Malaysia
Centre for the
Fourth Industrial
Revolution

WORLD ECONOMIC FORUM

In collaboration with Accenture

Industrial Transformation in ASEAN: A Cluster-Driven Model for Regional and Global Collaboration

WHITE PAPER

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Foreword

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The World Economic Forum, in collaboration with Accenture, launched the Transitioning Industrial Clusters (TIC) initiative,[1] which connects stakeholders across policy, industry, finance and technology to align on objectives, approach and strategy in building new industries and capabilities, while upgrading existing industries and skills. This includes sharing best practices and knowledge, pooling risks and expertise, as well as promoting pro-business regulatory policies and standards to enable transformational change at speed and scale.

Building on this mission, the TIC is also supporting the green transition of hard-to-abate industrial sectors, such as the production of concrete, aluminium and steel, which account for nearly 30% of global Scope 1 and 2 greenhouse gas (GHG) emissions. This rises to nearly 40% when including the hard-to-abate transport sectors, namely aviation, shipping and trucking.[2]

Today, TIC supports a rapidly expanding global network of 40 signatory clusters in 20 countries, contributing $508 billion to global gross domestic product (GDP), sustaining 4.6 million jobs and carrying the potential to reduce carbon dioxide equivalent (CO_2e) emissions by 877 million tonnes.[3] This is equivalent to the ninth-largest emitter globally, if it were a country.[4]

In South-East Asia, the Malaysia Centre for the Fourth Industrial Revolution (MYCentre4IR), hosted by MyDIGITAL Corporation and part of the World Economic Forum's global network, plays a central role in advancing the TIC agenda. As part of a global ecosystem of technology governance innovators, MYCentre4IR supports Malaysia's ambition to lead in sustainability, the energy transition and digital transformation, and has been instrumental in anchoring TIC's momentum in Malaysia and across the Association of Southeast Asian Nations (ASEAN).

As chairperson of ASEAN in 2025, the Prime Minister of Malaysia, Datuk Seri Anwar Ibrahim, announced that TIC will be adopted as a national agenda, uniting companies and public institutions to drive sustainable economic growth and development. Recognized as a national priority under the Malaysia Digital Economy Blueprint and aligned with the National Fourth Industrial Revolution Policy, National Industrial Masterplan and National Energy Transition Roadmap, TIC strengthens Malaysia's efforts to scale industrial transformation and accelerate the shift towards a more sustainable, competitive and digitally enabled economy.

Inspired by this bold and strategic vision, this paper takes a close look at how industrial clusters can catalyse more inclusive, resilient and sustainable growth among ASEAN economies. By sharing insights and practical pathways forward, this paper seeks to highlight the opportunities for trade, business and investment partnerships for policy-makers, public institutions, industry players, investors, and development partners in shaping and participating in a very exciting chapter of ASEAN's green transition and development.

Executive summary

South-East Asia requires coordinated, low-carbon industrial transformation through aligned policies, collaborative clusters and innovative finance for sustainable, resilient growth.

The Association of Southeast Asian Nations (ASEAN) – comprising **Brunei Darussalam, Cambodia, Indonesia, Lao People's Democratic Republic, Malaysia, Myanmar, the Philippines, Singapore, Thailand, Viet Nam and Timor Leste** – is home to over 670 million people[5] and generates a combined gross domestic product (GDP) of $3.8 trillion, making it the world's fifth-largest economy[6] in 2023.

ASEAN now stands on the cusp of a major industrial transformation. To sustain its growth trajectory and global competitiveness, the region must evolve towards a diversified, high-value and low-carbon industrial model.

Indeed, ASEAN is undergoing a profound **energy transition**. Total energy demand is rising by approximately 3%[7] annually, representing some of the fastest growth rates globally. Yet nearly 80%[8] of this demand is met by fossil fuels, deepening dependence on volatile imports and increasing fiscal strain. By the late 2020s, ASEAN is expected to become a net gas importer, while oil import bills could exceed $200 billion by 2050.[9] These pressures highlight the urgent need for a more resilient and sustainable energy model.

ASEAN countries have set bold renewable and net-zero targets not just to cut emissions but to strengthen energy and fiscal resilience. Implementation, however, remains uneven. Fragmented governance, high financing costs and divergent national priorities continue to slow progress, leaving a gap between regional ambition and tangible outcome. Closing this gap requires greater alignment, coordination and practical mechanisms for collective action.

Industrial clusters – geographic concentrations of interconnected industries, infrastructure and innovation – offer a powerful solution for transformation at both national and regional levels. For ASEAN, industrial clusters offer scale, cost efficiency and innovation, accelerating clean technology deployment, creating green jobs and strengthening global competitiveness through sustainable, low-carbon growth.

This white paper introduces a **playbook** that serves as a practical guide to translate strategic intent into tangible outcomes and accelerate ASEAN's industrial transformation. Complemented by real-world case studies, it provides both the direction and instruments to turn ambition into action.

ASEAN has made significant strides in advancing its energy and industrial transformation agenda. Achieving its ambitions will demand deeper and more coordinated regional collaboration. The World Economic Forum welcomes joint action for policy-makers, clusters and financiers across three key priorities:

1 Align policies and markets to accelerate transition

Achieving ASEAN's energy transition requires stronger policy alignment and market coherence across member states. Harmonizing technical and market standards such as grid codes, tariff structures and renewable energy credit (REC) mechanisms while gradually rebalancing fossil fuel incentives and developing a common carbon pricing and disclosure framework will strengthen investor confidence.

2 Build collaborative ecosystems

Industrial clusters can serve as collaborative ecosystems and testbeds for clean technologies like renewables, hydrogen and shared carbon capture networks reducing risks and cost. Pooling capital across public, private and financial partners enables shared infrastructure. Meanwhile, integrating offtake partners secures demand, reduces risk and enhances project bankability. These ecosystems can span national, regional and global networks.

3 Mobilize finance to scale the transition

ASEAN's transition demands large-scale capital mobilization through stronger collaboration and innovative financing from multilateral development banks (MDBs), international financiers, investors and governments. Progress through sustainable finance tools and funds is notable, yet financing levels remain insufficient for both green and transition finance. Governments can play a key role in strengthening de-risking through, for example, concessional finance, guarantees, tax incentives, viability gap funding, tripartite/contract for difference (CfD) contracts and public-private partnership (PPP) models, which are essential to attract private investments.

1 Context and opportunity

Rapid industrial growth and fossil fuel dependence heighten energy security risks; industrial clusters can drive resilient, competitive and low-carbon transformation.

$105 billion

in fossil fuel subsidies in 2022 alone from ASEAN.

South-East Asia stands at a pivotal inflection point, driven by robust economic growth, with gross domestic product (GDP) expected to expand around 4.7% annually in 2025 and 2026.[10]

Prosperity has brought rising energy demand, with the Association of Southeast Asian Nations (ASEAN) now being the fourth-largest energy consumer worldwide.[11] Nearly 80% of supply still comes from fossil fuels.[12] Meanwhile, coal provided 44% of electricity in 2023.[13] Fossil fuel subsidies reached $105 billion in 2022 alone,[14] domestic gas production is declining, and ASEAN is expected to become a net liquefied natural gas (LNG) importer by 2032, with demand forecast to surge 182% over the next decade.[15]

South-East Asia's remarkable growth is increasingly constrained by its energy model. The energy trilemma, balancing security, affordability and sustainability, **has become the defining challenge for both individual countries and the region.**

ASEAN members share a common direction in the energy transition, but each starts from a unique baseline. While national strategies must reflect local realities, energy security and deep decarbonization will demand regional collaboration across interconnected grids, gas networks and emerging low-carbon value chains such as hydrogen, ammonia and carbon capture.

At the regional level, ASEAN has established clear long-term ambitions, setting targets to reach 30% renewable energy in total primary supply, 45% renewable power capacity and a 40% reduction in energy intensity by 2030.[16] Overall, eight member states now have net zero commitments – most by 2050, with Indonesia targeting 2060.[17]

There has been encouraging progress. The Lao People's Democratic Republic–Thailand–Malaysia–Singapore Power Integration Project delivered the region's first multilateral, cross-border electricity trade.[18] Building on this momentum, by 2022 the region had achieved a 24.5% energy intensity reduction from 2005 levels; renewable energy reached 15.6% of total primary energy supply and 33.6% of installed power capacity.[19]

Yet the region remains off-track to meet its 2016–2025 ASEAN Plan of Action for Energy Cooperation (APAEC) goals. Energy intensity reduction lags the 32% target, and renewables' share in total supply is below the 23% mark. Meanwhile, fossil fuel consumption continues to grow.[20]

Amid these challenges lies a shared opportunity to align the energy transition with industrial transformation. Industry is the economic engine of ASEAN, the largest energy consumer among the end use sector and the second-largest CO_2

emitter.[21] Industry contributes around 34% of ASEAN's GDP, with manufacturing (as the largest sub-sector) making up around 20% of the region's GDP.[22] It is the fourth-largest manufacturing base in the world, and manufacturing gross output value could reach **$1.2 trillion by 2030**.[23] Concentrated within manufacturing hubs, industrial estates and port zones, this footprint offers a unique platform for coordinated, high-impact decarbonization.

Industrial clusters create the structures where national policy, private investment and regional collaboration converge.

For countries, industrial clusters can:

- **Accelerate clean technology deployment** in hard-to-abate sectors such as cement, steel and chemicals
- **Provide scale by concentrating industrial activity**, enabling efficient deployment of renewables, hydrogen and carbon capture across shared infrastructure
- **Lower costs and de-risk investments** through shared infrastructure and utilities and pooled investments
- **Drive green job creation and workforce transformation** by reskilling workers
- **Showcase that energy transition and development** can advance together

For the region, industrial clusters can:

- **Serve as anchor nodes for cross-border power trade and low-carbon hydrogen corridors**, aligning supply and demand across markets
- **Build investor confidence** through standardized frameworks, aggregated demand and scalable models
- **Strengthen regional and national competitiveness** by enabling coordinated industrial development that enhances ASEAN's position in global value chains and attracts sustainable trade and investment

Clean, efficient clusters will be pivotal in determining whether the region protects and grows its position as an attractive, competitive manufacturing base and an investment destination in a world increasingly shaped by carbon intensity and supply chain resilience.

> **ASEAN's industrial future depends on aligning sustainable energy ambitions with manufacturing competitiveness. This white paper illustrates how industrial clusters offer a practical route to deliver low-carbon growth and industrial competitiveness, a key focus of the International Energy Agency (IEA) Regional Cooperation Centre's work on energy manufacturing. By deepening collaboration across borders and sectors, ASEAN can move beyond the traditional trilemma mindset and demonstrate that energy security, emissions reduction and competitiveness can advance together.**
>
> Sue-Ern Tan, Head, IEA Regional Cooperation Centre

2

Clusters as catalysts of ASEAN's energy transition and industrial transformation

Examining the factors shaping ASEAN's energy transition highlights what influences progress and enables cluster development.

65%

energy demand rise expected by 2050 from 2023.

Industry accounts for around 47% of South-East Asia's total final energy consumption, with industrial energy demand expected to rise by 65% by 2050 from 2023 under the International Energy Agency's (IEA) Stated Policies Scenario.[24] **Industrial clusters are key levers to advance both ASEAN's industrial transformation and overall energy transition**.

Globally, electricity is increasingly driving industrial energy growth,[25] signalling a structural shift from fossil-intensive production to power-based industrial systems. This forms a strong link between ASEAN's energy transition and industrial transformation.

To understand the role clusters will have to play, it's crucial to understand these transformations at regional and national levels, and the unique challenges they face.

2.1 ASEAN – the region's energy transition and industrial transformation enabler

"ASEAN's Economic Pillar places the energy transition at the centre of its agenda. This effort is guided by APAEC, the region's principal blueprint for energy collaboration.

The region's progress in energy transition and industrial transformation is deeply rooted in a network of collaborative frameworks that align policy, infrastructure and energy transition priorities to enable a low-carbon, resilient future.

The ASEAN organization, comprising 11 member states operating under the principles of consensus collectively known as the "ASEAN Way", lies at the heart of these efforts. Figure 1 illustrates a number of key enablers driving ASEAN's initiatives on regional integration, industrial transformation, climate action and inclusive energy transition.

Building on its broader vision of regional integration, ASEAN's Economic Pillar places the energy transition at the centre of its agenda. This effort is guided by APAEC, the region's principal blueprint for energy collaboration.

Figure 2 illustrates ASEAN's energy transition priority areas and the institutional mechanisms that deliver them.

FIGURE 1 | **ASEAN key enablers**

ASEAN members

Indonesia, Malaysia, Singapore, Thailand, Phillipines — **Founding members**

Brunei Darussalam, Viet Nam, Lao PDR, Myanmar, Cambodia, Timor Leste — **Joined from 1984 through 2025**

ASEAN key enablers

ASEAN initatives on regional integration, industrial transformation, climate action, inclusive energy transition

ASEAN Economic Community (AEC) Blueprint 2025

Master plan advancing ASEAN's economic growth covering MSME development, digitalization, trade, investment, innovation, connectivity etc.

Master Plan on ASEAN Connectivity (MPAC) 2025

Strengthens physical and energy infrastructure connectivity, including the **ASEAN Power Grid**

ASEAN Plan of Action for Energy Cooperation (APAEC)

Aligned with AEC, strengthens regional energy security, affordability and sustainability, and accelerates the transition under phase 2 (2021–2025)

ASEAN Climate Change Strategic Action Plan (ACCSAP)

Guided by ASEAN State of Climate Change Report (ASCCR), steers coordinated regional climate mitigation and adaptation efforts

ASEAN Comprehensive Recovery Framework (ACRF)

Includes priority initatives, phases and lead sectoral bodies for ASEAN's collective socioeconomic recovery and future resilience

Consolidated Strategy on the Fourth Industrial Revolution (C4IR) for ASEAN

Accelerate ASEAN's digital transformation by aligning policies, skills and infrastructure for inclusive regional competitiveness

ASEAN Digital Masterplan (ADM) 2025

Provides a regional digital roadmap to promote digital infrastructure, innovation and cybersecurity

ASEAN Taxonomy for Sustainable Finance (V2)

Creates unified classification to unlock green transition finance in ASEAN

ASEAN Strategy for Carbon Neutrality

Outlines a collective strategy to accelerate the journey towards carbon neutrality

Roadmap for Multilateral Power Trade (AFMP)*

Defines a clear path for establishing a multilateral power market across ASEAN

*Roadmap is under development

Just and Inclusive Energy Transition (JIET)

Strategy to ensure the shift to low-carbon energy system is equitable and fair, and benefits all communities

Source: Association of Southeast Asian Nations (ASEAN). (2025). *ASEAN Economic Community Blueprint 2025*; Association of Southeast Asian Nations (ASEAN). (2025). *Master Plan on ASEAN Connectivity 2025*; Association of Southeast Asian Nations (ASEAN). (2025). *ASEAN Plan of Action for Energy Cooperation (APAEC) 2016-2025*; Institute for Global Environmental Strategies (IGES). (n.d.). *The ASEAN Climate Change Strategic Action Plan 2025-2030 Project*; Association of Southeast Asian Nations (ASEAN). (n.d.). *Implementation Plan of ASEAN Comprehensive Recovery Framework*; Association of Southeast Asian Nations (ASEAN). (n.d.). *Consolidated Strategy on the Fourth Industrial Revolution for ASEAN*; Association of Southeast Asian Nations (ASEAN). (n.d.). *ASEAN Digital Masterplan 2025*; Association of Southeast Asian Nations (ASEAN). (n.d.). *ASEAN Taxonomy for Sustainable Finance*; Association of Southeast Asian Nations. (n.d.). *ASEAN Strategy for Carbon Neutrality*; Association of Southeast Asian Nations (ASEAN). (n.d.). *Study on the Roadmap for Multilateral Power Trade in ASEAN*; Association of Southeast Asian Nations. (n.d.). *A Guide to a Just and Inclusive Energy Transition in ASEAN*.

FIGURE 2 | **ASEAN's energy transition priorities and mechanisms**

APAEC aligns with the AEC to strengthen regional energy security, affordability and sustainability, and accelerate the energy transition under phase 2 (2021–2025)

APAEC 2016–2025 phase 2
Priority areas

1. **ASEAN Power Grid (APG)**
   To expand regional multilateral electricity trading, strengthen grid resilience and modernization, and promote clean and renewable energy integration
2. **Trans-ASEAN Gas Pipeline (TAGP)**
   To pursue the development of a common gas market for ASEAN by enhancing gas and LNG connectivity and accessibility
3. **Coal and clean coal technology**
   To optimize the role of clean coal technology in facilitating the transition towards sustainable and lower-emission development
4. **Energy efficiency and conservation**
   To reduce energy intensity by 32% in 2025 based on 2005 levels and encourage further energy efficiency and conservation efforts, especially in transport and industry sectors
5. **Renewable energy**
   To achieve aspirational target for increasing the component of renewable energy to 23% by 2025 in the ASEAN energy mix, including through increasing the share of renewable energy in installed power capacity to 35% by 2025
6. **Regional energy policy and planning**
   To advance energy policy and planning to accelerate the region's energy transition and resilience
7. **Civilian nuclear energy**
   To build human resource capabilities on nuclear science and technology for power generation

APAEC 2016–2025 phase 2
Governance structure

ASEAN Ministers of Energy Meeting (AMEM)
Provides overall guidance, sets policy directions and issues directives to address key energy issues and challenges

ASEAN Centre for Energy (ACE)
Provides technical coordination, policy analysis, statistics, planning and fund-sourcing support, and facilitates integration of tasks across sectoral expery bodies (SEBs)/sub-sectoral networks (SSNs)

Senior Officials Meeting on Energy (SOME)
Determines implementation priorities, provides guidance and advice on APAEC strategies, oversees formulation and implementation of yearly work plans and updates AMEM annually

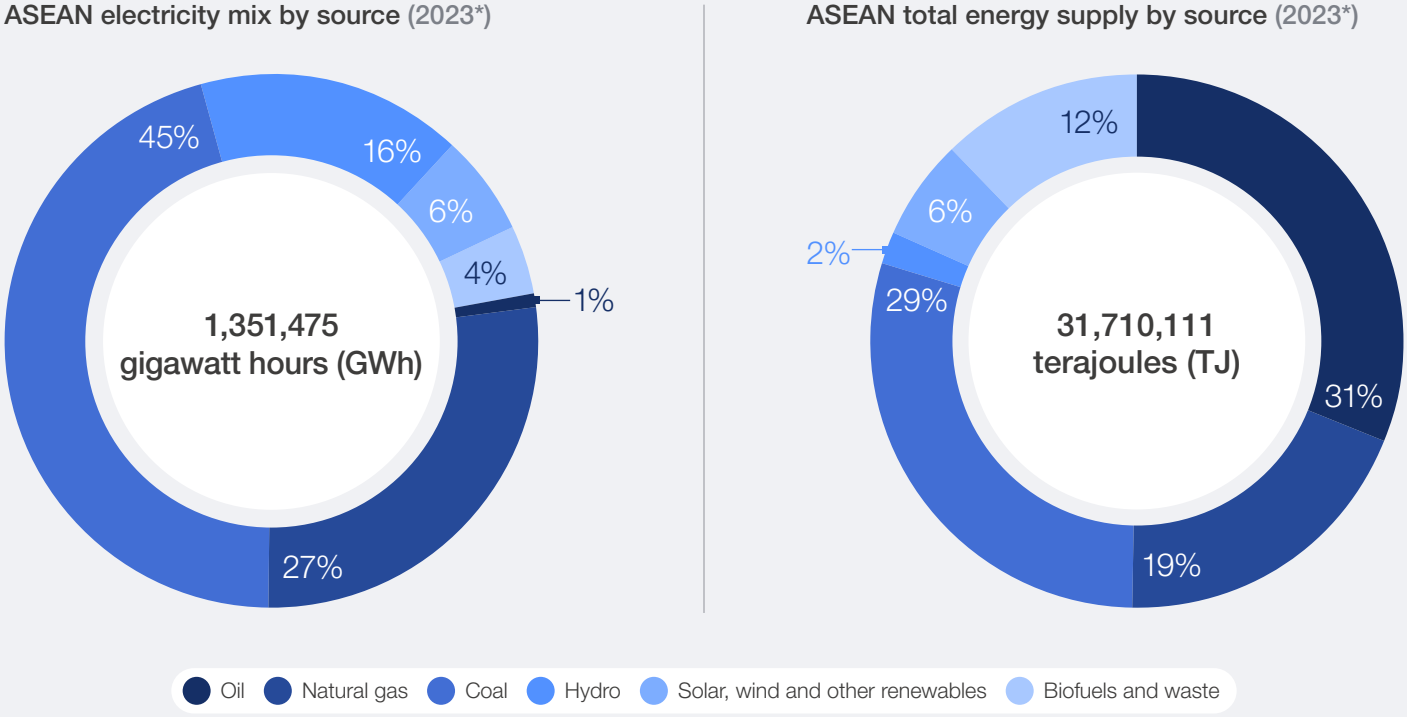
Sectoral Expert Bodies (SEBs) and Sub-sectoral Networks (SSNs)
Serve as implementing arms of SOME in their respective programme areas; develop work programmes and prepare project proposals and documents

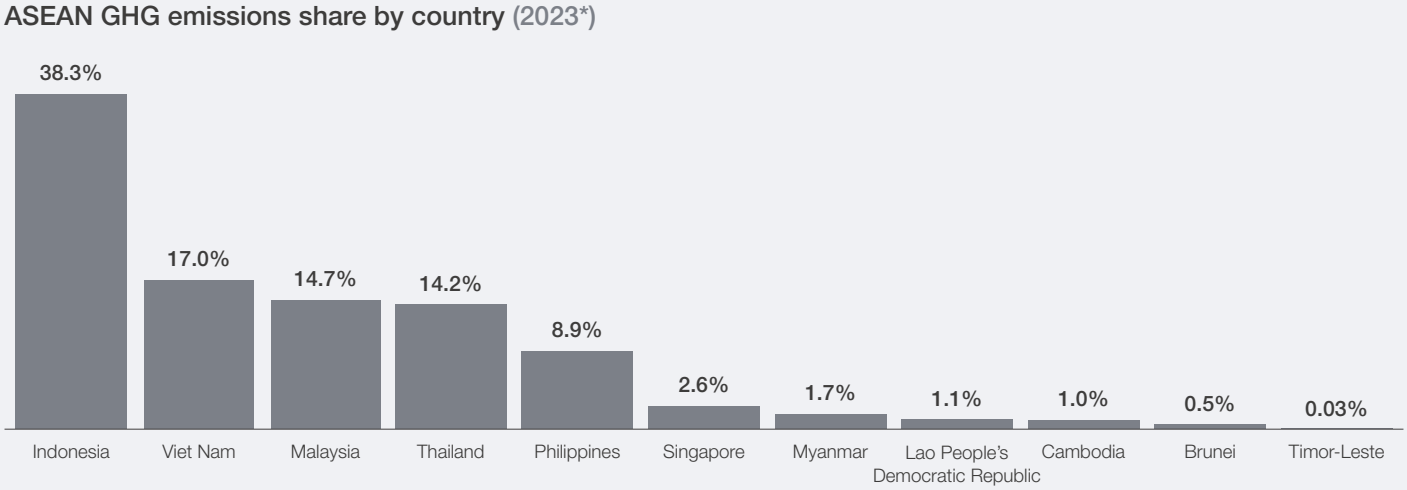
Source: ASEAN Centre for Energy (ACE). (n.d.). *ASEAN Plan of Action for Energy Cooperation 2016-2025 (APAEC) phase 1 & phase 2*.

2.2 ASEAN nations overview: balancing industrial growth and decarbonization

While ASEAN nations are advancing industrial growth, they also need reliable energy to balance security, growth and sustainability. The region's energy transition is shaped by varying natural resource availability, economic structures and policy ambitions across its member states. The region's cumulative energy mix is still heavily reliant on fossil fuels. The greenhouse gas (GHG) emissions profile shows that four countries contribute over 80% of emissions, with Indonesia alone accounting for 38%,[26] as illustrated in Figure 3.

FIGURE 3 **ASEAN energy and emissions profile**





*Data for Timor-Leste are based on 2022 figures.

Source: International Energy Agency (IEA). (n.d.). *Asia Pacific Total CO_2 Emissions.*

At the country level, energy transition pathways vary widely. These differing national contexts shape both the pace and nature of ASEAN's transition, underscoring the importance of regional coordination to achieve shared goals.

COUNTRY SPOTLIGHT

Indonesia

Indonesia, the world's largest archipelago, has one of the world's largest nickel reserves[27] and biodiesel production,[28] and aims to be a global EV battery hub[29] and a leading exporter of coal.[30]

Coal contributes to over 65% of its electricity generation,[31] although it holds around 40% of global geothermal reserves,[32] which contribute only about 3% of installed capacity. In 2023, the share of renewable energy in the electricity mix was around 13%, well below the 2023 target of 17.9%.[33] To accelerate the energy transition, Indonesia is implementing the Just Energy Transition Partnership,[34] revising its **Electricity Supply Business Plan (RUPTL)**,[35] reforming power purchase agreements, de-risking clean-energy investments, advancing a national **"super grid"**[36] and developing **green industrial parks in Kalimantan and Sulawesi**.

COUNTRY SPOTLIGHT

Viet Nam

Viet Nam is emerging as a global manufacturing powerhouse[37] with ambitions to become a global semiconductor hub[38] **and a regional leader in solar energy adoption**. It's harnessing its transition to drive growth and export competitiveness.

It aims for 80–85% power supply by renewable energy by 2050 and under the Power Development Plan 8 (PDP8) – harnessing its significant offshore wind potential[39] – while targeting coal plant decommissioning and expanded LNG imports to support grid stability.[40]

Renewable energy growth, however, has outpaced grid and storage capacity, leading to congestion and curtailment, while regulatory and investment bottlenecks have slowed further deployment. To address these, Viet Nam set out plans for grid modernization and advancing its Smart Grid Roadmap.[41]

Clean coal pilots, carbon capture, utilization and storage (CCUS) and green hydrogen initiatives, and plans to resume nuclear development at Ninh Thuan by 2030–2035[42] complement this.

COUNTRY SPOTLIGHT

Malaysia

Malaysia is one of the leading digital hubs and energy producers in Asia, handling 13% of global semiconductor assembly.[43] Its oil and gas dominance is anchored by one of the world's largest LNG complexes in Bintulu,[44] with natural gas contributing around 35% of electricity and renewable energy contributing below the 31% target for 2025 and 40% target for 2040.[45]

The country faces challenges in balancing energy security with the need to scale investment in cleaner alternatives. To advance the transition, Malaysia is modernizing the grid with smart technologies, positioning Bintulu as a low-carbon industrial cluster,[46] introducing guidelines for sustainable data centre development[47] and advancing cross-border clean energy trade in the Johor–Singapore Special Economic Zone (JS-SEZ).[48]

It is also pioneering carbon capture and storage (CCS) through initiatives such as the Kasawari offshore project[49] and launching hydrogen pilots in Sarawak and Peninsular Malaysia.[50]

COUNTRY SPOTLIGHT

Thailand

Thailand, as South-East Asia's largest automotive manufacturing base, is also seeking to develop itself as the region's EV hub.[51] This sits alongside a well-developed petrochemical sector anchored in the Map Ta Phut complex,[52] forming a carbon-intensive industrial base.

With **over 60% reliance on natural gas for electricity**,[53] **Thailand faces declining domestic natural gas production and reduced imports from Myanmar**.[54] Under the draft PDP, the country aims to have 51% share of renewable energy by 2037[55] and achieve net zero by 2050.[56] It is also expanding bioenergy projects[57] and cross-border hydropower imports from Laos,[58] investing in grid modernization through its Smart Grid Master Plan[59] and developing the Smart Park Industrial Estate to drive sustainable industrial growth.[60]

COUNTRY SPOTLIGHT

Philippines

The Philippines, an archipelagic nation of over 7,000 islands, ranks among the world's largest hubs for information technology, business process management[61] and nickel production,[62] and among the most attractive emerging markets for energy transition investment.[63]

The government targets 35% renewables by 2030 and 50% by 2040.[64] **Fossil fuels still supply** about **75%** of electricity generation, however, driving high electricity prices[65] amid coal import reliance and declines in domestic natural gas. In response, the country is increasing the share of renewable energy, awarding 1,392 renewable energy contracts under the Green Energy Auction Program[66] while scaling LNG infrastructure and taking early steps in hydrogen, nuclear and CCUS.

COUNTRY SPOTLIGHT

Singapore

Singapore, home to the world's second-busiest port, a top marine bunkering hub[67] and a major exporter of high-tech goods[68] and chemicals,[69] is at the forefront of the ASEAN energy transition.

Aiming to meet around one-third of its energy demand through low-carbon electricity imports by 2035,[70] its heavy reliance on imports and scarce land makes this transition complex.[71] In response, Singapore boosted solar deployment, becoming one of the world's most solar-dense cities, and also launched financing initiatives such as Financing Asia's Transition Partnership (FAST-P).[72] It is decarbonizing its energy and chemical hub through the Jurong Island refreshed direction[73], which focuses on new energies and low-carbon innovation in the energy and chemicals sector.

In parallel, it is advancing maritime decarbonization via the Maritime Singapore Decarbonization Blueprint and Tuas mega-port development. It is also exploring low-carbon technologies such as CCUS and hydrogen.[74]

> **Our vision for Jurong Island goes beyond decarbonizing a chemical and energy hub – we are redesigning the industrial ecosystem itself. By embedding sustainability, circularity, carbon management and collaboration into its core, we are building a blueprint to power the future of low-carbon innovation.**
>
> Jacqueline Poh, Chief Executive Officer, JTC Corporation

2.3 Challenges to ASEAN's energy transition

Addressing energy challenges is critical to strengthening the region's industrial base and sustaining its growth momentum.

Despite ASEAN's strong policy intent and institutional coordination, significant challenges remain.[75] ASEAN's consensus-based approach ensures inclusivity, but can also slow momentum. Its rotating chairmanships can shift regional focus over time. Addressing energy challenges is critical to strengthening the region's growing industrial base and sustaining its growth momentum.[76] The key challenges can be broadly categorized into policy, infrastructure and financing.

Policy barriers

- **Policy fragmentation**: Fragmented national targets, incentives and standards hinder regional coordination; ASEAN must shift from isolated national goals to deeper regional integration via the ASEAN power grid (APG), renewable energy credits and shared funds. This is essential to scaling the energy transition.[77] Inconsistent policies and frameworks (e.g. tariffs, wheeling charges) deter large-scale investment in the region,[78] while lack of harmonized technical standards (e.g. grid codes) hampers the development of a cooperative grid.[79] Absence of inter-ministerial working groups, unclear ministerial roles and weak inter-ministerial coordination leave companies in limbo on implementation decisions.
- **Fossil fuel subsidies and carbon pricing gaps**: Fossil fuel subsidies remain prevalent in several ASEAN countries, discouraging renewable investment.[80] Carbon pricing mechanisms are limited or inconsistent.[81] Although each country drives its own approach, absence of interoperable carbon registries and common market rules would limit cross-border opportunities.[82]
- **Human capital and workforce transition**: As education systems lag behind industry needs, with limited curricula, instructor shortages and weak academia–industry–government coordination, fragmented funding continues to widen the region's energy skills gap.[83] Meanwhile, the shift towards low-carbon industrial technologies risks displacing workers in carbon-intensive sectors.

> **Building a sustainable aviation fuels (SAF) plant is only half the journey. Without a clear policy mandate and government incentives, airlines remain reluctant to commit to long-term SAF offtake agreements. What would unlock real scale are binding blending targets, tax or subsidy support to bridge the price gap and recognition of certified feedstocks under global standards. With such a policy backbone in place, capacity expansion and airline adoption could progress much faster.**
>
> Chaiwat Kovavisarach, Group Chief Executive Officer and President, Bangchak

ASEAN will need $11.9 trillion by 2050 to fully transition across energy sectors.

Infrastructure barriers

- **Infrastructure gaps**: The region needs to roughly double[84] the transmission expansion to meet clean energy targets, but it is constrained by ageing grids, under-planned expansion, persistent misalignment between power generation and transmission planning, and fragmented regional cooperation. Countries lack cluster-level directives such as shared renewable systems or utilities, limiting economies of scale and slowing industrial transition.
- **Gas lock-in**: Gas plays an important bridging role in ASEAN's transition. ASEAN's gas lock-in stems from substantial infrastructure investments that create entrenched dependencies. This could limit governments' ability to pivot to cleaner alternatives. Proactive strategies are needed to ensure gas development remains supportive to the energy transition targets.
- **Digital infrastructure gaps**: ASEAN countries show uneven digital maturity, e.g. deployment of digital twins, AI and energy.

Financing barriers

- **Financing and investment gaps**: ASEAN will need $11.9 trillion[85] by 2050 to fully transition across energy sectors. A major barrier is ASEAN's high cost of capital for green projects, compounded by limited private investment, reliance on public funds, restricted financing options and policy uncertainty.[86] De-risking instruments and blended finance mechanisms are limited, while inconsistent sustainability disclosures raise investor due diligence costs to industrial players. Immature tokenization and digitalization of asset classes[87,88] further limit access to public spreads.
- **Market and regulatory constraints**: Most regional grids still transmit mixed green and brown electrons (restricting access to green finance) and require transition financing. Many ASEAN countries have liberalized electricity generation to allow private participation, but grid transmission, distribution and retail largely remain state-controlled, constraining broader private investment and competition.[89]

These barriers highlight the need for targeted solutions, and industrial clusters offer the most effective platform to overcome them by integrating efforts.

> **ASEAN's energy transition will not hinge solely on technology availability, but on the credibility and predictability of its financial and policy architecture. Investors are ready to deploy capital, but policy and market signals remain too uncertain to anchor capital at scale. The region's next leap requires moving from project-by-project deals to coordinated, system-level investment – where grids, industrial clusters and supply chains work in sync to make low-carbon growth bankable. If ASEAN gets this right, it could show that development and decarbonization can scale side by side.**
>
> Christina Ng, Managing Director, Energy Shift Institute

2.4 Strengthening industrial clusters' role in ASEAN's transition

As industrial output is concentrated in manufacturing hubs, industrial estates and port zones, industrial clusters become critical platforms.

Clusters provide a powerful lever to address ASEAN's systemic challenges, as they are deeply embedded across all dimensions of the economy – from energy production and consumption to supply chains, workforce development, innovation and infrastructure. They host both the highest-emitting facilities and are key GDP and job contributors. For instance, five Thailand industrial provinces – Ratchaburi, Chon Buri, Rayong, Saraburi and Samut Prakan – contribute heavily to both economic growth and emissions.[90]

Clusters can only function effectively within a strong enabling environment. Supportive policies, governance structures, clean energy investments, infrastructure and cross-border harmonization are critical to the success of industrial clusters. The eight interventions below outline what is required for clusters to serve as engines of ASEAN's energy transition.

1 Promote cluster decarbonization roadmaps to advance national targets:

Clusters can support national targets by publishing structured decarbonization roadmaps. Singapore's Jurong Island shows early progress, while the UK's Humber[91] cluster offers a strong reference with its Net Zero by 2040 plan.

> Industrial clusters thrive only when supported by strong policies, clean energy investment, robust infrastructure and cross-border alignment.

2 Align cross-border policies and technical standards:

ASEAN could boost investor confidence by accelerating the harmonization of cross-border policies, targets and standards. Ongoing initiatives like the APG[92] and the Harmonisation of Minimum Energy Performance Standards (MEPS)[93] show early progress, while the EU Energy Efficiency Directive offers a useful reference. Widespread adoption of ASEAN taxonomy and sustainability disclosures, gradual rebalancing of fossil-fuel incentives, and market reform to reward renewable energies and batteries are all needed to attract investments.

3 Develop an ASEAN-wide carbon pricing and market framework:

Emerging voluntary carbon markets offer ASEAN a chance to become a regional carbon trading hub. A shared architecture, with aligned protocols, interoperable registries and transparent credit tracking, would incentivize industries to adopt low-carbon technologies, and enable cross-border trade and investment.

4 Promote cluster-level low-carbon infrastructure:

Industrial clusters require clear directives for the development of shared low-carbon infrastructure such as renewable systems, energy efficiencies, circularity, digital monitoring, reporting and verification (MRV) systems and eco-buildings. Examples like Indonesia's Jababeka Industrial Estate[94] show progress, while directives for such standards (e.g. China's National Development and Reform Commission[95]) can cut costs and boost efficiency.

5 Accelerate grid expansion and corporate renewable access:

Upgrading, expanding and interconnecting ASEAN's power grids is a critical enabler for clusters, allowing them to access clean power. Complementing these efforts, market-based mechanisms such as renewable energy certificates, Viet Nam's Direct Power Purchase Agreement pilot and the Corporate Renewable Electricity Supply Scheme can empower clusters to directly procure renewable energy. Cross-border electron trading via the APG will also require market model innovation.[96]

6 Advance human capital development and workforce transformation:

ASEAN would require strengthened education and training systems, which would help to build energy and sustainability skills for green jobs.[97] Government and industry support workforce transitions in carbon-intensive sectors through reskilling and inclusive programmes will also be required.[98] Brightlands Circular Space cultivates a knowledge ecosystem advancing a sustainable chemical industry.[99]

7 Unlock scalable finance

Mobilizing public and private investment through green bonds, green sukuk, and blended and transition finance is essential. Existing mechanisms like the ASEAN Catalytic Green Finance Facility (ACGF) and FAST-P provide an initial foundation, while the European Investment Bank's (EIB) EU Green Bond Standard-aligned Green Bond exemplifies large-scale green finance.[100]

8 Deploy robust de-risking instruments

De-risking investments requires access to grants, concessional finance and government-backed capital – such as low-interest loans or loan guarantees.[101] Contracts for difference (CfDs), targeted tax credits and blended finance platforms provide facilitation mechanisms to better connect available capital with clusters' needs.[102] Targeted tools like viability gap funding, feed-in tariffs, auctions and standardized contracts can be used to unlock investment.[103] Additionally, tokenization and digitalization of physical assets can create new derivative forms for public market participation.

3

From strategy to scale: how ASEAN's industrial clusters are driving transition today

Clusters translate strategy into real industrial transformation progress through partnerships, policy advocacy, technological enablement and innovative finance.

This section highlights key examples across the four TIC pillars, offering practical insights for others embarking on similar transition journeys:

FIGURE 4 **The four pillars of TIC**

Partnerships

Cultivate collaboration and trust between co-located companies and public institutions to align on a shared vision.

Policy

Enable dialogue between policy-makers and industry, and inform policies to drive industrial transformation.

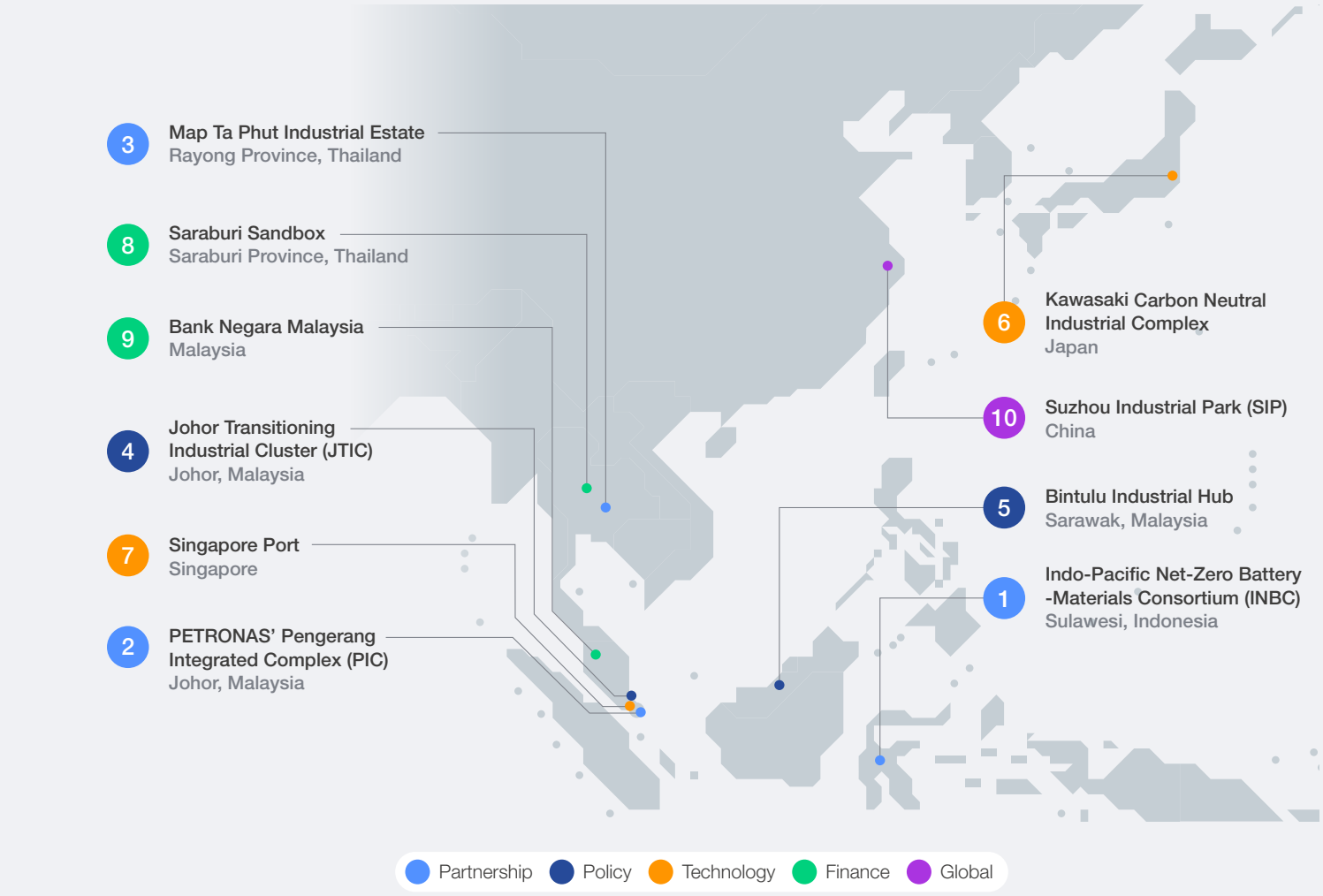
Technology

Deploy and scale low-carbon technologies and shared infrastructure for energy efficiency, renewables, hydrogen and carbon capture.

Finance

Mobilize capital by identifying innovative financing options to develop large-scale clean energy projects.

FIGURE 5 | **Geographical overview of case studies**



3.1 Partnerships

Across ASEAN, partnerships are driving coordinated industrial transformation. They build the necessary trust, shared accountability and cross-sector alignment. From cross-industry cooperation to cross-border collaboration, clusters demonstrate how collective action can accelerate the low-carbon transition far faster than isolated corporate efforts.

CASE STUDY 1

Indo-Pacific Net-Zero Battery-Materials Consortium: partnership for net-zero batteries

Context: Bakrie Group, Glencore and Envision have formed the Indo-Pacific Net-Zero Battery-Materials Consortium (INBC), a first-of-its-kind, cross-border partnership creating a fully integrated, low-carbon battery value chain. This partnership is anchored by Bakrie and Glencore in the upstream value chain for nickel mining and processing, and led by Bakrie and Envision downstream in clean energy generation, industrial park development, battery production and global distribution.

Objective: The partnership aims to produce 140 gigawatt hours (GWh) of nickel-based batteries (representing a 14-fold increase over Indonesia's estimated 2024 battery production capacity of around 10GWh[104]) and secure low-carbon battery materials for European markets while establishing Indonesia's first net-zero industrial park at Sulawesi.[105]

Intervention: Since its launch, the partnership has moved from planning to tangible implementation, advancing its net-zero industrial cluster in Sulawesi:

- By end of 2025, INBC aims to have half of its operations running on wind energy, with the remainder on natural gas as a bridge fuel as they explore longer-term options such as nuclear.
- Construction is under way at the Sulawesi Industrial Park, co-locating nickel and copper processing, battery manufacturing and recycling to reduce transport emissions.
- The consortium is collaborating with local governments on enhancing waste management, reducing landfill disposal and exploring ways to convert industrial waste into energy.
- Through Envision's digital expertise, the partnership is testing AI and digital tools to coordinate the global supply chain efficiently.

CASE STUDY 2

PETRONAS' Pengerang Integrated Complex (PIC): The PIPC's leading initiative driving Malaysia's low-carbon fuel future

Context: PETRONAS is setting up its first bio-refinery, marking a key milestone in advancing low-carbon fuels solutions within its refining, marketing and trading division. The project will produce sustainable aviation fuel (SAF) and hydrogenated vegetable oil (HVO), supporting Malaysia's energy transition and emissions reduction goals. It is listed as a catalytic project under the National Energy Transition Roadmap (NETR).

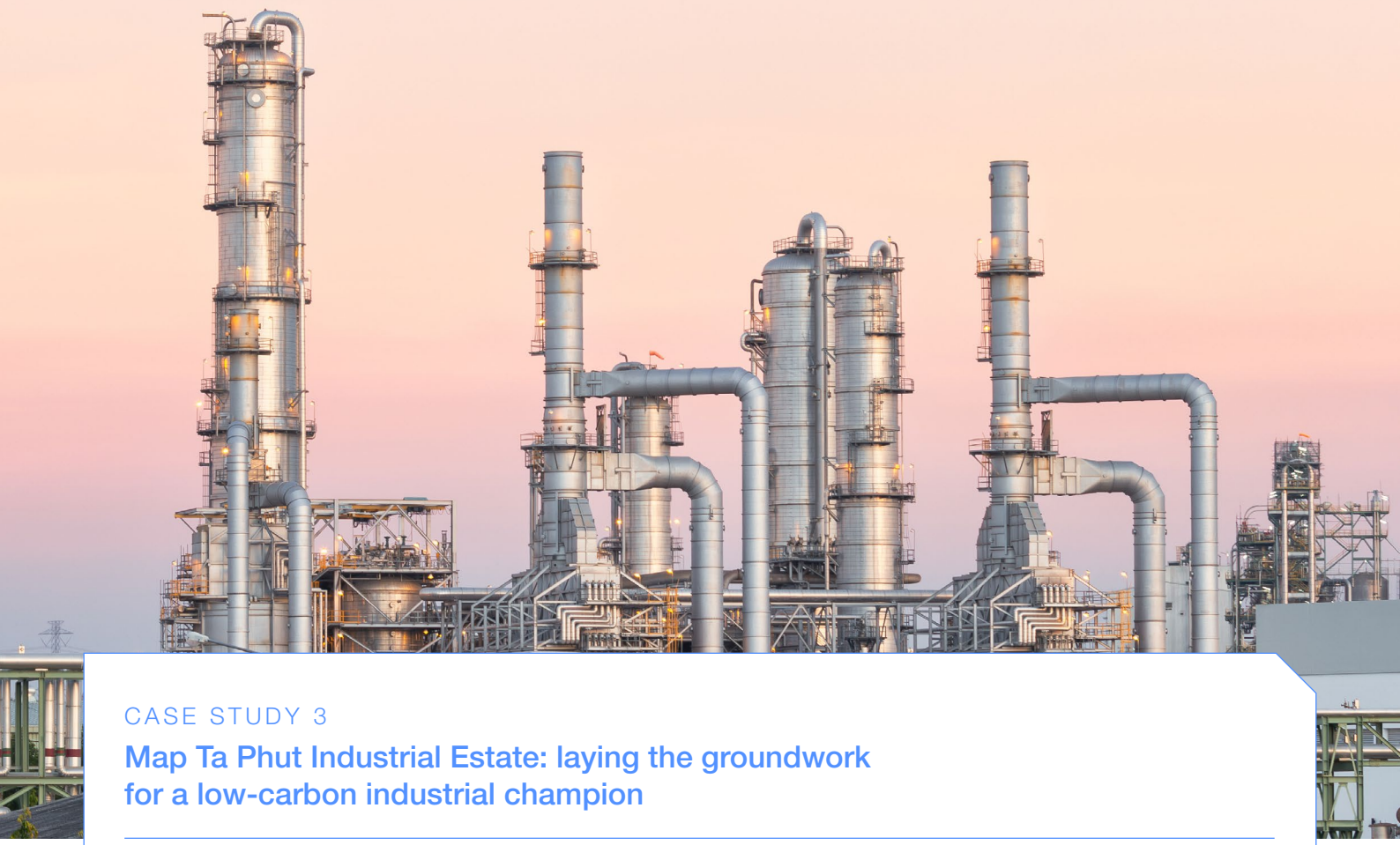
Objective: Recognizing the global energy transition required diversification beyond traditional oil and gas, and raising demand for sustainable fuel, PETRONAS aims to establish a regional hub for low-carbon fuels that meets domestic demand and captures export market potential.

Intervention: PETRONAS sought strategic partners with proven biofuel production expertise, technology leadership and market access. Enilive and Euglena emerged as the ideal collaborators to form a joint venture company, Pengerang Biorefinery. Enilive has demonstrated success in SAF and HVO production using Ecofining technology, extensive feedstock supply networks and strong European market presence. Meanwhile, Euglena complements this by bringing algae-based biofuel R&D capabilities and opening access to the Japanese offtake market.[106] The joint venture is intended to own and operate a biorefinery with a capacity of 650 kilotonnes per annum (ktpa), to be located within the Pengerang Integrated Complex.[107] The biorefinery is currently under construction and is designed to adapt to diverse feedstock options and evolving market dynamics. Used cooking oil (UCO) will be used as one of the main feedstocks, which requires robust supply chain strategies given its rising global demand and tightening availability. The project is progressing as planned and remains on track for its targeted start-up in the second half of 2028. Additionally, the joint venture will work with Pengerang Terminal (PT2SB) which is owned by Royal Vopak, Dialog, PETRONAS and the state of Johor, to expand dedicated biofuel storage infrastructure by 272,000 cubic metres.[108]

PETRONAS selected Johor's Pengerang Integrated Petroleum Complex for its biofuel's development, using state incentives, integrated infrastructure and proximity to petrochemical value chains, enabling operational efficiency and supporting the group's wider low-carbon transition ambitions. Also, they are collaborating with key ministries and ASEAN partners to harmonize SAF policies, secure feedstock supply, align blending mandates and position Malaysia as a regional low-carbon fuel leader.

> **As South-East Asia accelerates its shift towards cleaner energy, biofuels remain essential for strengthening energy security and reducing emissions. With the right policies, collaboration and continued innovation, the region can scale sustainable fuels that support global diversification into cleaner energy. Our biorefinery in Pengerang, which is currently being developed in partnership with ENI and Euglena, highlights how international partnerships and integrated clusters can expand regional supply of sustainable, low-carbon fuel.**
>
> Datuk Sazali Hamzah, Executive Vice-President and Chief Executive Officer, Downstream, PETRONAS

Note: This image is for illustrative purposes only and does not depict the Pengerang Integrated Complex.



CASE STUDY 3

Map Ta Phut Industrial Estate: laying the groundwork for a low-carbon industrial champion

Context: Map Ta Phut, Thailand's largest industrial estate and the world's eighth-largest petrochemical hub, spans around 10,000 acres and hosts more than 150 national and international companies, including PTT Global Chemical (PTT GC), SCG Chemicals, Dow Chemicals, Indorama Ventures, Covestro and Mitsui Chemicals Group. Despite its significant contribution to Thailand's GDP and exports, it remains heavily dependent on fossil fuels.

Objective: Map Ta Phut seeks to build on its existing interconnected infrastructure, shared gas pipelines, and power and water systems to evolve into a low-carbon industrial cluster and aims to position Map Ta Phut as a flagship of Thailand's industrial transition.

Interventions: Map Ta Phut is building momentum for a low-carbon transition through multi-level collaboration:

- Industry collaboration: Anchor firms such as PTT GC, SCG Chemicals and Global Power Synergy (primary supplier of power and steam) have built trust and shaped an informal partnership model. Importantly, the petrochemical value chain exhibits industrial symbiosis, where upstream producers supply intermediates to downstream polymers and specialty chemical producers.
- Government collaboration: Through representatives such as the Federation of Thai Industries (FTI) and the Petrochemical Industry Club of FTI (PEIT), the cluster works with the Department of Climate Change and Environment (DCCE) on sectoral regulations and incentives and it has established channels with the Ministry of Industry and the Ministry of Energy to address market reforms and renewable energy. Additionally, it collaborated with the Rayong provincial government and Industrial Estate Authority of Thailand for land, permitting and infrastructure, and included the World Bank in its decarbonization programme, ensuring local alignment.
- International collaboration: The cluster engages partners such as the World Bank and GIZ for funding and technical collaboration. With this existing industrial symbiosis, and by addressing issues such as system impacts (steam production) due to the introduction of renewables, they aim to establish a low-carbon cluster while advancing technologies such as CCUS, energy storage solutions and required investments.

3.2 Policy

Clear, predictable and coordinated policy signals anchor investor confidence and set the pace for transformation at early stages. In clusters, **policy acts as both enabler and integrator**, translating national ambitions into practical mechanisms that drive industry behaviour. Clusters serve as **test beds for policy learning**, helping governments refine standards, permitting rules and incentives before national rollout.

CASE STUDY 4

Johor Transitioning Industrial Cluster (JTIC): Advancing sustainable growth across Johor

Context: Iskandar Puteri, Sedenak, and the Pengerang cluster, located within the JS-SEZ, would form the Johor Transitioning Industrial Cluster (JTIC), an aspirational framework. Where Sedenak, through the Ibrahim Technopolis (iBTEC) and the Sedenak Tech Park (STeP), focuses on AI and digital activities, Iskandar Puteri focuses on biopharma, life sciences and manufacturing, and Pengerang (Pengerang Integrated Petroleum Complex) focuses on manufacturing, energy and logistics.

Objective: The JTIC is being outlined as a potential pathway to connect these complementary areas into an integrated, low-carbon industrial ecosystem over time, supporting cross-sector collaboration, high-value job creation, and sustainable industrial development aligned with Johor's long-term competitiveness and energy transition goals.

Intervention: Under the Johor Economic Transformation Plan (JETP), the JTIC concept provides an opportunity to transition Johor's growing industrial base. Key opportunities include the development of renewable energy sources and shared energy systems, building common carbon infrastructure, securing long-term renewable energy supply for hydrogen and derivative products, and circular economy solutions enabled by digital infrastructure.

These development envisaged under the JTIC concept would be undertaken in support of multiple existing state and federal planning frameworks, such as the Johor Sustainable Development Plan 2030, guiding economic and digital investment, major transport and infrastructure development, and environmental conservation;[109] the Johor Green Deal, focusing on promoting green energy, low-carbon cities and sustainable industries;[110] the Johor AI council initiative to drive the digital economy and AI development ecosystem in the state; the National Energy Transition Roadmap;[111] the New Industrial Master Plan 2030;[112] the 13th Malaysian Plan 2026–2030;[113] and Iskandar Malaysia's *Comprehensive Development Plan iii 2022-2030*.[114]

This broader policy environment also supports investment through fiscal and non-fiscal incentives under the JS-SEZ and related state mechanisms. Fiscal measures include special corporate tax rates and preferential tax treatment for knowledge workers. Non-fiscal support includes the Invest Malaysia Facilitation Centre Johor (IMFC-J) as a one-stop investment facilitation platform; the Johor Super Lane (JSL) to accelerate the investment and development process and create a competitive business-friendly environment;[115] and the Johor Talent Development Council (JTDC), which supports talent pipeline development aligned with industry needs.

> **Johor presents a compelling proposition for industry and investors seeking to deploy AI at scale within an industrial economy. Beyond incentives, the state's focus on governance, talent and cross-sector coordination, soon anchored by the Johor AI Council, helps reduce execution risk and supports more responsible and sustainable AI deployment.**
>
> Arina Binti Ramlee, Chief Technology Officer, Cybersolution Technologies

CASE STUDY 5

Bintulu Industrial Hub: industrial decarbonization through policy and technology integration

Context: Located on Sarawak's northern coast, Bintulu is Malaysia's LNG hub and the state's major energy export centre, with petrochemical, manufacturing and energy facilities supported by robust port and pipeline infrastructure.

Objective: Sarawak aims to transform Bintulu into Malaysia's flagship low-carbon industrial hub, anchored in the Post COVID-19 Development Strategy 2030's (PCDS) environmental sustainability pillar – one of its three strategic pillars, alongside economic prosperity and social inclusivity, supported by state-level policies and actions.

Intervention: Bintulu's low-carbon transformation is rooted in strong policies, which also enable technology deployment and strategic partnerships. Sarawak's energy future is guided by the Sarawak Energy Transition Policy (SET-P), which sets ambitious 2030–2050 targets across seven pillars – including renewables, hydrogen and CCUS.[116] Additionally, Sarawak is preparing to introduce a carbon levy as a pricing instrument to incentivize emission reduction among high-emitting sectors and attract green investment.[117] Together, these measures are driving clean energy projects across Sarawak, including:

- Hydrogen projects: The Sarawak Hydrogen Economy Roadmap (SHER) guides hydrogen development. Central to this strategy is the establishment of the Sarawak Hydrogen Hub in Bintulu, which will anchor flagship projects such as the H2ornbill and H2biscus projects, and position Sarawak as a clean hydrogen production and supply hub, aligning with the objectives of the National Energy Transition Roadmap (NETR).[118] Simultaneously, the Sarawak Government commissioned a feasibility study through the Bintulu Development Authority, assessing hydrogen-powered autonomous rail transit (ART) and buses to decarbonize public transport.[119]
- Carbon capture and storage: Harnessing its natural geological assets, including depleted hydrocarbon reservoirs and saline aquifers, Sarawak is strategically positioning itself as a regional hub for CCUS. PETROS, as Sarawak's state-owned oil and gas company, is leading the development of Samalaju. The Kasawari CCS Project serves as a key reference, enabling the commercial development of the high-CO_2 gas field and supporting Malaysia's first large-scale CO_2 injection.[120] To accelerate development, PETROS is currently working closely with Japan and Singapore to enable these projects to be financed and advanced with backing from international oil companies as part of their decarbonization plan.

> **Bintulu industrial cluster embodies Sarawak's strategic potential and our determination to shape the next era of clean industrial development. With established hydrogen and CCS projects now moving into commercial scale, we are building an integrated industrial ecosystem that attracts global partners, strengthens our energy transition and supports Malaysia's long-term economic competitiveness.**
>
> Datuk Amar Haji Mohamad Abu Bakar Bin Marzuki, Sarawak State Secretary, Sarawak, Malaysia

Image credit: Courtesy of Bintulu Port Holdings.

3.3 Technology

Deploying low-carbon technologies is a key factor in the energy transition and will define competitiveness in industrial clusters. Clusters provide controlled environments to pilot, integrate and scale technologies – from renewable systems and hydrogen networks to digital technologies and automation. Shared infrastructure and advanced digital systems can transform legacy assets into engines of clean, efficient and future-ready growth.

> **The shift to an eco-friendly hydrogen economy may be gradual, but it is already under way. Those countries and businesses that invest now and stay the course will ultimately lead the energy transition. History reminds us that no major energy transition has ever occurred in just a decade or two.**
>
> Kim Seo-Young, Founder and Chief Executive Officer, Hylium Industries

CASE STUDY 6

Kawasaki Carbon Neutral Industrial Complex: transitioning from fossil hub to hydrogen powerhouse

Context: The Kawasaki Coastal Area, once Japan's epicentre for crude oil and LNG imports, is transforming into a global frontrunner in hydrogen commercialization. With limited renewable energy potential, the cluster has identified **clean hydrogen, carbon capture, and regional optimization of energy** as the most viable pathways to secure competitiveness in a low-carbon economy. A council of nearly 100 stakeholders provides a platform for collaboration.

Objective: Building on this transformation, Kawasaki aims to establish itself as the **world's first commercial-scale liquefied hydrogen (LH_2) hub**, aligned with **Japan's 2050 net-zero ambition**.

Intervention: Kawasaki's low-carbon transformation is driven by large-scale hydrogen infrastructure and innovation.

- Hydrogen infrastructure development: Construction of the Kawasaki LH_2 Terminal began in 2025 as the "Liquefied Hydrogen Supply Chain Commercialization Demonstration" project subsidized by Japan's Green Innovation Fund. This terminal will be equipped with a 50,000m^3 liquefied hydrogen storage tank (the world's largest), alongside facilities for maritime cargo handling, hydrogen liquefaction and more. By 2030, the project will start operating the Kawasaki LH_2 Terminal and a newly constructed liquefied hydrogen carrier with the forefront technology, alongside Japan's completion of the technical and regulatory foundations for a commercial international hydrogen supply chain. From 2030 onwards, the aim is to import liquefied hydrogen into Japan using liquified hydrogen carriers. It is expected to handle about 30,000 tons of LH_2 annually, supplying industries and mobility across Tokyo. This milestone gives Kawasaki a first mover advantage in global hydrogen markets.
- Innovation: Shared cogeneration and utility optimization is projected to deliver 20% energy efficiency gains, while carbon recycling initiatives integrate captured CO_2 into synthetic fuels and materials, highlighting how innovation (not just emissions control) could drive long-term competitiveness in a net-zero future.

> **As Japan advances towards its 2050 net-zero ambition, Kawasaki is embracing a major transformation. One example is the construction of one of the world's first commercial-scale liquefied hydrogen terminals. Through technological innovation, we are committed to renewing our city as an industrial hub that achieves both net-zero emissions and economic growth.**
>
> Norihiko Fukuda, Mayor, Kawasaki City

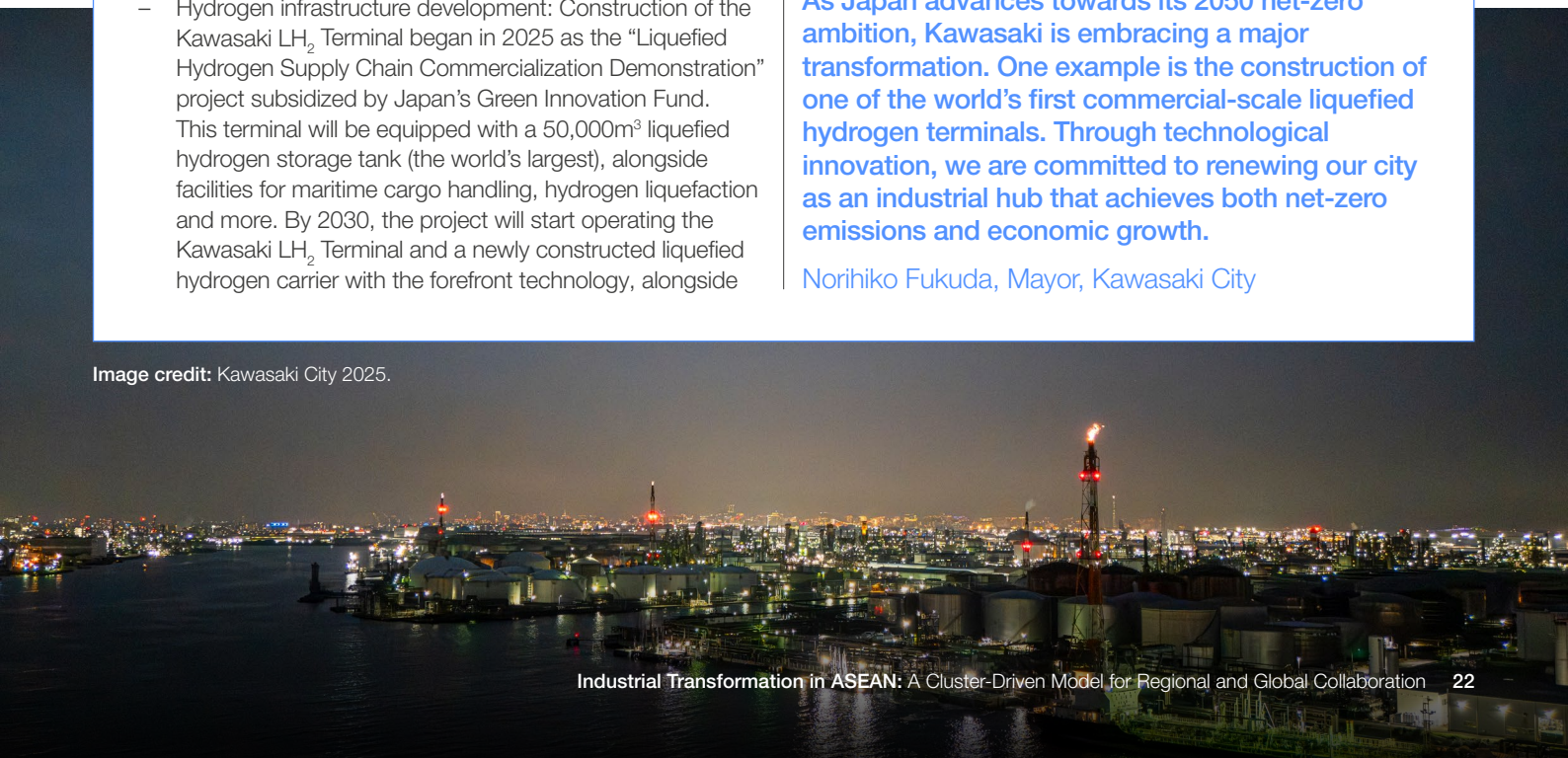
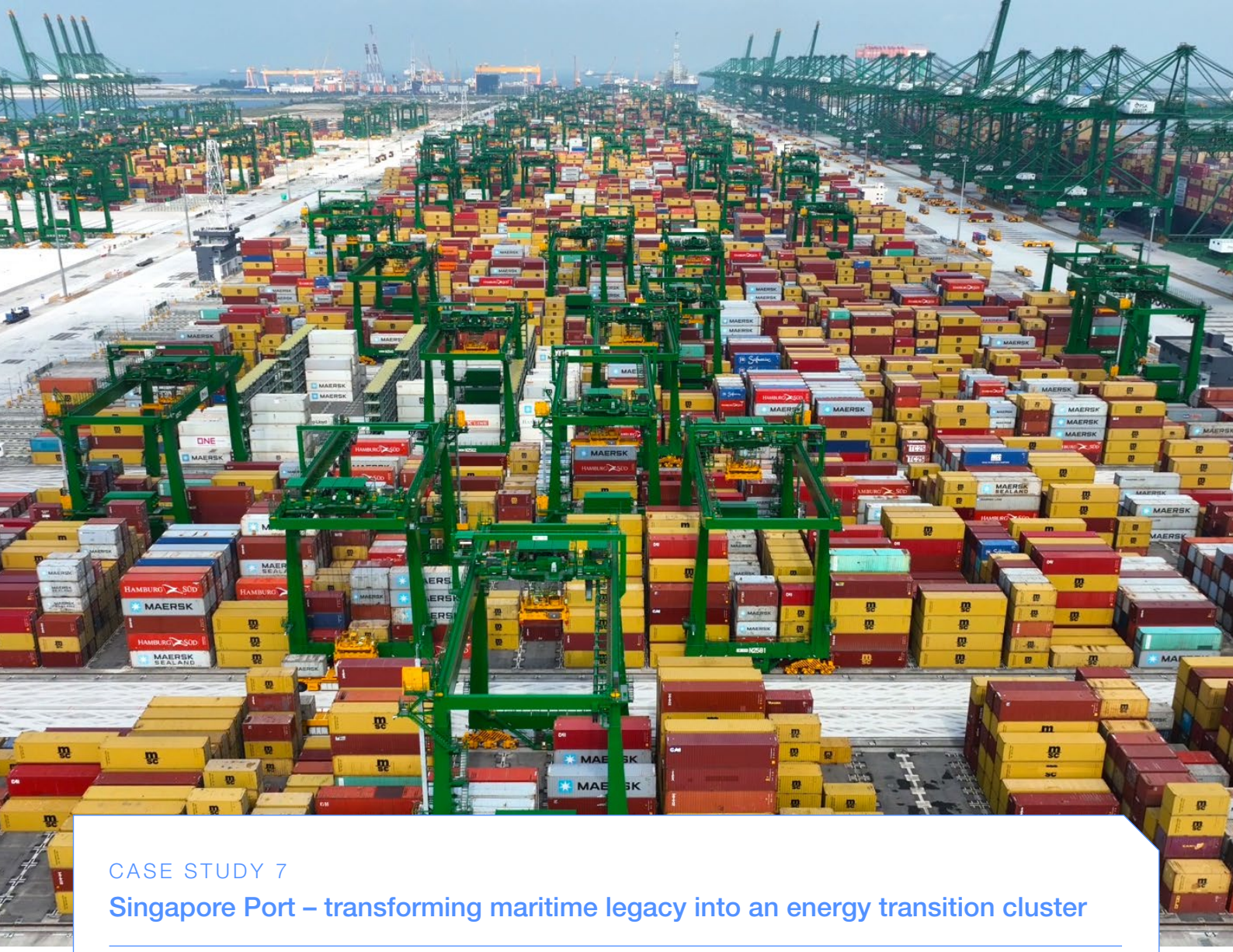


Image credit: Kawasaki City 2025.



CASE STUDY 7

Singapore Port – transforming maritime legacy into an energy transition cluster

Context: For decades, Singapore's four separate ports (Tanjong Pagar, Keppel, Brani and Pasir Panjang) powered its rise as a global shipping hub but caused fragmentation, inefficiencies and higher emissions. To address this, Singapore is consolidating all operations under Tuas Port, a next-generation port built to handle 65 million 20-foot equivalent units (TEUs) annually.[121]

Objective: Tuas Port aims to lead by example as a next-generation maritime hub, showcasing how technology-driven, sustainable port operation can strengthen Singapore's competitiveness in the international maritime sector while embodying the state's low-carbon transition agenda.

Intervention: Tuas Port operationalizes Singapore's low-carbon goals through advanced technology and sustainable design, supported by strategic collaborations:

- Smart operations and electrification: Tuas Port integrates over 400 automated guided vehicles, electrified yard cranes and remote-control towers. It is designed to be automated and intelligent, with AI and digitalPORT@SG. Meanwhile, smart grids are employed to optimize energy and turnaround.[122] These advancements collectively contribute to significant emissions reduction.
- More than half of the landfill used to create the new area came from recycled dredged materials. Corals in the area were relocated, with about 80% survival rate. The port platform is also built 5 metres above sea level to protect it from future climate risks.[123]
- Clean fuels: Tuas Port is positioning itself as a bunkering hub for hydrogen, ammonia and biofuels, supporting global decarbonization.
- Domestic leadership: The Maritime and Port Authority (MPA) leads port regulation and planning, including maritime digitalization and decarbonization efforts, safety and manpower development, while the PSA Singapore drives technology integration and operational innovation.
- International collaboration: Bilateral green and digital shipping corridors link the Port of Singapore to China (including Tianjin and Shandong), the Port of Rotterdam, the Ports of Los Angeles and Long Beach, Japan, Australia, India and the Republic of Korea.

Image credit: PSA Corporation.

3.4 Finance

Financing mechanisms underpin the energy transition by attracting capital flows, mitigating investment risk and accelerating the scale-up of clean energy infrastructure. Industrial transformation depends on timely, affordable and blended capital.

Well-designed financial mechanisms connect global capital with local opportunities. Clusters provide the proof-of-concept platforms financiers need to translate roadmaps into investable projects.

CASE STUDY 8

Saraburi Sandbox – mobilizing capital for industrial decarbonization

Context: The Saraburi Sandbox initiative, a public–private–people partnership launched in August 2023, is accelerating industrial decarbonization in Saraburi Province, which produces nearly 80% of Thailand's cement and is among the country's most emissions-intensive regions.[124]

Objective: The initiative aims to decarbonize the cement sector by aligning policies, mobilizing strategic finance and cultivating collaboration, positioning Saraburi as a decarbonization test area modelling a low-carbon industrial transformation.

Intervention: The Saraburi Cluster demonstrates how strategic financing, anchored in policy alignment and collaboration, unlocks transformation.

- Roadmap and financial catalyst: The Thailand 2050 Net Zero Cement and Concrete Roadmap,[125] developed by the Global Cement and Concrete Association (GCCA), the Thai Cement Manufacturers Association (TCMA) and SCG, aims for a 45% emissions cut by 2030 and net zero by 2050. Its visibility positioned Saraburi as Thailand's first low-carbon cement and industrial cluster.
- Global support: Recognition of the roadmap at the 2022 United Nations Climate Change Conference (COP27), where the GCCA facilitated dialogue with the Canadian government, secured CAD 8 million (Canadian dollars) from Canada's Green Fund to accelerate sector decarbonization. The support combines technical assistance and investment measures, including a mobile carbon capture unit.
- Public-private-people partnership: Uniting government, industry and local stakeholders enabled 85% low-carbon cement adoption, expansion of alternative fuels (biomass, solar energy, refuse-derived fuel), and renewable and energy crop pilots.
- Community impact: Partnerships supported regenerative projects, turning community waste into value, food-waste-to-protein biotechnology and ecotourism. They delivered local benefits and strengthened blended finance opportunities.

> **In a time of global uncertainty – from economic slow-down to tightening climate regulations and evolving sustainability standards – transitioning to a low-carbon, circular economy is not only an environmental responsibility but a necessity for long-term competitiveness and resilience.**
>
> **This journey demands public-private-people partnership, innovation and inclusion. The Saraburi Sandbox demonstrates how area-based PPP partnership can drive this transition and serve as a replicable model to accelerate industrial decarbonization and advance the nation's net-zero pathway.**
>
> Thammasak Sethaudom,
> President and Chief Executive Officer,
> Siam Cement Group (SCG)

Image credit: Courtesy of Saraburi Sandbox.

CASE STUDY 9

Bank Negara Malaysia: institutionalizing climate finance innovation in Malaysia

Context: Bank Negara Malaysia (BNM), Malaysia's central bank, plays a pivotal role in embedding climate considerations into financial systems. It has steadily advanced Malaysia's climate finance journey by launching the Climate Change and Principle-based Taxonomy (CCPT) and Value-based Intermediation Financing and Investment Assessment Framework (VBIAF). Through the Joint Committee on Climate Change (JC3), BNM and the Securities Commission Malaysia (SC) are collaborating with ministries and industry to pilot initiatives like Greening Value Chains and Greening Industrial Parks to scale innovative funding solutions.

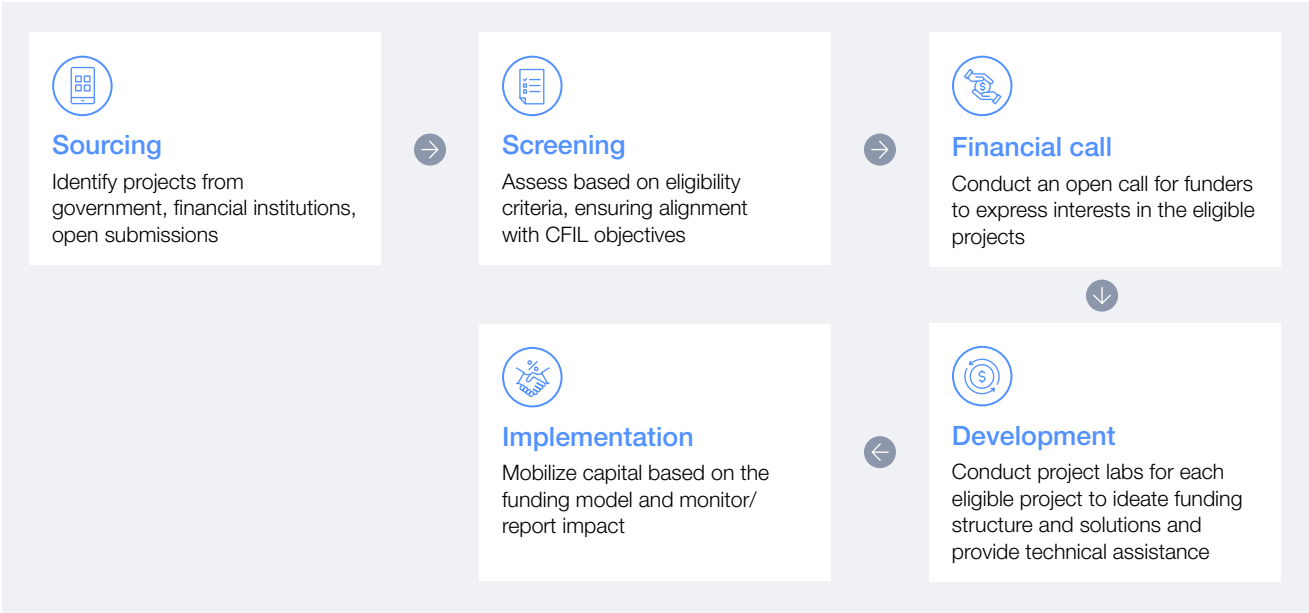
Objective: To address the funding gap in Malaysia's low-carbon transition, BNM and the Securities Commission Malaysia (SC), under the Joint Committee on Climate Change (JC3), launched the Climate Finance Innovation Lab (CFIL) in 2025. CFIL is a collaborative platform mobilizing public and private finance. It connects innovators, financiers, government and experts to unlock innovative funding solutions.

Intervention: The CFIL demonstrates how innovative ecosystems can enable strategic financing for the low-carbon transition.

- Framework: Administered by Bank Pembangunan Malaysia Berhad (BPMB) with support from the United Nations Development Programme (UNDP), CFIL adopts a modular approach to streamline the ideation and design of financial solutions. CFIL helps early ideas become investment- and funding-ready.
- Thematic priorities: CFIL prioritizes energy transition and green innovation, sustainable agriculture, circular economy, sustainable cities and nature-based solutions deliberately to support low-carbon initiatives, including efforts to help industrial parks decarbonize.
- Funding mechanisms: Solutions can be either conventional or Islamic in nature, including but not limited to transition loans, green sukuk and sustainability-linked sukuk. BNM's broader innovation push includes the 2025 Digital Asset Innovation Hub pilots such as tokenized green bonds and programmable payments that link fintech with sustainable finance. As of end-October 2025, a total of 24 projects with a total funding size amounting to $800 million were submitted through CFIL. One project has already secured funding, while other projects have undergone the accelerator programme to enhance their overall readiness.

> **Malaysia's energy transition represents a generational opportunity to upgrade and secure our industrial base, build a new growth sector, and attract high-value investments. Through the Climate Finance Innovation Lab, we are building a collaborative ecosystem that brings together private, public and philanthropic partnership to design, mobilize and scale innovative funding for low-carbon and climate-resilient industrial development. This effort is central to strengthening Malaysia's long-term economic resilience and competitiveness while ensuring a sustainable and inclusive future.**
>
> Madelena Mohamed, Assistant Governor, Strategy and Sustainability, Bank Negara Malaysia

BNM: five-stage process of CFIL

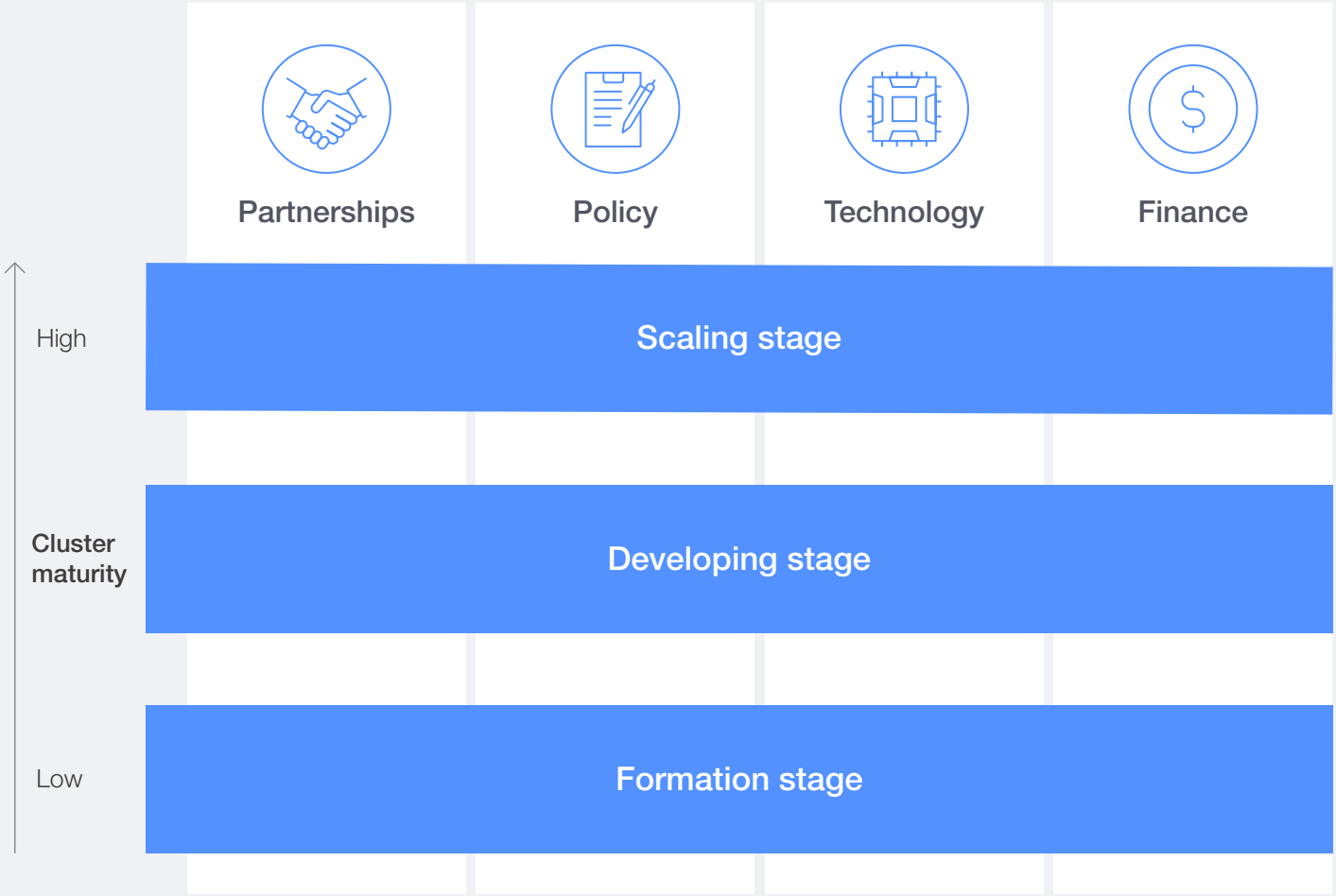


4

Industrial cluster playbook

The playbook can help ASEAN clusters, finance stakeholders and policy-makers mature strategically, translating ambition into coordinated action across four transformation pillars

FIGURE 6 **Stages of cluster maturity across key pillers**



While ASEAN's industrial clusters are progressing, to reach their full potential they need to mature further, and be equipped with a clear vision of what success looks like, a practical method to track progress and a pathway to translate ambition into measurable outcomes.

The cluster playbook serves as a practical guide to help clusters progress through their maturity journey, focusing on the four pillars – partnerships, policy, finance and technology.

This playbook is not a one-size-fits-all model – it is a strategic tool designed to guide not only clusters but also public institutions, governments, investors and financial institutions in translating ambition into coordinated action.

By adapting this playbook in their contexts, decision-makers can turn strategy into implementation – helping them to prioritize clusters and define policies that align with national and regional agendas, accelerating investment to build enabling infrastructure. The framework also supports monitoring progress and measuring impact, helping users target interventions where they deliver the greatest economic and environmental returns.

4.1 Formation stage

Cluster initiation sets the foundation by aligning diverse stakeholders on a shared vision, mapping opportunities and identifying early priorities to unlock momentum.

TABLE 1 **Formation stage**

Formation	1 Partnerships	2 Policy	3 Technology and infrastructure	4 Finance
Actions	– Engage the right partners (e.g. corporates, NGOs, knowledge partners and public-sector actors) to launch the cluster and align on shared goals. – Nominate champions to coordinate initial efforts. – Establish a basic governance structure and draft a high-level cluster charter that defines a shared vision. – Cultivate culture and workforce readiness. – Promote community and social alignment.	– Identify applicable policies and stakeholders across local, regional and national levels. – Catalogue likely incentives and subsidies (local and federal) – feed-in tariffs, tax credits, capital subsidies, concessional finance and grants. – Identify regulatory bottlenecks affecting shared infrastructure. – Prioritize immediate information gaps and rapid advocacy asks that reduce near-term pilot friction.	– Evaluate energy mix, efficiency levels and resource use. – Identify and map cluster members' decarbonization technology and infrastructure needs (e.g. CCUS, renewable energy, transport corridors, digital). – Build a cluster-level key performance indicator (KPI) baseline (GHG, GDP, jobs, water). – Undertake preliminary technical scans and assessments.	– Identify catalytic funding sources – e.g. multilateral development banks (MDBs), green funds, public grants. – Develop a list of viable investors for early signalling and requests for funding. – Catalogue required de-risking instruments for later stages (e.g. loan guarantees, first-loss capital, revenue support); identify responsible stakeholders. – Build business value case and funding requirements from preliminary technical scans, along with key market drivers.
Stage profile	Ad-hoc or informal coordination without structured governance or shared accountability	Minimal alignment with national or ASEAN transition targets; limited or passive engagement with policy-makers	Isolated firm-level clean tech adoption; minimal R&D; minimal shared infrastructure or circular initiatives; no/basic ESG tracking	Limited or no energy transition investment; traditional finance instruments only; limited project pipeline

4.2 Developing stage

At this phase, the focus shifts to developing actionable strategies, detailed financial models and priority project pipelines that balance ambition with tangible outcomes.

TABLE 2 **Developing stage**

Developing	1 Partnerships	2 Policy	3 Technology and infrastructure	4 Finance
Actions	– Define shared vision and set governance, communication and decision protocols. – Convene government, industry, finance and NGOs for aligned intent. – Launch preliminary roadmap and joint action plans – e.g. power purchase agreements (PPAs), waste circularity exchanges. – Engage international partners (e.g. EU, IEA) for best practices. – Sign memoranda of understanding (MoUs) and offtake commitments on short-, medium- and long-term cluster goals. – Partner with academia for training and R&D programmes.	– Ensure cluster goals align with the national energy transition while supporting more ambitious cluster- or firm-level commitments. – Map all relevant government policies and incentives, then seek formal cluster recognition to unlock tailored support. – Launch cluster-level policy advocacy, collecting joint asks e.g. streamlined permitting, tax incentives. – Engage with global clusters to understand localization of globally successful policies. – Formalize public-private dialogue platforms with relevant ministries and regulatory bodies.	– Identify priority projects that deliver shared value across stakeholders using criteria like emission reduction potential, scalability, cost-effectiveness and job creation. – Prioritize short-, medium- and long-term infrastructure and technology developments that maximize system value and bankability. – Establish an R&D ecosystem. – Launch pilot projects identified using the established R&D ecosystem. – Develop shared infrastructure, and initiate resource-sharing and reuse practices. – Develop ESG governance systems and tracking and reporting mechanisms.	– Develop detailed financial models, incorporating scenario and sensitivity analyses for shortlisted projects. – Host exploratory briefings and convene an institutional finance working group to secure financing. – Collaborate with local financiers to structure green products, such as Malaysia's CFIL. – Secure government, MDBs and private funding for pilot programmes. – Enhance project bankability through guarantees, offtake agreements and carbon pricing mechanisms.
Stage profile	Structured partnerships or MoUs established across key stakeholders, with some governance and shared outputs	Partial policy alignment and pilot coordination; occasional advocacy	Initial investment and shared infrastructure and technology under development; targeted R&D pilots; limited reuse/resource-sharing initiative, and ESG tracking with limited indicators	Early-stage investments limited to pilots; selective private participation; limited advanced instruments (e.g. green bonds, blended finance); several projects at pre-feasibility stage

4.3 Scaling stage

The final phase focuses on converting strategies into sustained outcomes by scaling pilots, securing investments and embedding systems that sustain long-term decarbonization impact.

TABLE 3 **Scaling stage**

Scaling	1 Partnerships	2 Policy	3 Technology and infrastructure	4 Finance
Actions	– Institutionalized coordination platform with an active and empowered steering committee driving strategic decisions. – Formalize a fully integrated roadmap with technology, investment and funding plans. Implement joint mechanisms between cluster members for services to harness economies of scale. – Launch structured knowledge exchange programmes to build cluster-wide capabilities. – Establish mature offtake structures and long-term demand commitments across the entire value chain, ensuring commercial certainty and enabling scalable investment. – Build comprehensive workforce transformation and community education programmes.	– Regular engagement with all levels of regulators and policy-makers helps to shape enabling policies for initiatives across the maturity curve to ensure regional and global benefits, e.g. mature-stage (subsidies) and early-stage (carbon pricing, R&D grants). – Integrate cluster strategy fully with ASEAN and country roadmaps while supporting more ambitious cluster- or firm-level commitments.	– Develop priority shared-infrastructure projects (e.g. renewables parks, shared utilities, digital infrastructure). – Scale up implementation by adopting clean technologies, moving from pilots to full rollouts and securing offtake agreements. – Deploy a centralized AI-enabled digital MRV and analytics platform to automate data capture, monitor performance and unify ESG reporting, while creating a scalable data foundation for future AI use cases across the cluster. – Formalize industrial symbiosis/circular economy practices.	– Secure funding by combining federal, regional and local grants, along with corporate and philanthropic contributions. – Access advanced financing instruments. – Develop a system value narrative that quantifies avoided emissions alongside co-benefits such as jobs, water savings and GDP contributions, and use case studies to demonstrate value to financiers and policy-makers.
Stage profile	Institutionalized multistakeholder partnerships with empowered governance driving co-created roadmaps, shared investment and long-term commitments	Strong alignment with national/ASEAN roadmaps; regular structured policy engagement	Operational shared infrastructure; broad clean technology adoption and commercialization; formalized circular economy systems and innovation ecosystems; mature and transparent ESG impact reporting	Diverse capital flows through advanced instruments and blended finance; broad private participation; multiple bankable projects backed by large-scale investments

> **As ASEAN accelerates its clean energy ambitions, AI will be a decisive catalyst in reducing the cost and time-to-market of next-generation renewable technologies. By accelerating technology innovation, improving manufacturing efficiency and optimizing deployment, AI can accelerate the energy transition and position the region as a competitive leader in the global clean technology economy.**
>
> Joel Li, Co-Founder, Cosmos Innovation

5

Expanding ASEAN's global connectivity

The region is emerging as a strategic industrial hub supported by its strategic partnerships with Japan, China, the EU and the US.

As ASEAN advances its energy transition, it is emerging as a strategic industrial hub in the global clean economy. Partnerships with Japan, China, the EU and the US are expanding access to technology, capital and regulatory expertise, enabling ASEAN to shape emerging green trade and supply chain standards. Through these collaborations, industrial clusters can localize green manufacturing, attract investment and secure long-term demand, positioning ASEAN as a pivotal node in the energy transition and sustainable growth.

Japan

Japan is acting as a **technology catalyst and regional integrator**. Through cross-national initiatives, it enhances diplomatic influence, sustains market relevance relative to China[126] and secures markets for its advanced technologies and resilient supply chains.[127] Japan is advancing a range of initiatives including hydrogen, ammonia and energy efficiency solutions through the Asia Zero Emission Community (AZEC).[128] Key initiatives include the Muara Laboh Geothermal Expansion (Indonesia), the Fuel-Ammonia Turbine (Malaysia), AZEC Developing Carbon Markets (DCM) and the Economic Research Institute for ASEAN and East Asia (ERIA), which is currently working on decarbonization roadmaps for Viet Nam and Indonesia.

China

China, as ASEAN's largest trade partner,[129] has invested over $2.7 billion in clean energy across ASEAN.[130] Clean energy trade amounted to $4.3 billion,[131] spanning solar modules, wind components, electric vehicles and batteries. China is also enhancing clean energy cooperation. The Electric Power Planning and Engineering Institute is working with select ASEAN partners to enable large-scale clean energy deployment. Complementing this broader cooperation, Global Energy Interconnection Development and Cooperation Organization (GEIDCO) is sharing grid expertise – including high-voltage DC technology – to support renewable integration.

CASE STUDY 10

Suzhou Industrial Park: a Singapore–China model for global partnership in industrial transformation

Context: Established in 1994 as the first flagship project between Singapore and China, the Suzhou Industrial Park (SIP) covers 278km^2, accounts for about 3% of Suzhou's area and contributes over 13% of Suzhou's GDP. It has evolved into a vibrant hub for high-tech industries and hosts over 5,000 foreign-funded projects (including more than 150 projects from more than 100 Fortune 500 companies).

Objective: Building on three decades of trusted collaboration and a robust governance framework that made SIP a testbed for policies (and later replicated in projects like the Sino-Singapore Tianjin Eco-City), Singapore and China are now harnessing the SIP as a platform to accelerate industrial transition.

Intervention: The partnership has taken major steps towards energy transition, achieving over 75% clean energy consumption by integrating clean energy projects.

- Circular use of industrial by-products and waste: Through systematic planning and infrastructure development, the cluster has formed a circular industrial chain that maximizes reuse of by-products like waste heat and sludge to produce biogas and biomass fuels, saving the equivalent of over 10,000 tonnes of standard coal annually.

- Clean energy systems: The partnership has established two major clean energy centres and launched projects including the Moon Bay, Suzhou Centre and China–Singapore Green Digital Park energy stations. Renewable capacity now includes nearly 500MW of distributed solar capacity, 356MWh of grid-connected energy storage (including three grid-side projects) and over 5,000 public EV charging points.

By aligning China's scale with Singapore's institutional strengths, SIP illustrates how global partnerships can accelerate energy transition, cultivate mutual competitiveness and provide replicable models for industrial clusters worldwide.

Image credit: Suzhou Industrial Park.

EU

The EU is engaging ASEAN through a mix of **regulatory cooperation and financial support.** The EU-ASEAN Energy Dialogue (launched in 2022) coordinates policy, reform and renewable deployment,[132] while the Global Gateway supports sustainable infrastructure to boost ASEAN's green transition and connectivity.[133] The EU has already allocated €105 million in grant funding, part of an indicative €180 million allocation to support green transition projects across ASEAN.[134] The EU provides technical assistance, capacity development and opportunities for dialogue and peer learning through Technical Assistance Facility to the Green Team Europe Initiative.[135]

US

The US is driving ASEAN engagement via the Indo-Pacific Economic Framework[136] and Clean EDGE Asia,[137] prioritizing energy security, sustainable development, and clean energy transition. In 2023, the US announced $5 billion in public and private financing for digital infrastructure, transport, healthcare and smart cities.[138] Additionally, to accelerate the development of sustainable critical mineral supply chains, the US is collaborating with Indonesia under the Minerals Security Partnership.[139]

> **Ports are the engines of global industrial transformation – and Bintulu and Samalaju Port are stepping up to lead. By advancing digitalization, automation, low-carbon energy and investment facilitation, we are enabling a new generation of green, globally connected industries.**
>
> Ruslan Bin Abdul Ghani, President and Group Chief Executive Officer, Bintulu Port Holdings

Conclusion

ASEAN at the cusp of major energy and industrial transformation

ASEAN stands at the cusp of a major industrial and energy transformation that will shape its competitiveness for decades to come. With rapid industrialization, urban growth and electrification driving some of the world's fastest-rising energy demand, the region's progress is both remarkable and complex. Sustaining ASEAN's growth and competitiveness will depend on how effectively it transitions to a low-carbon, high-value industrial model that enhances productivity, resilience and long-term fiscal stability.

Industrial clusters as engines of opportunity

Industrial clusters sit at the heart of this opportunity. Concentrating industries, infrastructure and innovation hubs, clusters are a key lever to advance both economic growth and the clean energy transition. ASEAN clusters are already demonstrating success by collaborating locally, nationally and across borders among companies, policy-makers, financiers, and academic and public institutions. However, for clusters to achieve the maximum impact, more of them must progress along a maturity journey – from vision and cluster formation to achievement of scale.

Call to action

The examples presented in this white paper show tangible outcomes that clusters can achieve, which serve as the basis for further work. ASEAN has made significant strides in advancing its energy and industrial transformation agenda. Achieving its ambitions will demand deeper and more coordinated regional collaboration.

The World Economic Forum welcomes joint action for policy-makers, clusters and financiers across three key priorities:

1 Align policies and markets to accelerate transition

Achieving ASEAN's energy transition requires stronger policy alignment and market coherence across member states. Harmonizing technical and market standards such as grid codes, tariff structures and REC mechanisms while gradually rebalancing fossil fuel incentives and developing a common carbon pricing and disclosure framework will strengthen investor confidence.

2 Build collaborative ecosystems

Industrial clusters can serve as collaborative ecosystems and testbeds for clean technologies like renewables, hydrogen and shared carbon capture networks reducing risks and cost. Pooling capital across public, private and financial partners enables shared infrastructure, while integrating offtake partners secures demand, reduces risk and enhances project bankability. These ecosystems can span national, regional and global networks.

3 Mobilize finance to scale the transition

ASEAN's transition demands large-scale capital mobilization through stronger collaboration and innovative financing between MDBs, international financiers, investors and governments. While progress through sustainable finance tools and funds is notable, financing levels remain insufficient for both green and transition finance. Governments can play a key role in strengthening de-risking through, for example, concessional finance, guarantees, tax incentives, viability-gap funding, tripartite/CfD contracts and public-private partnership models, essential to attracting private investments.

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