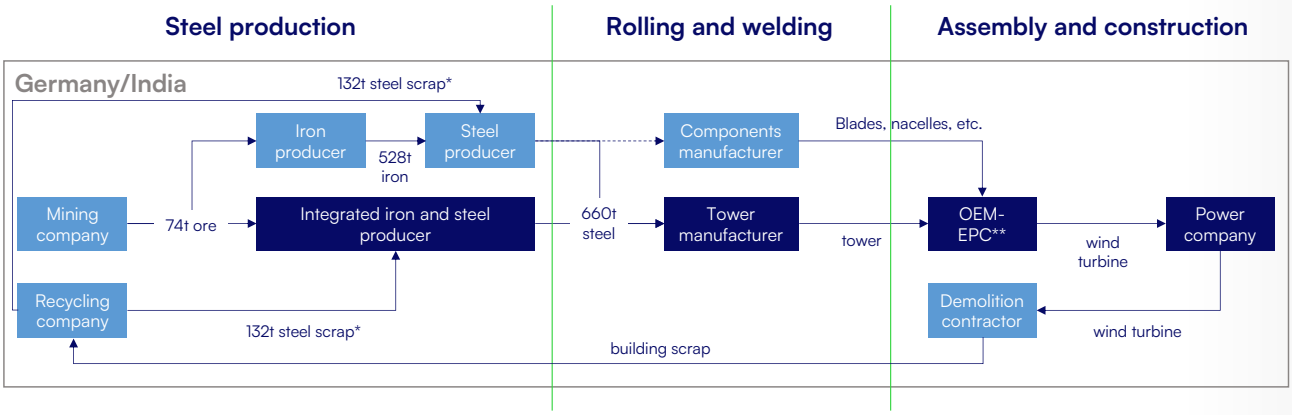
In the context of the energy transition, steel is relevant both as a major emitting industry and as the backbone of energy infrastructure.

In the context of the energy transition, steel is relevant both as a major emitting industry and as the backbone of energy infrastructure. Conventional steel production using coking coal in a blast furnace and basic oxygen blast furnace to produce (BF-BOF) emits 2.3 t_{CO2e}/t_{steel}, accumulating to a total of 2,700 Mt_{CO2e}/a.[80] At the same time, a modern onshore wind tower requires approximately 110 t_{steel}/MW, corresponding to about 80% of the mass of a fully realised wind turbine.[81] Emissions from steel production consequently contribute significant Scope 3 emissions to wind power.[82] Thus, fully decarbonising power generation means transforming steelmaking as well.

About three-quarters of today's global steelmaking capacity is still based on traditional BF-BOF plants. To reduce carbon emissions from steel, companies can increase the share of steel scrap (or focus fully on recycling scrap via the electric arc furnace (EAF) route), invest in carbon-capture technologies, or replace blast furnaces with direct reduced iron (DRI) units powered by natural gas and eventually renewable hydrogen. At this final stage, companies reduce their Scope 1 and 2 GHG emissions to 0.7 t_{CO2e}/t_{steel}.[83] Additionally, direct electrification of steelmaking via iron electrolysis is under development but has not been demonstrated outside laboratories. Given that steel products are bound in industrial assets or construction for decades, scrap availability is limited and a 100% recycling rate seems unlikely. Consequently, replacing coal-powered blast furnaces with DRI units is key to achieving full decarbonisation.[84]

Using natural gas in DRI units already reduces carbon emissions significantly to 1.43 t_{CO2e}/t_{steel}, yet implies continued dependence on fossil-fuel supplies and corresponding supply-chain risks. Given that available volumes of clean hydrogen are still limited, natural gas may nevertheless play a bridging role between reinvestment cycles in the steel industry and the effective deployment of sufficient and affordable clean hydrogen.[85]

Figure 7: The steel-to-wind-turbine value chain



The analysis focuses on the value-chain segments highlighted in dark blue.

* Assuming a recycling rate of 20%

** For onshore wind turbines, a majority of OEMs include EPC services in their offer



IMAGE CREDIT: ADOBE STOCK / ABCDSTOCK

Replacing coal-powered blast furnaces with DRI units is key to achieving full decarbonisation.

As an alternative to switching fuels, steelmakers may also opt to use carbon capture and storage. Analysts, however, do not see the technology playing a major role in the decarbonisation of steel, given the need for new CO_2 infrastructure connecting industrial sites to permanent storage sites, residual GHG emissions due to limited capture rates and leaks, and limited demonstration at scale.[86]

More than half of current steelmaking capacity is expected to be replaced by 2030. Companies therefore need to make investment decisions in favour of low-emission steel technologies in the near future if the steel industry is to comply with the targets of the Paris Agreement and reach net-zero emissions by 2050. Yet more than half of currently planned steel investment worldwide is still focused on new BF-BOF capacity, reflecting a similar share among India's announced projects. Germany's pipeline for steelmaking plants, on the other hand, is fully committed to DRI units combined with EAFs.[87]

While steelmakers need to reinvest heavily in their plants, the downstream value chain must only adjust to pricing and potentially supply geographies. The landscape of downstream users in the wind-power value chain, as well as adjacent segments outside the scope of this report, can be seen in Figure 7. This value chain encompasses the manufacturing of towers, nacelles, and blades, which are assembled by original equipment manufacturers (OEM). For onshore wind turbines, OEMs also typically provide and integrate engineering, procurement, and construction (EPC) services. Within this value chain, 97% of the steel is used for the tower, with the remainder used in the nacelle and foundations.[88]

The impact of hydrogen on wind turbine prices

To gauge the impact of green steel on wind power projects, H2Global considers three scenarios for India and Germany:

- the reference scenario based on BF-BOF technologies using coal (conventional input scenario, or CIS);
- a low-emission scenario (LES) using DRI-EAF technologies with natural gas;
- a renewable input scenario (RIS) producing steel compliant with the Low-Emission Steel Standard (LESS), eliminating 79% of the GHG emissions using DRI-EAF technology with renewable hydrogen.[89]

Following the direct analysis of the impact on steelmaking, the first-pass parametric model groups fossil fuels, electricity, and hydrogen under the category "energy" to simplify presentation, even though coal and hydrogen also act as reducing agents. As steel plants typically use some degree of scrap metal in their processes, and recycling scrap reduces GHG emissions compared to primary steel production, our calculation assumes a 20% recycling rate.

Steel production

Historically, steelmakers expanded production capacity by combining cheap and plentiful energy (mostly in the form of coal) and iron ore to meet demand during rapid industrialisation. This created major production hubs in central Europe, the east coast of the United States, and later China, India, and Brazil. With ambitious decarbonisation targets, supply-chain security, and socio-economic effects in mind, it is important to consider whether the next evolution of steelmaking will repeat this pattern.

Generally, BF-BOF steelmakers face three options. First, they may replace blast furnaces with DRI units and electric arc furnaces at existing sites, replacing coal with hydrogen as an input. Second, they may relocate entire plants to cost-optimal locations with low renewable energy costs in iron-ore-mining countries and export crude steel to demand centres. Third, they may move ironmaking to cost-optimal locations while retaining steelmaking near industrial offtakers, exporting iron or briquetted iron to steel plants.

Each option carries benefits and drawbacks. For advanced economies, the second and third option imply the loss of well-paid manufacturing jobs in exchange for reduced costs. Downstream industries could benefit from such cost reductions, however, potentially creating jobs in other sectors. For emerging and developing economies, such relocations present an opportunity to capture more domestic value and support job creation in countries that often have growing, young populations seeking to reduce youth unemployment.[90]

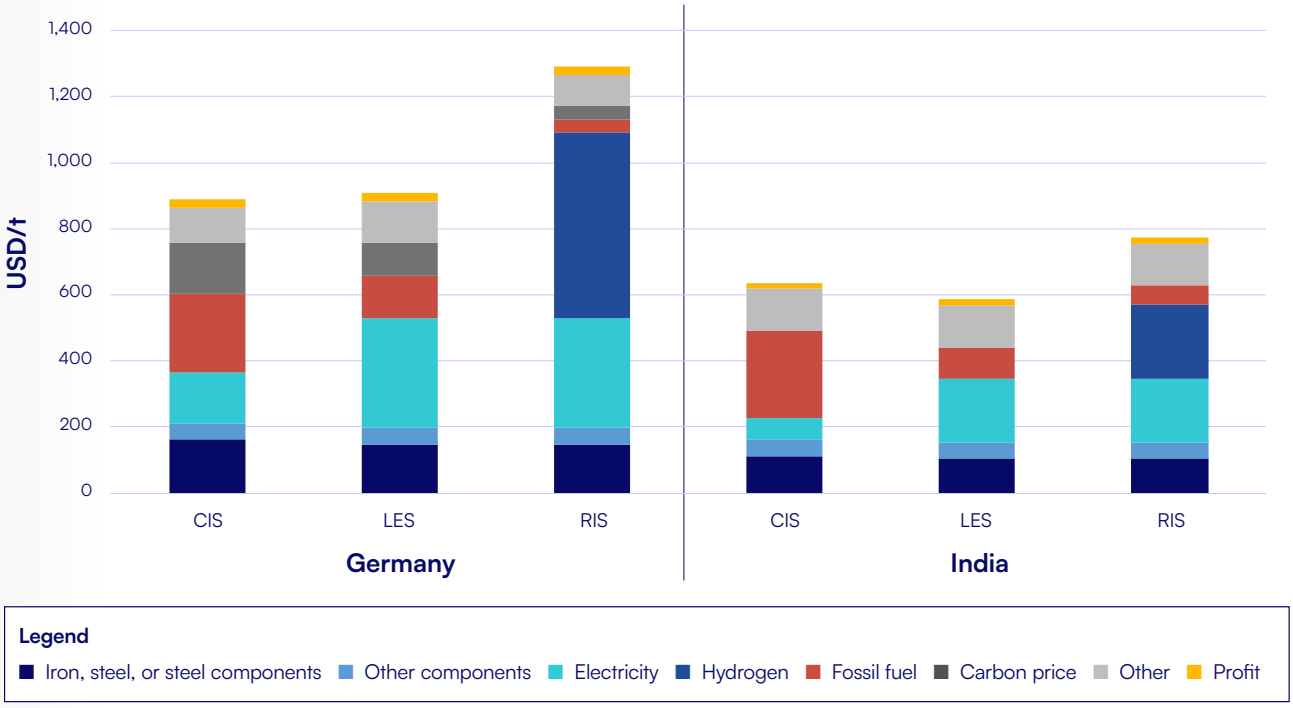
At the same time, established steelmaking nations offer large, skilled workforces and mature industrial ecosystems that facilitate market access and efficient operations. The two options retaining iron- and steelmaking in the same location can also capture thermal efficiencies when integrated with subsequent high-temperature processes such as continuous casting or hot rolling. Additionally, higher financing costs in many prospective green-iron exporting countries may tilt the business case in favour of keeping both stages in existing locations.[91]

For the steel-to-wind-turbine value chain, steel is typically hot-rolled into flat plates, which tower manufacturers subsequently cold-roll into tower segments before welding.



IMAGE CREDIT: ADOBE STOCK / SREERAJ

Figure 8: The cost impact of decarbonisation on steel prices in Germany and India[92]



Source: Authors' calculations based on JRC (2020), IEA (2023), IRENA (2023), WV Stahl (2023), BIR (2025), and BDSV (2026). Costs are for integrated iron- and steelmaking using a 20% recycled scrap input and 80% virgin iron. Iron ore is priced at 90 USD/t (Germany) and USD 51/t (India), and scrap steel at 237 USD/t. Carbon price is set at 80 USD/tCO_2 , with emission intensities of 2.3 t/t for BF-BOF, 1.43 t/t for DRI-EAF with natural gas, and 0.52 t/t for DRI-EAF using hydrogen. Renewable hydrogen costs are based on Box 1.

Given potential synergies from hot-rolling steel at the ironmaking plant, and the geopolitical and socio-economic interests of both India and Germany in retaining a maximum share of the value chain domestically, this report assumes that the full value chain downstream from iron-ore mining operates within India and Germany, respectively.

Figure 9 shows the cost impact of using DRI technologies and renewable hydrogen to decarbonise steel production. Overall, the analysis shows that DRI-H_2 increases steelmaking costs by 45% in Germany and 22% in India. This is notable given the absence of a carbon price in India, whereas German steelmakers pay 80 EUR/t_{CO2} in the CIS scenario, saving 156 EUR/t_{steel} by switching technology and fuel to hydrogen. Without the carbon price, the relative increase for Germany would be around 59%. These cost dynamics further imply that Indian steel becomes more competitive than German steel as producers transition from CIS and LES to RIS steel, with the bilateral cost gap widening from 29% to 40%. These changes are driven primarily by the cost of hydrogen compared with coal, alongside minor effects from increased electricity consumption.

Applying these cost increases to a 6 MW onshore wind turbine project, the effects are significant. For tower manufacturers, steel accounts for around 90% of total costs. Consequently, they are highly sensitive to shifts in global steel prices, which translate almost at a 1:1 ratio into tower costs (see Figure 9 and Figure 10). This sensitivity is lower for turbine OEM-EPCs, who have a more diversified cost structure given other components and higher labour costs (included under "other") due to skill profiles requiring higher education — with labour costs differing significantly between Germany and India. As a result, the cost increase is 19% for German turbine OEM-EPCs and drops 8% for turbine manufacturing in India.

Overall, the analysis shows that DRI-H2 increases steelmaking costs by 45% in Germany and 22% in India.

Under RIS conditions, power companies will face a cost increase of 15% in Germany, whereas Indian power companies' wind-power projects may present a slightly better business case, with a cost increase of 5% compared with conventional wind project. Notably, the LES scenario indicates an increase of only 1% for power companies in Germany, and a 2% cost reduction in India.

Figure 9: The impact of green steel prices on the wind-power value chain in Germany, calculated for a 6 MW onshore wind turbine

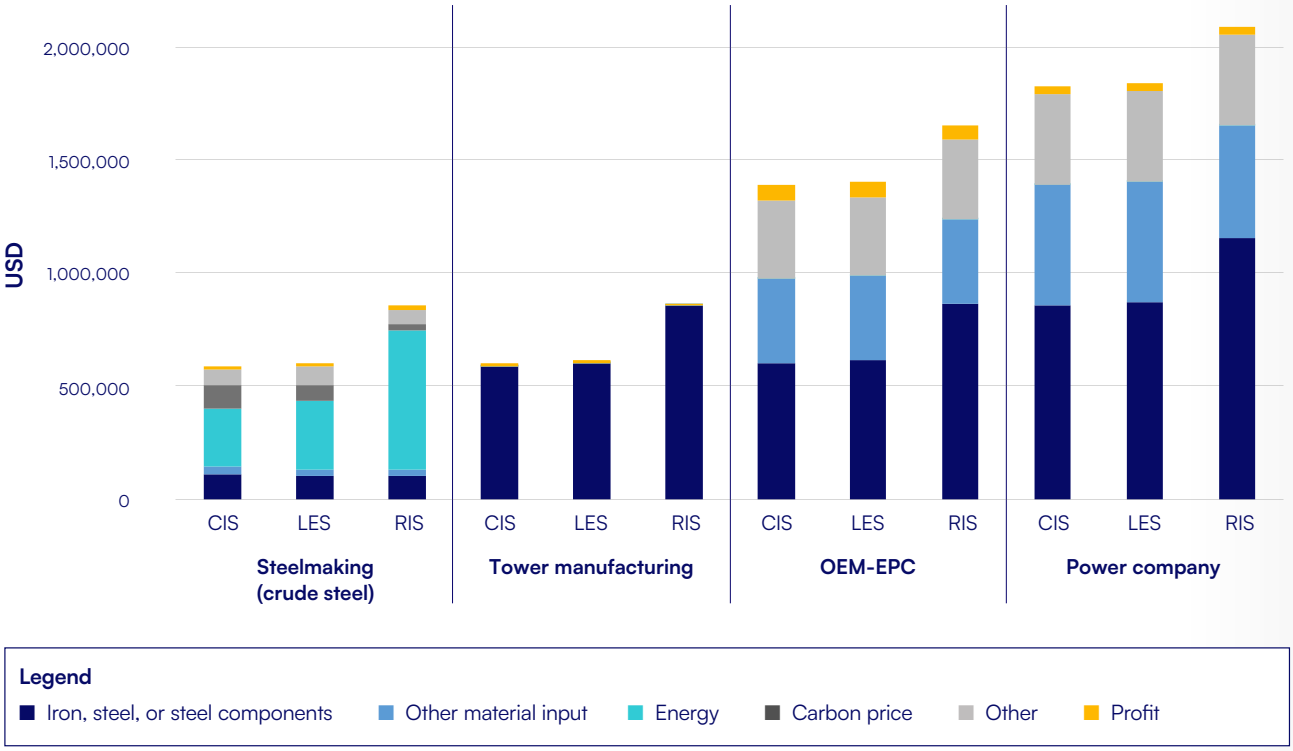
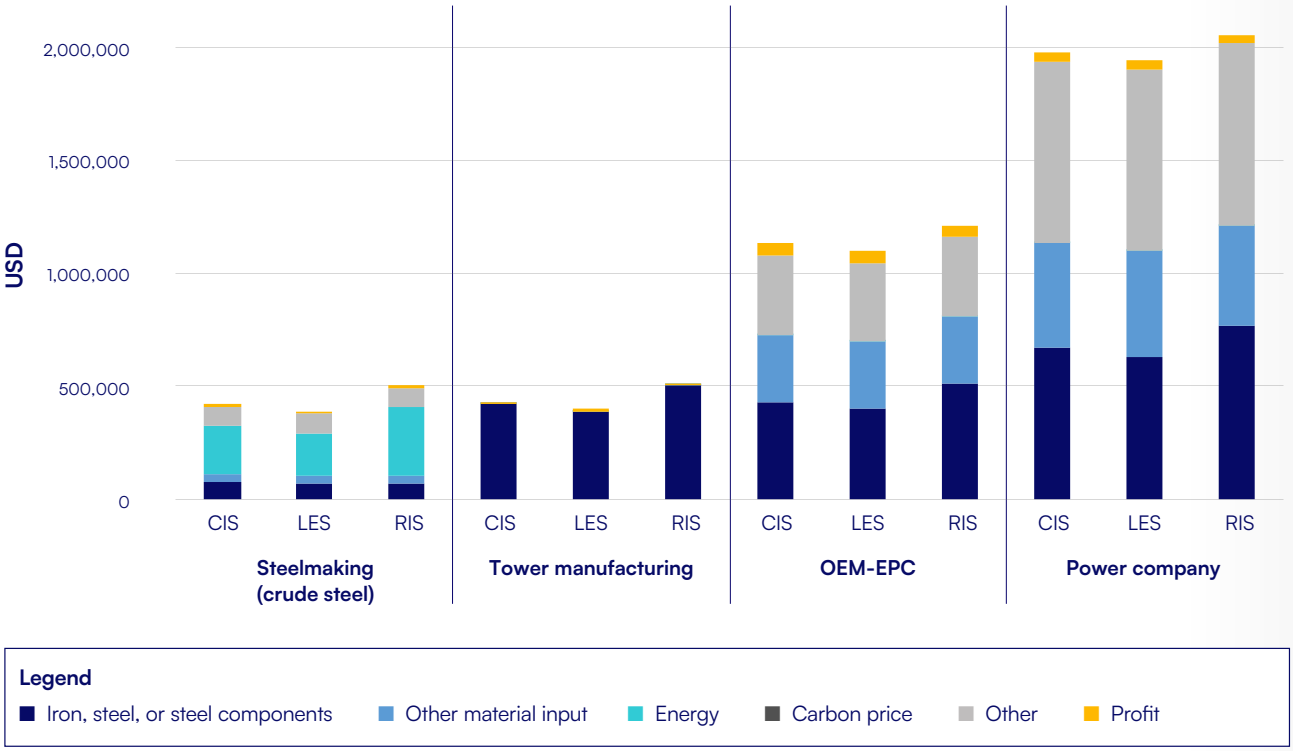


Figure 10: The impact of green steel prices on the wind-power value chain in India, calculated for a 6 MW onshore wind turbine



Sources for Figures 9 and 10: Authors' calculations based on steel costs and assumptions in Figure 8. Electricity prices and profit margins based on IEA (2026), *Electricity 2026*. Other costs and profits of OEM-EPCs are split proportionately between the categories "steel components" and "Other material input" for power companies to retain visibility of the cost of the steel tower. The analysis opted to use the lower-end values of publicly available data for "other material input" and "other" due to significant variation, leaving estimates for total wind turbine cost on the lower end of publicly available data.

From a value-chain perspective, this implies that power companies have the smallest cost gap to cover, while OEMs find themselves in the middle, as the gap requires cost-saving measures or support to match conventional project costs. Meanwhile, tower manufacturers and steelmakers face the **highest cost gaps and would require significant support** to introduce renewable-hydrogen-based solutions. The level of viable and necessary support, however, also hinges on the competitive landscape of each value-chain segment.

Competition in the wind-turbine value chain

Understanding the competitive environment of companies involved in the steel value chain is a prerequisite for assessing their ability to absorb a green premium. Companies exposed to intense competition and operating on narrow margins have little room to navigate increasing cost and depend heavily on a level playing field. Even companies with higher margins may be unable to tolerate significant green premiums if these do not lead to significant additional revenue from increased market access.

Steelmaking: Global overcapacity and high competitive pressure

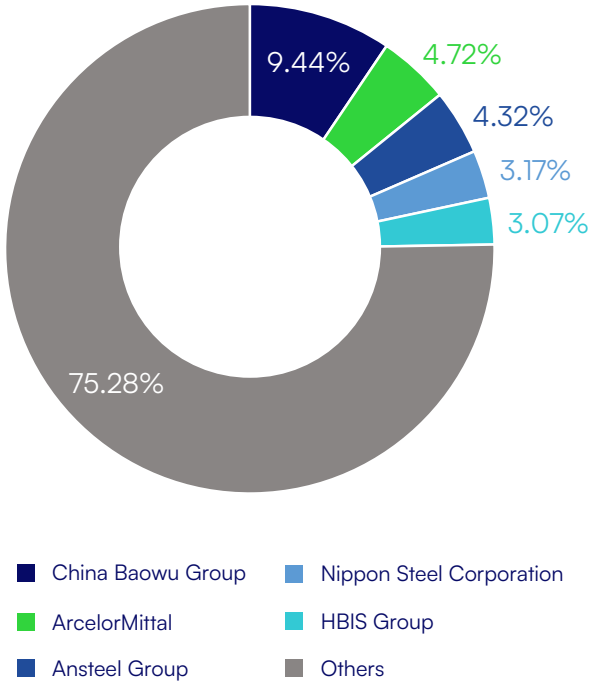
Even though steel exists in different grades, allowing for some degree of specialisation, the metal remains a commodity. This implies a reference price defined by global markets. Like most commodities, steel is consumed in large quantities, meaning that small movements in global prices accumulate quickly and have a significant effect on offtakers.

Global steel markets are valued at about USD 5.2trn, with an annual output of 1.8 Gt of crude steel. This market is dominated by China, which produces two-thirds of the world's crude steel and consumes half of it.

Global steel markets are valued at about USD 5.2trn, with an annual output of 1.8 Gt of crude steel. This market is dominated by China, which produces two-thirds of the world's crude steel and consumes half of it. The market remains highly competitive, with 75 companies producing more than 1 Mt/a. The world's largest steelmaker is the Chinese Baowu Group, holding 9.44% of the market.

Another two Chinese companies are among the top five producers: Ansteel Group (4.32%) and HBIS group (3.07%). However, second place goes to Luxembourg-based ArcelorMittal, with a 4.72% market share, and Japan's Nippon Steel Corporation (3.17%) takes fourth place (see Figure 11).[93]

Figure 11: Global market shares of TOP 5 steelmakers



Despite significant overcapacity, steelmakers are currently planning to add 847 Mt/a of capacity (including 340 Mt/a in BF-BOF) compared with 49 Mt/a of planned BF-BOF plant retirements.[94] Given the long lifespan of steel plants, policy makers need to act quickly to shift momentum in the global steel industry to improve industrial resilience and meet decarbonisation targets aligned with the Paris Agreement.

The German steel market is characterised by declining steel demand, which stood at around 27.1 Mt in 2024, with the five largest producers (thyssenkrupp, Salzgitter, ArcelorMittal, HKM, and Dillinger Hüttenwerke) accounting for an 85% market share. Production sites in Germany are exposed to high energy and labour costs, and steelmakers have responded to competitive pressure by specialising in high-quality steel grades; 59% of these are used in industrial manufacturing, ranging from automotive applications to wind-turbine tower manufacturing. Given this specialisation, Germany is significantly involved in the international crude-steel trade, importing about 18 Mt/a of mostly lower- and intermediate-grade steel while exporting about 23 Mt/a of high-grade steel.[95]



IMAGE CREDIT: ADOBE STOCK / TOM

Regarding decarbonisation strategies, the pipeline for new or replacement steelmaking capacity relies fully on EAFs (>12 Mt/a), while ironmaking is focused entirely on DRI (>5 Mt/a). As announced steelmaking projects exceed ironmaking projects, more than half of the projects clearly focus on the recycling route. ArcelorMittal also announced in 2025 that it will shelve all plans to build hydrogen DRI plants in Germany, despite being classified as an Important Project of Common European Interest (IPCEI) and receiving substantial CAPEX support.[96] Germany's largest steel producer, thyssenkrupp, is reassessing its strategy regarding the use of hydrogen, but has received a EUR 2bn support grant from the EU's IPCEI scheme. Salzgitter, receiving IPCEI support worth EUR 1bn, meanwhile signed an initial 10,000 t/a offtake agreement for renewable hydrogen with EWE, which will cover 6.5% of Salzgitter's clean hydrogen demand.[97]

India's steel market experiences high annual growth supported by an ambitious federal government steel strategy. The market is less concentrated than Germany's, but the five largest producers (JSW Steel, Tata Steel, Jindal Steel and Power, Jindal Stainless, and SAIL) still account for around 68% of capacity. Demand in India is driven mostly by construction— including large-scale transport, industrial, and energy infrastructure—and to some extent manufacturing. In addition, India also has large iron-ore reserves of its own and is the second-largest iron-mining country globally. With direct access to domestic iron reserves and diversified steel production covering grades suitable for all main offtakes in India, domestic steel production is largely self-reliant. The country nonetheless imports 9.7 Mt/a of mostly high-grade steel and exports 11.5 Mt/a of mostly basic and intermediate-grade crude steel.[98]

Steelmakers in India are also considering different routes for decarbonisation to retain access to export markets and comply with domestic clean air policies. For the most part, Indian steel plants are looking to expand the already notable capacity (14 Mt/a) of induction furnaces, which have the potential to increase the use of steel scrap. In absolute terms, India also has the largest announced DRI capacity under development in a single country (37.8 Mt/a), two-thirds of which still plans to use coal as a reducing agent. DRI capacity also represents only about 20% of planned capacity additions, which still prioritise BF-BOF development. The government of India is positioning itself as a leading country in decarbonising steel and has adopted a legal definition of green steel as a first mover. However, the chosen emission threshold of 2.2 t_{CO2e}/t_{steel} sits only slightly below the global average emission intensity for coal-fired BF-BOF.[99]

Given the expected cost increase from switching to DRI technologies, it is important to understand how sensitive steel users are to increases in steel prices. Economic studies covering price elasticities from 1960 to 2015 indicate that the fundamental role of steel in industrial manufacturing and infrastructure means that a sector-wide 10% cost increase would reduce demand at the new price level by only 1% to 2%. Conversely, the pricing power of individual steel producers is usually very limited because of the high substitutability of steel products and intense global competition. This implies that a transition of the steel sector depends heavily on a level playing field, with rules encouraging transformative investments throughout the industry simultaneously.[100]

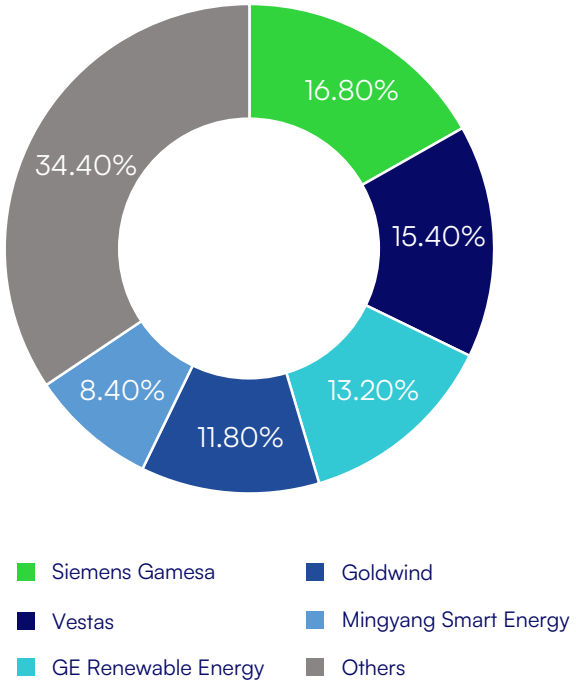
Overall, the German steel market is driven by high-quality products for industrial manufacturing in a stagnating market, facing a structural cost disadvantage because of energy costs. The Indian steel market, by contrast, is driven by high growth rates, cheap energy access, and a focus on construction, including complex infrastructure and energy projects. Indian steelmakers are nevertheless competing with Chinese and other steelmakers with similar specialisations. Given the average profit margins of the sector, this implies very limited financial space to decarbonise production.

Wind turbine manufacturing: Dominance of Chinese and Western companies

The value chain downstream from steelmaking is integrated to varying degrees, requiring a joint analysis of tower manufacturing, turbine assembly, and EPC contractors. Especially in onshore wind power, turbine OEMs often act as EPC contractors and thus as commercial integrators. OEMs may also be partially invested in tower manufacturing or license their technology to tower manufacturers if the tower and nacelle are part of an integrated design. This is the case, for example, with Nordex and Enercon.[101]

As the steel tower is an essential component of a wind turbine, price increases have a very limited effect on economy-wide demand for wind towers. This is also due to the lower cost share of the tower compared with the combined cost of the nacelle, blades, and the OEM-EPCs own costs.[102] OEM-EPCs operating in advanced economies have, however, shown that they are willing to switch to imported towers in response to price increases. In practice, a 1% increase in the price of locally produced wind towers relative to imported towers leads to a 3% to 5% increase in the ratio of imported to domestically produced towers purchased. This elasticity is likely to be lower in India, as the country protects its domestic industry through a 30% import tariff on wind turbine components.[103] Consequently, tower manufacturers depend on the appetite of OEM-EPCs to purchase green steel towers.

Figure 12: Global market shares of top 5 wind-turbine OEMs



The global market for wind turbines is valued at about USD 85bn and is highly concentrated, with the five largest companies accounting for about 65% of the market (see Figure 12). Western OEMs dominate the market — including Siemens Gamesa, Vestas, and GE Renewable Energy (alongside Nordex SE and Enercon, ranking seventh and ninth, respectively) — closely followed by Chinese OEMs (Goldwind, Mingyang Smart Energy, and Suzlon Energy). Importantly, wind turbines are often manufactured and assembled as close as possible to the final installation site to minimise the complexity and risks of transporting outsized components.[104]

Within the wind-power sector, onshore installations account for 73.5% of total market value.

Within the wind-power sector, onshore installations account for 73.5% of total market value and are expanding at an 8.5% annual growth rate, adding more than 170 GW/a to global capacity. This growth is mostly driven by public decarbonisation targets across the power sector (including municipal energy procurement), corporate clean-energy procurement driven by economic growth and data centres, and falling procurement costs.

In many regions, repowering existing wind farms and installing next-generation multi-megawatt turbines with rated capacities of 5-8 MW represent the dominant development pathway.[105]

Germany's wind-power sector is valued at USD 1.3bn (EUR 1.2bn) and, at 7.5%, is growing slightly slower than the global average. The country is the world's second-largest exporter of wind turbines. In 2025, it exported turbines with a combined installed capacity of 1.4 GW to world markets while importing 0.2 GW, predominantly from neighbouring countries. The domestic market is highly concentrated, with only six manufacturers selling wind turbines in 2025. Among the six, these firms dominate: Nordex SE, Vestas, and Enercon each hold approximately 30% of the market.[106]

India's existing wind-power capacity is currently entirely onshore.

India's existing wind-power capacity is currently entirely onshore; offshore projects are only now committing investments. The market is currently valued at USD 18.7bn (EUR 17.2bn). The fast-growing market (12% in 2025) is dominated by five companies with a country-wide impact led by India's own turbine OEM Suzlon Energy (25%), followed by a TPG-led consortium taking over former Siemens Gamesa market shares (16%), Envision (12%), GE Renewable Energy (8%), and Wind World India (7%). Developments in the Indian market have, however, been dynamic over the last decade, with frequent shifts in market shares. For India, off-grid renewable-hydrogen projects are expected to drive wind-power capacity expansion in addition to hybrid renewable tenders and data centre demand. Additionally, the states of Gujarat, Tamil Nadu, and Karnataka compel power companies to source wind power as part of their energy mix, guaranteeing offtake.[107]

The different competitive environments result in a striking contrast of cost effects between regional markets. In Asia, a 10% decline in costs for wind turbines is associated with an approximately 23% increase in annual deployment, whereas the same cost reduction is associated with an increase of only around 5% in Europe — with inverse effects for cost increases.[108] This suggests that Europe has a greater willingness and structural capacity to absorb higher costs, whereas the expansion of onshore wind in Asia remains more dependent on strict cost management.

An upward cost shock, such as one introduced through a green-steel mandate, would therefore be expected to have a stronger relative effect on deployment in Asia than in Europe.

In comparison, both the Indian and German wind-turbine markets are expanding quickly, with the German market being more concentrated among established competitors and the Indian market being highly dynamic. Government tenders and incentives play a big role in driving market development. The rapid growth of the sector may provide room for a green-steel-based niche to develop in both markets as well. The very volatile Indian sector, however, strongly prioritises cost advantages and local production over other aspects like durability, recyclability, and reduction of Scope 3 emissions, as demonstrated by the retreat of Siemens Gamesa from India's onshore market.

Key Takeaways

Steelmakers and tower manufacturers appear to be the stakeholders least able to absorb the green premium associated with renewable-hydrogen-based steel. Steelmakers operate in highly competitive global commodity markets and have limited pricing power, while transitioning to DRI-based production substantially increases production costs. In the scenarios assessed in this report, renewable-hydrogen-based steel raises steelmaking costs by approximately 45% in Germany and 22% in India. Tower manufacturers face similar exposure: steel accounts for around 90% of their production costs, meaning that higher steel prices translate almost directly into higher tower costs.

The ability to absorb the premium improves further downstream. Turbine OEM-EPCs have a more diversified cost structure, reducing the relative impact of higher steel prices to around 19% in Germany and 8% in India. For power companies, the effect is smaller still, with renewable-hydrogen-based steel increasing wind-project costs by approximately 15% in Germany and 5% in India. This suggests that the cost premium becomes increasingly diluted along the value chain, even though the absolute investment required remains significant.

Competitive conditions nevertheless constrain the extent to which these costs can be passed downstream. Individual steelmakers have little room to raise prices above international market levels, while tower manufacturers face the risk that OEMs will switch to lower-cost imported alternatives. This is particularly relevant in Germany and other open markets, where tower imports respond strongly to relative price differences. India is somewhat more protected by import tariffs, but its wind market is highly cost-sensitive and rapid deployment remains strongly dependent on low project costs.



IMAGE CREDIT: ADOBE STOCK / SYMBIOT

Overall, the analysis indicates that the green premium cannot be expected to be absorbed primarily by steelmakers or tower manufacturers under current market conditions. The strongest capacity to absorb additional costs lies further downstream, particularly with OEMs and power companies, but this willingness to pay does not automatically translate into stable demand for green steel.

Creating a reliable market therefore depends on mechanisms that transmit demand for lower-emission wind power upstream to steel producers, while maintaining a level playing field between competing producers and technologies.



IMAGE CREDIT: ADOBE STOCK / ZAKIR HOSSAIN



4

Instruments to support green premium transfer

Both fertiliser-to-plate and steel-to-wind-turbine value chains face significant barriers to recovering the green premium associated with the use of clean hydrogen. Market developments alone will not achieve significant and timely progress towards cleaner production or reduce reliance on fossil-fuel supply chains. Policymakers must therefore support the industry in a targeted way, allocating resources effectively and efficiently without distorting competition.

The key challenges for these value chains are:

- The fertiliser-to-plate value chain for rice faces high added costs at the ammonia and urea production stages, alongside a highly fragmented downstream market that complicates coordination and traceability.
- In the steel-to-wind-turbine value chain, high added costs for steelmakers, combined with intense international competition, coincide with a lack of commercial incentive to decarbonise steel production for wind turbines — as clean energy regulations assume zero GHG emissions for clean energy.

Overcoming these challenges will accelerate the uptake of clean hydrogen across industry. Support instruments tailored to the specific needs of each sector can unlock larger volumes of clean-hydrogen supply.

Standards and certification as an enabling condition

Support instruments rely on enabling regulation to be effective. First, companies need predictable rules to give them planning security. Predictability does not require immutable regulation, but key elements of the framework should remain stable to allow viable business cases to develop. Second, companies need clear and preferably internationally recognised standards for a product's environmental attributes. These must begin with definitions of clean hydrogen and its derivatives, and extend to green steel, and steel-based products, clean fertilisers, and sustainable food. Practical designs for value-chain-of-custody systems and certification are also part of this set-up.[109]

Standards and certification can facilitate global markets and international trade by providing a common basis for verifying product characteristics and sustainability claims. They allow products to be differentiated according to defined criteria and can support cross-border trade by improving comparability and reducing uncertainty for buyers. This is particularly important for products already traded as global commodities, such as ammonia, where compatibility and interoperability across certification schemes are critical.[110]

Support instruments rely on enabling regulation to be effective. First, companies need predictable rules to give them planning security. Predictability does not require immutable regulation, but key elements of the framework should remain stable to allow viable business cases to develop.

Certification systems should also extend beyond the hydrogen derivative itself to capture relevant information across the downstream value chain. This ensures that end products, such as fertilisers or steel-based products, demonstrably retain the environmental attributes of the low-emission hydrogen used in their production. At the same time, implementing these systems can impose additional



IMAGE CREDIT: ADOBE STOCK / ANATOLIYCHERKAS

burdens on farmers and other value-chain actors, including audit and inspection fees, documentation requirements, and the need for appropriate infrastructure and technology.[111]

Certification requirements and compliance challenges may differ across value chains depending on the size and number of products involved, as well as the number and profile of the actors involved. In the rice value chain, for example, certification may be required at the level of individual smallholders and it demands systems that remain stable over time to handle high-frequency consumer purchases. By contrast, the wind-turbine value chain involves larger, higher-value products traded in much smaller quantities among a limited number of industrial actors. Certification in this context may involve fewer products and actors, creating fundamentally different compliance and traceability considerations.

High fragmentation in some value-chain segments can further complicate certification. This is particularly evident in upstream rice production in India, where large numbers of farmers and millers need to be monitored and their product characteristics tracked throughout the value chain. For export-oriented supply chains, contract farming could help address this challenge by aggregating farmers, thereby streamlining data collection, monitoring, and compliance. By contrast, the wind-turbine value chain is less fragmented, with fewer actors involved in the relevant segments, potentially making certification and traceability more manageable.

If the low- or zero-emission characteristics of a product cannot be reliably demonstrated and verified, demand-side instruments will have limited effect. Standards and certification are therefore essential not only to ensure environmental integrity, but also to enable the market mechanisms that seek to create demand for products made with low-emission hydrogen.

Instrumental links in the value chain

To address market-introduction challenges, governments can choose from a menu of instruments. In 2025, H2Global assessed 31 instruments targeting direct hydrogen offtakers. That analysis showed that regulatory "sticks" like quotas and carbon pricing have a broad impact across multiple risks, while narrower economic "carrots" like double-sided auctions (DSAs), contracts-for-difference (CfDs), and CAPEX support effectively complement them. Policymakers are therefore advised to use a nested approach to support direct hydrogen offtakers.[112]

For this report, the analysis quantifies the volume of hydrogen that could be mobilised by instruments identified in H2Global's 2025 demand report as having medium-to-high effectiveness in supporting clean-hydrogen uptake. The assessment here excludes enabling conditions and focuses strictly on government-sponsored instruments (see Table 3). To keep the analysis clear, the report focuses on one instrument per group.[113]

Each instrument has specific preconditions for effective deployment. Carbon pricing, for example, is most effective in industries with high GHG emissions intensity. For the demand-side value chains assessed here, this primarily targets upstream hydrogen users (steelmakers and fertiliser producers). Similarly, DSAs and CfDs are most rapplicable where the cost gap between conventional and low-emission production is particularly pronounced, as is the case for urea and steelmaking.

Table 3: Selection of support instruments for clean hydrogen offtakers

Instrument group	Effectiveness score 2025[114]	Government-sponsored instrument	Included for modelling
Quota/mandate/bans	4.4	yes	yes
Carbon pricing (ETS, CBAM, carbon tax)	4.0	yes	yes
Political risk insurance	3.8	no	no
DSA / CfD	3.4	yes	yes
(Private) demand aggregation	3.3	no	no

Notes: The 2025 effectiveness score assigned an index value from 1 to 5 based on instrument performance across eight risk categories. The table includes only instruments with an effectiveness score greater than 3 that were not treated as enabling conditions in the original report. It excludes instruments that primarily improve general market conditions without directly affecting the cost gap. Public procurement is also excluded as governments do not directly purchase the products assessed in this report.

Each instrument was assessed for its applicable value-chain segments in light of market structures, implementation costs, and, where relevant, competitive effects, and its impact on hydrogen demand. Reflecting market and technical conditions as of August 2026, the evaluation aims to provide a broad estimate of what each instrument costs to implement rather than only its direct impact on targeted producers. Who exactly bears these costs depends on the instrument chosen, where in the value chain it takes effect, and whether subsequent subsidy regimes absorb part of the burden.

Quotas for using clean hydrogen

Quotas and mandates were identified as the most effective instruments to cover the various risks of offtakers in the 2025 H2Global analysis. Although quotas face high political hurdles given that they constitute a stark intervention in the decision-making of companies, they add a lot of value as they level the playing field for all participants. The equal obligation to use a certain share of clean hydrogen as a feedstock or fuel simultaneously imposes the same cost increase on all participants targeting the regulating jurisdiction as a market.

Costs for the industry would increase by USD 1.78—6.71bn, equivalent to 15—55% of the USD 12.26bn budget of the Ministry of Chemicals and Fertilizers allocated for the urea subsidy in 2026—27.[117]

To gauge the impact that quotas would have on hydrogen supplies, the report compares three ambition levels embedded in quotas of 11.2%, 25%, and 42%. The lowest ambition level serves as a lower-barrier entry point corresponding to the goal of India's National Hydrogen Mission to substitute fossil ammonia imports of 3 Mt/a with domestic renewable ammonia production.[115] The other two ambition levels represent quotas discussed in the proposed Industrial Acceleration Act of the EU (IAA) and established through the industry quota in the third Renewable Energy Directive (RED III). The three ambition levels were applied to both the ammonia and steel cases to enhance comparability.[116]

For the hydrogen-ammonia-urea segment, applying a modest quota of 11.2% renewable production to the urea sector would yield 3 Mt_{urea}/a. This corresponds to 0.3 Mt_{H2}/a, compared to 1.1 Mt_{H2}/a in the case of a 42% quota (see Table 4). Compared to the 5 Mt/a domestic hydrogen production target of the National Green Hydrogen Mission, this would account for 6—22% of this target.

Costs for the industry would increase by USD 1.78—6.71bn, equivalent to 15—55% of the USD 12.26bn budget of the Ministry of Chemicals and Fertilizers allocated for the urea subsidy in 2026—27.[117] Even though the quota does not inflict direct costs on the Indian government, the increase in production costs would indirectly affect its budget through the MRP. While India's budget might be able to absorb the costs associated with a lower quota, higher quotas would potentially require buy-in from advanced economies or multilateral financial institutions willing to support the decarbonisation of rice production while keeping end-user prices stable.

Table 4: Effects of renewable hydrogen quotas in urea production

Effect	Quota		
	11.2%	25%	42%
Induced renewable urea production (Mt/a)	3.0	6.7	11.3
Induced renewable ammonia demand (Mt/a)	1.7	3.8	6.4
Induced renewable hydrogen demand (kt_{H_2}/a)	304	681	1,144
CO_2 avoided (Mt_{CO_2e}/a)	1.3	2.9	4.9
Additional annual cost of urea (mn USD/a)	1,800	4,000	6,700

Cost of abatement derived from analyses in Chapter 2.



IMAGE CREDIT: ADOBE STOCK / CHAOSAMRAN_STUDIO

In the case of steel, the quota needs to be fulfilled by onshore wind-power OEMs. For comparability, ambition levels were applied to an annual onshore wind capacity addition of 6 GW, which aligns with the 5.79 GW and 6.06 GW Germany and India built in 2025.[118] A quota of 11.2% clean production applied to the steel sector would require 300,000 t/a in steel, implying 16,000 t/a in hydrogen. This rises to 1,100,000 t_{steel}/a, and 60,000 t_{H2}/a under a 42% quota, respectively (see Table 5).

Total steel costs would increase by USD 41—318mn, depending on the ambition level and in which of the two countries the steel was produced. Compared with the additional costs derived from quotas in the ammonia sector, these figures are almost negligible, reflecting the relative size of the two markets. It means, however, that a quota could help decarbonise wind-turbine manufacturing significantly at manageable cost, while providing anchor demand for first-mover steel plants. The 11.2% quota, for example, could cover 13—33% of the capacity of a medium-sized steel plant in Germany.[119]

Carbon pricing

Instead of prescribing the use of hydrogen, governments can use carbon pricing to incentivise companies to switch to less carbon-intensive technologies. While India does not yet apply a carbon price to products in either the fertiliser-to-plate or steel-to-wind-turbine value chains,[120] Germany, as an EU member state, has both an established emissions trading system and a carbon border adjustment mechanism.

Table 5: Effects of clean hydrogen quotas in steel production

Effect	Quota		
	11.2%	25%	42%
Induced green steel production (Mt/a)	0.3	0.7	1.1
Induced clean hydrogen demand (kt_{H_2}/a)	16	36	60
CO_2 avoided (Mt_{CO_2e}/a)	0.5	1.2	2.0
Additional annual cost of steel in Germany (million USD/a)	84	189	318
Additional annual cost of steel in India (million USD/a)	41	93	155

Cost of abatement derived from analyses in Chapter 3.

As companies can choose which technologies to deploy, a sufficiently high carbon price will not necessarily translate directly into clean-hydrogen uptake across industry. Steelmakers, for example, may instead invest in recycling capacity. Modelling complex substitution processes lies beyond the scope of this report. Instead, the simplified analysis below illustrates the carbon price required to establish cost parity with conventional technologies in both value chains. Assuming that all plant retrofits switch to clean-hydrogen technologies once parity is reached, and that half of eligible plants complete the transition by 2030, this create annual demand of 1,362 kt_{H2} for urea production and 72 kt_{H2} for wind-turbine steel.

As companies can choose which technologies to deploy, a sufficiently high carbon price will not necessarily translate directly into clean-hydrogen uptake across industry.

Urea production has a carbon intensity of 1.80 t_{CO_2e}/t (steam reforming without CCUS), 0.94 t_{CO_2e}/t (steam reforming with CCUS), or 0.73 t_{CO_2e}/t (electrolysis-based hydrogen feedstock with carbon sourced from nearby fossil-fuel industries). As shown in Figure 13, a carbon price of 139 USD/t_{CO_2e} for low-emission urea and 555 USD/t_{CO_2e} for renewable urea would bridge this gap.

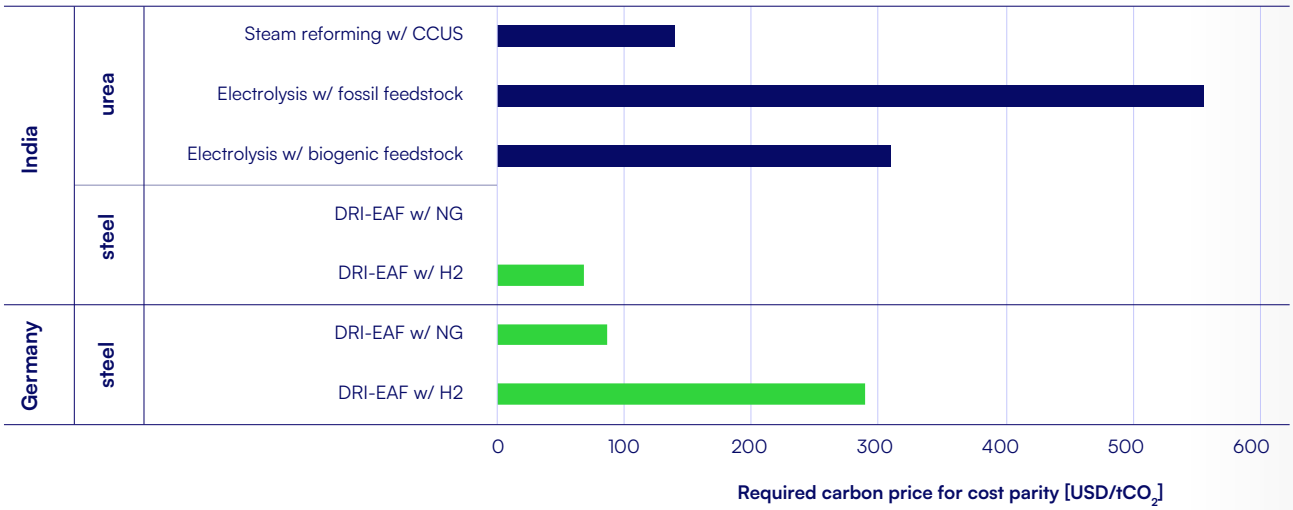
Renewable urea sourced with biogenic CO_2 would require a carbon price of 310 USD/t_{CO2e} to reach cost parity.

Low-emission urea production using CCUS technologies mitigates 80% of emissions at 20% of the additional cost of a fully renewable route. For producers using conventional methods, retrofitting CCUS assets is an obvious first step to comply with rising carbon prices. For Indian fertiliser producers, this applies not only to the domestic market, but also to potential exports to the EU, which would face equivalent carbon costs under the CBAM.

India's Carbon Credit Trading Scheme (CCTS) entered into force in April 2025, initially covering nine energy-intensive sectors, including fertilisers. Instead of setting absolute emission allowances like the EU ETS, the Indian scheme targets carbon intensity. The Ministry of Environment, Forest and Climate Change has, however, published intensity targets for only seven of the nine sectors, omitting fertilisers and iron and steel. Carbon prices under the Indian mechanism remain unknown at the time of writing, with the first CCTS transactions on domestic power exchanges expected in late 2026. Even current EU ETS prices, ranging between 80—95 EUR/$t_{CO2,}$ fall short of the carbon prices needed to reach cost parity.[121]

For steel, the gap between current EU ETS prices and the carbon prices for cost parity is much narrower. At a carbon intensity of 2.3 t_{CO2}/t for conventional steel and 0.52 t_{CO2}/t for green steel, the carbon price would need to reach 69 USD/t_{CO2} (India) and 290 USD/t_{CO2} (Germany), respectively, to close the cost difference at current input prices.

Figure 13: Carbon prices needed to reach cost parity in the steel-to-wind-turbine and fertiliser-to-plate value chains



Source: Authors' calculations based on cost developments in Chapters 2 and 3.

At the time of writing, the European ETS price stands at 95 USD/t_{CO2}, up from an average of 83 USD/t_{CO2} in 2025. Thus, it is very unlikely the ETS price will reach 200 USD/t_{CO2} in the near term, especially in the light of current political debates around implementing a slower phase-out of free allowances.[122]

The carbon price would need to reach 69 USD/tCO_2 (India) and 290 USD/tCO_2 (Germany), respectively, to close the cost difference at current input prices.

The government of India is currently considering a proposal for mandated emissions reductions relative to baseline-year levels for steel plants. Companies that overachieve their reduction targets could sell surplus credits to underperforming peers to help them avoid penalties. However, given the modest reduction target of 2.1—9.3% discussed in this proposal and its focus a single target year, this mechanism is unlikely to generate self-sustaining momentum.[123] While further reduction targets are planned, they are not included in the current draft.

Consequently, carbon prices in both countries is unlikely to bridge the full cost difference. Hydrogen accounts for more than 40% of green-steel production costs. India has a cost advantage in renewable hydrogen, but not in the fossil fuels used in conventional steelmaking. The cost gap between green and conventional steel is therefore narrower in India than in Germany, as is the carbon price required to achieve parity.

Double-sided auctions

In nascent markets, initial production costs are high and typically decline over time as economies of scale and learning effects take hold. Because offtakers have limited willingness to pay, a substantial gap emerges between production costs and market prices. A double-sided auction (DSA) bridges this gap using grants from public funding bodies or philanthropic donors.

For this analysis, the DSA emulates the design of the H2Global pilot auction, where a trading intermediary trades clean hydrogen derivatives based on competitive tenders.

The most competitive supplier wins a long-term offtake contract. The intermediary then sells the purchased product through short-term sales agreements in a series of demand-side auctions.[124] This approach generates the strongest competition for products with a strong commodity characteristic, making it most applicable at the stage of fertiliser and steel making in the two value chains analysed here.



IMAGE CREDIT: ADOBE STOCK / ATTACHAI

The analysis models three scenarios for a USD 1bn (EUR 920mn) grant disbursed over a ten-year period. It considers steel supply and offtake in Germany alongside fertiliser supply and offtake in India. In the first scenario, offtakers consistently bid at the conventional reference price, leaving the intermediary to absorb the entire green premium. The second scenario assumes offtakers are willing to pay 50% of the cost gap by year ten, while the third assumes near-complete coverage at 90% in the tenth year. Sales revenues allow the trading intermediary to exercise options to purchase additional contracted volumes from suppliers. As producers show markedly different appetites for volume risk, the analysis distinguishes between two hypothetical bids that offered optional volumes of 100% and 300% of the firm base volume per year, respectively.

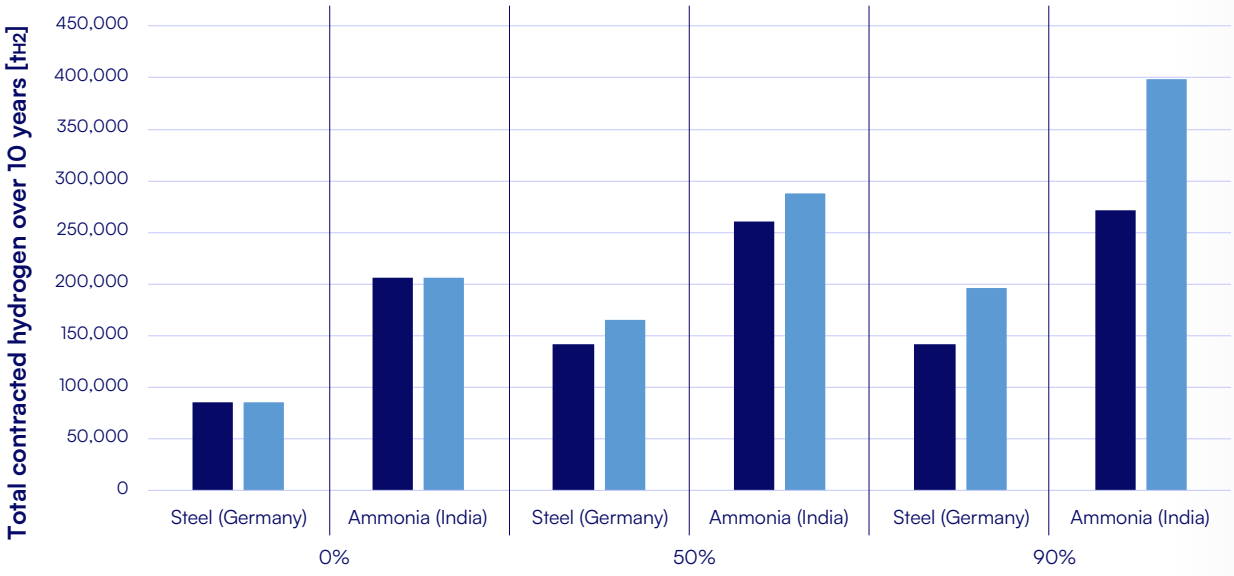
A double-sided auction (DSA) bridges this gap using grants from public funding bodies or philanthropic donors.

If the trading intermediary recovers only the conventional price, the optional volumes it can draw remain identical across all scenarios, totalling 85,657 t in the German case modelled here (see Figure 14). This volume of hydrogen is equivalent to 1.59 Mt of steel — roughly 14% of the capacity of thyssenkrupp's steel plant in Duisburg, North Rhine-Westfalia. If the offtaker were to produce ammonia and urea instead, they would be able to synthesize 482,302 t of ammonia and 846,145 t of urea, with the latter equivalent to approximately 73% of the annual urea production at the Yara Babrala plant in Uttar Pradesh, India.[125]

In India, the same budget would secure a significantly larger volume of hydrogen: 205 kt, or almost 2.5 times that procured in Germany. This factor, however, decreases to about 1.8 times in the scenario where the intermediary recoups half the green premium in the final sales auction. Indian steelmakers will provide 1.9 to 2.0 times the hydrogen capacity in the case that offtakers pay 90% of the green premium by year ten. In this last scenario, contracted total hydrogen supply reaches between 142 kt (Germany with 100% optional volume) and 400 kt (India with 300% optional volume).

Overall, a DSA achieves its highest impact where a closing price gap matches a significant optional volume. Accompanying regulation that drives offtakers' willingness to pay over time is therefore essential to maximise the efficiency of public spending.

Figure 14: Total hydrogen supply contracted over 10 years through a DSA



Source: Authors' calculations based on the analyses in Chapters 2 and 3. Baseline conventional costs at current market prices for ammonia (707 USD/t)

Box 3: CAPEX support for steel plants

Capital expenditure (CAPEX) support is the most direct way to create clean-steel production capacity. Few projects worldwide that plan to use renewable hydrogen in steelmaking have progressed beyond FID, and all have received significant support. Indeed, no clean steel projects aiming to use clean hydrogen has reached FID without CAPEX support. Governments have committed grants covering 9.5% and 56.5% of CAPEX for several prominent projects, including the DRI Vijayanagar Steel Unit (India), JSW Rayalaseema Steel (India), Power4Steel (Germany), SALCOS (Germany), Stegra (Sweden), and tkH2Steel (Germany).

The Power4Steel project in south-western Germany received the highest subsidy — almost USD 3bn for a capacity of 3.5 Mt/a — whereas the Vijayanagar plant received just USD 20mn, albeit for a subsidised steelmaking capacity of only 0.05 Mt/a. Higher support levels broadly correlate with higher domestic energy costs, reflecting government efforts to preserve local steelmaking capacity for strategic resilience.

Apart from the Stegra project, which is designed to operate entirely on renewable hydrogen from the outset, these projects plan to phase renewable hydrogen into their production processes gradually, depending on hydrogen availability and prices as well as market prices for green steel.

Key takeaways

Quotas provide the clearest route to creating sizeable and predictable clean hydrogen demand, but their cost implications differ substantially across value chains. In the urea sector, renewable hydrogen quotas of 11.2-42% would mobilize approximately 304-1,144 kt_{H_2} per year, corresponding to 6-22% of India's 5 Mt domestic hydrogen production target. This would come at an additional annual industry cost of approximately USD 1,780-6,710mn, with higher quota levels potentially requiring additional financial support to avoid passing costs through to end users. In wind-turbine steel, the same quota levels would mobilize a much smaller 16-60 kt_{H_2} per year, reflecting the smaller size of the market, while increasing annual steel costs by approximately USD 41-318mn depending on the quota level and production location. The analysis therefore suggests that quotas can generate substantial anchor demand for clean hydrogen, particularly in fertiliser production, while the comparatively moderate absolute cost in the wind-turbine steel value chain makes quotas a potentially manageable instrument for supporting first-mover green steel plants.

Carbon pricing could theoretically mobilize even larger annual hydrogen volumes, but only at carbon prices significantly above current levels. Under the report's simplifying assumption that half of eligible plants could switch to clean-hydrogen technologies by 2030 once cost parity is reached, carbon pricing could support around 1,362 kt_{H_2} per year in urea production and 72 kt_{H_2} per year in wind-turbine steel. Achieving these volumes, however, requires carbon prices sufficiently high to close the cost gap with conventional production. For urea, the required price ranges from 139 USD/t_{CO_2e} for CCUS-based production to 555 USD/t_{CO_2e} for renewable urea using fossil carbon, with renewable urea using biogenic CO_2 requiring about 310 USD/t_{CO_2e}. For steel, cost parity requires approximately 104 USD/t_{CO_2} in India and 213 USD/t_{CO_2} in Germany. These levels remain above prevailing carbon prices, particularly for fully renewable urea and German green steel, meaning that carbon pricing alone is unlikely to close the full cost differential in the near term.

Double-sided auctions can mobilize meaningful hydrogen volumes with a defined public funding envelope, while their efficiency increases as offtakers absorb more of the green premium. The chapter models a USD 1bn grant over ten years and shows that the hydrogen volume contracted depends strongly on production costs, buyers' willingness to pay and the amount of optional supply offered by producers. Where the intermediary recovers only the conventional product price, the model mobilizes around 86 kt_{H2} in Germany and 206 kt_{H2} in India over the funding period, demonstrating the significantly greater purchasing power of the same budget where hydrogen production costs are lower. As offtakers progressively cover the green premium and suppliers provide additional optional volumes, the same funding can stretch considerably further: in the scenario where buyers cover 90% of the green premium by year ten, total contracted hydrogen supply reaches between 142 kt_{H2} in Germany and 400 kt_{H2} in India, depending on the optional volume offered. The DSA therefore delivers the greatest volume per unit of public funding when declining cost gaps and rising willingness to pay allow the intermediary to reinvest sales revenues into additional hydrogen purchases.



IMAGE CREDIT: ADOBE STOCK / PRESSMASTER



5

Recommendations

The analysis in this report reveals a fundamental mismatch in the transmission of the green premium along clean-hydrogen value chains.

The analysis suggests that none of these instruments will suffice to jumpstart the market but will require carefully designed nested approaches to move the needle significantly.

The largest cost increases occur close to the point at which clean hydrogen is introduced:

Clean hydrogen remains substantially more expensive than its conventional counterpart, while hydrogen-based steel increases steelmaking costs by around 22% in India and 45% in Germany. Yet these increases become considerably smaller as they move downstream. For basmati rice, the resulting retail price increase amounts to approximately 1-13%, depending on geography and production pathway. For wind power projects using clean-hydrogen-based steel, the corresponding cost increase for power companies is approximately 5-15%.

The challenge is therefore not simply to reduce the green premium. Policymakers also need to create mechanisms that allow end-user demand and willingness to pay to travel upstream through the value chain to those actors making the decarbonisation investment. Neither markets nor single policy instruments are likely to achieve this on their own. Policy frameworks should combine enabling conditions with broad market signals and more targeted support, while adapting the instrument mix to the structure and competitive environment of each value chain.

1. Establish internationally interoperable standards and traceability across the full value chain

Policymakers should make internationally interoperable standards, certification and value chain traceability a prerequisite for instruments seeking to mobilise end-user willingness to pay.

End-users can only pay a premium for an environmental attribute that they can identify and trust. Certification therefore needs to extend beyond clean hydrogen itself and establish a credible link between the hydrogen production pathway and the final product purchased by an end-user. This applies to clean fertilisers and food products just as much as to green steel and steel-containing products. As these products frequently cross borders, national certification systems should be designed for interoperability rather than creating separate markets with incompatible definitions and requirements.

Implementation should reflect the structure of individual value chains.

Implementation should reflect the structure of individual value chains. The wind-turbine value chain involves comparatively few industrial actors and high-value products, making product-level traceability relatively manageable. The fertiliser-to-plate value chain is considerably more fragmented. In India, large numbers of farmers, millers and traders make certification costly and administratively demanding. Policymakers should therefore permit flexible but auditable chain-of-custody approaches and use aggregators — such as contract-farming arrangements, large processors or exporters — to reduce the compliance burden on small actors.



IMAGE CREDIT: ADOBE STOCK / YELLOW BOAT

In particular, policymakers should:

- develop mutually compatible definitions for clean hydrogen, clean and low-emission derivatives, green steel, low-emission fertilisers and relevant final products;
- ensure that certification captures environmental attributes throughout the value chain rather than ending at the first hydrogen derivative; and
- adapt monitoring and chain-of-custody requirements to the structure of individual sectors, avoiding systems whose transaction costs outweigh the value of the green premium they are intended to transmit.

The report's rice case illustrates the importance of this enabling condition particularly clearly: German consumers and retailers may be comparatively well positioned to absorb a small premium, but this willingness to pay cannot support clean fertiliser production in India without a credible chain of custody linking the final product to upstream production.

2. Use carbon pricing as the long-term backbone—but do not rely on it to close the cost gap alone

Governments should continue to internalise the climate externality through carbon pricing, while recognising that politically feasible carbon prices are unlikely to close the full cost-of-difference for clean-hydrogen technologies in the near term.

In principle, carbon pricing is the most technology-neutral instrument considered in this report. Rather than prescribing hydrogen use, it places a value on emission reductions and allows companies to identify the most cost-effective decarbonisation option. A sufficiently broad and predictable carbon price can therefore provide the long-term backbone of a clean industrial policy.

In practice, however, the carbon prices required to reach cost parity remain high. The analysis finds that renewable urea requires substantially higher carbon prices than prevailing levels, while the gap is smaller—but still significant—for hydrogen-based steel, particularly in Germany. Policymakers should consequently not make clean hydrogen deployment conditional on carbon prices eventually becoming high enough to close the full gap.

This limitation is particularly important for internationally traded commodities. If carbon costs differ substantially between markets, individual producers face a competitive disadvantage and may lose market share before cleaner technologies can scale. Carbon pricing frameworks should therefore be developed alongside measures that maintain a level playing field for domestic and imported products. Predictable trajectories, border measures where appropriate, and international alignment of carbon-accounting methodologies can reduce this risk.

Carbon pricing should consequently serve as the **baseline signal** against which more targeted instruments operate. As carbon prices rise, the amount of additional public or regulatory support required should fall. Quotas, auctions and contracts-for-difference should be designed with this interaction in mind rather than as permanent substitutes for carbon pricing. This nested approach follows directly from the report's finding that no single instrument can efficiently address the cost gap across all parts of either value chain.

Policymakers should consequently not make clean hydrogen deployment conditional on carbon prices eventually becoming high enough to close the full gap.

3. Create predictable market conditions through gradually increasing quotas and mandates

Where markets do not generate sufficient demand on their own, governments should use gradually increasing quotas or mandates to create predictable demand for low-emission products and give producers the confidence to invest.

Stable demand is particularly valuable for technologies requiring large and long-lived industrial investments. An announced trajectory that increases over time gives producers an opportunity to plan new capacity, allows supply chains to adjust and can stimulate learning and cost reductions. Quotas also have the advantage of applying an equivalent requirement to competing companies within the regulated market, reducing the first-mover disadvantage faced by individual firms. The quantitative analysis shows that quotas could create material anchor demand for clean hydrogen in both the fertiliser and wind-turbine cases.

Their design should nevertheless differ by value chain.

For **clean fertiliser**, a quota for renewable or low-emission ammonia is comparatively straightforward because the production pathway can change while the downstream product—urea—remains functionally equivalent.

Policymakers should avoid placing the cost of industrial decarbonisation disproportionately on sectors that are already contributing to the energy transition.

In India, implementation could initially focus on a limited number of large producers, including publicly controlled production capacity. Any quota must, however, account explicitly for the interaction with the MRP: under the current subsidy regime, higher production costs are largely transferred to the public budget rather than farmers or consumers. A nominally cost-free mandate can therefore create substantial indirect fiscal expenditure. Availability of a sustainable carbon source for renewable urea also needs to form part of the implementation strategy.

For **green steel**, demand-side product requirements may provide a more precisely defined starting point. Requirements for a gradually increasing share of low-emission steel in wind towers, for example, could create anchor demand from OEMs and power companies and transmit this signal upstream to steelmakers. Such requirements should be announced with sufficient lead time and rise progressively as supply develops.

However, policymakers should avoid placing the cost of industrial decarbonisation disproportionately on sectors that are already contributing to the energy transition. A green-steel requirement applying only to wind turbines could make wind power more expensive relative to fossil-based alternatives. Requirements should therefore form part of a progressively broader lead-market strategy covering other major steel-using sectors wherever feasible. The goal should be to create a market for green steel, rather than a green-steel niche confined to already sustainable technologies. A quota for just one steel-based product is unlikely to achieve this end. These considerations are also reflected in the team's recommendations for progressively introduced demand- and supply-side quotas.

4. Bridge the remaining cost gap with competitive, market-based instruments

Governments should use double-sided auctions and similar instruments to bridge residual cost gaps, while designing these instruments to phase down as private willingness to pay increases.

The modelling in this report demonstrates that the impact of a fixed public budget depends not only on production costs but also on how much of the green premium can ultimately be recovered from buyers. Under a double-sided auction, every additional contribution from the demand side reduces the amount of public funding required per unit and allows the intermediary to contract additional volumes. The effectiveness of such mechanisms therefore increases substantially when complementary regulation—such as carbon pricing or quotas—raises buyers' willingness to pay over time.

This implies that bridging instruments should be explicitly transitional. Public funding should close the part of the cost gap that the market cannot yet absorb, rather than permanently replacing demand-side willingness to pay. Auction designs can reinforce this principle through shorter sales contracts, optional supply volumes, declining support and repeated price discovery.

Instrument choice should also reflect product characteristics. Double-sided auctions are particularly suitable where products are sufficiently standardised to generate competition between suppliers and buyers. Renewable hydrogen derivatives such as ammonia are therefore well suited to this approach. The greater the product differentiation, the more difficult it becomes to compare bids and create a liquid secondary market. Highly specific steel grades may consequently require contracts-for-difference or competitively awarded project-specific support rather than a conventional double-sided auction.

In general, policymakers should favour competitive allocation mechanisms over administratively negotiated support wherever the product and market structure permit it. Competition reveals information about producers' actual funding requirements and can reduce the risk of overcompensation.

5. Target scarce public funding at first movers and at value-chain bottlenecks that cannot pass the premium on

Direct public financial support should focus on first movers, irreversible investments and value-chain segments that cannot credibly recover the green premium through the market.

The analysis shows that the ability to absorb additional costs varies considerably along both value chains. Steelmakers and tower manufacturers face much larger relative cost gaps than power companies at the end of the wind-turbine value chain. In the fertiliser-to-plate case, farmers have very limited market power and narrow margins, while maintaining India's MRP shifts the additional cost of renewable urea primarily onto the government budget.

In general, policymakers should favour competitive allocation mechanisms over administratively negotiated support wherever the product and market structure permit it. Competition reveals information about producers' actual funding requirements and can reduce the risk of overcompensation.

A uniform subsidy across the entire value chain would therefore allocate scarce public resources inefficiently.

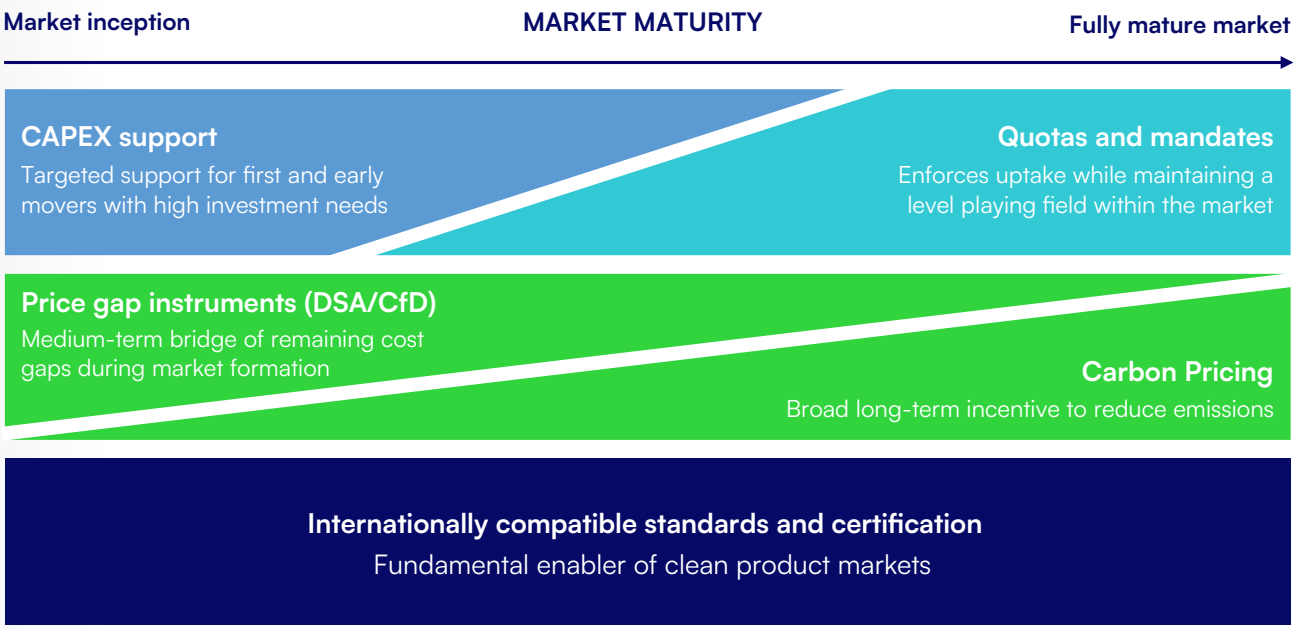
CAPEX support can remain justified for first-of-a-kind projects where large upfront investments and technology risks would otherwise prevent investment altogether. Its role should, however, diminish once technologies and supply chains mature. Grants should be allocated transparently and, wherever possible, competitively; include clear conditions regarding the subsequent use of clean hydrogen; and avoid creating an expectation that later projects will receive the same level of support. The experience assessed in this report shows that first-mover green-steel projects have so far relied heavily on public support, but this model is unlikely to be scalable across an entire industry.

The same principle has an international dimension. In globally integrated value chains, the country in which the expensive decarbonisation investment takes place is not necessarily the country in which consumers have the greatest capacity to absorb the premium. The fertiliser-to-plate case illustrates this mismatch: preserving affordable fertiliser for Indian farmers while decarbonising urea production could place substantial pressure on the Indian public budget, even though part of the resulting rice is consumed in higher-income export markets where the final price impact is comparatively small. At higher ambition levels, importing countries, private buyers and multilateral financial institutions should therefore explore mechanisms through which part of the premium can be transferred back to the producing country.

Taken together, these recommendations point towards a **nested policy approach** (see Figure 15). Internationally compatible standards and certification provide the foundation. Carbon pricing creates the broad long-term incentive to reduce emissions. Predictable quotas and mandates establish lead markets where this signal remains insufficient. Competitive auctions and contracts-for-difference bridge the remaining cost gap during market formation, while direct CAPEX support is reserved for first movers and exceptional investment barriers. As markets mature, the balance should progressively shift away from direct public support and towards carbon costs and end-user willingness to pay.

The objective is ultimately not to subsidise the green premium indefinitely, but to create the conditions under which it can be identified, transmitted through the value chain and increasingly internalised by the market.

Figure 15: A nested approach for using instruments supporting clean hydrogen uptake



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