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SHAPING GREEN INDUSTRIAL TRANSFORMATION IN INDIA: Some Lessons

Nagesh Kumar, Anjali Tandon, and Swati Verma[*]

Abstract: *India's development strategy is currently focused on harnessing the potential of the manufacturing sector through a range of industrial policy interventions to create decent new job opportunities for its youthful population. However, for late-industrializers like India, 'industrialize first and clean up later' is no longer an option, in view of their net-zero emission commitments. This paper reviews India's strategy and experiences towards green industrialization, covering interventions on the demand as well as supply side for achieving desired outcomes through building sustainable manufacturing capacities for clean energy transition, electrifying transport systems, and greening industrial processes. It overviews these interventions and achievements in the key sectors of energy, transport, and industry. It also summarizes the financial challenges involved in green industrialization and analyses the response of Indian companies and MSMEs to the need to embrace NZE targets and sustainability in their operations. It also discusses the importance of cooperation among the countries of the Global South and summarizes India's initiatives. The paper is concluded with a few lessons from India's experiences in green industrial transformation for other developing countries and for international cooperation on sustainable development.*

Keywords: *green industrialization, clean energy transition, sustainable manufacturing, operational sustainability, net zero, India*

JEL Classification: *O1, O2, O5, L6*

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1 Introduction: The Context for Green Industrialization

India is currently the fastest-growing large economy, having become the fourth largest in the world in 2025, and has adopted a vision to become a developed economy by 2047. The realization of the developed country vision needs to be underpinned by inclusive and sustainable prosperity for its citizens through the creation of decent job opportunities for India's youthful workforce. Structural transformation is the process that creates more productive and decent job opportunities. India has witnessed the transformation of an agriculture-dominated economy into a services-dominated one, bypassing industry, in particular the manufacturing sector. While the service sector has delivered robust growth rates, it has not been able to absorb workers, especially the unskilled and semi-skilled, in a proportionate manner. The inability to harness the full potential of manufacturing to underpin the structural transformation in India has adversely affected the creation of decent jobs. Since the adoption of the Make-in-India programme in 2014, India has been trying to harness the potential of the manufacturing sector through a range of industrial policy interventions, covering trade policy, public procurement, reducing compliance burden, providing industrial and logistics infrastructure, tax cuts, and production-linked incentives (PLI) for selected sectors, among other measures (see ISID 2025 for details).

Late-industrializers like India face another challenge to their industrialization strategies that is presented by the global commitments taken by them on climate action to achieve net-zero emissions (NZE) under the United Nations Framework Convention on Climate Change (UNFCCC). Hence, 'industrialize first and clean up later' is no longer an option, even with per capita emissions being among the lowest in the world. Therefore, they have to focus their industrial strategy on green industrialization, which helps to create decent jobs and incomes while addressing decarbonization targets. Green industrial policy has been the cornerstone of the re-emergence of industrial policy worldwide.

In that context, this paper reviews India's strategy and experiences towards green industrialization and draws lessons. It is structured along the following lines. It begins by setting the analytical framework that justifies strategic interventions for green industrialization, broadly termed as green industrial policy (Section 2). This is followed by a brief overview of the decarbonization targets adopted by India, achievement of which will require a major transformation of India's energy generation, transport systems, industrial processes, and consumption patterns (Section 3). India has evolved policies covering interventions on the demand as well as the supply side for achieving the desired outcomes in clean energy transition and electrification of transport systems, as well as industrial processes. We overview these interventions and achievements in the key sectors of energy, transport, and industry in Sections 4–6. We then briefly discuss India's efforts to transition from a linear to a circular economy (Section 7) and summarize the financial challenges involved in green industrialization (Section 8). The achievement of NZE goals by the country will be determined by the adoption of sustainability practices by the private sector. Therefore, Section 9 analyses the response of Indian companies and MSMEs to the

challenges of meeting NZE targets and achieving sustainability in their operations. Section 10 discusses the importance of international cooperation, especially among the countries of the Global South, and summarizes India's initiatives. The paper is concluded with a few lessons from India's experiences in green industrial transformation for other developing countries and for international cooperation on sustainable development.

2 Relevance of Green Industrial Policy: The Analytical Framework

State intervention in industrial development has been justified since Friedrich List made a case for high tariff barriers imposed in the US in its period of industrialization in the 19th century (List 1909), as documented by Chang (2002). The various strands of literature on state intervention include discussions of the developmental state, strategic trade theory, and New Structural Economics (Lin 2012). Strategic intervention is also justified because market failures inherent in industrial development do not allow investors to harness all the gains from their investment accruing to the society—including job creation, skill development, productivity gains, export competitiveness, technology development and its diffusion, vertical inter-firm linkages, knowledge spillovers, and national security considerations—that the manufacturing sector brings to the economy. Hence, in the absence of state support, there will be underinvestment in the sector. Technological and industrial upgrading has been fostered through government procurement, export subsidies, subsidized capital, and tariff protection. History is rich in lessons of strategic interventions employed by industrialized as well as industrializing countries, as documented extensively in the literature (e.g., Amsden 2001; Chang 2002; Kumar & Gallagher 2007; Nayyar 2019; Salazar-Xirinachs et al. 2014; Stiglitz et al. 2013). While industrial policy is credited with the emergence of China as the global manufacturing hub, India has had a more mixed record of success with the import-substituting industrialization (ISI) that was practised during the 1960s–80s, before the liberalization and reforms beginning in 1991. While ISI helped India to build capabilities in the generic pharma, automotive, and ICT software industries in general and created a diversified industrial base, it led to poor levels of productivity and competitiveness due to technological obsolescence (ISID 2025; Kumar 2023; Nayyar 2026; Nayyar & Nayyar 2024).

Industrial policy went out of fashion during the period of hyper-globalization, especially in the 1990s and early 2000s. However, with the retreat of globalization since the global financial crisis of 2008/09, industrial policy has gradually resurfaced. A recent IMF paper considers technology and innovation policy as the true industrial policy applied by East Asian countries 'to fix market failures that preclude the emergence of domestic producers in sophisticated industries beyond their comparative advantage', 'export-orientation', and the 'pursuit of fierce competition both abroad and domestically' (Cheriff and Hasanov 2019). Subsidizing upstream sectors generally minimizes policy mistakes (Juhasz et al. 2023; Rodrik et al. 2023).

Against that backdrop, green industrial policy has received much stronger support due to compulsions of climate action to achieve net-zero goals and market failures inherent in green products and technologies due to their global public goods nature and the mispricing of carbon emissions (Harrison et al. 2017; Rodrik 2014). Rodrik (2014) has argued that green industrial policy is needed to address such market failures. The case for green industrial policy is even stronger than for traditional industrial policy (Harrison et al. 2017). Furthermore, in India's case, green industries not only have the potential to become dynamic drivers of India's industrialization but also offer co-benefits, such as reducing the country's very high dependence on imported hydrocarbons and decreasing pollution levels, while advancing net-zero goals (ISID 2025).

The compulsion to achieve NZE has given the revival of industrial policy worldwide, including in the most advanced economies, a new legitimacy. For instance, in the US, once the greatest champion of free markets and globalization, the Biden Administration adopted industrial policy in 2022 with the CHIPS and Science Act, the Inflation Reduction Act, and the Infrastructure Investment and Jobs Act, which aimed to foster local manufacturing and innovation in semiconductor chips, electric mobility, and other new technology products through hundreds of billions of dollars in subsidies and tax breaks (Kumar 2024a). The European Union's new 'Green Deal industrial plan for the net-zero age' of 2023 sets out a European approach to boosting the EU's net-zero industry, through measures designed to improve its competitiveness, including the Net-Zero Industry Act of 2023, which aimed to simplify the regulatory framework for production in key technologies, besides adopting a Carbon Border Adjustment Mechanism (CBAM) to impose unilateral taxes on imports of certain carbon-intensive goods. China, meanwhile, has become a dominant player in the whole range of green industries through extensive industrial policy interventions (García-Herrero and Schindowski 2024).

The Indian experience of fostering a clean transition suggests that industrial policy is critical. Furthermore, industrial policy is normally thought to address supply-side interventions. However, as new green products and processes are generally more expensive to begin with than traditional ones, green industrial policy needs to address demand-side challenges as well in order to build demand for them (Kumar 2024b). Lema et al. (2025) argue that the successful pursuit of green industrial policies requires preconditions such as a sizeable domestic market, sophisticated innovation systems, and sector-specific capacity for learning and innovation, and that industrial policies include demand-side as well as supply-side interventions, as well as technology policies that can help a country to participate in global value chains and enhance its competitiveness and value addition. These interventions often include tax incentives, local content requirements, and financial support, supplemented by industrial support programmes besides technology and innovation (Lema et al. 2025). It becomes apparent from the ensuing discussion that the achievement of India's NZE targets is highly predicated on industrial policy, which takes different forms in different sectors.

3 India's Climate Action Goals and Strategies

Most countries in the world have adopted target dates for NZE under the UNFCCC. India's per capita emissions, at about one-third of the global average, are among the lowest, but given its largest population base, the country is the third largest emitter globally. At the Conference of Parties (COP) 26 held in Glasgow under the Paris Agreement, India committed to NZE by 2070. India has also committed to sub-targets of meeting 50% of energy requirements from renewable sources, reducing the emissions intensity of its economy by 45% (from its 2005 level), and reducing CO_2 emissions by 1 billion tonnes by 2030 (India, Ministry of Finance 2024). Achievement of these goals will require a major decarbonization of India's energy generation, transport systems, industrial processes, and consumption patterns.

The Indian government adopted a Long-Term Low Carbon Development Strategy (LT-LCDS) at the COP 27 under UNFCCC held in Sharm el-Sheikh, Egypt, in November 2022 to give a big push to green growth in the context of the new net-zero goals and targets (India, MOEFCC 2022). The LT-LCDS has articulated the approach adopted by India to achieve NZE and the 2030 subgoals and priorities, as well as targets for different sectors.

As a result of the proactive steps taken by the government, the emissions intensity of the economy has been falling. The *Economic Survey 2023/24* highlights how India's economic growth has decoupled from greenhouse gas emissions, the compound annual rate of emissions growth being a little over half of GDP growth during 2005–19 (India, Ministry of Finance 2024: 184). Furthermore, the share of renewable energy (RE) in the energy mix surpassed 50% in 2025, five years ahead of target. India was ranked highest among G20 countries in terms of the Climate Change Performance Index 2023 and the fifth best globally (Reserve Bank of India 2023: 130).

4 Industrial Policy for Clean Energy Transition

India has expanded its RE generation capacity in a very impressive manner over the past decade, from 39.5 GW in 2014 to 257 GW in 2025, which is the fourth largest globally. Nevertheless, its RE capacity will need to be nearly doubled over the next five years to meet the ambitious target of 500 GW RE installed capacity by 2030. Local equipment manufacturing capacity will have to expand in solar and wind energy, besides green hydrogen (gH_2), to enable the country to meet the 500 GW target. Furthermore, given that India's per capita electricity consumption is very low at around one-tenth of the US's and one-fifth of China's, the bulk of the expansion in energy production capacity will need to be built in the coming decades. Hence, a large local manufacturing base for clean energy equipment is vital for catering to the sharply growing demand for RE. The solar photovoltaic (PV) supply chain across all stages of production from polysilicon to wafers to cells to modules and panels has, over time, come to be dominated by China, which now

accounts for more than 85% of global capacity.[1] As also underlined by the International Energy Agency (IEA 2022), such dominance by China in the supply of PV equipment is not conducive to the rapid deployment that India would require in order to achieve the 2030 target. Besides, there is a possibility of abuse of its near-monopoly position by weaponizing it (García-Herrero et al. 2023). India has adopted both demand- and supply-side interventions to expand deployment as well as manufacturing capacity in RE.

4.1 Demand-side interventions: Boosting solar energy demand through reverse auctions

Long-term power purchase agreements (PPAs) provide revenue certainty for solar project developers, mitigating risks associated with volatile market prices and enhancing investor confidence. By offering stable and predictable returns, including support through viability gap funding (VGF) in a reverse auction, long-term PPAs have helped to attract investment in solar projects, thereby driving not only capacity expansion but also cost reduction. Compared with INR12.16 per kWh in 2010, the current solar tariffs in India are between INR2.50 and INR2.87 per kWh, which are around 20–30% lower than existing thermal power plants and up to 50% lower than new plants.[2] The cost range of solar power in India is among the lowest globally (The Economist 2022). Besides PPAs, which are tendered through the Solar Energy Corporation of India, initiatives such as net metering and renewable purchase obligations (RPOs) further bolster the attractiveness of solar investments and promote market competitiveness. The Solar Mission also incentivizes solar power deployment across utility-scale, rooftop, and off-grid segments. As the supply of locally made solar PV modules began to increase, the government in its Union Budget 2024/25 announced an ambitious plan for the rooftop solarization of 10 million households with 300 units of free electricity per month.

4.2 Supply-side interventions to create manufacturing capacity for solar PV equipment

Domestic production capacity for solar PV equipment in India has been very small and hardly able to support India's ambitious clean energy transition plans. In 2020, total capacity for production of PV modules was 15 GW but was limited to just 3 GW for upstream components like PV cells and virtually non-existent for higher upstream components of wafers/ingots or silicon wafers. Hence, the Indian government has focused attention on enhancing local manufacturing capacity of integrated high-efficiency solar equipment. The policy measures include incentivization of local production under production-linked incentives (PLI), infant industry protection, and preferences in public procurement. The PLI scheme announced in November 2020 included the manufacture of high-efficiency solar PV cells and modules. The Approved List of Module Manufacturers (ALMM), adopted in 2019

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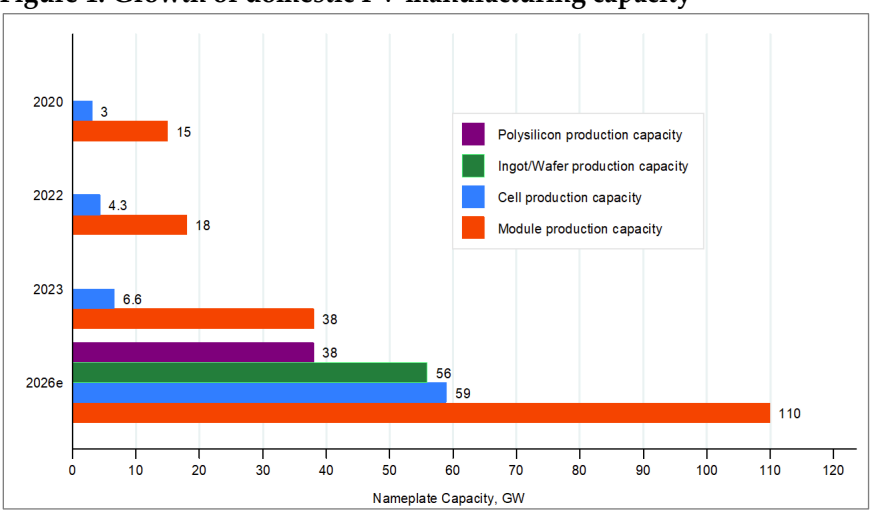
[1] See https://iea.blob.core.windows.net/assets/d2ee601d-6b1a-4cd2-a0e8-db02dc64332c/SpecialReportonSolarPVGlobalSupplyChains.pdf

[2] See https://energy.economictimes.indiatimes.com/news/renewable/indias-current-solar-tariffs-30-per-cent-lower-than-existing-thermal-power-costs-study/75887881#

to ensure quality standardization, was updated in 2023 to include 70+ Ministry of New and Renewable Energy (MNRE)-approved manufacturers with a capacity of 22.4 GW. In addition, the government has allowed only Class-1 local suppliers (with 50% or more local content) to bid for public procurement of solar PV modules, such as those on the ALMM. The sourcing of solar PV cells and modules was also limited to domestic sources for procurement under PM-KUSUM and the Grid-connected Rooftop Solar Programme Phase II, which are subsidized by the Government (PIB 2021). Furthermore, to provide infant industry protection for locally produced equipment, the government imposed a basic customs duty of 25% on cells and 40% on modules with effect from April 2022.

As a result of these initiatives, the backward deepening of local manufacturing capacity is beginning to happen. The implementation of PLI incentives awarded in two tranches (2021/22 and 2023) is likely to lead to the establishment of 51.6 GW capacity for the production of solar cells and modules, but also 44.2 GW of ingots/wafers and 27.4 GW polysilicon in upstream components over the coming few years. India achieved a production capacity of 100 GW of solar PV modules in 2025 (India, MNRE 2025a) and by the end of 2026 is expected to have a production capacity of 110 GW of solar modules, 59 GW of cells, 56 GW of ingots/ wafers, and 38 GW of polysilicon (Figure 1) (Gulia et al. 2023). The establishment of a large integrated capacity of 110 GW of modules will help the country not only to meet growing domestic demand and achieve the 2030 RE target but also to exploit scale economies and enhance competitiveness. Rising domestic production of solar equipment has helped to bring down import dependence steadily (Tandon 2025). As part of deepening domestic value chains, the government is progressively extending the local content criteria for public procurement to locally assembled 'cells' (from June 2026) and to domestically produced 'wafers', once their domestic production has been augmented in the coming years.[3]

Figure 1: Growth of domestic PV manufacturing capacity



Source: ISID (2025).

[3] See https://taiyangnews.info/markets/india-proposes-almm-iii-for-solar-wafers

4.3 Augmenting the domestic manufacturing base for wind turbines

India's wind energy sector is led by its strong indigenous wind power ecosystem, project operation capabilities, and manufacturing base of about 15 GW per annum. The country currently has the fourth highest wind-installed capacity in the world. The government is promoting private investment in wind power projects in the entire country through various fiscal and financial incentives such as accelerated depreciation benefits and concessional customs duty exemption on certain components of wind-powered electricity generators. India has also established a mandatory wind Renewable Purchase Obligation (RPO), applicable until 2030, that requires electricity distribution companies to increase wind energy consumption to 7% (India, Ministry of Power 2022). Guidelines for a tariff-based competitive bidding process for the procurement of power from grid-connected projects have also been issued to provide a framework for the transparent procurement of wind power. Wind energy is expected to contribute 100 GW to the 2030 target of 500 GW. The wind power industry has 70% domestic content, which is to be increased to 85% by 2030 under the *Aatmanirbhar* Wind Mission.[4]

4.4 Creating a green hydrogen value chain for the clean energy transition

Green hydrogen (gH_2) produced by the electrolysis of water using RE results in a clean and emission-free fuel and is an attractive option for the transition to a low-carbon future. By replacing fossil fuels, gH_2 can help to decarbonize several sectors, including transportation, shipping, steel, and fertilizers. It can also be used as a back-up energy source for RE plants, providing a constant and reliable source of energy. Hydrogen fuel cells have a high energy density and are more efficient than traditional combustion engines, making them an attractive option for powering vehicles. As an energy carrier, green hydrogen complements solar and wind energy by providing storage and transportation options. Given its tremendous potential for meeting net-zero targets, gH_2 is attracting a lot of attention globally, not least among latecomers, and entry strategies are being discussed (Altenburg and Strohmaier 2025).

India has launched the National Green Hydrogen Mission with an outlay of INR19,744 crores (USD2.36 billion) and a target of 5 MMT production capacity of green hydrogen per annum by 2030. The Mission focuses on demand creation in multiple sectors and on replacing imports of fossil fuels and fertilizers but also on exploiting gH_2 export potential. The Mission includes the Strategic Interventions for Green Hydrogen Transition (SIGHT) programme through the provision of incentives for electrolyser manufacturing and gH_2 manufacture. The Mission identifies key enablers, including results-oriented R&D activities, ease of doing business, facilitating infrastructure and supply chain logistics, appropriate regulations and standards, and capacity-building, besides the provision of financial incentives and land and water resources (India, MNRE 2023b). As the cost of gH_2

[4] See https://www.thehindu.com/news/national/tamil-nadu/india-expected-to-add-6-gigawatts-of-new-wind-energy-capacity-joshi/article70221015.ece

is currently high, for it to be viable as an energy source, subsidization would be needed for some time until volumes bring down costs through scale economies, as in the case of solar power (Shankar 2023). As a part of the Mission, the government invited bids for the production of 1.5 GW of electrolyser manufacturing and 0.55 MMT of gH_2 in 2023. Reliance Industries, Adani Group, Jindal India, Larsen & Toubro, and Bharat Heavy Electricals were among 20 companies submitting bids for the manufacture of electrolysers. Those submitting bids for gH_2 included Acme Cleantech, Sembcorp Green Hydrogen, CESC, Greenko ZeroC, and Avaada. The Strategic Hydrogen Innovation Partnership (SHIP) encourages public–private collaborations to advance research, develop competitive technologies, and foster innovation in gH_2 production and utilization. Some Indian states have also launched complementary green hydrogen policies, offering financial incentives and regulatory exemptions to support the National Mission.

4.5 Nuclear Energy Mission

Nuclear energy is being positioned as a reliable, low-carbon alternative to fossil fuels that complements renewable sources. India's current nuclear power capacity stands at 8.2 GW (2025), while the construction and commissioning of 10 new reactors with a combined capacity of 8 GW across Gujarat, Rajasthan, Tamil Nadu, Haryana, Karnataka, and Madhya Pradesh is under way. A new Nuclear Energy Mission announced in the Union Budget 2025/26, with an INR20,000 crore outlay, focuses on Small Modular Reactors (SMRs) and aims to operationalize at least five indigenously designed SMRs by 2033. The SMRs are expected to play a transformative role in diversifying India's nuclear portfolio by offering flexible, cost-effective, and safer alternatives to conventional large-scale reactors. Key polices aimed at facilitating private sector participation and investment include the Civil Liability for Nuclear Damage Act and the Sustainable Harnessing and Advancement of Nuclear Energy for Transforming India (SHANTI) Bill, which was introduced on 15 December 2025 and replaced the Atomic Energy Act 1962 to allow the private sector, including FDI, to operate nuclear plants and modernize safety regulations. The overall goal is to significantly increase nuclear energy's share to reach 100 GW by 2047, which will support energy transition and net-zero commitments.

4.6 National policy on geothermal energy

To diversify the RE portfolio, the government has recently announced a National Policy on Geothermal Energy (India, MNRE 2025b). Geothermal policy is designed to unlock the country's largely untapped geothermal potential by fostering research, innovation, and technology development. It also places emphasis on ecosystem strengthening, capacity building, and forging partnerships across public and private stakeholders. Through these measures, the Policy seeks to create an enabling framework that accelerates investment and operational deployment of geothermal technologies. Beyond energy generation, the Policy envisions broad-based applications of geothermal resources. These include providing clean power for grids, enabling district heating systems, supporting agricultural

processes such as greenhouse operations and drying, promoting aquaculture, and encouraging the use of ground source heat pumps (GSHPs) for energy-efficient cooling and heating solutions. Such applications reflect the potential of geothermal energy to deliver both climate and developmental benefits, particularly in rural and industrial clusters, where demand for low-cost, sustainable energy alternatives is rising.

4.7 Manufacturing ecosystem for energy-efficient lights and appliances

As Light Emitting Diode (LED) bulbs are up to 75% more energy efficient than traditional Incandescent and Compact Fluorescent (CFL) bulbs, the technology can play a key role in enabling electricity access with a lower carbon footprint. India's LED lighting market grew 130-fold in five years, from annual sales of 5 million bulbs per year in 2014 to about 670 million by 2018, while the price dropped dramatically from INR400 (USD6.4) in 2014 to about INR70 (USD1), as a result of government interventions. The market share for LEDs grew from 0.3% to 46%, surpassing that of incandescent, CFL, and tube light lamps. The main driver of India's rapid market creation was a policy initiative known as Unnat Jyoti by Affordable LEDs for All (UJALA), which procured LED bulbs for the national market through competitive bidding, allowing bulbs to be sold at profitable but lower-than-retail prices through kiosks and registered vendors. To make LED manufacturing in India globally competitive by removing sectoral disabilities, creating economies of scale, and enhancing exports, the government has implemented a PLI Scheme for White Goods and LED lights with a budget of INR6,238 crore. The scheme encourages the production of components or sub-assemblies like LED chip packaging, resistors, ICs, fuses, and other components of LED lights not manufactured in India in sufficient quantity by offering manufacturers a 4–6% incentive on the incremental sales.[5]

4.8 Enhancing energy efficiency of appliances through star rating

India's Bureau of Energy Efficiency (BEE) has established a star rating system for electrical appliances, which has helped in the adoption of efficient appliances. For example, there have been energy savings of 38% for air-conditioning units, 34% for refrigerators, 28% for water heaters, and 23% for washing machines. However, energy-efficient fans have failed to become popular because of significant cost differences, calling for government intervention to either subsidize more efficient fans or support the introduction of new technology to produce them more competitively (Ahluwalia and Patel 2022).

5 Industrial Policy for Decarbonizing the Transport Sector

The transport sector accounts for 14% of emissions in India. Hence, India has moved towards decarbonization through a switch-over to vehicles running on cleaner fuels and electric vehicles (EVs). India has also become a part of the global EV30@30 campaign,

[5] See https://www.investindia.gov.in/team-india-blogs/indias-led-sector-enhancing-local-ecosystem

targeting the goal of EVs accounting for at least 30% of new vehicle sales by 2030. To achieve this ambitious target, the Indian government has made several significant demand- as well as supply-side interventions, including incentives for the expanded local production of EVs, batteries, and their adoption, and the creation of a charging infrastructure.[6] As a result, EV penetration is already picking up. Electric two-wheelers (e-2Ws) in particular are becoming increasingly popular as their prices have become competitive with rising volumes and domestic competition. The domestic EV market is expected to reach 10 million annual sales by 2030, generating around 50 million direct and indirect jobs. EV adoption is targeted to reach 40% for buses, 30% for private cars, 70% for commercial vehicles, and 80% for two-wheelers by 2030.

5.1 Demand-side interventions

The Faster Adoption and Manufacturing of Electric Vehicles (FAME) scheme, initiated in 2015, provided an upfront incentive leading to a reduction in the effective price for customers for eligible vehicles produced in India. FAME II, launched in 2019 with a budget of USD1.2 billion, promoted hybrid/electric technology in transportation, supporting e-Buses, e-3Ws, and e-4Ws used in public transportation or for commercial use, besides e-2Ws. Furthermore, the government reduced the GST on EVs from 12% to 5% and the GST on chargers and charging stations for EVs from 18% to 5%. EVs also enjoy a waiver on road tax and are exempt from permit requirements for carrying passengers or goods. In addition, state-level EV policies tend to incentivize the adoption of EVs. The tax incentives on e-2Ws were, however, reduced when their cost was brought down to that of internal combustion engine (ICE) 2Ws.

FAME II was succeeded in 2024 by the PM Electric Drive Revolution in Innovative Vehicle Enhancement (PM e-DRIVE) Scheme to promote EV adoption in India through subsidies for buyers and funding for charging infrastructure. The scheme provides demand incentives for e-2Ws and e-3Ws, e-buses, e-trucks, and e-ambulances, while also supporting the establishment of public charging stations and upgrading testing agencies. In July 2025, the Ministry of Heavy Industries released guidelines for electric trucks under the PM e-DRIVE scheme—a vital first step in transitioning India's trucking sector. It is expected to support the deployment of approximately 5,600 e-trucks across the country (India, Ministry of Heavy Industries 2025).

5.2 Supply-side interventions

To foster domestic manufacturing of advanced technology products and investments in the value chain, a PLI scheme for the automotive sector was launched in September 2021, with a budget of USD3.1 billion. Several Indian companies have started manufacturing passenger EVs, including Tata Motors, Mahindra, and MG Motors. The manufacturers of electric buses include Olectra Greentech, VE (Volvo-Eicher), Tata Motors, the JBM Group,

[6] See https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1911399

and Ashok Leyland (through Switch Mobility), whose vehicles include e-double-decker buses. The e-2/3Ws segment has several players, including Greaves Electric Mobility, Ather Energy, ATUL Auto, Bajaj Auto, Electrotherm (India), Hero Electric Vehicles, Okinawa Autotech International, Omega Seiki Mobility (OSM), Ola Electric, Piaggio, and TVS Motor. What is important to note is the fact that some of these companies are also exporting EVs and e-2Ws from India, indicating a potential for India to emerge as a global manufacturing hub for e-2Ws and compact cars, a position it enjoys in the conventional ICE-based 2Ws. Several Indian state governments have introduced their own policies to create an enabling environment for EV purchase and local manufacturing, e.g. Tamil Nadu, Telangana, Gujarat, Maharashtra, Haryana, Rajasthan, Chhattisgarh, and Odisha.

Another notable fact is that local companies, namely Tata and Mahindra, have pioneered EVs in the passenger car segment, while leading MNC car makers, namely Maruti-Suzuki, Hyundai, Honda, and Toyota, have been rather slow to transition. Suzuki, the market leader in ICE-based passenger cars with a 45% market share in India, introduced its first EV only at the beginning of 2026. EV makers have been facing some challenges due to export restrictions imposed by China on rare earth magnets (REMs), a key component of EV motors. Some start-ups are working to develop motors that do not require REMs, while China agreed to relax restrictions in October 2025.

There is also a PLI Scheme for Advanced Chemistry Cell (ACC) Storage Batteries, launched in 2021 with a budget of USD2.1 billion to attract investment in the creation of giga-scale ACC manufacturing facilities in India with a capacity of 50 GWh. Three companies have been selected with a manufacturing capacity of 30 GWh and the second phase of the scheme is set to be launched soon. However, the strategy to build a large ACC battery manufacturing capacity based on lithium may face geopolitical challenges in view of the fact that the bulk of lithium resources and processing is controlled by China, creating a problem similar to that EV manufacturers are facing with respect to REMs.[7] Some companies have started producing lithium through the recycling of batteries by developing a circular chain, although it will be inadequate to meet the burgeoning demand.[8] In that context, India needs to explore the potential of sodium-ion and solid-state batteries among other technologies.[9] Therefore, India needs to step up R&D and innovation in the development of alternative chemistries that use materials abundantly available in the country and reduce dependence on imported materials.

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[7] See https://economictimes.indiatimes.com/industry/renewables/govt-mulling-another-production-linked-incentive-scheme-for-batteries-r-k-singh/articleshow/104463971.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst

[8] See https://www.india-briefing.com/news/indias-prospects-as-an-ev-hub-consumer-market-and-production-capacity-30157.html/

[9] See https://www.kpit.com/news/kpit-unveils-breakthrough-sodium-ion-battery-technology-to-alleviate-lithium-dependency/

5.3 Retrofitting existing vehicles

One option to increase the EV population in the country is retrofitting existing conventional ICE-based vehicles to convert them into EVs. In that context, SUN Mobility, a Bengaluru-based start-up and a battery-swap pioneer, has launched services for retrofitting ICE scooters, and plans to extend the swapping infrastructure across 22 cities.[10] Considering that there are 200 million scooters and over 10 million three-wheelers in the country, the retrofitting, which costs INR35,000 (around USD400) could help to multiply the EV population rapidly.

5.4 Innovation for green transport

Given the fact that the technology frontier for green industries is still evolving and yet to be matured, innovative activity can play an important role in helping Indian companies to take a leadership position in areas such as Li-Ion, Na-Ion, or solid state batteries, and solar PV cells. There is evidence that the legacy 2W manufacturers in India have increased their R&D activity in a significant manner in their race to retain their leadership, in the face of innovative new entrants such as Ola Electric, in the e-2W market. Annual R&D expenditure by top 2W companies has more than doubled over the past few years. For instance, between 2020/21 and 2024/25, R&D expenditure by Bajaj Auto rose by 47%, that of Hero MotoCorp by 93%, Eicher Motors by 105%, and TVS Motors by 210%.[11] This trend will hopefully be emulated by the producers of cars and commercial vehicles too, among other green industries.

5.5 Augmenting public charging infrastructure

The government has issued revised consolidated Guidelines and Standards for EV charging stations to expand the electric vehicle charging infrastructure nationwide, including private sector involvement, while petroleum marketing companies have announced plans to establish 22,000 EV charging stations in major cities and along national highways across the country. Infrastructure for battery swapping is also being strengthened. Ecosystem investments in charging and battery-swapping infrastructure, and urban planning guidelines support the development of electric mobility (Bhatt and Kodjak 2025).

6 Decarbonization of Traditional Manufacturing Sectors

Industry accounts for one-third of emissions in India. A substantial share of industrial emissions originates from a few highly energy-intensive core sectors—particularly steel, oil refining, and cement (the so-called hard to abate sectors)—while the remainder is

[10] See https://www.business-standard.com/industry/auto/sun-mobility-rewires-old-scooters-for-an-electric-second-life-125080401258_1.html

[11] See https://www.business-standard.com/industry/auto/ev-tech-focus-fast-tracks-rd-spend-hero-motocorp-tvs-cross-rs-1000-cr-125082501234_1.html

distributed across a diverse set of industries, including mining, brick kilns, pulp and paper, fertilizers, textiles, and petrochemicals.[12]

In 2012 the government introduced the Perform Achieve Trade (PAT) scheme mandating energy efficiency targets over a specified period for designated consumers (DCs) across sectors such as iron and steel, cement, aluminium, fertilizers, pulp and paper, and thermal power, including power plants and industrial installations. PAT is a cap-and-trade scheme that allows the trading of Energy Savings Certificates (ESCerts). The Bureau of Energy Efficiency (BEE) sets the targets for each of the DCs and those that overachieve their reduction targets are issued ESCerts. DCs failing to achieve the required levels must purchase ESCerts to pay for the shortfall. The PAT scheme operates in cycles of up to three years. The eighth cycle was notified in June 2023 and covers aluminium, cement, chlor-alkali, iron and steel, pulp and paper, and textiles, with a total energy saving target of 0.3370 million tonnes of oil equivalent (India, Ministry of Finance 2024: 183). The PAT scheme will be replaced by the Carbon Credit and Trading Scheme (CCTS) from 2026, as a part of the development of the National Carbon Market, envisaging a phased transition from voluntary carbon trading (via ESCerts) to a compliance cap-and-trade market. CCTS could also help India to address the challenge posed by CBAM and similar taxes imposed by the EU and UK governments on imports of carbon-intensive products such as steel and aluminium, especially if the CCTS imposed on them is similar to CBAM levies.

The inherent challenges in industrial decarbonization are primarily due to the high cost of the required technology, the lack of low-carbon alternatives, limited infrastructure, as well as the high capex requirements. In sectors such as aluminium and fertilizer production and petroleum refining, scrap recycling and the use of green hydrogen are being used as a part of decarbonization strategies. Cutting-edge technologies such as Carbon Capture, Usage, and Storage (CCUS) are also being encouraged through pilots in sectors such as iron and steel, and cement, both of which are also early adopters of green hydrogen.[13] The EU–India Clean Energy and Climate Partnership (CECP), signed in 2016, also aims to strengthen access to clean technologies through facilitating joint research initiatives and project development.[14] Among other areas, the CECP has a focus on RE integration with storage solutions and the hydrogen strategy.

Green hydrogen has emerged as an alternative to the use of fossil fuels as a feedstock for the decarbonization of both energy-intensive and hard-to-abate sectors. In steel-making, gH_2 can substitute coking coal for iron ore reduction; in fertilizer production, it can replace

[12] Note that the term 'hard-to-abate sectors' is used to refer to industries that are not necessarily energy-intensive but whose emissions are difficult to reduce on account of their process-related emissions and high heat requirements.

[13] See https://netzeroindia.org/industrial-decarbonization-in-india/#google_vignette

[14] See https://energy.ec.europa.eu/topics/international-cooperation/key-partner-countries-and-regions/india_en#:~:text=The%20EU%2DIndia%20Clean%20Energy,India's%20National%20Green%20Hydrogen%20Mission.

natural gas to make ammonia; and in oil refineries, H_2 is needed to desulphurize petrol and diesel. Currently, these industries are using grey H_2, which is more expensive (Ahluwalia and Patel 2022). However, the scaling-up of production of gH_2, bringing down its cost, can help to decarbonize these industries. In some sectors, decarbonization would require switching over to different processes—e.g. moving away from blast furnaces to arc furnaces for steel making—requiring access to significant financial resources as well as advanced technology. The government and industry need to work together to identify key sectors and requirements and create mechanisms for supporting them.

6.1 Cement

The cement industry has been part of PAT cycles since their inception, and in every cycle the industry has been able to overachieve its reduction targets. In PAT cycle I, it overachieved by 82% and in PAT cycles II and III, it overachieved by 49% and 75%, respectively (India, MOEFCC 2022).

6.2 Steel

Given its importance as a key core sector and India's role as the second-largest producer globally, steel is attracting much attention. The available technologies for producing green steel—where (green) hydrogen is used as a reducing agent in place of coal in ironmaking—are not yet commercially viable at scale. To address the challenge, in December 2024, the Indian government adopted a taxonomy that defines 'green steel' based on its carbon emissions intensity to encourage the adoption of sustainable production methods. It provides a framework for promoting green technologies by setting a benchmark for emissions thresholds, with the goal of driving investment in decarbonization and developing a green steel market. India's taxonomy uses a five-star rating system to categorize steel based on its emissions per tonne.

The Steel Research & Technology Mission of India (SRTMI) supports R&D and skill development for low-carbon technologies in steelmaking. In alignment with the country's Nationally Determined Contributions (NDC) targets under the Paris Agreement, steel is a sector with defined targets for reduction in CO_2 intensity from 3.1 tCO_2/tcs (2005) to 2.4 tCO_2/tcs by 2030.

The Indian government is also supporting pilot projects through funding to improve competitiveness. Under the National Green Hydrogen Mission, the Ministry of Steel has awarded seven pilot projects for the use of hydrogen in steel making.[15] These cover the use of 100% hydrogen in direct reduced iron (DRI) vertical shaft furnaces—to reuse the coal/coke consumed in the existing blast furnaces by using hydrogen—and for partial substitution of natural gas with hydrogen in vertical shaft-based DRI production.

[15] See https://steel.gov.in/green-steel-initiative

The government has also adopted a number of policies to encourage and facilitate green transition in the steel industry, including the following:

National Steel Policy

The National Steel Policy (NSP) puts special emphasis on steering the industry on a sustainable path through environmentally friendly practices, improved material efficiency,[16] use of new technology, and R&D to reach global efficiency standards in steel making (India, Ministry of Steel 2024). The government is considering a Green Steel mandate for a fixed share of green steel in the total output of the local steel-producing firms.

Green Public Procurement Policy

As part of the road map for greening the steel sector, the Green Public Procurement (GPP) Policy aims to increase government procurement of green steel from 2.2 million tonnes in 2026/27 (5% of total government steel procurement) to 10.6 million tonnes (15%) by 2031. The production of green steel is to be supported through interest subventions, financial incentives (such as subsidies under a PLI scheme), and a favourable regulatory environment (Narayan 2024). The GPP Policy ensures a sufficient offtake of green steel production, encouraging supply expansion to meet demand—particularly in infrastructure, which accounts for 40% of steel demand in India (Mazumdar 2025).

Steel Scrap Recycling Policy

Nearly 21% of total steel production in India is produced through the secondary (scrap-based) route, primarily using electric arc furnaces (EAF) and induction furnaces (IF) whose main input is ferrous scrap. Each metric tonne (mt) of scrap steel used in production results in an estimated reduction of emissions by 1.5 mt of CO_2. The Steel Scrap Recycling Policy 2019 promotes circularity, enhances scrap availability, and reduces import dependency. It aims for 35–40% of steel demand to be met via EAF and IF routes by 2030.

Though primarily used for the production of secondary steel under the EAF route, scrap steel is also used (although in limited quantities) in the basic oxygen furnace (BOF) route to enhance efficiency and reduce production costs. Domestic scrap supply in India is limited, the ship-breaking industry at Alang, located in Gujarat, serving as a key source—both due to its leading role in domestic ship recycling and as a major hub for processing imported scrap.

Electrification through RE of the secondary steel industry (SSI) sector, which is engaged in recycling scrap, could have a significant impact on overall emissions from the steel sector,

[16] i.e. lowering the iron ore intensity of steel production through measures such as improved beneficiation and pelletization of lower-grade ores, and higher process efficiencies in blast furnace and direct reduced iron routes.

also leading to corresponding savings in the use of iron by 1.4 mt, of coal by 0.74 mt, and of limestone by 0.12 mt.

7 From Linear to Circular Economy Approaches

Besides technological innovations, India is adopting a circular economy through various strategies such as extended producer responsibility (EPR). Key approaches include redesigning products for circularity, investing in advanced recycling and waste management technologies (e.g. co-processing plastic waste), fostering consumer awareness, and developing sectoral action plans.

The government has implemented various rules to control waste, such as Plastic Waste Management Rules, e-Waste Management Rules, Construction and Demolition Waste Management Rules, and the Metals Recycling Policy. These rules have been implemented in a bid to achieve sustainable economic growth. Committees have been formed for 11 focus areas to develop action plans for accelerating the transition from a linear to a circular economy. The committees will also take regulatory measures to ensure the efficient implementation of their recommendations and findings. The 11 focus areas are municipal solid waste and liquid waste, scrap metal, electronic waste, lithium-ion batteries, solar panels, gypsum, toxic and hazardous industrial waste, used oil waste, agricultural waste, tyre and rubber recycling, and end-of-life vehicles (ELVs). Focus is also on industries with high circularity potential, such as steel (utilizing scrap), cement (using fly ash), and textiles (fabric recycling and water reuse). Advanced technologies are being employed, like plasma pyrolysis for plastic waste and co-processing waste in cement kilns. The government is creating an ecosystem to support start-ups developing circular economy solutions, with a focus on technologies and business models that are both environmentally conscious and economically viable. It is also launching platforms like the National Plastic Waste Reporting Portal for online reporting to improve transparency and the management of plastic waste.[17]

A number of Indian companies have found fruitful business opportunities in the circular economy approach. For instance, Tata Steel devised a clever solution to its waste problem. They began selling slag, a byproduct of steelmaking, to cement companies. Cement companies, in turn, get cheaper raw materials. Similarly, ITC buys crop leftovers from farmers and turns this waste into paperboard for packaging their products. Mahindra Group's car recycling programme takes old vehicles apart and uses the materials in new cars. JSW Cement recycles fly ash from power plants and slag from steel mills for cement making.[18] Innovative ideas are also being generated for turning waste into useful products.

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[17] See https://blog.mygov.in/editorial/explore-new-avenues-in-indias-circular-economy/

[18] See https://hecs.in/circular-economy-in-indian-industries#:~:text=Based%20on%20waste%20generation%20and%20resource%20consumption,%2D%20fabric%20recycling%20and%20water%20reuse%20systems.

IIT Delhi, for instance, has developed a process to turn denim waste into high-quality knitted garments.[19]

8 Financing of Green Industrialization

Fostering new green industries as well as decarbonizing existing industries obviously requires major financial resources. It is estimated that to meet India's NDCs under the Paris Agreement, the nation will need to raise at least USD2.5 trillion between 2015 and 2030, or between USD160 billion and USD288 billion annually (Raj and Mohan 2025). Current green finance flows meet only a fraction of the resources needed to meet India's 2030 climate targets. The absence of a uniform, national 'green' taxonomy and standardized metrics creates confusion and raises concerns about 'greenwashing', deterring some investors. Many green projects have long gestation periods and high initial capital costs, which, combined with a perception of high risk, can lead to higher borrowing costs compared with conventional projects.

Given the scale of these challenges, financing has been a critical concern. India has attracted significant funding from global institutions such as the World Bank, Green Climate Fund, and Asian Development Bank (ADB), which have provided financial assistance for RE, climate resilience, and other sustainable projects. Indian companies, especially in sectors such as RE, transportation, and infrastructure, have increasingly turned to green bonds and sustainable investments to raise capital for environmentally friendly projects. The rise of environmental consciousness among Indian consumers and investors has also led to greater demand for financial products that align with sustainability principles.

India's green bond market is a growing segment of its financial landscape, designed to fund projects with positive environmental impacts and help the country to meet its significant climate financing needs. Both sovereign (government) and corporate green bonds are issued, with a total sustainable debt issuance reaching approximately USD55.9 billion by December 2024. The Indian government officially entered the green bond market in January 2023, issuing its first tranche of sovereign bonds worth INR8,000 crores to be exclusively used for public sector projects that reduce the carbon intensity of the economy, including RE (solar, wind), clean transportation (metro projects, rail electrification), energy efficiency (smart grids, green buildings), sustainable water and waste management, and biodiversity conservation. In total, the government raised over INR57,697 crore (approx. USD5.7 billion) between 2022/23 and 2024/25. The private sector, pioneered by Yes Bank in 2015, has also been a key driver, accounting for a large majority of India's green bond issuances. Major entities include NTPC, IREDA, PFC, and SBI, which often list their bonds on international exchanges such as those of London and Singapore. Municipal authorities in cities including Indore and Vadodara have also issued green bonds to fund local projects like solar power

[19] See https://www.indiatoday.in/education-today/news/story/iit-delhi-develops-process-to-turn-denim-waste-into-high-quality-knitted-garments-2769488-2025-08-11

plants and sustainable urban infrastructure (Singh and Shrivastava 2024). The market is regulated by the RBI and the Securities and Exchange Board of India (SEBI), which introduced disclosure requirements for 'green debt securities' in 2017, later aligning them with international standards (ICMA Green Bond Principles) to prevent greenwashing. Issuers must disclose environmental objectives, project selection processes, and ongoing reports on fund utilization and environmental impact, which are subject to external audits.

Driven by green industrial policy, solar PV, EVs, wind turbines, batteries, and green hydrogen value chains are taking shape and are attaining competitiveness to enter the export markets as scale builds up. India's experience in fostering green industrialization, through a unique and novel approach with limited fiscal resources, has attracted global attention. Direct fiscal expenditures by the state are kept at a minimum and narrowly scoped to specific technologies. Instead, most financing comes from state-owned enterprises and state-owned financial institutions, alongside financial de-risking by the distribution companies, with state-ensured demand and import barriers. Larsen (2025) finds the Indian experience of pursuing green industrialization with limited fiscal spending to be unique and debunks the myth that green industrial policy may not be feasible in countries under fiscal constraints or foreign resource flows. The evolving CCTS and the national carbon market is expected to provide an additional revenue stream for companies investing in emission-reduction projects.

9 Nudging Corporates and MSMEs Towards Net Zero

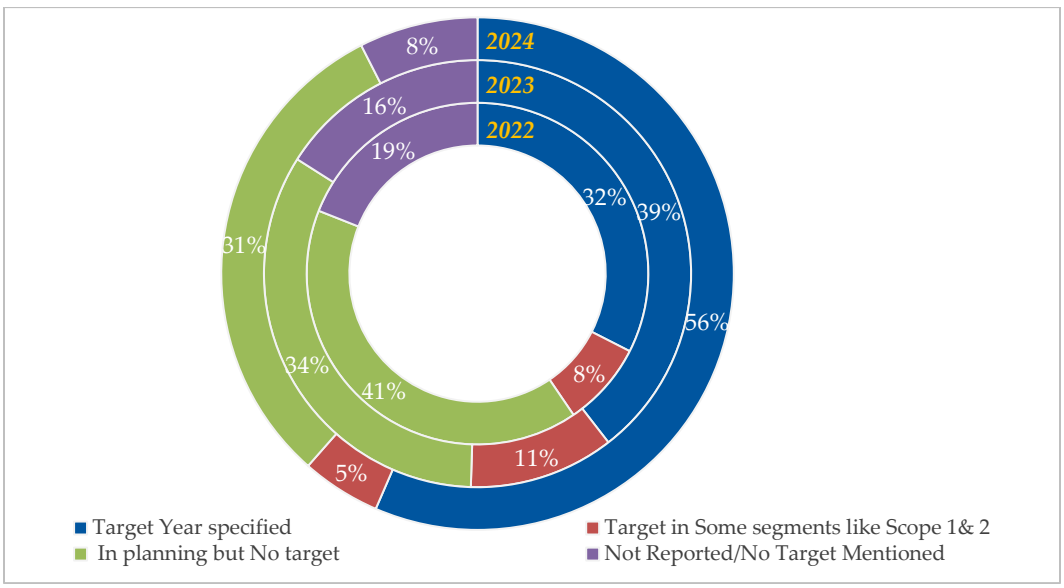
The adoption of sustainability practices by both large and small companies in the manufacturing sector is critical for the achievement of India's NZE goals. Hence, the Securities and Exchange Board of India (SEBI) introduced Business Responsibility and Sustainability Reporting (BRSR) disclosures, covering environmental, social, and governance (ESG) parameters, in May 2021. BRSR filing was required for the 1,000 largest listed companies (by market capitalization) voluntarily from 2021/22 and on a mandatory basis from 2022/23. BRSR is benchmarked to international sustainability reporting frameworks and provides detailed ESG data, both qualitative and quantitative. ISID analysed the BRSR returns of the top 200 manufacturing companies (all of which are among the top 1,000 companies required to report BRSR returns) across 15 manufacturing sub-sectors over the past three years, for which the data are now available (viz. 2022–24). Highlights of the analysis are summarized in the following sub-sections.

As will be shown below, the adoption of mandatory BRSR reporting has helped to enhance the environmental consciousness of Indian companies. More companies are adopting NZE targets, becoming conscious of reducing their carbon footprints, and adopting clean energy transition strategies. Their efforts are also being recognized at the global level. Over time, there is a need to deepen and broaden the scope of BRSR reporting. However, the vast bulk of Indian enterprises are MSMEs, which need to be sensitized towards adopting sustainable practices.

9.1 Adoption of NZE targets by companies

The trends in adoption of NZE targets among the 200 sample companies over the three years 2022, 2023, and 2024 are illustrated in Figure 2. It is observed that the share of sample companies that had mentioned a specific target year (2030, 2040, or later) for achieving carbon neutrality increased significantly from one-third of sample (32%) in 2022 to more than half of the sample (56%) in 2024. Including those that reported a target date in some segments (e.g. Scope 1 or Scope 2[20]) takes the total to 61% in 2024 compared with 40% in 2022 and 50% in 2023. As many as 31% of the companies in 2024 were in the planning stage for announcing a target date. The proportion of those reporting no target/no plan declined from 19% in 2022 to just 8% in 2024.

Figure 2: Distribution of sample companies by decarbonization target



Note: data labels show share (in %) of 200 sample companies.
Source: ISID computations based on annual reports of companies and web search.

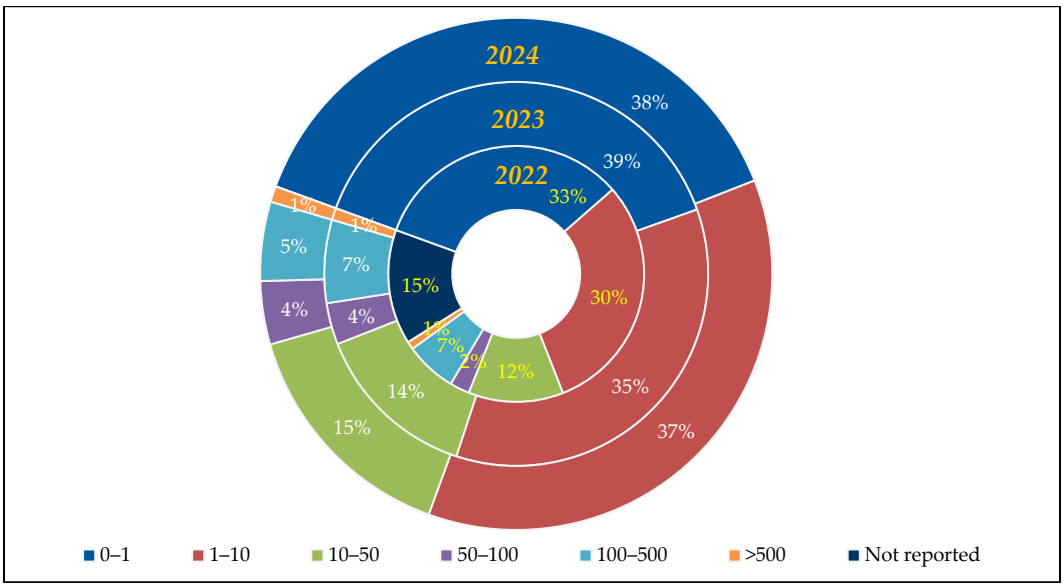
9.2 Trends in GHG emission intensity

The change in reported Scope 1 and 2 emission intensity (emission value expressed in $MtCO_2e$ per million rupees of turnover by 200 sample companies over the three years 2022,

[20] The globally followed framework of the Greenhouse Gas Protocol sorts greenhouse gas emissions into Scope 1 (direct GHG emissions that occur from sources that are owned or controlled by the company), Scope 2 (GHG emissions from the generation of purchased electricity consumed by the company), and Scope 3 (indirect emissions that are a consequence of the activities of the company but occur from sources not owned or controlled by the company): https://ghgprotocol.org/sites/default/files/standards/ghg-protocol-revised.pdf

2023, and 2024 is illustrated in Figure 3.[21] It can be observed that the share of sample companies that have Scope 1 and 2 emission intensity values of between 0 and 50 $MtCO_2e$ per million of turnover rose from 75% in 2022 to 88% in 2023 to 90% in 2024. This finding points to conscious efforts by the leading manufacturing companies to reduce carbon footprints through improved emission intensity.

Figure 3: Trends in emission intensity (Scope 1 & 2) of sample companies



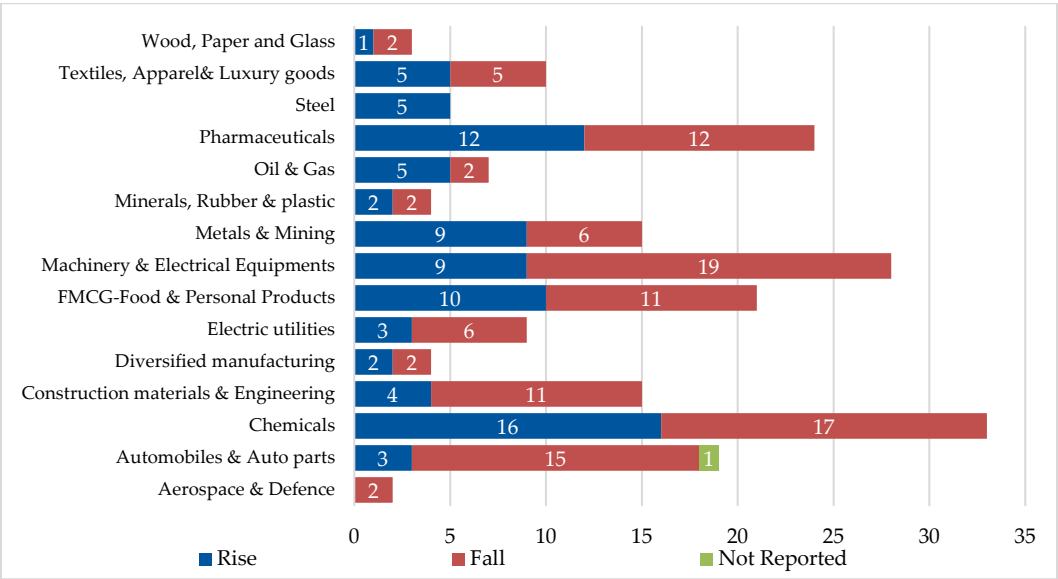
Note: data labels show share (in %) of the sample 200 companies. Emission intensity is measured in $MtCO_2e$ per million rupees of turnover. All sample companies reported their Scope 1 and 2 emission intensity in the years 2023 and 2024, but about 15% did not report their emission intensity in 2022, even though it was mandatory.
Source: ISID computations based on annual reports of companies and web search.

Different sectors of manufacturing face varying operational challenges in achieving emission reduction and decarbonization. Sector-wise change in Scope 1 and 2 emission intensity for the 200 sample companies over the 2022–24 period is indicated in Figure 4. A fall in Scope 1 and 2 emissions intensity is observed for the majority of sample companies in eight of the sub-sectors, and for half of the sample companies in four sub-sectors. This indicates conscious efforts towards reducing carbon footprint through improved environmental efficiency of production processes over this short period of just three years by most sample companies in these sub-sectors—which include various high-carbon-emitting manufacturing sub-sectors, such as machinery and electrical equipment, electric utilities, chemicals, automobiles and auto parts, and construction materials and

[21] Initially, emission values were expressed in annual reports in $MtCO_2e$ per rupee of turnover but, as companies reported in different units of currency (e.g. crores, thousands, millions, absolute rupees), the reported rupee values were standardized across companies in terms of million rupees and the final value for all companies in $MtCO_2e$ per million rupees of turnover was used for analysis in this study.

engineering (including cement production). However, in view of the data gaps in Scope 3 emission or intensity values, it would seem that achieving a complete value-chain decarbonization remains a major policy challenge in future, particularly in those sub-sectors associated with high carbon emissions.

Figure 4: Change in Scope 1 & 2 emission intensity for sample companies by sub-sectors in 2022–24



Note: data labels and horizontal axis show number of companies.
Source: ISID computations based on annual reports of companies and web search.

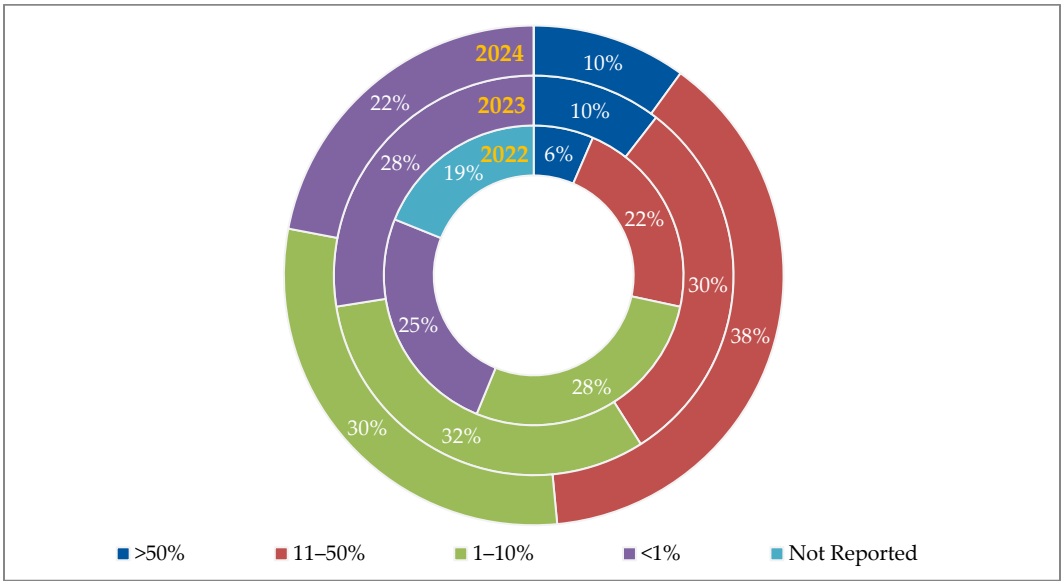
9.3 Clean energy transition

A key pathway to emission reduction is the clean energy transition. The distribution of the 200 sample companies by share of RE in total energy consumed in the years 2021, 2022, and 2023 is illustrated in Figure 5. The share of sample companies consuming between 11% and 50% of their energy from renewable sources increased steadily from 22% to 30% to 38% over the period, highlighting a positive consciousness and movement of manufacturing companies towards green transition. Moreover, 10% of the companies (up from 6% in 2022) were deriving over 50% of their energy requirements from renewable sources by 2024. Altogether, 48% of companies in 2024, up from 28% in 2022, were relying on RE significantly (more than 10%).

9.4 Sectoral patterns in clean energy transition

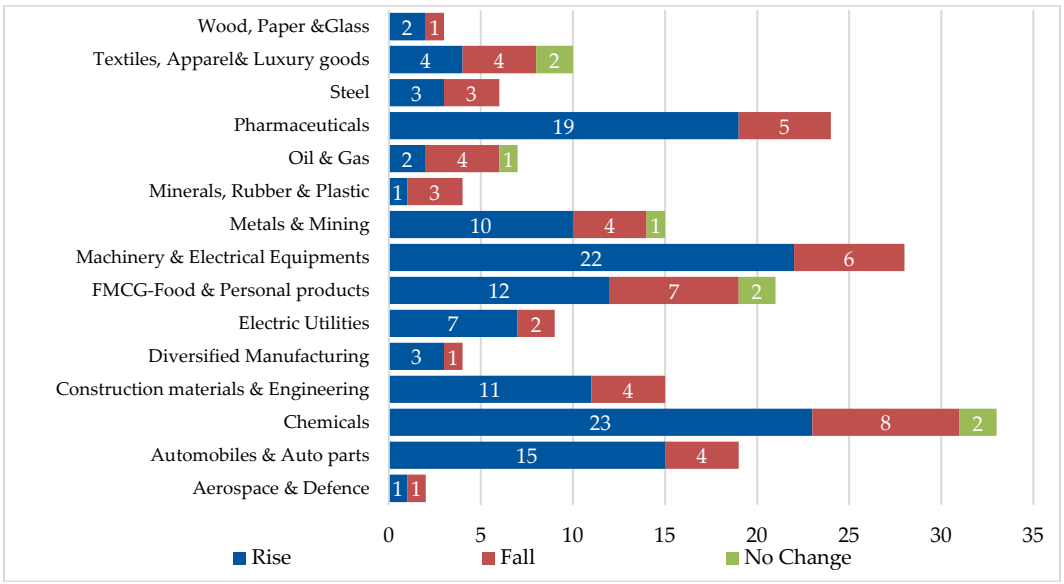
In 10 out of the 15 manufacturing sectors, the majority of companies reported a rise in share of RE in total energy consumption over the 2022–24 period (Figure 6). It is evident from this that companies across most manufacturing sub-sectors are effectively making efforts towards clean energy transition.

Figure 5: Distribution of sample companies by reliance on renewable energy in total energy consumed



Note: data labels indicate share (%) of 200 companies in each year.
Source: ISID computations based on annual reports of companies.

Figure 6: Distribution of sample companies by renewable energy transition across sectors in 2022–24



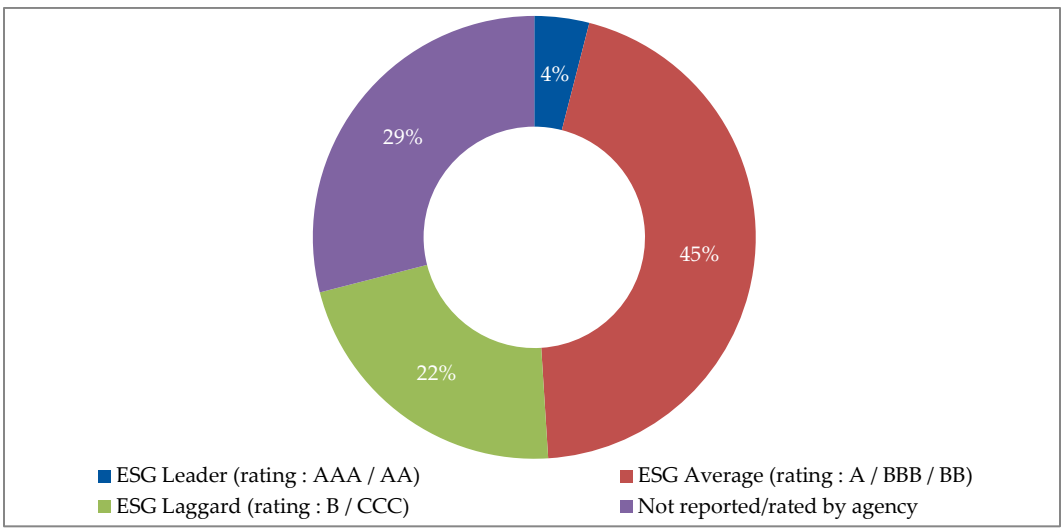
Note: data labels and horizontal axis indicate number of companies.
Source: ISID computations based on annual reports of companies.

9.5 Sustainability practices of Indian companies in a global comparative perspective

The sustainability practices of leading Indian companies are attracting global attention. For instance, eight Indian companies have been included among the 225 members globally of the World Business Council for Sustainable Development (WBCSD). Similarly, the S&P Global Sustainability Yearbook 2024, a benchmark for corporate sustainability performance, evaluated over 9,400 companies in 62 industries worldwide, only 759 having sufficiently high S&P Global Corporate Sustainability Assessment (CSA) scores to earn inclusion. As many as 33 Indian companies (including 21 manufacturing) featured among those 759 companies (ISID 2025).

MSCI, as a leading provider of analytical services for the global investment community, has been providing ESG ratings of Indian companies since 1999 and has produced time series data since 2007—initially on 2,900 and now on over 10,000 companies. Ratings are on a global seven-band scale from AAA (the highest ESG Rating) to CCC (the lowest[22]). These ratings are grouped into three categories: Leader (AAA and AA), Average (A, BBB, and BB), and Laggard (B to CCC). In the latest years' (2024 and 2023) ESG ratings of the top 100 Indian manufacturing companies, close to half of them were rated as Average, while four companies obtained Leader ratings and 22 were rated Laggards relative to industry peers[23] (Figure 7).

Figure 7a: ESG ratings of top 100 manufacturing companies by MSCI

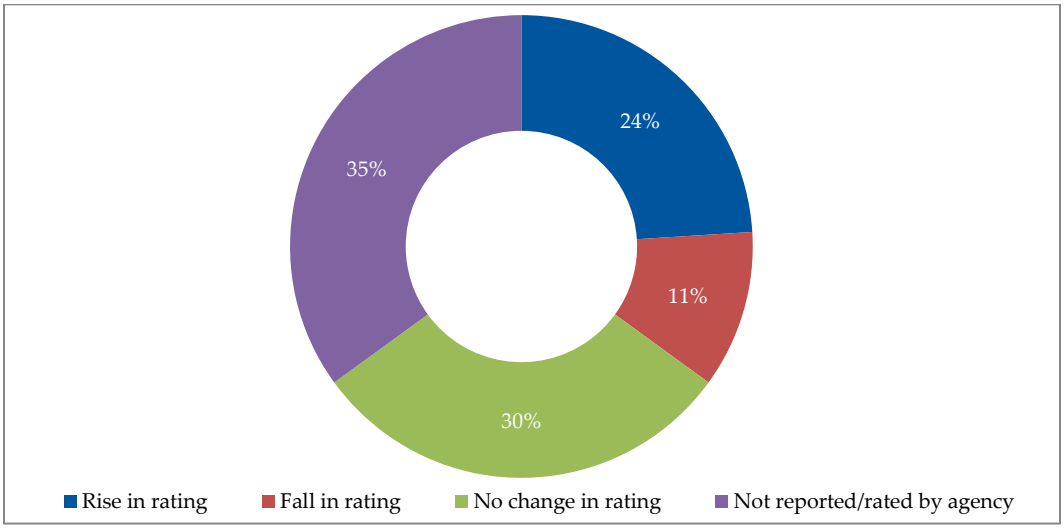


Note: Latest data: 2024 (24 companies), 2023 (47 companies).
Source: ISID (2025).

[22] There are no 'C' or 'CC' ratings in the scale; see https://www.msci.com/data-and-analytics/sustainability-solutions/esg-ratings

[23] See https://www.msci.com/our-solutions/esg-investing/esg-ratings-climate-search-tool; data were accessed between 25 and 31 May 2024. Reporting months vary across companies in any given year. Where there were two scores for a given company in any year, the latest score was recorded.

Figure 7b: Change in ESG rating of top 100 BSE manufacturing companies by MSCI (2019–23)



Source: ISID (2025).

9.6 Clean transition of MSMEs

The fragmented structure of India's many MSMEs, combined with their limited resources and low technological base, constrains their ability to adopt low-carbon pathways. Integrating MSMEs into decarbonization is important not only for lower emissions but also for inclusive and competitive growth across segments. The Ministry of MSME launched the Sustainable Zero Defect Zero Effect (ZED) Certification Scheme in 2022. Building upon the earlier ZED initiative introduced in 2016, the updated framework embeds sustainability as a pillar to encourage MSMEs to adopt practices that conserve energy, minimize waste, optimize resource use, and improve environmental consciousness, while simultaneously enhancing competitiveness in domestic and international markets. The scheme is voluntary and is open to all manufacturing MSMEs. It aims to create awareness, provide training, and extend both technical and financial support to facilitate the green transition of smaller enterprises. Key activities under the scheme are national and regional workshops, industry sensitization programmes, training for officials and consultants, gap assessments, certification, surveillance, and international benchmarking. The scheme also extends handholding support for process improvement, consultancy, and technology upgrading, thereby lowering the barriers for MSMEs to transition towards sustainability.

A distinctive feature of the ZED Certification Scheme is its graded recognition system, where enterprises are certified at three levels—Bronze, Gold, and Diamond—depending on the number of parameters assessed. The number of assessment parameters increases with the level of certification: 5, 14, and 20 parameters for Bronze, Gold, and Diamond gradings, respectively. Certification remains valid for three years and is issued against a nominal fee, with concessions for women-owned enterprises, units owned by members of disadvantaged social groups, and those located in North-Eastern, Himalayan, Left-Wing Extremism-affected, Island, and

aspirational districts. Firms participating in government cluster development initiatives such as SFURTI and MSE-CDP are eligible for an additional 5% fee waiver. ZED-certified MSMEs also receive financial assistance of up to 75% of the total cost of testing/certification (such as ISO certification), product testing, and lab approvals, the maximum subsidy being INR50,000 per year; and handholding support of up to INR200,000 for consultancy, and support in technology upgrading for zero-effect solutions of up to INR300,000.[24]

Besides certifications under the ZED scheme, much progress on the sustainability front by MSMEs could be achieved through common facilities created through self-help groups and cooperative approaches, as demonstrated by the Tiruppur Knitwear cluster (ISID 2025).

10 International partnerships and cooperation

International cooperation and partnerships, especially among the countries of the Global South, are critical to ensure sharing of development experiences and good practices, obviating the need to 'reinvent the wheel'. India has played an important role in building international partnerships and alliances to foster a clean transition, especially among Global South countries. These include the International Solar Alliance (ISA), established in 2015 jointly with France at the COP 21 in Paris to foster solar energy in tropical countries.[25] With 120 members or signatories, ISA's vision is driven by its 'Towards 1000' strategy, which seeks to mobilize USD1 trillion of investments in solar energy solutions by 2030 while delivering energy access to 1 billion people using clean energy solutions and resulting in the installation of 1,000 GW of solar energy capacity.[26]

India has also established the Coalition for Disaster Resilient Infrastructure (CDRI), an international initiative aimed at promoting the resilience of infrastructure systems to climate and disaster risks through research, knowledge-sharing, and capacity-building. Sweden and India co-chair the Leadership Group for Industry Transition (Lead-IT), a group of 18 major economies and companies that focus on decarbonizing heavy industries. One Sun One World and One Grid was created in 2021 with the UK to create grid connections to transmit solar power, as the sun is always shining somewhere (Ghosh 2023).

11 Concluding remarks and the way forward

The above discussion has underlined the compulsions and challenges of following the green industrial policy for India's industrial trajectory due to the NZE commitments it has made. Green industrial policy addresses greater market failures beyond industrial policy in general, given its potential to reduce dependence on imports of hydrocarbons and to mitigate urban pollution, which is becoming an important challenge in India's cities. Given that much of the

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[24] See https://blog.zedmsme.com/blog/government-subsidies-incentives-for-zed-certified-msmes/

[25] See https://pib.gov.in/PressReleaseIframePage.aspx?PRID=2071486#:~:text=The%20International%20Solar%20Alliance%20(ISA,energy%20access%20and%20climate%20change.

[26] See https://isolaralliance.org/about/background

country's energy and industrial capacity is yet to be built, green industrialization presents an opportunity to leapfrog into a more sustainable pattern of production. India has evolved strategies to raise its profile in the new green industries by creating a manufacturing ecosystem for solar PV modules, wind turbines, EVs and batteries, and green hydrogen, among others, through a variety of demand- and supply-side interventions. It has also adopted missions for enhancing energy efficiency in an effort to decarbonize traditional manufacturing sectors such as iron and steel, aluminium, and cement. However, decarbonization of some of the traditional industries would require efforts, resources, and technology beyond merely enhancing energy efficiency and switching over to gH_2. While government policy and actions are aimed at incentivizing investments in new green industries and decarbonizing the traditional sectors, the corporate response to today's sustainability compulsions is critical. In that context the analysis of the sustainability practices of a representative sample of the top 100 manufacturing companies in India through a review of their BRSR reports presents an encouraging picture. Leading Indian companies are setting a good example by adopting the net zero targets, their energy intensity and emission intensity is coming down, and attention paid to water conservation and recycling and sustainability of supply chains is rising. The sustainability practices of leading Indian corporates are also becoming recognized by the global benchmarking authorities, while MSMEs, which form the bulk of India's manufacturing sector in terms of numbers, are being encouraged by policy and incentives to adopt sustainable paths.

Some policy lessons that follow from the above analysis are as follows:

Industrial policy can help to foster competitive new green industries. The Indian experience of the past decade suggests that green industrial policy is clearly critical to harness the potential of new green industries that can become drivers of economic growth and the creation of decent jobs. Unlike traditional industrial policy, green industrial policy has to include both supply- and demand-side interventions.

Innovative activity can help in taking global leadership. Given the evolving state of some of these technologies—especially relating to sodium ion and solid-state batteries for EVs, and alternative technologies for solar cells and modules—large R&D programmes/missions may help India to obtain a leadership position in selected areas and give it leverage in others. Besides encouraging industrial R&D in emerging decarbonization technologies, India may incentivize the acquisition of knowledge in higher-value chain activities by encouraging joint ventures and outright buy-outs. There is also a need to understand India's complementary research capabilities across public research institutions to reorient its energy R&D (Gallagher and Easwaran 2022).

Supplies of critical minerals must be secured. Supplies of refined critical minerals and REMs are dominated by one country, which poses geopolitical risks and challenges. As these minerals form vital raw materials for some of the new green products, such as batteries, solar PV, wind turbines, and EVs, securing their supply is crucial if the green industrialization initiative of the country is not to be held up. India has established Khanij

Bidesh India Ltd (KABIL), a joint venture of public sector companies that undertakes the identification, acquisition, exploration, development, mining, and processing of strategic minerals overseas by building partnerships with mineral-rich countries (India, Ministry of Finance 2024). More such PLI schemes to ramp up local supply capacities, partnerships, and coalitions are therefore urgently needed.

Fostering corporate and MSMEs' sustainability is feasible. The SEBI mandate of BRSR reporting by the top 1,000 companies has the potential to foster good corporate sustainability practices by building peer pressure and stimulating investor interest. Hence, the reporting mandate could be extended gradually to the 5,000 top companies, then to 10,000 in the next few years. Furthermore, the scope of the BRSR reporting guidelines could be extended to cover some more desirable practices such as MSME development, indigenization of technology, and the progressive localization of supply chains. To build further stimuli to companies to implement sustainable practices, SEBI could require mutual funds and public financial institutions to take into account the BRSR reporting-based appraisal, along with financial performance and prospects, in their investment decisions. MSMEs, on the other hand, need to be supported to enhance their sustainability practices.

The carbon market needs to be developed to address the challenge of the CBAM as well as financing. The EU's proposed CBAM is going to be a big challenge for India's exports, particularly of steel. One of the options open to India is to impose its own Carbon Pricing Mechanism on the affected products at the same rate as the CBAM. This would obviate the CBAM and prevent double taxation. The revenue collected from carbon pricing could then be used to assist in decarbonizing Indian industry. Studies show that carbon taxes can also help to reduce emissions (Reserve Bank of India 2023).

New innovative financing instruments can facilitate decarbonization. India has evolved new and innovative ways to foster green industries with limited fiscal resources, but new instruments could include green bonds and green financing windows created by banks and other financial institutions. The greening of Germany's steel sector was facilitated by German development bank KfW's green loan programme, which helped to create an entirely new market for carbon-efficient steel (Mazzucato 2024).

International partnerships and alliances are vital to the Global South. India has played an important role in building international partnerships and alliances to foster a clean transition, especially in the Global South, by creating a new institutional architecture for sharing development experiences: viz. the International Solar Alliance (ISA), the Coalition for Disaster Resilient Infrastructure (CDRI), and the Global Biofuels Alliance (GBA). As a leading emerging economy, India's experiences and achievements could serve as a guiding light for other countries of the Global South, while new alliances on green supply chains, technology sharing, and securing supply chains of critical minerals could also be explored within the frameworks of Quad (bringing together Australia, India, Japan, and the US), the Indo-Pacific Economic Forum (IPEF), Brazil, Russia, India, China, and South Africa (BRICS), or I2U2 (India-Israel-US-UAE).

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