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India's Export Competitiveness In A Green Trade Era: Evidence From Environmental Goods And The CBAM

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Abstract: The paper examines India's evolving export competitiveness in environmental goods (EGs) within the context of the global transition to a low-carbon economy and the regulatory challenges posed by the European Union's Carbon Border Adjustment Mechanism (CBAM). Employing a mixed-method approach, the study combines descriptive trade analysis with the Revealed Comparative Advantage (RCA) framework and a sectoral vulnerability assessment. Data from ITC Trademap and UN Comtrade, based on the Asia-Pacific Economic Cooperation (APEC) classification of EGs, are analysed for the period 2015–2024. The findings reveal that India's EGs exports have grown more than twofold over the past decade, increasing from US$ 2.9 billion in 2015 to US$ 8.5 billion in 2024, though the share in overall merchandise exports remains modest at 1.9%. RCA results demonstrate diversification and improved competitiveness across clean technology categories, notably photovoltaic cells, electric motor parts, and renewable energy equipment. However, despite these gains, India's performance lags behind leading exporters such as China and the United States.

The paper also evaluates India's exposure to CBAM, identifying iron, steel, and aluminium exports as critically vulnerable due to their carbon intensity and high dependence on the EU market. The analysis highlights that while CBAM aims to prevent carbon leakage, it risks imposing additional compliance burdens on developing economies like India. Policy implications suggest that India must pursue dual objectives, expanding EGs exports through innovation and trade facilitation, while safeguarding broader export sectors against emerging climate-related trade barriers. Strengthened institutional support, decarbonisation pathways, and proactive engagement in international climate-trade diplomacy will be central to enhancing India's resilience and positioning in global green value chains.This study has been undertaken to investigate the determinants of stock returns in Karachi Stock Exchange (KSE) using two assets pricing models the classical Capital Asset Pricing Model and Arbitrage Pricing Theory model. To test the CAPM market return is used and macroeconomic variables are used to test the APT. The macroeconomic variables include inflation, oil prices, interest rate and exchange rate. For the very purpose monthly time series data has been arranged from Jan 2010 to Dec 2014. The analytical framework contains**.**

Index Terms - Environmental goods, Sustainable exports, Comparative advantage, Carbon Border Adjustment Mechanism, Green trade, Climate policy.

I. INTRODUCTION

Climate change is a quintessential collective challenge, while the costs of climate action may appear to outweigh the benefits for an individual nation but the aggregate gains from global emission reductions are significantly substantial. This paradox underlines the tension between green incentives at the national level and global imperatives. As the international community is advancing from national commitments to concrete regulatory action, the scenario of cross-border economic relations is also being restructured, placing further emphasis on aligning development strategies at country-level with global climate objectives. For emerging and ambitious economies like India, this presents a two-fold accountability, where climate commitments must not only address environmental responsibilities but also integrate seamlessly with the pursuit of inclusive and sustainable growth.

Trade is one of the relatively underexplored instruments in climate action, with the potential to facilitate access to energy-efficient goods and critical technologies, supporting both the energy transition and climate change adaptation, thereby contributing to more inclusive and sustainable patterns of development (United Nations Conference on Trade and Development [UNCTAD], 2019; World Trade Organization [WTO] & United Nations Environment Programme [UNEP], 2009; World Bank, 2020). The compelling need of leveraging this, enabling potential of trade becomes clearer when viewed against the mounting evidence on the economic costs of climate change. Kahn, Mohaddes, Ng, Pesaran, Raissi, and Yang (2019) find that a persistent increase in average global temperature by 0.04°C per year, in the absence of mitigation policies, will reduce world real GDP per capita by more than 7% by 2100. Each 1°C increase in global temperature reduces global GDP by about 12% (Bilal & Känzig, 2024). Meanwhile, increasing temperature volatility has been shown to depress growth rates in countries by roughly 0.3% per +1°C volatility increment (Alessandri & Mumtaz, 2022). Taken together these economic costs amplify the need of employing trade as a policy instrument to accelerate decarbonisation and economic resilience.

The global energy transition is also fundamentally reshaping patterns of comparative advantage in trade. The traditional fossil-fuel dependent economy was underpinned by hydrocarbon endowments, on the other hand the transitioning green economy increasingly rewards countries with renewable energy potential and the capacity to scale low-carbon technologies (World Bank, 2020; UNCTAD, 2021). Emerging economies including India, Brazil, and South Africa are already leveraging their solar and wind capacities to reposition themselves in global markets (International Renewable Energy Agency [IRENA], 2025). At the same time, advanced economies are consolidating their dominance in green industries through large-scale policy interventions. China's 14th Five-Year Plan on Modern Energy, the European Union's Green Deal, and the U.S. Inflation Reduction Act are the key policy interventions globally which provide both fiscal incentives and low-cost capital for renewable technologies (Zhang, Zhou, & Zhou, 2022; European Commission, 2020; White House, 2022).

For the aspiring *'Atmanirbhar'* and *'Viksit' Bharat,* policymakers need to simultaneously increase living standards, meet India's NDCs (including the *'Panchamrit'* commitments), and adapt to growing environmental risks. Consequently, Environmental goods (EGs) become strategic, on one hand they accelerate domestic clean-technology diffusion and at the same time are aligned with the ethos of *Vasudhaiva Kutumbakam*, facilitating India's contribution to the global public good by supporting equitable decarbonisation.

The Organisation for Economic Co-operation and Development (OECD) define the EGs and services industry as comprising "activities which produce goods and services to measure, prevent, limit, minimise, or correct environmental damage" (OECD, 1999, p. 9). This classification by OECD was analytically useful but limited in trade arena, as it contained 132 goods tied to older Harmonized System (HS)-2005 codes. Parallelly, the Asia-Pacific Economic Cooperation (APEC) in 2012 agreed on a narrower list of 54 EGs and the member countries committed to reducing tariffs on these goods to 5% or less by the end of 2020 (APEC, 2012). Meanwhile, the WTO attempted to advance a broader multilateral Environmental Goods Agreement (EGA), with proposals from the "Friends of Environmental Goods" group, but negotiations stalled in 2016 (WTO, 2016). In practice, the APEC list has become the de facto reference for empirical studies as it balances environmental relevance with trade practicality (Steenblik, 2021).

These varied EGs classification have broadly shaped measurement conventions and trade incentives for EGs, influencing supply responses worldwide. Amidst growing significance of EGs, taking into consideration the APEC classification, India's EGs exports have registered more than two-fold increase during the last decade supported by increased global demand for green technologies and India's gradual strengthening of production capacities in relevant green goods sector. Although the share of EGs in India's total merchandise exports improved, albeit modestly, from 1.1% to 1.9%, constituting a relatively small share of India's overall merchandise export basket. In terms of products also India's export portfolio is relatively constrained compared to other major players in EGs exports including China, USA, Japan and some countries of the European Union (EU). India has made measurable gains in export competitiveness for select EGs, yet its performance continues to across the EGs spectrum lags compared to peer economies.

While the discussion on EGs presents opportunities for green trade, regulatory shifts are simultaneously reshaping the arena of international trade. The EU's Carbon Border Adjustment Mechanism (CBAM), formally adopted in 2023 is currently in transitional phase and will apply in its definitive regime from 2026. The CBAM marks a pivotal development at the intersection of trade and climate policy. By pricing the carbon content of imports to mirror the EU's Emissions Trading System (ETS), CBAM seeks to prevent "carbon leakage." The CBAM initially covers only select industries including, cement, steel, aluminium, fertilizers, electricity, and hydrogen (European Commission, 2023; Cosbey, Droege, Fischer, & Munnings, 2019). However, CBAM like unilateral measures risk fostering "green protectionism," placing additional burdens on developing countries, which already face steep adaptation costs (Mehling, van Asselt, Das, Droege, & Verkuijl, 2019). Given the EU's position as India's second-largest export destination, industries covered by the regulation face elevated exposure to the compliance costs and market disruptions that CBAM may impose.

The remainder of the paper is structured as follows. Section 2 reviews the existing literature on EGs, comparative advantage, CBAM and literature on potential impacts of the regulation. Section 3 outlines the data sources and methodology employed for the empirical investigation. Section 4 presents and discusses the findings, and Section 5 concludes with summarizing the key outcomes accompanied by policy implications for key stakeholders.

II. Review of Literature

Environmental goods (EGs) are all the time more critical for advancing sustainable development. These goods offer a "triple dividend" by simultaneously contributing to environmental protection, technological upgradation, and economic growth. Empirical studies underscore that EGs can reshape comparative advantage within global trade, firm-level evidence from India confirms that greater renewable-energy intensity is associated with improved export performance in certain manufacturing sectors (Das, 2023). Cross-country and product-level analyses further demonstrate that jurisdictions with larger renewable energy usage and coherent industrial policy can cultivate competitive advantages in renewable-energy products (Kuik, Branger, & Quirion, 2019). Integration of institutional quality into trade theory further clarifies how governance and regulatory capacity influence a country's ability to leverage clean industries for economic and ecological gains (Shapiro, 2023).

For India, the role of EGs is particularly strategic. Despite being one of the fastest-growing economies, India's share in global trade of EGs remains modest, reflecting high dependence on intermediate inputs (Gupta & Prabhakar, 2025). Government of India has been implementing coordinated, demand-side measures (including, FAME and green hydrogen targets) (Ministry of Heavy Industries, 2019; Ministry of New and Renewable Energy [MNRE], 2023), supply-side instruments (PLI for solar and batteries) (Ministry of Heavy Industries, 2021), and regulatory programmes to build domestic capacity for EGs. Together with trade facilitation measures, these policies seek to raise production scale, lower unit costs, and improve export readiness for EG manufacturers.

Building on this policy and structural context, an important strand of literature has examined the extent to which countries, including India, hold RCA in environmental goods. These studies provide valuable insights into patterns of competitiveness, cross-country disparities, and the role of policy support in shaping green trade performance. Dahal (2018), studying about South Asia, finds that the region's environmental industries remain weak, with very few products achieving an RCA greater than one, though India performs relatively better than its immediate neighbours. Similarly, Kallummal (2014) demonstrates that India's RCA varies significantly depending on the classification list employed, while selected renewable energy technologies

such as solar modules and wind equipment exhibit competitiveness, India lags in most other categories. De Melo and Solleder (2018) further emphasize that under industrially oriented lists such as those of the APEC or WTO, most developing countries, including India, struggle to establish comparative advantage, though their performance improves when environmentally preferable products such as sustainable agricultural goods are included as a part of the EGs list.

Comparative evidence from other emerging economies highlights the role of sustained policy support in shaping green trade competitiveness. Xu, Liao, and Li (2023) observed that China's RCA in EGs has steadily increased from 2001 to 2020, with an average RCA above one, reflecting targeted industrial upgrading and state-led investment. India's uneven performance could be linked to weaker domestic regulatory pressures, stricter environmental regulations are positively associated with higher specialization in EGs, suggesting that India's comparatively less stringent policies may constrain its long-term competitiveness (Shapiro, 2023). Collectively, the literature on RCA broadly underscores both the opportunities and challenges for India in leveraging EG exports, particularly in the evolving global trade landscape shaped by instruments such as the EU's CBAM.

The EU's CBAM represents a landmark shift in global clean trade by making carbon content and environmental performance central to market access. While CBAM directly targets carbon-intensive sectors including steel, cement, and aluminium, its ripple effects may also influence environmental goods indirectly through compliance costs, reporting requirements, and the broader trend of "green protectionism" (Center for Strategic and International Studies [CSIS], 2023). Given CBAM's transitional implementation, the literature is dominated by ex-ante simulation and modelling studies. General equilibrium and CGE studies report heterogeneous welfare and trade impacts that depend critically on whether countries have domestic carbon pricing. Countries with such mechanisms may experience marginal welfare gains, with the United Kingdom being an exception, while those without are expected to face welfare losses. Export dependence on the EU market is a critical determinant of exposure; sectors with a higher EU share in their export basket are more vulnerable (Majumder, Mathur, & Pohit, 2024).

Other studies present contrasting estimates of CBAM's effects on India. Goldar et al. (2023) estimate that CBAM could lead to substantial trade contractions, with Indian iron and steel exports to the EU declining by 8–14% once carbon costs are internalized. In contrast, Majumder et al. (2023) argue that the effects may be minimal, predicting export reductions of only 0.07% for fertilizers, 0.62% for cement, 0.004% for aluminium, and 0.06% for iron and steel. These divergent results underscore empirical uncertainty and the sensitivity of outcomes to modelling assumptions and parameter choices. Complementary evidence from the World Bank's Relative CBAM Exposure Index highlights India's exposure, CBAM-related exports to the EU constituted about 19% of global CBAM exports, making India the third most exposed Asian economy by export dependence, with iron & steel and aluminium among the most exposed sectors (Park, Yamamoto, & Doong, 2023; World Bank, 2025).

Collectively, the literature highlights two interacting forces that frame India's policy challenge, primarily there is need to scale up EGs exports to capture green growth opportunities focusing on comparative advantage and secondarily the simultaneous requirement to assess potential impact on Indian industries from emerging trade regulations such as CBAM. Taken together, these strands of literature point to the need for a comprehensive understanding of how comparative advantage and regulatory pressures interact to affect India's exports, thereby assisting in more effective policy design and international trade strategy.

III. METHODOLOGY

The paper follows a mixed-method approach, combining descriptive EGs trade analysis with quantitative indicators of comparative advantage and regulatory exposure. The analysis starts with a descriptive overview of India's export performance in EGs, drawing on data from the International Trade Centre (ITC), UN Comtrade. The study follows the APEC classification of EGs, which comprises of 54 products at 6-digit HS sub-headings agreed upon in 2012. This list of 54 products at HS-6 has been updated to 61 products based on the updated HS classification of 2022. APEC list is chosen as it is widely applied in empirical literature and balances environmental relevance with trade practicality. Export values and growth rates are examined over 2015-2024, with disaggregation by major product categories and destination markets to establish a baseline of India's EGs trade profile. India's standing amongst top EGs exporters globally has been depicted followed by benchmarking of India's growth in EGs exports against Thailand, Vietnam, Indonesia, and Malaysia,

which are selected due to their baseline similarities with India starting from 2005, ensuring a consistent and comparable analysis.

To contextualize India's position in global EGs trade, comparative analysis is undertaken. India's relative competitiveness in EGs is measured using the Revealed Comparative Advantage (RCA) index developed by Balassa (1965). As per Balassa's (1965) measure, RCA index for country i for commodity j is:

$$RCA_{ij} = (x_{ji}/X_i) / (x_{jw}/X_w)$$

Where, x_{ji} : Exports of Commodity 'j' from Country 'i'

X_i : Total Exports from Country 'i'

x_{jw}: Total Exports of Commodity 'j' from World

X_w: Total Exports from World

An RCA greater than one indicates comparative advantage, while an RCA less than one indicates disadvantage. RCA values are calculated for each of the 61 EGs at the HS-6 level over the study period.

Finally, the last section elaborates on the EU's CBAM regulation and the potential Indian industry sectors which are anticipated to get impacted due to the regulation coming into effect. India's vulnerability to the EU's CBAM is evaluated by mapping the overlap between India's overall merchandise export basket and the EU's CBAM industry coverage. The vulnerability analysis employs a quadrant-based framework that categorizes sectors into four zones, critical vulnerability, persistent risk, early warning, and minimal exposure, based on India's export growth to the EU and the relative share of these product categories in the EU's import basket for the affected sectors.

IV. FINDINGS

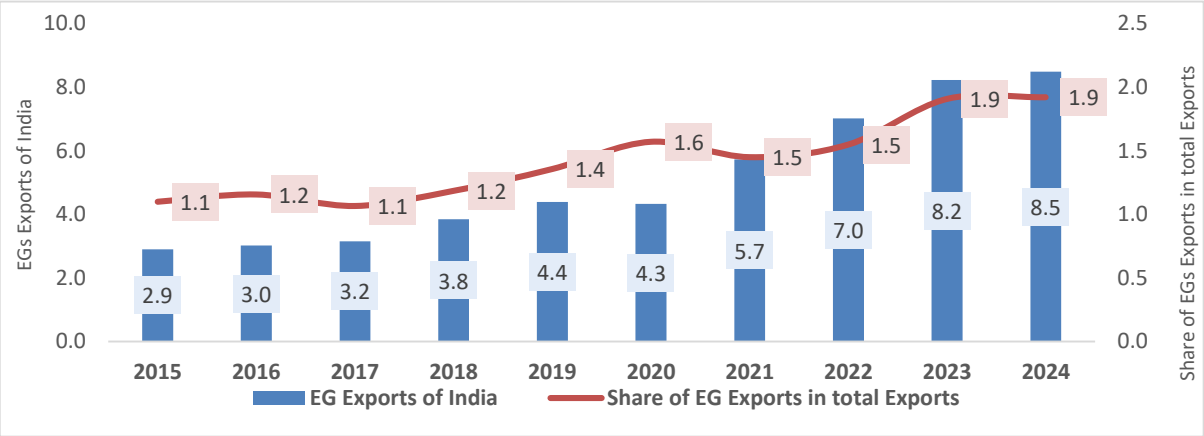
This section presents the empirical findings of the study in three sub-sections, aligned with the methodological framework.

4.1 India's EGs Exports Profile

During the last decade India's EGs exports have demonstrated a balanced upward trajectory, increasing from US$ 2.9 billion in 2015 to US$ 8.5 billion in 2024 **(Figure 1)**. The more than twofold increase reflects both expanding global demand for green technologies and India's gradual strengthening of production capacities in sectors such as renewable energy equipment, waste management technologies, and energy-efficient products.

The share of EGs in India's total merchandise exports has also improved, albeit modestly, from 1.1% to 1.9% during the last decade, reflecting the sector's growing significance, though it still constitutes a relatively small component of India's overall merchandise export basket. The sudden increase post-2015 is notable, as it coincides with global policy shifts toward low-carbon transitions largely stemming from the Paris Agreement in 2015, rising investments in renewable energy, and India's own domestic policy emphasis on solar and wind energy expansion under the National Action Plan on Climate Change (NAPCC). Another notable feature is the limited impact of the coronavirus pandemic and the swift recovery post-2020, reflecting India's resilience and the emergence of new market opportunities, particularly in Asia and Africa where competitive cost advantages strengthen its position.

Figure 1: India's EGs Exports (in US$ million) and share of EGs Exports in Total Exports (in %)



Source: ITC Trademap, UN COMTRADE

Table 1 highlights the evolving structure of India's top 10 EGs exports products. Aggregate EGs exports from India have registered a Compounded Annual Growth Rate (CAGR) of 12.7% during the last decade, underpinned by growing global demand for clean energy and sustainability-oriented technologies (UNCTAD, 2023). Once largely dependent on imports for its renewable energy generation, India is rewriting that narrative, with photovoltaic (PV) cells and panels (HS-854143) witnessing significant turnaround, from recording nil exports in 2015 and 2019 to now becoming India's leading EGs exports in 2024, amounting to US$ 1.5 billion. The demand is largely driven by the global solar boom, as countries pursue decarbonisation targets and expand renewable energy capacities (IEA, 2022). The largest importer for India's products under this category was the US, as it is one of the largest solar markets in the world. India leveraged the opportunity presented by the geopolitical tensions and the US's motivation to phase out Chinese imports wisely. However, the slight decline in India's exports in this segment in 2024, reflects vulnerability arising from price competition from China, which heavily dominates the global solar supply chain.

Parts for electric motors and generators (HS-850300) grew robustly recording a CAGR of 18.6%, supported by rising demand for renewable energy systems, electric vehicles, and electrification technologies (IEA, 2023). Similarly, parts of non-electrical engines and motors (HS-841290) recorded the highest CAGR among the major exports of around 21%, reflecting their importance in industrial machinery and sustainable manufacturing applications. Exports of mechanical appliances (HS-847989 and 847990) and parts of transformers/inductors (HS-850490) expanded steadily witnessing CAGR ranging between 8% to 13%, underscoring their role in enhancing energy efficiency and enabling low-emission industrial processes (WTO, 2022). Filtering equipment, both water purification machinery (HS-842121) and air/liquid filtration systems (HS-842199), also posted consistent growth, reflecting rising global demand for clean water and pollution control technologies, particularly in emerging economies facing acute environmental challenges (World Bank, 2021).

Table 1: Major EGs Exports of India (in US$ million)

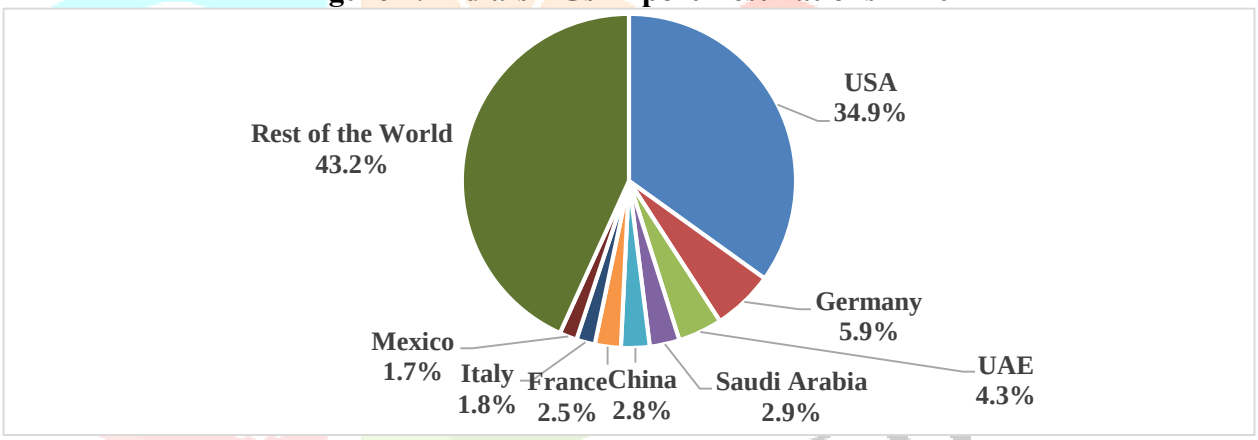
HS Code	Product	2015	2019	2023	2024	CAGR (10 years) in %
Total	**Total EGs Exports**	**2,900.7**	**4,386.4**	**8,230.3**	**8,487.6**	**12.7**
854143	Photovoltaic cells assembled in modules or panels	-	-	1,787.0	1,511.4	-
850300	Parts suitable for use solely or principally with electric motors and generators	278.0	692.3	1,145.7	1,294.9	18.6
847989	Machines and mechanical appliances, n.e.s.	305.1	377.0	533.1	599.5	7.8
850490	Parts of electrical transformers and inductors	186.6	281.9	449.3	498.6	11.5
847990	Parts of machines and mechanical appliances	123.5	214.3	305.2	357.8	12.5

HS Code	Product	2015	2019	2023	2024	CAGR (10 years) in %
841989	Machinery, plant or laboratory equipment, whether or not electrically heated	118.1	181.1	283.7	303.9	11.1
841290	Parts of non-electrical engines and motors, n.e.s.	52.6	96.4	219.1	282.0	20.5
903289	Regulating or controlling instruments and apparatus (excl. hydraulic or pneumatic)	199.1	226.4	279.6	258.5	2.9
842199	Parts of machinery and apparatus for filtering or purifying liquids or gases, n.e.s.	114.6	160.7	224.0	243.9	8.8
842121	Machinery and apparatus for filtering or purifying water	101.4	153.6	167.8	225.3	9.3

Source: ITC Trademap, UN COMTRADE

India's exports of EGs are primarily destined for economies with advanced sustainability commitments and significant demand for clean technologies. The USA emerges as a key destination, reflecting its high consumption of renewable technologies, pollution-control equipment, and environmentally friendly products **(Figure 2)**. Countries of the EU including German, France and Italy also absorb a significant share of India's EGs exports owing to its stringent environmental regulations and strong policy support for renewable energy and green industries.

Figure 2: India's EGs Export Destinations in 2024

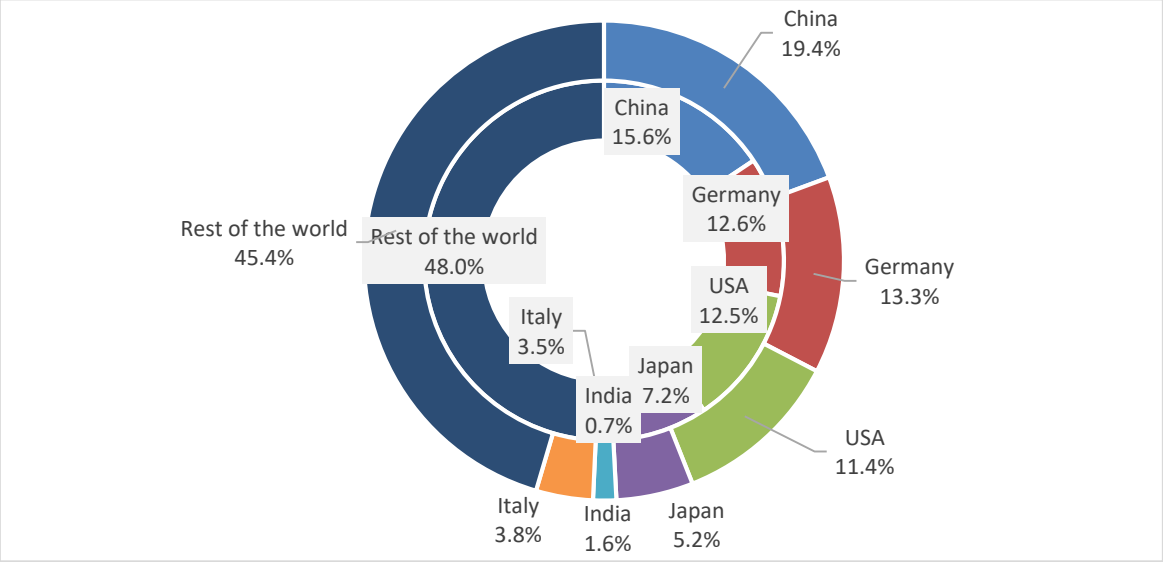


Source: ITC Trademap, UN COMTRADE

The geographical distribution of global EGs exports between 2015 (inner circle) and 2024 (outer circle) in **Figure 3** depicts a blend of continuity and structural shifts in global trade patterns. China has further consolidated its leadership, increasing its share in global EGs exports from 15.6% in 2015 to 19.4%, in 2024 underscoring its dominance in solar photovoltaic products, wind equipment, and other clean technologies. Germany and the USA remain significant players, though their relative shares show divergence, Germany has maintained a relatively stable position, while the USA's share declined moderately from 12.5% to 11.3%, reflecting slower export growth in clean energy manufacturing compared to domestic demand expansion.

A sharper relative decline is observed for Japan from 7.2% to 5.2%, pointing to competitiveness challenges and relocation of green technology production to lower-cost hubs in Southeast Asia. In contrast, India's global share has more than doubled, from 0.7% in 2015 to 1.6% in 2024, reflecting its expanding manufacturing base in solar modules, energy-efficient equipment, and related goods. Although still small in global terms, this increases signals India's emergence as a rising participant in EGs trade.

Figure 3: Top EGs Exporter in the World (in %) between 2015 and 2024



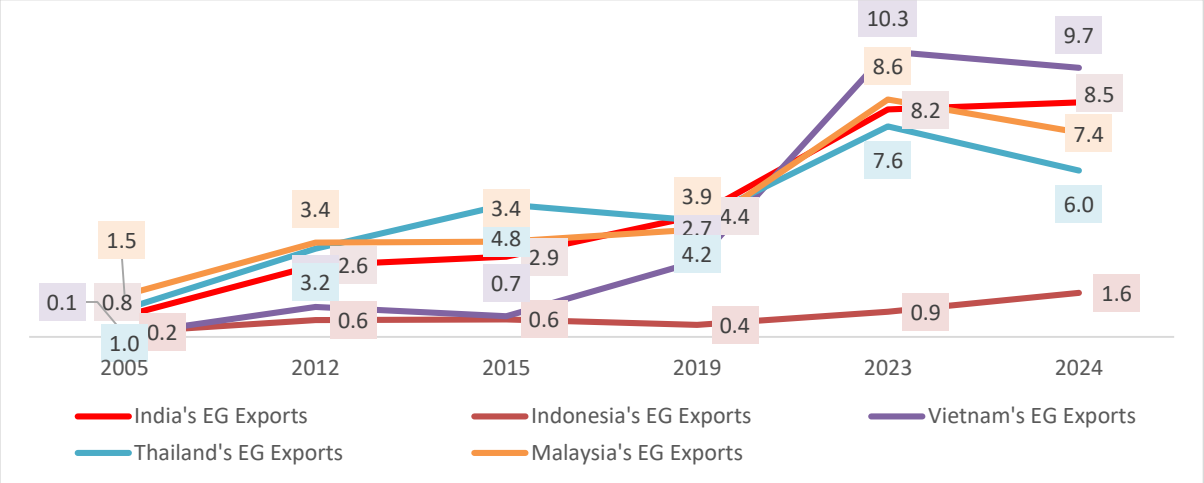
Source: ITC Trademap, UN COMTRADE

Figure 4 presents the evaluation of EGs export in countries including India, Indonesia, Vietnam, Thailand and Malaysia. As mentioned in the methodology section, the peer countries have been selected for better benchmarking of India's standing in EGs export. The comparative analysis highlights both regional dynamism and country-specific trajectories. India's EGs exports expanded more than tenfold, from US$ 0.8 billion in 2005 to US$ 8.5 billion in 2024, reflecting a steady and resilient upward trend. Growth in India's EG exports is underpinned by domestic policy thrust on renewable energy deployment and its cost-competitive manufacturing base, particularly in solar modules and energy-efficient equipment.

In contrast, Indonesia's exports remain relatively marginal, increasing from US$ 0.2 billion to US$ 1.6 billion, suggesting a limited industrial base in EGs sectors and heavy reliance on natural resource-intensive exports. Vietnam witnesses the sharpest take-off, with EGs exports starting behind India in 2005 at US$ 0.1 billion to reaching a peak of US$ 10.3 billion in 2023, before a slight dip in 2024. Nguyen (2022) highlights how Vietnam's proactive renewable energy policies, such as feed-in tariffs, legal reforms, and strategic investment incentives, have significantly accelerated the growth of its clean energy sector.

EGs export of Thailand and Malaysia exhibit more fluctuating trajectories. Thailand witnessed rapid rise in EGs export until 2015 reaching US$ 4.8 billion, but stagnated thereafter, suggesting competitive pressures and shifting production hubs in the region. Malaysia, meanwhile, maintained steady growth, peaking at US$ 8.6 billion in 2023 before moderating in 2024, likely reflecting cyclical global demand for electronics-related EGs. This comparative picture underlines both India's rising role and the heterogeneity of EGs export capacities across Asia.

Figure 4: EGs Exports of Select Peer Economies of India (in US$ billion)



Source: ITC Trademap, UN COMTRADE

4.2 Competitiveness Analysis

The paper employs the RCA index, originally proposed by Balassa (1965) to evaluate India's competitiveness in EGs exports. The RCA framework evaluates whether a country is relatively more specialized in exporting a particular product compared to the global average. An RCA value greater than one indicates a revealed comparative advantage, while a value less than one signals a disadvantage. Unlike absolute export growth figures, RCA provides a relative measure of competitiveness by controlling for the overall size of a country's exports and the global trade structure.

RCA comparison for India between 2005 and 2024 allows for a clearer understanding of the evolvement of country's competitiveness in global green exports scenario. Comparative RCA helps in understanding whether the almost ten times growth is absolute exports is also accompanied by a strengthening of comparative advantage or not. The cross-year comparison captures both the early stage of India's engagement with EGs exports and the subsequent evolution under the influence of global decarbonisation commitments, domestic renewable energy expansion, and integration into international supply chains.

The following **Table 2** presents India's RCA values for 2005 and 2024 for EGs with export value of greater than US$ 100, enabling an evaluation of shifts in competitiveness over the past two decades.

Table 2: RCA comparison for India's EGs Exports

HS Code	Products	RCA	
		2005	2024
854143	Photovoltaic cells assembled in modules or made up into panels	-	1.77
850300	Parts suitable for use solely or principally with electric motors	0.37	2.76
847989	Machines and mechanical appliances, n.e.s.	0.21	0.57
850490	Parts of electrical transformers and inductors, n.e.s.	0.80	1.71
847990	Parts of machines and mechanical appliances, n.e.s.	1.19	0.86
841989	Machinery, plant or laboratory equipment, whether or not electrically heated	0.95	1.41
841290	Parts of non-electrical engines and motors, n.e.s.	0.78	1.71
903289	Regulating or controlling instruments and apparatus	0.11	0.64
842199	Parts of machinery and apparatus for filtering or purifying liquids or gases, n.e.s.	0.49	0.71
842121	Machinery and apparatus for filtering or purifying water	0.27	0.99
850231	Generating sets, wind-powered	1.28	1.85
841199	Parts of gas turbines, n.e.s.	0.06	0.39
903180	Instruments, appliances and machines for measuring or checking	0.06	0.36
901580	Instruments and appliances used in geodesy, topography, hydrography, oceanography and hydrology	0.37	1.57
850164	AC generators "alternators", of an output > 750 kVA (excl. photovoltaic generators)	0.53	2.20

HS Code	Products	RCA	
		2005	2024
902610	Instruments and apparatus for measuring or checking the flow or level of liquids	0.49	1.00
842139	Machinery and apparatus for filtering or purifying gases	0.07	0.34
841990	Parts of machinery, plant and laboratory equipment	0.97	0.82
842129	Machinery and apparatus for filtering or purifying liquids (excl. such machinery and apparatus	0.12	0.42
847420	Crushing or grinding machines for solid mineral substances	0.72	1.57

Source: ITC Trademap, UN COMTRADE

The data presented in above table illustrate a marked structural shift in India's EGs export profile over the past two decades. In 2005, India displayed revealed comparative advantage (i.e. RCA ≥ 1) in only a few categories, notably wind-powered generating sets (HS-850231), parts of machines and mechanical appliances (HS-847990), and parts of laboratory equipment (HS- 841990). This reflects a relatively narrow specialization, largely concentrated in select machinery-related exports.

By 2024, India's RCA has broadened considerably, with multiple categories recording significant improvements. Photovoltaic (PV) cells and panels (HS-854143) emerged as a major strength with an RCA of 1.77, as a result of demand side push from expanding global demand and supply side incentive through schemes like PLI for high-efficiency solar PV modules and import substitution (safeguard and customs duties on Chinese imports) spurring domestic manufacturing and export growth.

Similarly, parts for electric motors and generators (HS-850300) recorded the sharpest rise in RCA from 0.37 in 2005 to 2.76 in 2024, highlighting India's integration into the global electric mobility value chains. Other categories such as large AC generators (HS-850164), gas turbine parts (HS-841199), and geodetic and hydrological instruments (HS-901580) also witnessed strong upward trends, pointing to diversification and technology upgrading.

Machinery related to water purification (HS-842121 and HS-842199) and air filtration (HS-842139) registered steady improvement in RCA reflecting domestic regulatory pressures and environmental challenges, which spurred technological adoption and manufacturing scale-up. Coupled with growing global demand for affordable sustainable solutions, enabling Indian firms to expand their export competitiveness in these sectors.

Taken together, the shift in competitiveness demonstrate a clear transition from India's earlier concentration in a limited set of machinery-related EGs towards a more diversified and technologically sophisticated export basket. However, sustaining this momentum will require continued policy support, innovation, and deeper integration into global green value chains.

4.3 Carbon Border Adjustment Mechanism

The European Union's, Carbon Border Adjustment Mechanism (CBAM) is a regulation for climate–trade policy with an aim to address carbon leakage by aligning the carbon cost incurred on imports with that borne by EU producers (while exporting) under the Emissions Trading System (ETS) (European Commission, 2021; Mehling et al., 2019). The ETS sets a limit on total emissions and allows companies to buy or sell permits, thereby putting a price on carbon to incentivize cleaner production. CBAM is one of its kind pioneering comprehensive carbon border adjustment schemes globally, attracting significant academic and policy debate (Cosbey et al., 2019), with particular concern regarding its implications for developing countries including India (UNCTAD, 2021)

CBAM is currently in transitional phase and will be applied in definitive regime from 2026. This gradual introduction is aligned with the phase-out of free allowances under the EU's ETS to support the decarbonisation of the EU industry. Several countries have objected to CBAM in response to which the EU has advanced two primary justifications. Firstly, that without the regulation it would be difficult for the EU to meet their net-zero emissions goal by 2050 and secondly that the EU's heavy industry is already paying more for emissions and without any prominent import tariffs, domestic industries would simply be forced out

of business by cheaper imports from countries without a carbon tax. Taken into consideration the lower tariff structures for polluting goods in comparison to green goods, bringing tariffs on polluting goods in line with those on clean goods would make a significant contribution to reducing carbon emissions.

The EU was India's second largest merchandise export destination in 2024 accounting for 17.8% of India's total merchandise exports in 2024, amounting to US$ 78.8 billion. In the EU, Netherland was India's largest export destination accounting for 5.6% of total merchandise exports, followed by Germany (2.4%), Italy (1.9%), France (1.8%) and Belgium (1.5%), among others. India's top export items to the EU include, petroleum oil, mobile phones, pharmaceuticals, diamonds, motor parts, electrical equipment and aluminium articles, among others.

While India's export basket to the EU is diverse, certain carbon-intensive sectors stand out for their vulnerability under emerging climate-trade regulations Based on high risk of carbon leakage and high emission intensity, CBAM will initially apply to exports of goods to the EU in the sectors including, cement, iron and steel, aluminium, fertilizers, hydrogen and electricity.

Impact of CBAM on India

The EU has encountered significant international opposition from many developing nations over the implementation of the CBAM, primarily from Brazil, South Africa, India and China, the BASIC countries, which is a group of the 4 large, newly industrialised, developing nations. In the ongoing transition phase of CBAM, exporters (through their EU importers) are required to report emissions embedded in goods they export to the EU, however there are no financial obligations regarding CBAM certificates as of now. Government of India and impacted industry sectors have raised apprehensions about sharing sensitive and confidential data with the EU to comply with reporting requirements.

In addition to CBAM, India's trade competitiveness is also expected to witness potential strain from new carbon pricing initiatives in partner economies. The United Kingdom (UK) has announced the introduction of its own CBAM from 2027, covering sectors such as steel, aluminium, cement, fertilisers, and hydrogen, aligned with the UK ETS (UK Government, 2023). Japan is similarly advancing its Green Transformation Emissions Trading Scheme (GX-ETS), to begin in 2026, along with a proposed carbon surcharge by 2028 (RIETI, 2023). These parallel measures, alongside the EU CBAM, underline the urgency of analysing sectoral vulnerabilities and designing suitable policy responses for India.

Table 3 presents broad sector-wise exports from India which will are covered under CBAM. The Annex II of CBAM regulation specifies Combined Nomenclature (CN) codes which are the EU's 8-digit customs classification system derived from the Harmonized System, used for tariff and trade statistics. The sector-wise data has been organized on the basis that, at the 4-digit level, CN codes align directly with HS-4 classifications. The analysis reflects the uncertainty arising to aluminium and iron and steel exports, with the EU being a major export destination for these products for India.

In 2022, India's aluminium exports to the EU were valued at approximately US$ 2.5 billion (**Table 3**). This accounted for nearly 23% of the country's total aluminium exports under the CBAM impacted HS codes, highlighting the concentration of EU as a major destination in India's export basket. However, following the introduction of the transition phase of CBAM, there was a significant decline in aluminium exports to the EU. By 2024, the EU's share has dropped to just 15% in total aluminium exports, with the export value reduced to less than half to US$ 1.09 billion. This decline in exports of aluminium products highlights the diminishing importance of the EU as a destination for Indian aluminium exports and reflecting the potential trade disruptions posed by evolving climate-related regulatory frameworks. As for iron and steel, the aggregate exports have seen moderation post the implementation of transition phase. For other sectors including, cement, chemicals, electricity and fertilizer the impact is relatively less significant because of the absence of exports under CBAM regulated product categories or the export concentration being less in absolute terms.

Table 3: Category-wise Exports of India to European Union for goods covered under CBAM (US$ millions)

Category		Aluminium	Cement	Fertiliser	Iron and steel	All CBAM products
	2019	436.7	2.3	0.2	3,269.8	3,709.1

Value of India's exports to the EU	2020	371.2	2.5	0.3	2,602.9	2,976.9
	2021	1,595.5	4.7	0.4	6,802.4	8,403.0
	2022	2,479.7	13.5	0.7	5,298.9	7,792.8
	2023	972.1	8.8	2.0	5,460.3	6,443.2
	2024	1,092.1	15.1	2.4	5,024.1	6,133.7
AAGR 2023 -2024		12.3%	72.0%	23.0%	-8.0%	-4.8%
CAGR 2005 – 2024		19.4%	10.8%	10.5%	10.6%	10.9%
EU's share in India's Total Exports	2023	13.5%	17.1%	2.1%	30.3%	24.0%
	2024	15.1%	23.9%	2.2%	29.6%	24.0%

Source: ITC Trademap, India EXIM Bank research

The above table focused on exposure of India's broad sectoral exports to the EU's CBAM. In contrast, **Table 4** disaggregates the impact of CBAM at the HS-4 level using CN codes, allowing a more granular examination of the product groups subject to CBAM regulations. The table below considers product categories with exports of more than US$ 200 million from India to the EU in 2024. The cells highlighted in red show the products where the share of the EU exceeds 50% in India's total merchandise exports, indicating high dependence on the EU as a destination for the exports of corresponding goods.

Within CBAM-covered products, under aluminium, unwrought aluminium (CN-7601) and under iron and steel, flat-rolled iron and steel products (CN-7208, 7209, 7210) emerge as the highly vulnerable categories. For instance, flat-rolled products of non-alloy steel, hot- or cold-rolled (CN-7210), recorded exports of nearly US$ 960 million in 2024, with the EU accounting for 76% of India's total exports in this category. Similarly, cold-rolled products (CN-7209) show a very high EU concentration, with 88% of India's exports destined for the EU market. On the aluminium side, unwrought aluminium (CN-7601) recovered strongly in 2024 with a 20% AAGR, reaching US$ 792 million, though EU share remains significant at 16%.

There are also several iron and steel products witnessing declining or volatile trends, underscoring their vulnerability under CBAM. Notably, hot-rolled flat products (CN-7208) fell by 17% between 2023 and 2024, while exports of screws, bolts, and fasteners (CN-7318) contracted by 20%. Despite these declines, the EU continues to absorb a significant portion of India's exports in these product groups, making them highly exposed to the financial implications of CBAM.

The early decline in exports of select products in the last 2 years signals how carbon pricing and regulatory uncertainty are already affecting India's competitiveness. This highlights the urgent need for the Indian iron and steel sector to transition toward low-emission production methods in order to retain market access and avoid future carbon costs. Collaborative R&D and global partnership is very essential for navigating the export market for countries like India predominantly emission intensive, and fossil fuel based in their manufacturing processes.

Table 4: Major goods exported by India to the EU covered by CBAM regulations (in US$ million)

CN Code	Product label	Category	India's exports to EU 2022	India's exports to EU 2023	India's exports to EU 2024	AAGR 2023 - 2024	Export share of EU in total exports 2024
TOTAL	**All products**		**73,457.9**	**75,221.8**	**78,763.7**	**5%**	**18%**
7210	Flat-rolled products of iron or non-alloy steel, of a width >= 600 mm, hot-rolled or cold-rolled	Iron and steel	521.4	936.4	960.4	3%	76%
7208	Flat-rolled products of iron or non-alloy steel, of a width >= 600 mm hot-rolled, not clad	Iron and steel	810.9	1,135.6	940.2	-17%	60%
7601	Unwrought aluminium	Aluminium	2,088.5	658.7	792.4	20%	16%
7222	Other bars and rods of stainless steel; angles, shapes and sections of stainless steel, n.e.s.	Iron and steel	522.7	545.8	514.4	-6%	47%
7326	Articles of iron or steel, n.e.s. (excl. cast articles)	Iron and steel	305.8	298.7	308.9	3%	22%
7209	Flat-rolled products of iron or non-alloy steel, of a width of >= 600 mm, cold-rolled "cold-reduced"	Iron and steel	185.7	303.0	303.7	0%	88%
7318	Screws, bolts, nuts, coach screws, screw hooks, rivets, cotters, cotter pins, washers	Iron and steel	333.6	306.1	245.5	-20%	28%
7202	Ferro-alloys	Iron and steel	184.5	255.3	221.0	-13%	15%
7219	Flat-rolled products of stainless steel, of a width of >= 600 mm, hot-rolled or cold-rolled	Iron and steel	298.7	161.2	218.0	35%	39%
7304	Tubes, pipes and hollow profiles, seamless, of iron or steel (excl. products of cast iron)	Iron and steel	239.8	222.2	201.1	-10%	43%

Source: ITC Trademap, India EXIM Bank research

Vulnerability assessment of Indian Exports under CBAM

A quadrant-based assessment of the vulnerability of Indian exports under the CBAM has been undertaken in the current section, based on two key axes, the **vertical axis** (measures CAGR of value of India's exports to the EU for 2005 to 2023) is split at **0.0837(8.37%)**, reflecting a practical growth threshold obtained from the CAGR of all products exported by India to the EU between 2005 to 2023. Although there is an uneven split of the quadrants, and higher CAGR values such as 20% may appear significant numerically but they are relatively rare and would place the majority of concerned sectors below the cut-off line, undermining the purpose of quadrant-based classification. Therefore, the chosen benchmark enables effective differentiation between growing and stagnant trade shares and reflects the present trends.

Similarly, the **horizontal axis** (measures EU's share in India's exports basket in 2023) is separated at 0.17 **(17%),** representing a high-dependence threshold, this is also chosen based on the EU's share in India's total merchandise exports in 2023. A sector with 17% or more of its exports directed towards the EU is considered

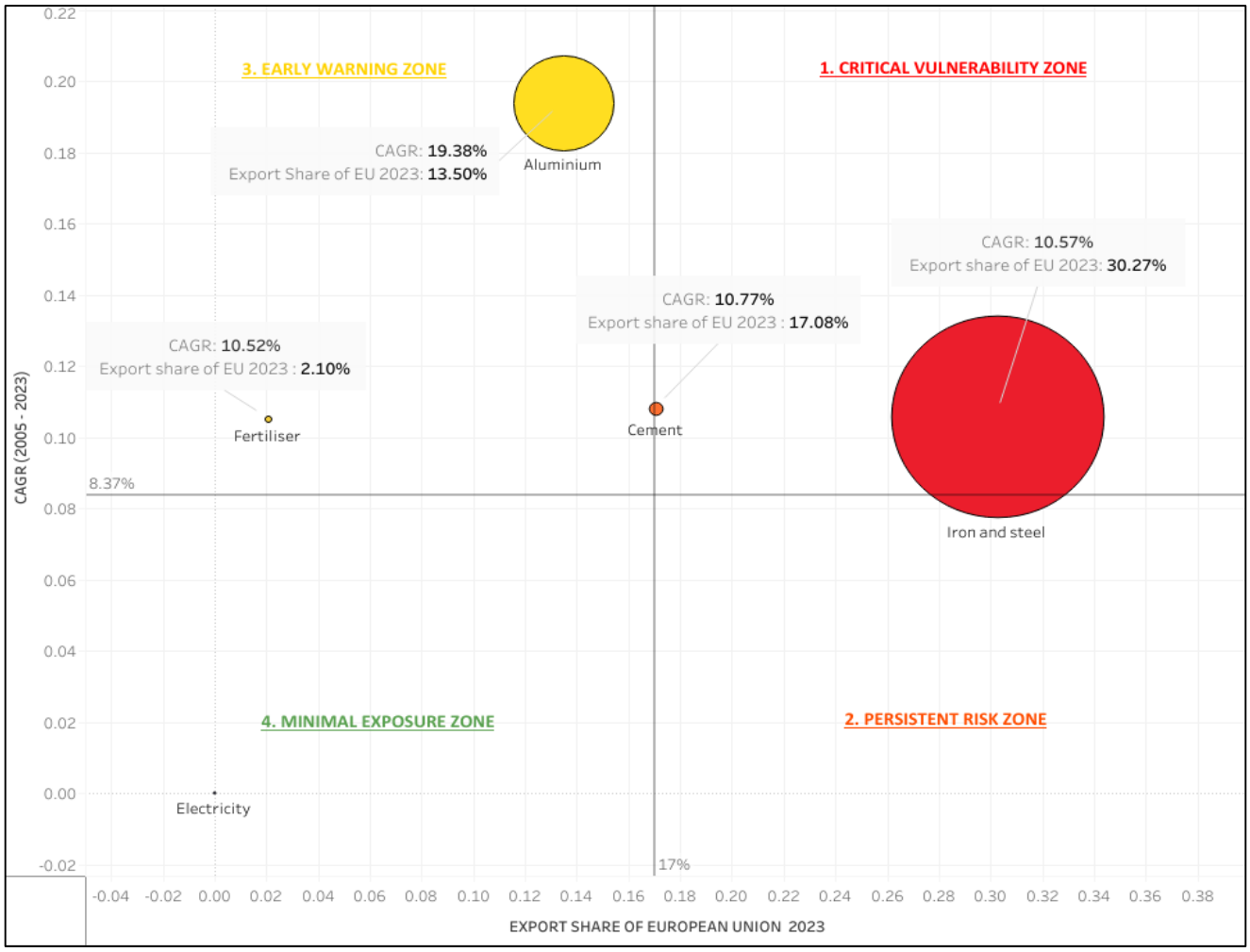
substantially reliant on that market, and thus more vulnerable to the CBAM. This threshold captures sectors with both current trade significance and regulatory exposure.

The four quadrants represent four risk zones:

- **Critical Vulnerability Zone** (High growth, high share of the EU in India's exports)
- **Persistent Risk Zone** (Low growth, high share of the EU in India's exports)
- **Early Warning Zone** (High growth, low share of the EU in India's exports)
- **Minimal Exposure Zone** (Low growth, low share of the EU in India's exports)

In the quadrant representation of **Figure 5** the size of the bubble reflects the value of exports to the EU, highlighting sectors including iron and steel and aluminium as relatively vulnerable. Iron and steel falls into the critical vulnerability zone, with exports over 30% destined for the EU. Cement, though smaller exports in absolute terms (US$ 15 million in 2024), also lies in this category due to a relatively high EU dependence of 17%.

Figure 5: Strategic Vulnerability of Indian Exports under CBAM:



A Quadrant-Based Assessment

Source: ITC Trademap, UN COMTRADE

Note: Export share and CAGR are given in decimals, and not in percentages

Aluminium and fertilisers are placed in the early warning zone, reflecting strong growth rate of 19.4% and 10.5% respectively, but lower market shares of the EU of 13.5% and 2.1%, leaving them exposed to future CBAM-related risks as exports expand. By contrast, chemicals and electricity are classified in the minimal exposure zone, as India has negligible export flows of these products to the EU. The findings clearly indicate that while the most immediate risks are concentrated in iron and steel, the dynamic growth of aluminium and fertiliser exports warrants close monitoring to prevent them from shifting into higher vulnerability categories over time.

5. Conclusion

India's EGs exports have strengthened significantly over the past decade, with improved revealed comparative advantage across clean-technology product groups, reflecting enhanced domestic policy frameworks and production capacities (UNCTAD, 2020; MNRE, 2023). The coming decade will witness unprecedented global demand for EGs as countries pursue net-zero emissions commitments. For India, with its ambitious Nationally Determined Contributions (NDCs) and clean energy targets, this presents both opportunities and challenges. Capturing this growing market will consolidate India's strategic role in climate action and green value chains.

Strategic interventions through strengthened compliance frameworks and targeted promotion of high-potential EGs categories will bridge existing gaps in India's export trajectory. Government initiatives including PLI scheme, Export Promotion Capital Goods (EPCG) program, and renewable energy incentives are well-positioned to catalyse growth if effectively integrated with trade-focused strategies.

Concurrently, India faces significant challenges in protecting its broader merchandise export portfolio from emerging climate-related trade regulations. The EU's CBAM and similar measures pose compliance burdens and cost pressures across multiple sectors of India's export economy, particularly in carbon-intensive industries such as iron, steel and aluminium, having significant export reliance on the EU. Safeguarding India's overall export competitiveness requires comprehensive institutional support systems, including centralized CBAM advisory services, carbon audit platforms, footprint tracking tools, and dedicated transition finance windows for exporters, particularly MSMEs. Additionally, accelerating low-carbon manufacturing pathways and scaling access to decarbonisation technologies across all export sectors will be essential. South Korea's experience with CBAM response task forces and firm-level assistance through its Ministry of Trade, Industry and Energy demonstrates how proactive government facilitation can reduce regulatory burdens while preserving market access (MOTIE, 2023).

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