India Insights Briefing:

Unlocking India's Clean Industrialisation Opportunity

ITA INDUSTRIAL TRANSITION ACCELERATOR

BCG

November 2025

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Introduction

About the ITA and Mission Possible Partnership

The Industrial Transition Accelerator (ITA) is a global multi-stakeholder initiative, launched at COP28, to catalyse decarbonisation across heavy-emitting industry and transport sectors that represent a third of global emissions. With expansive networks across industry, financial institutions, and governments, the ITA brings together global leaders to unlock investment at scale for the rapid deployment of decarbonisation solutions. Within three years, it aims to significantly grow the pipeline of commercial-scale, clean industrial projects to reduce emissions by 2030 and enable delivery of Paris Agreement-aligned ambition for these sectors.

The ITA is led by Co-Chairs H.E. Dr. Sultan Al Jaber (Minister for Industry and Advanced Technology of the UAE and COP28 President), Simon Stiell (UN Climate Change Executive Secretary), and Michael R. Bloomberg (UN Secretary-General's Special Envoy on Climate Ambition and Solutions), supported by the wider ITA Leadership Council.

The ITA Leadership Council members come from a variety of organisations — including international industry groups, intergovernmental institutions, and non–governmental organisations — with a broad set of viewpoints. These diverse views and rich expertise inform the work of the ITA Secretariat. The Leadership Council members welcome this publication, but they may not agree with every detail or recommendation. The organisations with which the Leadership Council members are affiliated have not been asked to formally endorse this publication.

The ITA Secretariat is hosted by the Mission Possible Partnership (MPP) which works with global institutions, corporate and finance conveners, and industry groups, among others, to speed up collective action for industrial decarbonisation.

The MPP is an independent non-profit organisation advancing global clean industry transformation. Since 2019, the MPP has been working with some of the most energy-intensive industries — aluminium, cement, chemicals, shipping, aviation and steel — to cut their global greenhouse gas (GHG) emissions. It mobilises business, finance, government, and civil society leaders to speed up the shift to clean materials, chemicals, and fuels. Having charted sectoral pathways to net-zero, the MPP continues to forge new territory, lifting the barriers to enable a critical mass of clean industrial projects to break ground by 2030. The MPP has people and partners on the ground in North America, Brazil, Europe, the Middle East, North Africa, India, and Australia.

Foreword

Faustine Delasalle
Executive Director, Industrial Transition Accelerator
CEO, Mission Possible Partnership

India's industrial base is expanding at remarkable speed. How the economy grows — what it makes, the markets it serves, how it is powered — will shape prosperity, competitiveness, and resilience for decades. Achieving the national vision of Viksit Bharat 2047 and climate targets will hinge on developing new industrial activities while transforming how industries produce. The clean industrial transition offers India a way to pursue three objectives at once — strengthen energy, food, and trade security, and build globally-competitive industries, while cutting GHG emissions.

India's clean project pipeline is real and significant: 65 clean industrial plants across chemicals, steel, cement, aluminium, and aviation, concentrated in states like Odisha, Gujarat, Andhra Pradesh, Karnataka, Maharashtra, Tamil Nadu, and Rajasthan. Most announced projects are in green chemicals, reflecting India's advantages in low-cost renewables and growing policy momentum. If fully realised, this pipeline could mobilise more than $150 billion in investment, create over 200,000 jobs, and abate 160–170 $MtCO_2e$ annually, equivalent to roughly 5–6% of India's national emissions.

For India, the stakes are highly strategic. International carbon measures such as the EU's Carbon Border Adjustment Mechanism (CBAM) are reshaping trade flows for emissions-intensive commodities; early decarbonisation will not only help protect India's global market share and jobs, it could enhance them. Emerging mandates create export opportunities where India can become a competitive low-carbon supplier, as a leader in the "new industrial sunbelt".

India's clean industrial pipeline consists of 65 projects, representing an opportunity to emerge as a global leader in clean industrialisation

While momentum is real, moving projects from announcement to Final Investment Decision (FID) remains a slow and difficult journey. Exchanges with Indian project developers have revealed that investment at scale is hindered by barriers like weak or uncertain green offtake at both domestic and international levels, limited instruments to bridge the green premium and high cost of capital for first-of-a-kind projects, gaps in technology readiness and localisation, and infrastructure bottlenecks such as electricity transmission constraints and right-of-way for CO_2 and renewables infrastructure. Continued progress on supportive policies and efficient permitting processes will help accelerate progress, supported by measures to ease feedstock and by-product market frictions.

A targeted set of interventions can help resolve these bottlenecks, including enhancing coordination at the level of key industrial hubs on clean energy infrastructure and community engagement and building platforms to boost collaboration along key industrial value chains from upstream energy, minerals, and equipment supply all the way to consumer-facing companies. Alongside these measures, efforts on the policy front to align Indian supply with standards in global lead markets, boost domestic demand for clean commodities, and accelerate permitting and approvals could fast track clean industrial projects.

India is well-positioned to become a global leader in clean industrialisation, boosting its economic growth and resilience, while cutting GHG emissions. Decisive action to move a first wave of projects toward financing and construction is now essential to transform this potential into reality.

About the Report

The Industrial Transition Accelerator (ITA) is working in several countries including Brazil, UAE, and Egypt, providing support to a pipeline of commercial-scale, deep decarbonisation industrial projects to accelerate their journey to 'Final Investment Decision.' In May 2025, the ITA started work in India, undertaking preliminary analysis of the country's pipeline of such projects and identifying the barriers and solutions to their investment.

This briefing highlights our key findings, informed by bilateral engagement with the developers of over 60 such projects and a range of relevant stakeholders. It describes the tremendous opportunity and context in which projects are being developed in India (Section 3), provides deep-dives on the state of play in each sub-sector and key barriers to investment (Sections 4, 5, and 6), and identifies emerging priorities for future work to overcome these barriers to fully realise India's clean industrial opportunity.

The report is intended to inform relevant decision makers including industry players, policymakers, industry associations, climate financers, offtakers, and other relevant stakeholders to understand the challenges to India's clean transition and ignite thinking for constructive interventions to overcome them. And it will inform the ITA's future work in India.

This report was led and prepared by the ITA in collaboration with BCG. This publication has been made possible with the support of the MPP. Learn more at ita.missionpossiblepartnership.org

The ITA expresses its gratitude to the following members.

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Boston Consulting Group partners with leaders in business and society to tackle their most important challenges and capture their greatest opportunities. BCG was the pioneer in business strategy when it was founded in 1963. Today, we work closely with clients to embrace a transformational approach aimed at benefiting all stakeholders — empowering organisations to grow, build sustainable competitive advantage, and drive positive societal impact.

Our diverse, global teams bring deep industry and functional expertise and a range of perspectives that question the status quo and spark change. BCG delivers solutions through leading-edge management consulting, technology and design, and corporate and digital ventures. We work in a uniquely collaborative model across the firm and throughout all levels of the client organisation, fuelled by the goal of helping our clients thrive and enabling them to make the world a better place.

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Executive Summary

Why Clean Industrial Development Matters for India

Challenge: Growth at Risk of Increased Dependence and Lock-in

Demand surge: As India advances towards Viksit Bharat 2047 ambition, rapid growth in housing, infrastructure, mobility, and manufacturing is driving sharp increases in demand for materials, chemicals, and fuels.

Import exposure: With current means of industrial production, meeting this demand will increase India's dependence on fossil-fuel imports, increasing vulnerability to price spikes, supply disruptions, and geopolitical shocks.

Trade headwinds: Tightening international regulations and buyer standards (e.g., embedded-carbon thresholds, border adjustments, green fuel mandates) threaten export competitiveness for carbon-intensive goods.

Emissions lock-in: New capacity built on legacy technologies creates decades-long emissions lock-in, making Net Zero 2070 costlier and harder, and constraining room for future policy and market flexibility.

Opportunity: Build Resilience at Home, Win Market Abroad

India's structural advantages: Clean industrial transition is underway globally with 1000+ clean projects in the pipeline. India is strongly-positioned to lead this transition driven by low-cost renewable energy, a dynamic private sector, and improving policy environment.

Clean feedstocks and energy: Scaling domestically-viable clean production pathways in heavy industry sectors via green hydrogen, carbon capture, utilisation, and storage (CCUS), biomass, electrification, and circularity can substitute fossil-fuel imports, improve trade balance, and secure supply chains.

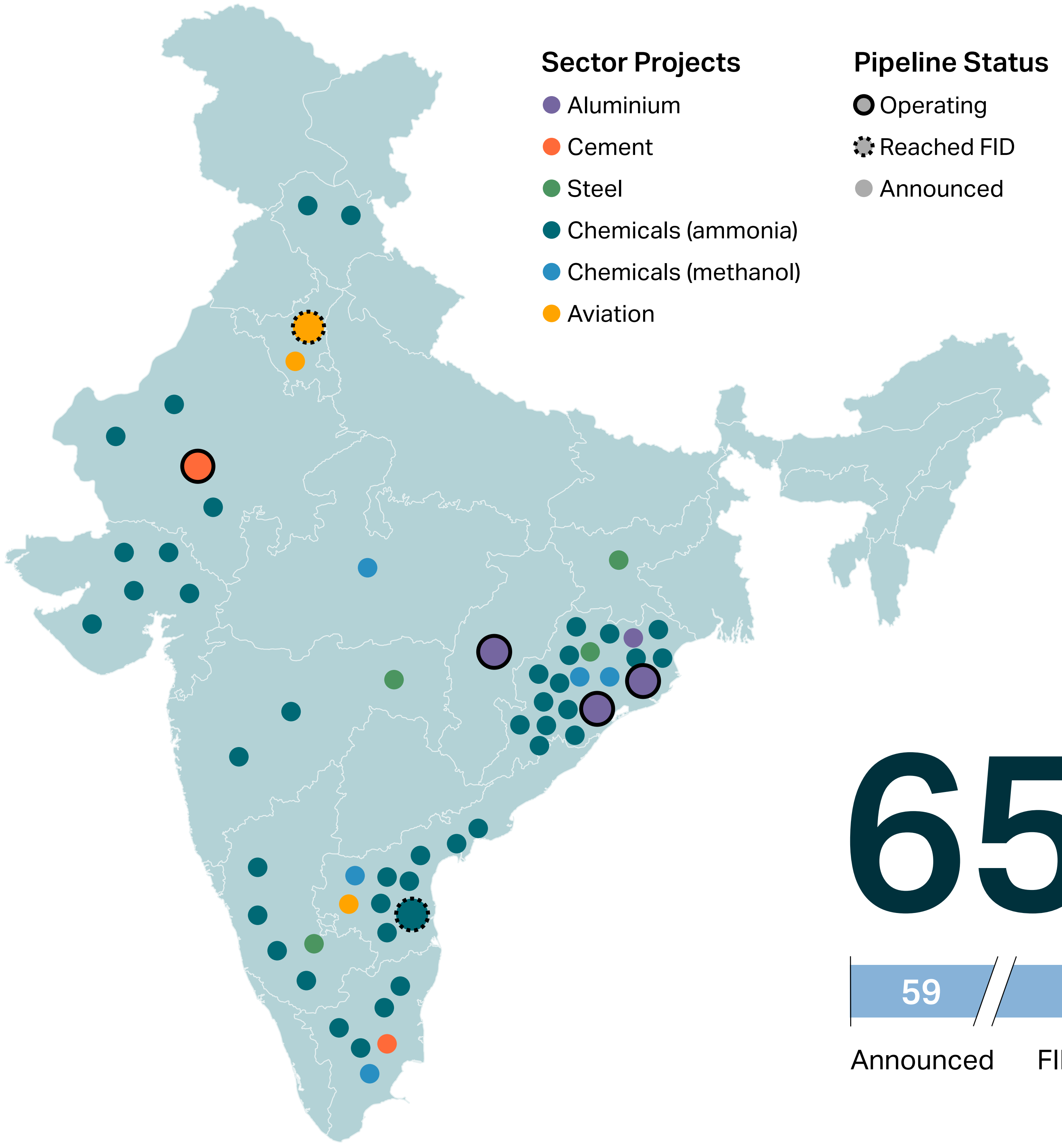
Sectoral competitiveness: Planning new clean capacity addition avoids expensive retrofits in the future and opens economic opportunity to capture premium export markets for clean commodities.

National benefits: The clean industry transition underpins energy security, industrial productivity, job creation, and innovation promoting the journey towards Viksit Bharat 2047 and Net Zero 2070.

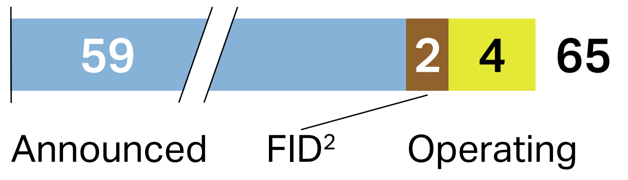
Call to Action: Move from Plans to Plants in the Next 18-24 months

Prioritise the deployment of a **first wave of commercial-scale clean industrial projects** within the **next 2–3 years** through structural interventions that address key demand, finance, and infrastructure gaps — laying the foundation for a sustainable and cost-effective industrial transition aligned with India's goals of **Viksit Bharat by 2047** and **Net-Zero Emissions by 2070**.

India's growing pipeline of clean industrial projects — now the third largest in the world after China and US — represents a tremendous opportunity for sustainable industrial development in the coming decades.



65 Clean Industrial Projects[1]



Sectoral pipeline distribution: Chemicals (ammonia and methanol) leading with ~80% of the announced projects

Sector	Announced	FID	Operating	Total
Chemicals	50	1		51
Steel	4			4
Aviation	2	1		3
Cement	1		1	2
Aluminium	2		3	5

Opportunity to cut emissions, unlock green investments, and generate employment

160-170
$MtCO_2e$ p.a.
Estimated abatement potential

150+ Bn
US Dollars
Estimated investment potential

200,000+
direct and indirect
Estimated employment potential

Note: 1. Pipeline has been selected as per ITA's criteria (more details in appendix) considering only commercial-scale projects. Non–exhaustive and includes 5 additional projects with no location specified. ITA parameters are broader in scope than MPP's Global Project Tracker (GPT). As a result, ITA's India pipeline maps 12 projects in addition to the 53 mapped by the GPT. 2. Final Investment Decision (FID)

India's Clean Industrial Transition: Key Takeaways

1 Industrial growth in India is accelerating rapidly, bringing both economic opportunity and rising emissions that demand a clean production shift

- **India is rapidly emerging as a global industrial hub,** with surging production and consumption in core heavy industries such as steel, cement, aluminium, chemicals, aviation, and shipping that is powering economic growth and employment.
- Current carbon-intensive means of production are driving a **steep rise in GHG emissions,** with heavy industry[1] already contributing nearly 20-25% of India's total emissions[2], while **increasing reliance on fossil fuel imports,** exposure to volatility in global energy prices, and the **risk of losing competitiveness in clean commodity markets.**
- **Clean industrial transition offers an opportunity to navigate the dual challenge** of sustained industrial growth while pursuing long-term economic resilience, sustainability, and export competitiveness.
- **India has unique strengths to enable clean industrialisation,** including policy momentum, corporate leadership, trade partnerships, and access to abundant low-cost clean electricity *(e.g., solar PV at $0.038/kWh vs $0.043/kWh globally in 2024).*

2 India hosts a growing pipeline of 65 commercial-scale clean industrial projects — unlocking massive export potential and clean growth opportunities

- **India's project pipeline is concentrated in green chemicals** (~80% of projects), with activity clustered in states like Odisha, Gujarat, Andhra Pradesh, Karnataka, and Maharashtra that offer abundant renewable potential and proactive industrial policies.
- The scale of the opportunity is massive, with an **estimated capital requirement exceeding $150 billion** to bring the current pipeline to full-scale operations.
- If fully realised, this pipeline could **reduce India's industrial GHG emissions by approximately 160–170 Mt CO_2e** annually, ~5-6% of India's total current emissions.[2]
- Preliminary assessments indicate the **potential to create over 200,000 direct and indirect jobs** across the value chains, embedding socio-economic benefits into India's broader decarbonisation goals.
- **The growing pipeline of projects offers a tremendous opportunity for India** to enhance long-term economic resilience and energy security, capture export markets in clean materials, chemicals, and fuels, while advancing towards its climate goals.

3 However, to date six projects are past FID (two at FID and four operating), as several systemic challenges continue to slow projects' progress towards FID

- **Projects at FID include two deep decarbonisation projects** – one green ammonia and one Sustainable Aviation Fuel, while four partly renewable-powered brownfield aluminium smelters are in operation.
- **Most significant barrier to FID is lack of premium demand.** Long-term binding offtake for clean products, even at a modest premium, remain limited, affecting revenue certainty and bankability.
- **Second, financing constraints:** First-of-a-kind assets face higher perceived risks and capital costs, especially where track records are absent. This is compounded by limited availability of early-stage funding for project development.
- **Third, gaps in supporting infrastructure,** from grid and transmission readiness to port handling and shared logistics, can extend timelines and increase costs.
- **Fourth, policy and regulatory uncertainty** and lack of sufficient support (incentives, mandates, etc.).
- **Finally, a range of other project-level and sectoral hurdles,** such as feedstock logistics or international certifications can create additional bottlenecks.

4 Addressing these barriers with pragmatic interventions is crucial to advance these projects towards FID and convert ambition into reality

This report presents a set of pragmatic interventions to address the on-ground challenges (select examples below):

- **Unlock premium markets:** Voluntary buyers' alliances, advance market commitments, public procurement, and regulatory mandates.
- **Bridge cost gaps:** Deploy carbon pricing mechanisms, public funding, and concessional finance to offset premiums.
- **Market-making:** Standardise procurement models and market mechanisms to enable supply-demand matching and transparent price discovery.
- **De-risk and improve bankability:** Use of blended finance, credit guarantees, and other targeted instruments to mitigate investment risk and lower the capital cost.
- **Coordinate infrastructure:** Establish public–private partnerships for planning and investment in shared infrastructure (power, ports, CO_2/H_2 transport and storage).
- **Support trade-ready supply:** Develop green corridors and ensure regulatory alignment with lead export markets.

Note: 1. Heavy industry includes steel, cement, aluminium, chemicals (ammonia and methanol), aviation, and shipping; **2.** Total GHG emissions = 2.96 BtCO2 in 2020 (India BUR–4)

3

India's Clean Industrialisation Opportunity

India is the fastest-growing major economy, with rapidly increasing consumption and greenhouse gas emissions — making clean industrialisation pivotal to its Viksit Bharat 2047 ambition

Industrial sectors account for nearly a quarter of India's gross domestic product (GDP) and serve as the backbone of economic growth. Home to over 1.4 billion people, India is the fastest growing major economy in the world, with a real GDP growth of 6.5%[1] in FY24–25. The heavy industrial sectors, including basic metals, chemicals and derivatives, and all forms of transport contribute ~11% to the country's gross value added (GVA), support employment for more than 11 million individuals, either directly or indirectly, and power India's journey to achieve its Viksit Bharat 2047 (developed economy by 2047) ambition.

Heavy industry sectors — aluminium, steel, cement, chemicals (ammonia and methanol), aviation, and shipping — are central to India's economic transformation and global competitiveness. These six sectors of the ITA's focus are major pillars and the backbone of any industrialised economy. India already ranks as the world's second-largest producer of steel, cement, and aluminium, and the third-largest producer of fertilisers (a major end-use sector of ammonia). Beyond meeting rising domestic demand, they are increasingly competitive in global markets: in FY24–25, India exported 4.86 million tons of steel[2] and 2.24 million tons of aluminium[3] to global markets including the US, Europe, Australia, the Middle East, and South and East Asia.

India's industrial output is projected to grow significantly, driven by strong domestic consumption, rising infrastructure investments, and expanding global demand. Rapid urbanisation, a rising middle class, and increasing per capita consumption are expected to drive demand for materials, chemicals, and fuels — projected to increase from 2024 levels to 2030 by more than 30–70% depending on the sector[4,5,6,7] (Fig. 1). Simultaneously, India's ambition to become a global manufacturing hub, enabled by export-linked policy reforms, infrastructure upgrades, and industrial corridor development, is catalysing investment in these capital-intensive sectors.

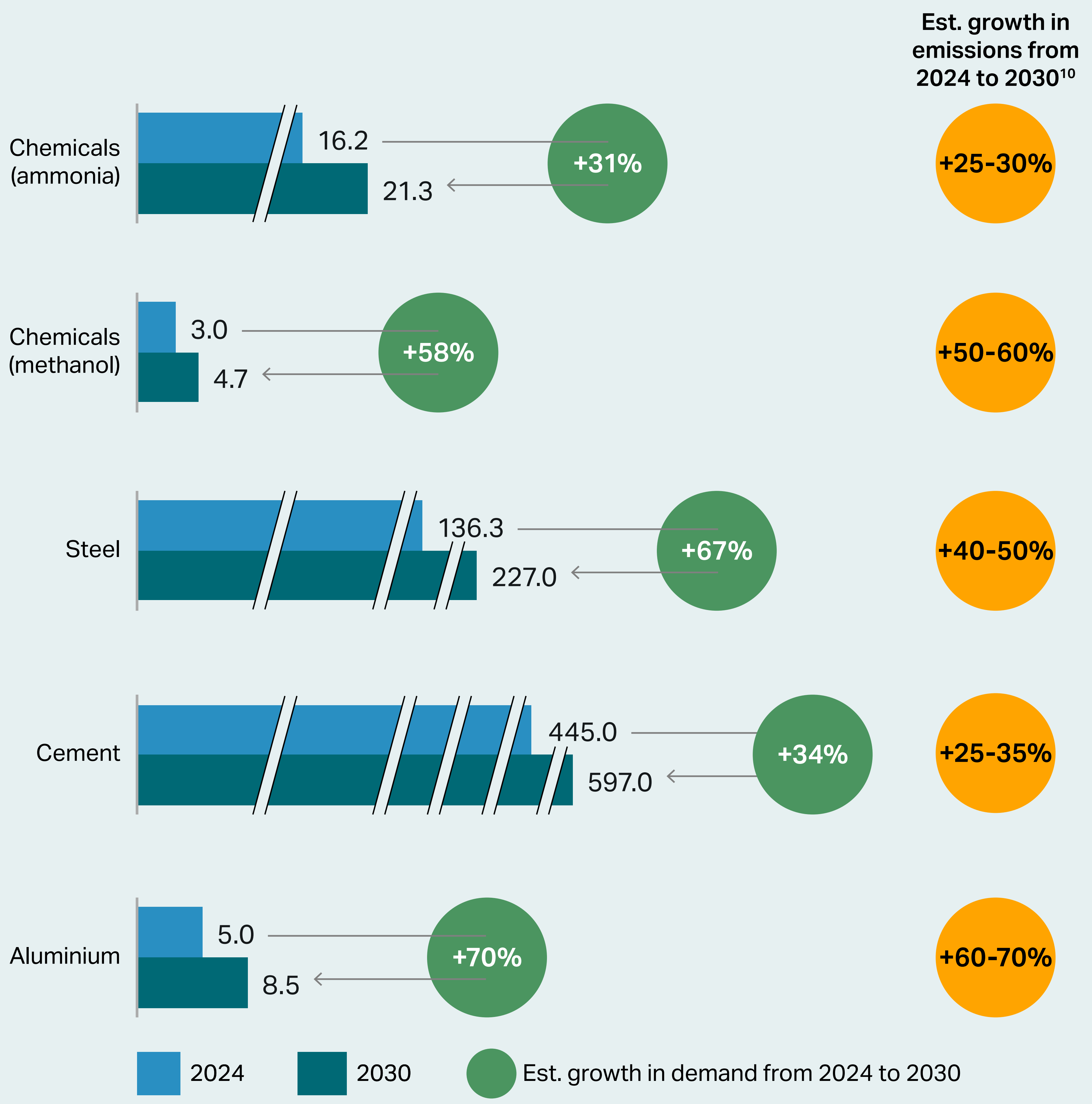
India's industrial growth is driving a steep rise in GHG emissions, with heavy industry poised to become the largest emitter before mid-century. As of 2020, India's total GHG emissions stood at 2.96 GtCO2e[8], contributing to 7–8% of global GHG emissions[9], making it the third-largest GHG emitter after China and US. The energy sector remains the dominant source, accounting for nearly three-quarter of the country's emissions, followed by agriculture, and industrial processes and product use. Together, the emissions from energy use and processes in heavy industry sectors[12] contribute nearly 20-25% of India's total GHG emissions[10]. If industrial growth remains fossil-intensive, sectoral emissions could rise by at least 30% by 2030 from 2024 levels (Fig. 1). As power and transport decarbonise, heavy industry is expected to take a much larger share, potentially becoming India's biggest source of GHG emissions by 2040.[11]

As India advances towards its Viksit Bharat 2047 vision, a core priority is to decouple economic growth from emissions. Cleaning industrial expansion and modernising heavy industry will define the pace and sustainability of development while positioning India as a global leader in economic strength and environmental action.

Note: **1.** MoSPI; **2.** April 2025 trend report by MoS; **3.** Final trade data by MCI; **4.** TERI – Towards a low carbon steel sector; **5.** Vision document for Aluminium in India by Ministry of Mines; **6.** TERI – Decarbonisation roadmap for the India cement sector; **7.** TechSci Research – India ammonia market; **8.** India BUR–4; **9.** Our World in Data country dashboard; **10.** Difference of 2024 emissions and estimated emissions (industry reports) in 2030 for BAU scenario; **11.** IEA India Energy Outlook (2021) report; **12.** Heavy industry includes steel, cement, aluminium, chemicals (ammonia and methanol), aviation, and shipping

Figure 1: Demand and GHG emissions growth from heavy industry sectors in India (2024–2030)

All figures in million tonnes per annum (MTPA) for respective good



Note: Other two ITA-focus sectors (aviation and shipping) not included here
Source: Secondary Research, BCG and ITA Analysis

India's competitive advantage in clean industrial production is driven by abundant low-cost renewables, corporate leadership, improving policy environment, and reinforced by international regulations

India stands among the global frontrunners in renewable energy production and affordability

India is a global renewable energy (RE) leader, crossing 240 GW of installed capacity[1] in 2025, ranking fourth worldwide, and meeting its target of 50% non-fossil electricity capacity five years ahead of schedule.

India is one of the most cost-competitive solar markets, with exceptional solar irradiance and rapidly falling costs. In 2024, the levelised cost of electricity (LCOE) for solar PV was \$0.038/kWh[2], well below the global average of \$0.043/kWh. Onshore wind also remains globally competitive at \$0.048/kWh[2], driven by strong wind corridors in Tamil Nadu, Gujarat, and other high-resource states.

India is proactively building grid flexibility with energy storage, setting path for requirement of more than 410 GWh of energy storage systems (ESS) by 2032, supported by progressive national and state-level policies to manage peak demand and rising renewable penetration.

These achievements position India to anchor global green value chains, enabling it to power clean industries at scale and compete as a leader in the low-carbon economy.

Leading corporates exhibit strong ambition and commitment towards sustainable growth

Leading corporates in India, across heavy industry, have publicly announced targets to achieve carbon neutrality well ahead of India's Net Zero 2070 target.

Legacy RE players are looking to diversify from green electrons to green molecules aiming to capture growing opportunities in the clean chemicals space.

Leading integrated steel producers have supplemented their ambitious net zero goals with interim targets of 1.8–2.0 tCO_2/tcs[3] by 2030, translating to 20–25% emission reduction from 2024 levels.

Several major cement manufacturers have committed to or set near-term Science Based Targets initiative (SBTi) targets. Many players also plan a 25–30% thermal substitution rate by 2030 and 100% renewable capacity by 2050.

All major aluminium producers have backed their net zero commitment by interim targets for 25–45% share of renewable electricity in operations by 2030.

The two leading airlines, Indigo and Air India, have aligned with International Air Transport Association (IATA) 2050 net zero target. Indigo, as a partner of World Economic Forum's Clean Skies for Tomorrow (CST) initiative, further aims to achieve a 10% sustainable aviation fuel (SAF) blend in aviation turbine fuel (ATF) by 2030.

India's policy frameworks focus on embedding climate action and implementing interventions

India's climate policy journey began with the NAPCC[4] in 2010, followed by stronger global engagement and the Paris Agreement in 2015, which anchored its decarbonisation efforts in a target-based framework. The first nationally determined contributions (NDC) update in 2022 raised ambition further, committing to 50% renewable energy in the power mix and a 45% reduction in GDP emission intensity from 2005 levels by 2030.

In recent years, India has shifted decisively towards implementation, with greater emphasis on decarbonising its industrial base. Flagship initiatives such as the **Carbon Credit Trading Scheme (CCTS), the National Green Hydrogen Mission (NGHM), and the Green Steel Taxonomy** are creating the enabling environment for a shift to clean industry.

India is actively engaged in multi-lateral efforts on industry decarbonisation through platforms like the **Leadership Group for Industry Transition (LeadIT) and Industry Deep Decarbonisation Initiative (IDDI).** These are to be bolstered by forthcoming policies including a **National Green Steel Mission, a CCUS (Carbon Capture, Utilization, and Storage) policy framework, and a Climate Finance Taxonomy** — together focused on driving technological change and climate-aligned investment.

International regulations are catalysing clean industrial transformation and re-shaping of value chains

Europe's Renewable Energy Directive (RED) II and III mandates requiring use of Renewable Fuels of Non-Biological Origin (RFNBO) – compliant green hydrogen and derivates in industrial and transport sectors creates a significant export opportunity for Indian producers to capture premium lead markets.

The EU's Carbon Border Adjustment Mechanism (CBAM) also poses a significant risk, potentially eroding Indian steel producer margins by ~\$25 million in 2026[5] and hundreds of million dollars annually by 2030 — driving the need for investment in low-carbon production facilities.

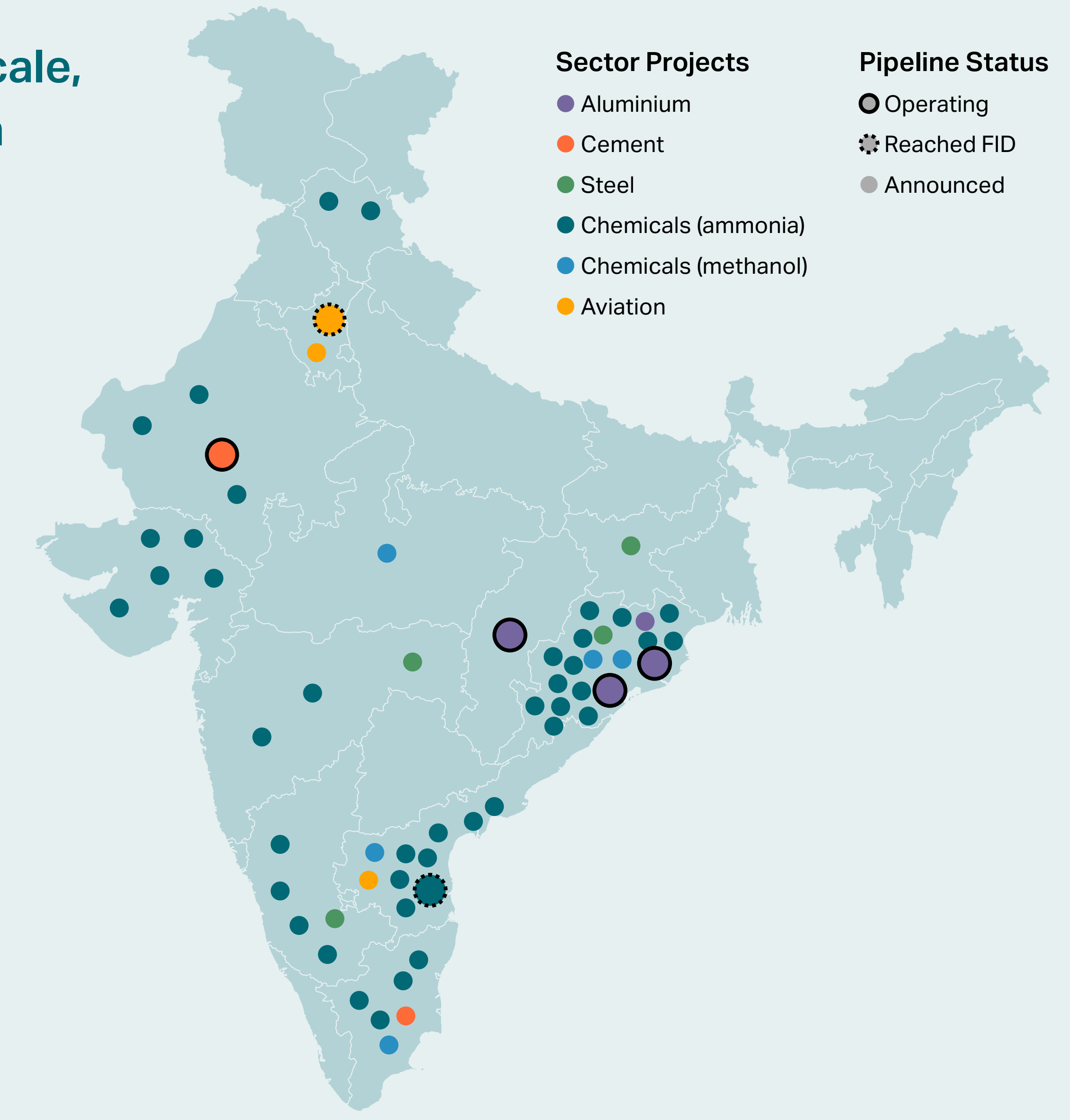
The International Maritime Organisation (IMO)'s Greenhouse Gas Fuel Intensity measure could add \$87–100 million annually in compliance costs for Indian carriers by 2030[6]. Use of sustainable fuels like clean ammonia and methanol are emerging as alternatives to traditional marine fuels.

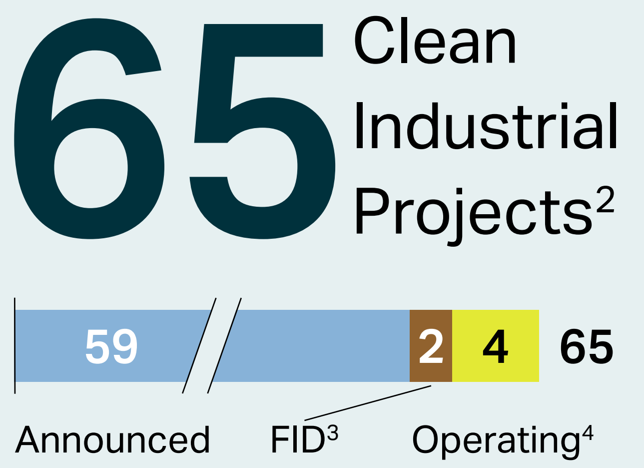
Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) mandates will impose \$0.5–2.3 billion in offsetting costs between 2027 and 2035[7] on India's two leading airlines, making SAF adoption critical to reduce emissions and avoid rising compliance expenses.

Note: 1. Ministry of New and Renewable Energy; **2.** International Renewable Energy Agency (IRENA); **3.** tCO_2 per ton crude steel; **4.** National Action Plan on Climate Change; **5.** Estimated as per current export of Indian steel to the EU (more than 40% of 4.86 MT), current average emission intensity of the industry (2.54 tCO_2e/tcs), and current expectation of CBAM tariff (\$100/tCO_2); **6.** Directorate General of Shipping, Government of India; **7.** TERI – Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) and Indian Aviation Industry

With 65 commercial-scale low and near-zero emissions projects in the pipeline, Indian industry demonstrates strong ambition and commitment to sustainable development

Figure 2: Pipeline of commercial-scale, low and near-zero emissions, clean industrial projects in India[1]



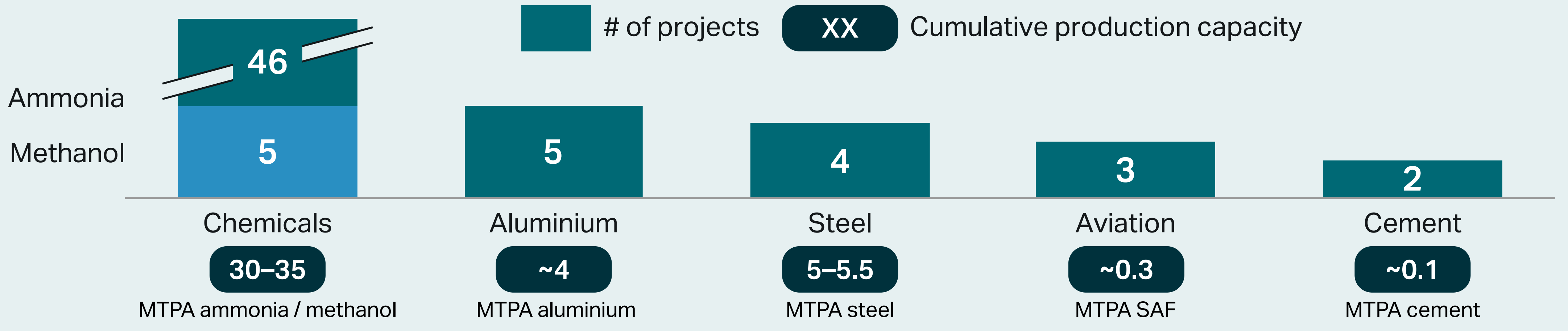


This project pipeline, along with pilot/demo-scale projects[5], reflects a growing opportunity for India to become a global leader in clean green industrial transition.

Project pipeline mapped based on ITA parameters[6]:

- **Sector relevance:** *target high-emission activities in ITA's 6 focus sectors[7]*
- **Commercial scale:** *target large-scale operations*
- **Deep-decarbonisation:** *significant emissions cuts with a pathway to near-zero*
- **Breakthrough technology:** *commercially promising but not widely adopted*

Figure 3: Distribution of ITA relevant projects across the focus sectors[1]



Chemical sector is advancing the fastest, accounting for ~80% of all announced projects, highlighting its strategic relevance:

- **Green ammonia:** Beyond its role in fertiliser and power production, ammonia is increasingly valued as an integral part of the global hydrogen economy as an efficient hydrogen carrier. It comprises 70% of the total pipeline, surpassing the NGHM target of producing 5 MTPA of green hydrogen by 2030.
- **Green methanol:** Though smaller in scale, presents a complementary pathway with both industrial and fuel applications, particularly in clean shipping.

Aluminium sector shows increasing appetite: Five projects include partially RE-powered smelters — backed by PPAs — signalling a shift to procurement of clean electricity to reduce the indirect emissions.

Steel sector shows increasing momentum: Four commercial-scale projects targeting green hydrogen-based steelmaking or CCUS. More than a dozen pilot/demo-scale projects in H–DRI (Hydrogen-based Direct Reduced Iron), hydrogen injection in BF, CCUS, scrap–EAF (Electric Arc Furnace) based steel, and biochar use in blast furnace (BF) have been recorded, with several planning to scale up to commercial-scale applications.

Aviation sector is in early stages but shows promise: Three commercial-scale projects for SAF production and more than 10 pilot/demo projects signal growing interest by industry in domestic and export markets.

Cement sector is in early stage of testing: Just two commercial projects focused on Limestone Calcined Clay (LC3) and CCUS, and 8–10 pilot projects exploring early-stage technologies such as kiln electrification, CCUS, and electrochemical calcination.

Note: 1. Pipeline has been mapped as per ITA's parameters. ITA parameters are broader in scope than MPP's Global Project Tracker (GPT). As a result, ITA's India pipeline maps 12 projects in addition to the 53 mapped by the GPT. **2.** Commercial–scale, non–exhaustive and includes 5 additional projects with no location specified; **3.** Final Investment Decision; **4.** Operating plants are considered past FID; **5.** 140+ pilot and demonstration scale clean industrial projects aligned with ITA criteria, in addition to the 65 commercial scale projects; **6.** Refer to the appendix for detailed ITA project selection criteria; **7.** Shipping sector is considered as an end–user of Chemicals. Shipping–related projects part of Chemicals pipeline

Project pipeline concentrated in states with abundant renewable power, strong policy support, and enabling infrastructure

Rajasthan | # Projects: 3 1

6-8 $MtCO_2e$ p.a. | $12-14 billion | ~39 GW

Rajasthan's pipeline is supported by its renewable potential harnessed by existing capacity and ~48 GW additional capacity under construction, a green hydrogen policy providing interstate electricity transmission charge waivers, and an estimated kaolin clay reserves of ~430 million tonnes.

Gujarat | # Projects: 5

8-10 $MtCO_2e$ p.a. | $13-15 billion | ~39 GW | ~155 MTPA

Gujarat's attractiveness for green ammonia projects is enhanced by its strategic access to the Red Sea maritime trade route, high ranking on ease of doing business parameters, and ~36GW expansion to the existing RE capacity.

Maharashtra | # Projects: 2 1

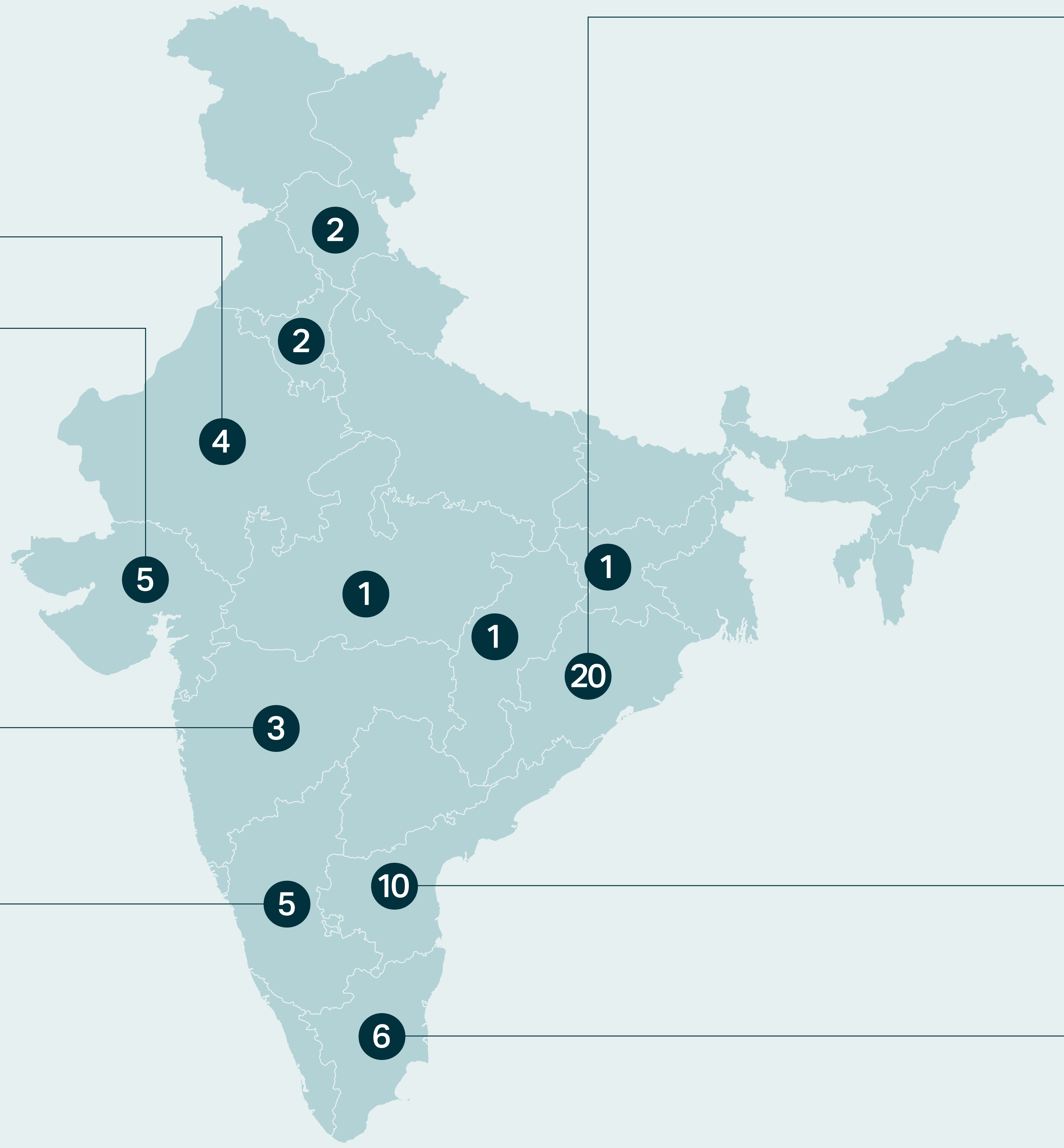
12-14 $MtCO_2e$ p.a. | $11-13 billion | ~27 GW | ~209 MTPA

Maharashtra had the highest gross state domestic product (GSDP) in India at~$455 billion in FY23–24 and attracted ~$94 billion in foreign direct investment (FDI) inflow over last six years reflecting the strength of the state's industrial ecosystem.

Karnataka | # Projects: 4 1

8-10 $MtCO_2e$ p.a. | $20-22 billion | ~25 GW | ~105 MTPA

Karnataka's industrial policy supports access to capital subsidies of up to 25% on fixed assets and up to 50% for sustainability initiatives, attracting investments in the state, testified by ~$63 billion FDI inflow in the last six years, ~20% share of total FDI in India.



Odisha | # projects: 16 1 3

72-75 $MtCO_2e$ p.a. | $28-30 billion | ~3 GW | ~289 MTPA

Odisha's industrial policies support green ammonia projects through exemption of electricity duty, cross-subsidies, interstate transmission charges for up to 20 years, and land allotment at concessional rates. The state's major ports at Paradip and Gopalpur (planned) further enhance its attractiveness for export-oriented projects.

Andhra Pradesh | # projects: 9 1

18-20 $MtCO_2e$ p.a. | $35-37 billion | ~14 GW | ~136 MTPA

Andhra Pradesh's support for green hydrogen projects via State goods and services tax (SGST) reimbursement and electricity charge waivers, has helped advance marquee green ammonia projects – including a project by AM Green (reached FID).

Tamil Nadu | # projects: 5 1

8-10 $MtCO_2e$ p.a. | $16-18 billion | ~26 GW | ~250 MTPA

Tamil Nadu's strong manufacturing base makes it an economic powerhouse, reflected by ~$305 billion GSDP in FY23–24. The flexible industrial promotion policy supports industries by offering options of capital subsidies or SGST reimbursements.

Sectors: Chemicals Steel Cement Aviation Aluminium # Projects X CO2 abatement Est. Investment RE Capacity Port Capacity (cargo)

Note: Pipeline has been mapped as per ITA's parameters. ITA parameters are broader in scope than MPP's Global Project Tracker (GPT). As a result, ITA's India pipeline maps 12 projects in addition to the 53 mapped by the GPT. The pipeline includes commercial–scale, non–exhaustive projects and includes 5 additional projects with no location specified | **Source:** Secondary research, BCG and ITA analysis.

Converting plans to plants would cement India's leadership, while advancing national strategic priorities - energy security, self-reliance, trade competitiveness, and sustainable growth

India can unlock its clean industrial pipeline, now third largest globally

Substitute imports to enhance economic resilience and self-reliance

India spent ~$220 billion on energy imports in FY24-25, accounting for more than 30% of the national import bill. The nation currently relies on imports for ~47% of natural gas[1], ~26% of coal[1] (including ~45% of coking coal[2]), and ~35% of ammonia[3] as sources of energy or feedstock in heavy industries. These dependencies expose India to global price volatility and supply shocks. Import substitution by shifting to cleaner production pathways provides a major opportunity. Scaling up production of alternatives like green hydrogen and derivatives can reduce vulnerabilities, secure long-term growth, and enhance India's trade balance.

Protect against international climate-related trade regulations

The international regulatory environment is tightening around carbon-intensive exports. For instance, under the EU's CBAM, Indian exporters could face an added cost of $3.01[4] per tonne of CO_2 on top of the EU carbon price of $100[5] per tonne, making India the third-most exposed country in Asia. In FY22–23, India's export of steel and aluminium to the EU accounted for ~10% of the EU-bound exports of ~$78 billion[6]. Without early decarbonisation, India risks losing cost competitiveness, market share, and downstream employment opportunities in emission-intensive industries.

Gain competitive advantage to capture export markets for clean commodities

While international mandates for low-carbon products present risks, they also create new opportunities for India. For example, CORSIA blending mandates are expected to create a ~$4.5 billion opportunity for SAF exports for India by 2050[7] (~8–10 MTPA of SAF[8], or ~5% of global demand), with Europe emerging as a key market. Similarly, green steel, green ammonia, and hydrogen derivatives are projected to be high-demand commodities as global buyers seek low-carbon supply chains and India is well positioned to capture these export markets.

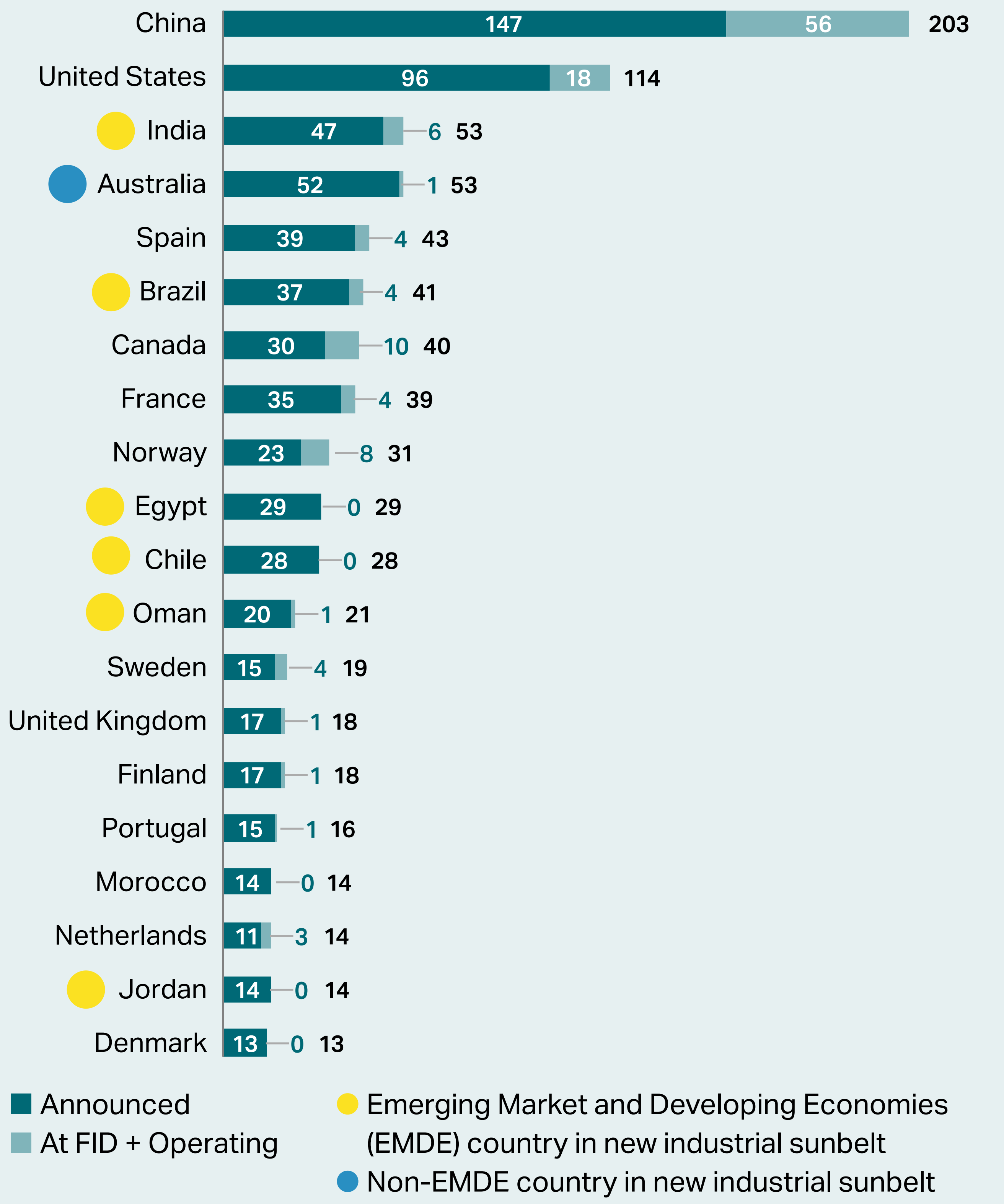
Unlock the third pillar of energy transition to achieve the nation's climate objectives

India has committed to achieving net zero emissions by 2070, reducing GDP emission intensity by 45% from 2005 levels by 2030, and sourcing 50% of its electricity from non-fossil fuels by 2030. These targets, among the most ambitious for a developing nation, align with India's "Viksit Bharat" vision of becoming a developed, self-reliant, and sustainable economy. Achieving this vision will require unlocking the third pillar of energy transition alongside renewable energy and energy efficiency — decarbonising industrial sectors that are India's growth engines.

A "new industrial sunbelt" is taking shape globally, comprising of countries having strong fundamentals for clean manufacturing — abundant low-cost renewables, competitive labour, and resource access. India hosts the largest pipeline in this sunbelt and third largest in the world[9]. Unlocking this pipeline is vital for India to position itself as a global hub for clean manufacturing and a self-reliant economy.

Figure 4: Total and announced clean projects[10]

Top 20 countries, by total project count



10. Comparison of global project pipeline is based on near-zero emissions projects mapped by the Global Project Tracker (GPT) to ensure consistency. Excludes 12 low-carbon projects in India that meet the ITA parameters but are not in scope for the GPT.
Source: MPP Global Project Tracker (November, 2025)

Note: **1.** National Energy Statistics 2025 by MoSPI; **2.** Final trade data by MCI; **3.** GIZ Report; 4. Asian Development Bank; **5.** The EU ETS carbon price from 2023; **6.** European Commission data on Trade and Security; **7.** Estimated assuming $1000/ton SAF cost (Sijie Ren, Decarbonizing Aviation: A Comparative Analysis of Power-to-Liquid and Biomass-Derived Sustainable Fuels), 8 MTPA production in India and 3.5 MTPA domestic consumption (Source: IATA); **8.** S&P Global; **9.** MPP Clean industry: transformational trends report

The project pipeline represents a tremendous potential to mobilize over $150 billion investment, create 200,000+ jobs, and abate 5–6% of annual national GHG emissions, once operational

India's current project pipeline represents a transformative investment opportunity, with an estimated capital requirement exceeding $150 billion[1] to reach operational status. To put this in perspective, the required investment is nearly twice the total FDI inflows India received in FY24–25 (~$81 billion)[2]. Much of this pipeline comprises of greenfield facilities, particularly in the chemicals sector, offering large-scale investment opportunities for developing renewable energy, hydrogen and port infrastructure, and core industrial production assets. These investments can accelerate India's industrial growth under the 'Make in India' initiative, strengthen domestic supply chains, and position the country as a global hub for clean industrial production.

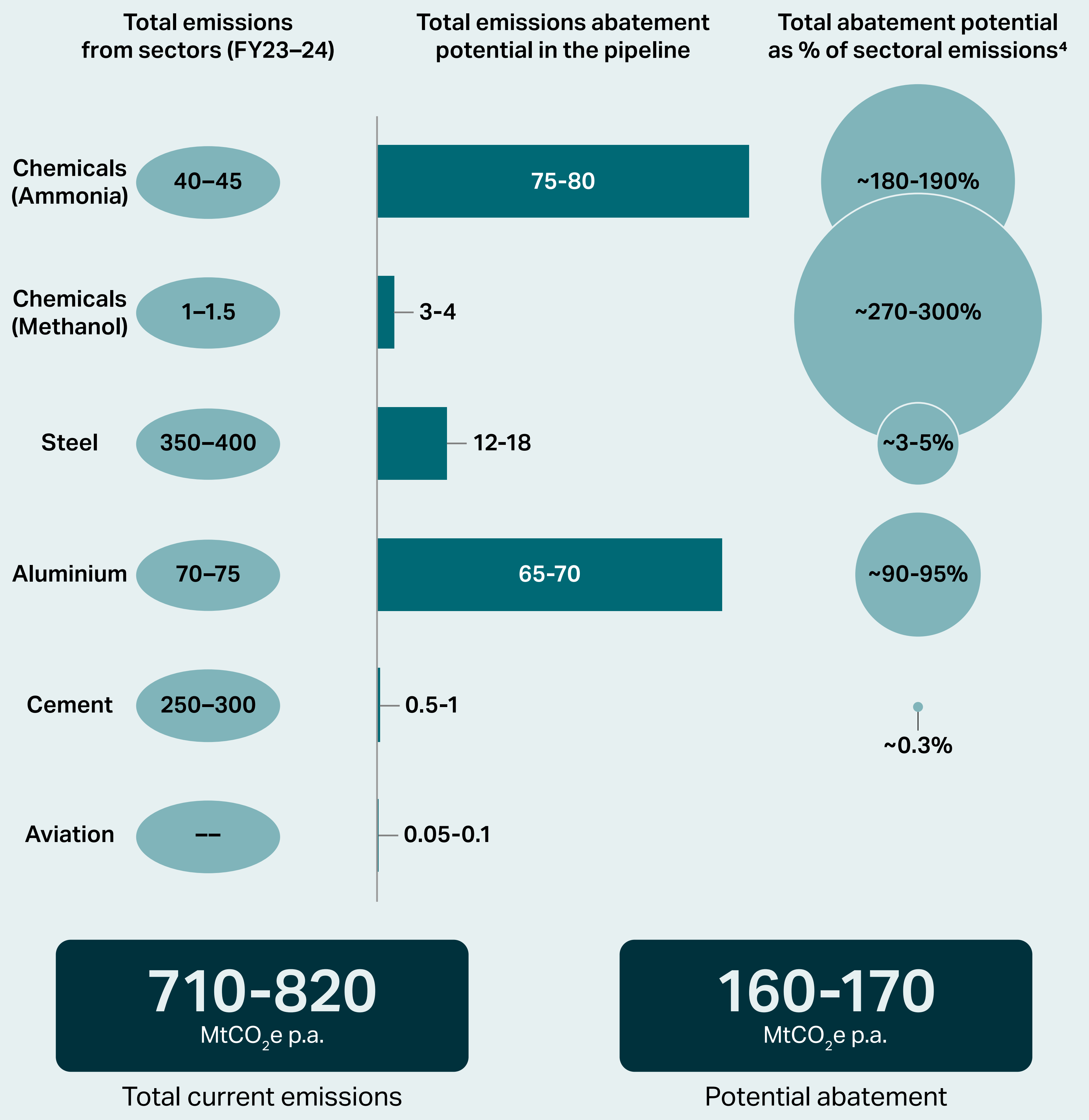
Once fully operational, this pipeline could reduce India's industrial GHG emissions by approximately 160–170 $MtCO_2e$ every year, equivalent to 20–25% of current emissions from these sectors and 5–6% of India's total annual GHG emissions[3]. The bulk of this abatement potential lies in green chemicals sectors, followed by core industrial sectors like aluminium, steel, and cement (Fig. 5).

In chemicals, the announced green ammonia and methanol capacity (51 projects with 30–35 MTPA capacity) exceeds the current national production, positioning these at the forefront of India's clean industrial transition. Developers are expected to build these projects in phases with first-phase capacities typically 0.1–0.3 MTPA to achieve scale economies. While realising the full abatement potential of the pipeline may be delayed (depending on global developments in the green hydrogen and derivates markets), building early momentum is critical. In aluminium, the pipeline already represents a sizeable portion of India's existing primary aluminium capacity, signalling the potential for sector-wide transformation in the near-term. The pipeline for steel and cement is small and thus offers limited immediate impact on sectoral carbon intensity. The multiple pilot projects underway would establish commercial viability and pave the way for scaled deployment of breakthrough technologies.

Alongside these environmental and industrial benefits, the transition promises generation of more than 200,000 direct and indirect jobs. The construction of greenfield facilities will create large numbers of jobs across engineering, logistics, and allied services, while operational projects will support long-term employment for skilled and semi-skilled workers. Early estimates suggest that this pipeline alone could generate hundreds of thousands of direct and indirect jobs across value chains, embedding socio-economic benefits into India's broader decarbonisation goals.

Figure 5: Emission Abatement Potential by Sector

All figures in $MtCO_2e$ per annum



Source: Pipeline analysis, Secondary Research, BCG and ITA Analysis

Note: 1. The figure of $150+ billion refers to the projects and dedicated energy infrastructure. Additional investment would be required to develop shared infrastructure like electricity transmission, ports, gas distribution, and others; **2.** PIB, Ministry of Commerce and Industry; **3.** Total GHG emissions, India = 2.96 BtCO2 in 2020 (India BUR–4);
4. Total abatement potential as a % of sectoral emissions is calculated by dividing the total emissions abatement potential by the total emissions from each sector for FY 23–24

Sector Deep Dives

4

Chemicals

India's distinct strengths in low–cost renewable energy generation, declining electrolyser capex costs, export–oriented hubs, and supportive government policies position it strongly to become a global leader in producing clean chemicals for domestic use and export.

India is emerging as a global hub for clean chemicals production, with a growing pipeline of projects that can reduce import dependence, enhance economic resilience, and tap into export opportunities

India is among the world's leading producers of ammonia but remains import-dependent. India ranks as the third-largest ammonia producer with an output of 17.4 MT in 2022–23[1], representing over 8% of global production capacity[2]. However, despite its large-scale domestic production, around 86% of domestic ammonia consumption is met through imports of ammonia, natural gas or ammonia embedded in fertiliser end-products[3]. In the same period, the country spent INR 1,370 billion (~$16.7 billion) to import natural gas[4], a substantial portion of which is directed towards ammonia production, and $2.25 billion to import ammonia[5].

Green ammonia offers India a strategic opportunity to reduce reliance on imports, strengthen food security, and build global competitiveness. As a critical fertiliser feedstock, ammonia currently exposes India to natural gas price volatility and supply chain disruptions. Substituting imports with domestic green ammonia production can help secure supply chains while supporting decarbonisation. At the same time, Indian producers can tap into global export markets. Global ammonia demand is projected to reach ~220 MT by 2030[6], with clean (green and blue) ammonia expected to account for 7% of supply (15 MT) according to BNEF (Bloomberg New Energy Finance)[7]. India is uniquely positioned to capture this opportunity, its production costs, estimated at 594–774 $/tonne[8], are already among the lowest globally. Recently discovered green hydrogen price of 3.82–4.65 $/kg under tenders by IOCL and BPCL[9] suggest even steeper near-term cost declines, reinforcing India's cost advantage. With this trajectory, India can both reduce import dependency and build an export-oriented green ammonia industry to serve premium international markets. This dual opportunity of import substitution plus export growth positions green ammonia as a cornerstone of India's food and energy security strategy and a key lever for industry decarbonisation.

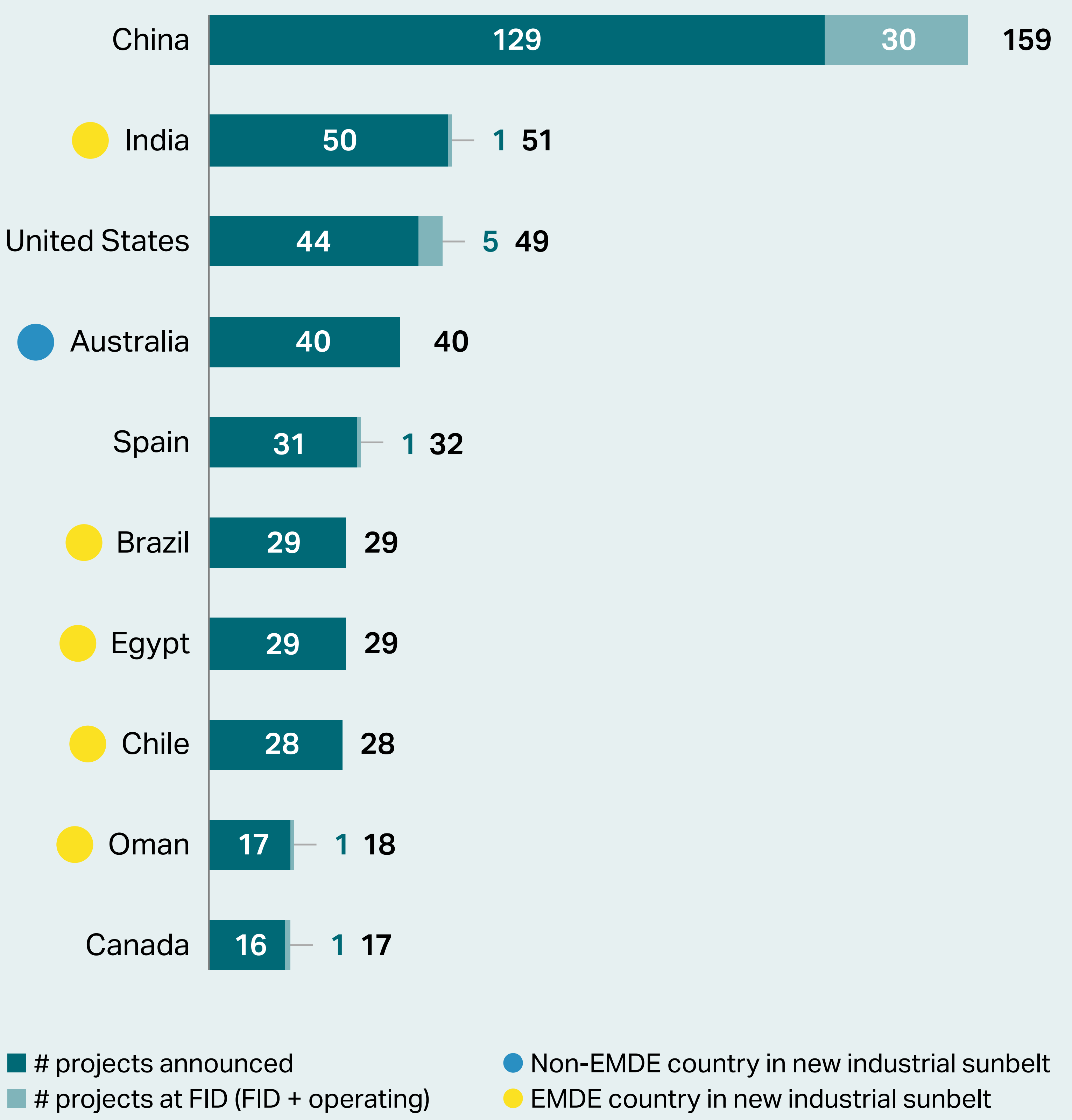
As with ammonia, green methanol offers a powerful lever to enable self-reliance through low-emission domestic production while aligning with India's decarbonisation goals. India consumed 2.97 MT methanol in 2022–23[4], growing at a projected ~15% CAGR through FY29–30[10]. However, with domestic production at just 0.7 MT, the country incurred an import bill of INR 75 billion (~$0.91 billion). Domestic production of green methanol can substitute imports while unlocking strategic export potential, especially as global shipping — the largest potential methanol-consuming sector — is pivoting to cleaner fuels under the expected IMO mandates.

India holds the second-largest global project pipeline for clean ammonia and methanol, behind only China, and is well-positioned to become a global hub in green chemicals production. India has a large pipeline of 51 projects, the highest among any country in the *New Industrial Sunbelt* — a region in global south spanning from Chile to Australia with strong fundamentals to produce cost-competitive green commodities. Yet, progress towards FID remains slow, with just one project having reached FID so far as compared to industrial powerhouses such as China and the US, progressing 30 and 5 projects to FID, respectively (Fig. 6). Accelerating this momentum is essential for India to emerge as a front-runner in the clean energy and industrial transition.

Note: **1.** FAI – Prospects of Green Ammonia in Fertilizer Industry; **2.** Ammonia Energy Association; **3.** CEEW Analysis; **4.** Energy Watch; **5.** GIZ report; **6.** IEA – Ammonia technology roadmap; **7.** BNEF – Ammonia Supply Outlook; **8.** Based on SECI (Solar Energy Corporation of India) Green Ammonia tender (Jun 2024 – Jun 2025) prices, after incorporating GST (CEEW Analysis); **9.** Indian Oil Corporation Limited, Bharat Petroleum Corporation Limited, S&P Global, JMK Research; **10.** Based on Niti Aayog 2030 projections on Methanol

The new industrial sunbelt, is rapidly becoming the centre of clean chemical production, fuelled by robust project pipeline, with India leading the charge among EMDEs.

Figure 6: Clean chemicals (ammonia and methanol) pipeline for top 10 countries.



Note: The ITA prioritises low-emissions ammonia and methanol production in the chemicals sector, as both commodities are expected to play a critical role in decarbonising the global chemicals industry.

Electrolytic hydrogen-based production route is emerging as the leading pathway for green chemicals production in India, supported by strong fundamentals and policy push

Electrolytic hydrogen-based green chemical production is emerging as the leading pathway in India, underpinned by the country's low-cost RE, government subsidies, and technology maturity (Technology Readiness Level (TRL) 8–9). In contrast, other tech pathways remain at early stages. Globally, blue hydrogen is being advanced as transitional pathways, especially in the US, China, and the Middle East, where natural gas is abundant and CO_2 storage infrastructure is relatively mature. In India, however, limited domestic gas availability, high Liquefied Natural Gas (LNG) import dependence, and the absence of large-scale CO_2 transport and sequestration systems make blue pathways commercially unviable in the near-term. Biomass-based routes also offer significant abatement potential but face challenges of high logistics costs, fragmented feedstock supply, and inconsistent quality. Methane pyrolysis is at conceptual stage, with no commercial-scale projects globally.

Table 1: Technology pathways, abatement potential, maturity, and commercial readiness

Production Route	Description	Max. Abatement Potential[1]	Maturity and Adoption
Electrolytic (Green) hydrogen	Combine nitrogen with hydrogen produced via electrolysis of freshwater using RE	Up to 90%	**Proven technology with TRL 8–9 (2030);** ~50 commercial scale projects in India
Blue hydrogen (grey hydrogen with CCUS)	Production from natural gas using a steam methane reformer but with addition of CCUS	Up to 85%	**Globally, mature tech with TRL 7–9 (2030);** No single commercial project in India due to infra and cost challenges
Bio-mass based hydrogen	Gasification or reforming of biomass to produce necessary hydrogen	Up to 90%	**Globally, emerging tech with TRL 6–7 (2030);** No commercial scale project in India due to logistical challenges
Methane pyrolysis	Thermochemical split of methane into hydrogen and solid carbon; green chemical synthesis using resultant low-carbon hydrogen	Up to 90%	**Conceptual stage with TRL 3–4 (2030);** with no demonstrations

Low Medium High

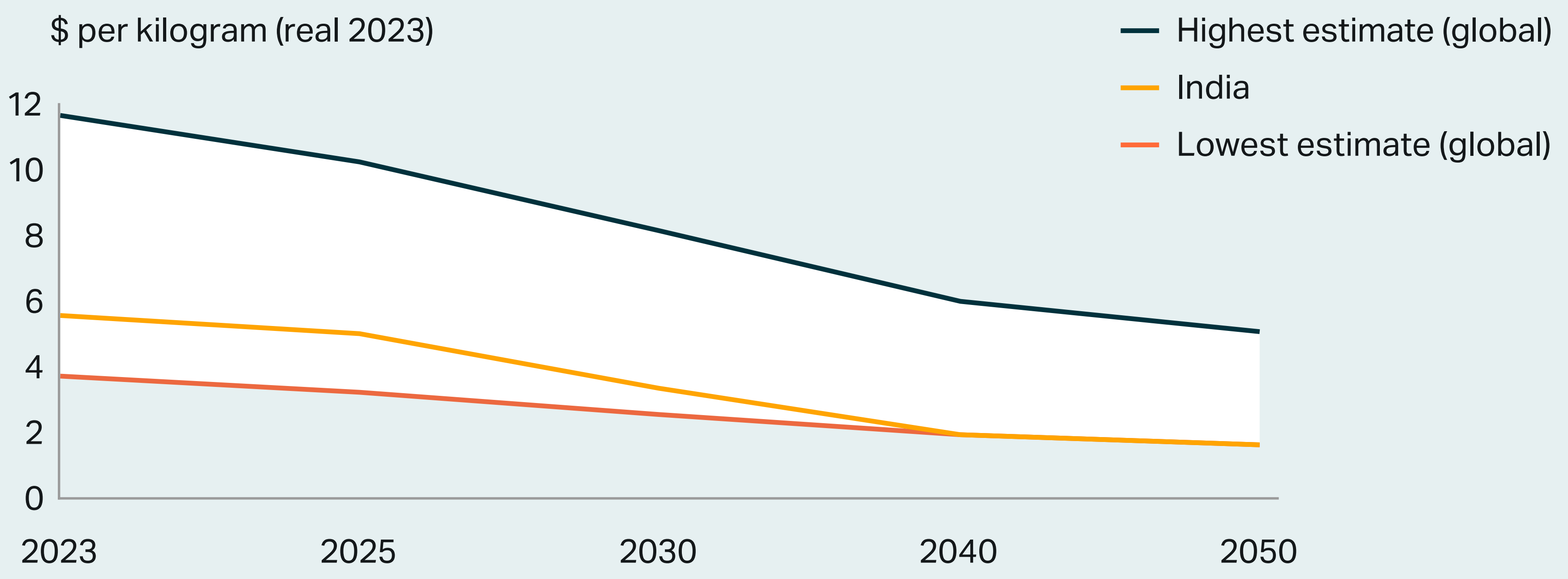
Note: 1. Upper bound for abatement of cement embodied carbon for each individual lever assuming no other levers are implemented; abatement impact of combinations of levers will be less than simple sum because of abatement overlap between levers; estimates are approximate due to diversity of feedstock and production processes; **2.** IRENA Report on Renewable Power Generation Costs; **3.** BNEF Analysis; **4.** S&P Global, JMK Research Source: Secondary Research (WEF reports, academia reports, industry reports etc.) forTRL (Technology Readiness Level)

India is emerging as one of the lowest-cost producer of green hydrogen globally, driven by:

1 **Strong policy push: NGHM was launched to position India as a global leader in the clean energy transition.** The mission sets bold targets and pairs them with strong incentives — production subsidies (INR 13,050 Cr, ~$1.57 billion) and electrolyser manufacturing support (INR 4,440 Cr, ~$0.53 billion), plus concessional wheeling, demand-side support and payment security via Solar Energy Corporation of India (SECI) tenders. Several states add to this with land at concessional rates, stamp duty waivers, Goods and Services Tax (GST) reimbursements, and interstate RE charge waivers, together accelerating project development.

2 **Abundant low-cost RE: India's levelised cost of hydrogen (LCOH) is projected to fall to 3–3.5 $/kg H_2 by 2030, much lower than the global average of 5–6 $/kg H_2,** positioning India among the countries with the lowest projected costs for green hydrogen production (Fig. 7). This is due to low-cost RE[2] and cheap electrolysers (prices are projected to decrease by 20–30% in 2030 from 2023 levels, eventually stabilising at ~$0.37 per watt by 2050)[3]. Recently concluded tenders for Green hydrogen (H2) by IOCL and BPCL discovered green hydrogen price at 4.65 $/kg and 3.82 $/kg respectively[4], one of the lowest in the world, supporting the projected trajectory for the LCOH in India.

Figure 7: Global LCOH estimates, 2023–2050



Source: BNEF Hydrogen Cost Outlook 2025

India's large pipeline of projects reflects industry players' confidence in their potential to deliver highly cost–competitive clean chemicals at scale to global markets

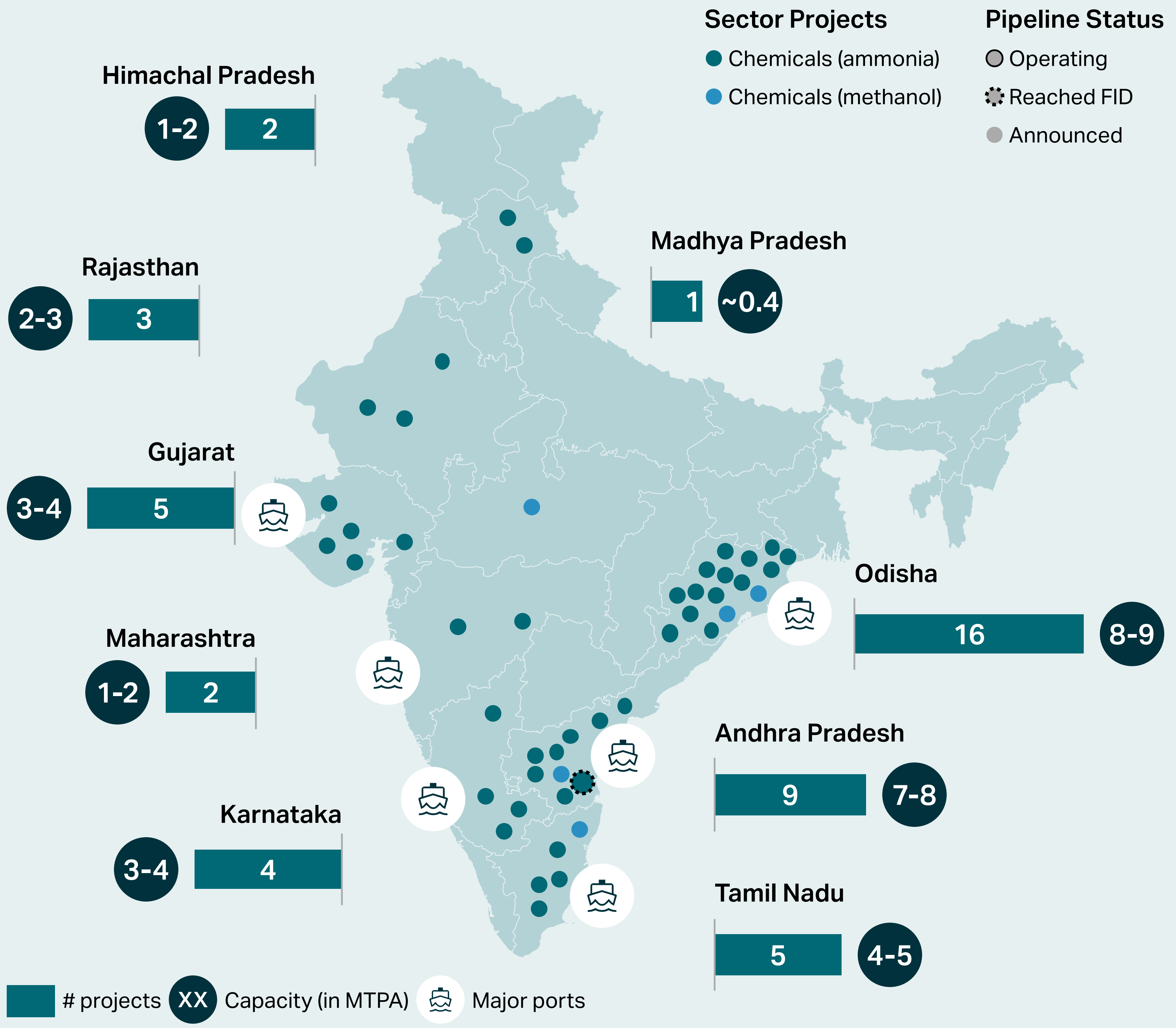
India has one of the largest green ammonia and methanol project pipelines globally, and the largest amongst EMDEs, with 51 projects. This pipeline could unlock ~$130 billion in investment, create thousands of green jobs, and expand India's green hydrogen capacity beyond 6 MTPA by 2030, surpassing the NGHM target of 5 MTPA. Green ammonia dominates the pipeline with 46 projects and ~30 MTPA capacity. While ammonia dominates the pipeline, green methanol projects are taking shape. At least five commercial-scale projects are underway, including the V. O. Chidambaranar Port bunkering pilot, which will provide 750 m^3 of storage and anchor India's role in coastal green shipping corridors. This reflects growing confidence in methanol as a bridge between hydrogen production and carbon utilisation pathways.

Five states dominate the pipeline, positioning themselves as regional hubs with a large share of projects led by established RE players. Odisha, Andhra Pradesh, Tamil Nadu, Gujarat, and Karnataka are emerging as green industrial hubs, owing to access to natural resources, trade infrastructure, and enabling policy environments (Fig. 8). Odisha leads in planned capacity, supported by proximity to major ports (Paradip, Kakinada, Kandla, Tuticorin) that provide crucial infrastructure for exports. Just six major developers — AM Green, ACME, National Thermal Power Corporation (NTPC), ReNew, Ocior, and Avaada, account for approximately half of the announced pipeline capacity, with the rest distributed amongst 20+ players. Most major RE players have announced at least one project driven by the strategic decision to diversify from green electrons into green molecules. These players are well positioned to leverage their strong balance sheets and project execution experience to take on the high capex of hydrogen-based production.

Export optimism underpins the pipeline as mandates and incentives in international markets are creating regulatory pressures and premium market openings that are set to reshape global trade flows. The green ammonia industry is banking on India's ability to supply cost-competitive green chemicals to global markets, particularly where direct ammonia use avoids costly reconversion in sectors such as fertilizers and power. This ambition is backed by regulatory mandates and supply-side incentives in the EU, Japan, and South Korea, through measures such as the EU's RED III and Japan's Contracts for Difference, opening lead markets for green hydrogen and its derivatives. Global supply for green ammonia is expected to reach up to 15 MTPA by 2030[2] (Fig. 9). The EU alone plans to import ~10 MTPA of renewable hydrogen under REPowerEU Plan by 2030[3].

Demand for green methanol is also expected to develop, especially in shipping, where the IMO's new GHG reduction measures (MEPC 83, effective 2027) will require shipping companies (including ~14% of Indian-flagged ships) to shift gradually towards sustainable zero emissions fuels (SZEFs). India is well positioned to capture these high-value opportunities, particularly to supply to hubs like Singapore, emerging as Asia's anchor for green bunkering corridors[4].

Figure 8: The ITA has identified 51 announced commercial-scale green ammonia and methanol projects aligned with its parameters[1]



Represents a huge opportunity for the country

30-35	~130	6-6.25	80-85
Green ammonia/methanol capacity (MTPA)	Est. investment (USD billion)	Est. Green hydrogen required (MTPA)	Est. carbon abatement ($MtCO_2e$ p.a.)

Note: 1. Pipeline has been identified as per ITA's criteria (details in appendix section); It also includes 4 projects where the location is unspecified; **2.** BloombergNEF report; **3.** Hydrogen Energy – European Commission announcement; **4.** The Silk Alliance is a multi-stakeholder partnership exploring the adoption of zero emission fuels for vessels that bunker in Singapore to trade across Indian and Pacific Oceans; Estimates suggest requirement of 3 MTPA green methanol and 0.3 MTPA green ammonia by 2030
Source: BCG and ITA Analysis

India is structurally advantaged to serve this demand due to its cost competitiveness. The levelised cost of green ammonia in India discovered through the tenders by SECI is already one of the most competitive globally. Estimated at 594–774 $/tonne[1], it is nearly half the price of EUR 1,000/tonne ($1,160/ tonne) discovered in Germany's H2Global auction in 2024[2]. The weighted average price of green ammonia is now nearly competitive with grey ammonia compared to the five-year weighted average landed import price of grey ammonia of ~$560 per tonne (excluding the temporary Russia-Ukraine-induced spike, Fig.10). Green ammonia is rapidly closing the cost gap — and the tailwinds of cost stability, decarbonisation mandates, and enabling policy frameworks are increasingly shifting the economics in its favor. Accounting for volatility from external shocks further strengthens the case for transition to green ammonia, underscoring its potential to stabilise supply chains and hedge against fossil fuel-linked price swings.

While the landed price of Indian exports will be higher due to the absence of domestic subsidies and the added costs of complying to global market standards, India still holds one of the strongest cost positions globally. This has been enabled by:

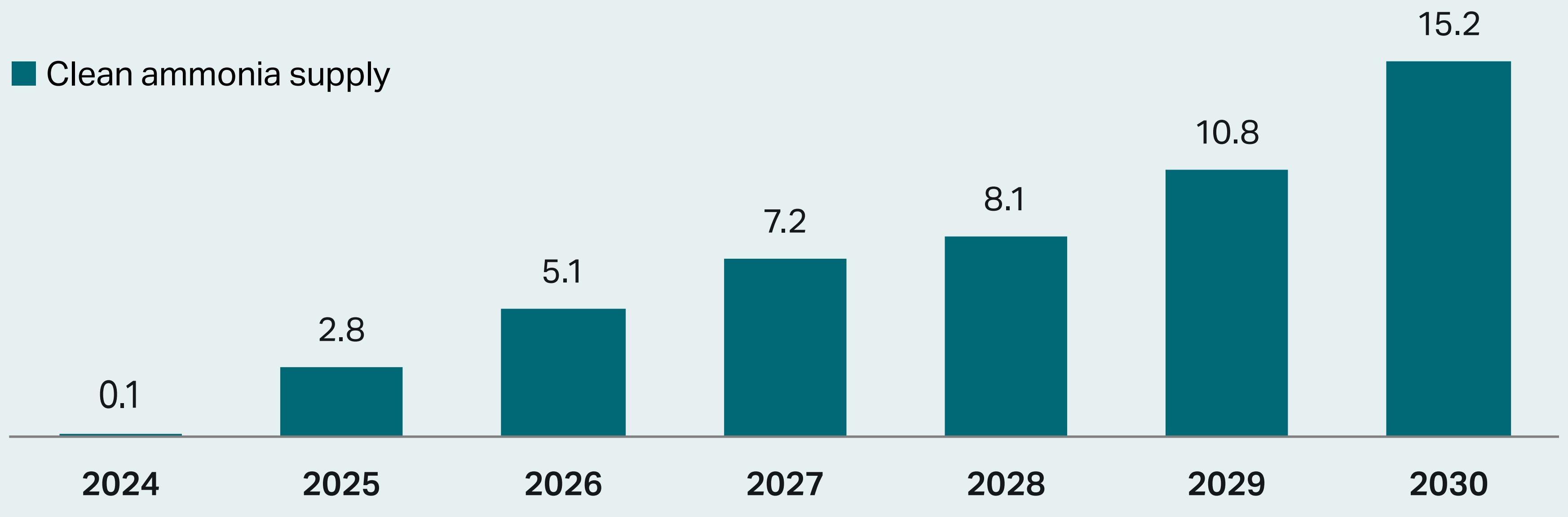
- Flexible "green-hydrogen" definition in India, allowing grid banking and semi-baseload operations of electrolysers, significantly reducing capex. In contrast, RFNBO-compliant hydrogen in the EU requires oversized electrolysers and variable operations, driving higher capital costs
- Production and electrolyser manufacturing subsidies awarded under the NGHM
- Lower transportation costs through SECI's push to co-locate renewable ammonia production near existing fertiliser manufacturing plants
- Guaranteed medium-term offtake (10 years) and robust payment security mechanisms via SECI tenders reduce revenue risk, unlock access to commercial financing, and strengthen project economics

The strong pipeline can move from plans to plants to seize the opportunity. Majority of announced projects have remained stuck at the announced stage for over two years. Progress has been slow, with only one project — AM Green's green ammonia projects in Kakinada (0.5 MTPA, part of its total announced capacity) — having reached FID. A handful of developers have advanced to the Front-End Engineering Design (FEED) stage, but they face major hurdles: securing long-term offtake at a green premium, inadequate supporting infrastructure, and complex international regulatory requirements. The real test for India lies in converting its vast announced pipeline into operational assets, establishing itself as both an export leader and a builder of resilient domestic markets.

Figure 9: 15 MT of clean ammonia supply could be reached by 2030

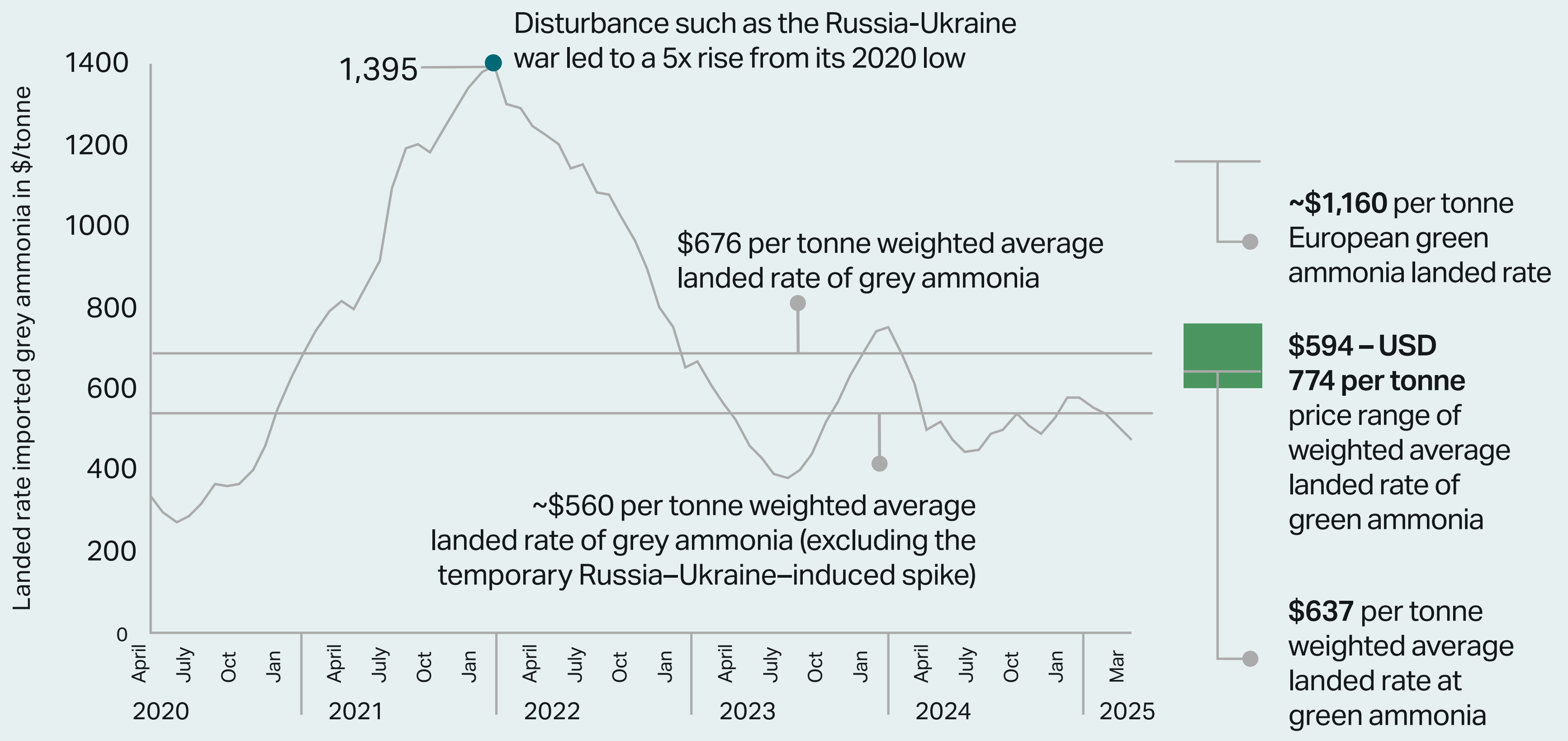
Probability-adjusted clean ammonia supply forecast

All figures in million tonnes per annum (MTPA)



Source: BloombergNEF

Figure 10: Discovered price of green ammonia compares favourably with weighted average landed rate of grey, indicating commercial viability



Source: CEEW Analysis, BCG and ITA Analysis

Note: 1. Based on SECI (Solar Energy Corporation of India) Green Ammonia tender (Jun 2024 – Jun 2025) prices, after incorporating GST (CEEW Analysis); **2.** CEEW Analysis

Addressing three critical bottlenecks to scale up clean chemical projects in India: long-term offtake at premium, infrastructure readiness, and access to low-cost finance (1 / 2)

Bilateral consultations with project developers reveal three critical enablers for bankability and financing. Understanding these industry setbacks is vital to addressing the underlying drivers of delayed execution.

A Securing long-term binding offtake agreements at premium are critical for project bankability

Without clear and consistent demand signals, green chemical projects struggle to become bankable and secure project finance. Developers typically require binding offtake agreements of at least 10–15 years to take an FID, and many prefer longer 20-year terms, which improve project economics and lower premium requirements. However, long-term binding contracts at a premium are not materialising.

Potential to scale the domestic green ammonia market in near-term is limited. The domestic anchor demand — fertiliser sector — is heavily regulated and subsidised, leaving thin margins and little room to pay a green premium. The Government's first step via SECI's Green Ammonia tender under the NGHM (~0.724 MTPA across 13 tenders) is a foundational step, but well below potential supply from the pipeline. In fact, the awarded volumes cover only a share of the total announced capacity, leaving developers without bankable offtake for the balance and slowing FIDs. Moreover, near-term domestic demand is likely to be limited to displacing imported ammonia for non-urea fertilisers (e.g., NPK/NAP)[1], where the premium is relatively small; and beyond fertilisers, there are no immediate demand sources or mandates that guarantee long-term offtake at scale. At current price points, scaling domestic tenders much beyond ~2–3 MTPA in the near term appears unlikely, leaving producers to prioritise exports.

Global buyers have yet to demonstrate strong willingness to pay a green premium and enter long-term binding offtake agreements. Given domestic market constraints, most producers are targeting exports to international markets, primarily Europe, Japan, South Korea, and Singapore. However, buyers in these markets remain cautious, expecting future cost declines and fearing the risk of locking into higher-priced supply. This hesitancy is compounded by regulatory uncertainty in the EU, where implementation of RED II/RED III[2] regulations at the member state level has been delayed. Further complicating the landscape are stringent (and non-harmonised) clean hydrogen standards and regulations across lead markets. For example, RFNBO[3] norms under the EU regulations mandate strict time correlation of RE for hydrogen production and have standards on the use of CO_2 from non-biogenic sources, making compliance for Indian projects both technically and financially challenging.

In global markets, H2Global is the most significant double-sided auction mechanism to enable scale-up of green hydrogen and derivates market, yet the scale remains small. H2Global has mobilised €5.8 billion in committed funds, with expanded auctions — including green methanol and potentially e-SAF. Several Indian players have placed bids in the second tender (launched in Feb 2025), which is backed by €2.5–3 billion, split into five lots spanning exports from Africa, Asia, South America and Oceania, North America, and the EU[4]. However, the capacity allocated is modest with auctions averaging at 0.04–0.05 MTPA.

In the shipping sector, while the IMO's draft regulations signal progress, the expected short-term targets would be insufficient to drive strong near-term demand for Sustainable Zero Emission Fuels (SZEF) such as green ammonia and e-methanol. Shipping companies too remain conservative — investing in dual-fuel vessels and relying on LNG as a transitional fuel rather than committing to SZEF offtake.

Limited bankable demand is preventing suppliers from securing sufficient offtake to reach economies of scale. Developers report uncertainty on optimal plant size but indicate that 0.1–0.3 MTPA modules are needed to achieve economies and improve unit economics. This is backed by pipeline data that records developers announcing multi-phase projects totalling up to ~1 MTPA across 3–4 phases. However, with inadequate demand, only a fraction of this capacity is locking in offtake agreements. Consequently, only a small share of the pipeline is likely to come online in the next few years, provided the contracted demand materialises.

To unlock large-scale investment, demand creation can accelerate through stronger policy instruments, including procurement standards, blending mandates, and fiscal incentives. Simultaneously, market-making mechanisms such as SECI's tenders and international platforms like H2Global can play a critical role in aggregating supply and demand and providing price discovery for green chemicals.

Note: 1. NPK (Nitrogen, Phosphorus, and Potassium) and NAP (Normal Ammonium Phosphate – Nitrogen, Phosphorus); **2.** Renewable Energy Directive II/ III; **3.** Renewable Fuels of Non-Biological Origin (renewables-based hydrogen and e-fuels); **4.** H2Global press release/ website

Addressing three critical bottlenecks to scale up clean chemical projects in India: long-term offtake at premium, infrastructure readiness, and access to low-cost finance (2 / 2)

Bilateral consultations with project developers reveal three critical enablers for bankability and financing. Understanding these industry setbacks is vital to addressing the underlying drivers of delayed execution.

B Access to debt financing and cost of capital continues to be a major hurdle for project viability

The financing landscape for green ammonia and methanol projects in India is still in its early stages. While institutional interest is increasing, demonstrated by commitments such as REC Limited's signing of agreements worth $6 billion in 2023[1] to support green hydrogen and ammonia initiatives, accessing debt remains challenging. Where debt is available, the cost of capital is significantly higher than for conventional RE projects, creating a major hurdle for the viability of these investments, especially for First of a Kind (FOAK) projects.

One of the primary reasons for this difficulty lies in the high project-specific risks associated with green hydrogen derivatives projects. Unlike country risk, which lenders are generally willing to take, project risk is both real and perceived to be high. Market risk is a major factor: unlike renewables with long-term Power Purchase Agreement (PPA), green chemicals projects are struggling to find binding long-term offtake. Technology risk remains high due to the lack of an established performance track record for large-scale electrolysers and related systems, compounded by limited lender expertise and resulting conservative assessments. Additionally, counter party credit worthiness is a concern. As a result, projects rely on very high equity contributions — often 50–70% versus ~30% for RE projects — raising costs and limiting the number of projects that can advance. This issue is accentuated for smaller developers, who typically have weaker credit ratings and balance sheets, making it harder to fund early-stage development and equity for high-risk projects compared to large corporates. The impact of financing costs on overall project economics is particularly stark: an increase in the cost of capital from 10% to 20% can drive up the LCOH by up to 73%[2] (holding all other cost factors constant). High sensitivity underscores how critical cost of capital is in determining competitiveness of capital-intensive projects and the need for de-risking interventions.

To address these challenges, de-risking mechanisms and innovative financing structures are essential. Key interventions include credit guarantees and sovereign-backed risk-sharing instruments to lower perceived project risk, concessional and blended finance to reduce capital costs, and instruments such as green bonds to attract institutional investors. Additionally, equity co-investment by value-chain partners, including offtakers, can align incentives and strengthen bankability. Development finance institutions and multilateral banks also have a catalytic role to play in anchoring early projects and crowding in commercial capital. Most important however, is securing bankable offtake contracts.

C Lack of adequate transmission, port infrastructure, and supply-chain readiness (CO2 for fertilisers and methanol) restrict scalability of green chemicals

Expansion of grid infrastructure for large-scale green hydrogen projects is a constraint. India is rapidly expanding RE capacity, adding 15–20 GW annually[3]. Transmission networks are already under significant strain, with permitting delays, land acquisition challenges, and congestion in renewable-rich regions slowing project execution. Recent measures, such as Gujarat's INR 29,000 crore investment under Green Energy Corridor III[4] to create robust transmission network, are encouraging. Yet a coordinated national-scale response is required to address grid bottlenecks that could undermine the availability of low-cost renewable power for large scale projects.

Port infrastructure also remains underprepared to handle the specialised requirements of green chemical exports. Facilities for storage, handling, and bunkering of green hydrogen derivatives are in their infancy. Unlike oil and LNG, India currently lacks shared infrastructure for green chemicals and fuels, which raises costs and delays execution timelines. Developing common-user terminals and integrating them into industrial clusters will be crucial to build viable export hubs, particularly if India seeks to compete with regions like the Middle East and Australia, which are already investing heavily in port logistics.

A further constraint lies in the limited availability of CO_2 — an essential feedstock for green fertiliser and methanol production. India lacks basic CCUS ecosystem, making it difficult to align green hydrogen production with sustainable CO_2 sourcing. A large share of available CO_2 is expected to be fossil-derived (from non-biogenic sources) but international regulations (e.g., the EU and the IMO) restrict its use in green chemicals production beyond a specific timeframe. This gap not only constrains domestic project viability but also risks locking India out of premium export markets unless alternative biogenic or direct air capture CO_2 pathways are scaled.

Note: 1. REC Limited Press release; **2.** OECD report on financing cost impacts on cost competitiveness of green hydrogen in emerging and developing economies; **3.** IFRI Report on Unlocking India's Energy Transition; **4.** Public announcements by Gujarat govt.

Steel

While India's growing steel demand is currently set to be met through carbon-intensive production assets, producers can leverage low-cost renewables, a rapidly developing green hydrogen ecosystem, and policy momentum to pivot towards low-emissions steel production — avoiding future lock-ins and unlocking global competitiveness.

As India's iron and steel industry expands rapidly on carbon-intensive pathways, transition to clean production can avoid carbon lock-in and unlock trade opportunities

India is the world's second-largest producer of crude steel and the largest producer of direct reduced iron (DRI), with rapidly growing domestic demand. As of FY24–25, India's crude steel production stands at ~152 MT[1] annually, contributing ~2% to national GDP[1] and accounting for ~8% of global crude steel[1] and ~40% of global DRI[1] production. Driven by strong demand from infrastructure, consumer goods, and automobiles, India has become a major consumption hub. Though India's per capita steel consumption is less than half the global average (~220 kg[2]); the country aims to reach 160 kg per capita consumption[1] and 300 MTPA production capacity[1] by 2030. Fuelled by domestic demand, the Indian crude steel production recorded the fastest growth among the world's top 10 producers and is further poised for a massive scale-up. According to the Global Energy Monitor, India's ironmaking capacity is announced to double[3] and its steelmaking capacity to triple[3] in coming years, while other major producers have announced to add only ~20–60%[3] to their existing capacities (Fig. 11A and 11B).

The iron and steel industry is also the country's largest industrial source of GHG, contributing an estimated 10–12% of the national total. It is also among the most energy- and emissions-intensive globally: in FY23–24 its average intensity was ~2.54 tCO_2/tcs[1] versus a global average of ~1.91 tCO_2/tcs[2]. This gap stems largely from the technology mix — 90% of primary iron in India is produced via coal-based BF and rotary-kiln DRI[1], with greater share of capacity in BF. Indian steel plants with BF units on average emit 2.4–2.5 tCO_2/tcs, typically 30–40% higher than similar units in European countries like Germany and Sweden. Adoption of best available technologies (BATs) is gradually closing this gap but their penetration, particularly in the smaller-scale steel plants, remains limited.

Planned investments in cost-effective but carbon-intensive assets risk locking the industry into high emissions pathways and out of emerging low-emissions steel markets. BF account for ~80% of additional ironmaking capacity[3] and basic oxygen furnaces (BOF) for ~55% of additional steelmaking capacity[3] (Fig. 11A and 11B). The reliance on fossil-based routes reflects the need to meet domestic demand cost effectively in the absence of viable low- or near-zero-emission alternatives such as green hydrogen and carbon capture. Constraints in access to high-grade iron ore, natural gas, and bioresources further restrict the shift to cleaner pathways. At the same time, overcapacity in the global markets (creating downward pressure on prices) and rising competition from Asian producers have weakened Indian steel exports in recent years. These exogenous pressures erode profit margins and constrain the industry's ability to invest in transitional and near-zero emissions technologies. The current trend presents a significant risk of locking in massive carbon emissions over the coming decades. Further, with commitments from global steel consumers for reduction of carbon footprint from purchased materials, failure to transition to low carbon steel would result in significant loss of export opportunities for Indian producers.

The Indian steel sector and the Government of India demonstrate a strong intent to overcome the challenges to shift towards low-emissions pathways. With abundant renewable energy potential, a rapidly developing green hydrogen ecosystem, and a supportive policy landscape, India has an opportunity to position itself as a global leader in cost-competitive, low-carbon steel production. In 2025, the government (in consultation with the industry) has set a target to reduce emission intensity to below 2.2 tCO_2/tcs by FY29–30, aligned with the CCTS. Policy momentum is building further through the NGHM and the upcoming National Green Steel Mission. With the support of initiatives like LeadIT, near-term efforts focus on deploying commercially viable BATs, expanding RE use, and increasing scrap utilisation, while piloting low-carbon alternatives such as green hydrogen, biochar, and CCUS.

Note: 1. Ministry of Steel report; **2.** World Steel data; **3.** Global Iron and Steel Tracker by Global Energy Monitor; **4.** Top 6 producers account for ~80% to global operating capacity for iron; **5.** Top 6 producers account for ~65% to global operating capacity for steel; Steel emission intensity measured as tonne CO2 per tonne of crude steel (tCO2/tcs)

India's fossil-based expansion is nearly as large as next five countries for iron and twice as large for steel production, posing a risk of long-term carbon lock-in

Note: The charts present data for plants with more than 0.5 MTPA capacity only, and hence, might not represent the total capacity

All figures in MTPA

Figure 11A: Ironmaking capacity by route for top six countries[4]

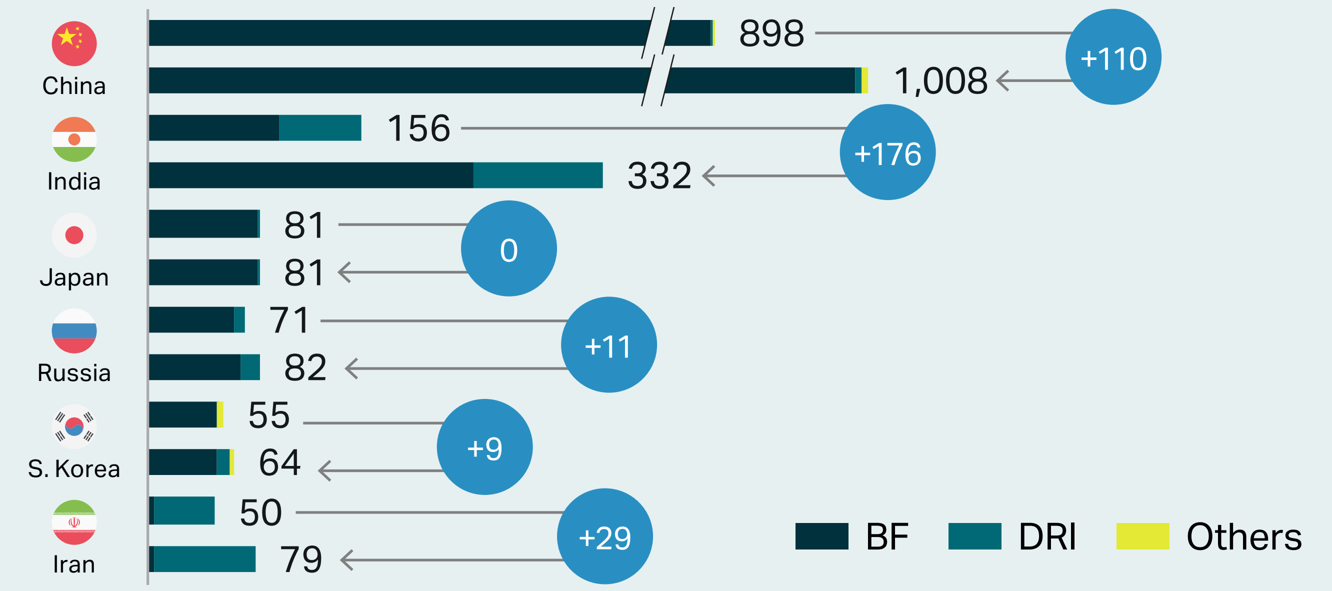
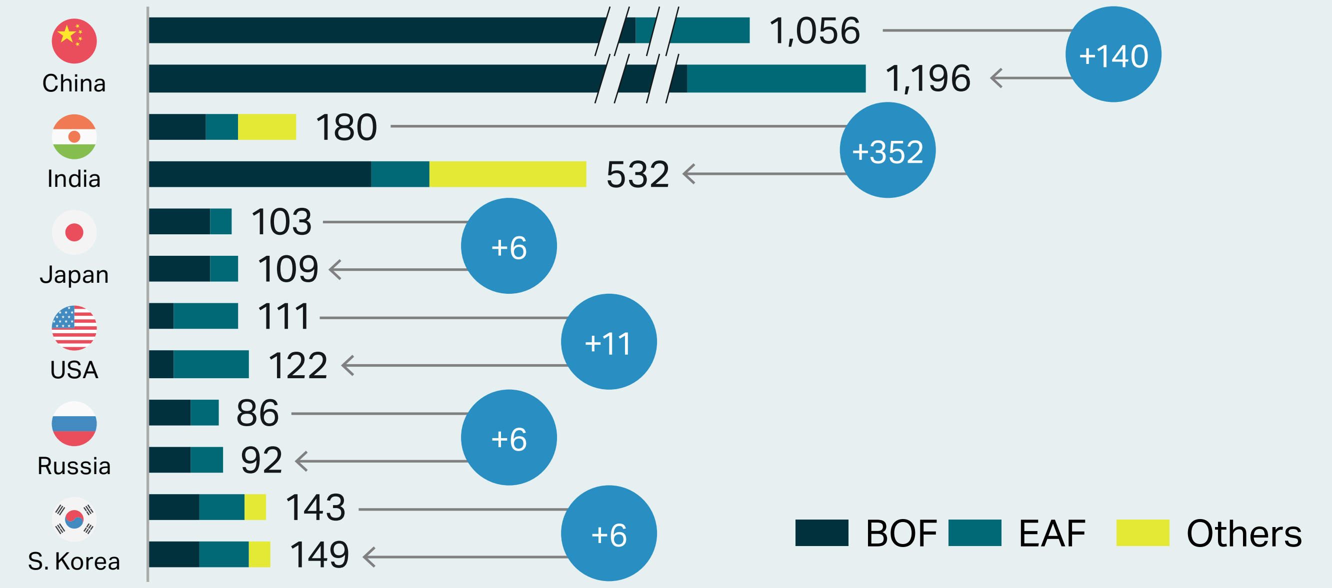


Figure 11B: Steelmaking capacity by route for top six countries[5]



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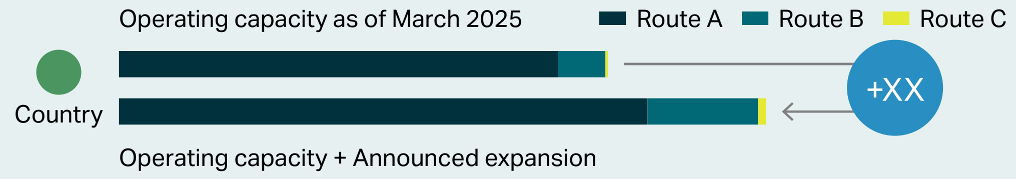


Source: Ministry of steel for operating capacity in India, Global energy monitor for operating capacity in other countries and announced expansion for all countries

Scaling up First-of-a-Kind projects across multiple low and near-zero emissions pathways for primary iron and steelmaking is imperative to establish their suitability, commercial viability, and scalability

With significant headroom for growth, India's steel sector is well placed to explore a mix of low-carbon technologies. The most promising pathways include:

- **Hydrogen-based ironmaking:** Globally, hydrogen in ironmaking can cut emissions by 15–95%, depending on the route. In India, green hydrogen injection into vertical shaft DRI[2] units shows the greatest potential, while hydrogen injection into BF offers only limited benefits. High green hydrogen costs and limitations on using low–grade iron ore remain major barriers, though alternatives under development such as the H-DRI-ESF[3] (smelt) + BOF route could address ore quality issues. Natural gas-based DRI[2], often viewed as a transitional pathway, faces cost and price volatility challenges in India.
- **Carbon capture with BF-BOF[1]:** Given India's large existing and planned fossil-based capacity, CCUS is a critical decarbonisation lever for the BF-BOF route, which has few scalable alternatives. However, low CO2 concentration in flue gas leads to high capture costs (~$50/ tCO_2), technology scalability is low, utilisation pathways are limited, and India's storage ecosystem is under-developed, making large-scale deployment challenging.
- **Scrap utilisation:** Increasing scrap use can avoid up to 70% of emissions compared to primary steelmaking. Today, India's use of scrap is constrained by limited domestic availability and reliance on imports. However, growing steel consumption and policy measures to promote circularity are expected to boost access to high-quality scrap in the years ahead.
- **Direct electrification/electrolysis:** Emerging solutions such as low-temperature and molten oxide electrolysis are still at early stages but could replace smaller coal-based DRI[2] units in the long term. These pathways depend on abundant clean power — an area where India has a strong advantage.

Bringing online FOAK projects would help establish clear pathways for the transition, while futureproofing the Indian steel industry from shifts in global markets. FOAK projects across multiple low-emissions routes can help establish the business model, enable "learning-by-doing", build confidence amongst stakeholders, and open opportunities for producers to capture opportunities in the global export markets for green steel in the coming decades.

Table 2: Low-emissions iron and steelmaking technology pathways, abatement potential, maturity, commercial readiness, and cost

Production Route	Description	Max abatement potential[4]	Maturity and widespread adoption	Cost of Abatement
Hydrogen based DRI (H-DRI)	Natural gas DRI[2] transition to H-DRI	Up to 90%	**Nascent technology (TRL 7)** with one commercial scale project in India; limited by natural gas availability	$200–250/tonne
	100% green hydrogen DRI	Up to 99%	**Nascent technology (TRL 6)** with a few pilot scale projects in India; adoption limited by cost of green hydrogen	$200–250/tonne
CCUS	BF-BOF[1] unit with CCUS	Up to 60%	**Nascent technology (TRL 5)** with a few pilot projects exploring feasibility for scaled adoption	$110–180/tonne
	Coal DRI-EAF/EIF[5] unit with CCUS	Up to 90%	**Development stage (TRL 4)** with no comprehensive study in India; higher unit cost due to small size	$110–480/tonne
	Gas DRI-EAF unit with CCUS	Up to 90%	**Mature technology (TRL 9)** with one commercial and multiple pilot scale projects in India	$100–180/tonne
Direct electrification/ electrolysis	Molten oxide electrolysis in arc furnace at 2000°C	Up to 90%	**Development stage (TRL 4)** with no comprehensive study in India; early testing underway by Boston Metal, an US-based startup	-
	Low temperature electrolysis at <110°C	Up to 90%	**Development stage (TRL 4)** with no comprehensive study in India; early testing underway by Electra, an US-based startup	-
Scrap-EAF	Replacement of iron with steel scrap	Up to 70%	**Proven technology (TRL 9)** with widespread use of scrap in varied proportions across existing units	$50–110/tonne

Low Medium High

Note: 1. BF-BOF: Blast Furnace-Basic Oxygen Furnace; **2.** DRI: Direct Reduced Iron; **3.** H-DRI-ESF: Hydrogen-based Direct Reduction Iron with Electric Smelting Furnace; **4.** TERI – Achieving green steel: Roadmap to a net zero steel sector in India; **5.** DRI-EAF/EIF: Direct reduced iron-Electric arc furnace/Electric induction furnace;
Source: Secondary research, BCG and ITA analysis

India’s project pipeline demonstrates a growing momentum to pilot and scale-up clean steelmaking technologies, led by major industry players and supported by the Indian government

The current pipeline of projects in India’s steel sector is characterised largely by retrofitting of existing assets and brownfield expansions, signifying an incremental yet important shift towards low-emissions production. In the near-term, major industry players are focused on adopting BATs, and piloting novel technologies including hydrogen-based DRI, hydrogen injection in BF and carbon capture across DRI and BF units. These pilot and demonstration projects are critical for industry to learn the technical characteristics and establish financial viability of next-generation technologies before scaling to commercial-scale applications.

Use of green hydrogen is in early stages with just two commercial-scale projects being announced. The first project is a 4 MTPA green steel project by JSW low-carbon steel (to be carried out in two phases of 2 MTPA each) involving phased transition of a natural gas-based plant to green hydrogen. In a major development, JSW Steel would soon commission one of the first projects in India to partially use green hydrogen in DRI[1] unit at its Vijayanagar plant, deploying a 25 MW electrolyser. Other project is a pilot for green hydrogen injection into BF by Steel Authority of India Limited (SAIL). Beyond these two projects, a handful of small-scale pilots, some supported by the Ministry of Steel, are testing green hydrogen integration across both BF and vertical shaft DRI units. These projects demonstrate early momentum across leading steel producers. Successful scaling of these initiatives hinges on achieving commercial viability through cost decline in green hydrogen production and structuring of de-risked business models, including securing offtake for premium low-carbon steel.

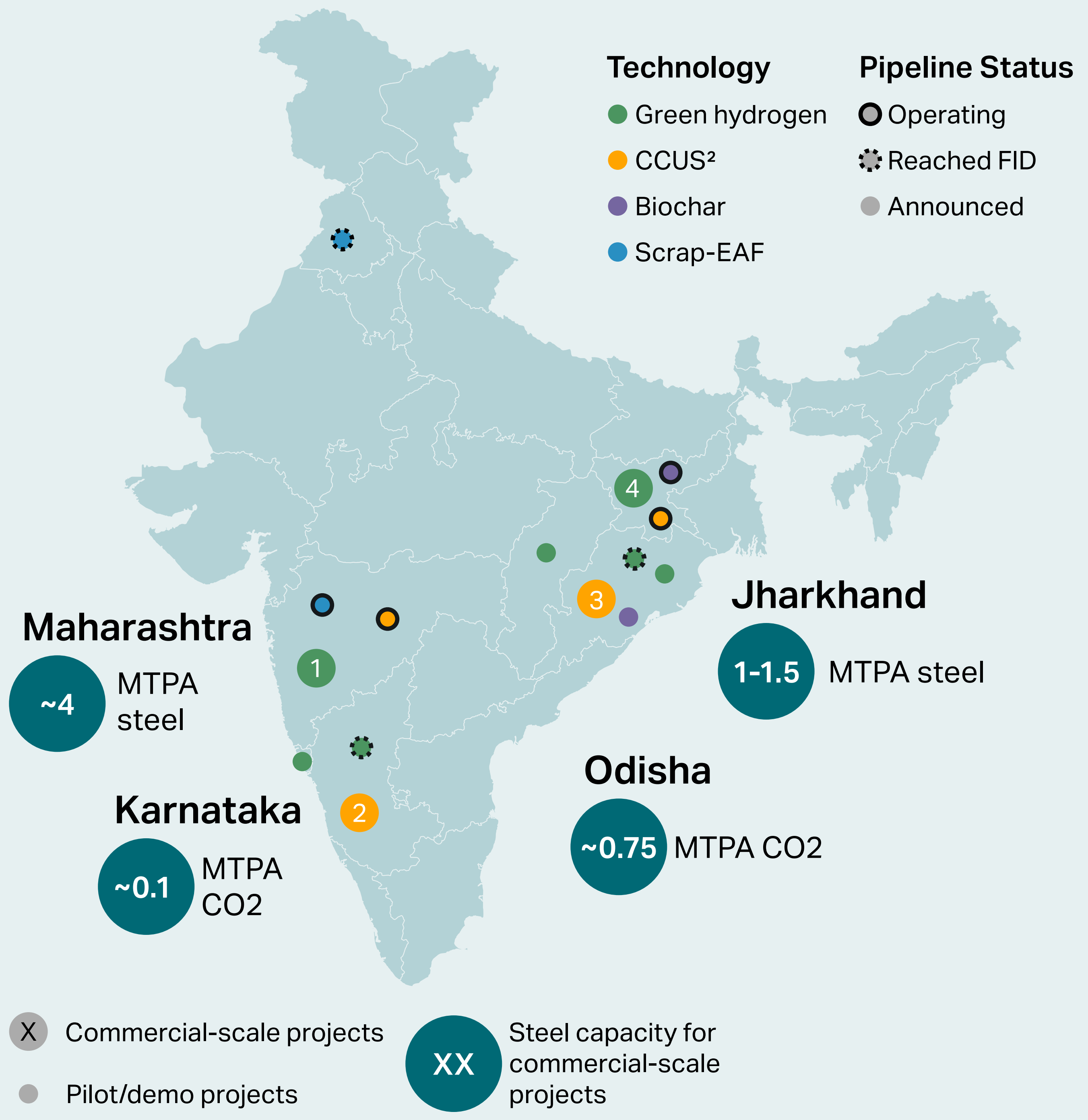
Progress on CCUS[2], a critical decarbonisation lever for India given the large base of existing fossil-based assets and a large pipeline of BF-BOF[3] plants, is limited. The pipeline includes one commercial-scale carbon capture and utilisation (CCU) project by Jindal Steel Limited, where capture units are already installed but require CO2 utilisation partnerships to qualify for green steel production. In addition, several pilot-scale plants are underway, including two facilities that have been operational for nearly a decade, serving as proof-of-concept for large-scale adoption. However, the lack of demand for green steel, in both domestic and international markets, and dearth of clear utilisation and storage pathways for captured CO2 remain a significant barrier to scale-up.

Other low-carbon pathways in the pipeline include scrap-based steelmaking and the use of biochar as a substitute for coking coal, with two pilot projects in each category. While these represent cost-effective and near-term transition options, their scalability is constrained by limited long-term sustained availability of high-quality scrap and the absence of standardised feedstock for biochar production.

India's project pipeline is geographically concentrated in the major steel belts of India. Maharashtra and Karnataka, constituting the western belt, offer proximity to manufacturing industries and thus, provide downstream logistical advantage to steel plants. Odisha, Jharkhand, and Chhattisgarh, constituting the eastern belt, provide access to vast mineral reserves, thereby improving raw material security for the plants.

Most of the projects in the pipeline belong to the legacy Indian steel producers such as JSW Steel, Jindal Steel Limited, and SAIL. There are a growing number of pilot projects across emerging ironmaking and steelmaking technologies, supported by national initiatives like LeadIT.

Figure 12: The ITA has identified four commercial-scale and several pilot/demo projects that align with ambition of low carbon steel production[4]
(commercial-scale projects numbered 1-4)



India's iron and steel project pipeline represents a steadily growing economic opportunity for the country

5-5.5 Low carbon steel capacity (MTPA)

12-15 Est. carbon abatement ($MtCO_2e$ p.a.)

6-8 Est. investment (USD billion)

Note: 1. DRI: Direct Reduced Iron; **2.** CCUS: Carbon Capture, Utilisation, and Storage; **3.** BF–BOF: Blast Furnace – Basic Oxygen Furnace; **4.** Pipeline has been identified as per ITA's criteria (details in appendix section); It also includes 2 projects where the location is unspecified;

International regulatory pressures, domestic policy support, and corporate leadership are major factors driving momentum behind clean steel projects

A CBAM as a catalyst for transition planning to capitalise on the EU opportunity

The introduction of the EU CBAM is a critical driver for major Indian steelmakers to accelerate their transition towards low-emission production pathways. The EU currently accounts for over 40% of India's steel export portfolio[1], with Italy as the largest importer, followed by Belgium and other key markets such as Spain, Denmark, Poland, and Portugal.

The CBAM tariffs could potentially erode the margins by ~$25 million in 2026[2], and potentially rising to hundreds of million dollars by 2030, impacting cost competitiveness of Indian producers and posing a serious risk to the long-term viability of Indian exports to the EU.

However, CBAM alone may not be sufficient to trigger an industry-wide shift towards low and near-zero emissions steel production. The impact of CBAM may be limited to a few players and impact on overall Indian steel industry may be modest as exports to the EU represent only about 1.4% of India's total steel production. This share could decline further as domestic demand increases relative to the stagnant demand in Europe.

But there is a strategic opportunity for Indian producers to capture a greater share of the EU market by transitioning early to low-emission technologies. India's structural advantages in producing low-cost green hydrogen could position it as globally competitive green steel producer. Capitalising on this advantage would not only safeguard existing export revenues but also unlock new economic opportunities as global buyers increasingly demand green steel.

B Domestic policy reforms shaping an enabling environment for transition

In recent years, progressive steps have been taken by the Indian government to promote low-carbon transition of the sector. Major initiatives include:

- **Green steel roadmap and action plan** setting a vision for transition of the sector in line with national targets.
- **Green steel taxonomy** creating a market distinction for low-emissions steel based on a tiered rating system for steel produced below threshold of 2.2 tCO2/tcs.
- **CCTS** sets emission-intensity reduction targets at individual plant level and establishes a market mechanism to trade carbon credits.
- **Announcement of INR 5000 Crore (~$0.56 billion) in performance-based incentives** for adoption of clean-steel tech, with ~80% earmarked for small players.
- **Anticipated implementation of the National Green Steel Mission** which could introduce production-linked incentive schemes and public procurement mandates for green steel (as defined in the taxonomy).
- **INR 455 Crore (~$0.05 billion) in grants for pilot projects deploying green hydrogen in BF[3] and DRI[4] units** have been allocated under the NGHM to promote early testing. The Steel Research and Technology Mission of India also seeks to actively support research and development on novel tech that address context-specific barriers.

While instrumental, the existing and planned initiatives are still insufficient to drive low and near-zero emissions projects recorded in the pipeline. These flagship projects require targeted support to address viability gaps, offtake issues, and regulatory challenges.

C Ambitious targets and voluntary action by industry leaders paving the way

The pipeline of flagship projects is being driven by a handful of leading companies, including JSW Steel, Jindal Steel Limited and SAIL. These companies have set ambitious climate commitments (with several players aiming for climate neutrality by 2050) and have access to internal capabilities, financial resources, and operational efficiencies required to deploy capital-intensive technologies. Recently, a consortium of private players from India including ArcelorMittal Nippon Steel India (AM/NS India), JSW Steel, and others international players — Hyundai Steel, BHP, Chevron, Mitsui — launched a ground-breaking study to assess technical and commercial feasibility of CCUS hubs across Asia with a major focus on India.

By contrast, India's fragmented secondary steel sector, which accounts for roughly 40% of the country's crude steel production, remains constrained by limited resources and is more likely to prioritise incremental, low-cost measures like energy efficiency rather than breakthrough technologies.

As seen in global markets and across other industrial sectors, corporate leadership plays a decisive role in the early stages of transition. Large integrated players willing to absorb higher risk and upfront costs are paving the way for FOAK projects. Their investments are critical to demonstrate technical feasibility, provide cost benchmarks, and create learning-by-doing effects, which can trigger a snowball effect across the sector, reducing uncertainty and building confidence among financiers, policymakers, and smaller producers. However, strong corporate leadership also needs to be backed by enabling policies tailored to support ambitious projects and enable industry-wide diffusion of these technologies.

Note: 1. Ministry of Steel data; **2.** Estimated as per current export of Indian steel to the EU (more than 40% of 4.86 MT total steel exports), current average emission intensity of the industry (2.54 tCO2e/tcs), and current expectation of CBAM tariff ($100/tCO2); **3.** BF: Blast Furnace; **4.** DRI: Direct Reduced Iron;

Addressing three critical bottlenecks to advance clean steel projects in India: premium green demand, lowering the cost of feedstock and financing, and establishing business case for CO2 utilisation and storage

Bilateral consultations with project developers reveal three critical enablers for bankability and financing. Understanding these industry setbacks is vital to addressing the underlying drivers of delayed execution.

A Securing forward contracts for offtake is the most critical requirement for transition to low-emissions steelmaking

Producers are looking for assurance of green demand through forward offtake contracts at a price premium to take FID. However, major consumer segments for steel — infrastructure, housing, capital goods, and automobiles, are price-sensitive and are not expected to offer green premium. While there have been public announcements by select companies for reduction of emissions from purchased goods (Scope 3)[6] including steel, these have not yet translated into formal commitments. Steel industry also reports lack of willingness to pay green premium by international offtakers, indicating a global shortage in green demand.

Stepping up of both voluntary procurement in end-use segments and regulatory mandates for use of low-emissions steel, is required to break the industry's inertia and improve bankability of projects. High growth sectors like wind energy, could spur near-term demand for clean steel in conjugation with high-volume sectors like infrastructure and automobiles. Additionally, capacity building and sharing of best practices on structuring of long-term forward contracts — an uncommon practice in India — are essential to build confidence and promote trade partnerships.

Initiatives like SteelZero and First Movers Coalition are working towards bridging the supply-demand gap by targeting voluntary action, but further efforts, particularly on building demand via regulations, are required to drive material action.

B Access to low-cost financing and securing affordable supply of feedstock needed to optimise costs and minimise the premium

Affordable access to both feedstock — natural gas and green hydrogen — and long-tenor, low-cost finance is critical to reducing production costs and narrowing the green premium for hydrogen-based steelmaking. Today, hydrogen DRI[1] production costs are 60–80% higher than conventional routes, with green hydrogen prices in India averaging 4–5 $/kg[2]. While projections indicate a decline to 3–3.5 $/kg by 2030[3], the industry requires a transitional pathway to de-risk early investments. Share of natural gas-based DRI, considered as a transitional pathway before shifting to hydrogen, is small and scale-up is constrained by high cost of imported natural gas, exposure to volatile global LNG prices, and last mile connectivity to steel plants.

On the financing side, access to low-cost debt remains a major hurdle. Project bankability and financing costs are tied to securing offtake agreements and adopting risk-sharing models, such as equity co-investment by value-chain partners. However, the industry (including supply-chain players) have limited experience in structuring and executing innovative models for novel technologies. The absence of sovereign-backed loans, credit guarantees, and other de-risking instruments keeps financing costs high, undermining project viability. Without these enablers, execution of green projects will remain challenging.

C Clarity on CO2 utilisation pathways and framework for CO2 sequestration are critical for a net-zero transition

CCUS[4] is expected to be a key decarbonisation lever for India's steel industry, given the dominance of the BF-BOF[5] route in current operations and future capacity additions. However, its adoption faces multiple challenges. **The high upfront capital costs of capture units combined with uncertain revenue streams undermine financial viability.** Current market prices for CO_2, at $20–30/t$CO_2$[2], are 30–40% lower than the $40–50/t$CO_2$[2] required for CCU projects to break even. Furthermore, long-term utilisation potential is limited; the expected demand for CO_2-derived products is far smaller than the sector's emissions, creating structural constraints.

Global regulations such as the EU's RED III and the IMO regulations on international shipping could drive some utilisation demand. However, restrictions on the use of non-biogenic CO2 (fossil-based CO2 captured from industrial off-gases) under these standards and lack of certifications further limits the utilisation potential.

There are several other options for storage of captured CO_2 deep beneath the surface in depleted oil and gas reservoirs, un-mineable coal fields, deep saline aquifers, and basalt formations. But the potential for these geographical features has not been explored enough to promote investments. Encouragingly, NITI Aayog is working on a CCUS policy framework that could address some of these challenges and help create an enabling environment.

Note: 1. DRI: Direct Reduced Iron; **2.** Bilateral consultations with industry players, BCG and ITA analysis; **3.** BNEF Hydrogen Cost Outlook 2025; **4.** CCUS: Carbon Capture, Utilisation, and Storage; **5.** BF-BOF: Blast Furnace – Basic Oxygen Furnace;
6. Scope 3 refers to all indirect greenhouse gas (GHG) emissions that occur in a company's value chain, encompassing both upstream and downstream activities not owned or controlled by the company

Aviation

India's rapidly growing aviation sector is well positioned to transition to SAF, meeting domestic demand while emerging as a global leader and exporter, supported by strong resource availability.

As international regulations drive aviation decarbonisation, India has a strategic opportunity to capture a significant share of the emerging global demand for SAF

India is the world's third-largest aviation market, and it is growing rapidly. India accounted for ~4% of global traffic in 2024[1]. Despite serving more than 240 million passengers in FY24–25[2], India's air travel per capita remains well below global peers, highlighting vast room for growth. Rapid economic expansion and a growing middle class will drive future demand. The Ministry of Civil Aviation projects that passenger traffic could double by 2030. This growth will be supported by the government's infrastructure push — operational airports have already increased from 74 in 2014 to 162 in 2025, with a target of 350 by 2047[2] — and by rapid fleet expansion, with Indian carriers holding an order book of over 1500 aircraft in 2024.

Aviation contributes over ~2.5%[5] of global GHG emissions. To address these emissions, International Civil Aviation Organisation (ICAO) adopted the CORSIA in 2016. From 2027, airlines will be mandated to offset emissions from international operations above 2019 levels[6] through reductions or carbon credit purchases. For India, where international aviation is expanding faster than in many mature markets, exposure to compliance costs is disproportionately high. Industry estimates suggest that India's two leading carriers could face $0.5–2.3 billion in costs between 2027–35[4]. This makes decarbonisation measures urgent, particularly through adoption of SAF. Currently approved pathways can produce drop-in SAF with ~50–80% lower life-cycle carbon footprint, and these can be blended up to 50%[7] with the conventional jet fuel without significant engineering changes.

Global demand for SAF is accelerating under regional mandates and international initiatives. The EU's ReFuelEU Aviation regulation and the UK's SAF mandate require 2% SAF blending in aviation fuel by 2025, rising to 6% by 2030. CORSIA and coalitions like the WEF Clean Skies for Tomorrow are reinforcing the regulatory push. Despite rapid ramp up of production facilities, global SAF production in 2025 is estimated at 2 million tonnes[8], equivalent to just 0.7% of the total demand for aviation fuel. Projections suggest the demand for SAF could rise to 10–17 MTPA by 2030 (Fig. 13)[8,9]. Mandated and voluntary airline commitments could boost the demand to more than 20 MTPA, potentially outpacing supply.

India is well placed to emerge as a leading SAF producer, with studies indicating the potential to produce 8–10 MTPA by 2040, equivalent to ~5% of global demand[10]. India's advantage stems from availability of feedstock like biomass, agricultural waste, used cooking oil, and green hydrogen. The production capacity could be even higher with early actions from the domestic players and adequate policy support. Domestic demand for SAF is expected to reach ~4.5 MTPA[10], leaving significant surplus for exports to premium markets like the EU, UK, and US. However, India needs to act fast as several Southeast Asian states, like Singapore, Malaysia, Thailand, Indonesia, and the Philippines are exploring SAF production[11] and are expected to compete with India for a share in the global SAF demand. For India, early policy support and decisive industry action would be critical to secure a competitive share of this emerging global market.

Global SAF demand is estimated at 10–17 MTPA by 2030, could reach 370 MTPA by 2050

All figures in Million tonnes per annum

Figure 13A: Projected global demand for SAF by 2030

All figures in MTPA

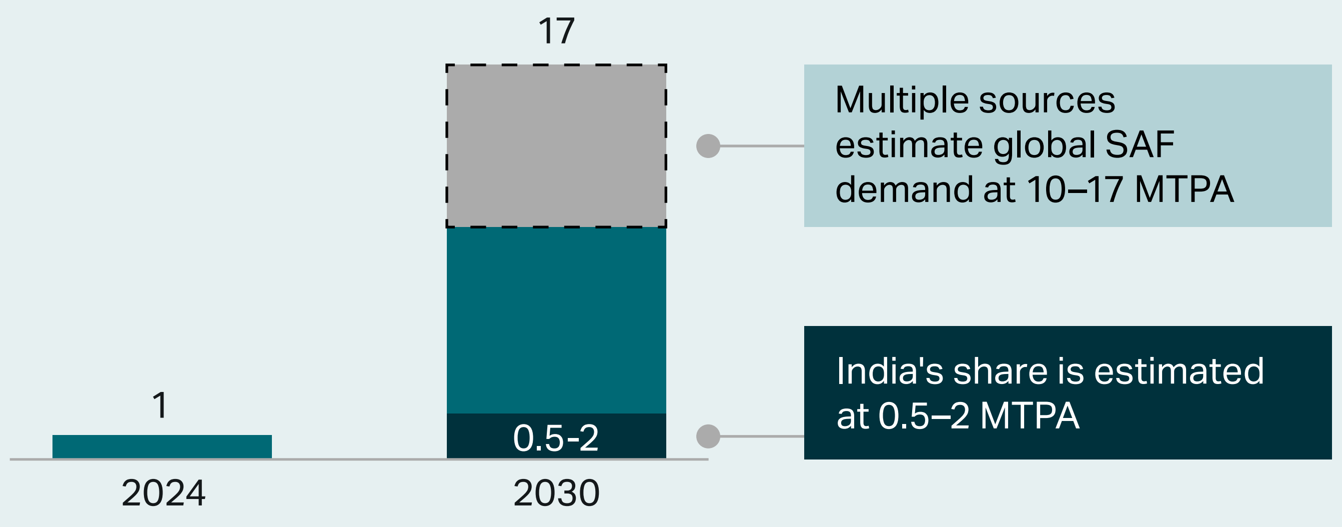
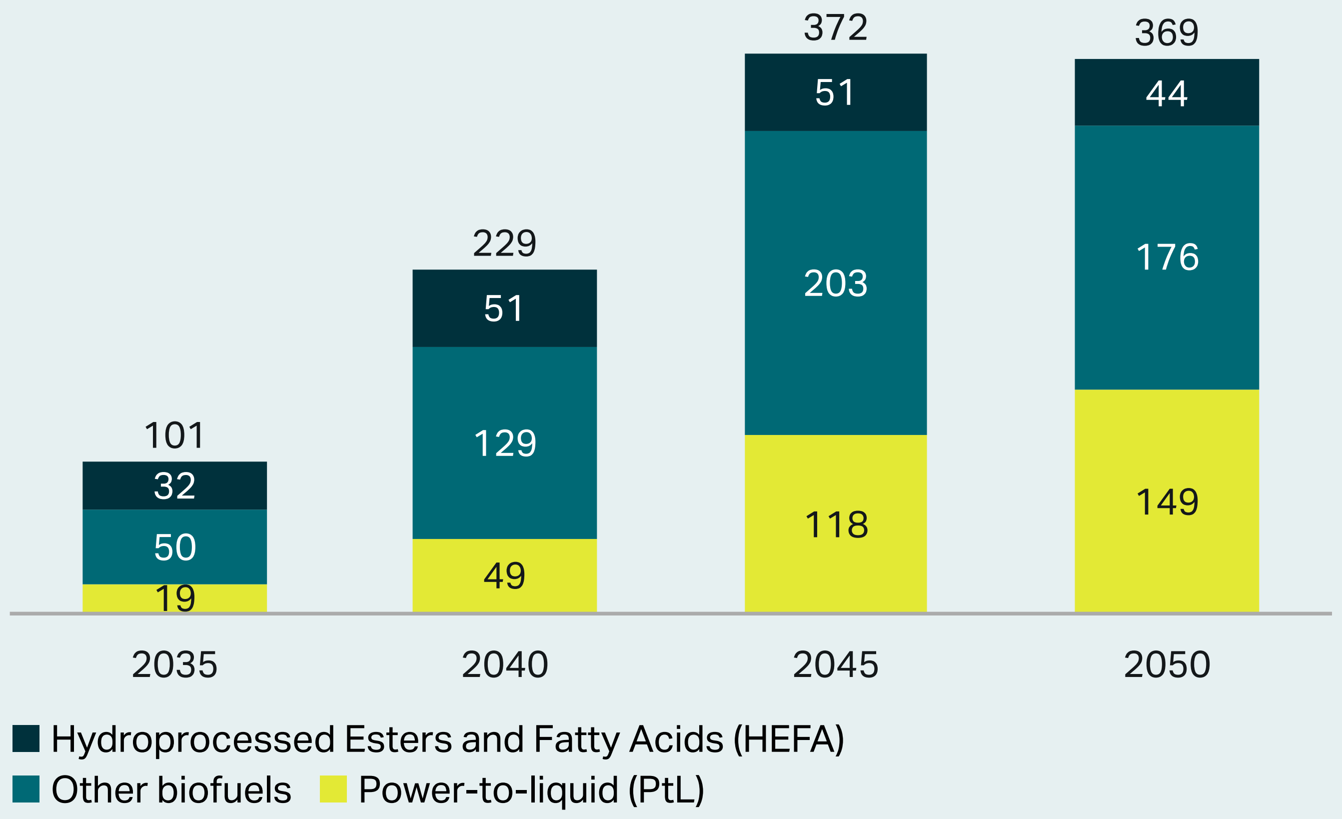


Figure 13B: Projected global demand for SAF by 2050 (MPP Prudent Scenario1)

All figures in MTPA



Note: 1. Under MPP prudent scenario - trajectory for net zero GHG emissions by 2050 relying on technologies already available or entering the market in coming decades
Source: BCG SAF market model, MPP

Note: **1.** IATA Sustainability and Economics based on data from DDS ; **2.** Ministry of Civil Aviation; **3.** CAPA Centre for Aviation report; **4.** TERI – CORSIA and Indian Aviation Industry; **5.** Our World in Data report; **6.** Baseline for CORSIA mandate is set at 85% of 2019 international aviation emissions by respective airlines; **7.** IATA Net Zero 2050; **8.** WEF report – Financing sustainable aviation fuels; **9.** BCG SAF Outlook; **10.** S&P Global review article; **11.** Roundtable on Sustainable Biomaterials report

India's project pipeline is positioned to explore multiple pathways for SAF production, supported by varied feedstock availability and steadily improving policy environment

HEFA-based SAF production is emerging as the leading pathway in India, followed by alcohol-to-jet (AtJ) pathway, supported by availability of feedstock, lower cost of production, and mature technology. Other pathways such as gasification followed by the Fischer-Tropsch (FT) process and power-to-liquid (PtL) are at early stages constrained by low indigenous technology maturity, high capex, and logistical challenges.

Table 3: Technology pathways, abatement potential, maturity, commercial readiness, and cost

Production Route	Description	Maximum Abatement Potential[1]	Production Cost[1] ($/tonne)	Abatement Cost[1] ($/ tCO2)	Feedstock Availability and Access	Maturity and Widespread Adoption
HEFA	Conversion of used cooking oil and other waste fats into jet fuel through hydrogenation	**Up to 85%**	1000–1250	130–160	**Medium:** High consumption but poor recovery rate due to lack of formalisation	**Mature technology (TRL 7-9)** with one commercial project in India
GFT	Gasification of biomass to produce syngas, converted into jet fuel	**Up to 90%**	1125–2500	210–520	**Medium:** Large solid waste generation but lack of proper processing	**Development stage (TRL 4-6)** with no projects in India
AtJ	Conversion of ethanol from agri-waste and industrial off-gases to jet fuel	**Up to 70%**	1125–2750	420–1020	**High:** High domestic production due to policy incentives	**Nascent technology (TRL 6-8)** with a few feasibility studies
PtL	Conversion of green hydrogen and captured CO_2 to fuel	**Up to 90%**	~4375	1510–2190	**Low:** Large announced capacity for green hydrogen but lagged project development	**Development stage (TRL 4-6)** with one active feasibility study

Low Medium High

Note: **1.** ICAO SAF Rules of Thumb – Global cost and pricing for SAF; **2.** Ministry of Housing and Urban affairs; **3.** ICAO Working Paper for SAF in India; **4.** ICAO ACT–SAF report – sustainable feedstock in India

India's SAF pipeline consists of three large scale projects and one pilot across different technology routes. The state-run petroleum company IOCL is constructing a 0.035 MTPA plant to convert used cooking oil to SAF. Once operational, this plant might be sufficient to meet the 1% SAF blending mandate in India in 2027. There is one commercial scale project announced by NGEL in Andhra Pradesh with an estimated capacity of 0.2 MTPA PtL SAF production. Another project has been announced by a joint venture between IOCL and LanzaJet based on the latter's AtJ technology with a capacity of 0.085 MTPA in Haryana. Mangalore Refineries and Petroleum Limited has announced a pilot project for HEFA-based SAF production in Karnataka.

India is well poised to become a leading SAF producer due to several drivers:

1 **Feedstock availability to support multiple production pathways:** Owing to a large consumer base, India produces approximately 50 million tonnes of municipal solid waste[2], 20 million tonnes of used cooking oil,[3] and more than 650 million tonnes of biomass[4] including 230 million tonnes of surplus agricultural residue[4] annually across the country which are suitable for SAF production. Further, availability of low-cost green hydrogen is expected to improve rapidly by 2030.

2 **Supportive policies:** The National Biofuels Policy provides interest subvention, while the JI-VAN scheme extends viability gap funding for ethanol production units — measures that could expand ethanol availability and enable producers to fetch higher price premiums when diverting to SAF. At the national level, India has announced a SAF blending mandate of 1% by 2027, scaling to 5% by 2030. The Ministry of Civil Aviation recently concluded a feasibility study for SAF (with ICAO and with support from the EU), signalling initial steps towards a broader policy framework. State-level initiatives are also emerging: the Uttar Pradesh government released a draft policy proposing land subsidies, GST reimbursements, and other financial incentives to attract SAF projects.

Addressing four critical bottlenecks to advance SAF projects in India: offtake assurance from domestic and export markets, targeted policy support, infrastructure development to ensure feedstock access, and access to low-cost project financing

Bilateral consultations with project developers reveal four critical enablers for bankability and financing. Understanding these industry setbacks is vital to addressing the underlying drivers of delayed execution.

A Binding agreements for offtake across domestic and global markets are needed to advance SAF production

Unlocking SAF production in India hinges on offtake assurance in domestic and export markets. While the blending mandates have been announced by Indian government from 2027 and ReFuel mandates are already in effect in the EU, the formal channels for offtake are not fully developed. The market demand is forming with commitment for SAF procurement announced by more than 80 international carriers, including Indian carriers Indigo (as a partner of WEF's Clean Skies for Tomorrow initiative, it aims to achieve a 10% SAF blend in ATF by 2030) and Air India (has signed Memorandum of Understanding (MoU) with Indian Oil for SAF). But the announcements need to convert into binding offtake agreements for projects to develop.

India's domestic SAF market also faces uncertainty in price and volumes. The implementation roadmap for SAF blending mandates is not clear and the only SAF project at FID (by IOCL, India's leading aviation fuel provider), is expected to cover most of the demand under a 1% blending mandate by 2027. Competition for limited domestic demand may increase if more projects are commissioned, potentially impacting the financial returns and viability of SAF investments.

B Differentiated policies would drive investments in SAF alongside other biofuels

There is stiff competition for SAF feedstock from industries like power, biogas, and petroleum products. The co-firing of biomass in thermal power plants, mandated by the government, swipe away a significant share of industrial grade collections, and rest goes to the compressed biogas sector. The directive of ethanol blending in petrol diverts most of the waste-generated alcohol to petroleum companies.

The existing policies for promotion of biofuels provide funding and financial incentives but do not differentiate SAF from the other biofuels. Given the scale of required investment and cost of production for SAF is significantly higher than ethanol, biodiesel, etc., the current policies have limited impact on progressing SAF projects in India. A national level policy framework would de-risk financial investment through demand mandates, viability gap funding, production linked incentives, interest subventions, etc.

C Ensuring access to feedstock sources is critical to tap the domestic SAF potential

India's opportunity for scaling-up SAF production is plagued by the issue of sustained access to feedstock despite plentiful availability. The infrastructure needed to collect, sort, transport, and store American Society for Testing and Materials (ASTM) International-approved raw materials in a cost-effective way remains grossly underdeveloped.

Used cooking oil presents the most viable near-term opportunity but the key streams are dispersed, there is improper reusage despite regulatory frameworks, and the collection network is spread thin. Looking ahead, agricultural residues and municipal solid waste present a strong medium-term opportunity, however the fragmented generation and traditional practices of disposal by combustion lead to low rate of recovery.

Targeted efforts at municipal level are required to streamline collection and sorting of domestic waste and create economic value across upstream value chain activities for SAF production.

D Access to low-cost financing is needed to improve commercial feasibility of SAF projects

Access to low-cost financing, especially for project development, is a major barrier. Establishing greenfield SAF production facilities requires substantial upfront investment, with development of supporting infrastructure, supply-chains and ecosystem adding to the cost. Developers show limited appetite to fund early-stage project development, which is critical for testing the viability of alternative production pathways and business models.

With no commercial scale projects currently in operation, the industry does not have a relevant benchmark to assess the financial viability of SAF projects. Consequently, investor confidence remains slow, and risk perception is high — driving up the cost of capital.

Accelerating FOAK projects by early movers is critical to demonstrate technical feasibility, validate business models, and de-risk investment. Successful projects can catalyse broader deployment and enable India to capture the growing opportunities in the global SAF market.

Cement

Building on its strong production base, improving efficiency levels, and ambitious net-zero commitments, India's cement sector has the opportunity to become a global example in balancing industrial growth with low-carbon transition.

As a cornerstone of India's economy and the world's second-largest producer, the cement industry has an opportunity to leverage its strong base and lead the transition to low-carbon pathways

The Indian cement industry — world's second largest in terms of production capacity (770 MTPA)[2] — is a backbone of country's economy. Indian cement industry's share in global installed capacity stands at 8-10% (770 MTPA)[2], with the sector contributing around more than 1% of GDP and supporting more than one million jobs[3]. Yet, despite this scale, India's per capita cement consumption of 290 kg is less than half the global average of ~540 kg[9]. This consumption gap, combined with India's continued infrastructure push and rapid urbanisation, is expected to drive sustained growth of 6.5–7.5% annually through FY29–30[4], outpacing most other major markets.

India's cement sector faces a steep decarbonisation challenge but is starting from a relatively strong base. As the second-largest industrial GHG emitter after iron and steel, cement accounts for about 7-8% of India's total CO_2 emissions[1]. It is also one of the hardest to abate sectors given the reliance on fossil fuels for combustion in kilns and a large share of process emissions from limestone calcination, which require expensive breakthrough solutions. Despite this inherently carbon-intensive production profile, Indian cement producers have already made notable efficiency gains. The sector's current average emission intensity stands at 0.60–0.65 tCO_2 per tonne of cement[5], close to the global average of ~0.6 tCO_2/t[6]. This progress reflects a decade of sustained investments in best-available efficiency technologies and the early rollout of waste heat recovery systems (WHRS), which have proven to be cost-effective, providing a solid foundation for transitioning to low-carbon cement production.

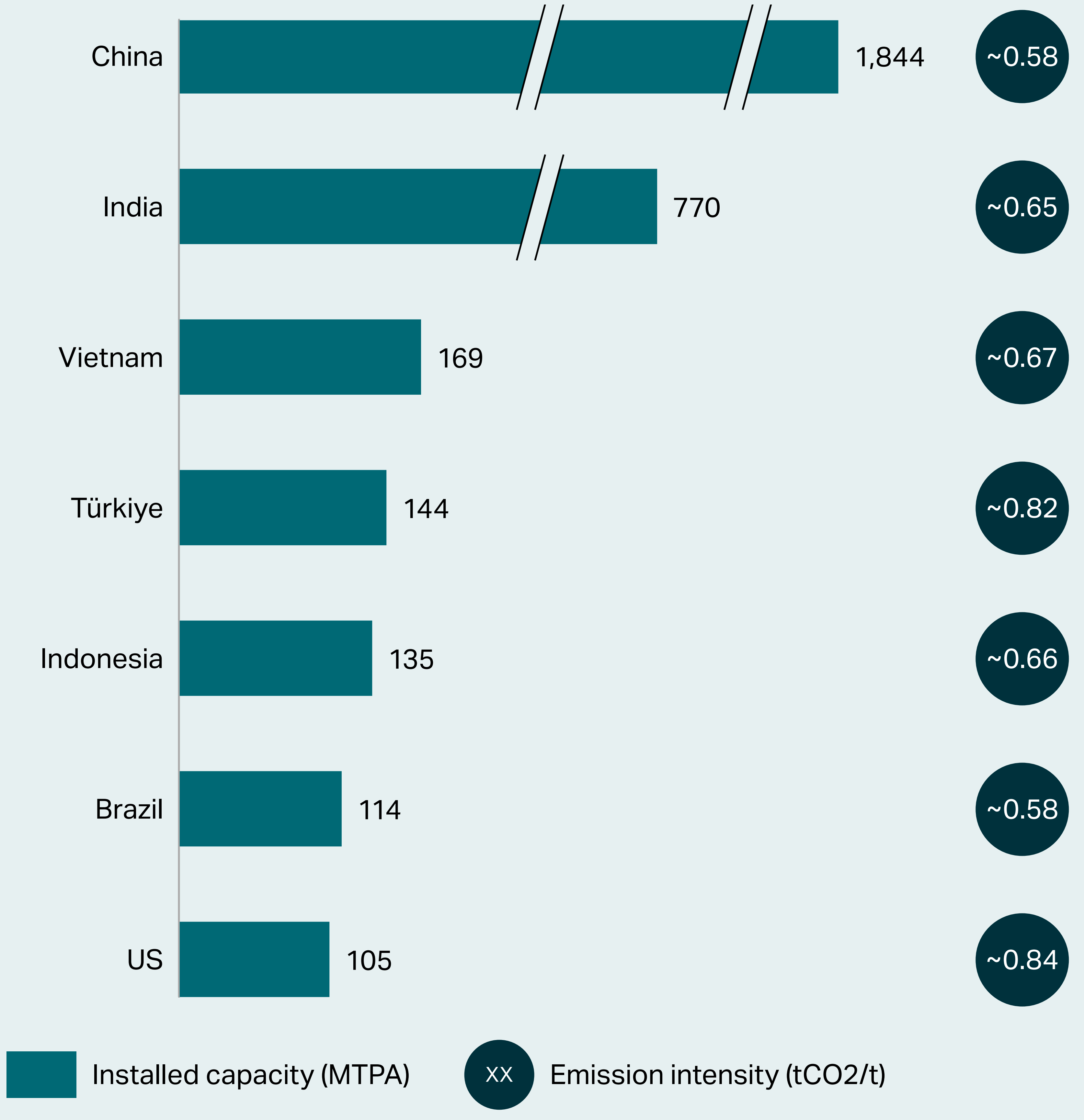
Policy push, early-stage technology development support, and corporate leadership are paving way for low-carbon transition. India's cement sector is beginning to align around both regulatory and voluntary decarbonisation measures. The MoEFCC[6] now mandates 186 cement plants to cut their greenhouse gas emission intensity (GEI) by 2–3% between 2025–27[7], creating an accountability baseline for the industry. While modest, these targets are expected to strengthen over time. In parallel, leading companies such as UltraTech, Dalmia, JK Cement, and JSW Cement have set net-zero timelines for 2040–2050, with interim goals around scaling renewable energy, raising thermal substitution rates (TSR), expanding WHRS, and piloting breakthrough technologies such as CCUS and kiln electrification. Government and industry are also investing in building the CCUS ecosystem — NITI Aayog is developing a national CCUS policy framework to accelerate adoption and enable CO_2 value chains, while the Department of Science and Technology (DST) has launched five CCUS testbeds to build technical know-how. At the global level, India's collaboration with Sweden through LeadIT reinforces this momentum, with cement identified as a priority sector for advancing early-stage, low-carbon projects.

The path towards further reductions in emissions abatement is challenging due to several technological, economic, and market barriers. However, India's cement industry can leverage its existing capabilities to become a global leader in balancing industrial expansion with low-carbon growth.

Note: 1. GCCA and TERI Decarbonisation Roadmap for the Indian Cement Sector; **2.** Global energy monitor as of May 2025 (installed capacity); **3.** JMK Research Cement Report; **4.** CRISIL MI&A Research, Mordor Intelligence; 5. Based on data published for cement plants (production capacity and emission intensity in GEI Target Rules 2025); **6.** IEA Analysis on Cement Sector; Ministry of Environment, Forest, and Climate Change; **7.** MoEFCC targets; **8.** Latest emission intensity numbers in the past 3-5 years; **9.** DPIIT Annual Report 2024-25
Source: BCG and ITA Analysis

India ranks second in installed capacity globally, with emission intensity close to some of the peers

Figure 14: Installed capacity in million tonnes per annum (MTPA) (as of May 2025) and emission intensity in the past 3–5 years[8]



Source: Global energy monitor (installed capacity); Secondary research

The industry faces a dual challenge to further reductions in emission-intensity: scaling commercially-proven solutions while advancing First-of-a-Kind breakthrough technology projects

Achieving deep decarbonisation in the cement sector will require more than incremental measures. While mature levers to address indirect (Scope 2)[7] emissions are already widely adopted and can deliver cost savings, they offer only ~15% abatement and do not address process (calcination) emissions.

India needs a clear roadmap to scale FOAK[1] projects that demonstrate low and near-zero emission technologies to address emissions from clinker production accounting for 85–90% of scope 1 and 2 emissions[2]. While fossil-based Supplementary Cementitious Materials (SCMs) such as fly ash and slag currently deliver 25–50% abatement against Ordinary Portland Cement (OPC), their availability will decline as the power and steel sectors decarbonise. The next generation of solutions vary in maturity:

- Immediately scalable options like LC3 (can be cost-effective provided sufficient demand to unlock economies of scale) and higher AFR use can achieve 30–50% abatement; and
- Novel technologies such as CCUS, kiln electrification, and electrochemical calcination hold the potential for 30–90% abatement but face technological, economic, and market-related challenges.

Early deployment is critical — not only to cut emissions but also to build technical know-how and investor confidence for long-term transformation. Without this, the sector risks being locked into conventional pathways incompatible with net-zero goals.

The pathway to scaling deep decarbonisation solutions is marked by significant challenges. While LC3 cement shows near-term commercial promise, adoption is held back by weak consumer demand and the absence of regulatory mandates. CCUS remains prohibitively expensive, with progress limited to pilots, feasibility studies, or stalled projects. In parallel, the industry has set a target of reaching a 25% Thermal Substitution Rate (TSR) by 2030 — modest compared to markets like Austria, where the average TSR is 79%[3]. Many Indian plants already use Alternative Fuels and Raw Materials (AFR) with TSR levels of 5–15% but scaling to ~30% remains difficult due to limited availability of homogenous waste, lack of a centralised inventory, logistical hurdles, and high costs of biomass and municipal solid waste (MSW) processing units (84% and 43% higher than petcoke[3]).

Despite obstacles, on ground momentum behind testing and adoption of low- and near-zero emissions technologies is beginning to build. India hosts two announced FOAK commercial-scale projects: a LC3 production facility by JK Cement in Rajasthan and a large CCUS plant by Dalmia Bharat in Tamil Nadu (progress contingent on market conditions). Other companies like JK Lakshmi are exploring LC3 projects in collaboration with academia and international research institutions. In parallel, DST has supported five CCU testbeds, signalling national appetite for experimentation and innovation. Leading players such as UltraTech, JSW Cement, Ambuja etc. are piloting cutting-edge technologies including ZeroCal electro-chemical calcination process and kiln electrification. The near-term challenge is to translate this momentum into bankable, scalable projects that can move beyond feasibility studies.

Table 4: Technology pathways, abatement potential, maturity, commercial readiness, and cost

Technologies	Description	Maximum Abatement Potential[4]	Cost of Abatement ($/tCo2)	Maturity and Widespread Adoption
Non-fossil based Supplementary Cementitious Materials (SCMs) (e.g., LC3)	Reducing clinker content using non-fossil based SCMs (calcined clays)	Up to 50%	(-20)-25[5]	**Proven technology (TRL 7, pre-2030) with commercial viability driven by demand** – two commercial projects in India
Alternative fuels and raw material (AFRs)	Substitute fossil fuels with AFRs such as bio-mass and RDF/MSW[6]	Up to 30%	40-80	**Mature tech; while 5–15% TSR is common in Indian cement plants, scaling to 30% is constrained** due to infrastructure and supply-side constraints
CCUS	Install a CO_2 capture unit at the cement kiln to either store or reuse CO_2	Up to 90%	100-140	**Still in the prototype stage (TRL 6, 2030) with limited deployment (5 CCU test beds)** in India due to high cost and infrastructure challenges
Kiln electrification	Switch to renewable electricity to heat cement kiln	Up to 30%	-	**Emerging tech (TRL 5-6, 2030)** with limited demos in India and globally
Electro-chemical calcination process (ZeroCal)	Decomposing limestone into calcium hydroxide and hydrochloric acid, bypassing the calcination stage	Up to 90%	-	**In early stages of development** with only one project globally
Energy efficiency technologies	Includes measures like WHR, process optimisation, etc. for energy savings	Up to 15%	(-40) -(-15)	**Mature technologies,** widely known and implemented

Low Medium High

Note: 1. First-of-a-kind; **2.** GCCA and TERI Decarbonisation Roadmap for the Indian Cement Sector (Niti Aayog, 2022); **3.** CEEW Report; **4.** Upper bound for abatement of cement embodied carbon for each individual lever assuming no other levers are implemented; abatement impact of combinations of levers will be less than simple sum because of abatement overlap between levers; estimates are approximate due to diversity of feedstock and production processes; **5.** Assumed LC3 (Limestone Calcined Clay) production at scale equivalent to OPC production in India; **6.** Refuse-Derived Fuel (RDF) and Municipal Solid Waste (MSW); **7.** Scope 2 refers to indirect greenhouse gas (GHG) emissions from the generation of purchased electricity, steam, heat, or cooling that a company consumes. **Source:** Secondary Research (WEF reports, academia reports, industry reports etc.) for TRL (Technology Readiness Level), max abatement potential and cost of abatement; BCG and ITA analysis

Improving value-chain and infrastructure readiness, building green demand, and viability gap funding can help advance low-carbon cement projects in India

Bilateral consultations with project developers reveal three critical enablers for bankability and financing. Understanding these industry setbacks is vital to addressing the underlying drivers of delayed execution.

A Unlocking low-cost capital is the most critical to scale breakthrough technologies

Industry faces two distinct challenges: first, early-stage funding for project DevEx is severely lacking, limiting the ability to undertake pilots, feasibility studies, and demonstration projects; second, securing project financing for CapEx is constrained by the absence of a viable business case. Investors and lenders remain cautious, citing high technology performance risks and lack of sufficient premium demand. In a highly price-sensitive market like India, the challenge is compounded — technologies such as CCUS could more than double cement production costs compared to conventional methods, with little room to pass on cost premiums to consumers.

India has begun to lay the foundations for sustainable finance in the sector. The draft climate finance taxonomy recognises cement as a hard-to-abate sector, creating a pathway for capital to flow into low-carbon investments. Leading players have also tapped sustainability-linked instruments *(e.g., UltraTech's $400 million sustainability linked bonds (SLB) in 2021 and $500 million SLB in 2024; JSW's $100 million sustainability linked loans (SLL) via MUFG and BNP Paribas)*[1].

These instruments remain insufficient in scale and scope to bridge the financing gaps for breakthrough projects. For early-stage DevEX needs, grants, technical assistance facilities, and first-loss capital can help de-risk pilots and demos. For large-scale CapEx, blended finance funds, credit guarantees, and value-chain co-investment — coupled with stronger engagement from Development Financial Institution and multilateral lenders — are needed to crowd in private investment at scale.

B Addressing infrastructure and feedstock gaps key to scale existing and near-commercial, low-carbon solutions

Net-zero transition in India's cement sector is being held back by value chain and infrastructure bottlenecks.

- **LC3:** The availability of suitable clay reserves is geographically limited, concentrated largely in Rajasthan and Gujarat. Unlike limestone, these reserves have not been publicly mapped or validated by government agencies — assessments to date have been conducted primarily by private players — leaving industry without the certainty needed to plan investments at scale.
- **AFR:** Lack of a homogeneous supply chain for MSW-based refuse-derived fuel (RDF) results in unpredictable fuel quality, adversely impacting kiln efficiency and limiting the growth of thermal substitution rates. The absence of a centralised inventory system further restricts efficient sourcing of high-quality, high-volume AFR across regions.
- **CCUS:** Value-chain bottlenecks are even more pronounced. India is yet to establish a dedicated CO_2 transportation and storage ecosystem required to manage large volumes of captured CO_2. While NITI Aayog has completed mapping of 26 sedimentary basins, storage development remains at the pre-commercial stage, with no operational large-scale CO_2 storage or injection infrastructure in place.

Coordinated policy response is required to unlock bottlenecks in infrastructure and supply-chain readiness for scaling commercial solutions.

C Robust demand signals critical to drive producer investment in novel solutions

Despite early signs of interest — such as pioneering commercial use of LC3 in Maharashtra in partnership with IIT Delhi and Rocky Mountain Institute (RMI) — **the overall demand for green cement remains very limited.** Awareness among architects, designers, and green building consultants is still low, while the highly price-sensitive nature of India's construction market makes it difficult to absorb even a modest cost premium. On the other hand, the absence of long-term field data on the durability of LC3 further weakens offtakers' confidence.

At a policy level, national guidelines for Green Public Procurement are yet to be established, even though state governments and think tanks have begun proposing frameworks, including RMI's recommendations on embedding low-carbon cement in public infrastructure projects. Without clear demand signals from large buyers such as government agencies, infrastructure developers, and real estate firms, producers remain hesitant to commit to large-scale capacity.

Building robust demand signals anchored in awareness campaigns, performance data, and demand side standards and regulations are essential in creating market confidence and improve producer appetite to undertake capital-intensive investment.

Note: 1. Public announcements/ Press releases by Ultratech and JSW

Aluminium

By harnessing India’s abundant low-cost renewable energy and declining energy storage costs, the aluminium sector can position itself among the world’s lowest-emission producers at globally competitive prices.

Transition to clean aluminium production offers a significant near-term opportunity to cut industrial emissions, while meeting growing domestic demand and enhancing trade competitiveness

Meeting rapidly growing domestic demand while remaining globally competitive creates both urgency and opportunity for India to reposition as a hub for low-emission aluminium production. Producing 4.1 MT of aluminium in FY23–24, the sector contributes ~0.3% to GDP and supports around two million jobs across refining, smelting, and downstream value chains[1]. As the world's second-largest producer (~6% of global output[1,2]), India's aluminium sector underpins infrastructure, automotive, and urbanisation, while being deeply integrated into global trade. Domestic demand is poised to double to ~9 MT by 2033[2], as the per capita consumption catches up with global average. At the same time, trade competitiveness has recently come under strain: exports to Europe fell by 34% between 2022–2024 in anticipation of the EU's CBAM[3], the US imposed tariffs of up to 50%, Asian demand, especially from Japan, remains weak, and global buyers are tightening procurement standards with over 7000 SBTi companies have set emissions reduction targets in line with climate science.

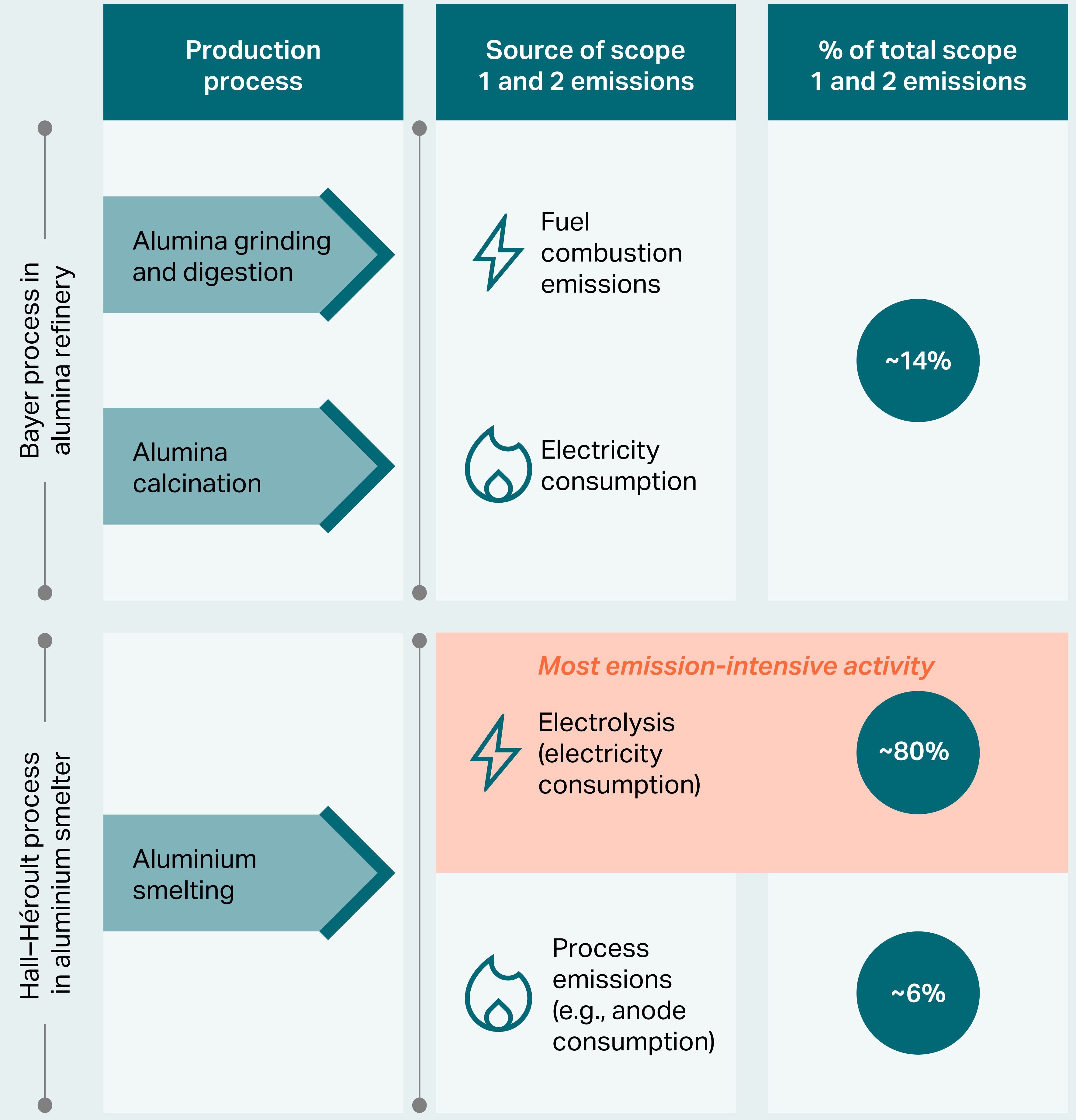
Switching aluminium smelters to renewable power is the fastest, lowest-cost lever to cut industrial emissions and protect export competitiveness. The sector contributes 2–3% of India's industrial GHG emissions[1], with a carbon intensity of ~17–18 tCO_2/t[4,1] versus a global average of ~15 tCO_2/t[1], because ~80% of its footprint comes from captive or grid-backed thermal power (Fig.15). Replacing this electricity with round-the-clock (RTC) renewables can deliver immediate material reductions at a modest INR 1–2/kWh premium (recent SECI RTC auctions cleared ~INR 5.06–5.07/kWh), a cost that is likely far lower than expected exposure of the EU-bound exports under CBAM. Abundant low-cost renewable power offers the near-term pathway to slash aluminium's share of industrial emissions while safeguarding India's position in international markets.

Policy and industry actions are beginning to set a foundation for transition. The MoEFCC[5] has introduced Greenhouse GEI reduction targets of 2–6% for 13 aluminium smelters and refineries by 2027. All three major producers, Vedanta, Hindalco, and NALCO, have declared net-zero ambitions with interim renewable integration targets. These early steps send positive signals but fall short of what is needed to match international decarbonisation benchmarks and protect India's aluminium trade position.

The pathway forward requires overcoming structural barriers to scale low-emission production. Renewable power is now cost-competitive and provides a clear pathway for transition, but high upfront investment in energy storage systems bottlenecks in transmission and distribution networks, and reliance on imported battery components raise project execution risks. Addressing these constraints at pace will be critical for embedding aluminium at the centre of India's clean industrialisation story — helping the sector capture domestic demand, sustain exports, and avoid long-term carbon lock-in.

With ~80% of aluminium sector emissions from electricity use, switching to RE-powered smelters could mitigate a significant share of industrial emissions

Figure 15: Aluminium manufacturing process, source and % of scope 1 and 2 emissions



Note: **1.** JMK Research and Analytics Report on Aluminium Sector in India; **2.** AL Circle's Report on Aluminium sector; **3.** Ministry of Commerce and Industry (BCG and ITA Analysis); **4.** Based on data published for aluminium plants (production capacity and emission intensity in GEI Target Rules 2025); **5.** Ministry of Environment, Forest, and Climate Change

Scaling renewable-powered smelters to deliver immediate, cost-effective, and large-scale abatement, and demonstration of next-generation technologies to address direct emissions are key priorities

Aluminium decarbonisation can follow two routes — primary production and secondary production.

Primary production: Relative to other hard-to-abate sectors (steel, cement), decarbonising primary production of aluminium hinges overwhelmingly on clean power — up to ~80% of potential abatement can be achieved by RE-powered smelters alone. This presents a strategic opportunity for India to cut emissions sharply, protect trade competitiveness, and meet tightening global supply-chain expectations.

Indian producers have begun to move, with a recorded pipeline of five projects: three already operating with signed PPAs and two major greenfield expansions announced by Vedanta and Rio Tinto. Designed to meet India's surging domestic demand and safeguard export competitiveness, these projects together represent ~4 MTPA of potential green aluminium capacity and an abatement opportunity of ~70 $MtCO_2e$ annually. Yet large-scale adoption is being slowed by high upfront capital requirements, battery storage costs, and transmission infrastructure bottlenecks.

Beyond renewable smelters, other novel technologies such as inert anodes, electrification, mechanical vapour recompression, and CCUS are still at very early stages in India, with no recorded pilot/demo-scale projects and potentially long lead times before material impact.

On the secondary route, aluminium recycling offers one of the most energy-efficient pathways, using up to 95% less energy than primary production[7]. As of 2024, secondary production capacity stood at 2–2.2 MTPA[7]. Recent moves — e.g., Hindalco's plan for a recycling and segregation facility in Gujarat, aligned with the global approach Novelis's, (a wholly-owned subsidiary of Hindalco and leading global producer of secondary aluminium) — signal intent by companies to scale the secondary route. However, scalability is constrained by limited domestic scrap availability, and inadequate collection/segregation systems.

Table 5: Technology pathways, abatement potential, maturity, commercial readiness, and cost

Route	Technologies	Description	Maximum Abatement Potential[1]	Cost of Abatement ($/tCo2)	Maturity and Widespread Adoption
Primary route	**RE-powered smelter**	Transition from coal-based power to renewable energy	Up to 80%[3]	50-60	**Mature tech (TRL 10-11)** with large-scale deployment constrained by technical, economic, and policy factors
Primary route	**Inert anode**	Replace carbon-based anodes, no carbon oxidation – instead O2 is released	Up to 15%[2]	~25	Still at the nascent stage, with **limited demonstrations**
Primary route	**Electric boilers/ calciners**	Reduce thermal energy emissions in the refining process	Up to 10-15%	-	**Early adoption globally (TRL 9, 2030)** with limited deployment in India
Primary route	**Mechanical Vapour Re-compression (MVR)**	Install on the refinery, capture and reuse otherwise wasted heat	Up to 8%	-	**Emerging technology (TRL 7, 2027)** with deployment still in early to mid stages
Primary route	**CCUS**	Carbon offset tech to capture, store and reuse Co2	Up to 90%[5]	120-140	**At the concept stage (TRL 3, 2030)** with no demonstrations in India
Primary route	**Energy efficiency measures**	Includes WHR, cell ops optimisation and other measures for energy savings	Up to 14%	(-60)-30	**Mature technologies,** widely known and implemented
Secondary route	**Scrap-based aluminium (recycling)**	Recycle aluminium scrap to aluminium, 95% more energy efficient than primary production	Up to 90%[4]	15-25	**Mature technologies,** large-scale adoption limited by scrap availability

Low Medium High

Note: 1. Upper bound for abatement of aluminium embodied carbon for each individual lever assuming no other levers are implemented; abatement impact of combinations of levers will be less than simple sum because of abatement overlap between levers; estimates are approximate due to diversity of feedstock and production processes; **2.** Assumes no carbon oxidation and 1000 MW less energy requirement using inert anodes; **3.** Assumes ~100% use of renewable electricity displaces ~100% of fuel combustion emissions; **4.** Assumes 95% more energy efficient than primary production; **5.** Captures all scope 1 CO_2 emissions from the calcination and anode consumption process and emissions from captive fossil-based power plants; **6.** WEF Report; **7.** JMK Research and Analytics Report on Aluminium Sector in India
Source: Secondary Research (WEF reports, academia reports, industry reports etc.) for TRL (Technology Readiness Level), max abatement potential and cost of abatement; BCG and ITA analysis

Addressing energy storage, transmission, and demand challenges is essential to unlock bankability of low-emission aluminium projects

Bilateral consultations with project developers reveal three critical enablers for bankability and financing. Understanding these industry setbacks is vital to addressing the underlying drivers of delayed execution.

A Energy storage remains the critical bottleneck in delivering RTC renewable power

Large-scale deployment of energy storage for RTC RE faces challenges that extend beyond technology costs: delays in land acquisition and grid connectivity hinder integration, complexity of offtake structures slows the finalisation of PPAs, and lack of value-stacking opportunities for battery services reduce economic viability of projects. On the supply side, the absence of large-scale domestic battery storage manufacturing forces reliance on imports, leaving projects exposed to global supply chain and foreign exchange (FX) risks.

The government has taken important steps to address these barriers through Viability Gap Funding (INR 5,400 crore) and Production-Linked Incentive schemes (INR 18,100 crore) to support deployment of 30 GWh of Battery Energy Storage System (BESS) capacity and develop 50 GWh of advanced chemistry cell manufacturing, respectively[1]. In parallel, ISTS charge waivers for standalone storage projects commissioned before June 2025 are helping reduce landed costs and improve project viability. Despite these initiatives, the current plans fall short of scale required. The Central Electricity Authority projects ~411 GWh of storage capacity needed by 2031–32 to achieve renewable targets, far above today's pipeline.

A coordinated mix of targeted policy and regulatory interventions, financial innovation, and domestic capacity building can help push energy storage technologies become the backbone of RTC renewable power supply, enabling aluminium and other sectors to move decisively away from captive thermal power.

B Addressing right-of-way issues to support rapid scale up of grid infrastructure

The cost of and timeline for delivery of RE smelters depend on reliable transmission infrastructure. Smelters are concentrated in the east (Odisha, Chhattisgarh, Jharkhand), while the richest solar and wind resources are located in the west and south (Rajasthan, Gujarat, Karnataka, Tamil Nadu). This geographic mismatch makes long-distance, interstate transmission indispensable. Yet, India's transmission system faces mounting constraints that risk slowing the shift to RE.

Securing right-of-way (ROW) for new high-voltage corridors is a major bottleneck. In India, acquiring ROW is often contentious: disputes over compensation, fragmented land ownership, and opposition from farmers and communities frequently cause multi-year delays. According to NITI Aayog, over 70% of national infrastructure projects remain at a basic stage of development due to land acquisition and corridor-related issues.

The government has taken steps to ease ROW bottlenecks, including the Electricity Transmission Rules, 2021, which introduced centralised planning and uniform land compensation norms. However, underlying issues including fragmented decision-making, weak enforcement, and social resistance remain. Unlocking transmission capacity will require stronger coordination across central, state, and local agencies, transparent compensation, and alignment of RE growth with transmission build-out.

C Create strong demand signals for low-carbon aluminium to improve project bankability

While procurement of low-carbon aluminium is gaining momentum globally (led by automotive and packaging OEMs under sustainability mandates), India's domestic demand remains weak and concentrated on recycling rather than low-carbon primary aluminium. Early adopters — such as Dabur with 100% recyclable cans, Tata using 40% recycled aluminium in vehicles, and Vedanta's Restora products — are positive signals but remain isolated. By contrast, global leaders are moving faster: Apple sources aluminium from RE smelters, while Mercedes aims to cut aluminium's carbon footprint in its vehicles by 90% by 2030.

A nationwide Green Public Procurement policy could create anchor demand for low-carbon aluminium. While frameworks have been proposed, no regulatory requirement currently compels adoption by end-use sectors.

Without stronger demand signals through voluntary commitments or mandates, producers will struggle to secure financing for capital-intensive green projects and risk losing competitiveness in global supply chains.

Note: 1. PIB announcements

5

Bright Spots: Showcasing India's Clean Projects

ACME partners with IHI Corporation Japan for Phase I of a pioneering green ammonia project in Odisha

Green ammonia projects at advanced stage with required statutory approvals and robust implementation readiness

ACME Green Ammonia Plant – Project information

Location:
Gopalpur, Odisha

Phase:	Capacity:
I	400 KTPA Ammonia *(with IHI Corporation)*
II	400 KTPA Ammonia
III	400 KTPA Ammonia

Technology:
Electrolytic green hydrogen for green ammonia *(Tech Provider: Casale)*

Partners:
- ACME
- IHI Corporation

Significant impact potential for India and the world

~3 MtCO_2e p.a.
Carbon abatement potential (per annum) *(combined Phase I, II, and III)*

~$5 Billion
Estimated investment
(combined Phase I, II, and III)

1600 MW RE – Phase I
Dedicated RE supply (solar PV: 1550 MW; wind: 60 MW)

Pioneer project
One of the largest and most advanced Green Ammonia projects in India

Key success factors driving the clean transition

Phased development roadmap
Standardised the size of ammonia production block (1200/ 400 KTPA) for easier implementation and faster execution

Robust policy landscape
NGHM and Odisha state clean energy policy support green hydrogen and its derivatives projects

Established leadership
Successfully commissioned the first integrated green ammonia plant in India in 2021 (capacity: 5 TPD)

Ambitious organisation targets
ACME Group aims for a portfolio of 10 MTPA Green Ammonia (or its equivalent hydrogen) by 2032

Key levers to accelerate project implementation

- Long-term offtake assurance at green premium
- Policy advocacy for scaling domestic and international demand
- Harmonisation of standards and regulations across lead markets

The journey of ACME Green Ammonia Project

2022
MoU signed with Government of Odisha

2024
Offtake term sheet signed between ACME and IHI Corp

H1 2025
- ✓ FEED completed by Aker Powergas
- ✓ Joint venture established between ACME (70%) and IHI Corp (30%)
- ✓ Land lease signed for 50 years
- ✓ Major statutory approvals applied

~2030
Expected completion (Phase I – 400 KTPA)

Post 2030
Phase II and III - Capacity expansion by 800 KTPA Green Ammonia

Phase I Project Milestones

SECI Tender win – A defining milestone for ACME

H2 2025
SECI awarded 6 Green Ammonia tenders out of 13 to ACME (370 KTPA)

~2029
Expected completion of Green Ammonia Facility[1] for SECI

1. Potential supply location yet to be finalised

NGEL[1] Green Hydrogen Hub – India's first integrated hub, bolstering domestic green energy production

FOAK hub with development of multiple green chemicals like ammonia, methanol, SAF, and urea

NGEL Green Hydrogen Hub – Project information

Location:
Pudimadaka, Andhra Pradesh

Phase:	Year:	Capacity:
I	2028	0.3 MTPA Ammonia
II	Q1-2029	1.2 MTPA Ammonia
III	Q2-2029	0.5 MTPA Methanol
IV	2032	0.5 MTPA SAF/Urea

Technology:
Electrolytic green hydrogen and carbon capture for green chemicals

Partners:
- NTPC
- Others

Significant impact potential for India and the world

~5 $MtCO_2e$ p.a.
Carbon abatement potential (per annum)

~$22 Billion
Estimated investments

20 GW RE
Development of 7 GW RTC renewable energy capacity

FOAK in India
India's first green hydrogen and its derivatives hub

Key success factors driving the clean transition

Ambitious organisation targets
NTPC, the parent organisation of NGEL, has adopted a target of 60GW+ RE capacity by 2032

Phased development roadmap
Project divided in four phases across seven years, with demonstrations planned for other green chemicals

Increased autonomy
Government approval for enhanced flexibility to NTPC for increased investments in NGEL

Robust policy landscape
NGHM and AP state clean energy policy support green hydrogen projects

Key levers to accelerate project implementation

- Long-term offtake assurance at green premium
- Permissive international certification and trade policies
- Policy for scaling domestic and international demand

The journey of NGEL Green Hydrogen Initiatives

2025	2025	Q1 2027	Q2 2027	2028-2029	Q2 2029	2029	2032
0.07 MTPA Ammonia purchase agreement with SECI	FID expected for Phase I – 0.3 MTPA Ammonia	Demo plant for ethanol	Demo plant for SAF	Phase I - 0.3 MTPA Phase II – Capacity expansion to 1.5 MTPA Ammonia	Phase III - Capacity expansion to 0.5 MTPA Methanol	Demo plant for urea	Phase IV - Capacity expansion to 0.5 MTPA SAF or Urea

Note: 1. NGEL – NTPC Green Energy Limited, a subsidiary of National Thermal Power Corporation (NTPC)

AM Green secured FID on the first phase of its 1.25 MTPA Green Ammonia plant in Andhra Pradesh

Marking India's only green ammonia project to achieve FID, positioning the country as a frontrunner in global clean energy transition

AM Green Ammonia Plant – Project information

Location:
Kakinada, Andhra Pradesh

Phase:	Capacity:
I	0.5 MTPA Ammonia
II	0.75 MTPA Ammonia

Technology:
Electrolytic green hydrogen for green ammonia
(Tech Provider: John Cockerill)

Partners:
- AM Green
- Others

Significant impact potential for India and the world

~3 $MtCO_2e$ p.a.
Carbon abatement potential (per annum)

~$1.5 Billion
Estimated investments

1300 MW RTC RE
Enabled through 4500 MW of solar and wind hybrid capacity

Flagship project in India
Only green ammonia project reached FID till date

Key success factors driving the clean transition

Experienced leadership
Deep understanding of the energy transition and the ability to manage significant risks and capital investment

Strong partnerships
Securing agreements with major offtakers like Yara, Keppel, and Uniper provides crucial demand assurance

Robust policy landscape
NGHM and Andhra Pradesh state clean energy policy support green hydrogen and its derivatives projects

Project structuring
Cost optimisation via. project architecture (RTC RE + alkaline electrolyser) and technology partnerships to reduce green premium

Key levers to accelerate project implementation

Long-term offtake assurance at green premium

Policy advocacy for scaling domestic and international demand

The journey of AM Green Ammonia Project

2023-2024
AM Green signed MoU with NTPC and SVJN Green Energy for power supply

2024
FID reached in Aug 2024 for 0.5 MTPA

2025
- ✓ EU RFNBO compliant (certification from CertifHy)
- ✓ Offtake terms with:
  - Yara Clean Ammonia (50% from the first phase)
  - RWE supply,
  - Uniper, etc.

2026
Expected completion in H2 2026 *(Phase I – 0.5 MTPA)*

Post 2026
Phase II- Capacity expansion by 0.75 MTPA Green Ammonia

ReNew – Advancing India's green ammonia and methanol transition

One of the country's largest green chemicals projects, unlocking opportunities across industry, shipping, and global value chains

Green Ammonia Project

Project information

Location:
Paradip, Odisha

Phase:	Capacity:
I	0.3 MTPA
II	0.4 MTPA
III	0.4 MTPA

Technology:
Electrolytic green hydrogen for green ammonia

Impact potential

~1.3 $MtCO_2e$ p.a.
Carbon abatement potential (per annum)

~$2 Billion
Estimated investments

Green Methanol Project

Project information

Location:
Odisha

Capacity:
0.275 MTPA Green Methanol

Technology:
Electrolytic green hydrogen + CO_2-to-methanol synthesis

Impact potential

~442 $KtCO_2e$ p.a.
Carbon abatement potential (per annum)

~$2.2 Billion
Estimated investments

Key success factors driving the clean transition

Institutional strength
ReNew's core strength in utility-scale RE solution to supply competitive power for green chemical projects

Joint venture and partnerships
ReNew's joint venture with IOCL and L&T, help stabilise supply chains and foster the growth of the green hydrogen sector

Strategic location in Odisha
Proximity to ports and industrial clusters enhances export readiness and integration into domestic value chains

Key levers to accelerate project implementation

- Long-term offtake assurance at green premium
- Policy advocacy for scaling domestic and international demand and non-biogenic CO_2 usage
- Orchestrate value chain partnerships *(e.g., feedstock supply from CCUS projects)*

The journey of Green Ammonia Project

2025	2026	2029	Later
✓ 50% FEED done ✓ Compliant to RFNBO (certifHY)	Target FID in 2026 (100% FEED by Q2)	Target commission in Q1 2029	Phase II and III - capacity expansion by 0.8 MTPA

Phase I Project Milestones

The journey of Green Methanol Project

2023	2025	2029	Later
Odisha government approval	Land identified	Target commission in Q4 2029	Capacity expansion

JSW Green Steel (Salav) – Leading the transition to green hydrogen-based steelmaking in India

FOAK hydrogen-DRI plant in India

JSW Green Steel (Salav) – Project information

Location:
Salav, Maharashtra

Phase:	Year:	Capacity:
I	2028	2 MTPA Steel
II	2030	4 MTPA Steel

Technology:
Scrap + NG based DRI;
Planned transition to H-DRI

Partners:
- JSW Steel
- JSW Energy

Significant impact potential for India and the world

~10 $MtCO_2e$ p.a.
Carbon abatement potential (per annum)

~$7 Billion
Estimated investments

>10%
Share of production in the global green steel demand[1]

FOAK in India
One of the largest green steel plants in the world

Key success factors driving the clean transition

Implementation readiness
Pilot-scale project for green H-DRI to be commissioned by 2025 at Vijayanagar plant

Diverse corporate ecosystem
Competitive advantage arising from upstream group companies like JSW Energy

Technology foresight
Commitment for early adoption of emerging and breakthrough technologies

Institutional strength
Robust parentage and strong leadership ensuring governance and strategic continuity

Key levers to accelerate project implementation

- Demand and offtake assurance
- Expedited necessary clearances
- Access to low-cost financing
- Supporting infrastructure development

The journey of JSW Green Steel Project

2024	2025	2025	2026	2028	2030	Later
Completion of feasibility study	Establishment of **JSW Green Steel** as a separate entity	Land acquisition for the plant	**FID target**	Completion of Phase I – Total capacity of **2 MTPA**	Completion of Phase II – Total capacity of **4 MTPA**	Capacity expansion to **10 MTPA**

Note: 1. IGSC report by WWF, CII, and EY Parthenon pegs global green demand at ~35 MTPA

Jindal Steel (Angul) – Advancing low carbon steelmaking through carbon capture and utilisation

One of the world's largest carbon capture technology implementations in an integrated steel plant

Jindal Steel (Angul) – Project information

Location:
Angul, Odisha

Implementation:
Carbon capture plant ready; Utilisation plants coming up

Technology:
Carbon capture from DRI and syngas off-gases

Partners:
Expression of Interest by green hydrogen derivatives, mineralogical, and crude algae/ biomass developers for utilization

Significant impact potential for India and the world

~1.18 $MtCO_2e$ p.a.
Carbon abatement potential (per annum)

Pioneer CCU plant
One of the largest carbon capture plants in the world

Cross-sector impact
Utilisation across clean fuels, food and beverages, minerals, and other industries

Key success factors driving the clean transition

Organisational learning
Learning curve for CCU technology through early development of pilot projects

Industrial ecosystem
Immediate availability of land, power, and utilities for use by carbon utilisation plants

Strong intent for FID
Multiple possible support scenarios being worked out with local and global financial institutions showcasing deep intent for project to reach FID

Diverse corporate ecosystem
Competitive advantage arising from upstream group companies aspiring to implement green hydrogen derivatives products

Key levers to accelerate project implementation

- Strong value chain for CO2 offtake
- Policy for non-biogenic CO2 usage
- Supporting infrastructure development
- Viability gap financing for CO2 utilisation

The journey of Jindal Steel (Angul) CCU Plant

*Timelines Indicative

2014	2024	2025	2030*	2035*
Commissioning of first carbon capture unit	Operational carbon capture capacity of 3600 TPD	Invitation for Expression of Interest (EoI) for utilisation	Phase I: Commissioning of utilisation plants (2000 TPD)	Phase II: Commissioning of utilisation plants

IOCL and LanzaJet (Joint Venture) – Early movers for SAF production in India

FOAK project for SAF production in India via Alcohol-to-Jet (AtJ) technology

IOCL and LanzaJet – Project information

Location:
Panipat, Haryana

Implementation:
Pre–FEED stage

Technology:
LanzaJet technology for Alcohol-to-Jet SAF

Partners:
- Indian Oil
- LanzaJet
- Others (under discussion)

Significant impact potential for India and the world

~88k tonnes p.a.
SAF production capacity (per annum)

~$250 Million
Estimated investment potential

Flagship project
One of the first AtJ based SAF plants in India

Key success factors driving the clean transition

Corporate risk sharing
Project to be developed in JV model by IOCL and LanzaJet. Other partners may join post FEED

Diverse set of expertise
Strong technology and marketing expertise introduced by the two players in JV

Proven technology
Tech demonstrated in 2016, certification and transcontinental flights in 2018. World's first integrated AtJ commercial plant on ground at Georgia, US

Regulatory momentum
SAF blending mandates for international aviation creating marketing pull for SAF

Key levers to accelerate project implementation

- Demand and offtake assurance
- Indicative blend targets converted to mandates
- Secure long–term supply of feedstock
- Access to low-cost financing

The journey of IOCL and LanzaJet JV Plant

2023	2023	2025	2026	2028-2029	Later
Signing of MoU for SAF exploration	Indicative SAF blending targets announced by GoI	Project in Pre–FEED stage	FEED and FID (target)	Start of SAF production	Capacity expansion

Critical Bottlenecks to FID and Potential Solutions

6

Several barriers to FID are at play: lack of green demand, limited access to low-cost finance, and broken value-chain linkages emerging as most prominent across sectors, followed by infrastructure readiness and regulatory hurdles

Barriers

1 Market Demand and Offtake

A. **Lack of anchor offtake and price premium**

B. **Limited buyers' experience and willingness to enter into long-term binding contracts**

C. **Clean product price and market scale uncertainty**

D. **Clean product adoption hesitancy by consumers** *(e.g., cement)*

2 Financing and Viability

A. **Lack of suitable instruments to bridge the green premium**

B. **High cost of capital for FOAK projects and lack of suitable de-risking instruments** *(e.g., guarantees, blended finance, etc.)*

C. **Limited experience in structuring new business models**

D. **Limited internal and external funding available for DevEx**

3 Value Chain and Ecosystem

A. **Limited offtake of by-products** at a price premium *(captured CO2)*

B. **Limited availability, accessibility, and affordability of feedstock** *(e.g., MSW, calcined clay, green H2)*

C. **Lack of value-chain and cross-sectoral co-ordination** *(e.g., between CO2 capture and utilisation projects)*

4 Infrastructure

A. **Transmission** and **storage** infrastructure constraints for RE expansion

B. **Right-of-way resistance** (for CO2 pipelines, RE corridors)

C. **Inadequate capacity of shared infrastructure** (e.g., port infrastructure for ammonia exports, CO2 transport, and storage)

5 Regulatory landscape

A. **Lack of clarity and high uncertainty in trade policy** *(e.g., CBAM, RED II/ III)*

B. **Stringent regulatory requirements in lead markets** *(e.g., RFNBO compliance)*

C. **Delay or long lead-time in obtaining permits/ clearances**

D. **Limited institutional capacity to evaluate new technologies** *(delays policy implementation)*

6 Tech Maturity and Localisation

A. **Import dependencies** *(e.g., electrolysers)*

B. **Limited test beds or technology piloting support**

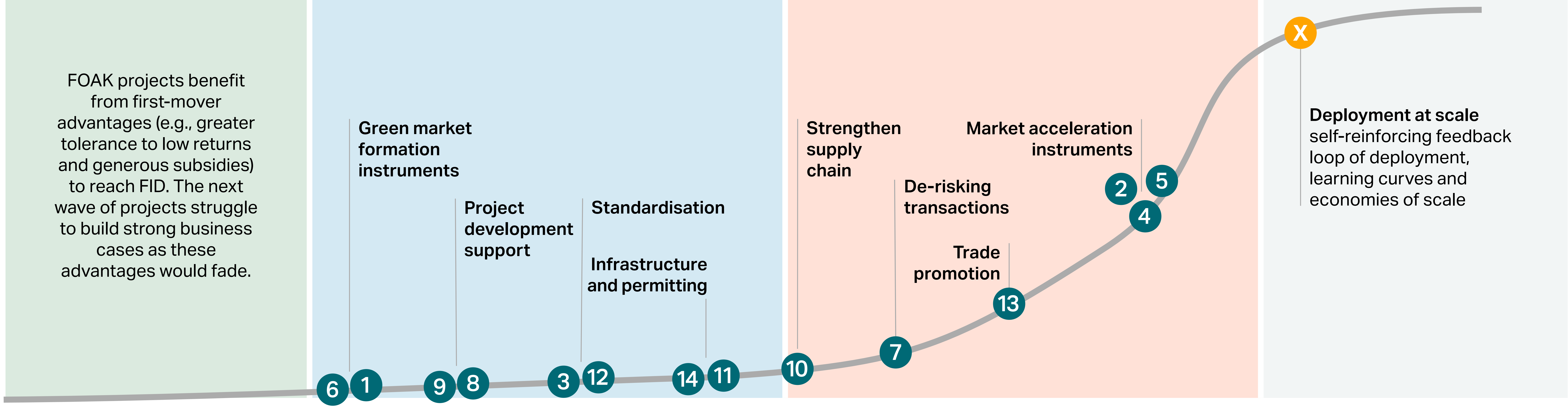
C. **Limited public data on techno-commercial feasibility** of various tech solutions and comparison against alternatives in domestic and international markets

	1 Market Demand and Offtake	2 Financing and Viability	3 Value Chain and Ecosystem	4 Infrastructure	5 Regulatory landscape	6 Tech Maturity and Localisation
Chemicals	1A 1B 1C	2A 2B	3A 3C	4A 4B 4C	5A 5B 5C	5A
Steel	1A 1B 1C	2A 2B 2C	3A 3B 3C	4A 4B 4C	5A 5B 5C	5B 5C
Cement	1A 1C 1D	2A 2B 2D	3A 3B 3C	4B 4C	5D	5B 5C
Aviation	1A 1C	2A 2B 2D	3B 3C	4C	5D	5A 5C
Aluminium	1A 1C	2A 2B		4A 4B	5D	5B 5C

Barrier criticality for clean projects in the sector: High Medium Low | **Barrier applicability to sector** XX

A combination of coordinated policy, financial market-making, and value-chain related interventions required to fast track projects and reach tipping points that unlock exponential deployment of clean materials, chemicals, and fuels

Market Development Phase	Inception	Formation	Acceleration	Deployment at scale
Goal	Bring tech. to commercial readiness and plan transition	Establish long-term business case for low-carbon projects [FOAK projects]	Accelerate scale and pace of transactions [scale from FOAK to Nth of a Kind (NOAK) projects]	Convince the bulk of market to buy low-carbon product



Market demand and offtake

1. Unlock premium lead markets
2. Scale demand via. standards and regulations
3. Standardise procurement models and contract structures
4. Enable supply-demand matching and transparent price discovery
5. Shape end-consumer preferences

Financing and viability

6. Lowering green premium
7. Risk Sharing, transfer and absorption
8. Capabilities building and financial and business structuring support
9. Project DevEx support

Value-chain and infrastructure

10. Address co-ordination failure across value chain to secure feedstock supply and by-product offtake
11. Build shared supporting infrastructure

Regulatory

12. Aligning standards and certifications across lead markets
13. Trade policy and export promotion
14. Streamline clearances and right-of-way

Demand creation through market-making mechanisms, procurement standards, mandates and consumer awareness is critical to break the demand-supply mismatch for clean products

Barriers	Functions	Suggested interventions	Implementation timeframe	Most relevant sectors	Primary actors: Suppliers	Govt.	Ecosystem[1]	Financial Inst.
Market demand and offtake	**1. Unlock premium lead markets**	**Develop private buyers' alliances to secure voluntary commitments to procure clean products at a premium** *(e.g., Clean Energy Buyers Alliance, First Movers Coalition, etc.)*	Medium-term	Steel, Cement, Aviation, Aluminium	✓		✓	✓
		Establish win-win trade partnerships and develop green export corridors through bilateral policy dialogues *(e.g., India-EU for green chemicals)*	Medium-term	Chemicals, Steel	✓	✓	✓	✓
	2. Scale demand via. standards and regulations	**Introduce green public procurement in public infrastructure (with preferential treatment) and demand-side mandates for private sector,** in a phased manner	Medium-term	Chemicals, Steel, Cement, Aluminium		✓	✓	
	3. Standardise procurement models and contract structures	**Develop purchase agreement playbooks/toolkits tailored to Indian industry to standardise long-term binding agreements,** *(e.g., the Green Purchase Toolkit by ITA and WBCSD[2])*	Short-term	Chemicals, Steel, Aluminium	✓		✓	✓
		Advance market commitments for use of demonstration-scale volumes from FOAK projects *(e.g., in marquee public projects)*	Short-term	Chemicals, Steel, Cement, Aluminium	✓	✓	✓	
	4. Enable supply-demand matching and price premium discovery	**Scale existing market intermediaries and replicate in other commodity sectors** *(e.g., SECI and H2Global),* bridging long-term offtake and short-term procurement gap	Medium-term	Chemicals, Steel, Aviation	✓	✓		✓
	5. Shape end-consumer preferences	**Consumer awareness campaigns** *(e.g., for LC3 cement)* **and end-consumer incentives** *(e.g., tax incentives for cars)* to boost consumer preference for clean products	Medium-term	Steel, Cement, Aviation, Aluminium		✓	✓	

Impact Timeline: Short-term (<12 months) Medium-term (<24 months) Long-term (>24 months) | **Sectors:** Chemicals Steel Cement Aviation Aluminium

Note: 1. Ecosystem includes financial institutions, tech providers, raw material providers, policy think-tanks, etc.; **2.** World Business Council for Sustainable Development

Carbon markets, low-cost capital and tailored de-risking instruments can be scaled to improve project viability and crowd-in commercial capital for clean industrial projects

Barriers	Functions	Suggested interventions	Implementation timeframe	Most relevant sectors	Primary actors: Suppliers	Govt.	Ecosystem[1]	Buyers
Financing and viability	**6.** Lowering green premium	**Tap international carbon markets and other carbon pricing-based mechanisms** *(e.g., Article 6.2 Bilateral or Article 6.4 Centralised Carbon Markets, Contracts for Difference)*	Medium-term	Chemicals, Steel, Cement, Aviation	✓	✓	✓	
		Supply-side incentives *(e.g., subsidies, tax credits, interest subvention for FOAK projects)*	Medium-term	Chemicals, Steel, Cement, Aviation, Aluminium	✓	✓		
	7. Risk sharing, transfer, and absorption	**Expanding concessional lending by State-backed financial institutions to clean industrial projects** *(Leveraging existing schemes by IREDA, SBI, NABFID, SIDBI[2] etc.)*	Short-to-Medium-term	Chemicals, Steel, Cement, Aviation, Aluminium		✓		✓
		Scaling transition finance instruments (Loans/Bonds) backed by a robust climate taxonomy, sectoral transition pathways, and corporate transition plans	Short-to-Medium-term	Steel, Cement, Aviation, Aluminium	✓	✓	✓	✓
		Credit guarantees and enhancement products for clean projects (export credit guarantees, performance guarantees, payment security mechanisms, revolving funds, etc.)	Medium-to-Long-term	Chemicals, Steel, Cement, Aviation, Aluminium		✓	✓	✓
		Innovative financial mechanisms to reduce CapEx burden, link payments with the operating model *(e.g., leasing models for electrolysers and carbon capture units)*	Medium-term	Chemicals, Steel, Cement, Aviation	✓		✓	✓
	8. Capabilities building/financial and business structuring support	**Clean Industrial Project Financing Playbook** with blueprints to structure de-risked business models across project archetypes in different sectors	Short-term	Chemicals, Steel, Cement, Aviation, Aluminium	✓		✓	✓
	9. Project DevEx support	**Set up pooled fund instruments/financing facilities** to deploy low-cost financing via grants, convertible equity, etc., for early-stage project development expenditure	Medium-term	Chemicals, Steel, Cement, Aviation, Aluminium		✓	✓	✓

Impact Timeline: Short-term (<12 months) Medium-term (<24 months) Long-term (>24 months) | **Sectors:** Chemicals Steel Cement Aviation Aluminium

Note: 1. Ecosystem includes tech providers, raw material providers, policy think–tanks, etc.; **2.** Indian Renewable Energy Development Agency; State Bank of India, National Bank for Financing Infrastructure and Development, Small Industries Development Bank of India

Coordinated action on to address infrastructure gaps, value-chain linkages, and regulatory hurdles will accelerate movement of projects towards bankability

Barriers	Functions	Suggested interventions	Implementation timeframe	Most relevant sectors	Primary actors: Suppliers	Primary actors: Govt.	Primary actors: Ecosystem[1]	Primary actors: Buyers
Value-chain and infrastructure	**10. Address co-ordination failure across value chain and sectors to secure feedstock supply and by-product offtake**	**Value-chain co-ordination platforms** with participation from different heavy industry sectors, technology suppliers, offtakers, and ecosystem players	Short-term	Chemicals, Steel, Cement, Aviation, Aluminium	✓		✓	✓
		Localised assessment of raw material sources *(e.g., calcined clay)* **and by-product offtake markets** *(e.g., captured CO2),* including volumes, price, quality, etc.	Short-to-Medium-term	Chemicals, Steel, Cement, Aviation			✓	
		Hyper-localised mapping of regions with suitable economics for production (and export), evaluate infrastructure gaps and engage authorities for long-term infrastructure planning	Short-to-Medium-term	Chemicals, Steel, Cement, Aviation		✓	✓	
	11. Build and accelerate supporting infrastructure	**Establish a public-private hub infrastructure co-ordination entity** to aggregate local demand for H2 and/or CO2 infrastructure while planning, de-risking, and funding shared infrastructure	Long-term	Chemicals, Steel, Cement, Aviation, Aluminium	✓	✓	✓	✓
		Community engagement campaigns at a cluster level to bring together project developers, local governments and communities to develop compelling cases for clean industrial projects and address resistance to infrastructure build-out/reduce lead-time to RoW	Medium-to-Long-term	Chemicals, Steel, Cement	✓	✓	✓	
Regulatory landscape	**12. Aligning standards and certifications across lead markets**	**Policy dialogues with lead markets to align regulatory standards in these markets with supply characteristics of Indian producers** *(e.g., the EU RFNBO and the IMO compliance and its alignment with specifications of green chemicals project in India)*	Medium-term	Chemicals, Steel, Aviation		✓	✓	
	13. Trade policy and export promotion	**Policy briefs and Track 2 dialogues** addressing uncertainty in trade policy *(e.g., CBAM, RED II/ III),* supporting win-win bilateral trade partnerships etc.	Medium-term	Chemicals, Steel, Aviation		✓	✓	
	14. Expediting clearances and right-of-way	**Single Window Clearance (SWC): Expand and strengthen implementation of existing SWC at centre and state level, or create new mechanisms,** for clean industrial projects to streamline and fast-track permitting, land and environmental clearances, etc.	Medium-term	Chemicals, Steel, Cement, Aviation, Aluminium		✓	✓	

Impact Timeline: Short-term (<12 months) Medium-term (<24 months) Long-term (>24 months) | **Sectors:** Chemicals Steel Cement Aviation Aluminium

Note: 1. Ecosystem includes financial institutions, tech providers, raw material providers, policy think–tanks, etc.

ITA India Project Support Programme

About the ITA Project Support Programme

Heavy industry sectors contribute 30% of global GHG emissions[1], presenting a significant challenge to achieving global net-zero targets. While technologically mature solutions for deep decarbonisation in these sectors are emerging, their deployment and operation costs often exceed those of conventional fossil fuel-based alternatives. Consequently, projects implementing these solutions face difficulties in establishing compelling investment cases and reaching FID.

To address this challenge, the ITA aims to improve the bankability of and catalyse investment in commercial scale decarbonisation projects across key sectors. Its operating model is to mobilise key stakeholders in industry, government, finance, and civil society to create better conditions for such projects, thereby strengthening their investment case and easing their path towards FID.

Recognising that projects are strongly influenced by their local conditions, the ITA is undertaking a series of in-country Project Support Programmes. The ITA's operating model is currently being deployed in select countries and regions, prioritising emerging economies where the future of industrial growth is expected to occur.

The ITA's activities in India will follow a two-phased approach highlighted in Fig. 17.

In Phase I, the ITA has mapped over 65 projects in its six key sectors in India. In late 2025, the ITA will transition to implementing the India Project Support Programme. This phase will see the programme undertake a series of interventions to design and implement solutions needed by projects to overcome their key barriers to FID and mobilise the necessary stakeholders to make those solutions a reality.

The topics of those interventions will be prioritised and informed by the needs of the projects formally selected by the ITA in India. The interventions will be carried out in a way that helps the selected projects progress towards FID, while also benefiting the wider pipeline of projects in the country, both current and future. The key target outcome of the Implementation Phase is to support 10–15 projects in India take concrete steps towards, and ideally reach, FID in 2026 by COP31, enabling them to be operational by 2030.

Figure 17: The timeframe of ITA Project Support Programme

The ITA's activities will be carried out in phases

Project Nirmaan (Phase I, May-Oct 2025)
Map and analyse project pipeline, identify barriers to FID and opportunity for ITA support, and partner with Indian government and corporates

ITA India Project Support Programme (Phase II, Nov 2025 – Dec 2026[2])
- Support selected projects in collaboration with existing initiatives
- Align on potential solution(s) and identify target stakeholders
- Orchestrate solution implementation to FID

Note: 1. MPP (2024), MPP Global Project Tracker: Mapping the pipeline to 2030 goals for industrial decarbonisation ; **2.** The country programme might continue beyond stated timeline

8 Appendix

ITA Project Selection Parameters

Given the breadth of ITA's mission, there is a broad range of projects and activities it could potentially support. To narrow its focus and maximise impact, the ITA uses the following parameters to prioritise projects for engagement and selection.

- **Sector relevance:** Projects linked to assets in the priority sectors of a programme (in the case of India, chemicals (including shipping), steel, aviation, cement, and aluminium). Ideally, projects should address the most emissions-intensive activities globally in these sectors. For example, ammonia production, aviation fuel production and use, ironmaking, clinker production, and aluminium smelting.
- **Commercial scale:** Projects deploying decarbonisation technologies at a significant scale. While specific capacity expectations vary by sector, projects should generally aim for nominal output capacities in the range of hundreds of thousands of tonnes per year or millions of tonnes per year (for larger-scale facilities) — being flexible basis India's context and sector.
- **High decarbonisation potential:** Projects with the capability to operate at a significantly lower emissions intensity compared to conventional processes and potential to reach near-zero emissions over time. This includes projects with the capability to do this immediately upon becoming operational, as well as 'transitional' projects, whose initial phases can meaningfully reduce emissions in the near term and are accompanied by future plans to achieve greater reductions. Both greenfield (emissions avoidance) and brownfield (emissions reduction) projects are considered. Incremental improvements are only prioritised when they aim to transition an already low-emissions facility towards near-zero emissions[1].
- **Breakthrough technologies:** Projects employing technologies that have been demonstrated at scale and have reached/are close to reaching commercial maturity but have not yet achieved widespread deployment in the target country.

These parameters ensure that the ITA's efforts are focused on transformative projects with the potential to significantly impact emissions reduction in key industrial sectors. Projects 'selected' by the ITA on the basis of these parameters are then promoted by the ITA as flagship examples and used to inform programme activities.

Note: ITA's parameters includes broader in scope than MPP's Global Project Tracker and includes low-carbon projects (the latter focuses primarily on near-zero emissions projects).

Note: 1. The terms "low–emissions" and "near–zero emissions" are imperfect and vary according to context. The ITA's application of this parameter is informed by leading international standards wherever possible.

Thank You

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