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Greening the Economy as an Economic Development Paradigm: An ASEAN Perspective

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Abstract:

This paper analyzes ASEAN's transition toward a green economy, focusing on four dimensions: foreign direct investment (FDI), trade in environmental goods, emissions intensities, and green innovation. The region has attracted nearly $90 billion in cleantech FDI between 2013 and 2023, surpassing other emerging peers, and its environmental goods trade is expanding, led by Singapore, Malaysia, Thailand, and Vietnam. Cleantech industries are relatively low in emissions intensity, comparable to EU benchmarks. However, structural weaknesses persist. Green FDI remains less than one-fifth of total inflows, environmental goods account for only a modest share of exports, and ASEAN contributes under 1% of global green innovation. Most critically, the electricity sector is nearly four times more carbon-intensive than the EU's, reflecting heavy reliance on fossil fuels. ASEAN's competitiveness in the global low-carbon transition will depend on scaling green investment, diversifying exports into advanced clean technologies, and strengthening innovation ecosystems. Accelerating the decarbonization of electricity, alongside supportive regulatory frameworks such as carbon pricing and sustainable finance standards, will be essential. With decisive action, ASEAN can position itself as a leader among developing regions in the global green transition; without it, the region risks marginalization.

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1. Introduction

Over the past decade, sustainability has increasingly moved to the forefront of societal, political, and economic debates. Since the signing of the Paris Agreement in 2015, net-zero targets have been announced or are under consideration in 145 countries, covering nearly 90% of global greenhouse gas emissions.[5] Major economies are translating these commitments into far-reaching policy and financial packages. The European Union's Green Deal and the United States' Inflation Reduction Act channel hundreds of billions of dollars into low-carbon infrastructure, energy efficiency, and clean technology. In Asia, China's pledge to reach peak carbon emissions by 2030 has been embedded in its broader strategy of "high-quality development," prioritizing sustainable industrial upgrading. These measures are already reshaping the global economic landscape by altering investment flows, reconfiguring supply chains, and introducing trade-related climate instruments such as the EU's Carbon Border Adjustment Mechanism (CBAM).

Within this shifting global context, ASEAN occupies a unique position. It is one of the world's fastest-growing regions, contributing an estimated 11% of global growth through 2030, with average annual GDP growth of around 5% (ARMO 2024). At the same time, it is among the most vulnerable regions to climate change impacts due to its geography, reliance on natural resources, and climate-sensitive sectors such as agriculture and fisheries. ASEAN's rapid development has been underpinned by energy-intensive industrialization: the bloc is the world's fourth-largest energy consumer,[6] with over 75% of its electricity still generated from fossil fuels.[7] This reliance on coal, oil, and natural gas amplifies the region's carbon intensity, raising concerns about the sustainability of its growth trajectory.

ASEAN policymakers increasingly recognize the tension between development and decarbonization. At the 28th UN Climate Change Conference (COP28), four member states – Brunei, Malaysia, Singapore, and Thailand – pledged to triple renewable energy capacity by 2030. Carbon pricing instruments are also emerging: Singapore introduced Southeast Asia's first carbon tax, while Indonesia launched an emissions trading system, with Malaysia, Thailand, and Vietnam developing similar frameworks. At the regional level, the ASEAN taxonomy for sustainable finance represents an effort to direct investment toward activities consistent with long-term decarbonization while avoiding greenwashing. These initiatives signal that ASEAN economies see the green transition not merely as an environmental imperative but also as a condition for sustaining their global competitiveness.

The green economy model provides a conceptual framework for this balancing act (Georgeson et al. 2017). The United Nations Environment Programme (UNEP) defines a green economy as "low carbon, resource efficient and socially inclusive," emphasizing growth driven by investments that reduce emissions, conserve resources, and protect biodiversity.[8] Scholars stress that such an economy must be transformational: rather than adding green sectors alongside carbon-intensive industries, the very structure of the economy must shift toward cleaner modes of production and consumption (Ferguson, 2015). This is especially critical for

[5] https://climateactiontracker.org/global/cat-net-zero-target-evaluations/ , accessed in September 2024.
[6] https://www.weforum.org/stories/2025/06/asean-energy-transition-meeting/, accessed in September 2024.
[7] https://tuftshemispheres.org/2024/11/05/powering-asean-in-2050-and-beyond/, accessed in September 2024.
[8] https://www.unep.org/regions/asia-and-pacific/regional-initiatives/supporting-resource-efficiency/green-economy, accessed in September 2024.

ASEAN, where high-carbon electricity and manufacturing threaten to offset gains from growing investment in renewable energy and clean technologies.

This paper seeks to landscape the current state of ASEAN's green economy, focusing on four interrelated pillars: foreign direct investment, trade in environmental goods, emissions intensities, and green innovation. On FDI, ASEAN has attracted nearly $90 billion in cleantech investment between 2013 and 2023, surpassing the United States and outperforming other emerging economies like China and India. Yet this represents less than one-fifth of the bloc's total inward FDI, underscoring the need to scale green capital inflows. On trade, ASEAN's exports of environmental goods are substantial in absolute terms – dominated by Singapore, Malaysia, and Thailand – but remain modest as a share of total exports, suggesting limited specialization in low-carbon industries. In terms of emissions, cleantech industries in ASEAN are far less carbon-intensive than the regional average and comparable to EU benchmarks. However, the bloc's electricity sector is nearly four times more emissions-intensive than the EU's, reflecting entrenched fossil fuel dependence. Finally, in green innovation, ASEAN contributes less than 1% of global patents in environmental technologies, with activity concentrated in Singapore and Malaysia, while other member states lag behind.

The analysis is situated within broader debates on the link between environmental regulation and competitiveness. Traditional economic thinking viewed regulation as a cost burden that undermines firms' competitive position. This was challenged by Porter (1991), who argued that stringent but well-designed environmental policies could stimulate innovation, lower costs, and enhance competitiveness – an idea now widely known as the Porter Hypothesis. Empirical evidence remains mixed. Albrizio et al. (2014) find that impacts on productivity tend to fade within five years, while Ambec et al. (2011) highlight stronger links between environmental regulation and innovation than between regulation and firm-level competitiveness. Reviewing more than 100 studies, Cohen and Tubb (2018) conclude that positive impacts of environmental regulation are more likely to appear at the state, regional, or national level than at the facility, firm, or industry level – though in both cases, statistically insignificant results are most common. Such evidence aligns with the "strong" version of the Porter Hypothesis, which holds that stringent but flexible environmental regulation can drive innovation and, over time, enhance competitiveness at the macro level. More recent studies, such as provincial-level evidence from China, suggest that environmentally induced research and development (R&D) can significantly promote green total factor productivity (GTFP), outperforming traditional R&D (Zhao et al. 2022). These findings provide a useful backdrop for examining ASEAN, where regulatory frameworks are still evolving, and where the tension between competitiveness and decarbonization is particularly acute.

Recent literature highlights both the opportunities and challenges facing ASEAN's transition to a green economy. McKinsey & Company (2023) argue that to meet climate commitments, ASEAN countries must accelerate the scale-up of green technologies, many of which remain costly and inefficient. They highlight that innovation is required not only in technological design – illustrated by the nearly 90 percent reduction in solar costs between 2010 and 2020 – but also at the organizational level, where firms can improve efficiency through new operating models, construction methods, and supply chain management. Complementary studies by the OECD (2023) and the Asian Development Bank (ADB, 2021) underscore the social dimension of this transition, noting that a green economy in Southeast Asia has the potential to generate significant employment opportunities, provided policies actively promote inclusivity and invest in reskilling, safety nets, and labor market access. The most comprehensive analysis is offered by Bain & Company (2024), which maps the development of ASEAN's green economy across policy progress, private investment flows, and sectoral dynamics. Their findings indicate that while power remains the largest investment sector, industrial waste and green buildings

have experienced the fastest annual growth. Importantly, the report also identifies a growing share of domestic investment alongside a decline in non-ASEAN foreign capital, suggesting a reorientation toward regionally driven green finance. Collectively, these studies indicate that ASEAN's green transition depends on a dual strategy of accelerating innovation and strengthening local investment, while ensuring that the benefits are distributed equitably through inclusive policy frameworks.

In this light, the paper connects three strands of literature. First, it contributes to the study of the scope and structure of the green economy, providing new empirical evidence on how ASEAN economies are aligning trade and investment patterns with green development. Second, it engages with the innovation literature, particularly the Porter Hypothesis, by documenting green innovation in ASEAN. Third, it situates ASEAN's experience within the context of policy change and global economic integration, emphasizing the implications of carbon pricing and sustainable finance regimes for the region's competitiveness.

The rest of the paper is structured as follows. Section 2 analyzes cleantech FDI trends in ASEAN, comparing them with other regions. Section 3 examines trade in environmental goods and emissions intensities, highlighting both opportunities and bottlenecks in decarbonization. Section 4 evaluates ASEAN's position in green innovation, drawing on patent data to assess relative specialization and quality. Section 5 considers the evolving regulatory environment, including carbon pricing and sustainable finance frameworks. Section 6 concludes by synthesizing the findings and discussing implications for ASEAN's transition toward a green economy.

2. Cleantech FDI landscape in ASEAN

We start by providing a definition of cleantech. Clean technology, or "cleantech," refers to any process, product, or service that reduces negative environmental impacts through improved efficiency, resource conservation, or pollution control. The cleantech sector is made up of companies that design, produce, or service such clean technologies.[9]

In recent years, this sector has taken on particular significance in ASEAN, where rapid growth and sustainability goals have created strong demand for clean solutions. Between 2013 and 2023, ASEAN attracted around $90 billion in cleantech foreign direct investment (FDI), positioning the region as a fast-growing hub for sustainable investment (Figure 2.1). This inflow surpasses that of the United States and reflects a combination of rapid economic growth, rising energy demand, and ambitious decarbonization commitments. Investors have been particularly drawn to ASEAN's opportunities in solar, wind, hydropower, and energy efficiency, supported by favorable demographics and government policies that seek to balance development with sustainability. ASEAN's relative openness to foreign capital and its role as a strategic node in the Asia-Pacific energy transition have further enhanced its appeal.

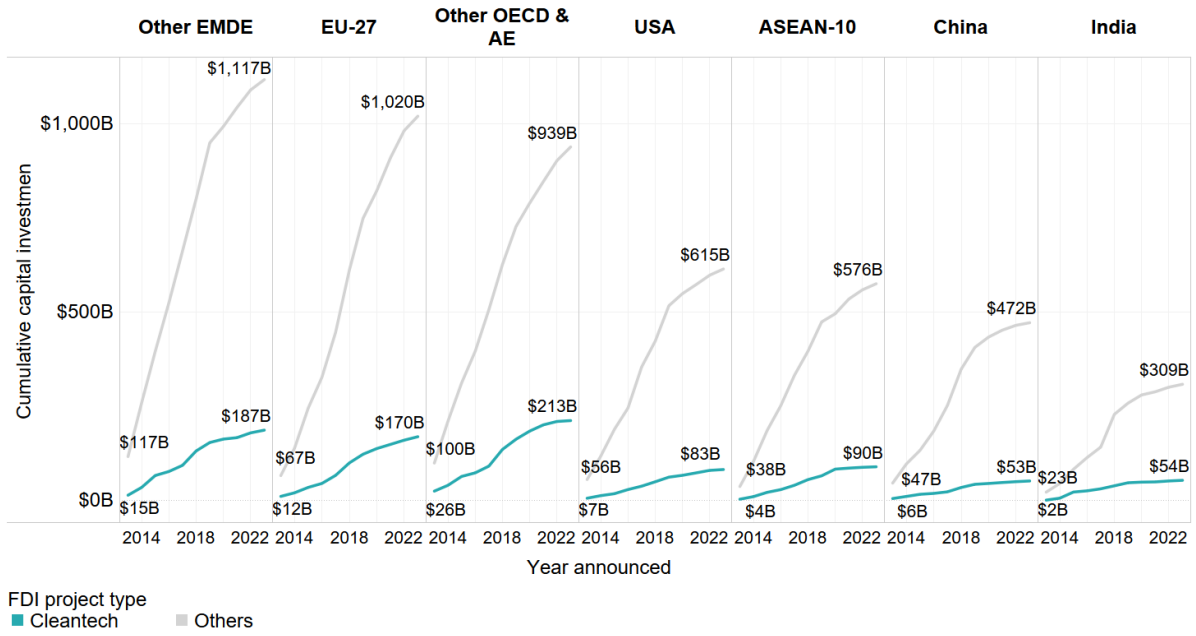
At the same time, cleantech represents only a fraction of the region's overall investment profile. Out of the $666 billion in total inward FDI during the same period, just $90 billion – less than one-fifth – was directed toward sustainable industries. This highlights a persistent gap between ASEAN's ability to attract foreign capital and the share of that capital aligned with its clean energy and low-carbon transition.

[9] https://techisland.io/cleantech-sector , accessed in September 2024.

From a global perspective, ASEAN's cleantech performance reflects both opportunities and limitations. Advanced economies such as Other OECD & Advanced Economies ($213 billion) and the EU-27 ($170 billion) far outpace ASEAN, demonstrating stronger policy frameworks and deeper investor confidence in low-carbon markets. Even the United States, with $83 billion in cleantech FDI out of $698 billion total, rivals ASEAN's absolute level. Against this backdrop, ASEAN still trails more mature economies by a wide margin.

When compared with emerging economies, ASEAN's record is more favorable in absolute terms. The region's $90 billion in cleantech FDI exceeds both China's $53 billion and India's $54 billion. However, because ASEAN also recorded the largest inflows of non-cleantech FDI ($576 billion, compared with China's $472 billion and India's $309 billion), ASEAN's relative efficiency is not markedly higher than other developing regions regarding channeling foreign capital towards its cleantech sector.

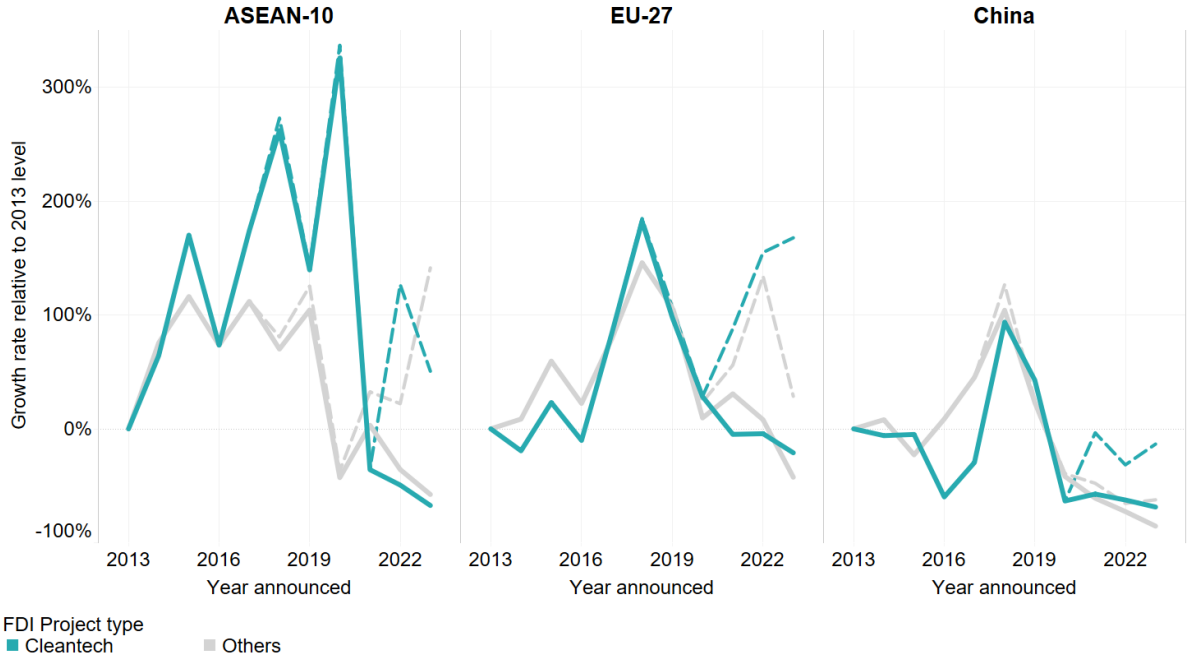
Figure 2.1: Global inward FDI (cumulative 2013-2023)



Source: ACI's analysis using Orbis Crossborder Investment data. Notes: EMDE refers to Emerging Markets and Developing Economies, AE refers to Advanced Economies.

ASEAN's growth trajectory has been dynamic but volatile. Between 2015 and 2019, cleantech inflows surged dramatically, with growth rates exceeding 300% relative to 2013 levels (Figure 2.2). Much of this was driven by waves of renewable energy and energy-transition projects. Yet, growth collapsed, and completed project volumes fell sharply during 2020–2021, reflecting the combined effects of the pandemic and project delays. Despite this downturn, the pipeline of announced projects suggests renewed momentum, with ASEAN regaining investor attention starting from 2022. This volatility underscores both the risks of external shocks and the underlying strength of ASEAN's attractiveness to cleantech investors.

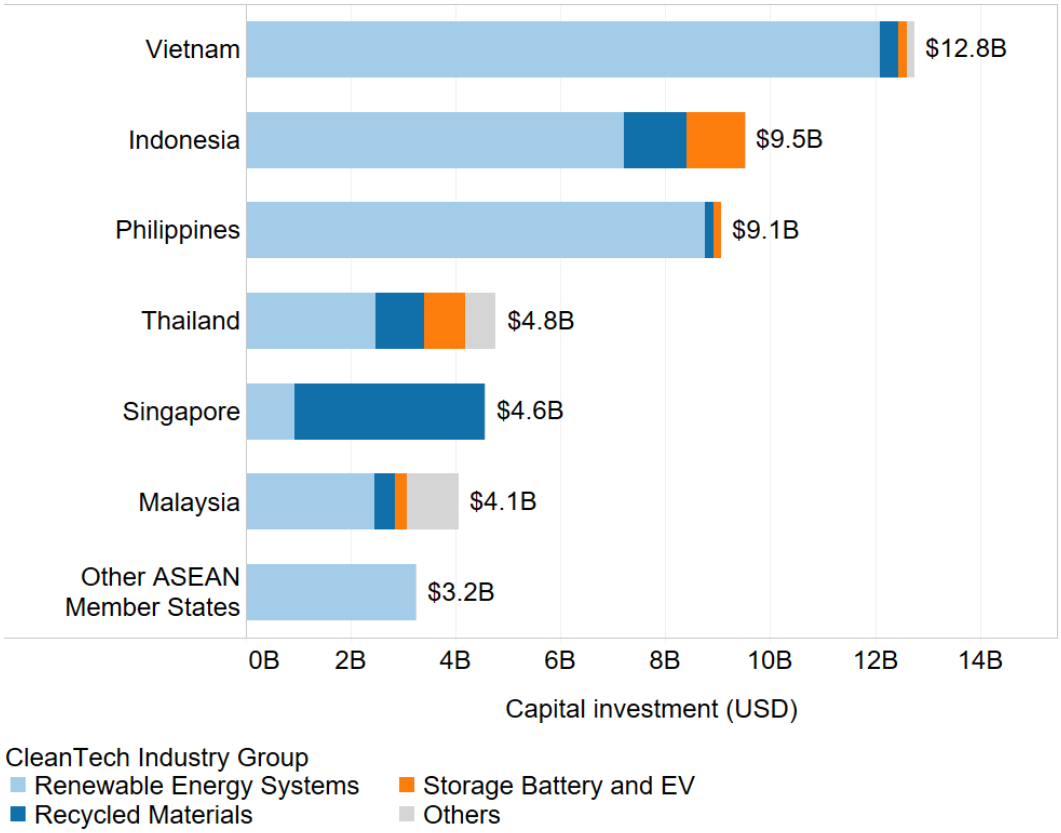
Figure 2.2: Growth rate of inward FDI by project type and status (2013-2023)



Source: ACI's analysis using Orbis Crossborder Investment data. Notes: Solid lines represent completed projects. Dashed lines represent projects that had been announced but not yet completed in 2023.

Within the bloc, investment patterns reveal specialization and diversification (Figure 2.3). Vietnam leads with $12.8 billion, mainly directed into large-scale renewable energy, highlighting its emergence as a hub for foreign investment in clean power. Indonesia ($9.5 billion) has drawn substantial flows into renewables, battery storage, and electric vehicles, reflecting its growing role in the global EV (Electric Vehicle) supply chain. The Philippines ($9.1 billion) has concentrated almost entirely on renewable energy, signaling its strategic shift away from fossil fuels. Mid-tier economies such as Thailand ($4.8 billion) and Singapore ($4.6 billion) show more diversified profiles – Thailand across renewables, storage, and recycled materials, and Singapore in circular economy solutions, where its innovation-driven model compensates for limited space for large-scale renewables. Malaysia ($4.1 billion) sits slightly lower, with moderate diversification but less scale than its neighbors. Other ASEAN members collectively secured $3.2 billion, mostly in renewables, indicating growing but still modest participation.

Figure 2.3: ASEAN's completed FDI projects by cleantech industry group (2013-2023)



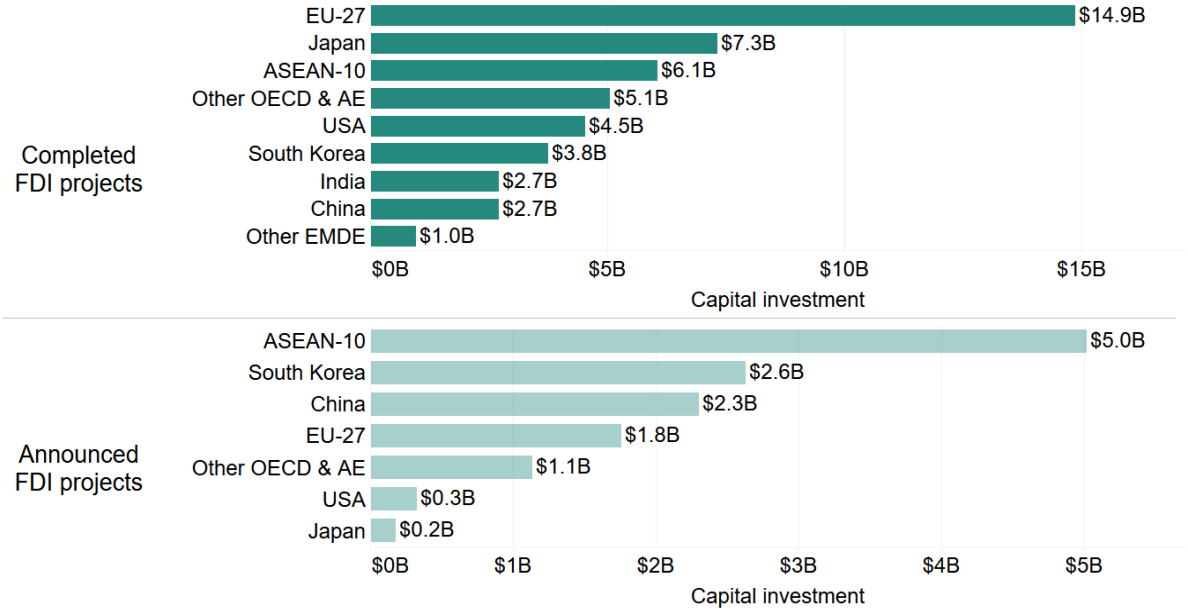
Source: ACI's analysis using Orbis Crossborder Investment data.

The sources of cleantech FDI also highlight shifting dynamics. For completed projects, the EU-27 is the largest contributor, with $14.9 billion, nearly double Japan's $7.3 billion (Figure 2.4). Europe's leadership reflects its strong climate policies and drive to globalize sustainable finance, while Japan continues its long-standing role in Southeast Asian infrastructure and energy. ASEAN itself has also emerged as an important intra-regional investor, with $6.1 billion in completed projects, reinforcing regional integration. Other significant contributors include Other OECD & AE ($5.1 billion), the USA ($4.5 billion), and South Korea ($3.8 billion). China and India are smaller but growing players, each with $2.7 billion, while other EMDEs remain marginal at $1 billion.

Looking at announced projects, the picture shifts considerably. The ASEAN-10 themselves are now the leading source, with $5.0 billion in pipeline commitments, pointing to stronger intra-regional capital circulation. Northeast Asian partners – South Korea ($2.6 billion) and China ($2.3 billion) – are also set to expand their roles. By contrast, the EU and Japan, historically dominant sources, appear less engaged in future projects, with only $1.8 billion and $0.2 billion announced, respectively. US commitments are also limited at $0.3 billion.

This shift suggests that while Europe and Japan anchored ASEAN's cleantech FDI in the past, the next wave will be driven increasingly by regional and intra-Asian sources. ASEAN's growing role as both recipient and investor reflects the maturation of its capital markets and its positioning within the global clean energy supply chain. However, sustaining momentum will require stronger policy consistency, more efficient project implementation, and continued efforts to align broader FDI flows with sustainable development objectives.

Figure 2.4: Sources of ASEAN-10's cleantech FDI (2013-2023)



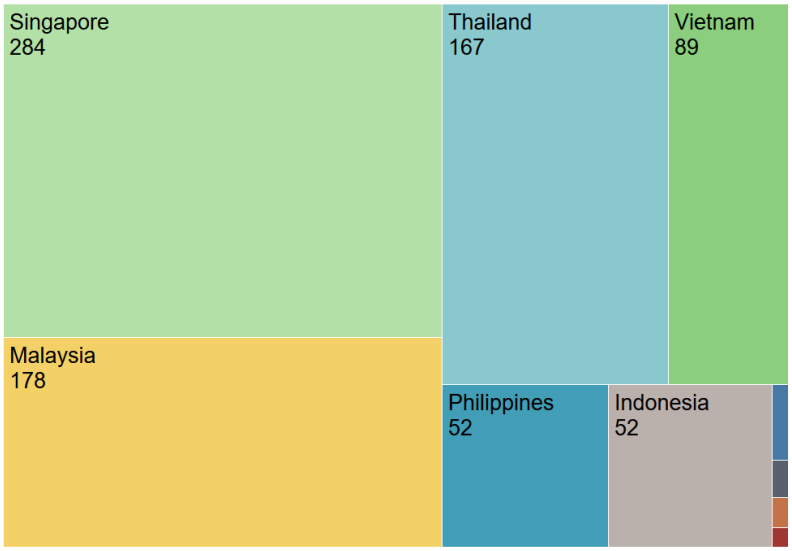
Source: ACI's analysis using Orbis Crossborder Investment data.

3. ASEAN's Environmental goods trade and emission intensities

While cleantech FDI highlights ASEAN's growing role as a hub for sustainable investment, trade dynamics and industrial emissions provide another critical perspective. Examining environmental goods exports and the emission intensity of industries sheds light on how investment flows translate into competitiveness and sustainability outcomes. Together, these dimensions show both the opportunities ASEAN has to lead in green sectors and the challenges it faces in decarbonizing its broader economy.

Figure 3.1 highlights the leaders in ASEAN's environmental goods exports between 2011 and 2021. In absolute terms, Singapore ($284 billion), Malaysia ($178 billion), and Thailand ($167 billion) dominate, reflecting their positions as advanced manufacturing hubs and regional trade gateways. Vietnam ($89 billion) also holds a significant position, leveraging its growing integration into global electronics and renewable energy supply chains. This establishes ASEAN as an important player in the global market for environmental goods, with several members already embedded in green technology value chains.

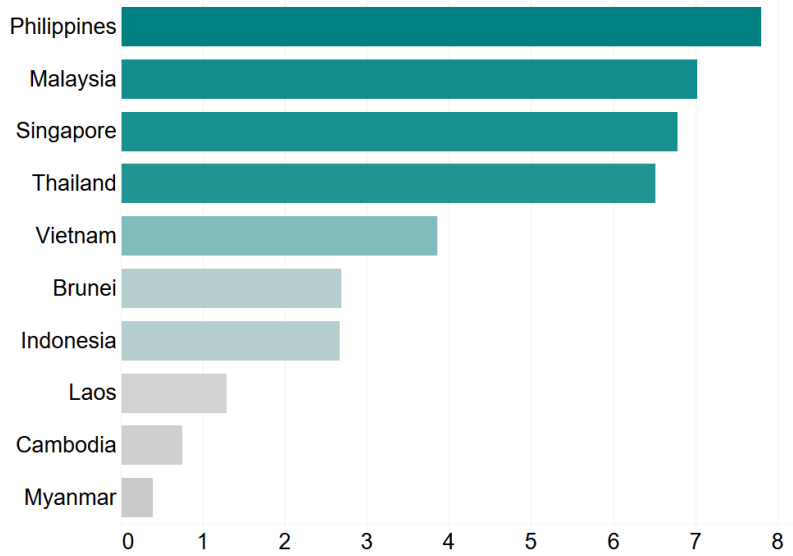
Figure 3.1: Total environmental goods exports (billion USD) (2011-2021)



Source: ACI's analysis using data from IMF Climate Change Dashboard, Trade in Environmental Goods, 2023

The story shifts, however, when environmental goods are measured as a share of total exports. As shown in Figure 3.2, the Philippines recorded the highest share at 7.8%, followed closely by Malaysia (7.0%), Singapore (6.8%), and Thailand (6.5%). This suggests that the environmental goods still represent a modest segment of their export baskets. Although Singapore, Malaysia and Thailand lead in terms of absolute export values, environmental goods are embedded within these countries' broader, diversified trade structures. By contrast, Indonesia and Vietnam, with even smaller shares at 2.7% and 3.9%, respectively, exhibit a comparatively slower progress than their neighboring countries in integrating environmental goods into their export composition. This contrast between absolute and relative measures shows that ASEAN's green trade strengths are uneven across the bloc.

Figure 3.2: Average environmental goods exports as share of total exports (2011-2021)

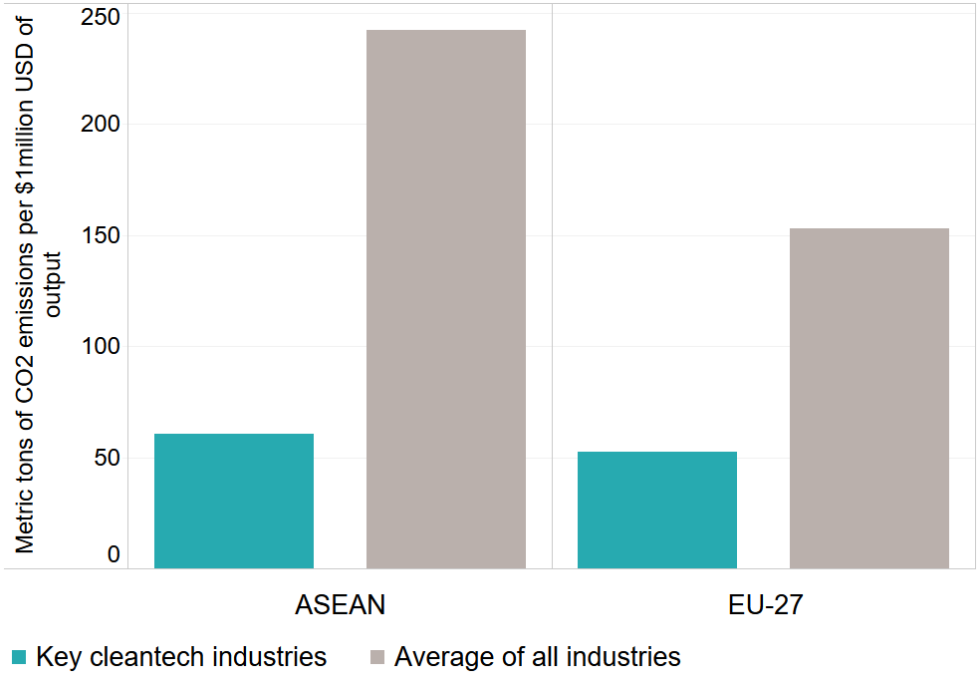


Source: ACI's analysis using data from IMF Climate Change Dashboard, Trade in Environmental Goods, 2023

Exports tell only part of the story. The competitiveness of cleantech industries also depends on how emission-intensive they are compared to the broader economy. Figure 3.3 shows that ASEAN's cleantech industries emit 60.1 metric tons of CO_2 per $1 million of output, a fraction of the regional cross-industry average of 242.2 metric tons. This fourfold gap highlights the potential role of cleantech in driving a low-carbon transition. Encouragingly, ASEAN's cleantech emissions intensity is comparable to the EU's, suggesting that in relative terms the region's green industries are globally competitive. The real challenge lies in ASEAN's wider industrial base, which remains far more carbon-intensive than that of advanced economies.

This disparity has two key implications. First, scaling cleantech could deliver rapid reductions in ASEAN's carbon footprint given the large gap between clean and traditional industries. Second, policy efforts must extend beyond cleantech to diffuse cleaner technologies and efficiency gains into carbon-heavy sectors such as energy, transport, and heavy manufacturing. Without addressing these wider industries, ASEAN's relative gains in cleantech risk being overshadowed by its high-emission economic core.

Figure 3.3: Comparison of emissions intensities of key cleantech industries vs. cross-industry average



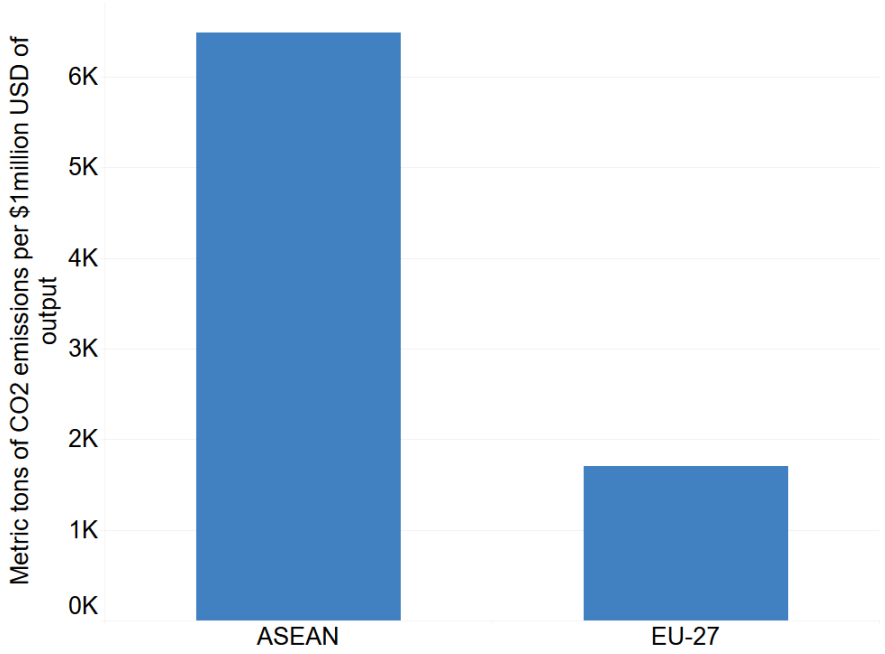
Source: ACI's analysis using data from IMF Climate Change Dashboard, CO2 Emissions, Emissions Intensities, and Emissions Multipliers, 2022

The electricity sector exemplifies this structural weakness. As shown in Figure 3.4, ASEAN's power generation is extraordinarily carbon-intensive, emitting over 6,000 metric tons of CO_2 per $1 million of output – almost four times higher than the EU average of under 1,700. This reflects the region's continued reliance on coal and other fossil fuels as base-load sources, with renewables yet to scale sufficiently to offset fossil dominance. The sector's high intensity not only inflates ASEAN's overall emissions but also leaves its economies exposed to global energy price volatility and emerging mechanisms like the EU's CBAM.

The implications are clear. To capitalize on its growing trade in environmental goods and strong cleantech emissions performance, ASEAN must accelerate the energy transition. This requires major investment in solar, wind, hydro, and geothermal energy, alongside grid modernization and storage technologies. At the same time, the cleantech FDI already flowing

into ASEAN – outlined in the previous section – can be leveraged to strengthen renewable power and decarbonize electricity. Linking investment, trade, and emissions together, ASEAN has an opportunity to reinforce its competitiveness while pursuing a lower-carbon growth model.

Figure 3.4: Comparison of emission intensity of electricity sector



Source: ACI's analysis using data from IMF Climate Change Dashboard, CO2 Emissions, Emissions Intensities, and Emissions Multipliers, 2022. Note: Electricity sector refers to "Electricity, gas, steam, and air conditioning supply".

Taken together, ASEAN's environmental goods trade and emission intensity profile illustrate both the promise and paradox of greening the economy as a development paradigm. On one hand, the region is strengthening its role in global green value chains, exporting environmental goods at competitive levels and nurturing cleantech industries that are relatively efficient by international standards. On the other hand, ASEAN's wider industrial and energy systems remain deeply carbon-intensive, with electricity generation in particular posing a structural bottleneck. This duality underscores that ASEAN's pathway to green development cannot rely solely on expanding cleantech exports and investments; it must also tackle the harder challenge of transforming its traditional, fossil-heavy economy. Achieving this balance – leveraging trade and FDI while reducing systemic emissions – will be central to ASEAN's ability to align economic growth with sustainability and to establish greening the economy as a credible development paradigm.

4. Green Innovation

The previous section highlighted how ASEAN is strengthening its role in the global trade of environmental goods while grappling with high industrial and energy-sector emissions. To fully understand how the region can shift toward a greener development paradigm, it is essential to examine the innovation dimension. Patents provide a direct lens into technological

progress, revealing both the scale and quality of green invention as well as the international networks that support it.

Patent data is one of the most widely used tools for tracking technological development. It offers rich bibliographic information on inventors, applicants, and technical fields, which can be categorized through systems such as the International Patent Classification (IPC) or the Cooperative Patent Classification (CPC). For green innovation specifically, three main methodologies are applied: the OECD's ENV-TECH system (OECD 2012; Urbaniec et al. 2021), the IPC Green Inventory developed by WIPO, and the Y02/Y04S tagging scheme introduced by the EPO (Favot et al. 2023). Among these, ENV-TECH is most widely used in empirical studies (Haščič and Migotto 2015; Haščič, Silva, and Johnstone 2015) because it groups environment-related technologies into eight categories, offering a structured framework for analysis (Table 4.1).

Table 4.1: OECD's ENV-TECH classification system

Group	Description
1	Environmental management
2	Climate change mitigation technologies (CCMT) related to energy generation, transmission or distribution
3	Capture, storage, sequestration or disposal of greenhouse gases
4	CCMT related to transportation
5	CCMT related to buildings
6	CCMT related to wastewater treatment or waste management
7	CCMT in the production or processing of goods
8	Climate change mitigation in information and communication technologies (ICT)

Source: OECD

For large-scale analysis, researchers often rely on PATSTAT, a comprehensive patent database covering over 100 offices worldwide. Its standardized formats enable cross-country comparisons of patent applications, publications, citations, and family relationships[10]. This study uses the Autumn 2022 edition of PATSTAT, with missing inventor and applicant country codes imputed following the methods described in Ge et al. (2022).

Between 2001 and 2020, global innovation activity was highly concentrated in East Asia, North America, and Europe. China alone produced over one million inventions, accounting for 44% of the global total, while Japan and South Korea also contributed substantial shares (Table 4.2). In stark contrast, the ASEAN-10 accounted for only 3,981 inventions (0.2%) and 18,181 patent applications (0.5%). Compared with other emerging economies, ASEAN's position is weak: EMDEs as a group produced 54,415 inventions and 139,581 applications, while Other OECD

[10] A set of applications that are filed to protect the same inventions, whether or not in different jurisdictions, can be grouped into the same patent family. Typically, a patent family is viewed as a unit of invention, reflecting the innovation output.

and advanced economies reached far higher numbers. This pattern underscores ASEAN's marginal role in global innovation.

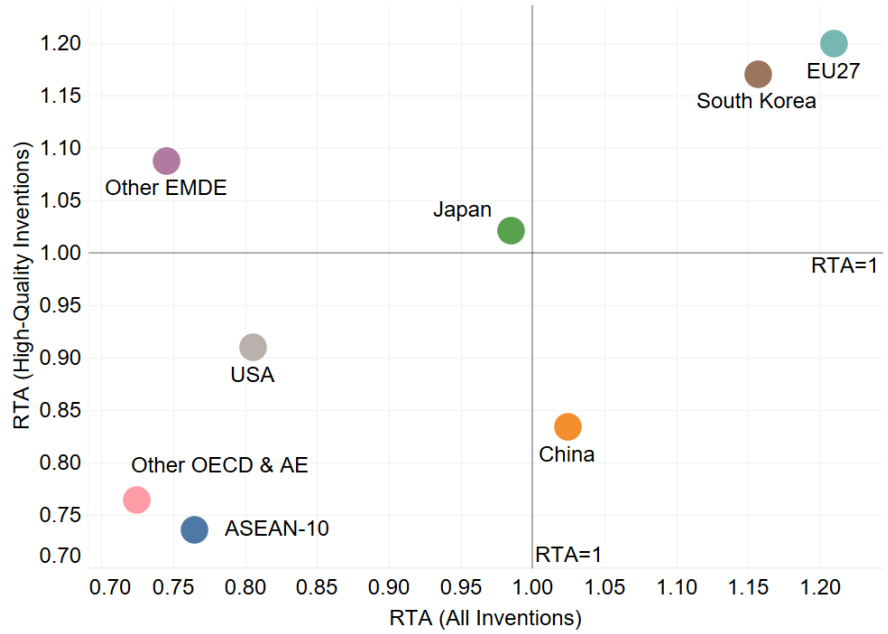
Table 4.2: Global Innovation Activities (2001-2020)

	Inventions			Patent Applications		
Inventor Country/Application Authority	Number	Share	Rank	Number	Share	Rank
China	1,059,686	44.4%	1	1,329,158	33.6%	1
Japan	501,110	21.0%	2	643,636	16.3%	2
South Korea	260,288	10.9%	3	366,841	9.3%	4
EU27	242,887	10.2%	4	240,554	6.1%	7
USA	182,198	7.6%	5	613,601	15.5%	3
European Patent Office (EPO)	-	-	-	301,788	7.6%	5
Other OECD & Advanced Economies (AE)	82,523	3.5%	6	289,978	7.3%	6
Other Emerging Markets and Developing Economies (EMDE)	54,415	2.3%	7	139,581	3.5%	8
ASEAN-10	3,981	0.2%	8	18,181	0.5%	9

Source: ACI's analysis using PATSTAT database (2022 autumn version). Notes: The AE and EMDE groupings follow the International Monetary Fund's classification. Inventions invented in 2001-2020: patent families with the earliest filing years in 2001-2020. Patent applications filed in 2001-2020.

The Revealed Technological Advantage (RTA) measure provides further insight into specialization. The RTA itself is calculated as the share of environmental inventions in a country's total inventive activity, divided by the corresponding global share – where values above 1 indicate relative specialization, and values below 1 suggest weaker engagement compared to the world average. As shown in Figure 4.1, ASEAN lies well below the RTA=1 threshold for both overall and high-quality environmental inventions with the earliest filing years in 2001-2020. High-quality inventions, defined as patent families with more than two members, reflect high perceived commercial value, as applicants are willing to incur additional application costs to secure the patent protection. ASEAN's low performance in both dimensions suggests a dual gap: the region produces relatively few green technologies, and only a small proportion of those are sufficiently impactful. By contrast, EMDEs show an RTA above 1 for high-quality inventions, while advanced economies and East Asian leaders outperform across the board.

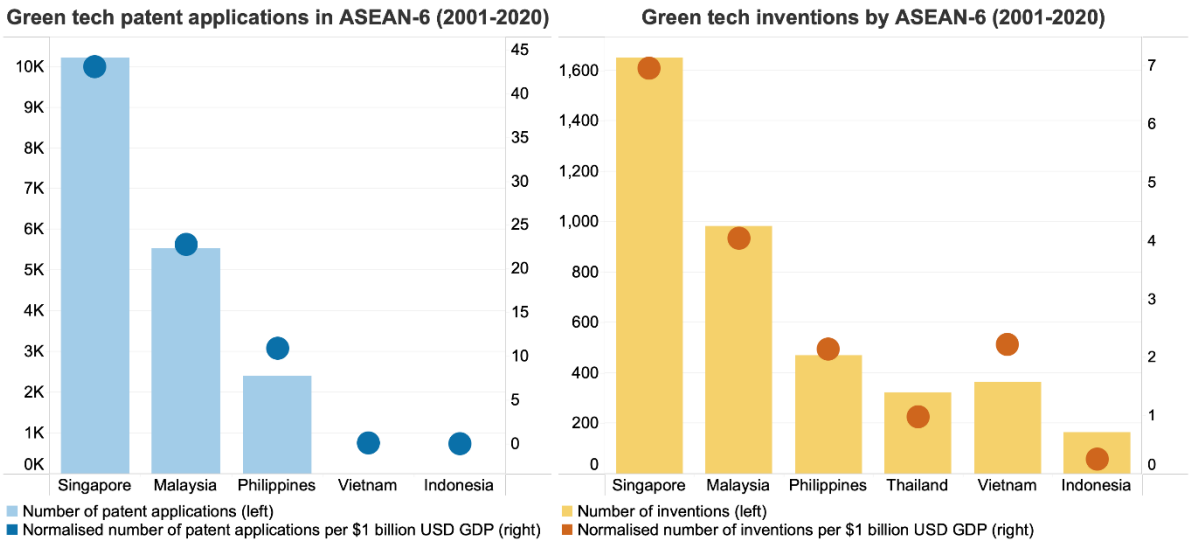
Figure 4.1: ASEAN's position in the environmental revealed technological advantage matrix



Source: ACI's analysis using PATSTAT database (2022 autumn version).

Zooming into the region, Figure 4.2 illustrates green patenting in the ASEAN-6. Singapore dominates with over 10,000 applications and 1,600 inventions, followed by Malaysia and the Philippines. When normalized by GDP, Singapore again emerges as the strongest performer, reflecting not only its economic size but also its innovation intensity. Malaysia performs respectably, while the Philippines shows moderate strength, especially relative to its economy. In contrast, Vietnam and Indonesia remain underrepresented, signaling gaps in their innovation ecosystems despite their large markets. The data underscore a clear asymmetry: Singapore, and to a lesser extent Malaysia, are building innovation hubs, while most other ASEAN members lag substantially.

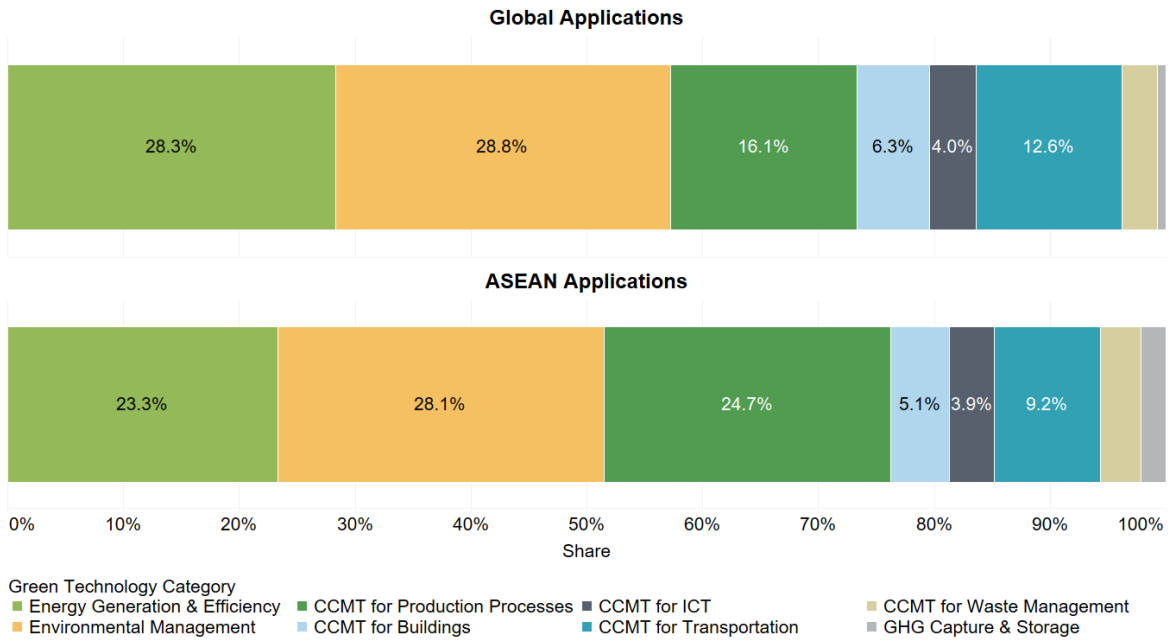
Figure 4.2: ASEAN 6 countries' position as Green Innovation Hub and Market



Source: ACI's analysis using PATSTAT database (2022 autumn version). Note: The normalised number is obtained by scalling the number of patent applications (or inventions) with each country's average GDP from 2001 to 2020.

The composition of green patent applications also reveals ASEAN's priorities. As shown in Figure 4.3, 28.1% of patents are in environmental management, aligning with the region's industrial base. A second prominent category is climate change mitigation technologies (CCMT) for production processes (24.7%), which is much higher than the global average of 16.1%, reflecting ASEAN's focus on waste, pollution, and resource management. By contrast, ASEAN lags in energy generation and efficiency (23.3% vs. 28.3% globally) and in transportation-related CCMTs (9.2% vs. 12.6% globally). Areas such as buildings, waste management, and greenhouse gas (GHG) capture remain marginal. The pattern suggests that ASEAN's innovation agenda is reactive – focused on managing environmental pressures – rather than proactive in advancing frontier technologies central to the global energy transition.

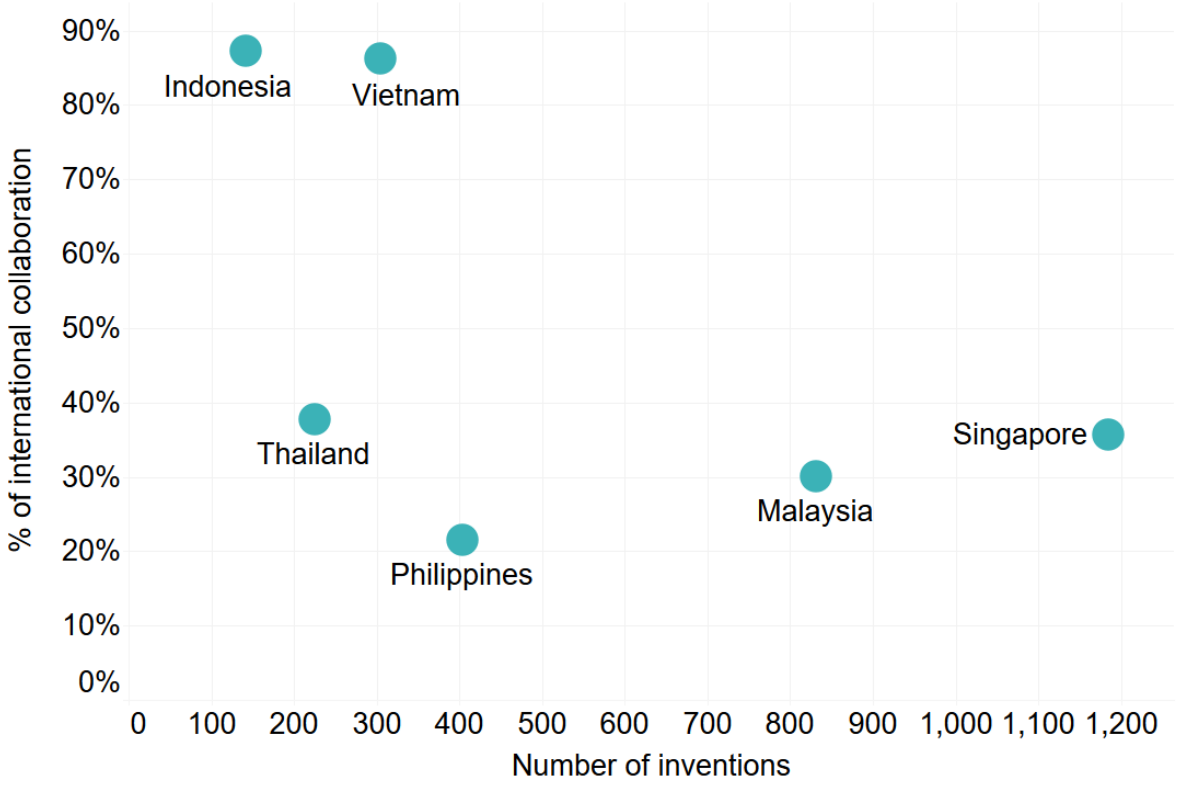
Figure 4.3: Top green technologies applied globally and in ASEAN



Source: ACI's analysis using PATSTAT database (2022 autumn version).

International collaboration adds another layer to the picture. Figure 4.4 shows that Singapore and Malaysia generate the highest number of green inventions but rely relatively little on international co-invention, reflecting stronger domestic capacities. Indonesia and Vietnam, by contrast, produce fewer inventions but show collaboration rates above 80%, indicating dependence on foreign partners for innovation. Thailand and the Philippines occupy a middle ground, though the Philippines shows notably low collaboration. These patterns highlight the fragmentation of ASEAN's innovation landscape: some countries generate volume but collaborate little, while others depend heavily on external knowledge networks.

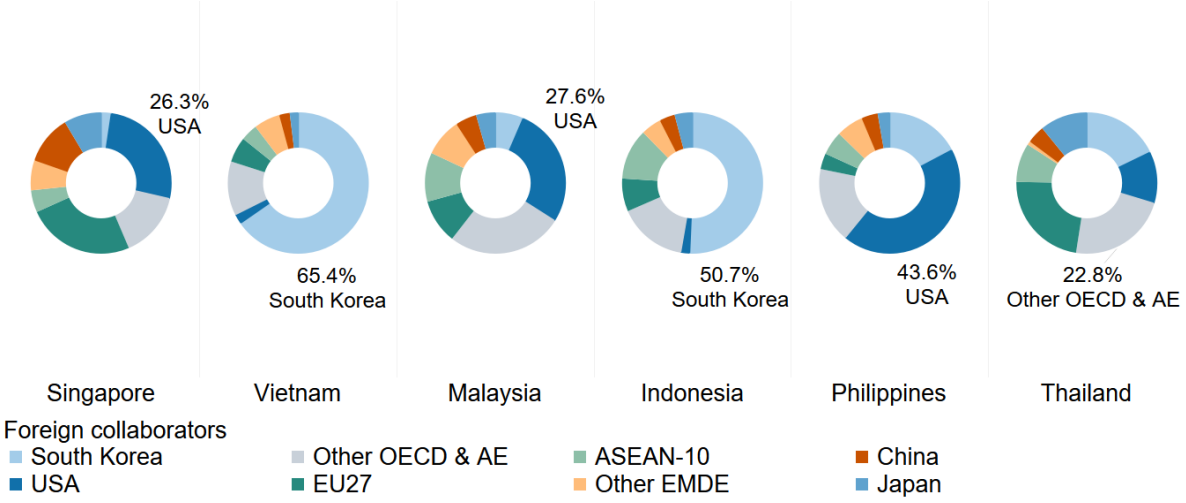
Figure 4.4: Green patent families by ASEAN-6 inventors (2001-2020)



Source: ACI's analysis using PATSTAT database (2022 autumn version).

Finally, Figure 4.5 maps ASEAN's foreign collaborators. Vietnam and Indonesia rely overwhelmingly on South Korea, often tied to manufacturing supply chains, electronics, and infrastructure projects. However, such heavy concentration means these two countries are vulnerable if Korea's outward FDI or technology flows shift. Similarly, the Philippines depends heavily on the US, reflecting historical links and current outsourcing and Information and communications technology (ICT) connections. But again, the lack of balance means potential disruptions in US–Philippines relations could create significant innovation gaps. This underscores the importance of diversifying collaboration to strengthen resilience.

Figure 4.5: Foreign collaborators of ASEAN-6 inventors (2001-2020)



Source: ACI's analysis using PATSTAT database (2022 autumn version).

On the other hand, Singapore and Malaysia maintain more diversified partnerships, particularly with the US, EU, Japan, and other OECD countries, reflecting their deeper integration into global innovation systems. This diversification reduces dependency risk and signals their role as regional hubs for multinational R&D and cleantech investment. Thailand engages across a broader set of partners, though from a smaller base.

Taken together, ASEAN's green innovation profile reflects both progress and vulnerability. The region has pockets of strength, particularly in Singapore and Malaysia, and is making contributions in environmental management technologies. Yet in terms of scale, quality, and global integration, ASEAN lags not only behind advanced economies but also behind its emerging peers. Without stronger investment in R&D, better commercialization incentives, and more balanced collaboration networks, ASEAN risks remaining a marginal player in global green innovation at a time when technological leadership is critical to sustainable development.

5. A rapidly developing regulatory environment

ASEAN's trajectory must also be understood against the backdrop of a rapidly evolving regulatory environment. Two areas stand out: carbon pricing and sustainable finance.

Domestic initiatives on carbon pricing are emerging across the region, including Singapore's carbon tax and Indonesia's emissions trading system (ETS). These mechanisms can create incentives for cleaner production and encourage firms to invest in efficiency and low-carbon technologies (NCCS Singapore, n.d.). At the same time, external measures such as the EU's CBAMpresent challenges. By imposing a carbon cost on imports, CBAM could erode the competitiveness of ASEAN exports to European markets, particularly for carbon-intensive goods (Ghosh, Gao & Kim, 2023). This dual pressure – domestic incentives and external penalties – underscores the urgency of decarbonizing ASEAN's production base.

Alongside carbon pricing, financial frameworks are playing a growing role in shaping capital flows. The EU Taxonomy for Sustainable Activities, Singapore's Finance for Net Zero Action Plan, and the ASEAN Green Bond Standards illustrate how definitions of "sustainable" investment are being codified. Clear taxonomies can direct capital into priority sectors and reduce the risks of greenwashing (EU Commission, n.d.). Yet fragmentation across different frameworks remains a challenge: the lack of harmonization between regional and international standards risks slowing cross-border capital flows and complicating investment decisions (Spaans & Wheeler, 2024).

Overall, the regulatory environment presents both opportunities and constraints for ASEAN. Well-designed domestic carbon pricing and harmonized sustainable finance standards could accelerate the region's green transition. However, failure to align with international frameworks risks exposing ASEAN economies to competitiveness losses and financial marginalization in global markets.

6. Conclusion

ASEAN's progress toward greening the economy reflects a dual reality of momentum and constraint. On the one hand, the region is emerging as a significant destination for cleantech FDI, with $90 billion attracted between 2013 and 2023, surpassing the United States and outperforming other emerging peers such as China and India. ASEAN's role in environmental goods trade is also expanding, led by Singapore, Malaysia, and Thailand, with Vietnam rapidly

integrating into global supply chains. Cleantech industries themselves are relatively low in emissions intensity, performing on par with the EU.

On the other hand, structural weaknesses remain evident. Cleantech FDI represents less than one-fifth of total FDI, environmental goods exports form only a modest share of most countries' export baskets, and ASEAN contributes less than 1% of global green innovation. Perhaps most pressing, the region's electricity sector is nearly four times more carbon-intensive than the EU's, reflecting heavy dependence on coal and fossil fuels. This undermines the gains achieved in cleantech and exposes ASEAN to policy shocks such as CBAM.

Moving forward, ASEAN will need to deepen cleantech investment by expanding the proportion of foreign direct investment directed into renewable energy, storage, and sustainable infrastructure. While $90 billion in cleantech FDI is impressive compared to other emerging economies, it remains small relative to ASEAN's overall inflows, underscoring the need to align capital more deliberately with the green transition.

Equally important is scaling and diversifying ASEAN's green trade. Environmental goods exports are growing but remain concentrated in a handful of economies and sectors. For ASEAN to fully harness the opportunities of the global low-carbon transition, environmental goods must form a larger share of national export baskets and extend into frontier technologies such as renewable energy equipment, clean mobility solutions, and advanced carbon mitigation tools.

ASEAN must also strengthen its innovation ecosystems. With less than 1% of global green inventions, the region risks falling behind in the technologies that will define future competitiveness. Increased R&D spending, stronger commercialization incentives, and institutional support are needed to stimulate invention. At the same time, international collaboration should be balanced with domestic capability-building to ensure both the scale and quality of green innovation.

Finally, accelerating the energy transition will be essential. The electricity sector's extremely high carbon intensity highlights the urgency of reducing coal dependence and rapidly scaling renewable power. Investments in grid modernization and storage technologies will be equally important to ensure stability and integration. Without decarbonizing electricity, ASEAN's progress in cleantech, trade, and innovation will be overshadowed by the structural weight of fossil-fuel dependence.

In sum, ASEAN stands at a crossroads. Regulatory frameworks – domestic carbon pricing, sustainable finance standards, and international measures like CBAM – will increasingly shape competitiveness. If ASEAN can align investment, trade, innovation, and policy around a coherent low-carbon strategy, it has the potential to lead among developing regions in the global energy transition. Without decisive action, however, it risks remaining a marginal player in a world where sustainable competitiveness is no longer optional but essential.

References

Asian Development Bank. (2021). Green recovery strategies for Southeast Asia (ADB Brief No. 173). https://www.adb.org/sites/default/files/publication/684966/adb-brief-173-green-recovery-southeast-asia.pdf

Albrizio, S., Koźluk, T., & Zipperer, V. (2014). Empirical evidence on the effects of environmental policy stringency on productivity growth (OECD Economics Department Working Papers No. 1179). OECD Publishing. https://doi.org/10.1787/5jxrjnb36b40-en

Ambec, S., Cohen, M. A., Elgie, S., & Lanoie, P. (2011). The Porter Hypothesis at 20: Can Environmental Regulation Enhance Innovation and Competitiveness? Discussion Paper 11-01. Resources for the Future. https://media.rff.org/documents/RFF-DP-11-01.pdf

AMRO (2024). ASEAN+3 Regional Economic Outlook 2024: Chapter 1, Macroeconomic Prospects and Challenges. https://amro-asia.org/wp-content/uploads/2024/04/AREO-2024-C1.pdf

Bain & Company. (2024). Southeast Asia's Green Economy 2024 report. https://www.bain.com/globalassets/noindex/2024/bain_report_southeast_asias_green_economy_2024.pdf

Cohen, M. A., & Tubb, A. (2018). The impact of environmental regulation on firm and country competitiveness: A meta-analysis of the Porter hypothesis. Journal of the Association of Environmental and Resource Economists, 5(2), 371–399. https://doi.org/10.1086/695613

European Commission. (n.d.). EU taxonomy for sustainable activities. Retrieved from https://finance.ec.europa.eu/sustainable-finance/tools-and-standards/eu-taxonomy-sustainable-activities_en

Favot, M., Vesnic, L., Priore, R., Bincoletto, A., Morea, F. (2023). Green patents and green codes: How different methodologies lead to different results. Resources, Conservation & Recycling Advances, 18, 200132.

Ferguson, P. (2015). The green economy agenda: business as usual or transformational discourse? Environmental Politics, 24(1), 17-37. https://doi.org/10.1080/09644016.2014.919748

Georgeson, L., Maslin, M., & Poessinouw, M. (2017). The global green economy: a review of concepts, definitions, measurement methodologies and their interactions. Geo: Geography and Environment, 4(1), e00036. https://doi.org/10.1002/geo2.36

Ghosh, J., Xi, G., & Won, K. J. (2023). Implications of the EU Carbon Border Adjustment Mechanism for the ASEAN's Industries. Policy Brief. Energy Studies Institute. Retrieved from https://esi.nus.edu.sg/docs/default-source/bulletin/esi-pb-69_implications-of-the-eu-cbam-for-the-asean-s-industries.pdf?sfvrsn=4e5cfa22_1

Haščič, I., & Migotto, M. (2015). Measuring environmental innovation using patent data.

Haščič, I., Silva, J., & Johnstone, N. (2015). The use of patent statistics for international comparisons and analysis of narrow technological fields.

McKinsey & Company. (2023). To meet climate goals, green tech needs to get bigger, faster – the plant-as-a-product approach could help. https://www.mckinsey.com/featured-insights/future-of-asia/countries-and-regions/southeast-asia/southeast-asia-perspectives/to-meet-climate-goals-green-tech-needs-to-get-bigger-faster-the-plant-as-a-product-approach-could-help

National Climate Change Secretariat (NCCS). (n.d.). Carbon Tax. Retrieved from https://www.nccs.gov.sg/singapores-climate-action/mitigation-efforts/carbontax/

OECD. (2023). Towards greener and more inclusive societies in Southeast Asia. OECD Publishing. https://www.oecd.org/en/publications/towards-greener-and-more-inclusive-societies-in-southeast-asia_294ce081-en.html

OECD. (2012). Indicators of Environmental Technologies (ENV-Tech Indicators). OECD.

Porter, M. E. (1991). America's green strategy. Scientific American, 264(4), 168. https://doi.org/10.1038/scientificamerican0491-168

Spaans, J., & Wheeler, D. (2024). Taxonomies - why the world needs harmonization but not uniformity. Retrieved from https://www.aoshearman.com/en/insights/ten-lessons-in-sustainability-regulation/taxonomies-why-the-world-needs-harmonization-but-not-uniformity

Zhao, S., Cao, Y., Feng, C., Guo, K., & Zhang, J. (2022). How do heterogeneous R&D investments affect China's green productivity: Revisiting the Porter hypothesis. Science of the Total Environment, 825, 154090. https://doi.org/10.1016/j.scitotenv.2022.154090

Urbaniec, M., Tomala, J., and Martinez, S. (2021). Measurements and trends in technological eco-innovation: Evidence from environment-related patents. Resources, 10(7):68.

Appendix

A.1 NAICS2017 Codes for Cleantech Sector

CleanTech (level1)	CleanTech (level2)	NAICS2017	NAICS2017 description
Renewable Energy Systems	Energy Generation	221111	Hydro-electric Power Generation
		221113	Nuclear Electric Power Generation
		221114	Solar Electric Power Generation
		221115	Wind Electric Power Generation
		221116	Geothermal Electric Power Generation
		221117	Biomass Electric Power Generation
		221118	Other Electric Power Generation
	Related Industries	221121	Electric Bulk Power Transmission and Control
		221122	Electric Power Distribution
		221310	Water Supply and Irrigation Systems
		221320	Sewage Treatment Facilities
		237130	Power and Communication Line and Related Structures Construction
		238150	Glass and Glazing Contractors
		238160	Roofing Contractors
		238170	Siding Contractors

		238210	Electrical Contractors and Other Wiring Installation Contractors
		238220	Plumbing, Heating and Air-conditioning Contractors
		238310	Drywall and Insulation Contractors
		322110	Pulp Mills
		322121	Paper (except Newsprint) Mills
		335991	Carbon and Graphite Product Manufacturing
		335999	All Other Miscellaneous Electrical Equipment and Component Manufacturing
Biofuels	Farming	111110	Soybean Farming
		111120	Oilseed (except Soybean) Farming
		111150	Corn Farming
	Ethyl Alcohol Manufacturing	325193	Ethyl Alcohol Manufacturing
	Other Manufacturing	324191	Petroleum Lubricating Oil and Grease Manufacturing
		324199	All Other Petroleum and Coal Products Manufacturing
		325199	All Other Basic Organic Chemical Manufacturing
Recycled Materials	R&D	541713	Research and Development in Nanotechnology
		541714	Research and Development in Biotechnology (except Nanobiotechnology)
		541715	Research and Development in the Physical, Engineering, and Life Sciences (except Nanotechnology and Biotechnology)

	Waste Treatment	562111	Solid Waste Collection
		562112	Hazardous Waste Collection
		562119	Other Waste Collection
		562211	Hazardous Waste Treatment and Disposal
		562212	Solid Waste Landfill
		562213	Solid Waste Combustors and Incinerators
		562219	Other Nonhazardous Waste Treatment and Disposal
		562910	Remediation Services
		562920	Material Recovery Facilities
		562991	Septic Tank and Related Services
		562998	All Other Miscellaneous Waste Management Services
Energy Efficiency	Storage Battery	335911	Storage Battery Manufacturing
	Vehicle	336320	Motor Vehicle Electrical and Electronic Equipment Manufacturing
Consulting	Environmental Consulting	541620	Environmental Consulting Services
	Regulation and Administration Consulting	926120	Regulation and Administration of Transportation Programs
	Regulation and Administration Consulting	926130	Regulation and Administration of Communications, Electric, Gas, and Oth

Minerals and Metals	Minerals and Metals	212230	Copper, Nickel, Lead, and Zinc Mining
		212291	Uranium, Radium, Vanadium Ore Mining
		212299	All Other Metal Ore Mining
		327999	All Other Miscellaneous Nonmetallic Mineral Product Manufacturing
		333611	Turbine and Turbine Generator Set Units Manufacturing