# How green manufacturing is reshaping India's industrial landscape

**February 2025**

EY Parthenon

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# Foreword

India is pursuing two important goals to achieve eminence in the global order– becoming a developed nation by 2047 and achieving Net Zero by 2070. Despite great strides made in renewable energy capacity, the country continues to depend heavily on imported fossil fuels and is a major contributor to overall global greenhouse gas emissions annually. As the fastest growing large economy in the world, India's energy and industrialization path as it stands now and the way it will progress over the next two decades has profound global implications in terms of both the environment as well as impact on the economy.

The Indian government has strategically prioritized the expansion of green energy capacity – solar, wind, hydro and biogas – while also promoting green technologies and products like Electric Vehicles and Carbon Capture, Utilisation and Storage (CCUS). Global regulations, competitive positioning, and changing customer preferences are also a few factors accelerating the need for green industrialization.

The government's goal of 500 GW of installed renewable energy capacity by 2030 is ambitious but achievable – the country has already achieved 209.4GW as of January 2025. The focus on manufacturing solar panels and wind turbines will only speed up the renewable energy capacity creation while also creating jobs and adding to the GDP. The government also launched the National Green Hydrogen Mission in 2023 to make India one of the leaders in the Green Hydrogen ecosystem. The next step necessarily must be greening manufacturing processes, going beyond the current strategies of substituting fossil fuel with green fuels in industries and also focusing on CCUS to capture final emissions. As this report explains, changing manufacturing processes will involve making conscious production strategies that move away from the current processes. And it will involve ensuring that the changes take place in the industries with highest emissions – Steel, Cement, Automobiles, and Oil & Gas.

As India's steel sector gears up to scale production capacities in response to increasing demand, expansion of 'green steel' production pathways can align with the goal of net-zero emissions. Major steel manufacturers are adding new capacity through production of green or near-zero emission steel using Green Hydrogen in Direct Reduced Iron (GH2-DRI) processes for primary steel production, and through scrap utilization in electric arc furnaces (EAFs) powered by renewables for secondary producers. Blast furnace and basic oxygen furnace (BF-BOF) steelmakers could also achieve substantial cost savings via decarbonization initiatives, thereby mitigating the financial impact of carbon taxes or the necessity of buying emissions permits.

Similarly, the Cement industry, which accounts for 6% of India's emissions, has maintained a strong focus on 'Green Cement,' which is made utilizing alternative materials like fly ash and slag to reduce clinker content, resulting in lighter and stronger structures while minimizing waste. In the Oil & Gas sector, all public and private companies have set Net Zero targets and are implementing multiple initiatives such as large-scale biofuel blending and strategic collaborations, building almost 20 GW of renewable energy capacity, piloting use of Green Hydrogen as a fuel as well as feedstock and CCUS.

This report details the stage at which green manufacturing is in India currently – and what needs to be done to accelerate it.  The hurdles in the way include higher upfront capex and opex costs and lack of a proper ecosystem to boost green manufacturing and industrialization. The path forward will need incentives and policy push, R&D, private-public partnerships and access to capital.

**Rajiv Memani**
Chairman and CEO,
EY India

# Executive Summary

India's commitment to achieving net-zero emissions by 2070 represents a transformative pledge in the fight against climate change and a significant step toward sustainable development. As one of the world's largest contributors to greenhouse gas emissions, the country's actions carry profound global implications, both environmentally and economically. Acknowledging the urgency of reducing its carbon footprint, India has strategically prioritized the expansion of renewable energy capacity and the advancement of green technologies. These efforts signal a strong dedication to transitioning away from fossil fuel dependency, thereby fostering a cleaner and more resilient future. The country's approach underscores a dual focus: ensuring economic growth while mitigating environmental impact, balancing industrial progress with ecological responsibility. This commitment necessitates a well-defined roadmap encompassing policy reforms, technological advancements, and cross-sector collaborations, all of which are vital to achieving the ambitious net-zero target.

Central to India's decarbonization journey is the rapid expansion of its renewable energy sector, a critical element in its long-term sustainability strategy. The government has set a formidable goal of reaching 500 GW of installed renewables capacity by 2030, a move designed to reduce reliance on conventional energy sources while stimulating local industries. The manufacturing of solar panels, wind turbines, and other renewable energy infrastructure is expected to generate employment, attract investments, and bolster domestic supply chains. Complementing this push is the National Green Hydrogen Mission, launched in January 2023, which aims to position India as a leader in the emerging hydrogen economy. By decarbonizing traditionally high-emission sectors such as steel, cement, and oil & gas, the initiative seeks to accelerate the transition to a low-carbon industrial landscape. The policy framework supporting these efforts includes financial incentives, regulatory enhancements, and collaborative research endeavors, all of which are crucial to scaling up clean energy solutions and reducing the overall carbon footprint of energy-intensive industries.

An in-depth analysis of India's industrial emissions highlights the significant role of the steel, cement, oil & gas, and power sectors as primary contributors to greenhouse gas emissions. Projections indicate that, within the next 15 years, emissions from these sectors could reach approximately 2 gigatons of CO2 annually, underscoring the urgency of comprehensive decarbonization measures. The whitepaper explores the complexities involved in transitioning to greener manufacturing processes, noting that high initial capital costs and technological limitations pose considerable challenges. However, the potential benefits of adopting sustainable practices outweigh the risks, with long-term cost reductions, regulatory advantages, and enhanced competitiveness driving industry-wide transformation. The document advocates for policy-driven incentives, increased investment in research and development, and the establishment of carbon pricing mechanisms to accelerate the adoption of clean technologies. These measures would provide industries with a structured approach to reducing emissions while ensuring economic viability and market stability.

Several key drivers are propelling India's green manufacturing efforts, including global compliance mandates, competitive market pressures, shifting customer expectations, and strategic climate capital allocation. Indian industries are aligning with international sustainability frameworks such Science-Based Targets initiative (SBTi), ensuring they remain competitive in a rapidly evolving global marketplace. The push for green manufacturing

is also fueled by growing investor confidence in sustainable business models, as companies that prioritize environmental responsibility are better positioned to attract capital and secure long-term financial stability. Furthermore, businesses that proactively integrate green technologies into their operations stand to gain a significant competitive advantage as global supply chains transition towards sustainability. This shift necessitates strong policy interventions, strategic partnerships, and continuous innovation to ensure that Indian industries remain at the forefront of the global green economy. The interplay between government support, industrial adaptability, and international collaboration will be instrumental in defining the success of India's green transformation.

A sector-specific approach to decarbonization is essential to achieving net-zero emissions, and India is actively pursuing targeted strategies across various industries. The steel sector, the second largest in the world, is exploring carbon capture technologies to reduce the carbon intensity of its Blast Furnace-Basic Oxygen Furnace (BF-BOF) production route. Similarly, the cement industry, responsible for approximately 6% of India's total CO2 emissions, is investing in green cement alternatives and carbon capture and storage (CCUS) technologies. The oil and gas sector, a cornerstone of India's energy landscape, is integrating green hydrogen solutions to curtail emissions while maintaining energy security. In the power and utilities domain, modernization efforts are underway to reduce emissions from coal-fired power generation, with a focus on expanding renewable energy integration. The transition to electric vehicles (EVs) is also a critical component of India's decarbonization strategy, with ambitious targets set for EV adoption across multiple vehicle segments.

The success of these initiatives hinges on continued investment, technological advancements, and policy support, reinforcing India's commitment to a sustainable economic trajectory. As the nation accelerates its transition to a low-carbon future, coordinated efforts among policymakers, industry leaders, and global stakeholders will be essential to realizing its ambitious net-zero goals.

# 01

## Key sectors advancing through the sustainability imperative

India's total GHG emissions in the year 2024 stood at 4.13 gigatons of $CO_2$ emissions, contributing ~7.8% to the global GHG emissions[1]. At COP26 (2021) Global Climate Summit in Glasgow, India had set the ball rolling by announcing intent to achieve net-zero emissions by 2070. Since then, India has made significant strides in advancing green technologies, fostering innovation, developing clean energy value chains, and establishing a robust policy framework to support its transition to sustainable practices. Central to this progress is the expansion of renewable energy production, with the country aiming to achieve 500 GW of installed capacity by 2030. This has spurred domestic manufacturing of solar panels, wind turbines, and related technologies, reducing reliance on imports and fostering local industries.

India is positioning itself as a pivotal force in the global green hydrogen economy, leveraging hydrogen's potential as a clean and adaptable energy source to drive its decarbonization. The National Green Hydrogen Mission, launched in January 2023, encourages the production and utilization of this clean energy source. Green hydrogen is set to play a vital role in decarbonizing sectors like steel, cement, and transportation, significantly reducing the nation's carbon footprint.

The government has also introduced measures to promote 'green steel,' a sustainable alternative for one of the most carbon-intensive industries. Additionally, policies that encourage energy efficiency and the adoption of clean technologies in manufacturing complement these efforts.

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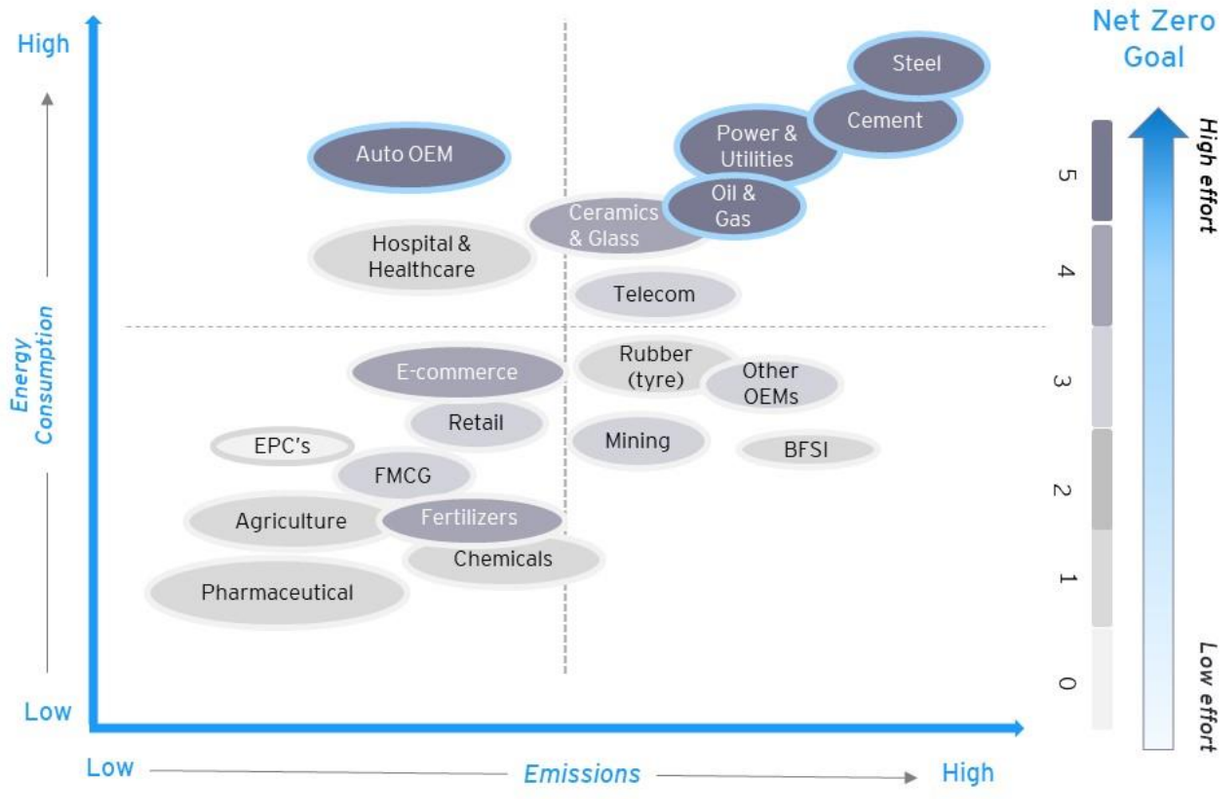
**Figure 1: Sector advancing through sustainability imperatives**




[1] European Commission, 2024, GHG emissions of all world countries

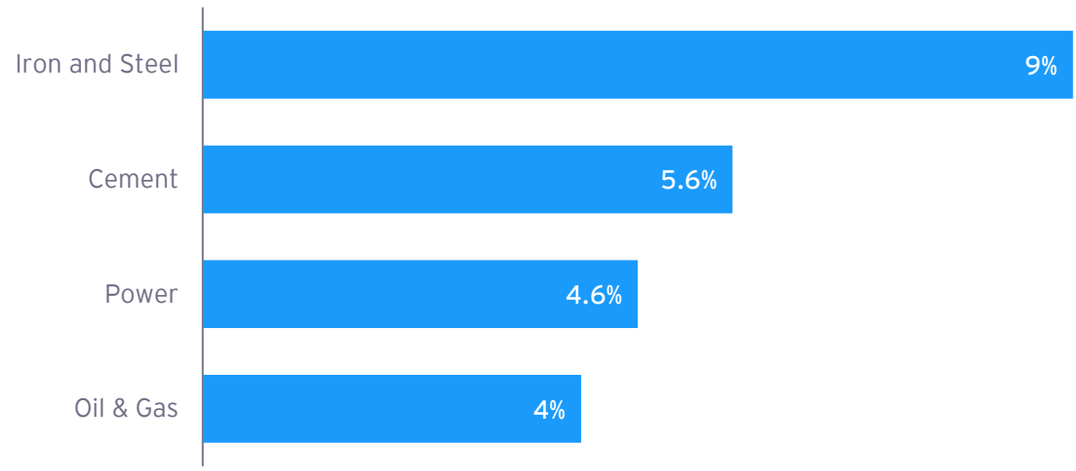
Historically, the industrial and power sectors have been the primary contributors to India's emissions. Approximately one-third of these emissions originate from the steel and cement industries, another one-third from the power sector, with the remainder attributed to transportation and other sectors.[2]

Critical industries like Steel, Cement, Power & Utilities, Oil & Gas, Auto-OEMs are high energy consuming and high emitting. These industries are pivotal for economic growth and hence its quintessential for them to decarbonize their production processes if India is to meet its emissions-reduction goals.

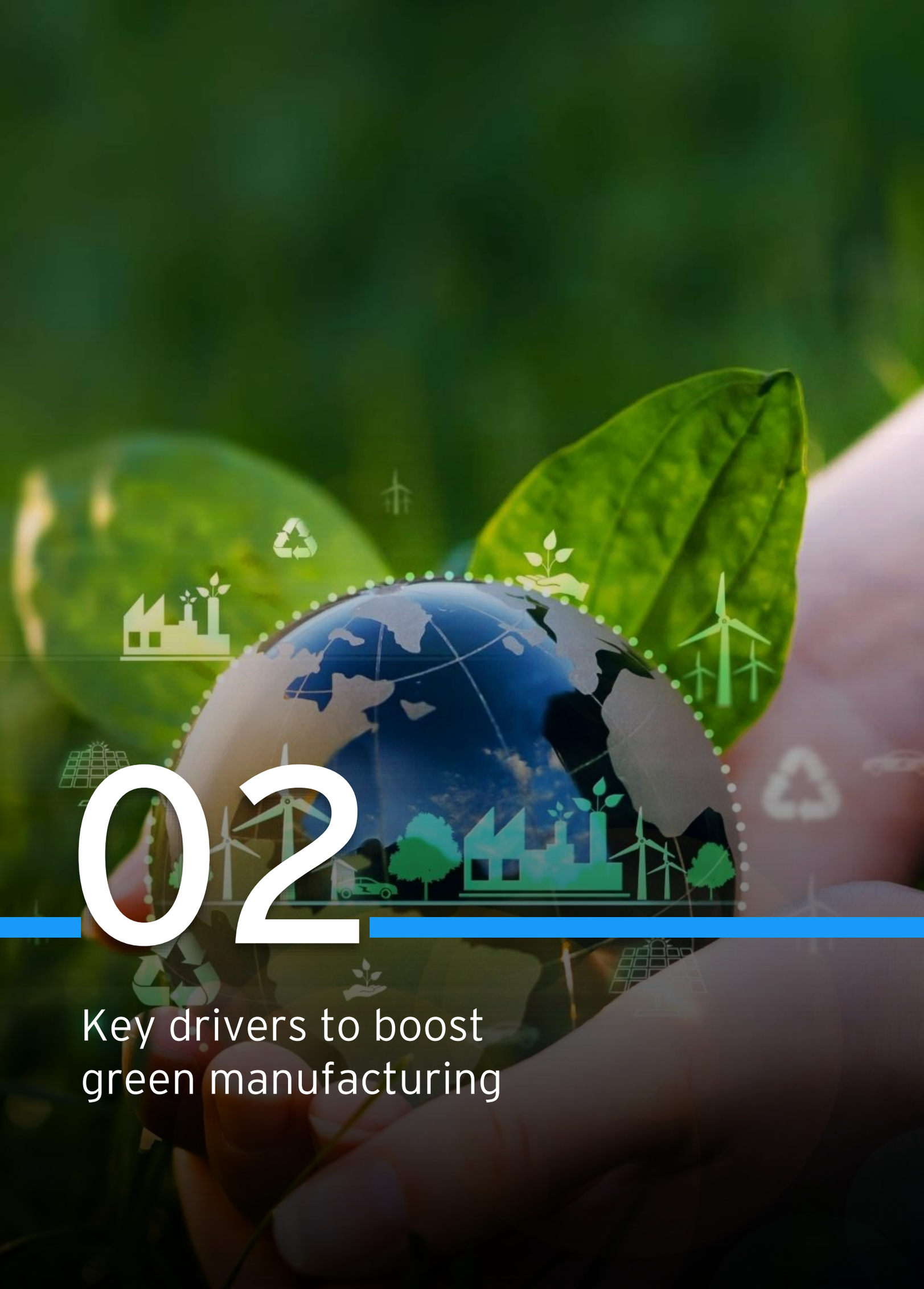
The emission contribution of these sectors is expected to grow in the coming years. EY analysis indicates that the critical manufacturing sectors would reach a mark of ~2 gigaton CO2 emissions annually in the next 15 years.

There are significant costs, and technical complexities involved in decarbonizing these industries. In India, the government, the private sector, and a range of stakeholders are pursuing carbon abatement strategies to make these manufacturing industries greener and more sustainable. Through this article, we discuss the green manufacturing efforts in these critical sectors of the Indian economy. We aim to cover greening of Steel, Cement, Oil & Gas, Automotive and Power & Utilities.

**Figure 2: GHG Emission CAGR (Past 20 years)**




[2] MoPNG, Energy Transition Advisory Committee



# 02

## Key drivers to boost green manufacturing

Green manufacturing is increasingly driven by global and domestic compliance mandates, competitive pressures, customer expectations, and strategic climate capital allocation. Achieving net-zero compliance is critical for exporters, with mechanisms like the Carbon Border Adjustment Mechanism (CBAM) and potential carbon taxes influencing costs. Domestically, initiatives like Indian Carbon Markets, RE100, and alignment with frameworks such as SBTi and BRSR Core are setting new benchmarks. Businesses that adopt these practices early can gain a competitive advantage as the peers commit to ambitious net-zero targets, SBTi goals, and renewable energy transitions. Customer demand is another key driver, as clients increasingly prioritize suppliers who align with science-based targets to reduce emissions across the value chain. Furthermore, leveraging climate capital by strategically investing in product diversification, renewable energy, and sustainability initiatives enables firms to align with their net-zero objectives while fostering innovation and long-term resilience.

## Driver: Compliance Net Zero

**Description**

Compliance mandates play a pivotal role in accelerating green manufacturing by enforcing standards that align with sustainability goals. The implementation of 'carbon tax', though absent in India currently, is a significant mechanism under consideration. The Indian government is progressing towards establishing Indian Carbon Markets (ICM), a system designed to reduce carbon emissions through trading, while also curbing fossil fuel subsidies and increasing taxes. On a global scale, mechanisms like the Carbon Border Adjustment Mechanism (CBAM) ensure that imports with high embedded carbon emissions are taxed fairly, encouraging industries to adopt greener processes to remain competitive in the European Union market.

Frameworks like the Science-Based Targets initiative (SBTi) further reinforce compliance by requiring companies to set emission reduction targets in line with the Paris Climate Agreement. With over 4,000 companies globally committing to these targets, businesses are compelled to align their supply chains with these standards, especially when scope 3 emissions exceed 40% of their total emissions. Additionally, the Business Responsibility and Sustainability Reporting (BRSR) framework introduced by SEBI is now mandatory for the top 1,000 listed companies in India, emphasizing ESG compliance.

Climate-focused initiatives, such as RE100, EV100, and EP100, also drive green manufacturing by promoting commitments to renewable electricity, electric vehicle adoption, and improved energy efficiency. These programs help businesses achieve operational sustainability while meeting compliance requirements.

## Driver: Competitive Advantage

**Description**

Competitive advantage is a key driver for green manufacturing as industries worldwide embrace sustainable practices to stay ahead in the market. Competitors are increasingly committing to ambitious net-zero targets and timelines, aligning with frameworks such as the Science-Based Targets initiative (SBTi), RE100, and circular economy principles.

To gain an edge, companies can adopt several levers to reduce emissions and enhance operational efficiency. Circularity practices, such as recycling and reusing materials, minimize waste and resource consumption while fostering sustainable production cycles. Transitioning to renewable energy sources significantly lowers carbon footprints and aligns operations with the global clean energy goals. Carbon capture, utilization, and storage (CCUS) technologies offer innovative solutions for industries to address hard-to-abate emissions. Process optimization, including energy-efficient manufacturing techniques, reduces resource use and operational costs. Green feedstock substitution and sustainable supply chain by prioritizing suppliers committed to low-carbon practices ensures long-term compliance with environmental standards.

## Customer's Ask

**Description**

Customer demand is a significant driver of green manufacturing as businesses increasingly focus on reducing their direct and indirect emissions footprint. Climate-conscious customers are prioritizing suppliers who align with science-based targets, such as those set by the SBTi. Many clients now mandate compliance with these frameworks, ensuring suppliers contribute to their own sustainability goals. This shift is particularly important as companies seek to address Scope 3 emissions, which are often the largest share of their carbon footprint.

Green manufacturing practices enable businesses to meet these customer expectations while unlocking market potential. By producing low-carbon products, manufacturers can cater to the growing demand from climate-conscious consumers and businesses seeking sustainable solutions. Beyond compliance, green manufacturing opens avenues to create value-added offerings, build stronger supplier-customer relationships, and establish a competitive edge. As customers increasingly prioritize sustainability in procurement decisions, aligning with their expectations not only ensures market relevance but also drives long-term growth.

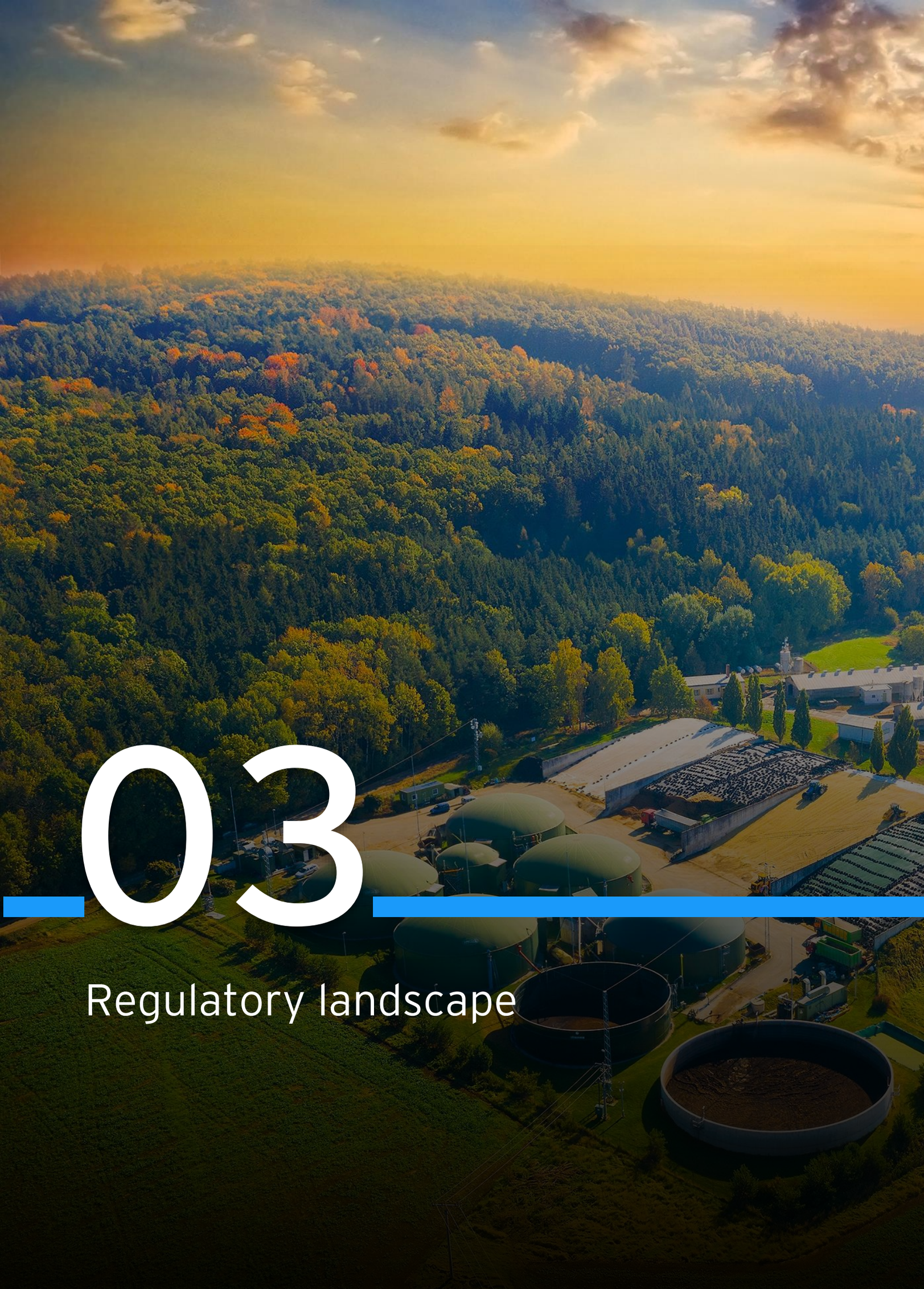
## Climate Capital

**Description**

Climate capital plays a crucial role in driving green manufacturing by enabling companies to strategically allocate resources toward sustainable growth and innovation. By investing in product diversification and new energy initiatives, businesses can achieve their net-zero objectives while maintaining a competitive edge. Switching to renewable energy sources, such as solar and wind, not only reduces emissions but also lowers operational costs, leading to improved profit margins over the long term. Similarly, incorporating low-carbon fuels, like biofuels, into the product mix helps companies achieve emissions reductions while enhancing profitability. The adoption of green hydrogen, both as a fuel and feedstock, offers a transformative pathway for industries to decarbonize and achieve a profitable transition to sustainable operations.

These targeted investments in green technologies and processes enable companies to future-proof their operations, capture emerging market opportunities, and align with evolving regulatory frameworks and customer expectations. Climate capital, therefore, is not just an enabler of sustainability, but a strategic driver of business resilience and growth.

**In conclusion,** the journey toward green manufacturing is not merely a response to external pressures, but an opportunity to redefine business success through sustainability. It is a strategic pivot where environmental stewardship aligns with innovation, unlocking new growth avenues and future-proofing operations. Companies that proactively embrace green manufacturing shall not only meet regulatory and market demands but also position themselves as leaders in the transition to a low-carbon economy. This transformation goes beyond compliance or competition - it is a chance to create lasting value for stakeholders, drive systemic change, and contribute meaningfully to global climate goals.



# 03

## Regulatory landscape

Regulations and policies play a crucial role in driving the transition to green manufacturing, particularly for hard-to-abate sectors such as Steel, Cement and Oil & Gas. As highlighted earlier, these sectors are characterized by high energy intensity, significant carbon emissions, and complex supply chains, making voluntary measures insufficient to achieve meaningful environmental impact. Robust policies provide clear frameworks, incentives, and accountability mechanisms to encourage the adoption of cleaner technologies, efficient resource utilization, and renewable energy integration. Recognizing this imperative, the Government of India has started implementing targeted policies and regulatory measures aimed at decarbonizing these critical sectors, setting the foundation for a sustainable industrial future.

| Sector | Schemes and policies in place |
|---|---|
| **Steel** | **Green Steel Mission**[3]: This mission, with an estimated cost of INR15,000 crore, aims to help the steel industry reduce carbon emissions and progress towards the net-zero target. It includes incentives for using renewable energy and mandates for government agencies to purchase green steel.<br><br>**National Green Hydrogen Mission:** Spearheaded by the Ministry of New and Renewable Energy, this mission integrates the steel sector into the broader goal of producing and using green hydrogen. It includes pilot projects for producing Direct Reduced Iron (DRI) using 100% hydrogen and using hydrogen in existing blast furnaces to reduce coal/coke consumption.[4]<br><br>**Steel Scrap Recycling Policy**[5]**:** This policy aims to increase the availability of domestically generated scrap, promoting resource efficiency and supporting the production of green steel. |
| **Cement** | **PAT Scheme**[6]: This scheme was launched in 2012 to enhance energy efficiency of large-scale industries.<br><br>**Waste management rules**[6]: Industrial units should replace 5% of the fuel with Refused derived fuel (RDF), use of high calorific waste in cement plants for co-processing instead of disposing this hazardous waste.<br><br>**Fly ash utilization policy 2009**[6]: All power plants need to achieve 100% utilization of fly ash, denies the use of red clay brick kiln within 300 km from a thermal power plant and thermal power plant should provide fly ash for brick manufacturing and bear the transportation cost. |
| **Oil & Gas** | **National Green Hydrogen Mission**[7]**:** seeks to link the hydrogen economy with renewable energy growth, targeting the production of 5 MMT (Million Metric Tons) of green hydrogen (GH2) annually by 2030. With a budget allocation of INR19,744 crore for the period 2023–24 to 2029–30, the mission aims to reduce $CO_2$ emissions by 50 MMT per year and establish India as a global leader in green hydrogen production, utilization, and export. Green H2 would greatly help refineries reduce their emissions from SMR-based Hydrogen Generation Units (HGUs). |

[3] Ministry of Steel, December 2024, Green Steel Mission
[4] Ministry of New and Renewable Energy, October 2024, Launch of Pilot projects in Steel Sector under the National Green Hydrogen Mission
[5] Ministry of Steel, November 2019, Steel Scrap Recycling Policy
[6] Alliance for Energy Efficient Economy, December 2020, Reducing Cement Sector Emissions
[7] Ministry of New and Renewable Energy, 2023, MNRE Website

| Sector | Schemes and policies in place |
|---|---|
| | **Upstream for CCS/CCUS**[8] task force set up by MoPNG, to provide a 2030 roadmap for carbon capture, utilization, and storage (CCUS) for upstream E&P companies.<br><br>**Galvanizing Organic Bio-Agro Resources Dhan (GOBARdhan)**[9] scheme to promote circular economy by utilizing organic waste such as agriculture residues, and cattle dung to produce biogas, compressed biogas, and Bio-CNG<br><br>**Ethanol Blending Mandates**[10]: Successful 10% ethanol blending with petrol program, GoI advancing 20% ethanol blending targets from 2030 to 2025 for petrol, and 2030 for diesel<br><br>The Ministry of Petroleum and Natural Gas (MOPNG) has introduced several measures under the **National Biofuels Policy 2018**[11] and the **Sustainable Alternative Towards Affordable Transportation (SATAT)** initiative to promote biofuels and reduce dependency on fossil fuels. The policy classifies biofuels into Basic and Advanced categories, prioritizing second-generation (2G) ethanol and municipal solid waste (MSW)-to-drop-in fuels. Financial support includes a INR5,000 crore Viability Gap Funding (VGF) package for 2G ethanol refineries over six years, alongside tax incentives and higher pricing for 2G fuels compared to first-generation (1G) biofuels. Additionally, it encourages ethanol production from unfit crops such as sugar beet and rotten potatoes.<br><br>**Global Biofuel Alliance**[12]: Formed under India's G-20 presidency, facilitating adoption of global best practices in terms of technical support, lesson in policy and trade insights. |
| Power & Utilities | **National Renewable Energy Act (NREA):** Aims to unify various RE policies, creates legal foundation for RE targets and regulations.<br><br>**National Action Plan on Climate Change (NAPCC):** Specific missions for RE, including National Solar Mission, National Wind Energy Mission, enhances RE use.<br><br>**Solar Parks Scheme**[13]**:** Facilitates development of large-scale solar parks, provides infra-support to solar parks with +20MW capacity.<br><br>**National Electricity Plan 2023 (NEP 2023)**[14]**:** This outlines India's roadmap for power generation, transmission, and energy security over the next decade, with a strong emphasis on clean energy transition and achieving net-zero emissions by 2070.<br><br>**PM-Surya Ghar Muft Bijli Yojana**[15]: 60% subsidy is provided on the cost of solar systems up to 2 kW capacity. The scheme is expected to benefit one crore households, reducing electricity bills and allowing households to earn income by selling surplus power to local Distribution Companies (DISCOMs). |

[8] MoPNG, Draft Roadmap for CCUS for Upstream E&P companies
[9] National Portal of India, 2024, GOBARdhan Scheme
[10] PIB, 2024, India Ethanol Push: A Path to Energy Security
[11] MoPNG, 2018, 2022, National Biofuel Policy - 2018
[12] MoPNG, 2024, About Global Biofuel Alliance
[13] Enter Climate, 2023, India's Solar Park Scheme: Scope for the Private Sector
[14] Central Electricity Authority, 2023, National Electricity Plan
[15] National Portal of India, PM – Surya Ghar Muft Bijli Yojana

| Sector | Schemes and policies in place |
|---|---|
| Auto OEM | **FAME II Scheme**[16]**:** Support for 5,00,000 e-three-wheelers, 7,000 e-buses, 55,000 e-passenger vehicles, and a million e-two-wheelers with a budget of INR10,000 crore.<br><br>**PLI-ACC Scheme**[17]**:** Launched by Department of Heavy Industry with a budget of INR18,100 crore for advanced chemistry cell battery storage manufacturing.<br><br>**Battery Swapping Policy**: Intended to standardize EV battery standards across India and promoting EVs in time-sensitive service sectors such as deliveries and inter-city transportation and is expected to perform well for 2W and 3W vehicles and influence EV penetration.<br><br>**Duty reduction on EV**[18]**:** Budget included proposal to reduce duties on nickel ores from 5% to 0%, nickel oxide from 10% to 0% and ferro nickel from 15% to 2.5% to enhance battery manufacturing ecosystem in India.<br><br>**Vehicle scrapping policy**[19]**:** This policy was launched in 2021 which aimed to phase out old and unfit vehicles to reduce pollution and promote the adoption of modern and fuel-efficient vehicles and provide concession of 15% and 25% in case of transport and non-transport vehicles respectively.[20]<br><br>**E-vehicle policy**: This policy is expected to promote India as a EV manufacturing destination with latest technology thus promoting high production volumes at lower costs and requires a minimum investment of INR4,150 crore with a timeline of three years for setting up manufacturing facilities with up to 50% localization up to the fifth year.[21] |

[16] E-Vehicle Info, Government Policies and Incentives for Electric Vehicles in India
[17] E-Vehicle Info, Government Policies and Incentives for Electric Vehicles in India
[18] E-Vehicle Info, Government Policies and Incentives for Electric Vehicles in India
[19] TERI, 2023, Vehicle Scrappage Policy in India
[20] PIB, August 2024, Vehicle Scrappage Policy 2021
[21] Press Information Bureau, March 2024, Government approves E- Vehicle policy to promote India as a manufacturing destination for EVs

# 04

# Decarbonizing hard-to-abate sectors

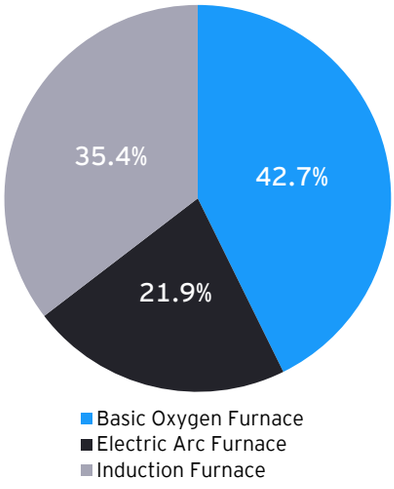
Green manufacturing focuses on minimizing the environmental impact of production processes while maintaining economic viability and quality standards. It involves adopting energy-efficient technologies, using renewable energy sources, reducing waste through recycling and reusing materials, optimizing resource consumption and other decarbonization levers for low or close to zero emission products. Digital tools also play a significant role in monitoring and reducing energy usage and emissions. At the forefront of this transition, we are delving deeply into sectors like Steel, Cement, Oil & Gas, Power & Utilities, and Automotive, aiming to innovate and implement sustainable practices that drive meaningful change in these industries.

## 4.1 Steel

The steel industry is a cornerstone of India's economy, contributing approximately 2.5% to the national GDP and providing employment to about 2.5 million people, both directly and indirectly[22]. India holds the position of being the second-largest steel producer globally, with its crude steel output amounting to approximately 144.3 million tons during the fiscal period of 2023-24[23].

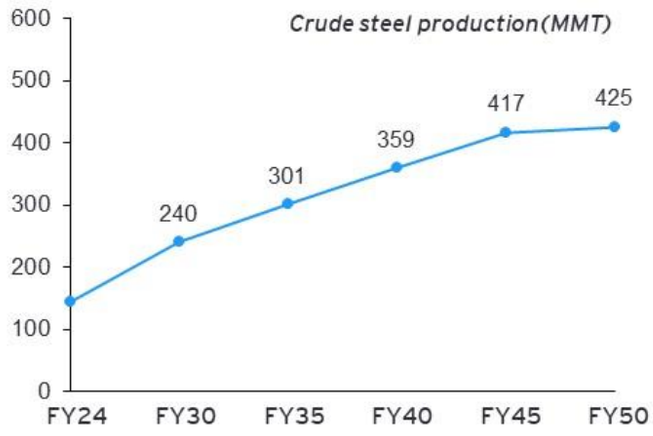
In the Indian steel industry, the Blast Furnace-Basic Oxygen Furnace (BF-BOF) route is the most common, contributing to approximately 43% of total steel production. Induction Furnaces (IF) are responsible for about 35% of the output, and Electric Arc Furnaces (EAF) for around 22%. While a minority of producers use steel scrap as the principal input in IFs and EAFs, the majority rely on Direct Reduced Iron (DRI) produced using coal-based rotary kilns. Similar to the BF-BOF method, the coal-based DRI-EAF/DRI-IF processes of steelmaking are linked to significant CO2 emissions

**Figure 3: Steel production routes in India**




Source: Ministry of Steel, Annual Report 2023-24

**Figure 4: India's crude steel production projection**

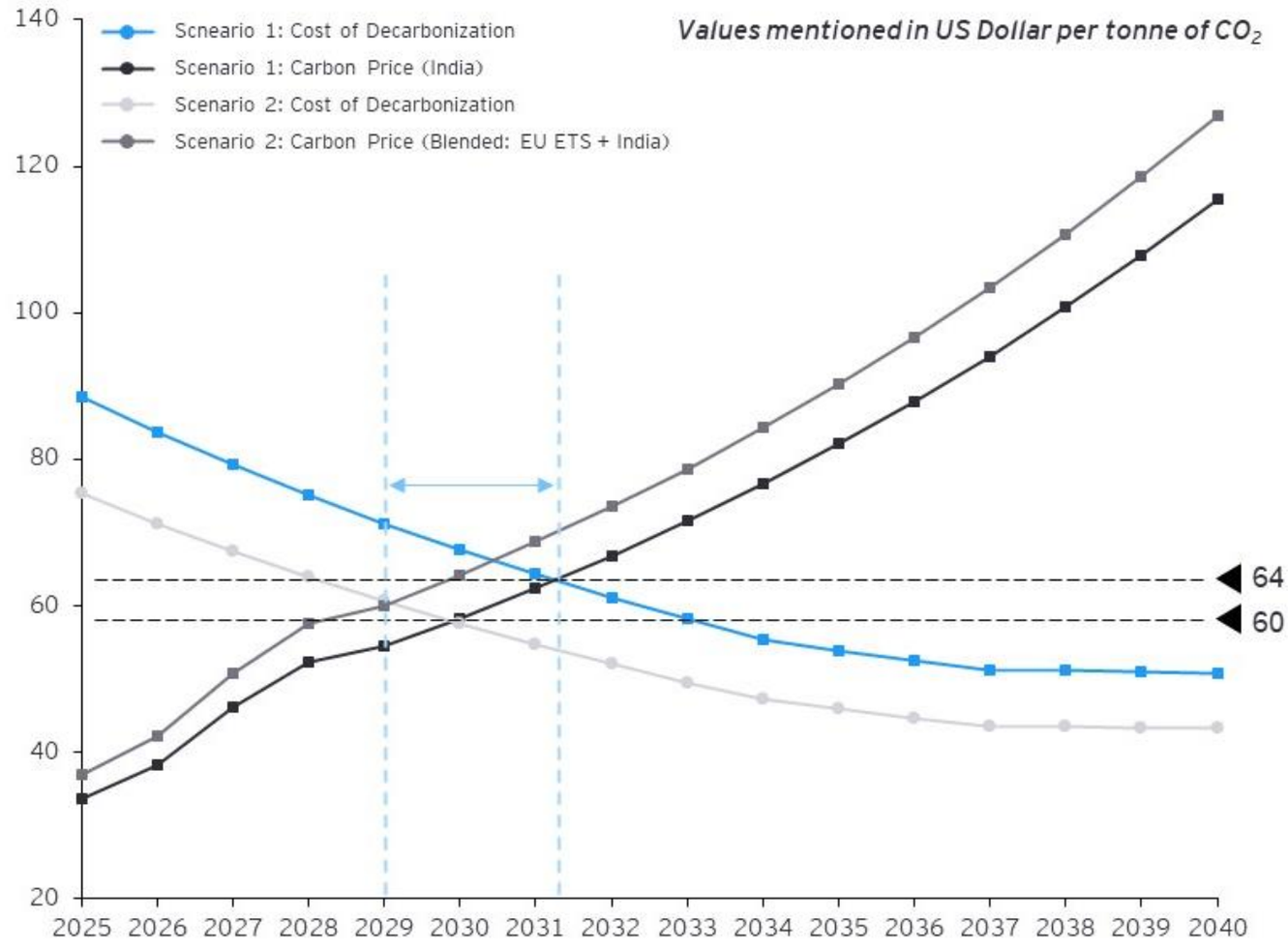



Source: Ministry of Steel, EY Analysis

[22] FICCI, February 2023, India Steel Expo
[23] Ministry of Steel, Annual Report 2023-24

The acceleration of India's economy, combined with governmental initiatives to boost local manufacturing, substantial investments in infrastructure, and the quick pace of urban development, are the primary factors fueling the increase in steel production to meet the country's escalating demand for steel[24]. The Ministry of Steel, in anticipation of an expected surge in demand, has set ambitious targets under the National Steel Policy (NSP) to reach an annual capacity of 300 million tons and elevate production to 255 million metric tons per annum by FY31[25]. As India's steel sector gears up to scale production capacities in response to increasing demand, it is crucial to prioritize the expansion of 'green' steel production pathways to align with the goal of net-zero emissions. Despite this imperative, recent declarations and ongoing projects **indicate a growing preference for the BF-BOF route** within the country.

**Figure 5: Cost of $CO_2$ abatement v/s carbon price for BF-BOF**

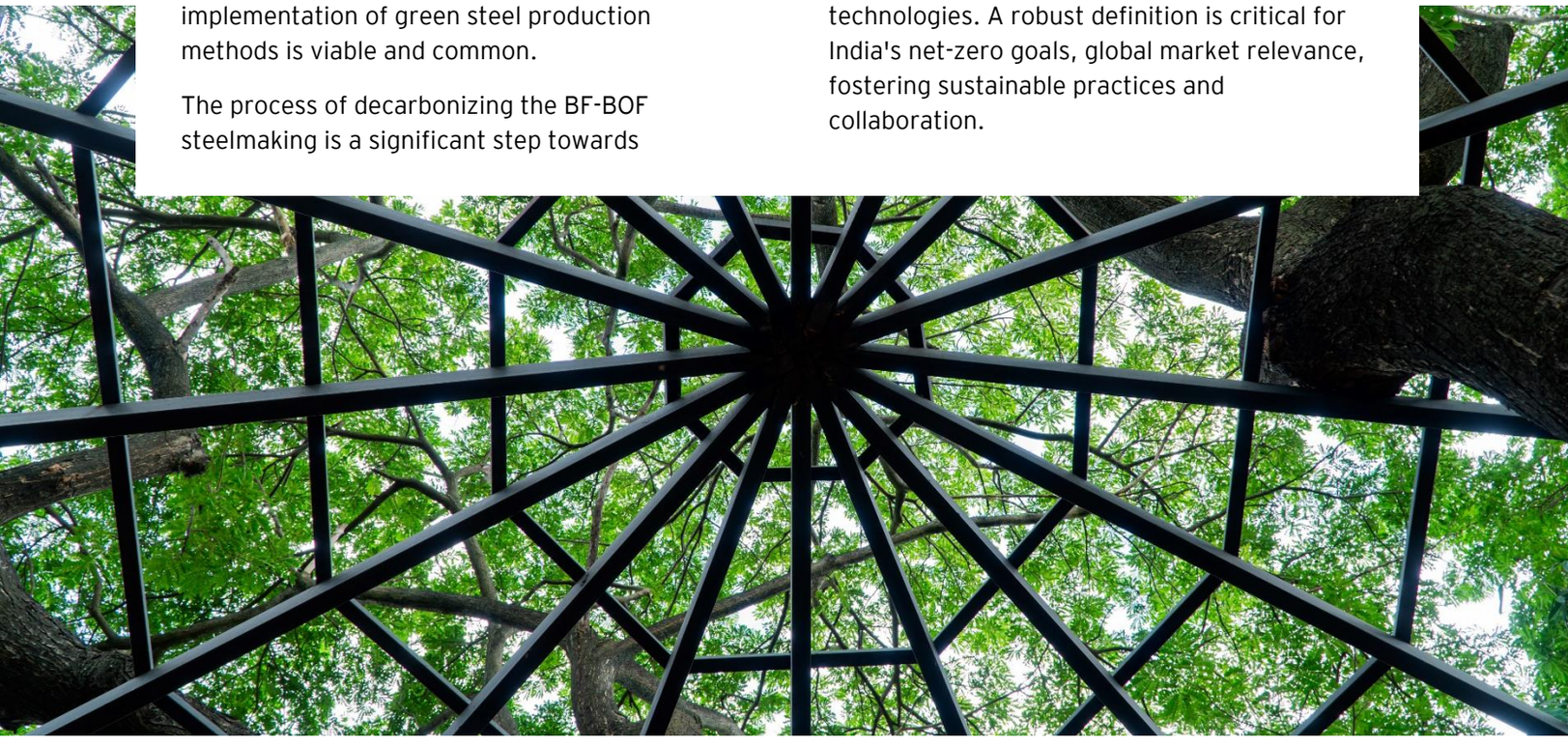



Source: EY analysis

[24] Joint Plant Committee, August 2024, Indian Steel Industry – A Trend Report
[25] Ministry of Steel, May 2017, National Steel Policy

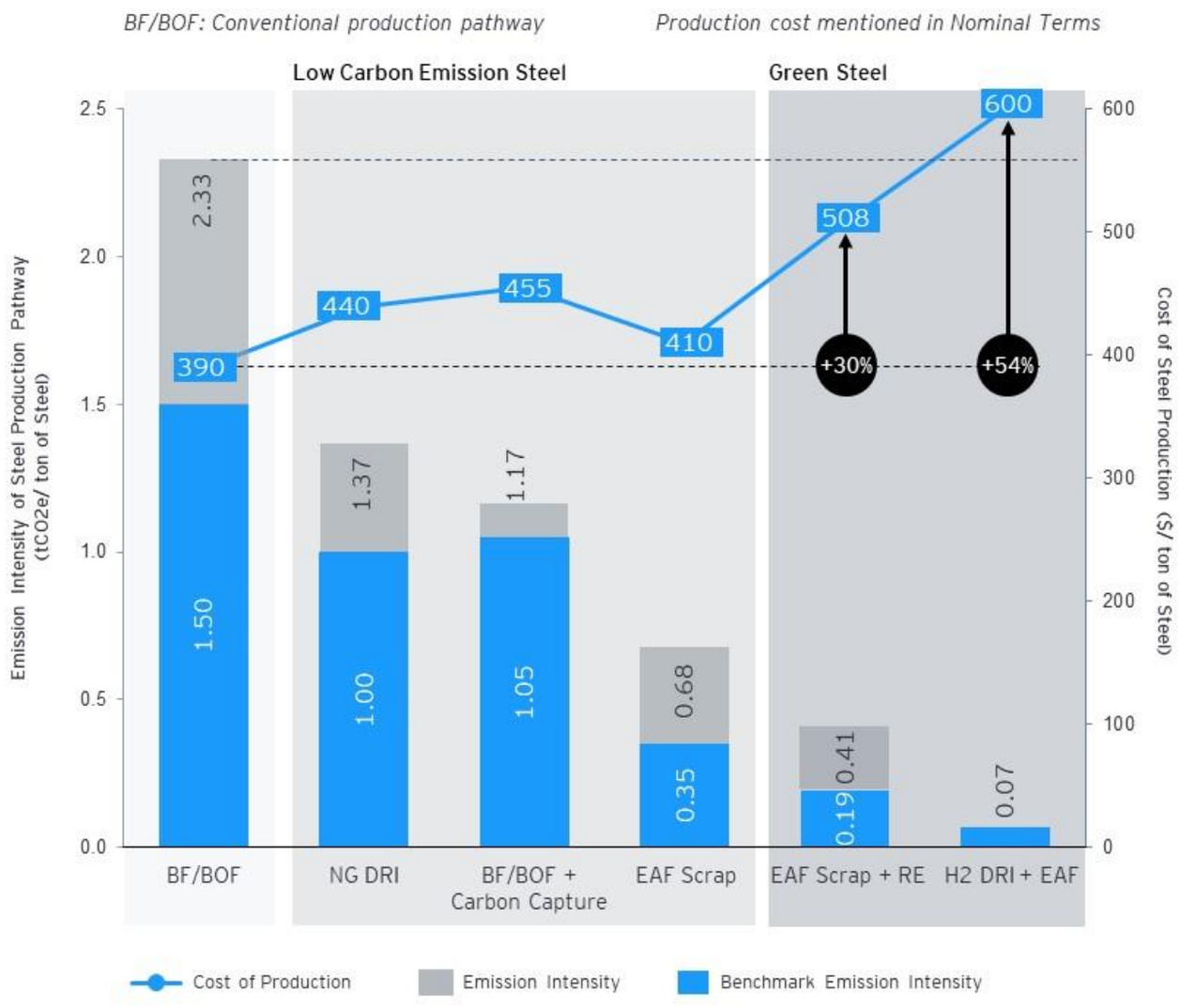
Hence, it becomes equally important to decarbonize the current and upcoming BF-BOF setup. Our analysis suggests that decarbonization initiatives like **carbon capture, renewable power, energy efficiency, and alternate fuels like green hydrogen injection in blast furnace** are the critical levers to decarbonize the BF-BOF steelmaking production pathway. It is anticipated that, **between 2029 and 2031, Indian BF-BOF players are likely to start benefiting from their investments in decarbonization technologies.** This shift is anticipated to be driven by economic factors, as the projected cost of carbon in India is expected to surpass the costs associated with $CO_2$ abatement. By reducing $CO_2$ emissions at a cost that is below the prevailing carbon price, BF-BOF steelmakers in India could achieve substantial cost savings, thereby mitigating the financial impact of carbon taxes or the necessity of buying emissions permits. This approach also lays a strong foundation for the sustained operation of the newly built BF-BOF plants, as these decarbonization measures are crucial during the interim phase before the full implementation of green steel production methods is viable and common.

The process of decarbonizing the BF-BOF steelmaking is a significant step towards reducing $CO_2$ emissions in steel production. **However, the continued dependence on fossil fuels presents a challenge**. Therefore, it is crucial for the Indian steel industry to transition to 'green' steel production methods to achieve net-zero targets. Globally, there is no universal definition of green steel, but various standards and initiatives address its production, demand, and financing aspects. Near-zero steel emissions range from 0.05 to 0.4 tons of $CO_2$ per ton of steel, depending on the scrap ratio, as defined by ResponsibleSteel and the IEA.[26] Initiatives like IDDI, SteelZero, and the First Movers Coalition align with this but differ in procurement targets and timelines. **India's steel ministry recently defined green steel with emissions under 2.2 tons per ton of finished steel.**[27] This threshold limit of green steel definition will be reviewed every three years. However, adopting <0.5 $tCO_2/t$ steel aligns better with global decarbonization goals. This stringent benchmark drives innovation, supports global competitiveness, boosts export demand of low carbon steel, and mitigates climate risks by promoting near zero emissions steelmaking technologies. A robust definition is critical for India's net-zero goals, global market relevance, fostering sustainable practices and collaboration.



[26] Ali Hasanbeigi and Adam Sibal, January 2023, What is Green Steel? Definition and Scopes from Standards, Initiatives, and Policies around the world
[27] Press Information Bureau (PIB), December 2024, India's Green Steel Taxonomy

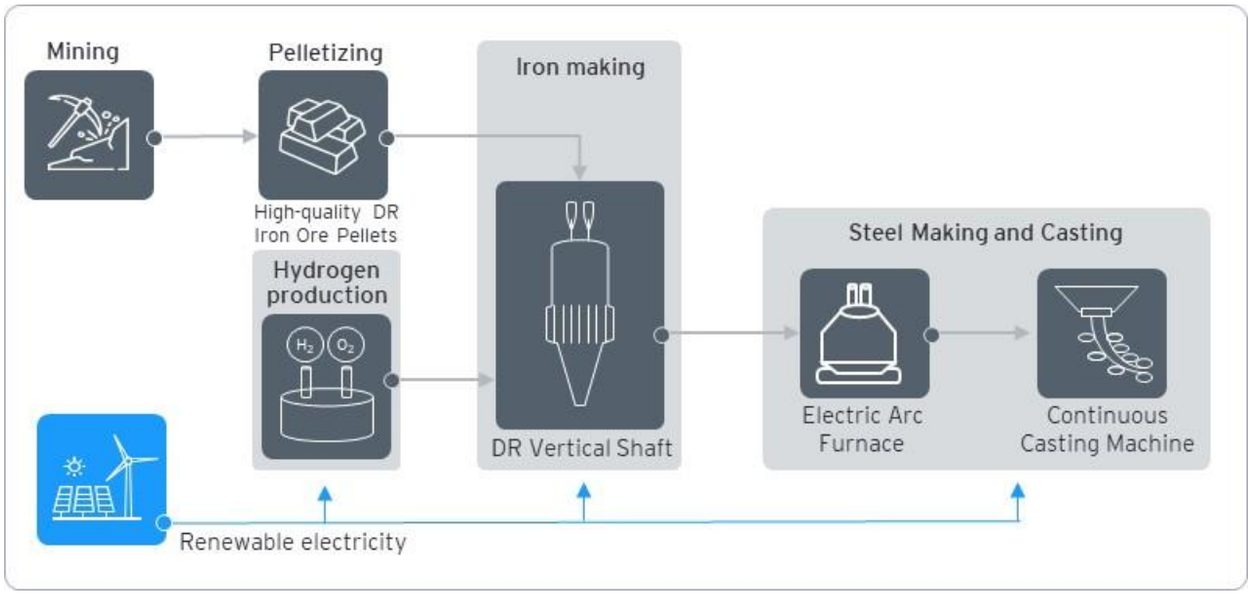
Figure 6: Emission intensity & cost of steel production pathways in India




Source: EY analysis

Current standards and industry consensus suggest that the production of green or near-zero emission steel is feasible using Green Hydrogen in Direct Reduced Iron processes for primary steel production, and through Scrap utilization in EAF powered by renewables for secondary producers. As these innovative technologies gain traction, it is imperative for Indian steel manufacturers to embark on a journey of decarbonization by adopting these methods. **When renewable energy sources power a Scrap-Based Electric Arc Furnace, the emission intensity is 82% lower compared to the conventional BF-BOF method.** Additionally, the Green Hydrogen-Based Direct Reduced Iron (H2-DRI) process achieves a remarkable **97% reduction in emissions relative to the BF-BOF.**

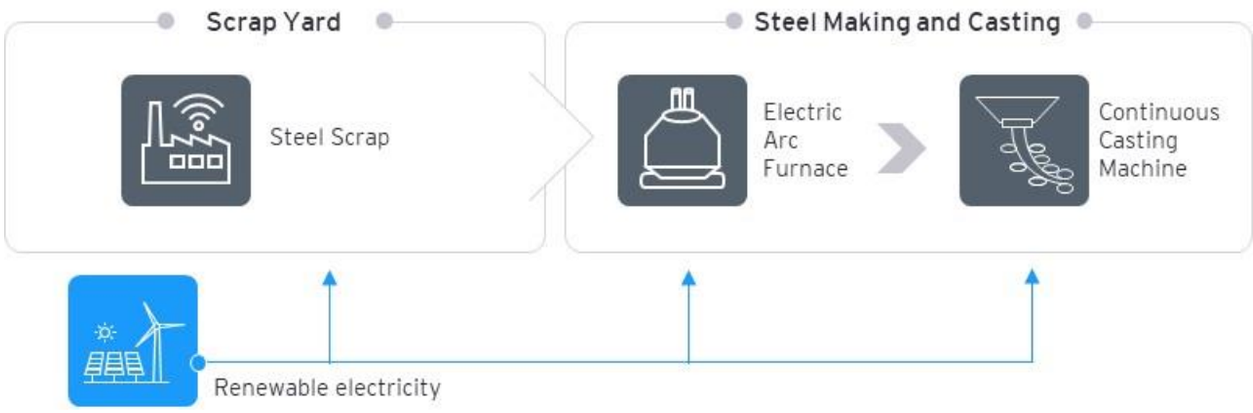
Figure 7: Green steel production pathway - GH2 DRI-EAF steelmaking




Source: EY analysis

| | |
|---|---|
| **Key raw materials required** | 1. High grade iron ore (Fe > 67%) and lower impurities<br>2. Green hydrogen as reducing gas in DR Shaft<br>3. Carbon injection and slag forming additives in EAF |
| **Brief process description** | The steelmaking process using green hydrogen begins with the electrolysis of water, powered by renewable electricity, to generate hydrogen. This green hydrogen acts as the reducing gas in the process. Iron ore pellets are fed from the top of a shaft furnace, while the green hydrogen is introduced from the bottom. This process results in the formation of Direct Reduced Iron and water vapor as a byproduct. The DRI is then fed into an Electric Arc Furnace for steelmaking. This step can be done either as cold charging or preferably hot charging of DRI, leading to potential energy savings and increased productivity during the steelmaking process. The liquid steel undergoes casting, followed by rolling and other downstream finishing processes. |
| **Key challenges** | 1. Unavailability of high-grade iron ore can attract additional gangue<br>2. Increased slag volume in low grade iron ore<br>3. $H_2$-DRI based DRI has lower melting efficiency due to absence of carbon content<br>4. Nitrogen management during steelmaking process<br>5. High upfront capital costs (40% higher than conventional)<br>6. GH2 production and use is up to 80%-120% costlier than fossil fuels<br>7. Water intensive (10 liter Distilled water for one kg hydrogen production) |

Figure 8: Green steel production pathway - scrap based EAF with RE




Source: EY analysis

| | |
|---|---|
| **Key raw materials required** | 1. Scrap is the primary raw material<br>2. Fluxes like dolomite, limestone, etc.<br>3. Ferroalloys such as FeMn, FeSi, etc. |
| **Brief process description** | The steel production process begins with the formulation of a scrap recipe, which involves combining various types of scrap materials such as bushelling, shredded scrap, bundles, etc. These materials vary in size and density and are assembled in scrap bucket according to the specific needs of the process.<br>The recipe is then introduced into an electric arc furnace (EAF) for melting. Following the charging of the scrap, electric current is passed through electrodes to generate a high-intensity heat that melts the scrap. The subsequent stage involves refining the molten metal and forming slag, which is facilitated by the addition of specific additives. To achieve the desired steel grade, various alloying elements are incorporated. This high-energy process has the potential to achieve near-zero emissions when integrated with renewable energy sources, thereby enhancing the sustainability of this secondary steelmaking route. |
| **Key challenges** | 1. Unavailability of substantial scrap in India and globally<br>2. Tramp elements like Cu in scrap<br>3. Scrap based EAF is an energy intensive process, and switching to RE would be capital intensive |

| Company[28] (non – exhaustive) | Description |
|---|---|
| SAARLOHA<br>A KALYANI GROUP COMPANY | ▪ The company offers two unique certificates under KALYANI FeRRESTA™, and KALYANI FeRRESTA™ PLUS as green steel<br>▪ KALYANI FeRRESTA™ has an emission intensity of less than 0.19 tCO2e per ton of crude steel or less than 0.35 tCO2e per ton of rolled steel<br>▪ KALYANI FeRRESTA™ PLUS offers net-zero GHG emission intensity for both, crude and rolled steel<br>▪ Both the certificates use GHG Protocol ISO 14404-2:2013 and ISO 14064-1 (2018) |

[28] Companies, Certificates, and Description are publicly available information on company's respective website

To achieve India's green steel ambitions, collaboration among the government, industry, and other stakeholders is vital. The government should introduce or strengthen the supportive policies, including incentives for green hydrogen production, renewable energy adoption, and investments in decarbonization technologies like Carbon Capture. Industry leaders must prioritize innovation by **accelerating the transition to low-carbon steelmaking methods, scaling up renewable-powered EAFs, and deploying $H_2$-DRI technologies**. Collaboration with academia and R&D institutions is essential to address technical challenges and reduce costs. Stakeholders, including financial institutions, should **facilitate investments in decarbonization projects** and foster **international partnerships to adopt global best practices**. Such collective efforts shall ensure sustainable growth in India's steel sector while meeting net-zero goals.

# 4.2 Cement

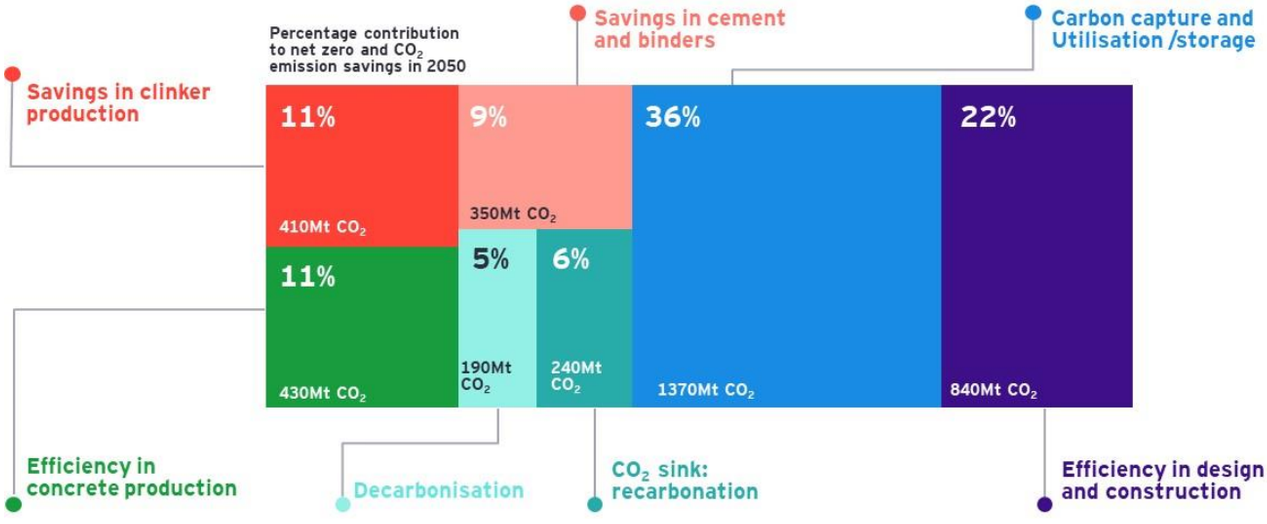
Globally, 8% of all $CO_2$ emissions come from the cement industry, taking the absolute value to over 1.6 billion metric tons of $CO_2$. In India, the statistics stand at approximately 6% and 180 million $MTCO_2$, respectively.[29]

The future of a global net-zero transition is highly dependent on a sustainable push by the cement and concrete sector, and regulatory- as well as consumer-led demands have been creating a slow and steady paradigm shift in the cement industry.

Experts believe that **'green' cement can reduce the emission intensity and impact of regular cement by up to 80%.** Recognizing the need to decarbonize the sector, the Global Cement and Concrete Association (GCCA) has defined its net-zero roadmap in alignment with the Conference of Parties (COP) and although no formal definition exists for low-carbon cement, it essentially means cement with reduced emissions.

**Levers are given as follows:**

**Figure 9: Actions to a net zero future**



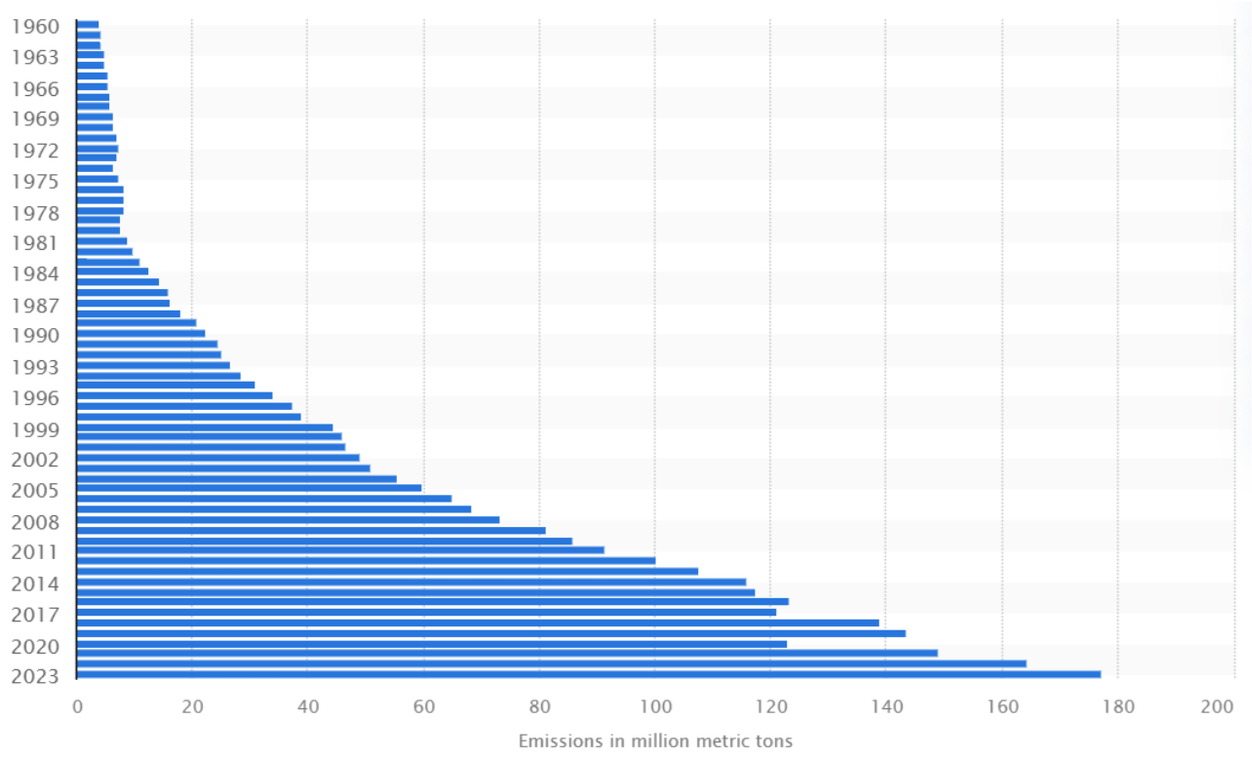

Source: GCCA

[29] Green Power to Account for 42% of Cement Companies' Power Mix by 2025: ICRA

India has always been a key market player when it comes to cement, being the world's second-largest cement producer.

2023 saw the Indian green cement market was valued at US$2.31 billion and projected to grow at a CAGR of 5.58% through 2029. **As of 2024, the Indian green cement market is valued at approximately USD 2.31 billion and is projected to grow at a Compound Annual Growth Rate (CAGR) of 5.85% through 2029, reaching an estimated USD 3.28 billion by that year. 2024 also saw India's installed cement capacity amount to 553 MMT with a production level of 298 MMT annually.**[30]

**Figure 10: GHG emissions from cement industry, million metric tons**




Source: Statista

**Green cement minimizes emissions by using alternative materials and low-carbon production techniques. Primary raw materials for this include industrial waste products like blast furnace slag and fly ash, reducing the clinker-to-cement ratio and an effort to close the loop across the cement production value chain as well.**

**There are multiple types of green or low-carbon cements, including:**

- **Ekkomaxx Cement:** Contains 95% fly ash and 5% renewable additives, with a significantly reduced carbon footprint and enhanced durability
- **Ferrocrete Cement:** Made from silica and iron byproducts, potentially carbon-negative through CO2 curing

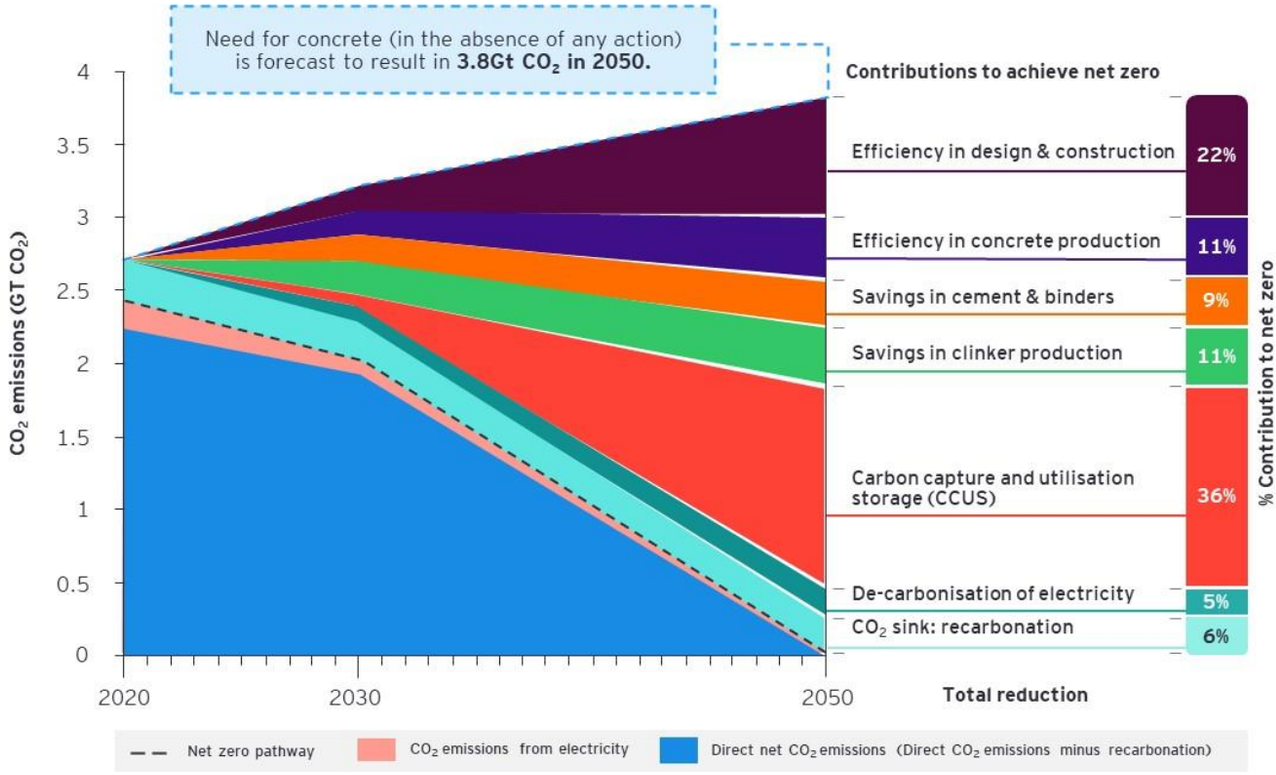
[30] The Business Research Company, January 2025, Green Cement Market Report 2025

- **Sequestrated Carbon Cement:** Utilizes seawater and CO2 in its production process
- **Magnesium Oxychloride Cement (MOC):** Offers high compressive strength but has challenges with steel corrosion.
- **Geopolymer Cement:** Made from industrial by-products, emitting 95% less CO2 than traditional cement.

Though green cement comes with dominant opportunity to access, there are quite a few **challenges in its adoption — cost implications, technical barriers and market resistance being key**. To implement carbon capture and storage (CCUS) significantly rises the costs, almost doubling the price of green cement and the low carbon dioxide concentration in cement flue gases makes carbon capture expensive and complex. There is also a basic **consumer-habit resistance** because of the time-tested nature of traditional cement.[31]

Decarbonizing India's cement industry comes at a huge cost, amounting to more than US$330 billion in capital expenses and over US$3 billion in annual operating expenses[32]. With dedicated efforts to decarbonize the sector, **India is looking at alternative methods such as reducing clinker** – cement with a higher blending ratio, adoption on electric kilns and CCUS to name a few. While CCUS seems to be a suitable alternative to curb emissions from the sector, its integration into existing infrastructure brings along significant challenges in terms of higher capital investments and operational costs. Efficient adoption of carbon capture technologies creates the need for financial support through incentives and government backing such as tax incentives, grants and subsidies.

**Figure 11: Pathways to decarbonize cement industry**




Source: India Cement Review

[31] India Cement Review, April 2023, Green Cements and Potential Challenges
[32] India Cement Review, February 2024, Charting a Cleaner Future

As discussed above, green cement manufacturing emphasizes on efficiency and sustainability across various dimensions. It utilizes alternative materials like fly ash and slag to reduce clinker content, resulting in lighter and stronger structures while minimizing waste through sustainable practices such as modular construction and prefabrication. **The production process consumes about 20% less energy than traditional methods, leading to lower operational costs and enhanced performance metrics, including higher early strength and improved durability. By incorporating recycled materials, green cement promotes circular economy and reduces clinker production by up to 30%,** significantly lowering associated $CO_2$ emissions. Furthermore, carbon capture utilization and storage (CCUS) technologies can be integrated into existing plants to capture emissions effectively, with captured $CO_2$ being repurposed for synthetic fuels or stored geologically to mitigate climate change impacts. The transition to renewable energy sources, along with energy efficiency improvements, further supports decarbonization efforts. Additionally, investments in reforestation and soil carbon sequestration enhance carbon sinks, contributing to re-carbonization while supporting biodiversity and sustainable land use practices. Overall, green cement manufacture represents a comprehensive approach to reducing environmental impact while enhancing the efficiency of construction processes.

CCUS pilot plants have been set up in India but not for cement sector. With growth prospects for cement sector due to lower per capita cement consumption (260 kg) as compared to global average (540 kg), there is potential for cement-based CCUS facilities to be established across on-shore and off-shore emission clusters as the transportation and storage sites[33]. In addition to the infrastructural development, policy framework is expected to pay a pivotal role in overcoming impediments that restrict the adoption rates and making this decarbonization route commercially viable.

To promote CCUS in cement industry, there is a crucial need to develop a national strategy or long-term targets for $CO_2$ storage and develop a regulatory framework that governs CCUS activities to promote adoption rates. Additionally, high capital and operational costs create the need for fiscal incentives such as carbon pricing, carbon taxes and public finance policies to navigate this economic barrier. While such frameworks are expected to overcome compliance and economic challenges, India needs to develop policies such as green procurement agreements to create demand for low-carbon cement primarily through public procurement which account for 40%-60% of the total cement demand in India[34].

Despite these hurdles, In 2021**, Dalmia Cement became India's first cement company to have received a green accreditation from the Green product rating for Integrated Habitat Assessment (GRIHA) council hence producing 'green' cement.** In 2024, Ambuja Cement, ACC Limited and Ultratech Cement got added to the list with Ambuja and ACC getting certified for their blended cement products and Ultratech being recognized as the India's largest producer of green cement, at 69% (as of 2024) of its total sales have been that of green cement. In 2024, as per credit rating agency ICRA, it is projected that green cement shall make up 40-42% of the total power mix of major cement companies in India by the second quarter of 2025.

UltraTech Cement has positioned itself as a leader in sustainable construction through its GreenVantage initiative, which emphasizes the production and utilization of green cement. This initiative is part of UltraTech's broader commitment to decarbonization and reducing the environmental impact of its operations. The company has made significant strides in this direction, achieving a 12% reduction in specific net $CO_2$ emissions compared to FY17 levels. Specifically, UltraTech's Arakkonam and Ginigera cement works have transitioned to operating entirely on renewable energy for extended periods, resulting in the reduction of over

[33] GCCA, June 2024, CCUS in Indian Cement Industry
[34] GCCA, September 2024, CCUS in Indian Cement Industry: Policy & Financing Frameworks

38,500 tons of carbon emissions combined. By adopting alternative fuels through co-processing, UltraTech has also supported 80 municipal corporations in India, diverting waste from landfills while meeting a substantial portion of its energy needs with waste-derived fuels.

**UltraTech's sustainability strategy is underpinned by ambitious targets aligned with the Global Cement and Concrete Association's (GCCA) Climate Ambition 2050 framework**. The company aims to achieve 100% renewable energy sourcing by 2050, with interim targets to increase green energy usage to 85% by 2030 and 60% by FY26. To facilitate this transition, UltraTech has invested in innovative technologies such as the RotoDynamic Heater™ (RDH), which utilizes electrification from renewable sources for heating processes in cement production, thereby eliminating fossil fuel dependency. The organization is also enhancing its logistics operations by introducing electric and CNG/LNG trucks as part of its commitment to sustainable transport.

The GreenVantage initiative not only focuses on environmental sustainability but also encompasses social responsibility through community engagement and development projects. UltraTech has positively impacted over 1.6 million people across 507 villages in India by investing in education, healthcare, and infrastructure improvements.[35]

## 4.3 Oil & Gas

India is now a more than $3 trillion economy and is projected to reach **$7 trillion by 2030**[36]**.** This growth shall largely be accompanied by rising energy needs for the country. The oil & gas sector is the backbone of the country's energy needs and shall play a pivotal role in shaping the energy transition journey of India. The sector is divided into three major segments: Upstream, Midstream and Downstream.

**UPSTREAM EMISSIONS**

- **Drilling operations:** Emissions from use of fuel/power for drilling
- **Well Completion & Production:** Fugitive Emissions
- **Flaring:** Emissions from burning of excess gas
- **Tank Storage:** Emissions from storage tanks due to vapour release
- **Gas processing:** Emissions from gas processing

**MIDSTREAM EMISSIONS**

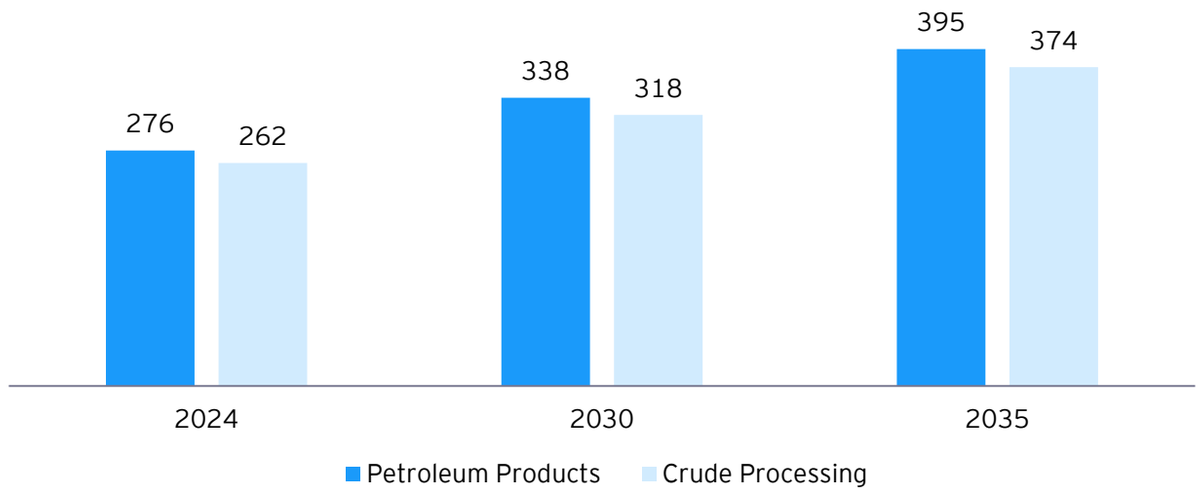
- **Pipelines Leaks:** Methane fugitive emissions during transportation
- **Compressor stations:** Emissions from compressor operations
- **Tanker Loading & Unloading:** Volatile Organic Compounds (VOC) emissions from tankers

**DOWNSTREAM EMISSIONS**

- **Refinery Operations:** Emissions from flaring, combustion processes (heavy emitting)
- **Product Storage & Distribution:** Emissions from improper product handling

[35] Greenvantage, 2024, UltraTech Cement's Sustainability Effort
[36] DD News, 2023, India set to be World's Third Largest Economy by 2030

Figure 12: Growth projections (Based on 15-year CAGR)




Source: EY analysis

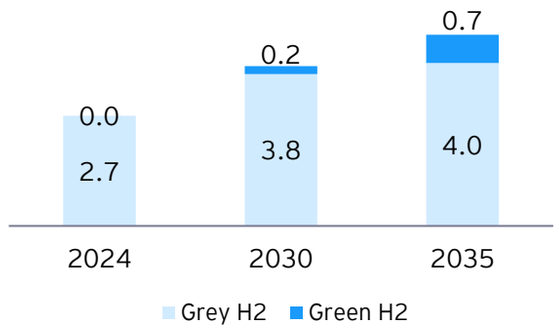
While emissions occur at each of these segments, refining (downstream) contributes to majority of emissions for this sector. India is the fourth largest refiner in the world, with 22 operational refineries, comprising 18 in the public sector, one joint venture, and three privately owned facilities. India's current crude processing capacity stands at 256.8 million metric tons per annum (MMTPA), with projections indicating it will rise to approximately 374 MMTPA by 2035. Similarly, petroleum product processing is expected to increase from around 276 million metric tons (MMT) in 2024 to approximately 395 MMT by 2035, assuming a business-as-usual scenario[37].

In 2024, the PSUs and JV emitted around **~ 65 MMT of $CO_2e$** and the private refineries emitted **~38 MMT of $CO_2e$**. With the planned expansion, assuming no decarbonization initiatives are put into practice, the emission numbers may double under the business-as-usual (BAU) scenario. India is one of the fastest growing economies in the world entering its Amrit Kaal period (present – 2047). Within this period the country must ensure energy security, environmental sustainability, and energy equity (affordability and accessibility). Hence, there is a pressing need to accelerate decarbonization efforts in the oil and & gas sector.

Green hydrogen is being seen as a prominent lever for decarbonizing the oil & gas sector. It could replace grey hydrogen in the process of desulphurization and cracking and could also serve as an energy/fuel substitute for refinery operations in the long term. The hydrogen requirement in refineries is currently at **~2.7 MMT**[38], and the complete quantity is being captively produced by the refineries using the Steam Methane Reforming (SMR) process. Hence, they emit close to ~24 MMT of $CO_2$ from their hydrogen generation units (HGUs). Injection of green hydrogen would directly reduce the emissions for HGUs. **With 15% of green H2 injection in the refinery operations, we shall be able to prevent around ~6.3 MMT of $CO_2e$ emissions by 2035**.

[37] EY Analysis, 2024, Oil and Gas processing data from PPAC database for analysis
[38] EY Analysis, 2024, Data for Petroleum Products sourced from PPAC reports.

**Figure 13: Estimated injection of green H2 in crude processing**



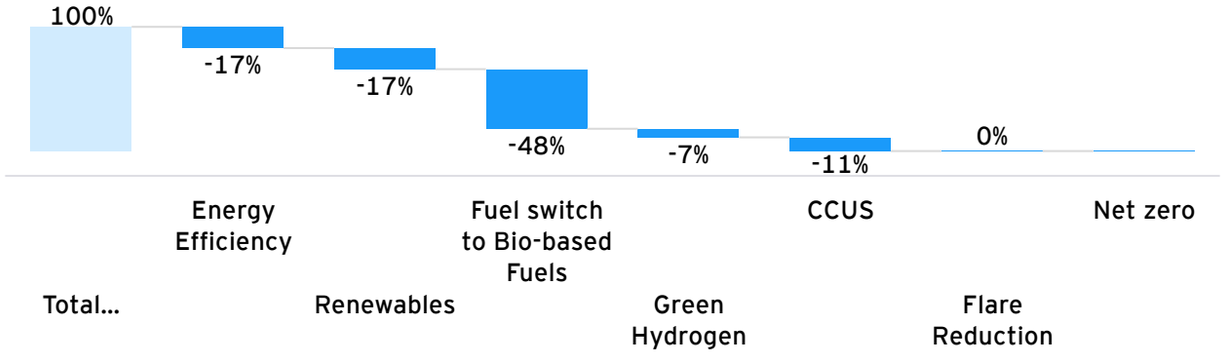

Source: EY analysis

While for gas companies, green H2 blending with city gas distribution networks is being explored. Green H2 blending with NG would reduce the combustion emissions for the CGD supply. **GAIL has successfully blended 2% of hydrogen (V/V) in natural gas supply** in the CGD network through Avantika Gas Ltd. (AGL) operating in Indore, Madhya Pradesh[39].

Currently green H2 is priced at $6 – 7 per kg, which is 3 - 4x the price of grey hydrogen which at $1.5 per kg of H2. Hence, the Indian government has introduced several fiscal and non-fiscal initiatives to bridge the price gap in the medium term. The **'SIGHT' program** was launched by GoI with an objective to produce 5 MMTPA of green H2 by 2030. The O&G sector has responded with a surge of investment in the green H2 space. According to the announcement made by **O&G players till 2024, ~ 2.1 MMT of green hydrogen capacity should be operational by 2030**[40].

Carbon capture and utilization (CCU)/CCUS, yet to mature, is being seen as a medium-term lever for carbon offset. Global players have already done strategic investments in CCU, which can further be used for enhanced oil recovery (EOR). **ONGC is planning to sequester ~2.21 million tonnes of $CO_2$** emissions, while Oil India conducted a prefeasibility study for establishing $CO_2$ storage in saline aquifers of Jaisalmer, Rajasthan. While Indian Oil has set up two plants of 460 KtPA. **ONGC and IOC are collaborating** for India's first industrial-scale carbon capture project at the **Koyali refinery, aims to sequester 5-6 million tons of $CO_2$ by 2040**. A task force called 'Upstream for CCU/CCUS' has been set up by MoPNG to provide a 2030 roadmap for CCUS. Another major lever for decarbonization of the O&G sector is renewable energy (RE). RE would reduce the Scope 2 emissions for O&G sector, also aid the clean electrification of refinery operations. With the announcement made by the **O&G players ~ 20 GW of renewable energy assets should be online by 2040**[41].

**Figure 14: Potential of emission reduction by different levers, HPCL (2024)[42]**




*Source: EY Analysis (data from HPCL annual reports, BRSR sustainability reports)*

[39] GAIL (India) Ltd, 2022, GAIL Press Release
[40] PPAC Journal, 2024, Special Issue on Net Zero plans of oil and gas companies
[41] PPAC Journal, 2024, Special Issue on Net Zero plans of oil and gas companies
[42] The percentages have been rounded off to 0 decimal places

While renewable energy, green H2 and CCU are major levers directed at reducing the emission in refinery operations. There are other levers aimed at reducing the consumption of energy at refineries, while few others aimed at reducing the consumption of petroleum products. O&G companies are investing in electric vehicles (EV) space, while also aiding in setting up sufficient EV charging infrastructure. IOCL has set up close **~9,200 EV charging and 85 battery swapping stations** to help electric mobility in the country. While **Jio-BP**, BP's JV with Reliance has set up over **240 fixed charging stations with over 4,000** charging points. Focus is also directed towards bio-based fuels and synthetic fuels, the **Ethanol Blended Petrol (EBP)** program aims to achieve **20% blend of ethanol with petrol by 2025**, while the blend with diesel must be achieved by 2030. The company is also collaborating with technology player Lanzajet for setting up Sustainable Aviation Fuel (SAF) plants[43]. Numaligarh Refinery is also planning to set up a **10 KTPA facility producing SAF through PSA off gas**[44].

While for **emission reduction in the upstream operations** several levers are being explored, like, diversifying power sources for on-site operations. Equinor's successful integration of the Johan Sverdrup field, an offshore asset located 140 kilometers from the coast, into the onshore renewable electrical power grid underscores the viability of sustainable power solutions in remote offshore environments. Tackling fugitive emissions is also a significant challenge for upstream players. **Leak detection and repair (LDAR) programs and vapor recovery units (VRUs)** are being deployed, while **double mechanical seals, dry gas seals** are also being installed. CCUs as lever is relevant for upstream players, offering additional revenue through EOR. Some successful $CO_2$ injection projects are **Permian Basin (USA), Canadian oil sands development using Steam Assisted Gravity Drainage (SAGD)**[45], etc.

Major oil & gas players in India have set their net-zero emissions targets driven by both regulatory pressures and market demands for cleaner energy solutions. Key players who have set ambitious targets for decarbonization are highlighted below[46]:

- **Oil India Limited (OIL), Gas Authority of India Ltd. (GAIL):** OIL has joined the Oil & Gas Decarbonization Charter (OGDC), committing to achieve net-zero emissions by 2040. GAIL has set net-zero emissions target as 2040 as well.
- **Indian Oil Corporation (IndianOil):** IndianOil aims for net-zero operational emissions by 2046.
- **Oil and Natural Gas Corporation (ONGC):** ONGC has set a more immediate goal, targeting net-zero operational emissions by 2038. The company plans to invest approximately INR 2,00,000 crores in decarbonization efforts, focusing on enhancing energy efficiency and adopting renewable energy sources
- **Bharat Petroleum (BPCL) and Hindustan Petroleum (HPCL)** have set their net-zero emissions target as 2050

Few of the initiatives that are driving the decarbonization in the oil & gas sector:

- **National Green Hydrogen Mission (NGHM)**[47] seeks to link the hydrogen economy with renewable energy growth, targeting the production of 5 MMT (Million Metric Tons) of green hydrogen (GH2) annually by 2030. With a budget allocation of INR19,744 crore for the period 2023–24 to 2029–30, the mission aims to reduce $CO_2$ emissions by 50 MMT per year and establish India as a global leader in green hydrogen production, utilization, and export.

[43] Publicly available reports for IOCL - annual reports, BRSR, sustainability reports
[44] PPAC Journal, 2024, Special Issue on Net Zero Plans of oil and gas companies
[45] Oxford Institute of Energy Studies, 2016, The Future of Canadian Oil Sands
[46] Companies, Certificates, and Description are publicly available information on company's respective website
[47] MNRE, 2023, National Green Hydrogen Mission Document

- The Ministry of Petroleum and Natural Gas (MOPNG) has introduced several measures under the **National Biofuels Policy 2018**[48] and the **Sustainable Alternative Towards Affordable Transportation (SATAT)** initiative to promote biofuels and reduce dependency on fossil fuels. The policy classifies biofuels into Basic and Advanced categories, prioritizing second-generation (2G) ethanol and municipal solid waste (MSW)-to-drop-in fuels. Financial support includes a INR5,000 crore Viability Gap Funding (VGF) package for 2G ethanol refineries over six years, alongside tax incentives and higher pricing for 2G fuels compared to first-generation (1G) biofuels. Additionally, it encourages ethanol production from unfit crops such as sugar beet and rotten potatoes.
- Other initiatives include **Ethanol Blended Petrol (EBP) program** – 20% ethanol blending in petrol by 2025, **Pradhan Mantri JI-VAN Yojana (2019)** – launched to create 2G ethanol capacity in India and to provide financial support to Integrated Bioethanol projects[49]
- **SATAT Initiative**[50]**:** Aims to reduce LNG imports by two-thirds by producing Compressed Bio-Gas (CBG) and bio-manure. The initiative includes a Compressed Bio-Gas Blending Obligation (CBO), requiring blending by 2025–26. During FY 2023–24, 19,724 tons of CBG were sold, supported by pipeline infrastructure for injection into the City Gas Distribution (CGD) grid.
- **GOBAR-DHAN Scheme**[51]**:** Focuses on converting agricultural waste into compost, biogas, and bio-CNG, improving rural cleanliness and economic prospects.
- **Repurpose Used Cooking Oil (RUCO):** Facilitated by the Food Safety and Standards Authority of India (FSSAI), this initiative converts used cooking oil into biodiesel.[52]
- **National Solar Mission, National Wind-Solar Hybrid Policy (2018)** has also pushed the O&G sector to push more investments into the renewable energy sector.

Some notable case studies of O&G companies foraging strategic collaborations across the value chain with technology providers and investors to stay ahead of the curve in their decarbonization journey:

**Case study - Collaborations across value chain by O&G players**[53]

| | Collaborations with… | | | |
|---|---|---|---|---|
| O&G companies | Tech providers | Investors/ finance | Green portfolio | Advisory |
| IndianOil | JV with **Panasonic Energy** which shall provide technology for manufacturing cylindrical lithium-ion cells for two- and three-wheeler EVs and energy storage systems | Financed by **USTDA**, carbon capture project to capture 700 KTPA of $CO_2$, supported by Dastur International and Dastur Energy for low-carbon H2 | Collaborating with **LanzaJet** to explore SAF, JV with **Praj Industries** for 2G ethanol production, JV with **LanzaTech** for off-gas to 3G ethanol prod., JV | Collaborating with IIT Kharagpur to develop a 57L water capacity type 3 composite cylinder for green hydrogen storage |

[48] MoPNG, 2018, 2022, National Biofuel Policy - 2018
[49] National Portal of India, Pradhan Mantri JI-VAN Yojana – GoI Website Page
[50] MoPNG, SATAT Page on MoPNG website
[51] National Portal of India, GOBAR DHAN – GoI Website Page
[52] FSSAI Website, RUCO
[53] Companies, Certificates, and Description are publicly available information on company's respective website

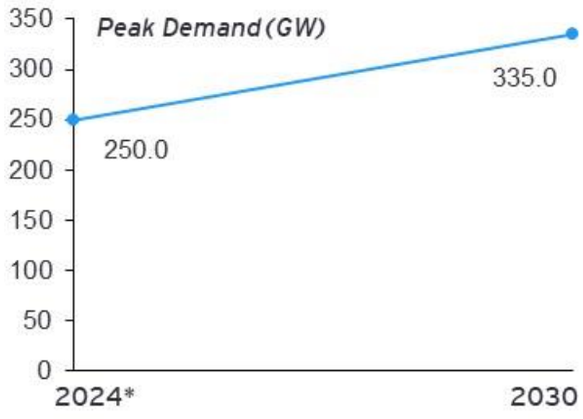
| | Collaborations with... | | | |
|---|---|---|---|---|
| O&G companies | Tech providers | Investors/ finance | Green portfolio | Advisory |
| | | production at Koyali refinery | with **Sun Mobility** to offer battery swapping via IOC's **37,000+** fueling stations | |
| | Collaboration with **BARC** to scale up Alkaline Electrolyzer technology for green H2 production | Collaborating with **ARYA**, a GPS Renewable Subsidiary, which secured INR100 crore in funding to develop CBG projects | Collaborating with **Ather Energy** to expand India's EV charging network converting 7,000 retail outlets into energy stations, JV with **Sembcorp Green Hydrogen India and GPS Renewables** to develop green H2 and CBG projects, respectively | Collaboration with leading institutions like Curtin University addressing challenges in process efficiency |

**Challenges and recommendations**: While a lot has happened in the Indian O&G space towards net-zero emissions, some considerable challenges remain. One of the major challenges is in terms of emission baselining. Before even beginning to implement emission reduction strategies, companies in O&G need to baseline their Scope 1, 2 and 3 emissions. Though several companies like IOCL, GAIL, ONGC have started accounting and monitoring their emissions annually, many have not started GHG accounting as an annual practice. A standard platform can be maintained for emission reporting of O&G companies by MoPNG. This would necessitate companies to take up GHG accounting on an annual basis. The companies also need to take up lifecycle emission accounting to properly gauge and manage emissions at each step of the value chain. Another major roadblock is the quantum of investments required for green transition of the India O&G sector. More than $600 billion would be required globally to reduce the oil & gas emission intensity by half till 2030. Green bonds, social impact bonds could be explored as alternative funding sources. The companies could set up **Internal Carbon Pricing (ICP)** to incorporate the cost of carbon in their financing decisions. Companies are slowly starting to invest in R&D for low-carbon technologies. **BPCL has invested around $11.69 million into low-carbon R&D expenditure**, while companies like Total Energies, BP have increased their green investments by two or three-folds in 2023-24 as compared to their 2020 expenditures. Indian Oil has invested ~$28.9 billion and BPCL $12.05 billion into green energy investments. Yet, a lot more investments in clean energy and R&D is required for a smooth green transition.

# 4.4 Power & Utilities

India's power and utilities sector stands at a pivotal juncture, underpinning the nation's economic growth and energy transition goals. With an installed **capacity exceeding 430 GW**, India ranks as one of the world's top power producers, driven by a diversified energy mix of coal, renewables, hydro, and nuclear power.

**Figure 15: Power demand to grow at a CAGR of 5% till 2030**




*Source: EY analysis (data from MNRE, PTI)*

India is accelerating its power generation capacity, fueled by demand from EVs, data centers and industrial electrification. The peak demand for power in India is projected to grow at a CAGR of 5% till 2030, as shown in the graph.

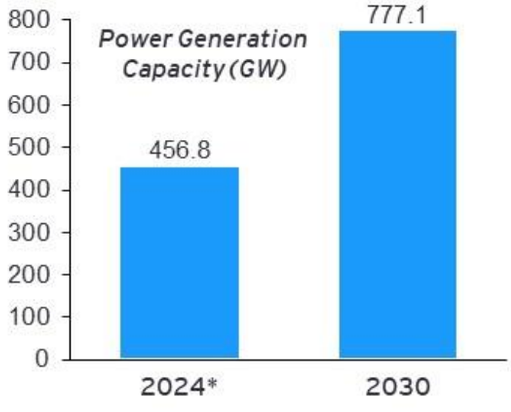
With energy demand projected to double by 2040, India is steadfast in modernizing its power systems, integrating advanced technologies, and fostering innovation to achieve a secure, inclusive, and sustainable energy future. The per capita electricity consumption, currently around **1,255 kWh/year**, is set to grow significantly as energy access improves[54]

As the third-largest renewable energy market globally, India has achieved over **125 GW of renewable capacity** and is ambitiously targeting 500 GW of non-fossil fuel capacity by 2030. This aligns with its commitment to net-zero emissions by 2070. Key government initiatives, including the National Solar Mission, Green Energy Corridors, and the Revamped Distribution Sector Scheme, are accelerating the expansion of clean energy infrastructure, enhancing grid reliability, and promoting sustainability.

The power and utility sector are a major contributor to India's greenhouse gas emissions, primarily due to its reliance on coal-fired power generation. There are certain key statistics that highlight the proportion of emission from India's power sector.

With a grid emission factor **of 0.727 tCO2/MWh,** India's average is **~1.53 times of the global average.** Emissions from this sector increased almost eight percent in 2023 to reach a record high of **1.4 billion metric tons** of carbon dioxide equivalent ($GtCO_2e$). India's high grid emission factor implies that electrification of processes alone (e.g., electric vehicles or industrial operations) may not lead to significant emission reductions unless paired with a cleaner grid. Countries like Sweden or Iceland, with grid emission factors near zero due to extensive use of hydro or geothermal energy, highlight how policy support and investment in renewables can transform emission profiles.

**Figure 16: India power generation capacity (*as of Nov 2024)**




*Source: MNRE, PTI*

Coal power accounted for roughly 95 percent of this total, at **1.34 $GtCO_2e$**. Since 2000, power

[54] PIB, 2022, Ministry of Power implements significant schemes to increase energy efficiency

sector emissions in India have more than tripled. In recent years, the total $CO_2$ emissions from thermal power plants have shown a rising trend, with estimates indicating that emissions could reach approximately **1165 million tonnes by 2026-2027**. Decarbonizing coal-based power plant involves the implementation of various levers:

- **Fuel switching:** 5% to 10% reduction in emissions when co-firing with 10% to 15% biomass, depending on the blend ratio and biomass sourcing
- **CCUS:** 80% to 90% of carbon emissions from flue gas can be captured, though actual utilization or storage efficiency depends on infrastructure and technology
- **Efficiency improvement:** 15% to 20% reduction in emissions due to improved thermal efficiency and reduced coal usage
- **Process optimization:** 2% to 5% reduction in emissions by minimizing inefficiencies and operating the plant at optimal load levels
- **Digital tools:** 1% to 3% reduction in emissions through better fuel management, predictive maintenance, and minimizing unplanned outages
- **Waste heat recovery:** 5% to 8% reduction in emissions by utilizing waste heat to generate additional power and offset fuel usage

As we enter 2025, the global perspective on green power and utilities reveals a dynamic landscape characterized by rapid advancements in renewable energy technologies, shifting consumer behavior, and evolving regulatory frameworks. According to the International Energy Agency (IEA), renewable energy sources are expected to account for over one-third of the world's electricity generation by 2025, driven primarily by solar and wind power. This transition is not merely a response to environmental concerns but also a strategic move to enhance energy security and economic resilience in the face of increasing global electricity demand, **projected to grow by 4% due to economic recovery** and the rising need for electricity to support emerging technologies such as artificial intelligence and electric vehicles (EVs).

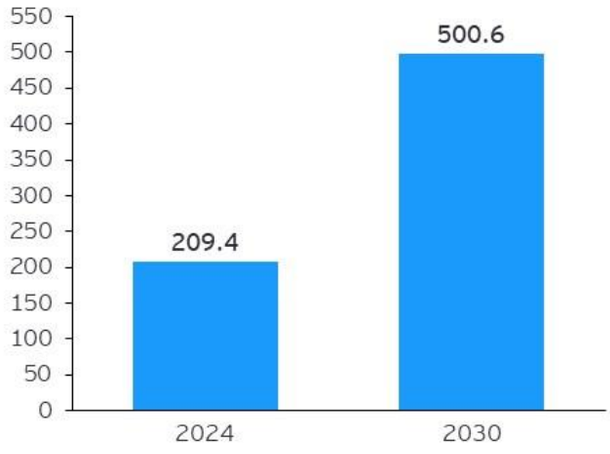
Solar energy is set to dominate this transformation, with projections indicating that it may meet nearly half of the global growth in electricity demand through 2025. The continuing advancements in photovoltaic technology and decreasing costs are making solar power more accessible, leading to increased installations of both large-scale solar farms and rooftop systems. In regions like the United States, solar energy is anticipated to surpass coal as a major source of electricity generation, thereby contributing significantly to national decarbonization efforts.

Concurrently, offshore wind energy is poised for substantial growth, particularly in Europe, where capacity is expected to double by 2025. Countries such as the U.K., Germany, and Denmark are leading this charge, supported by technological advancements that enhance turbine efficiency and reduce costs.[55]

The IEA also forecasts that over **1,700 GW of battery capacity shall be added globally by 2035**, reflecting the growing importance of storage technologies in ensuring grid stability and reliability and the rise of electric vehicles is expected to significantly increase electricity demand, further pushing reliance on renewable sources, also as a means for EVs to store and supply energy back to the grid during peak demand periods.

[55] Diversegy, 2025, Renewable Energy Trends 2025: What To Expect

Figure 17: India's RE installed capacity (GW)

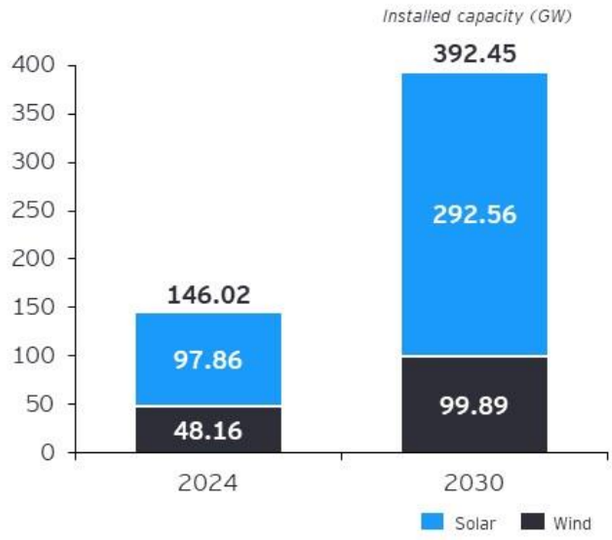



*Source: MNRE, PTI*

India's green power and utilities sector is also increasingly becoming a significant player in the global renewable energy landscape, reflecting a broader trend towards sustainability and decarbonization worldwide. As of January 2025, India has **surpassed 209 GW of installed renewable energy capacity**, positioning itself as the 3rd largest renewable energy producer globally, following China and the United States. India is committed to **achieve 500 GW of renewable energy capacity by 2030,** as outlined in its Nationally Determined Contributions under the Paris Agreement. The economic implications of India's shift towards renewable energy are substantial.

Solar and wind energy are the leading renewable electricity sources in India, driving the nation's transition toward sustainable and clean energy. In 2024, the total installed capacity is about **146 GW, comprising 97.86 GW of solar and 48.16 GW** of wind energy. By 2030, the capacity significantly is likely to increase to about 392 GW, with **solar energy dominating at 292.56 GW, while wind energy reaches 99.89 GW**. This indicates a nearly threefold increase in total capacity, driven primarily by the rapid expansion of solar energy, which grows by almost 200 GW, highlighting a clear emphasis on solar as a key driver of renewable energy development.

Figure 18: Installed capacity of solar and wind in India (GW)




*Source: MNRE, PTI*

The sector is expected to attract investments exceeding **US$32 billion by 2025**, driven by government initiatives and increasing participation from private players. This influx of capital may not only enhance India's energy security, but also create over a million jobs in the renewable sector in 2023 alone. The government's commitment to scaling up domestic solar photovoltaic (PV) and wind turbine manufacturing is a crucial aspect of this strategy, aimed at reducing dependence on imported technologies and fostering local industries. Again globally, the renewable energy sector is on track to meet 35% of electricity demand by 2025, with solar and wind power leading the way. In this context, India is leveraging its vast solar potential, with initiatives like the International Solar Alliance facilitating collaboration among over 120 countries to promote solar energy adoption. By 2024, India had achieved a remarkable 30-fold increase in solar power capacity since 2014, underscoring its commitment to harnessing clean energy.

Technological advancements play a vital role in this transition. The integration of smart grid technologies enhances the efficiency and reliability of electricity distribution systems, while innovations in energy storage solutions are critical for managing the intermittent nature of renewable sources like solar and wind. The **National Electricity Plan 2023 (NEP 2023)**, adopted in May 2023, envisages adding considerable solar and wind capacity by 2031-32, 311 GW and 82 GW[56], respectively.

Consumer behavior is shifting towards greater acceptance of renewable energy solutions, driven by government incentives and rising awareness of climate change issues. Programs like the **PM-Surya Ghar Muft Bijli Yojana**, which provides free electricity up to 300 units per month for low-income households, have led to significant adoption of rooftop solar systems across the country. To keep up pace with shifting consumer pattern, India's power and utility sector is witnessing a significant shift towards renewable energy, driven by various companies that are implementing innovative technologies and projects. Here is a notable case study from leading one of the leading firms in the Power & Utilities sector[57]:

| Organization | Initiatives |
|---|---|
| एनटीपीसी NTPC | ▪ The company aims to achieve **60 GW** of renewable energy capacity **by 2032**, accounting for nearly **50% of its total portfolio**.[58]<br>▪ As of now, the company has **3.9 GW** of **operational renewable capacity**, with projects under construction and in development **adding over 7 GW**.<br>▪ In addition, the organization has also taken emission reduction initiatives and has committed to make **~10% of generation** fleet carbon free by 2032, compared to 2012 levels.<br>▪ Its transition to renewable energy exemplifies its commitment to sustainability and innovation, positioning itself as a key player in India's clean energy transformation while contributing significantly to global decarbonization efforts. |

To accelerate the decarbonization of India's power and utility sector, a comprehensive strategy must prioritize **renewable energy expansion, grid modernization, and energy storage solutions.** Leveraging solar and wind capacity, coupled with investments in green hydrogen and carbon capture technologies, can enable a cleaner energy mix. Policy reforms, financial incentives, and public-private partnerships are crucial to drive innovation, ensure affordability, and achieve India's net-zero targets efficiently.

[56] Ministry of Power, 2023
[57] Companies, Certificates, and Description are publicly available information on company's respective website
[58] NTPC, 2025, Renewable Energy Report

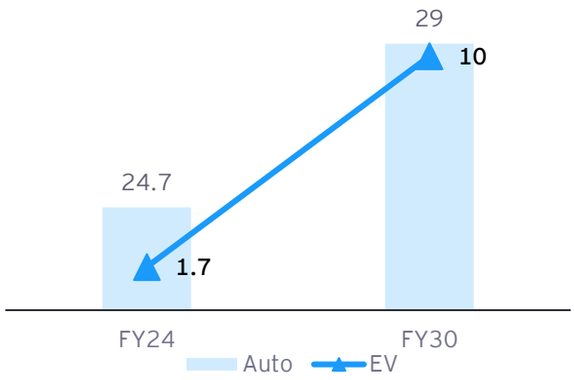
# 4.5 Auto-OEM

India is world's third largest automotive market with 7% to 8% GDP contribution[59] **with 28.4 million units produced and 24.7 million unit sales in FY24[60].** With concerns around rising emissions and net-zero targets owing to Paris Climate Agreements, decarbonizing the auto sector is crucial to achieve the necessary climate goals. The transport sector contributes ~12% of India's emissions, amounting to 315 $MtCO_2$ eq[61]. With robust historic growth, India's auto industry **achieved a market size of INR 20 trillion in FY2024** and is expected to maintain the trajectory till the end of decade[62]. Rise in urbanization and economic growth has propelled the auto sector growth with the evolving trend of vehicle ownership, thus escalating emissions. This makes it imperative for the auto sector to undergo a green transition and play a pivotal role in becoming a net-zero economy by 2070.

The sector's green transition has been accelerated by the rising electric vehicle penetration which recorded 1.7 million EV sales in FY24 with a whopping 42% growth from FY23[63] and hold immense potential in the ever-expanding India's automotive market with projections to achieve 10 million EV sales by 2030[64].

India's EV adoption shall be primarily driven by passenger vehicle segment while the 2W segment continues to dominate the EV market. For the logistics sector, it needs to increasingly adopt commercial electric vehicles to significantly contribute to emission reduction across road transportation sector.

**Figure 19: India's automotive and EV market, million units**



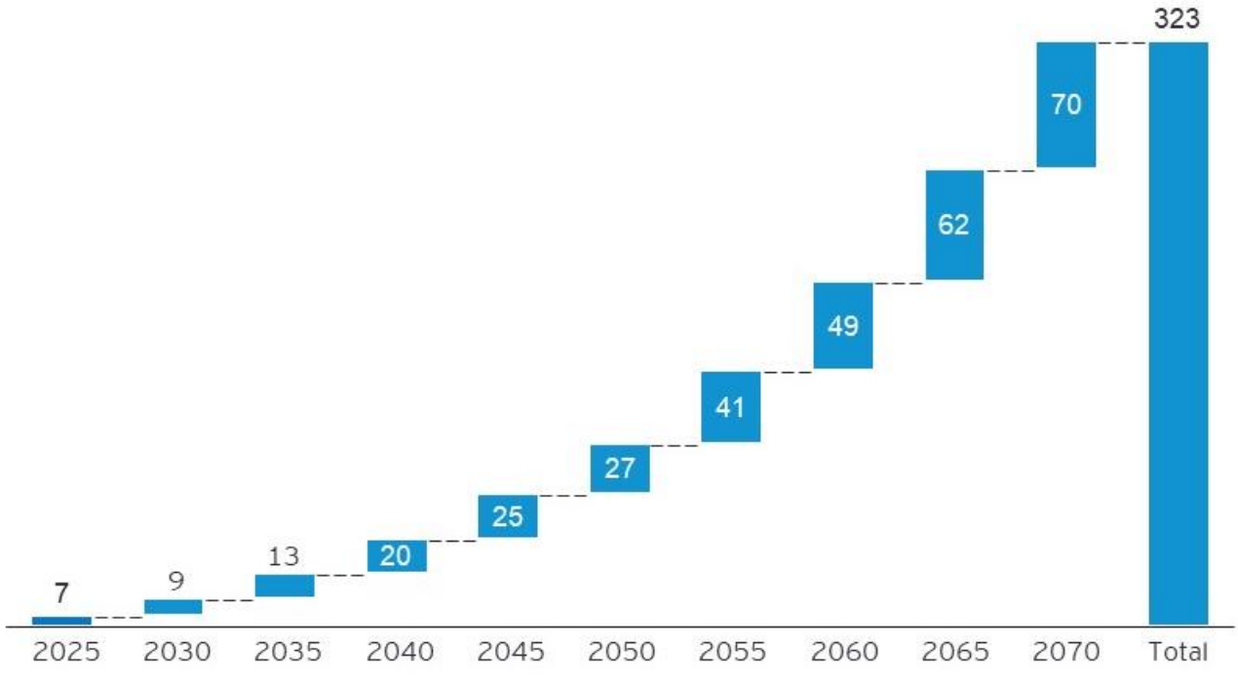

Source: Climate and Sustainability Initiative

While consumers showcase readiness to adopt EVs as their preferred mode of transport owing to awareness about climate concerns, India is yet to harness full potential of electric mobility and provide the necessary infrastructure through significant investments and compliance measures. Electric mobility penetration in India is expected to be in line with the net-zero targets and is **poised to achieve 70% sales penetration in commercial cars, 30% for private cars, 40% for buses and 80% for two and three wheelers**[65]. While India targets to achieve complete penetration of electric mobility to comply with the net-zero targets by 2070, India needs to navigate through multiple challenges, primarily the lack of charging infrastructure for EVs. As of March 2022, **India had over one million EVs but only 1,742 public charging stations**, highlighting the infrastructure gap[66]. The establishment of charging networks involves substantial fixed and variable costs, making financial returns uncertain and deterring private investment. Land acquisition, access to electricity connections, and capital availability further complicate the process. Additionally, the

[59] TERI, May 2024, India's Journey To Net Zero
[60] CMIE, FY24, India automotive production and sales
[61] TERI, May 2024, India's Journey To Net Zero
[62] IBEF, September 2024, Auto industry hits US$ 238.32 billion: SIAM
[63] CMIE, FY24, India EV production and sales
[64] The Economic Times, September 2024, EV sales to reach 10 million units by 2030: Union Minister
[65] Niti Aayog, April 2019, India's Electric Mobility Transformation
[66] Niti Aayog, April 2019, India's Electric Mobility Transformation

uneven distribution of charging stations, with a concentration in commercial areas and a lack in residential regions, limits convenience for EV users, particularly for long-distance travel.

**Figure 20: Total investments required for net zero transition, US$b**




Source: Climate and sustainability initiative

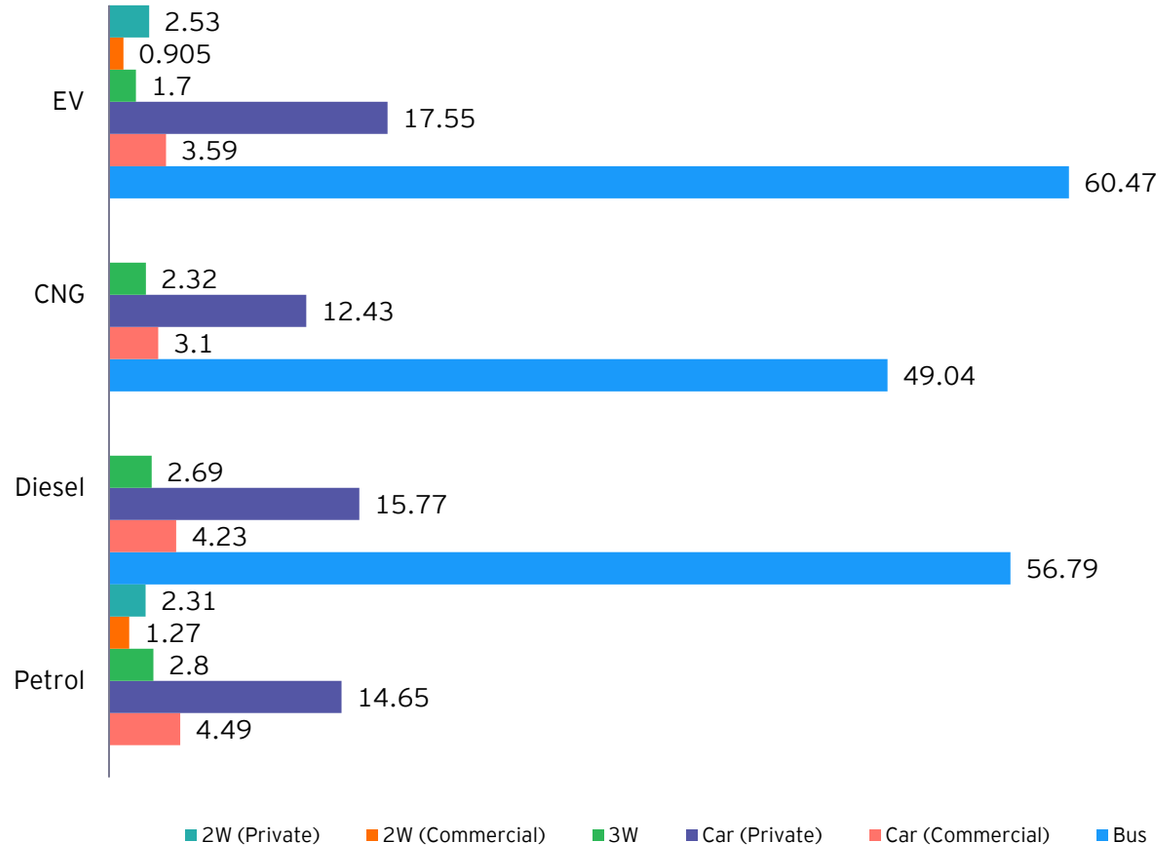
Electric vehicles are on a definitive path of becoming a dominant mode of passenger transport in the future and to accomplish this, **India needs a total investment of more than US$300 billion by 2070** and fully decarbonizing the sector[67]. This transition is expected to witness higher initial investment costs due to higher dependance of OEM on component suppliers. While electrification is expected to significantly reduce carbon emissions, a report by Climate and Sustainability Initiative indicates that this **decarbonization effort could yield a US$14.1 trillion revenue generation opportunity by 2070** with cars contributing more that 70% share followed by commercial vehicles[68].

This transition would be achievable only when India navigates through the roadblocks by **securing vehicle loans of US$9.6 trillion and cater to the annual battery demand of 1,716 GWh which would require ~US$200 billion investment by 2070[69].** Additionally, for India to lead EV manufacturing, there is a rising need for incentivizing manufacturers and create awareness about clean energy technologies. Efforts to address these challenges include increased government spending, streamlined data-sharing initiatives, and investments by companies like Tata, PMI, Hyundai, and BYD in localized production to reduce costs. Despite these efforts, the affordability and accessibility of EVs and charging infrastructure remain critical to driving widespread adoption and overcoming market barriers. Currently, India's EVs ownership rates are being influenced by favorable government schemes and policies, thus effectively propelling the green transition,

[67] Climate and Sustainability Initiative, August 2024, India's Auto Industry: Mapping the Course to Net Zero by 2070
[68] Climate and Sustainability Initiative, August 2024, India's Auto Industry: Mapping the Course to Net Zero by 2070
[69] Climate and Sustainability Initiative, August 2024, India's Auto Industry: Mapping the Course to Net Zero by 2070

but cost of EVs continues to be a key barrier for market penetration. However, advances in battery technologies and availability of multiple EV models are expected to reduce the EV prices and make them more affordable for consumers.

**Figure 21: Total cost of ownership across vehicle categories (INR/km)**




Source: TERI – India's journey to net zero

While electric vehicles are on the definitive path of becoming dominant modes of passenger transport in the future, relatively more pristine fuel options like compressed natural gas (CNG) supplement the drive to control emissions across the Indian automotive sector. CNG vehicles are seen reducing nearly 15% to 27%[70] greenhouse gases compared to conventional fuels, making them more cost-effective and contributing towards the wide adoption in the personal mobility segment. India holds a significant share of the global CNG market, with Maharashtra, Gujarat, Uttar Pradesh, Haryana, and Delhi accounting for 85% of CNG passenger vehicles, driven by tier-I cities. Tier-II cities are also adopting CNG vehicles due to lower ownership costs, supported by the government's planned expansion of the CNG pipeline network.

India's leading multinational automotive OEM has sold over 50,000 units in India's EV market till date under four fleet brands and intends to expand it to 10 brands by 2025[71]. Growing consumer willingness to purchase EV and ever-rising conventional fuel prices proved to be an advantage for this OEM to command a market

[70] TERI, May 2024, India's journey to net zero
[71] IJCSBE, April 2023, TATA Motors Limited: A Revolution in Electric Cars - A Case Study

lead. This company is constantly compared with global EV pioneer but managed to garner significant attention due to its lower prices, making it the only player operating in the affordable EV segment with designs custom to the Indian terrain. Factors that help the OEM produce affordable costs include vertical integration within the group to make significant strides in EV manufacturing plans and plans to announce a localization strategy for cells and batteries and possess the adequate financial and R&D strength to continue striving.

Another Indian-based global auto OEM marked its entry in India's EV market when its subsidiary acquired another EV company in 2012. While this product was only meant for B2C market and didn't witness adequate success, the group strategically shifted to B2B segment in 2014 by selling new generation products to various startups and continued to add a line of EVs by 2017 and gained the first mover advantage in the industry. Moreover, its strong geographic presence and efficient customer relationships proved to be beneficial in establishing its arrival in global EV market. Robust connections to suppliers and other stakeholders across the value chain with competent technology infrastructure and advancements helped this OEM become a market success.

Indian government has introduced various policies to support the automotive and clean technology sectors, including initiatives like Make in India, the Automotive Mission Plan 2026, and the National Electric Mobility Mission Plan 2020 and battery swapping policies to enhance EV adoption. However, this transition also brings challenges, including disruptions to the automotive value chain and workforce adjustments. To ensure a successful transformation, India's automobile sector must harness technology and innovation, prioritize worker resilience, and promote affordable, accessible and sustainable mobility options. Additionally, promoting electrification across other vehicle categories creates a need for newer kinds of vehicle loans with long tenures and economical costs. Stakeholders across the value chain need to create a solution framework for both short-term and long-term and improve finance flows across the ecosystem and have urged the government to introduce reforms for tax rebates, simplified GST and infrastructure investments. In addition to incentivizing provisions for manufacturers, the government could also incentivize demand by issuing guidelines and frameworks for EV consumers, which include purchase subsidy, registration tax, road tax, interest subvention and scrappage incentive. While there are efforts to improve domestic charging infrastructure by adopting the Bharat AC-001 standard specified by the Bureau of Indian Standards (BIS), India needs to enforce guidelines for standardized and inter-operable chargers. Moreover, the current vehicle scrapping policy needs to introduce variations that could help distinguish between ICE and EV and can leverage the early mover advantage in defining a global EV recycling policy which focusses on e-waste management and battery recycling and can help India secure share of critical metals (lithium, nickel, cobalt and manganese) demand.

# 06

## Forging the path ahead

**While significant strides have been made towards green manufacturing in India, there is a need for a concerted effort from both the government and industries to accelerate this transition. Below are key recommendations for stakeholders to chart the way forward:**

1. **Policy and regulatory support**: The government should strengthen existing policies and introduce new regulations to incentivize the adoption of decarbonization and green technologies across all sectors. This includes setting clear targets for $CO_2$ emissions reduction, providing tax benefits for green initiatives, and establishing a robust carbon pricing mechanism of US$100/t$CO_2$ by 2040 to encourage investment in low-carbon technologies.
2. **Financial incentives and subsidies**: To offset the high initial costs associated with transitioning to green manufacturing and infrastructure, the government should offer financial incentives such as grants, low-interest loans, and subsidies for companies investing in renewable energy, energy efficiency, and carbon capture and storage technologies. Viability gap funding can be explored by the government to bridge the price ap of grey and green hydrogen. Currently, green hydrogen, which is a prominent decarbonization lever, is priced around US$7/kg $GH_2$ which is around four times the price of grey hydrogen.
3. **Research and development (R&D)**: Increased funding for R&D is essential to drive innovation in green technologies. The government and industry should collaborate with academic institutions to develop cost-effective and scalable solutions for decarbonization. Indian PSUs have invested US$12 million into R&D expenditure in low carbon technologies, with potential for more funding towards such R&D initiatives.
4. **Infrastructure development**: The government should prioritize the development of infrastructure necessary for the production and distribution of green hydrogen, the establishment of charging networks for electric vehicles, and the expansion of renewable energy capacity. For instance, India needs a total investment of more than US$300 billion by 2070 for net-zero transition of the auto sector. It is, thus, necessary for the government and industry to collaborate towards the infrastructure development for low carbon technologies.
5. **Skill development and job creation**: As the green industrialization process shall create new job opportunities, there should be a focus on skill development programs to prepare the workforce for the emerging green economy.
6. **Public-Private Partnerships (PPPs):** Encourage PPPs to leverage the strengths of both sectors in financing and executing large-scale green projects, sharing risks, and ensuring the successful implementation of green initiatives. A leading oil & gas PSU has partnered with a prominent EPC player and one of the largest Indian IPP to develop green hydrogen and its derivates in India.
7. **Consumer awareness and demand creation:** The government, in partnership with industry, should launch awareness campaigns to educate consumers about the benefits of green products and create demand for them through green procurement policies. The regulators should come up with mandates on green products consumption.
8. **Standardization and certification**: Developing and enforcing standards for green products and processes is essential to ensure quality and performance. Certification programs can aid consumers in identifying and trusting green products, which in turn can boost demand. For instance, the Indian government has established a standard for defining green steel, characterized by an emission intensity of less than 2.2 tons of $CO_2$ per ton of finished steel.
9. **International collaboration**: Companies should engage in international partnerships to learn from global best practices, access advanced technologies, and participate in global green supply chains. This engagement could facilitate the indigenization of critical components and equipment, ultimately helping companies to achieve better cost economics.
10. **Monitoring and reporting**: Regulatory bodies, including government agencies, and industry associations, should establish stringent monitoring and reporting systems to track greenhouse gas emissions and assess progress toward decarbonization goals. They are encouraged to utilize frameworks like the Business Responsibility and Sustainability Report (BRSR) to bring more companies, particularly from sectors that are difficult to decarbonize, into the scope of greenhouse gas accounting and life cycle emission assessments. Such measures are crucial for enabling informed, data-driven policy decisions.

# Acknowledgments

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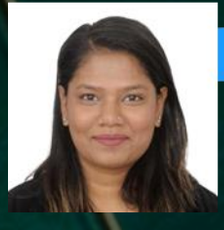

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