# Decarbonising Southeast Asia's Hard-to-Abate and High-Emitting Sectors:

## Transition Finance, Technologies, and Policy Approaches

ERIA
Economic Research Institute for ASEAN and East Asia

ADB

METI
Ministry of Economy, Trade and Industry

**Decarbonising Southeast Asia's Hard-to-Abate and High-Emitting Sectors: Transition Finance, Technologies, and Policy Approaches**

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# List of Abbreviations

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|---|---|
| **ACC** | Advanced Chemistry Cell |
| **ACE** | ASEAN Centre for Energy |
| **ACGF** | ASEAN Catalytic Green Finance Facility |
| **ACMF** | ASEAN Capital Markets Forum |
| **ADB** | Asian Development Bank |
| **AEO8** | 8th ASEAN Energy Outlook |
| **AFD** | Agence Française de Développement |
| **AGXC** | Asia Green Transformation Consortium |
| **AIMS** | ASEAN Interconnection Masterplan Study |
| **AMS** | ASEAN Member State/s |
| **APAEC** | ASEAN Plan of Action for Energy Cooperation |
| **APG** | ASEAN Power Grid |
| **APS** | Announced Pledges Scenario |
| **ASEAN** | Association of Southeast Asian Nations |
| **ATB** | ASEAN Taxonomy Board |
| **ATF SG** | Asia Transition Finance Study Group |
| **ATFG** | ASEAN Transition Finance Guidance |
| **ATS** | AMS Targets Scenario |
| **AZEC** | Asia Zero Emission Community |
| **BAS** | Baseline Scenario |
| **BESS** | battery energy storage system |
| **BF-BOF** | blast furnace-basic oxygen furnace |
| **BIMP-EAGA** | Brunei Darussalam–Indonesia–Malaysia–Philippines East ASEAN Growth Area |
| **BNM** | Bank Negara Malaysia |
| **CAPEX** | capital expenditure |
| **CBAM** | Carbon Border Adjustment Mechanism |
| **CBI** | Climate Bonds Initiative |
| **CCGT** | combined-cycle gas turbine |

| | |
|---|---|
| **CCUS** | carbon capture, utilisation, and storage |
| **CFPP** | coal-fired power plant |
| **PRC** | People's Republic of China |
| **$CaCO_3$** | calcium carbonate |
| **CaO** | calcium oxide |
| **CCS** | carbon capture and storage |
| **CIPP** | Comprehensive Investment and Policy Plan (Indonesia) |
| **CNS** | Carbon Neutral Scenario |
| **$CO_2$** | carbon dioxide |
| **DFI** | development finance institution |
| **DMC** | developing member country |
| **DMO** | domestic market obligation |
| **DPO** | domestic price obligation |
| **DRI** | direct reduced iron |
| **EAF** | electric arc furnace |
| **EDL** | Electricité du Laos |
| **EER** | emissions exposure reduction |
| **EGAT** | Electricity Generating Authority of Thailand |
| **EIA** | environmental impact assessment |
| **EIB** | European Investment Bank |
| **EOR** | enhanced oil recovery |
| **ERIA** | Economic Research Institute for ASEAN and East Asia |
| **ESG** | environmental, social, and governance |
| **ETM** | Energy Transition Mechanism |
| **EU** | European Union |
| **EV** | electric vehicle |
| **EVN** | Vietnam Electricity |
| **FACTS** | flexible alternating current transmission system |

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|---|---|
| **FAST-P** | Financing Asia's Transition Partnership |
| **FDI** | foreign direct investment |
| **$Fe_2O_3$** | iron ore |
| **FIRR** | financial internal rate of return |
| **FOAK** | first-of-a-kind |
| **FSA** | Financial Services Agency (Japan) |
| **G20** | Group of Twenty |
| **GBP** | Green Bond Principles |
| **GCCSI** | Global CCS Institute |
| **GCF** | Green Climate Fund |
| **GDP** | gross domestic product |
| **GFANZ** | Glasgow Financial Alliance for Net Zero |
| **GHG** | greenhouse gas |
| **GSS+** | green, social, sustainable, and other labelled |
| **GX** | green transformation |
| **H2-DRI** | hydrogen-based direct reduced iron |
| **HVDC** | high-voltage direct current |
| **ICE** | internal combustion engine |
| **ICMA** | International Capital Market Association |
| **ICT** | information and communication technology |
| **IEA** | International Energy Agency |
| **IFRS** | International Financial Reporting Standards |
| **IPP** | independent power producer |
| **IRENA** | International Renewable Energy Agency |
| **IRR** | internal rate of return |
| **ISSB** | International Sustainability Standards Board |
| **JCTB** | Japan Climate Transition Bond |
| **JETP** | Just Energy Transition Partnership |
| **KPI** | key performance indicator |
| **Lao PDR** | Lao People's Democratic Republic |
| **LCER-FI** | Low-Carbon Energy Research Funding Initiative |

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|---|---|
| **LCFS** | low-carbon fuel standard |
| **LCOE** | levelised cost of energy |
| **LEILAC** | Low Emissions Intensity Lime and Cement |
| **LNG** | liquefied natural gas |
| **LTMS-PIP** | Lao PDR–Thailand–Malaysia–Singapore Power Integration Project |
| **MDB** | multilateral development bank |
| **MEMR** | Ministry of Energy and Mineral Resources (Indonesia) |
| **METI** | Ministry of Economy, Trade and Industry (Japan) |
| **MOEJ** | Ministry of the Environment (Japan) |
| **MRV** | measurement, reporting, and verification |
| **N2O** | nitrous oxide |
| **NDC** | nationally determined contribution |
| **NOx** | nitrogen oxides |
| **NPV** | net present value |
| **OECD** | Organisation for Economic Co-operation and Development |
| **OPEX** | operating expenses |
| **PaSTI** | Partnership to Strengthen Transparency for co-Innovation |
| **PAGE** | Policy Analysis for the Greenhouse Effect |
| **PDMO** | Public Debt Management Office (Thailand) |
| **PEA** | Provincial Electricity Authority (Thailand) |
| **PLI** | Production Linked Incentive (India) |
| **PLN** | Perusahaan Listrik Negara (Indonesia's state electricity company) |
| **PPA** | power purchase agreement |
| **PPP** | public–private partnership |
| **PV** | photovoltaic |
| **R&D** | research and development |
| **RAB** | regulated asset base |
| **RAS** | Regional Aspiration Scenario |
| **REE** | rare earth elements |
| **RMP** | Resource Mobilization Plan (Viet Nam) |
| **RUPTL** | Rencana Usaha Penyediaan Tenaga Listrik (Indonesia's electricity supply business plan) |

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|---|---|
| **SDG** | Sustainable Development Goals |
| **SFWG** | Sustainable Finance Working Group (G20) |
| **SLB** | sustainability-linked bond |
| **SLL** | sustainability-linked loan |
| **SLLB** | sustainability-linked loan bond |
| **SMEs** | small and medium-sized enterprises |
| **SOE** | state-owned enterprise |
| **SOx** | sulphur oxides |
| **TCFD** | Task Force on Climate-Related Financial Disclosures |
| **TLP** | Technology List and Perspective for Transition Finance in Asia |
| **TNB** | Tenaga Nasional Berhad (Malaysia's national electricity company) |
| **TRACTION** | Transition Credits Coalition |
| **TRL** | Technology Readiness Level |
| **UK** | United Kingdom |
| **US** | United States |
| **VGF** | viability gap funding |
| **VRE** | variable renewable energy |
| **WACC** | weighted average cost of capital |

## Units of Measure

| | |
|---|---|
| **GW** | gigawatt |
| **GWh** | gigawatt-hour |
| **$H_2$** | hydrogen |
| **kV** | kilovolt |
| **kWh** | kilowatt-hour |
| **Mt** | million tonnes |
| **$MtCO_2$** | million tonnes of carbon dioxide |
| **$MtCO_2e$/year** | million tonnes of carbon dioxide equivalent per year |
| **Mtoe** | million tonnes of oil equivalent |
| **MW** | megawatt |
| **MWh** | megawatt-hour |
| **MWp** | megawatt peak |
| **$Nm^3$** | normal cubic metre |
| **$tCO_2e$** | tonne of carbon dioxide equivalent |
| **TW** | terawatt |
| **TWh** | terawatt-hour |

# Glossary of Terms

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| **Announced Pledges Scenario** | A scenario that illustrates the extent to which announced ambitions and targets can deliver the emissions reductions needed to achieve net zero emissions by 2050. |
| **ASEAN Capital Markets Forum (ACMF)** | A forum established in 2004 under the Association of Southeast Asian Nations (ASEAN) Finance Ministers that comprises capital market regulators from the 10 ASEAN jurisdictions (Brunei Darussalam, Cambodia, Indonesia, the Lao PDR, Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Viet Nam). |
| **ASEAN Catalytic Green Finance Facility (ACGF)** | A regional blended finance platform launched by the ASEAN Finance Ministers and administered by the Asian Development Bank (ADB) to support low-emission infrastructure through loans and technical assistance. |
| **ASEAN Interconnection Masterplan Study (AIMS) III** | A study that explores the viability of multilateral electricity trading in the ASEAN region to enhance grid resilience and modernisation to provide affordable and resilient electricity supply and accommodate higher shares of renewable energy in the grid. |
| **ASEAN Member States Targets Scenario (ATS)** | A scenario projecting the future development of ASEAN energy systems if Member States do what is needed to fully achieve their own national energy efficiency and renewable energy targets, as well as their climate commitments, but do not make adjustments to reflect ASEAN regional targets. |
| **ASEAN Plan of Action for Energy Cooperation (APAEC)** | The regional blueprint for the energy sector under the ASEAN Economic Community, which plays a vital role in shaping a sustainable energy future for the region. |
| **ASEAN Power Grid (APG)** | Major initiative aimed at connecting the electricity networks of the 10 ASEAN Member States to enhance energy security, promote regional integration, and facilitate electricity trade. |
| **ASEAN Taxonomy for Sustainable Finance** | A multi-tiered classification system designed to guide investments in sustainable projects and activities across ASEAN, including both green and transitional activities. |
| **Asia GX (Green Transformation) Consortium (AGXC)** | Consortium composed of regulators, private financial institutions, and public and multilateral institutions that aim to promote and orient finance towards a just and orderly transition in Asia. |
| **Asia Transition Finance Study Group (ATF SG)** | A private-led initiative comprising private financial institutions and key stakeholders, including public authorities and industry players across Asia, which collaborates globally to support a just and orderly energy transition by facilitating dialogue and accelerating the implementation of transition finance. |

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| **Asian Development Bank (ADB)** | A regional development bank focused on Asia and the Pacific that provides loans, technical assistance, grants, and equity investments to promote social and economic development. |
| **Baseline Scenario (BAS)** | A scenario that describes the development of the concentration of greenhouse gas emissions in the atmosphere under the assumption that no further efforts to reduce emissions will be made. |
| **Blended finance** | Combining concessional finance from donors or third parties alongside development finance institutions' own account finance and/or commercial finance from other investors, to develop private sector markets, address the Sustainable Development Goals, and mobilise private resources. |
| **Carbon Border Adjustment Mechanism (CBAM)** | The tool of the European Union (EU) to put a fair price on carbon emitted during the production of carbon-intensive goods that are entering the EU, and to encourage cleaner industrial production in non-EU countries. |
| **Carbon capture, utilisation, and storage (CCUS)** | The technological process of capturing carbon dioxide from or before it enters the atmosphere, and then transporting and storing it (carbon sequestration) permanently. |
| **Carbon credits** | Certificate representing carbon dioxide equivalents that is either prevented from being emitted into the atmosphere or removed from the atmosphere. |
| **Carbon neutrality** | Cutting greenhouse gas emissions to close to zero, with any remaining emissions absorbed by forests and oceans. |
| **Carbon Neutral Scenario (CNS)** | An aspirational model that outlines a pathway to net zero emissions by 2050, assuming rapid deployment of clean technologies and deep system-wide transformation. |
| **Climate Bonds Initiative (CBI)** | An international organisation dedicated to mobilising global capital for climate action through the development of standards and certification for climate-related investments. |
| **Combined-cycle gas turbine (CCGT)** | A technology that uses the hot exhaust from the gas turbine to generate steam, which then drives a steam turbine, maximising energy output. |
| **Developed markets** | High-income countries (including Singapore) with mature, well-regulated financial systems and deep capital markets that feature low perceived investment risk. |
| **Developing member countries (DMCs)** | Member countries of ADB that are categorised as 'developing' (47 in 2025, of which 4 have graduated). https://www.adb.org/sites/default/files/page/615371/adb-classification-dmcs-2025.pdf |

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| **Development finance institution (DFI)** | Specialised financial entities that provide funding for economic development projects, particularly in developing countries, to promote sustainable growth and social impact. DFIs can be categorised into several types based on their structure and funding sources. |
| **Domestic market obligation (DMO)** | A regulation set by Indonesia's Ministry of Energy and Mineral Resources in 2022 that mandates local coal miners to supply about 25% of their coal production to the domestic market. |
| **Economic Research Institute for ASEAN and East Asia (ERIA)** | An international economic research and policy organisation established in Jakarta, Indonesia in 2008 by a formal agreement amongst leaders of 16 countries in the East Asian region. |
| **Emission exposure reduction (EER)** | A forward-looking indicator developed by the Glasgow Financial Alliance for Net Zero to quantify the avoided greenhouse gas emissions attributable to a financed entity's transition plan, by comparing a projected business as usual baseline with a climate-aligned transition scenario. |
| **Environmental impact assessment (EIA)** | A systematic process for identifying, predicting, and evaluating the environmental effects of proposed projects or policies before decision-making. |
| **Finance emissions** | Greenhouse gas emissions associated with the loans and investments made by financial institutions. These emissions are attributed to the financial institution based on its proportional share of the total financing provided to a company or project. |
| **Financing Asia's Transition Partnership (FAST-P)** | A Singapore-led blended finance initiative in collaboration with key global public, private, and philanthropic partners to catalyse sustainable finance flows into Southeast Asia. FAST-P aims to mobilise up to US$5 billion to de-risk and finance transition and marginally bankable green projects in Asia. |
| **First-of-a-kind (FOAK)** | A pioneering or novel infrastructure or technology project that is the first of its type deployed commercially at scale. FOAK projects often face higher risks, untested operational models, elevated capital costs, and limited financing options. |
| **Flexible alternating current transmission system (FACTS)** | Technologies used to enhance the reliability, capacity, and controllability of alternating current power transmission networks; help manage power flow; improve voltage stability; and reduce transmission losses – supporting more efficient grid operation and the integration of renewable energy. |
| **Foreign direct investment (FDI)** | An investment made by an individual or company in one country into business interests in another country, with the intention of establishing a lasting interest. |

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| **Glasgow Financial Alliance for Net Zero (GFANZ)** | A global coalition of financial institutions committed to accelerating the net zero transition. |
| **Green bond (loan)** | Any type of bond or loan instrument whose proceeds are used in part to fund projects that make a substantial contribution to an environmental objective. |
| **Green Bond Principles (GBP)** | A set of voluntary guidelines developed by the International Capital Market Association to promote transparency, disclosure, and integrity in the green bond market. |
| **Green Climate Fund (GCF)** | Multilateral climate fund established under the United Nations Framework Convention on Climate Change (UNFCCC) to support climate adaptation and mitigation efforts in developing countries. The GCF provides grants, loans, equity, and guarantees through accredited entities to finance low-emission, climate-resilient development pathways. |
| **Green finance** | Financing for activities and projects that are already aligned with low-carbon, climate-resilient goals (e.g. renewable and energy efficiency). |
| **Green, social, sustainable, and other labelled (GSS+)** | An umbrella term referring to thematic debt instruments that channel capital towards environmental and/or social objectives. The GSS+ label includes green bonds/loans, social bonds/loans, sustainability bonds/loans, and sustainability-linked bonds/loans. |
| **Greenwashing/ Transition-washing** | Misleading claims about the environmental or transitional impacts of investments or projects. |
| **GX bonds** | Sovereign bonds issued by Japan to fund decarbonisation and industrial transformation aligned with the country's net zero targets. |
| **Hard-to-abate sectors** | High emissions-intensity industries that are difficult to decarbonise due to their dependence on fossil fuels for high-temperature heat, feedstocks, or process emissions or for which green technologies are not currently feasible at scale. |
| **High-emitting sectors** | Sectors with significant absolute emissions, particularly coal-fired power generation, which remains a dominant source of electricity in many ASEAN Member States and is responsible for a large share of regional power sector emissions. |
| **International Capital Market Association (ICMA)** | A global organisation that develops frameworks for sustainable bonds, including the Green Bond Principles and Climate Transition Finance Handbook. |

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| **International Financial Reporting Standards (IFRS)** | Global accounting standards issued by the IFRS Foundation, designed to bring transparency and comparability to financial reporting across jurisdictions. |
| **International Sustainability Standards Board (ISSB)** | A standard-setting body under the IFRS Foundation tasked with developing global sustainability-related disclosure standards, including climate-related financial information. |
| **Japan Climate Transition Bond (JCTB)** | A sovereign bond issued by the Government of Japan to finance investments aligned with its long-term decarbonisation strategy, particularly in transitional technologies and infrastructure. |
| **Just Energy Transition Partnership (JETP)** | A multi-country platform to support coal-dependent emerging economies in transitioning to clean energy while ensuring social equity. Funding is provided through grants, concessional finance, and private capital. |
| **Lao PDR–Thailand–Malaysia–Singapore Power Integration Project (LTMS-PIP)** | A flagship ASEAN power trading initiative that enables cross-border electricity trading to improve regional grid stability and support the energy transition. |
| **Low-Carbon Energy Research Funding Initiative (LCER-FI)** | A multi-agency initiative that aims to develop low-carbon energy technologies in hydrogen and carbon capture, utilisation, and storage (CCUS) to support the decarbonisation of the power and industry sectors. |
| **Low-carbon fuel standard (LCFS)** | A regulatory mechanism that sets carbon intensity targets for fuels, encouraging producers to shift towards lower-emission alternatives such as biofuels, hydrogen, and electricity. |
| **Low-carbon hydrogen** | Hydrogen produced with significantly reduced greenhouse gas emissions compared with conventional fossil-derived hydrogen. Includes green hydrogen (from renewables via electrolysis) and blue hydrogen (from natural gas with carbon capture). |
| **Monitoring, reporting, and verification (MRV)** | Systems or a structured process for monitoring emissions and verifying reductions to ensure credibility in carbon accounting and compliance. |
| **Multilateral development bank (MDB)** | International financial institution that provides concessional loans, grants, and technical assistance to support development and climate projects, especially in low- and middle-income countries. |
| **Nationally determined contribution (NDC)** | National climate action plans submitted under the Paris Agreement, outlining each country's targets for emissions reduction and adaptation. |

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| **Organisation for Economic Co-operation and Development (OECD)** | An intergovernmental organisation promoting economic cooperation, policy coordination, and sustainable development amongst high- and middle-income countries. |
| **Policy Analysis of the Greenhouse Effect (PAGE) model** | An integrated assessment model linking emissions, climate change, and economic impacts, used for estimating climate-related gross domestic product (GDP) losses. |
| **Production Linked Incentive (PLI)** | A flagship scheme launched by the Government of India to boost domestic manufacturing and attract investment in key sectors, including renewables, electric vehicles, and green hydrogen. |
| **Regional Aspiration Scenario (RAS)** | A forward-looking energy or climate scenario that reflects the collective ambition of a region – in this report, Southeast Asia – to achieve sustainable development and energy transition goals. Unlike business-as-usual projections, RAS incorporates enhanced commitments, technological advancements, and regional cooperation. |
| **Regulated asset base (RAB)** | A valuation method used to determine the investment base of utility companies for regulated returns, often applied in energy infrastructure pricing. |
| **Sustainability-linked bond (SLB)** | A bond where the financial or structural characteristics are tied to the issuer's achievement of predefined sustainability performance targets. |
| **Sustainability-linked loan (SLL)** | A loan where interest rates or terms vary based on the borrower's achievement of sustainability targets, supporting broader corporate environmental, social, and governance (ESG) improvements. |
| **Sustainability-Linked Loans financing Bonds (SLLBs)** | Any type of bond instrument (i) where the proceeds or an equivalent amount will be exclusively applied to finance or refinance, in part or in full, a portfolio of new and/or existing eligible SLLs aligned with the SLL Eligible Portfolio; and (ii) which are aligned with the four components in the SLLB Guidelines, directly inspired by the Green Bond Principles, Social Bond Principles, and Sustainability Bond Guidelines. |
| **Sustainable finance** | Financial activities and instruments that incorporate ESG criteria to promote long-term sustainability and responsible investment outcomes. |
| **Sustainable Finance Working Group (SFWG)** | A G20 or ASEAN-level technical group focused on scaling sustainable finance through taxonomy development, disclosure alignment, and financial innovation. |

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| **Task Force on Climate-related Financial Disclosures (TCFD)** | A framework developed by the Financial Stability Board to improve climate-related financial risk disclosures by companies, focusing on governance, strategy, risk management, and metrics. |
| **Technology List and Perspectives for Transition Finance in Asia (TLP)** | A reference framework developed by ERIA to guide transition finance through credible technologies. It provides a categorised list of technologies and sectoral perspectives relevant to transition finance in Asia, particularly for high-emitting industries. |
| **Technology Readiness Level (TRL)** | A scale from 1 to 9 used to measure the maturity of a technology, from basic principles (TRL 1) to commercial deployment (TRL 9). Commonly used in climate and innovation finance. |
| **Transition bonds/loans** | Debt instruments used to finance climate transition activities that are not yet 'green' but are aligned with a credible and science-based pathway towards net zero. Intended for hard-to-abate or high-emitting sectors. |
| **Transition Credits Coalition (TRACTION)** | A multi-stakeholder platform that brings together financial institutions, policymakers, carbon market participants, and technical experts to develop robust frameworks for integrating high-integrity carbon credits into transition finance mechanisms. In Asia, TRACTION supports the creation of innovative financing solutions that accelerate industrial decarbonisation, especially in hard-to-abate sectors, by leveraging voluntary and compliance carbon markets. |
| **Viability gap funding (VGF)** | Public financial support to make infrastructure projects financially viable, often used in public–private partnerships and clean energy projects where expected revenues are below commercial thresholds. |
| **Variable renewable energy (VRE)** | Renewable energy sources like solar and wind that vary depending on environmental conditions. |
| **Weighted average cost of capital (WACC)** | A calculation of a firm's cost of capital, reflecting the relative costs of debt and equity. Lowering WACC is key for financing capital-intensive climate infrastructure at scale. |

# Acknowledgement

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# Foreword

Southeast Asia is set for substantial growth over the next decade. The region's continued use of unabated fossil fuel power generation and its rapidly expanding manufacturing sectors mean that greenhouse gas emissions are likely to rise as economic expansion drives energy demand. Existing old energy infrastructure represents high-emitting sources with long operational lifespans, while industrial assets such as steel, petrochemical, and cement plants are similarly long-lived and present hard-to-abate emissions. These sectors face significant barriers in shifting from high-emitting fossil fuel dependence to pragmatic transition technologies for their power and thermal requirements. This presents a significant challenge: balancing environmental concerns with continued growth.

The Asia Zero Emission Community (AZEC) was established in March 2023 to foster cooperation towards carbon neutrality and net-zero emissions across Asia, involving 11 partner countries (Australia, Brunei Darussalam, Cambodia, Indonesia, Japan, the Lao People's Democratic Republic, Malaysia, the Philippines, Singapore, Thailand, and Viet Nam). At the Second AZEC Ministerial Meeting in August 2024, the Ministry of Economy, Trade and Industry (METI), Asian Development Bank (ADB), and Economic Research Institute for ASEAN and East Asia (ERIA) signed a memorandum of cooperation on transition finance in Southeast Asia. This report represents a key outcome of that cooperation.

Transition finance aligns credible transition plans with the mobilisation of sustainable capital over long-term horizons. It supports sectors where solutions are complex and capital-intensive, anchoring investment in resilient energy infrastructure. Transition finance is also a critical enabler for decarbonising high-emitting and hard-to-abate sectors that have not been sufficiently considered by conventional financing. However, it is essential to establish a common understanding of transition finance. Building on METI's existing roadmaps, ERIA's Technology List and Perspectives, and ADB's projects as case studies, this report assesses relevant technologies, policies, and the corresponding financial mechanisms that can help achieve Southeast Asia's sustainability goals.

The launch of this report is particularly timely. As the region gains momentum in cross-border connectivity for clean energy and emission reductions, high-emitting and hard-to-abate assets must further explore and pursue decarbonisation strategies.

We hope this report will serve asset owners, developers, financial institutions, research institutions, and government bodies, and contribute to the acceleration of a just and orderly energy transition throughout the region.

1 October 2025

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# Executive Summary

Southeast Asia is experiencing rapid urbanisation, industrialisation, and economic expansion, which are driving up energy consumption and greenhouse gas emissions. Although Southeast Asia accounts for just 6% of global gross domestic product (GDP), it is amongst the fastest-growing emitters, with emissions rising 2.2% annually. The region is highly vulnerable to climate change impacts, threatening food security, infrastructure, and biodiversity. While the energy transition offers benefits, it also presents challenges in balancing decarbonisation with energy security and economic growth.

This report focuses on decarbonising Southeast Asia's hard-to-abate and high-emitting sectors, primarily the power and industrial sectors, which collectively account for over 70% of projected emissions. These sectors face unique technical, financial, and policy challenges including:

- **Continuous economic growth and rising energy demand:** Countries in the region continue to face rising energy demand and emissions due to their heavy reliance on coal and other fossil fuels. They remain locked into a trajectory where development is closely tied to carbon-intensive energy, while the rise of electrified technologies (e.g. electric vehicles, cooling systems, and data centres) is reshaping demand and placing added pressure on power systems.

- **Locked-in capital in carbon-intensive infrastructure:** A significant challenge lies in the region's young fleet of coal-fired power plants and recently developed industrial facilities. These assets are often backed by long-term contracts such as power purchase agreements, making early retirement financially and politically difficult. This creates a lock-in effect, where this region is committed to early retirement but risks significant stranded assets and financial losses without financial solutions.

- **Limited attractive investment projects and capital flow:** Despite Southeast Asia's vulnerability to climate change, this region's climate-aligned investments face low internal rates of return, high perceived risks, and weak bankability. High capital costs and lack of de-risking tools further discourage investors. In addition, climate finance typically excludes brown-to-green projects, focusing only on activities already aligned with low or zero emissions. Transition finance, on the other hand, is designed to support high-emitting and hard-to-abate sectors in their journey toward decarbonisation, enabling funding for credible transition plans and technologies that improve climate performance over time.

- **Immature variable renewable energy integration system:** Countries in the region face significant challenges in integrating variable renewable energy like solar and wind into their power systems. This integration challenge also extends to the industrial sector. Without a flexible grid and resilient infrastructure, industries may be reluctant to adopt renewable-based energy solutions due to concerns over power quality, cost volatility, and operational disruptions.

- **Limited technology advancement:** Technological maturity in critical decarbonisation areas – such as green hydrogen, carbon capture, and industrial electrification – remains limited in Southeast Asia. Many technologies are still at the pilot stage globally and face high costs, limited supply chains, and infrastructure gaps in the region. For industrial sectors like steel, cement, and chemicals, decarbonisation often requires a complete redesign of production systems, new feedstocks, and extensive infrastructure. The lack of technical expertise, limited pilot projects, and weak enabling environments all contribute to slow progress in deploying advanced low-carbon solutions.

- **Limited regional collaboration and interoperability:** Southeast Asia's energy transition is hindered by fragmented policies, inconsistent standards, and limited cross-border cooperation. Differences in regulatory frameworks, energy mixes, and market structures prevent the region from leveraging its full collective potential. Although regional cooperation offers opportunities for more efficient and lower-cost transitions, such as through shared renewables or hydropower, Southeast Asia still lacks a coherent institutional framework to drive interoperability and policy alignment.

- **Limited enabling policies:** Policy and regulatory frameworks across countries in the region remain underdeveloped or inconsistent when it comes to supporting the energy transition. Subsidies for fossil fuels, unclear carbon pricing mechanisms, and limited green procurement reduce investor confidence and market momentum. Transition technologies like carbon capture, utilisation, and storage (CCUS) and low-carbon hydrogen lack long-term policy support or incentive structures, making it difficult for projects to scale.

- **Building a just and inclusive energy transition:** While a just and inclusive energy transition is not a barrier, ensuring it is another major challenge. The shift to low-carbon systems must consider affordability, equitable access, and the socio-economic impact on vulnerable communities. Policies need to include workforce reskilling, social protection measures, and mechanisms for engaging affected communities.

The report proposes a mix of technology adoption, policy reform, and transition finance to unlock emission reductions. It highlights the importance of integrated roadmaps, regional power interconnection, just transition principles, and public–private collaboration. Using scenarios from the 8th ASEAN Energy Outlook, the report illustrates pathways towards a net zero future under varying ambition levels. The roadmap prioritises early action in energy efficiency, the acceleration of renewable energy deployment, and a gradual phase-down of unabated coal. The electrification of transport and industry will further drive up electricity demand, making clean power supply central to economy-wide decarbonisation. The roadmap also calls for policy actions such as carbon pricing, removing fossil fuel subsidies, and aligning national power development plans with net zero targets.

Transition finance plays a critical role in enabling Southeast Asia's shift from carbon-intensive energy systems to low-carbon alternatives, particularly in hard-to-abate and high-emitting sectors. However, the region continues to face major financing gaps due to weak project bankability, high perceived risks, and a lack of de-risking mechanisms. While trillions in global climate finance are needed to stay on track with the Paris Agreement goals, Southeast Asia's share remains insufficient, with financing costs significantly higher than in developed markets. Mobilising both public and private capital – through blended finance, clearer taxonomies, sovereign guarantees, and transition-linked instruments – is essential to support investments in technologies like CCUS, low-carbon hydrogen, and grid infrastructure. Strengthening enabling policies and shifting investment criteria from pure bankability to broader impact potential could unlock more inclusive and climate-aligned capital flows across the region.

In the conclusion, the report highlights the importance of collaborative action across Southeast Asia and beyond to accelerate the region's just and orderly energy transition. Regional cooperation is essential to unlock opportunities such as cross-border electricity trade, harmonised standards, and joint technology development. Southeast Asia could benefit significantly from partnerships with advanced economies, international organisations, and private actors to enhance technical capacity, access finance, and share innovation. Realising Southeast Asia's decarbonisation goals will require a transformative shift in policy, finance, and institutional frameworks. Inclusive governance is essential, ensuring that governments, industry, and civil society are actively engaged in shaping transition strategies that are both equitable and effective. Coordinated regional action can accelerate progress, reduce inequality, and enhance energy security while enabling the region to grow sustainably and competitively in the face of the global climate crisis.

# Chapter 1

## Introduction to Southeast Asia's Energy Transition

## 1.1. The imperative to decarbonise Southeast Asia

Southeast Asia is a thriving region that contributes about 6% of global gross domestic product (GDP) (IMF, 2023). Its economy expanded by more than 51% from 2015 to 2023, driven by rapid population growth, urbanisation, and industrialisation. This strong economic momentum has led to a sharp increase in energy demand, which has more than doubled since 2000. However, the urgency to decarbonise Southeast Asia's energy systems is not driven by energy demand alone. It is also a response to the growing threat of climate change, to which the region is especially vulnerable.

From 1990 to 2020, Southeast Asia's greenhouse gas (GHG) emissions grew at an annual rate of 3% (Zarim and Sastry, 2024) and accounted for about 5% of global emissions in 2022 (IEA, 2022b). If Southeast Asian countries do not act decisively, they risk locking in carbon-heavy infrastructure that will derail climate goals and weaken long-term energy resilience.[1]

Recognising this, all the countries in the region are parties to the Paris Agreement and have submitted nationally determined contributions (NDCs) outlining their climate commitments. These include targets to increase renewable energy capacity, improve energy efficiency, and reduce GHG emissions. While renewable energy has expanded over the past 2 decades (2000–2023) – led by hydropower, bioenergy, and geothermal – solar and wind have also made notable progress, particularly in countries like Viet Nam (IEA, 2024d). Decarbonisation in this region is therefore crucial not only for meeting domestic energy needs, but also for fulfilling global climate goals and protecting the region from escalating climate risks.

While Indonesia, Thailand, and Viet Nam have made important strides in deploying renewables – reaching 13.3 gigawatts (GW), 12.6 GW, and 47.8 GW of capacity, respectively, by 2023 (IRENA, 2025b) – the region still falls short of its energy transition targets, and renewables still make up a relatively small share of the overall energy mix. Fossil fuels, especially coal, remain dominant, supplying most of the growth. Coal's share of the regional energy mix jumped from 9% in 2000 to 28% in 2025, with Indonesia leading production and exports. The power sector remains heavily coal-based, especially in countries like Indonesia and the Philippines, while others like the Lao People's Democratic Republic (Lao PDR) have leveraged hydropower more effectively (Figure 1.1). The countries in the region have not yet unlocked the full potential of renewable energy; energy efficiency; carbon capture, utilisation, and storage (CCUS); clean hydrogen; and cogeneration/trigeneration technologies to drive deep decarbonisation largely due to their ongoing dependence on fossil fuels for baseload power.

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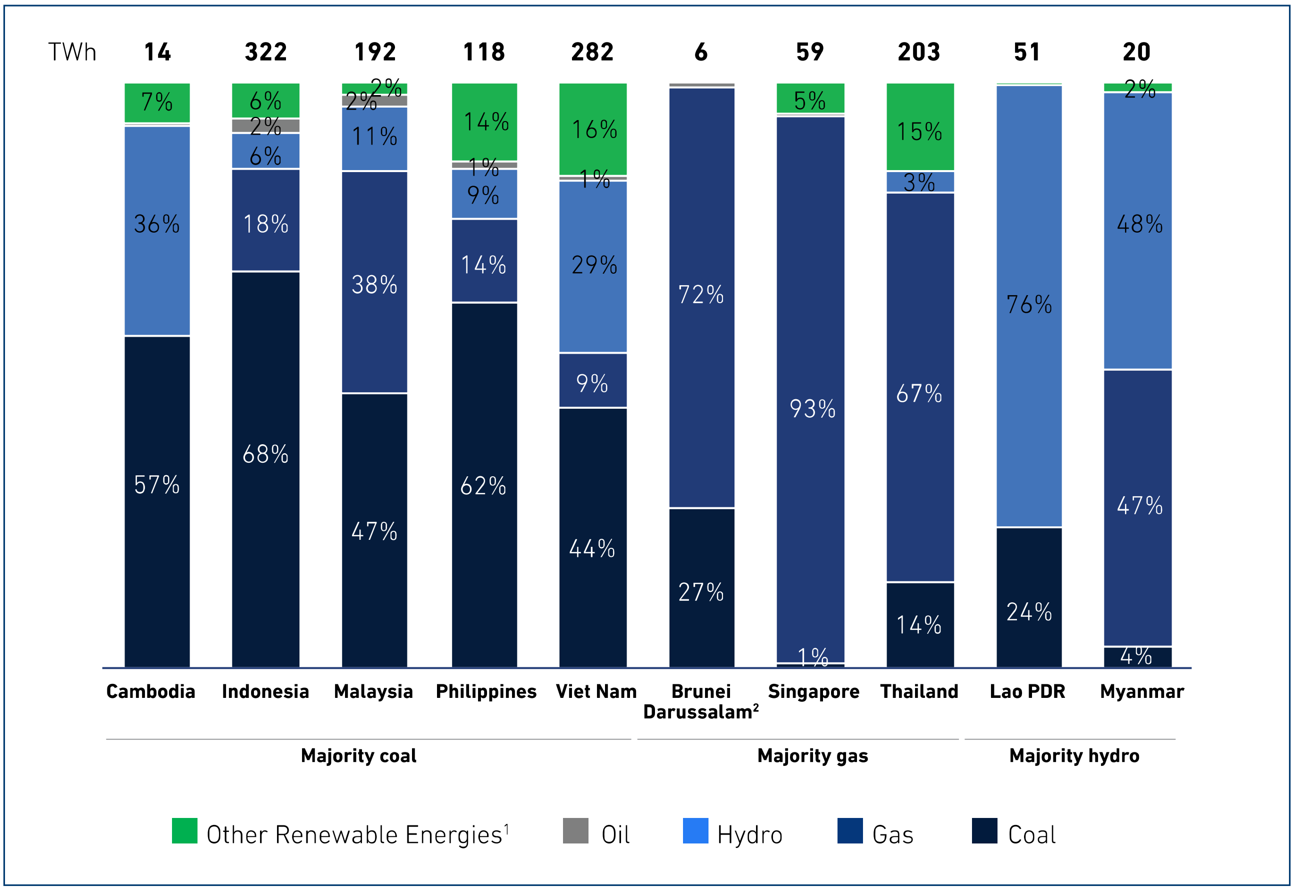
[1] This lock-in is partly under way, with a large stock of young coal power plants in the region. Without decisive action, further investments risk deepening dependence on carbon-intensive infrastructure, undermining climate goals and long-term energy resilience.

The potential of renewables and clean technologies remains underutilised across Southeast Asia, held back by limited policy support, inconsistent investment, and infrastructure gaps (IEA, 2023a). To meet growing energy demand while cutting emissions, countries need to accelerate the deployment of clean and low-carbon technologies and enhance regional cooperation for a more sustainable energy future (IRENA, 2022). Industry has been a major driver of rising energy use across all fuel types. The surge in steel production, particularly stainless steel supported by local nickel resources, has significantly boosted coal demand. Manufacturing has also expanded rapidly, with Southeast Asia becoming a key player in global supply chains for electronics, vehicles, textiles, and food products – all of which rely heavily on electricity and natural gas. This industrial momentum has outpaced energy supply in some areas, particularly natural gas, where demand has nearly doubled since 2000 while production rose only 20%.

**Figure 1.1: Generation Mix in Southeast Asia, 2023 (TWh)**



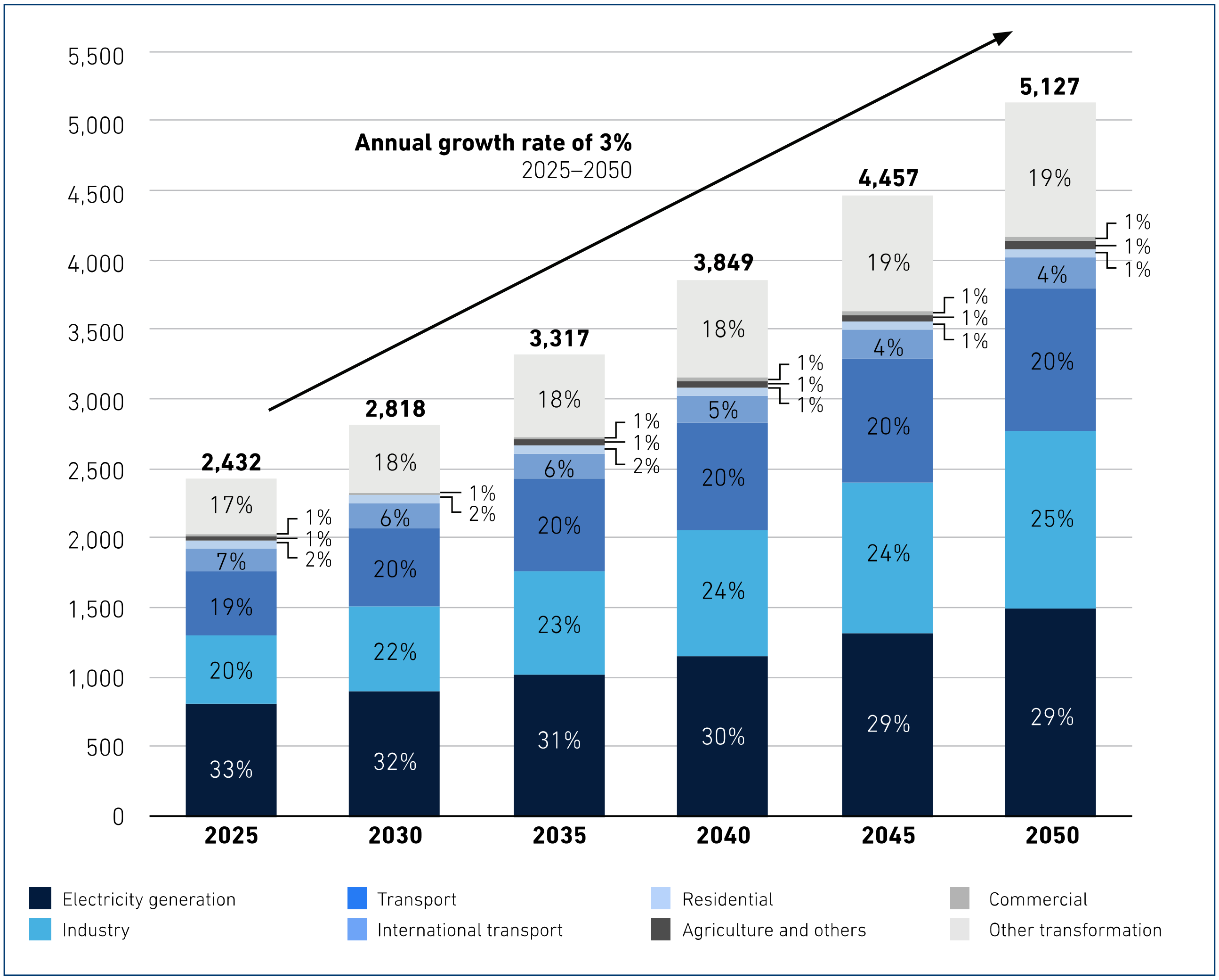

[1] Includes biomass, solar, wind, and geothermal

[2] Accounts for auto producers as well

Source: Enerdata, published country plans, and nationally determined contribution commitments.

Without implementing decarbonisation measures, Southeast Asia's annual emissions (Figure 1.2) are projected to increase by 3% annually, potentially doubling from 2025 to 2050. The main contributors to this emissions growth are the power, industry, and transport sectors, which together account for over 70% of total projected emissions in 2025. Across sectors, emissions are expected to see further growth due to increasing populations and GDP (Figure 1.2): all the decarbonisation measures adopted will have to sustainably support the region's economic growth.

**Figure 1.2: Annual Emissions of Southeast Asian Countries by Sector, Baseline Scenario (Mt $CO_2$e)**




$MTCO_2e$ = million tonnes of carbon dioxide equivalent.

Source: 8th ASEAN Energy Outlook.

The gap in energy use between higher- and lower-income countries in the region is widening, and as the region grows, so will its emissions. The Association of Southeast Asian Nations (ASEAN)'s target to achieve a 23% share of renewable energy by 2025 under the ASEAN Plan of Action for Energy Cooperation (APAEC) Phase II, 2021–2025 was an important target. However, progress has been slower than expected, with the region's renewable energy share reaching only 15.6% as of 2022 (ACE, 2024a). Several factors contribute to this gap and are explored in the next chapter.

Countries have also undertaken various commitments to decarbonise their energy sectors, which are reflected in their NDCs or outlined in their energy and climate plans, as shown in Table 1.1.

**Table 1.1. Plans and Commitments for Decarbonisation in Southeast Asian countries**

| | |
|---|---|
| **Brunei Darussalam** | Increase the share of renewables in its total power generation by 30% by 2035, as part of its commitment to reduce carbon emissions and move towards net-zero by 2050. |
| **Cambodia** | Increase the use of renewable energy to 70% in power generation mix by 2030. |
| **Indonesia** | Achieve 23% of renewable energy use by 2025 and 31% by 2050. |
| **Malaysia** | Achieve 31% share of renewable energy in its national installed capacity mix by 2025, increasing this to 40% by 2035, and further raising it to 70% by 2050. |
| **Philippines** | Achieve 35% of electricity generation from renewables by 2030 and 50% by 2040. |
| **Viet Nam** | Renewable energy sources like wind, solar, and biomass to account for about 48% of the country's total installed power capacity by 2030, increasing this to 63% by 2050 in line with its National Power Development Plan 8 (PDP8). |
| **Singapore** | Produce 2 GW solar by 2030 and import up to 4 GW of low-carbon electricity by 2035. |
| **Thailand** | Increase the share of renewables in the energy mix to 51% by 2037. |
| **Lao PDR** | Achieve a 30% renewable energy share in total energy consumption by 2025. |
| **Myanmar** | Increase the share of renewable energy in the total energy mix to 11–17% by 2030 by generating 2,000–3,070 MW of renewable energy. |
| **ASEAN** | Increase the renewable energy share to 23% of the ASEAN energy mix and the share of renewable energy in installed power capacity to 35% by 2025, while reducing energy intensity in the ASEAN region to 32% by 2025. |

ASEAN = Association of Southeast Asian Nations, GW = gigawatt, MW = megawatt.

Sources: Enerdata, country energy plans, and commitments to nationally determined contributions.

Although setting goals is crucial, ensuring that they are integrated into national development plans is also important. With urbanisation accelerating and energy demand climbing, especially in fast-growing cities, governments have a chance to leapfrog with cleaner technologies. Prioritising renewable energy, energy efficiency, and low-carbon industry now will avoid costlier transitions later and create jobs in emerging green sectors across the region.

**Exposure to climate-related risks**

Before exploring the challenges of the energy transition, it is crucial to recognise what is at stake: Southeast Asia is one of the most climate-vulnerable regions globally, facing severe and wide-ranging risks. Climate change will likely reduce agricultural productivity, particularly rice yields in the Mekong Delta, and heighten health risks from heat stress and disease. Rising seas and stronger storms threaten low-lying cities and disrupt water access, agriculture, and public health, such as in Jakarta, Bangkok, and Ho Chi Minh City. Labour productivity will decline due to extreme heat, and energy demand for cooling will rise sharply. Damage to coastal infrastructure, coral reef extinction, and loss of biodiversity and forests further amplify the region's exposure. Moreover, understanding the economy-wide implications of climate change, beyond individual sector impacts, is complex. Climate-related risks – both physical (e.g. extreme weather and sea-level rise) and transition-related (e.g. policy, market, and technology shifts) – are increasingly relevant for Southeast Asian economies. Over 30 years of multidisciplinary integrated assessment research has combined efforts from climate, environmental, and economic disciplines to address this challenge. Studies indicate that Southeast Asia is expected to suffer GDP losses ranging from 1.7% due to 1.0°C of global warming to 12.5% from 4.8°C of warming.

In the *Asian Development Outlook 2023 Thematic Report,* ADB provided country-specific estimates of climate change's economy-wide effects in Southeast Asia, using the Policy Analysis of the Greenhouse Effect (PAGE) model, a widely used integrated assessment model that links emissions, climate outcomes, and economic damages (ADB, 2023b). For Indonesia, the Philippines, Thailand, and Viet Nam, the study estimates a mean annual GDP loss of 2.2% by 2100, considering only market impacts like agricultural production and coastal inundation. Including non-market impacts related to health and ecosystems, the loss could reach 5.7% of GDP, and considering catastrophic risks, it could be as high as 6.7% (ADB, 2009).

Clearly, Southeast Asia has much at stake in addressing climate change, raising the question of what measures are needed to avoid such damage to the region's economies.

This outlook also highlights the uneven impact across sectors, with agriculture, labour productivity, and coastal infrastructure bearing the brunt of climate risks. These sectors support millions of jobs and sustain food and water security across the region. Ignoring these trends could deepen inequality, strain public budgets, and reverse development gains. Southeast Asia has an opportunity to shift course by prioritising climate resilience in national planning and redirecting investment towards more adaptive, inclusive growth.

**About this report**

The complexity of the energy transition in Southeast Asia lies in the need to decarbonise the energy sector while meeting rising demand. Countries must strike a balance between energy security, affordability, and sustainability, while managing growing physical risks from climate change.

This report aims to identify and assess hard-to-abate and high-emitting sectors in Southeast Asia that are critical to achieving meaningful GHG reductions. 'Hard-to-abate sectors' in this report are high emissions-intensity industries that are difficult to decarbonise due to their dependence on fossil fuels for high-temperature heat, feedstocks, or process emissions or for which green technologies are not currently feasible at scale. Typical examples include the chemical, cement, and steel industries. 'High-emitting sectors' include those with significant absolute emissions today, particularly coal-fired power generation, which remains a dominant source of electricity in many Southeast Asian countries and is responsible for a large share of regional power sector emissions.

Rather than covering sectors where low-carbon solutions are already commercially viable and scaling, such as electric vehicles (EVs) or energy-efficient appliances, this report focuses on sectors where decarbonisation is technically, economically, or institutionally more complex, and where significant innovation, capital, and policy coordination are required. The report seeks to highlight the importance of hard-to-abate and high-emitting sectors in Southeast Asia's overall emissions profile, to assess the key barriers and enablers for decarbonising these sectors, and to propose actionable strategies – technical, financial, and policy-related – that can support their transition while ensuring economic resilience and promoting social inclusion and energy security.

In line with this objective, the report focuses on the power and industry sectors, as these represent the largest sources of emissions in Southeast Asia and face some of the most significant challenges in transitioning to low-carbon alternatives. Coal-fired power generation, in particular, accounts for a major share of energy-related emissions in Southeast Asia, while heavy industries such as steel, cement, and chemicals are key hard-to-abate sectors that currently lack cost-effective decarbonisation solutions at scale. Addressing these sectors is therefore essential for achieving deep emission reductions and enabling broader decarbonisation across the economy.

Chapter 1 presents the key challenges impeding the transition, while Chapter 2 presents the measures to enable the energy transition today, with roadmaps for the power and industrial sector. Chapter 3 presents illustrative case studies that demonstrate how transition pathways are already unfolding in the region, and Chapter 4 provides conclusions, with a call for collaboration. The report draws on the AMS Targets Scenario (ATS) and Clean Energy Scenario (CNS) from the 8th ASEAN Energy Outlook (AEO8) (Box 1.1) to guide the analysis. Ultimately, achieving a just and orderly transition will require careful navigation of trade-offs between inclusive economic growth, environmental protection, and the safeguarding of livelihoods and vulnerable communities.

## Box 1.1: The AMS Targets Scenario and Carbon Neutral Scenario of the 8th ASEAN Energy Outlook

The 8th ASEAN Energy Outlook, developed by the ASEAN Centre for Energy (ACE) in collaboration with national experts from ASEAN Member States (AMS), provides a comprehensive analysis of the region's energy landscape and future scenarios.

The report discusses the energy scenarios and key assumptions for the energy outlook of the Association of Southeast Asian Nations (ASEAN), focusing on achieving regional targets by 2025 and beyond. The scenarios include the Baseline Scenario (BAS), the AMS Targets Scenario (ATS), the Regional Aspiration Scenario (RAS), and the Carbon Neutral Scenario (CNS). Each scenario assumes different sets of energy targets and policies, with a gradual increase in the level of effort put forth, to predict the impacts on energy consumption, supply, electricity generation, access, carbon dioxide emissions, and other cross-cutting issues. For this report, the ATS and the CNS are used as the two boundaries for the future.

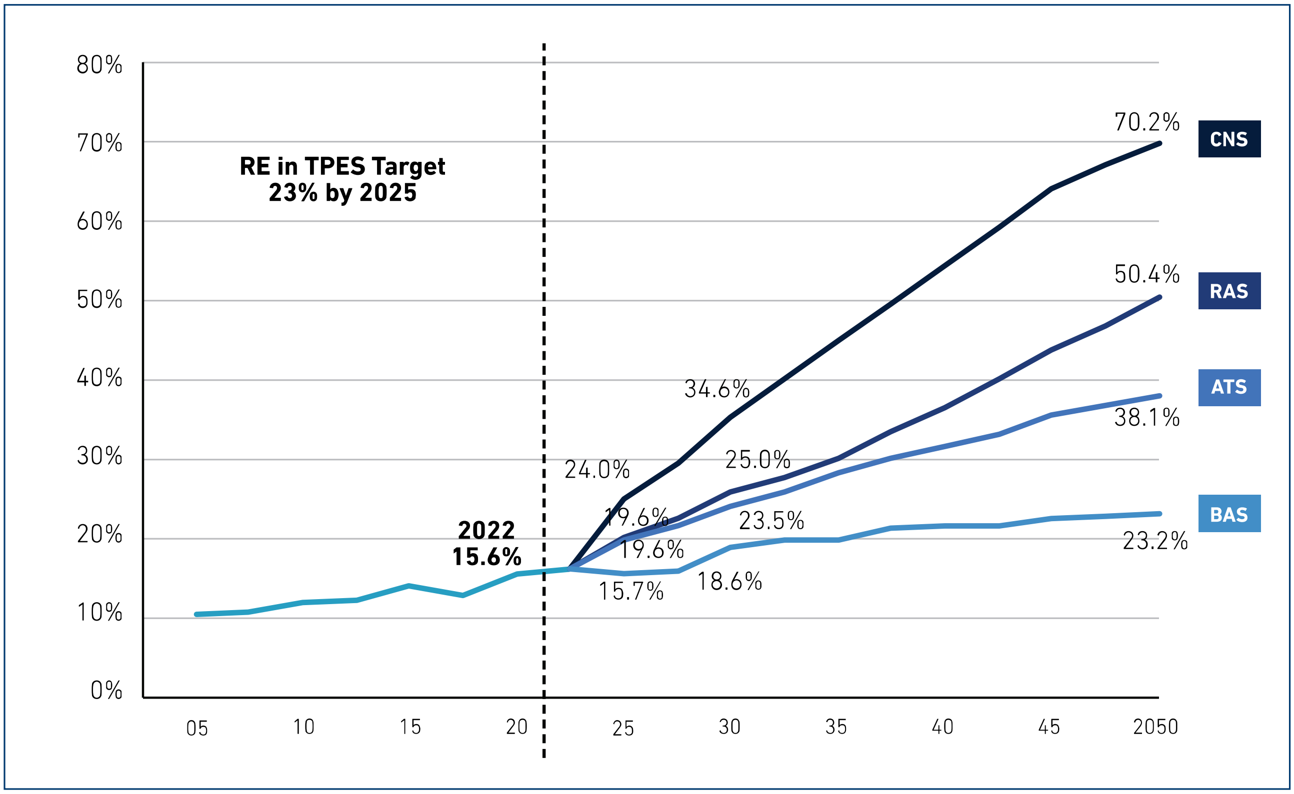
The ATS represents a policy-driven pathway aligned with official national strategies, particularly in achieving energy efficiency and renewable energy targets. It incorporates each country's power development plans, installation targets, and firm capacity additions. The scenario includes modelling interventions designed to meet the unconditional energy-related targets under AMS' NDCs. Compared with the BAS, the ATS reflects a higher level of ambition in clean energy deployment while maintaining energy security and affordability.

The CNS is an ambitious and aspirational scenario to achieve net zero carbon emissions by 2050. It explores the most ambitious decarbonisation efforts using the least-cost optimisation of net zero technologies, aligned with the ASEAN Strategy for Carbon Neutrality. The CNS goes beyond current policies and explores transformative shifts in the energy system, including higher electrification rates, rapid renewable energy scaling, early retirement of fossil fuel assets, and carbon capture deployment. While not a prediction, it provides a long-term vision for deep decarbonisation under strong policy commitment and international cooperation.

Both scenarios, as developed in the 8th ASEAN Energy Outlook, serve as strategic tools for ASEAN policymakers to assess trade-offs between energy access, affordability, environmental impact, and economic development in the context of a just and orderly energy transition.

Source: ACE (2024a).

**Figure 1.3: Renewable Energy Share of TPES across Scenarios, 2005–2050**




ATS = AMS Targets Scenario, BAS = Baseline Scenario, RAS = Regional Aspiration Scenario, CNS = Carbon Neutrality Scenario, RAS = Regional Aspiration Scenario, RE = renewable energy, TPES = total primary energy supply.

Source: ACE (2024a).

# 1.2. Key challenges impeding a large-scale transition

Decarbonising Southeast Asia's hard-to-abate and high-emitting sectors is a complex task with a range of challenges. While there are many obstacles, the most pressing can be broadly grouped into three broad challenges (financial, technical and policy) and fundamental one (Figure 1.4). These challenges continue to slow real-world progress and contribute to the growing gap between what has been achieved and what is urgently needed.

**Figure 1.4: Summary of Key Challenges to Scaling up Energy Transition**


VRE = variable renewable energy.

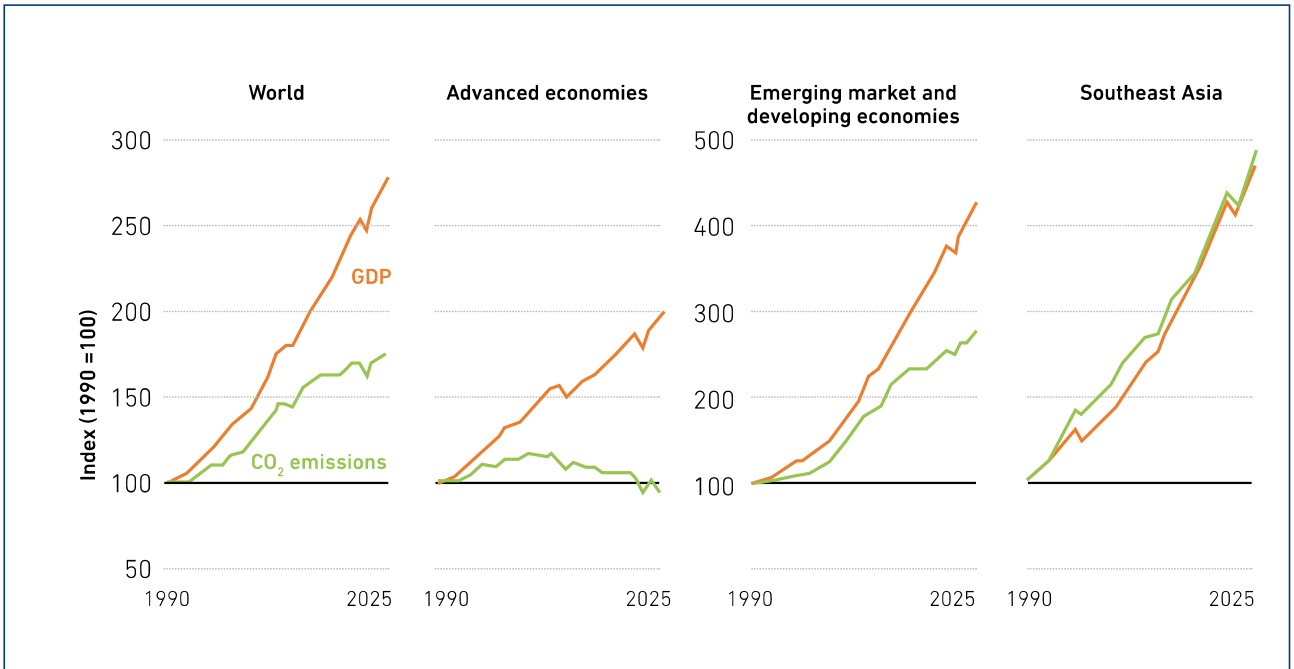
Source: Authors.

## 1.2.1. Fundamental Challenge

**1. Continuous economic growth and rising energy demand**

One of the core challenges in decarbonising Southeast Asia is that the region is still in a phase of rapid economic expansion. Strong population growth, rising industrial activity, and increasing urbanisation continue to drive demand across all sectors. Southeast Asia now contributes about 6% of global GDP, and its economy has grown by more than 45% from 2013 to 2023. Since 1990, energy demand in Southeast Asia has roughly tripled, and carbon dioxide ($CO_2$) emissions have increased by about 250% (Figure 1.5). Unlike advanced economies where emissions have begun to decline, Southeast Asia still show a strong link between economic growth and rising emissions driven heavily by coal plants and carbon-intensive industrial development.

**Figure 1.5: GDP and $CO_2$ Emissions Trends by Region, 1990–2023**



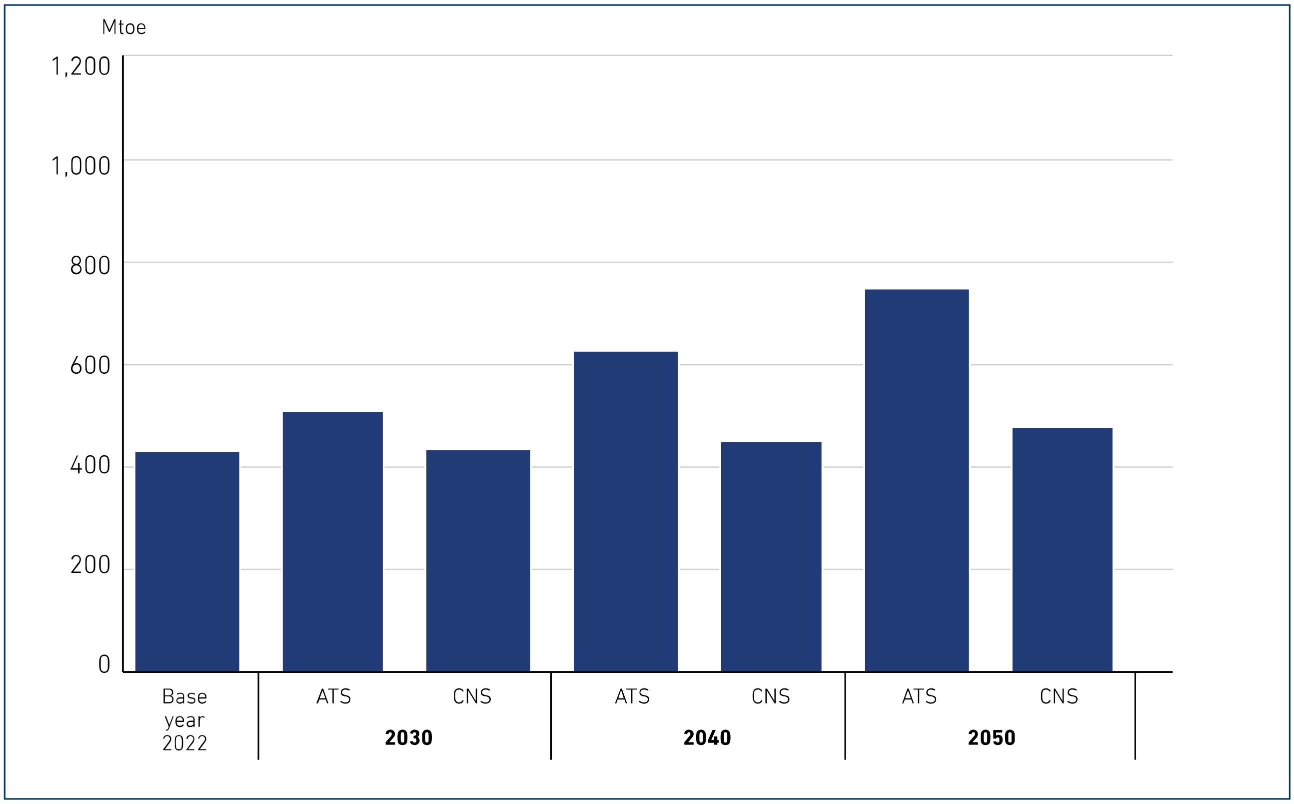

$CO_2$ = carbon dioxide, GDP = gross domestic product.

Note: GDP expressed in 2023 United States dollars in purchasing power parity terms.

Source: IEA (2024d).

This trend is not set to stabilise, unless policy actions are undertaken. While the estimated growth differs by climate scenario, the ATS projects regional energy consumption to almost double by 2050 compared with 2022 levels, driven by rapid economic development, population expansion, and increased industrial activity. Even in the CNS, energy demand would increase compared with 2022 levels (Figure 1.6).

**Figure 1.6: Total Final Energy Consumption across Scenarios in Southeast Asia (Mtoe)**




ATS = AMS Targets Scenario, CNS = Carbon Neutral Scenario, Mtoe = million tonnes of oil equivalent.

Source: ACE (2024a).

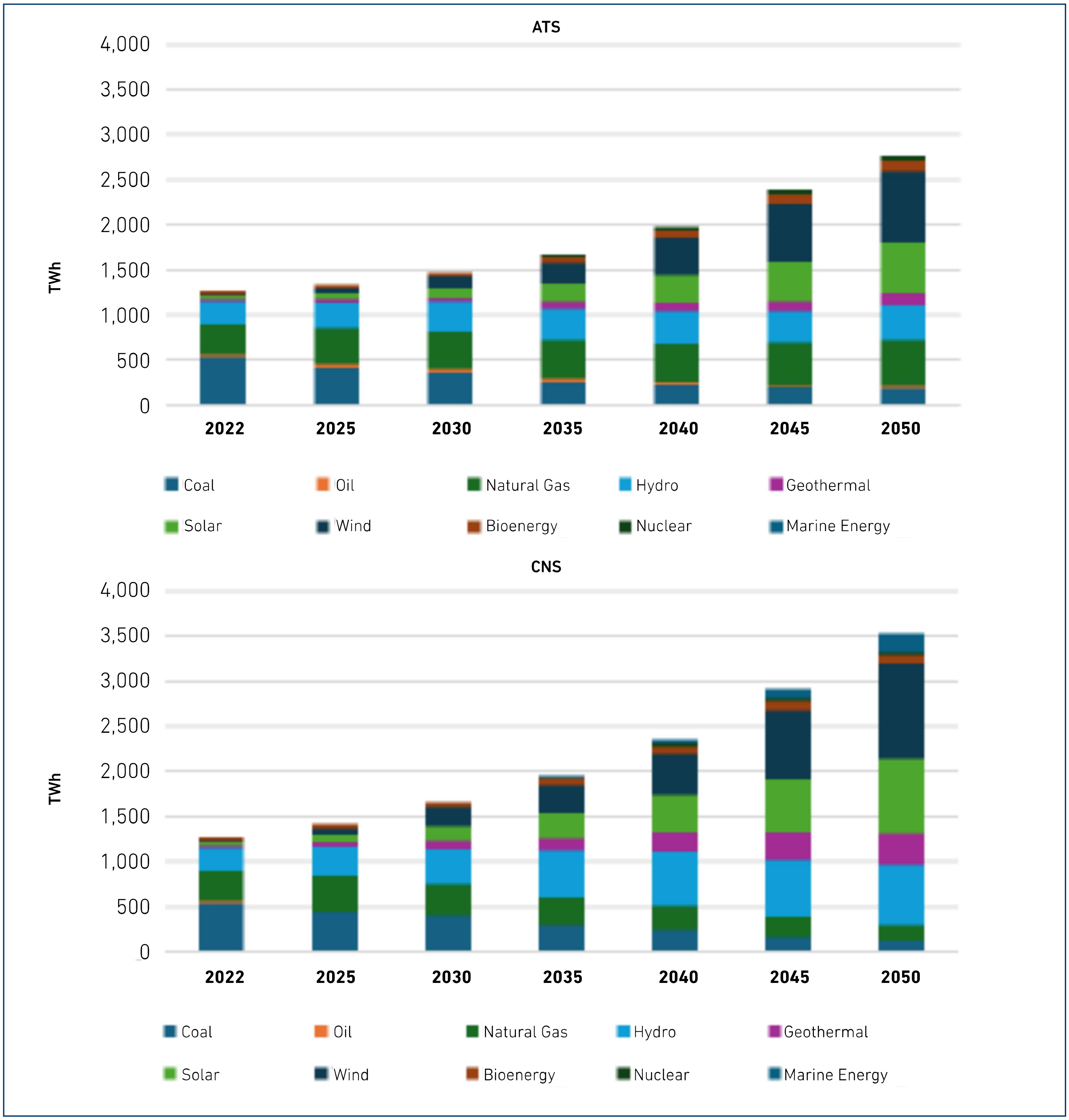
### Power sector

To meet the rapidly growing energy demand and ensure reliable electricity supply, most countries in Southeast Asia continue to depend heavily on thermal power generation, particularly coal and natural gas. Coal accounted for 80% of power sector emissions in 2023 and produced almost half of the region's electricity in 2022, while natural gas contributed almost one-third (ACE, 2024a).

Indonesia, the Philippines, Thailand, and Viet Nam have committed to significantly increasing their renewable energy capacity as part of their NDCs under the Paris Agreement (Table 1.1). This is reflected in notable advances in wind, solar photovoltaic (PV), and hydropower projects. For instance, in 2024, Indonesia announced that it plans to retire all coal-fired power plants (CFPPs) within the next 15 years and build over 75 GW of renewable energy capacity by 2040 (Reuters, 2024a). However, Regulation No. 10/202, the 'Roadmap for the Energy Transition in the Electricity Sector' issued by Indonesia's Ministry of Energy and Mineral Resources in April 2025, does not set a firm deadline for the coal phaseout. Thailand, similarly, has updated its Power Development Plan (PDP) 2024 to increase the share of renewables in its electricity mix to 51% by 2037 (Climate Policy Database, 2025). Solar power will make a significant contribution to this ambitious objective, with a target of 36,500 megawatts (MW). While these developments signal growing ambition, they are not limited to these four countries. Other countries have also outlined renewable energy targets, but progress remains uneven.

This trend is reflected in the ATS, where these kinds of commitments are met. The CNS shows a similar trend, with increased renewable energy penetration but also an increased electric load (to fuel electrified loads) and reduced dependence on fossil fuels (Figure 1.7).

**Figure 1.7: Electricity Generation by Fuel Type in Southeast Asia- ATS (above) vs CNS (below) (TWh)**




ATS = AMS Targets Scenario, CNS = Carbon Neutral Scenario, TWh = terawatt-hour.

Source: ACE (2024a).

The growing demand for electric loads in Southeast Asia increases these challenges. Energy landscape in this region is shifting, with cooling, EVs, and data centres quietly reshaping demand profiles across the region. Air conditioning is no longer optional, especially in dense urban areas where temperatures and humidity are rising. Governments are accelerating EV adoption through incentives and mandates, while global tech companies are building data centres that require uninterrupted power and intensive cooling year-round. These technologies do not follow the patterns of legacy demand. They blur the lines between peak and off-peak and expand faster than most power planners are prepared for. They are now central to how energy is being used, and there is a need to include them in the planning of the power systems in the energy transition.

**Box 1.2: Data Centre Expansion in Southeast Asia**

Data centres in Southeast Asia are expected to grow significantly due to the increasing deployment of 5G (Fifth Generation), the rapid adoption of cloud services, and the rising interest from hyperscale cloud providers. Governments in the region are also providing strong support through tax incentives, foreign direct investment allowances, and regulated deployment standards. Additionally, tightening data privacy regulations across Southeast Asia are driving the demand for local data centres. Data centre capacity is expected to grow substantially from 2023 to 2027 in several ASEAN Member States. Indonesia's capacity is projected to grow from 175 megawatts (MW) to 621 MW (and up to 1,000 MW in 2030), making it the largest market in the region. Thailand's capacity is expected to increase from 75 MW to 205 MW, while Viet Nam's capacity will rise from 70 MW to 170 MW. The Philippines will see its capacity grow from 45 MW to 153 MW.

This rapid expansion will place a significant strain on the electricity grid in these countries. Data centres are expected to drive a substantial portion of the total energy consumption, with Indonesia's data centres alone requiring about 10,000 gigawatt-hours annually by 2030. The high energy consumption for cooling and information technology (IT) equipment will increase operational costs and environmental impact. The monopolised electricity markets in most Southeast Asian countries make it challenging to deploy reliable data centres, and the low share of renewable energy in the energy mix poses a challenge for sustainable growth.

Source: Authors' analysis (unpublished).

### Industry

In 2022, industrial energy consumption grew by about 20% from 2019 levels, representing 43% of the total energy consumption in the region. Rapidly expanding industrial sector in Southeast Asia is a driver of economic growth both regionally and globally. The region's industrial value added is projected by the International Energy Agency (IEA, 2024d) to grow at an average annual rate of 3.5% until 2050, outpacing the global average of 2.2%.

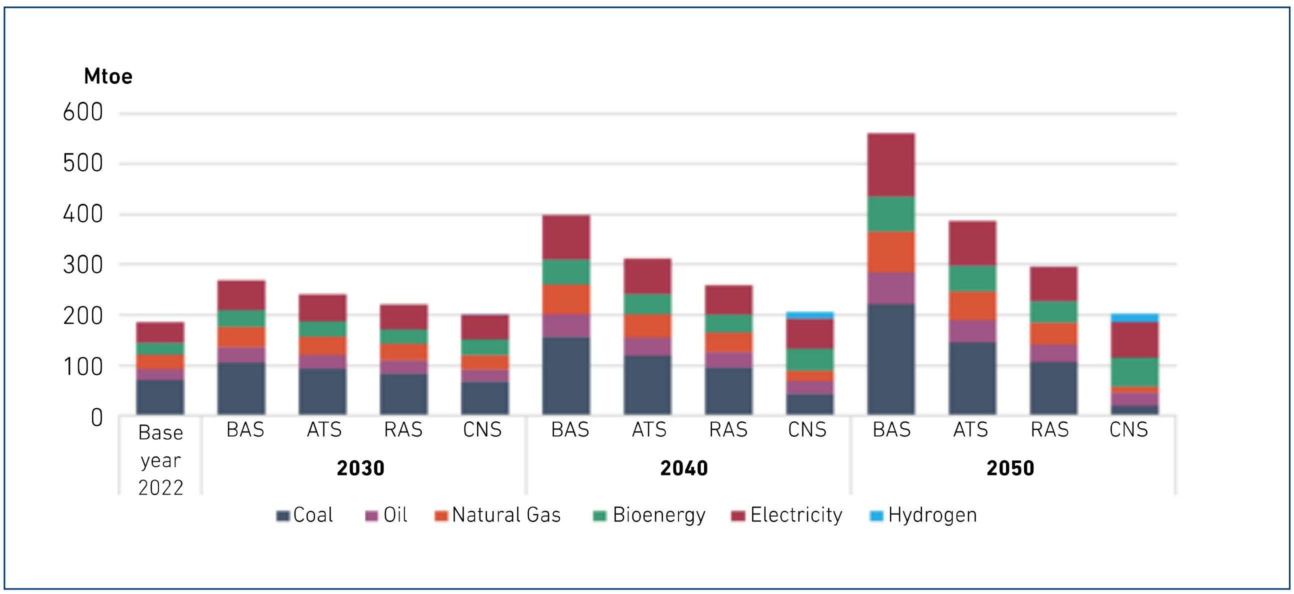
However, the industrial sector accounts for 28% of Southeast Asia's energy-related carbon dioxide ($CO_2$) emissions due to its existing fuel mix. Energy-intensive industries consume 60% of industrial energy and are expected to see the highest increase in demand in the coming years. At present, these industries primarily depend on coal, which meets 44% of their energy needs, particularly for high-temperature heat (Figure 1.8). The rest of the industrial sector relies mainly on electricity (38%), along with significant shares of natural gas (18%) and bioenergy (22%). The energy mix varies across Southeast Asia, with Indonesia and Viet Nam using their domestic coal reserves, while Thailand and Malaysia maintain a more diversified mix with higher shares of natural gas and renewables.

All industrial subsectors in Southeast Asia are expected to grow faster than the global average. Iron and steel production is set to nearly triple by 2050, with Indonesia and Viet Nam leading this expansion. The production of non-ferrous metals, including aluminium and nickel, is also projected to rise, particularly in Indonesia and Malaysia. The chemical industry is poised for strong growth, nearly doubling in size by 2050, with Thailand leveraging its established industrial base and infrastructure. Indonesia remains amongst the world's top three ammonia exporters, while Malaysia is advancing its methanol production capacity.

The rise in industrial output is projected to drive a 65% increase in energy demand, from almost 200 million tonnes of oil equivalent (Mtoe) in 2022 to almost 400 Mtoe in 2050 under the ATS. In the CNS scenario, the energy consumed remains around the same.

Under the ATS, the region's reliance on fossil fuels in industry will see an increase in demand, surpassing today's total industrial consumption, while bioenergy and electricity (mostly from fossil fuels) will add 139 Mtoe. Coal will continue to be a major energy source, making up 38% of the industrial energy mix in 2050. In the CNS, coal and oil will continue to be used, but at much smaller shares, while energy efficiency interventions will make the energy demand lower while maintaining industrial output.

**Figure 1.8: Industry Consumption by Fuel across Scenario (Mtoe)**




ATS =AMS Targets Scenario, BAS = Baseline Scenario, CNS = Carbon Neutral Scenario, Mtoe = million tonnes of oil equivalent, RAS = Regional Aspiration Scenario.

Source: ACE (2024a).

## 1.2.2. Financial Challenges

**2. Locked-in capital in carbon-intensive infrastructure**

**Power sector**

As mentioned above, reliance on coal is particularly significant, as over 40% of power generation mix in Southeast Asia still relies on CFPPs. Fast-growing electricity demand and relatively young CFPPs could lock these countries into high emissions for decades, with plants averaging less than 15 years old and as low as 8 years old in Viet Nam compared with the 30–40 years typical of CFPPs in the European Union (EU) and North America (Figure 1.9).

One of the major hurdles to addressing emissions from CFPPs is that they are shielded from market competition. CFPPs in Southeast Asia are either financed by state-owned utilities or built based on a single-buyer model where independent power producers (IPPs) transact with a single utility on the basis of regulated pricing.[2] At the economic heart of these projects is the power purchase agreement (PPA), signed between the single buyer and the project company. This agreement ensures a stable cash flow for the project company to service its debt and generate returns for shareholders (Ma et al., 2025).

Many of these CFPPs are financed by foreign investors, with host governments signing contracts that promise lucrative returns for years. Considering that the economic lifespan[3] of a coal plant is around 30 years, and a technical lifetime around 50 years, many of these plants should be taking decarbonising measures, including shutting them down decades ahead of schedule, to align with global climate goals. This challenge is exacerbated by the region's pipeline of planned CFPPs.[4]

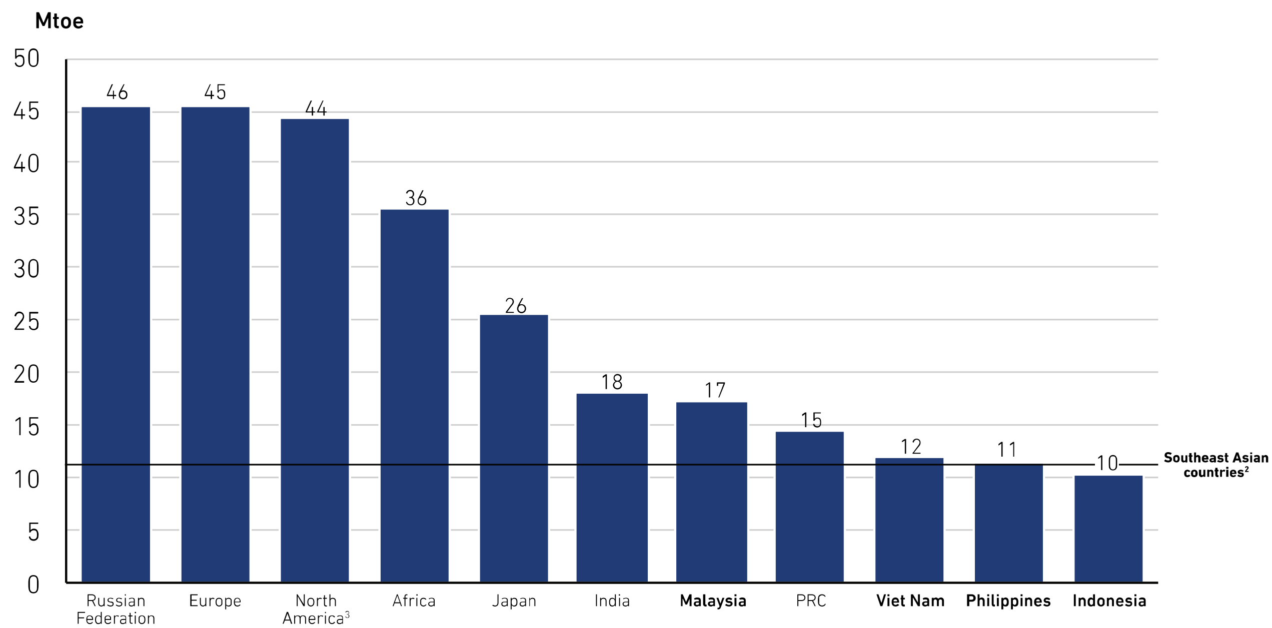
Ending coal power would mean shutting down many CFPPs years or decades ahead of schedule, which would conflict with PPA contracts or cause financial losses for state-owned utilities. Early retirement of coal assets is highly capital- and time-intensive, as both local and foreign investors may need to be compensated for forgone earnings and stranded assets. Failure to address these financial risks could undermine investor confidence and dampen future foreign direct investment (FDI) in the power sector. CFPPs make up significant portions of the installed capacity in Indonesia, Malaysia, the Philippines, and Thailand. This dependency makes the transition to renewables more challenging, both from a technological and financial perspective, as the transition requires substantial up-front investment in clean energy technologies. As such, transitioning away from these assets would require innovative financing and policy support.

[2] An exception to this is the Philippines, where a coal plant may have power supply agreements with multiple distribution utilities and can also sell electricity in the wholesale market.

[3] Economic lifespan refers to the typical period required to fully recover the initial capital investment.

[4] In 2022 alone, Southeast Asia (Viet Nam, the Philippines, Indonesia, and Cambodia) accounted for 11% of newly commissioned global coal power capacity, highlighting the region's continued reliance on coal expansion despite global decarbonisation efforts (Global Energy Monitor et al., 2023).

**Figure 1.9: Average Age of Existing CFPPs[1] in Selected Countries and Regions, 2025**




CFPP = coal-fired power plant, PRC = People's Republic of China, GW = gigawatt,

[1] Only include operating and mothballed coal power plants.

[2] While the graph only shows Southeast Asian countries with >10 GW of existing coal capacity, the figure is based on nine countries (Brunei Darussalam, Cambodia, Indonesia, the Lao People's Democratic Republic, Malaysia, Myanmar, the Philippines, Thailand, Viet Nam), excluding Singapore, where data are not available.

[3] Includes Canada and the United States.

Source: Global Energy Monitor (2025a).

## Industry

Hard-to-abate industries (i.e. carbon-intensive industries with no electrification alternative)[5] are similarly young and face significant decarbonisation challenges due to recent investments in assets. Hard-to-abate industries typically operate with mature infrastructure and technologies that necessitate fossil fuels.

Some of the equipment have a relatively long operational life – often spanning 20–30 years – compared with typical investment cycles and replacing them ahead of their useful life would require additional financial support to recover the return on invested capital. In addition, there is no signal of interest in investing in green technologies, with a preference instead for financially secure fossil-based solutions.

[5] See the 'About this report' section for the definition of hard-to-abate industries – carbon-intensive industrial sectors or subsectors where deep decarbonisation is particularly challenging due to the limited availability or viability of electrification alternatives for key processes such as steel production, cement manufacturing, and chemicals, thus remaining reliant on fossil fuels or other carbon-emitting energy sources.

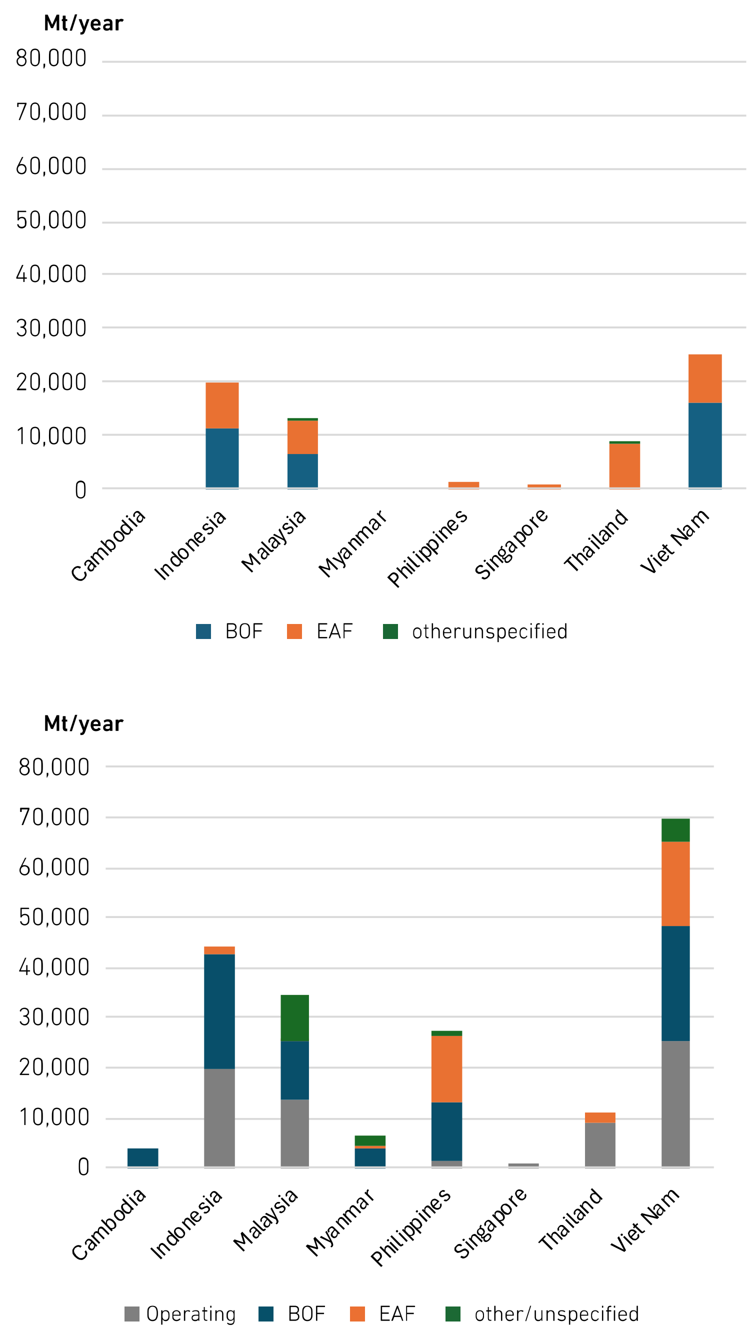
For instance, 49% of the primary steel production process in Southeast Asia in 2024 used the coal-based blast furnace-basic oxygen furnace (BF-BOF) route to produce a total of 34 million tonnes (Mt) per year of capacity (Figure 1.10). In contrast, 33.8 Mt of steel capacity in the region used the electric arc furnace (EAF) route (mostly to produce secondary steel, i.e. recycled). However, based on the projects announced and in construction, these numbers are expected to increase. The BF-BOF total capacity could reach 111.0 Mt/year, while the EAF route will only achieve 68.5 Mt/year in 2024.

A blast furnace can operate for about 40 years before refurbishment, and options for decarbonisation of the technology are limited and not commercially available – only one carbon capture and storage (CCS) project for blast furnaces has been announced in the world. CCS for direct reduced iron (DRI) is instead tested in the United Arab Emirates. The Al Reyadah facility, commissioned in 2016 at Emirates Steel, captures about 0.8 Mt of $CO_2$ per year from a natural gas-based DRI plant and uses it for enhanced oil recovery. However, in 2023, it captured only 26.6% of the gas-based steel plant's emissions (Nicolas and Basirat, 2024). Additionally, hydrogen-based direct reduced iron (H2-DRI) is emerging as a low-carbon steel production technology. Although its commercial-scale deployment is still being developed, H2-DRI offers the potential to cut emissions by replacing natural gas with green hydrogen.

While this section focused on the steel industry, similar decarbonisation challenges are present in other hard-to-abate sectors such as cement, petrochemicals, and aluminium, which also rely on carbon-intensive processes and long-lived assets with limited low-emission alternatives commercially available today.

Without financial, political, and technological support, it is unlikely that hard-to-abate industries will be decarbonised soon. This underscores the importance of mechanisms like the EU Carbon Border Adjustment Mechanism (CBAM) (Box 1.3), which drives decarbonisation by creating both incentives and financial pressure for cleaner production. The CBAM highlights the need for developing countries to consider complementary financial support policies (e.g. carbon pricing, tax incentives, or transition funding) to ensure that their industrial sectors remain competitive while accelerating the shift towards low-carbon technologies.

**Figure 1.10: Steel Capacity by Route in Southeast Asia, 2024 (above) and Accounting for Projects Announced and in Construction (below) (Mt/year)**




BOF = basic oxygen furnace, EAF = electric arc furnace, Mt = million tonnes.

Source: Global Energy Monitor (2025b).

### Box 1.3: Carbon Border Adjustment Mechanism

The European Union (EU) Carbon Border Adjustment Mechanism (CBAM) is designed to put a price on carbon emissions embedded in certain goods imported into the EU. The CBAM aims to level the playing field between domestic and imported goods by imposing a fee on carbon-intensive imports such as cement, iron and steel, aluminium, fertilisers, electricity, and hydrogen. The CBAM is in its transitional period (October 2023 to the end of December 2025). During this time, importers are required to submit quarterly reports detailing the embedded emissions of relevant imports, but they are not yet obliged to purchase or surrender CBAM certificates. Full implementation will begin in January 2026, when importers must start buying CBAM certificates corresponding to the carbon content of their imports. Reporting will shift to an annual basis and will be subject to more rigorous verification and auditing procedures.

The estimated impact of the CBAM on the Southeast Asian countries varies significantly due to their differing reliance on exports to the EU and the carbon intensity of these exports. For example, in Viet Nam, the CBAM could lead to annual forgone revenue of about US$830 million for exporters of steel, aluminium, and plastics covered by the mechanism (based on an EU Parliament proposal). This equates to reducing its annual gross domestic product (GDP) by about 0.6%, while Indonesia might see a decline of 0.1% of GDP. Conversely, countries like Cambodia, the Lao People's Democratic Republic (Lao PDR), Myanmar, and Singapore are likely to experience minimal impacts as their primary exports fall outside the scope of the CBAM. The initial financial burden of the CBAM on ASEAN exporters may be modest, but as the mechanism expands and export volumes rise, the long-term threat to ASEAN's competitiveness in the European market could become significant. To mitigate these impacts, ASEAN Member States are encouraged to adopt more ambitious carbon pricing, enhance energy efficiency, and invest in low-carbon technologies.

ASEAN = Association of Southeast Asian Nations
Source: New Climate Institute (2023).

#### 3. Limited attractive investment projects and capital flow

Despite Southeast Asia facing some of the highest risks from climate change, the region continues to fall short in securing the climate finance needed to meet Paris Agreement targets. Many projects still struggle to attract investment due to weak financial returns, high perceived risks, and limited bankability (ADB, 2023c).

At the core of this issue are weak financial projections and low internal rates of return, often compounded by high project-specific, reputational, and macroeconomic risks. These risk factors, ranging from permitting delays to unclear regulatory frameworks, undermine investor confidence and limit access to affordable capital.

Macroeconomic pressures, such as inflation and currency volatility, also push up financing costs and erode returns, making it even harder to raise funding. Without strong risk mitigation tools, concerns over principal repayment persist and financing flows remain inadequate.

Globally, the climate finance gap is widening. To stay on track with the Paris Agreement, annual investment must grow at least fivefold – reaching US$7.5 trillion by 2030 and more than US$8.8 trillion from 2031 to 2050 (CPI, 2024b).

But in Southeast Asia, the challenge is even tougher. According to the 8th ASEAN Energy Outlook , the total annual investment needed under the ATS is expected to reach US$32 billion by 2050, which is 16% more than the US$27 billion required under the BAS (ACE, 2024a). This means not only boosting funding for power generation, but also for energy efficiency, transport, and other end-use sectors. Not only must finance be redirected, but it must also be reshaped by technology type and by region. Achieving carbon neutrality requires a sharp reduction in investments in coal, oil, and gas, along with total investment of US$6 trillion for clean power – including renewables – and modern grid infrastructure worldwide, over the entire period from 2023 to 2050.

In emerging markets and developing economies, particularly those in Southeast Asia massive investments are required, and scaling up financing for a net zero industry will necessitate mobilising all available sources, including local, foreign, public, and private ones. According to recent research by the Organisation for Economic Co-operation and Development (OECD) and the Climate Club, to bring industrial emissions into line with net zero pathways, annual global investments in low-carbon technologies for industrial decarbonisation must rise threefold to fivefold by 2030 compared with current levels (OECD and Climate Club, 2024). Yet these countries still struggle with structural investment and increasing public and private funding will be crucial to launching low-carbon projects. Importantly, experience from hard-to-abate sectors like steel, cement, and chemicals illustrates how public bilateral and multilateral financial assistance has been instrumental in mobilising private capital. To understand what is holding back investments, the Asia Transition Finance Study Group has been examining the risks associated with energy transition technologies (Figure 1.11). While all technologies involve some risk, transition-related technologies face even greater challenges, such as project delays, weak policy support, and reputational uncertainties. These risks often discourage investor participation or push financing costs higher through added premiums. In turn, this makes it more difficult to execute projects at scale. Establishing a strong, consistent policy environment would help reduce these barriers, lower capital costs, and improve investor confidence, opening the door to faster progress on the ground. The OECD's Climate Club Financial Toolkit highlights the importance of deploying targeted de-risking instruments, such as sovereign guarantees, political risk insurance, performance guarantees, and first-loss capital, to mitigate specific risks related to counterparties, policy shifts, and underperformance (OECD and Climate Club, 2025). The toolkit also mentioned that layering financing instruments, such as concessional loans, with tax credit can be especially effective in strengthening the investment case for early-stage or hard-to-abate technologies like CCUS and hydrogen.

In some countries, renewable energy projects also face currency and inflation risks, especially when tariffs are fixed in local currency and lack adjustments for economic shifts. Some projects have secured currency hedging mechanisms to address this, but these can be quite expensive and may not work well in every context (Benoit et al., 2022).

## Figure 1.11: Highlighting the Impact of Risks on Project Economics

Risk applicability: Strong | Partial | Limited

### Simplified mapping of key risks to selected climate technologies in Asia[1]

| | Zero-emission technologies | | | | Transition technologies | | |
|---|---|---|---|---|---|---|---|
| **Risks** | **Solar PV** | **Wind** | **BESS** | **Nuclear** | **CCUS** | **Coal plant retirement** | **Sustainable fuels co-firing** |
| **Cash flow risk** | Complex dependencies e.g., business model, weather, market conditions, regulatory structure | | | | No/uncertain revenue streams | | Demand for coal and gas power |
| **Credit risk** | Complex dependencies e.g., capital structure, credit rating of project owner | | | | Business model not proven at scale | | Demand for coal and gas power |
| **Development risk** | Long and unpredictable permitting process, grid and storage cost | | | Complex permitting | Emerging regulation | Permitting & planning | Emerging regulation |
| **Construction risk** | Emerging technologies and best practices | | | Complex technology | Scaling-up/ deployment complexity | Remediation & demolition | Emerging technology |
| **Operating risk** | Dependency on weather and energy market | | Degradation and flammability | Feedstock availability | Scaling-up/ deployment complexity | N/A | Emerging technology |
| **Transport and storage risk** | Curtailment risks | | N/A | Prevention and mitigation costs | Leakage and capacity risks | N/A | |
| **Technological risk** | Mature technology | | | | Not yet proven at industrial scale | N/A | Evolving technology |
| **Environmental risk** | Infra ecosystem interference | | Limited impact | Radiation risk | Infra ecosystem interference | Positive impact | Continued emissions |
| **Social risk** | NIMBY | | Limited impact | NIMBY | Potential societal health risks on HSE incidents | Labor force reduction | Fossil fuel burning health risks |
| **Reputational risk** | Neutral/positive societal perception | | | Potentially controversial | Neutral/positive societal perception | | Greenwashing risk |
| **Regulatory risk** | Dependency on environmental, climate and energy policy and fiscal policy | | Strong dependency on environmental, climate and energy policy, as well as energy security, social stability, and market development | | | | |
| **Political risk** | Similar to regulatory risk | | Similar to regulatory risk | Feedstock supplier | Similar to regulatory risk | | |
| **Currency and interest rate risk** | Common risk | | | | | | |
| **Force majeure risk** | Common risk | | | Magnifying potential | Common risk | | |
| **Legal risk** | Common risk | | | | | | |

**Impact on project economics**

↑ Operational cost | ↑ CAPEX cost | ↑ Cost of capital

**Impact on key metrics**

↑ LCOE | ↑ Abatement cost | ↑ IRR

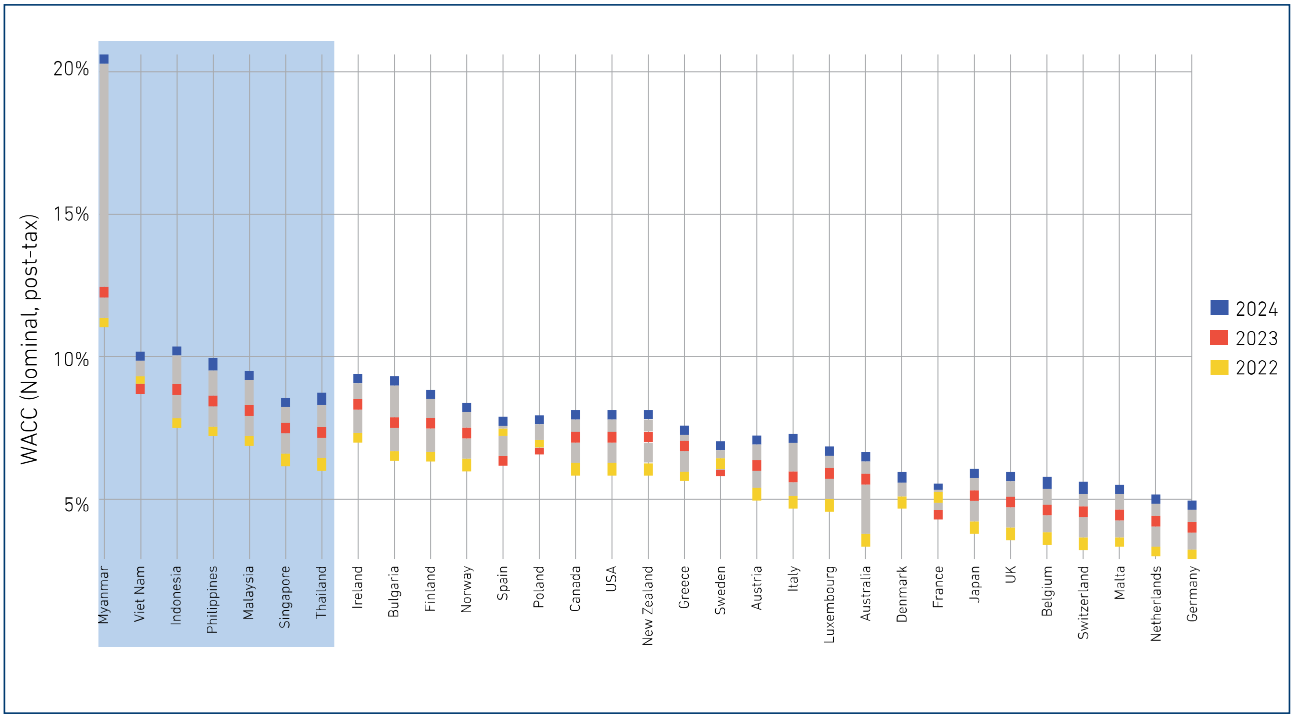
BESS = battery energy storage system, CAPEX = capital expenditure, CCUS = carbon capture, utilisation, and storage, HSE = health, safety, and environment, IRR = internal rate of return, LCOE = levelised cost of electricity, N/A = not applicable, NIMBY = not in my backyard, PV = photovoltaic.

[1] Risk mapping may change depending on nature of technology, country and market contexts, and objective of the financing.

Source: ATF SG (2024).

As a result, the cost of capital in Southeast Asia is significantly higher than in developed markets[6] (Figure 1.12). For example, the levelised cost of energy (LCOE) for a representative solar PV or onshore wind project increases by about 80% when the cost of capital rises from 2% to 10% (IRENA, 2023b).

**Figure 1.12: Nominal, Post-Tax Weighted Average Cost of Capital for Utility-Scale Solar PV Projects by Country, 2022–2024**




PV = photovoltaic, UK = United Kingdom, US = United States, WACC = weighted average cost of capital.

Source: IRENA (2024b).

Transition technologies such as natural gas with carbon capture and low-carbon hydrogen face some of the toughest investment challenges. While policy frameworks like the ASEAN taxonomies for sustainable finance now recognise these transitional activities, their practical operability remains challenging. This acknowledgement has yet to translate into clear regulatory certainty or strong market signals. Many projects often operate in uncertain policy environments, lack clear regulatory pathways, and attract scrutiny over long-term sustainability. In addition, the economic case for these technologies remains weak in many Southeast Asian countries, particularly for low-carbon hydrogen, which also faces high production costs, limited transport, and trade infrastructure. These factors make projects harder to finance, pushing investors to demand higher returns and raising the overall cost of capital. As a result, even promising projects struggle to move forward.

6 Developed markets refer to high-income countries (including Singapore) with mature, well-regulated financial systems and deep capital markets that feature low perceived investment risk.

Since 2024, there has been a growing call to shift the investment focus from bankability to impact potential, prioritising climate, environmental, and socio-economic goals. Traditional metrics of bankability often overlook projects that deliver high social and environmental value but struggle to attract private finance (IRENA, 2024a). This approach remains more common amongst philanthropic organisations, however, whose involvement in the energy transition remains limited in scale, geography, and scope (IRENA, 2024c). Moreover, there is still no widely accepted framework to assess impact potential and funding efficiency in achieving these outcomes. Making the case for this shift is critical, especially in markets where bankable clean energy projects are scarce, but the development impact is significant.

Financing energy transition activities also tends to cause a temporary spike in Scope 3 emissions. This happens because financial institutions often need to invest in carbon-intensive sectors or activities (to support decarbonisation efforts). These financed emissions contribute to their Scope 3 emissions, leading to an overall increase in the institution's carbon footprint and reported emissions in the short term. This spike typically persists until the transition to lower-carbon alternatives is successfully completed. However, this temporary increase presents challenges in managing financed emissions, particularly due to the complexities of accurate measurement.

One approach that reflects efforts to capture these dynamics is the emissions exposure reduction (EER) methodology developed by the Glasgow Financial Alliance for Net Zero (GFANZ). Although promising, the practical application and standardisation of such methodologies remain limited. The EER framework is voluntary and not required by regulators or financial reporting standards, leading to uneven adoption across institutions (GFANZ, 2024).[7] As a result, financial institutions may be reluctant to provide loans for fuel switching projects, as any fossil fuel use still contributes to their Scope 3 emissions. The short-term rise in reported emissions could conflict with financial institutions' portfolio decarbonisation targets or environmental, social, and governance (ESG) performance metrics. While some of these projects may be bankable, they are often not attractive to investors due to reputational risks and concerns over the high carbon footprint of thermal assets. Addressing investor concerns, outlining investor enablers, and mitigating risks – such as through clear transition finance taxonomies, life cycle emissions assessments, and eligibility criteria – are needed to support certain transactions while balancing the energy trilemma and advancing decarbonisation and just transition goals.

## 1.2.3. Technical Challenges

**4. Immature variable renewable energy integration system**

Historically, power systems have relied on a relatively simple assumption: power would flow from centralised, large plants linked electro-mechanically (i.e. with a large rotating mass) to the power grid, and, with a unidirectional flow of electrons, energy would reach the consumers at the end of the grid. This approach varied minimally if the power systems were based on coal, gas, nuclear energy, or hydropower.

[7] Through pilot case studies, financial institutions show that EER is currently best suited to support internal processes, including transaction due diligence, sensitivity analyses, performance measurement, and engagement with clients and portfolio companies. The intended use of the measure and whether it is applied at the entity level or at the transaction or asset-specific level can further affect the calculation process and data inputs used to produce the EER.

However, the energy transition involves increasing the use of variable renewable energy (VRE) sources, such as wind and solar, whose output is variable and weather dependent. In addition, they are scattered geographically, which means the traditional centralised power system design is unfit for the energy transition. This challenge is compounded by the low levels of regional interconnection of grids within countries, partly due to the archipelagic nature of several countries in Southeast Asia, which limits the ability to balance supply and demand across regions efficiently. To manage variability in net load, planners must ensure sufficient flexible resources within the power system. Understanding the maximum scale, speed, frequency, and uncertainty of changes in VRE output is essential to determine the necessary system flexibility.[8] System flexibility is an ability of any power system, which must respond to counter demand-side variability at any given moment of the day (power users do not follow specific schedules based on power plants' availability). Gas-fired and hydropower plants have historically been designed to deal with the variability of demand and maintain grid stability, which makes them convenient as the main source of flexibility and system services, and therefore suitable candidates to provide the additional flexibility needed due to increased VRE generation.

Evaluating existing flexible resources in an area shows the extent of variability the system can handle. Flexible resources vary by region and may include hydroelectric plants, gas plants, demand-side management, interconnections with nearby grids, and storage capacity. Additionally, flexibility can extend beyond the electricity sector, involving heat and transport through technologies like electric thermal storage and electric vehicles. Variable power plants can also provide forms of flexibility by adjusting their output when needed.

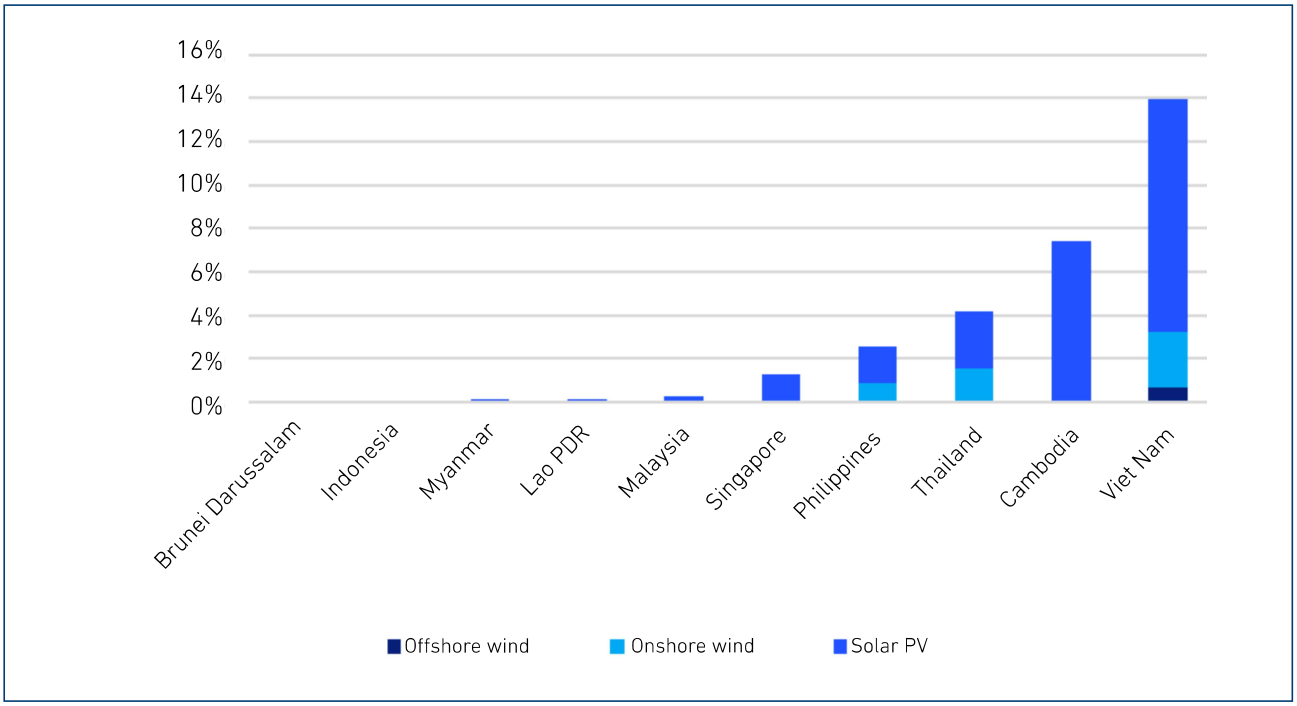
The challenges related to VRE integration and the increased need for system flexibility depend on the share of VRE in a power system. The IEA has developed a framework to classify power systems based on the VRE share and provide policymakers with a 'ladder' of solutions against the 'wall of challenges' they may encounter when addressing VRE integration issues (IEA, 2020).

Countries in Southeast Asia are at varying stages of VRE integration, which refers to small shares of VRE, specifically solar and wind, except Viet Nam (Figure 1.13). For example, in Indonesia, the current VRE share in the power system of the state electricity company (PLN) is less than 0.4% (IESR, 2024). At this stage, the VRE share is minor compared with the overall electricity demand. In this phase, system operators do not need to adjust operations to account for VRE. The system behaves much the same as it did before the first VRE plant was added – unless the new plant is unusually large relative to the system, its effect is negligible. Any impact tends to be local, near the connection point.

That said, the development of VRE plants cannot be overlooked. Developers need clear information about where they can connect to the grid, and local infrastructure must be able to handle new connections. It is also crucial to focus on technical standards – grid codes or connection standards – that define how VRE plants interact with the grid. While all power plants must follow such standards, VRE installations may need some extra requirements. These include adding VRE forecasting and power flow predictions to system operations and updating operational rules to better integrate renewables, especially through greater use of interconnectors.

8 Flexibility refers to a power system's ability to quickly adjust electricity production or consumption in response to variability. It is typically measured in the megawatts (MW) available to ramp output up or down within a specific time frame.

**Figure 1.13: Shares of VRE Across Southeast Asian countries, 2022**




PV = photovoltaic, VRE = variable renewable energy.

Source: IEA (2024b).

Furthermore, the electricity grid is crucial for the success of the energy transition, as its ability to expand and adapt to rising electrification will determine whether the power system can be transformed. As access and distribution increases, the grid must be expanded, modernised, and in some cases be replaced at a much faster pace. Achieving the necessary pace will require both technological adoption and new policy measures, including faster permitting processes.

Storage plays a key role in enhancing grid flexibility and maintaining system security, especially during VRE deployment. Today, most deployed storage capacity comes from pumped hydropower. Other technologies in use include compressed air energy storage, batteries, flywheels, and liquid air storage. Storage is also used to relieve local congestion, delivering both reliability and economic benefits, even when its cost per megawatt-hour exceeds that of generation or other solutions. As VRE penetration grows, storage becomes increasingly important for the overall system security. Long-duration (seasonal) storage will not be needed until later stages.

In the current phase, system integration issues come from the grid, not from the nature of VRE plants. Developers are more concerned about grid capacity and curtailment risks: weak or unreliable grid infrastructure poses risks for stable offtake, as the curtailment risk increases, affecting the predictability of project revenues. Slow transmission infrastructure development creates delays for renewable energy projects, hindering their timely integration into the grid. According to the IEA, more than 1,650 GW of renewable capacity are in advanced stages of development and awaiting grid connection, highlighting the global queues driven by grid investments and system integration measures that are not keeping pace with rapid deployment of renewables (IEA, 2023c).

Countries in the region are at a pivotal point in their energy transition, yet many continue to face major hurdles in scaling up the systems and capabilities needed to support a higher share of VRE. This means that while solar and wind capacity may be growing, the supporting infrastructure, such as advanced grid operations, forecasting tools, and energy storage systems, need to keep pace. Without timely action to strengthen these enabling conditions, Southeast Asia risks falling behind in meeting its renewable energy targets and ensuring a stable, reliable power supply.

While solar and wind capacity in Southeast Asia is steadily growing, integrating these resources effectively into national grids remains a major challenge. The issue goes beyond variability – many countries lack the necessary grid flexibility, forecasting systems, and interconnection infrastructure to manage higher shares of VRE. Without real-time forecasting, flexible grid operations, and robust interconnection, the grid will struggle to maintain stability as VRE penetration increases. Many countries still lack sufficient grid flexibility and clear market signals to support storage, curtailment protocols, and demand-side management.

Countries like Thailand and Viet Nam are already showing how targeted reforms can make a difference, though challenges persist. Viet Nam, for instance, has rapidly expanded its solar capacity, but now faces curtailment issues due to grid limitations and a lack of real-time dispatch systems (IEA and Imperial College London, 2023). Thailand has made progress in demand-side management, including time-of-use tariffs and pilot projects for industrial load control, but still lacks large-scale deployment of battery storage (OECD, 2024). Malaysia has taken early steps to expand rooftop solar and implement net energy metering, but coordination challenges and limited incentives have slowed broader deployment (IRENA, 2023a). Indonesia, with one of the largest power systems in the region, continues to face grid reliability issues, while grid development delays and curtailment are major risks for investors in renewable resources and contractual structures limit the flexibility of the young thermal fleet (IEA, 2022). Singapore, though smaller in scale, has focused on regional interconnectivity and is exploring green electricity imports as a strategy to manage its land constraints (Carnicelly, et al., 2024). These country experiences highlight that while momentum exists, efforts must deepen and widen across the region to create a resilient and flexible energy system. These examples show that while progress is happening, it is not yet systemic or sufficient.

### 5. Limited technology advancement

#### Power and industry sectors

Technology advancement in Southeast Asia's power and industry sectors is characterised by significant progress in renewable energy initiatives, green manufacturing clusters, and transition technologies. However, despite significant progress, multiple sector- and technology-specific challenges slow the pace of transition.

Some emerging technologies such as low-carbon hydrogen offer considerable promise, yet they remain in the infant stage and are not yet viable for widespread use globally.

Another area of concern lies in grid infrastructure. Many countries in Southeast Asia lack the requisite experience for undertaking complex subsea cabling projects, which are essential in the archipelagic region. The global supply of high-voltage direct current (HVDC) cables is also constrained, with Southeast Asian countries facing stiff competition from Europe and North America (IEA, 2024d).[9] This scarcity poses a risk of delays for strategic initiatives such as the ASEAN Power Grid (Chapter 3).

CCS technologies also encounter a range of practical challenges. Beyond their high capital costs and limited deployment, successful implementation necessitates extensive development of $CO_2$ transportation and storage infrastructure. For cross-border CCS projects being considered in several countries, an additional barrier lies in the absence of viable business models. If structured around a storage fee, for instance, these projects must secure long-term offtaker agreements. Coordinated efforts amongst emitters, pipeline operators, and storage providers – both domestically and regionally – are imperative. Equally important is the establishment of a credible monitoring, reporting, and verification (MRV) framework to guarantee the long-term integrity of stored $CO_2$. Currently, the absence of pilot projects, limited technical expertise in reservoir management, and inadequate risk assessment protocols contribute to sluggish progress and elevated costs. Additionally, CCUS may be easier to implement for industrial applications compared with power plants due to the typically higher concentration of $CO_2$ emissions in industrial processes.

Industries in Southeast Asia remain highly reliant on uninterrupted firm power, currently dominated by fossil fuels, particularly coal, which is projected to continue accounting for a significant share of the fuel mix through 2050 under the APS. The transition to renewable energy in the industrial sector presents additional challenges due to the need for stable and continuous energy supply to maintain operations. If a switch to cleaner energy is to be made, it will require robust action in four critical areas:

- Energy efficiency improvements to reduce overall consumption and emissions intensity.
- Electrification of industrial processes wherever feasible to leverage clean power.
- The adoption and scaling of clean fuels such as low-carbon hydrogen, ammonia, synthetic methane, or advanced biofuels to substitute for fossil-based thermal energy.
- CCS to address process-related emissions in hard-to-abate sectors like cement, steel, and chemicals.

These shifts are technologically and economically demanding, particularly in hard-to-abate sectors such as steel, cement, and chemicals, and will require strong enabling frameworks, policy certainty, and public–private coordination across the region.

For the industry sector, challenges underline the complexity of decarbonising multiple sectors and highlight the need for continued innovation, large-scale deployment, and collaboration across industries and sectors to address these interconnected issues. Five common hurdles are:

- **Technology maturity and innovation:** Numerous critical solutions, such as low-emissions steelmaking and the use of hydrogen, are still under development. These emerging technologies have not yet achieved the level of economic competitiveness required to displace established fossil fuel-based systems, unless they are supported by strong policy frameworks or targeted financial incentives.

[9] IEA (2024c: 31) highlighted that the global manufacturing capacity for HVDC cables is highly concentrated, with long lead times and limited suppliers, creating bottlenecks. The report also noted that Europe and North America are ramping up HVDC deployment plans, intensifying competition for this limited supply.

- **Infrastructure overhaul and reconfiguration:** Transitioning to low-carbon industrial processes frequently entails a complete redesign of existing production systems. For instance, transitioning from the traditional blast furnace-basic oxygen furnace (BF-BOF) route to the direct reduced iron-electric arc furnace (DRI-EAF) pathway in steelmaking requires entirely new infrastructure and access to higher-grade raw materials.

- **Need for additional inputs and resources:** Large-scale decarbonisation efforts depend on a stable and sufficient supply of alternative feedstocks, such as low-carbon hydrogen, sustainable biomass, and clinker substitutes. These resources typically rely on renewable energy systems or innovative production methods, adding new layers of technical and logistical complexity.

- **Cross-sector dependencies:** The decarbonisation of heavy industry is closely linked to advancements in other sectors. For instance, progress in hydrogen production and CCS technologies is critical for the steel and cement industries, while the plastics sector depends on low-emissions electricity and low-carbon hydrogen to replace fossil-derived inputs.

- **Challenges with emerging fuels:** Fuels like ammonia, hydrogen, and biofuels offer significant potential, yet face major hurdles to deployment. These include questions of technical feasibility, compatibility with existing infrastructure, and high production costs. Ensuring safe combustion, retrofitting power plants, building new storage and distribution systems, and developing robust supply chains are all essential prerequisites. Currently, these fuels are more expensive than conventional alternatives, requiring substantial improvements in production efficiency and scale to become cost competitive.

**Sector-specific industrial characteristics and implications for decarbonisation**

Decarbonising hard-to-abate sectors requires understanding of their technical and process-related emission profiles. For example:

- **Cement production:** Cement is manufactured by adding gypsum and other additives to ground clinker, which is produced by calcining and rapidly cooling a mixture of limestone, clay, silica stone, and other components in a kiln. During this process, limestone, primarily composed of calcium carbonate ($CaCO_3$), is calcined to produce clinker. This reaction converts $CaCO_3$ into calcium oxide (CaO), the main component of clinker, and releases $CO_2$ as a byproduct.

  Process-related CO2 emissions account for a significant portion of total emissions from cement production. About 60% of these emissions result from the chemical dissociation of $CaCO_3$ during clinker production (World Economic Forum, 2023). While $CO_2$ emissions can be reduced by increasing the use of CaO-containing waste materials and reducing the clinker ratio, these measures offer only limited reductions. Since a significant portion of these emissions cannot be eliminated through energy efficiency improvements or fuel conversion, technologies such as CCUS are essential.

  However, implementing CCUS in cement production entails several technical challenges. $CO_2$ capture methods using liquid solvents have already been utilised in various industrial applications, but they are energy intensive and face issues such as solvent degradation and emissions management. The oxy-combustion method, which has the potential to reduce energy consumption, is still in the early stages of application in cement production and may require a redesign of the production process to accommodate operation in an oxygen-rich environment.

- **Steel production:** The main steel manufacturing methods are BF-BOF and EAF. Of these, conventional BF-BOF generates significant direct $CO_2$ emissions. In the BF-BOF method, iron is first produced in a blast furnace and processed into steel products by adjusting its composition in a basic oxygen furnace. $CO_2$ is emitted during the reduction of iron ore with carbon. Coal is commonly used as a carbon material due to its abundant supply and low cost. Up to 55% of $CO_2$ emissions in the BOF originate from the iron ore reduction stages in blast furnaces (Carbon Trust, 2011).

  One promising approach to reduce these emissions is the partial substitution of coal with hydrogen in a modified blast furnace. However, since $CO_2$ emissions still occur, the introduction of offset technologies such as CCUS is necessary. It is theoretically possible to eliminate $CO_2$ emissions by using 100% hydrogen as the reductant, but this solution is still far from commercialization phase (see Section 3.1.5).

  One of the challenges in introducing CCUS to steel production is that integrated steel mills using BF-BOF generate $CO_2$ from multiple emission points. Capturing $CO_2$ from all these points requires substantial and complex capital investment, making the overall cost extremely high.

- **Chemical industry:** Chemical industries often operate with concentrated $CO_2$ streams in processes such as ammonia or ethylene oxide production, making them cost-effective targets for early deployment of CCUS technologies.

  Take ammonia production as an example. It is produced by the direct reaction of hydrogen and nitrogen in the presence of a catalyst (Haber-Bosch process), and the process of reforming natural gas or coal to produce hydrogen results in $CO_2$ emissions.

  Green hydrogen, generated by electrolysing water using electricity from renewable energy sources, generates no $CO_2$ emissions during its production. As of today, cost of green hydrogen production remains relatively high (two to three times in already favourable areas), making its widespread adoption difficult.

  In contrast, blue hydrogen, which incorporates CCS, can achieve an 85%–97% reduction in $CO_2$emissions compared with traditional hydrogen production at a lower cost (Gordon, 2022). Introducing CCUS into the chemical industry, including ammonia production, presents several technical challenges. Chemical plants often have several emission points, and the $CO_2$ concentrations in the emission stream can vary widely; low $CO_2$ concentrations can significantly increase the cost of $CO_2$ purification. In addition, $CO_2$ purity can vary between facilities, necessitating standardised infrastructure specifications for $CO_2$ transportation and storage.

These characteristics suggest that a one-size-fits-all approach – such as a blanket shift to clean energy – is impractical for industrial decarbonisation. Tailored policy frameworks, technology support mechanisms, and cross-border coordination will be essential to address the unique needs of each sector. As mentioned above, CCUS can be a viable option for decarbonising hard-to-abate sectors, but various technical challenges must be addressed to make it a reality.

# 1.2.4. Policy Challenges

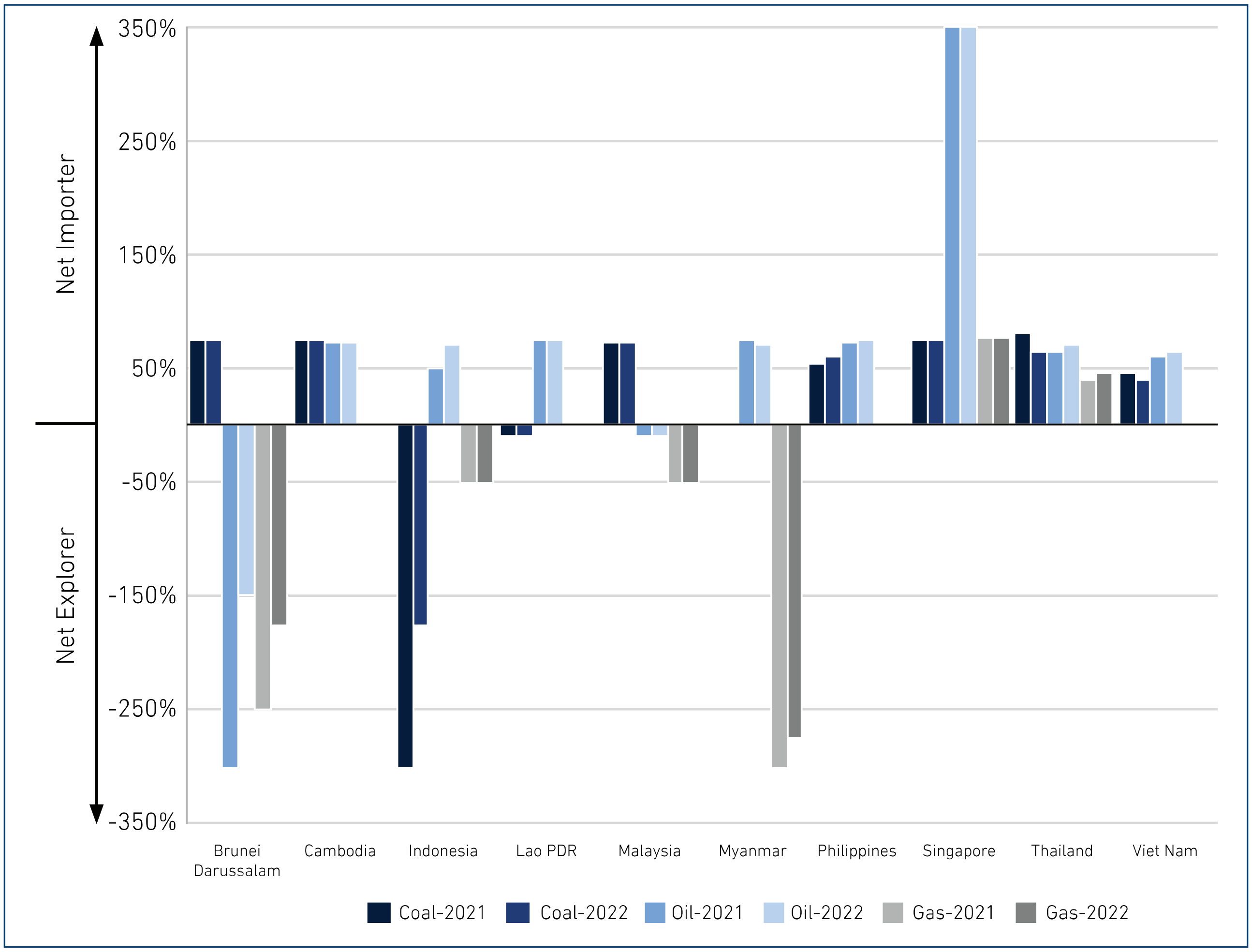
**6. Limited regional collaboration and interoperability**

Asia's limited energy independence and the highly politicised nature of energy resources add complexity to the region's energy landscape.

Despite growing interdependencies, energy transition in Southeast Asia remains complex due to the region's diversity. Countries vary significantly in their natural resource endowments, geographical conditions, energy consumption patterns, and levels of technological advancement. This heterogeneity results in different starting points for each country's energy mix and shapes their unique challenges and national renewable energy targets. As such, a one-size-fits-all approach to the transition is impractical. The energy transition challenges differ from country to country, and any roadmap must be tailored to meet the specific needs and circumstances of each nation.

Most countries in Southeast Asia are net importers of fossil fuels (Figure 1.14). Despite increases in domestic production, rising energy demand implies that this trend will likely persist unless strong action is taken to revert its course. The fluctuations in import and export figures, along with variations in energy trade, reflect the diverse economic and resource conditions across the region. These differences inevitably result in varied national and regional energy policies. The absence of an aligned policy approach and a regional regulatory agency to govern power exchange between grid systems operating under varying regulations poses a major barrier to cross-border energy trade.

**Figure 1.14: Fossil Fuel Dependency by Country in Southeast Asia, 2021 vs 2022**




Note: A negative dependency rate indicates a net exporter of energy. Values exceeding 100% indicate an accumulation of stocks.
Source: ACE (2024a).

Countries operate under distinct policies, standards, taxonomies, and regulatory frameworks for the energy transition. This variance hampers collaboration and prevents the region from fully leveraging its collective scale, limiting the potential to develop cost-competitive pathways towards carbon neutrality and sustainable growth. In addition, growing demand for energy to meet domestic needs limits consensus in regional energy agreements.

For power generation, regulatory and economic difficulties can arise from different pricing mechanisms and market structures when creating an integrated regional power market, complicating the price calculation of traded electricity. The region lacks a standardised wheeling charge, and stakeholders hold different views on its methodology.[10] When two grids are connected, however, the benefits can be substantial (Box 1.4). Economies like Malaysia and the Lao PDR, which have cleaner power grids, are increasingly well positioned to attract energy-intensive industries seeking to lower their carbon footprint.[11]

### Box 1.4: The Benefit of Cross-Border Trade – the West Kalimantan-Sarawak Power Interconnection

The West Kalimantan–Sarawak Power Interconnection is a high-priority energy project under the Brunei Darussalam–Indonesia–Malaysia–Philippines East ASEAN Growth Area (BIMP-EAGA) Implementation Blueprint. It involves constructing a 275-kilovolt (kV) double-circuit transmission line from Bengkayang in West Kalimantan, Indonesia to Mambong in Sarawak, Malaysia.

The construction of the 275 kV transmission line and associated substations was completed in 2022, and the interconnection became operational the same year, allowing for the import of electricity from Sarawak to West Kalimantan. Additionally, new transmission networks within West Kalimantan were constructed, and new households were connected to the electricity grid.

The total project cost was about US$153.04 million, co-financed by the Asian Development Bank (ADB) and the Agence Française de Développement (AFD). ADB provided a loan of US$48.76 million, AFD co-financed with US$38.76 million, and the remainder was financed by the Government of Indonesia and the state electricity company (PLN). The financial internal rate of return (FIRR) for the project was initially calculated at 30%, significantly higher than the weighted average cost of capital (WACC) of 1.87%. Upon project completion, the FIRR was recalculated at 55.9%, with a financial net present value of US$173.6 million, discounted at the WACC. The high FIRR was primarily due to cost savings from reduced fuel expenses for diesel generation. Indeed, interconnections drive resource sharing: for example, the cross-border link with Sarawak allowed hydropower imports that displaced diesel generation in West Kalimantan, reducing the average cost of generation in West Kalimantan from US$0.25 per kilowatt-hour (kWh) in 2009 to US$0.10 per kWh in 2022. The project also contributed to reducing carbon dioxide emissions by 1.8 million tonnes.

Sources: ADB (2023d) and Independent Evaluation Department, ADB (2024).

[10] Power wheeling is not yet permitted in Indonesia, but the government has proposed its inclusion in the new and renewable energy bill to enable private entities to sell electricity directly to consumers through the state-owned grid. In Viet Nam, the government issued Decree No. 57/2025/ND-CP on 3 March 2025, establishing a direct power purchase agreement mechanism that allows renewable energy generators to sell electricity directly to large consumers via private lines or the national grid. However, this mechanism is limited to domestic transactions and does not yet support cross-border or regional wheeling arrangements.

[11] There is significant demand from data centres and the expansion of manufacturing industries. ASEAN's manufacturing sector is forecast to grow from US$0.7 trillion to US$2.3 trillion from 2018 to 2029 (Setyawati and Nadhila, 2024).

### Box 1.5: Benefits of Cross-Border Trade – Monsoon Wind Power Project

The Monsoon Wind Power Project in the Lao People's Democratic Republic (Lao PDR) is a significant Asian Development Bank (ADB) initiative involving a US$692.55 million financing package to build a 600-megawatt wind power plant in Sekong and Attapeu provinces. This project, comprising 133 wind turbines, will be the largest wind power plant in Southeast Asia and the first in the Lao PDR.

The project aims to export and sell power to neighbouring Viet Nam, leveraging the Lao PDR's untapped wind resources to diversify its energy portfolio. This cross-border power supply is expected to reduce annual greenhouse gas emissions by at least 748,867 tonnes of carbon dioxide equivalent. Energy exports from this project will generate foreign exchange earnings for the Lao PDR, funding national development projects and infrastructure improvements. Additionally, it will enhance regional cooperation, improve energy security for importing countries, and potentially lead to technology transfer and advancements in energy efficiency and production techniques. By exporting energy, the Lao PDR can reduce its reliance on domestic consumption, thereby diversifying its economic portfolio and fostering sustainable economic growth.

Source: ADB (2023a).

For a successful and inclusive transition, regional collaboration is essential. Strengthening interoperability through unified standards, policies, and ambitions, including alignment on sustainable finance taxonomies that acknowledge transitional activities, will foster knowledge exchange, technology sharing, and capability building, ultimately accelerating the region's progress towards its sustainability goals.

**7. Limited enabling policies**

The transition to a low-carbon economy in Southeast Asia is hindered by a range of policy-related challenges. These challenges can be broadly categorised into issues related to regulatory frameworks, political will, market structures, and incentives. Addressing these challenges is crucial for creating a conducive environment for decarbonisation efforts.

One of the primary obstacles is the varying energy policies and regulations across countries. These differences reflect this region's diversity and its foundational principles of national sovereignty and non-interference. The lack of harmonisation complicates efforts to create an integrated regional power market, as regulatory and economic difficulties can arise from different pricing mechanisms and market structures, particularly in the absence of frameworks that reflect the carbon intensity of power, which are essential for valuing emissions and accelerating decarbonisation. While such diversity can present technical and economic barriers to cross-border energy trade, it also allows for regionally coordinated approaches, such as interconnection and technical harmonisation, to complement nationally determined energy strategies. For instance, the heterogeneous market structure in the region complicates the price calculation of traded electricity, making it challenging to establish a unified market.

Additionally, growing demand for energy to meet domestic needs often takes precedence over regional cooperation, leading to fragmented efforts and missed opportunities for collective progress. This is compounded by varying political will amongst governments, with some less committed to implementing the necessary changes required for the development of initiatives like the ASEAN Power Grid (APG) (Chapter 3).

The region also faces challenges related to contractual and policy uncertainty risks. Fluctuating or inconsistent feed-in tariffs, offtake agreements, and PPAs create an unstable investment climate. This uncertainty is exacerbated by permitting and licensing issues, where complex and time-consuming regulatory approval processes often lead to delays in project timelines. Moreover, the unclear policy vision and governance in many countries create uncertainty for investors, reducing confidence in the bankability of projects. Uncertainty surrounding the terms of PPAs, especially at lower power price levels, raises questions about the commercial viability of renewables projects for developers and financiers. This is further complicated by land availability issues, where limited suitable land for project development, especially for solar energy, exacerbates challenges. Competition for space and regulatory delays hinder progress, making it difficult to scale up renewable energy projects. Clear policies, on the other hand, can provide substantial support for investment (Box 1.6).

Regulatory inconsistencies also play a role in slowing the development of bankable projects. Inconsistent policies, such as periodic bans or changes to renewable energy schemes, increase investment risks and create an unpredictable environment for developers and investors. This is compounded by the lack of incentives in most countries. IRENA highlighted how policy intermittency and lack of long-term commitment can impede renewable investment across the region (ACE, 2018). Frequent changes in support schemes, such as sudden tariff revisions or programme discontinuations, undermine investor confidence. Furthermore, policy inaction or delays, due to shifting political priorities, have held back renewable deployment and grid integration in Southeast Asia.

The absence of a robust emissions trading system or sufficiently high carbon taxes to incentivise fuel switching, coupled with government subsidies that keep coal significantly cheaper than alternative fuels, hinders the transition to cleaner energy sources. Additionally, local content requirement policies in some countries significantly hinder the adoption of alternative energy technologies.

The increasing demand for energy and the rising expectations for scaling renewable energy sources require evolving policy changes. For example, a growing power system will need to address basic challenges, such as streamlining permitting processes and resolving land acquisition issues, which will require regulatory reform.

While there has been increasing recognition of the need for industry decarbonisation, the level of enabling policies varies significantly across countries. While some countries in Southeast Asia have taken notable steps towards supporting industry decarbonisation, others are still in the early stages of policy development. In many cases, strategies for industrial decarbonisation remain unaligned with targets set in countries' NDCs, creating a disconnect between ambition and implementation. No cohesive, comprehensive regional policy framework specifically targets industrial decarbonisation, and most individual country policies remain growth focused with limited access to subsidies or tax breaks for adopting cleaner technologies.

For example, Singapore has introduced a carbon tax and outlined clear goals under its Green Plan 2030. Malaysia is moving forward with its National Energy Transition Roadmap, which includes specific measures to support cleaner industries. Indonesia is exploring ideas like renewable-powered industrial zones as part of its long-term climate strategy, although these are still early-stage efforts. On the other hand, countries like Cambodia, the Lao PDR, and Myanmar have yet to define clear strategies for industrial decarbonisation. Even in Thailand, where climate action is more advanced, policies for industry remain scattered and lack strong financial incentives to encourage companies to switch to low-emission technologies.

Finally, the lack of taxonomy interoperability across the region creates confusion and uncertainty for potential developers and investors. Differences in scope and definition across taxonomies make it challenging to establish clear guidelines for sustainable investments, complicating efforts to attract the necessary capital for decarbonisation projects.

### Box 1.6: PPPs as Catalysts – Cambodia Large Solar PV Projects

The first utility-scale solar power project in Cambodia, with a capacity of 10 megawatt peak (MWp), was in Bavet City, Svay Rieng Province, bordering Viet Nam. The plant went through an international competitive bidding process involving public–private partnerships (PPPs).

A PPP led by Sunseap won the bid, securing a 20-year power purchase agreement (PPA) at US$0.091 per kilowatt-hour (kWh), significantly lower than the national average of US$0.30 per kWh. The PPP included a take-and-pay commitment and provided for risk mitigation and dispute resolution. The auction implementation clarified multiple contractual and institutional issues, helped build technical capacity in the state power utility, and established a competitive bidding process for utility-scale photovoltaic (PV) projects in a frontier market. In addition to the technical assistance, the Asian Development Bank (ADB) provided a US$9.2 million debt package to finance the project, including a concessional loan of US$3.25 million, a US$3.25 million loan from the Canadian Climate Fund for the Private Sector in Asia, and a US$2.7 million 14-year loan from a commercial bank.[a] These loans covered 69% of the project capital expenditure (CAPEX), valued at US$13.3 million, with US$1.36 million spent on the local purchase of goods and services during construction. Apart from local value creation, benefits include the avoidance of diesel- and coal-based power generation and the substitution of electricity imports from Viet Nam with domestic generation. The project's economic internal rate of return is calculated at 14.9%.

The plant now dispatches more than 14 gigawatt-hours (GWh) a year, avoiding about 8,250 tonnes of carbon dioxide annually. This project supported prototype contractual arrangements for private investment in Cambodia's grid-tied solar projects. It also helped to pilot test institutional and contractual arrangements, assisting Electricité du Cambodge (EDC) and sector stakeholders to familiarise themselves with operating a utility-scale solar PV project and giving them the confidence to tender more solar PV projects.

The Prime Road National Solar Park Project builds on this success. The project involves the development of a 60-megawatt (MW) solar PV power plant, which achieved a record-low utility-scale solar tariff in Southeast Asia at US$0.03877 per kWh. This competitive bidding process ensured transparency and attracted significant private sector investment, demonstrating the effectiveness of PPPs. The total project cost is estimated at US$43.6 million, with financial support including a US$8.1 million loan package from ADB and a US$4.2 million loan from the Canadian Climate Fund for the Private Sector in Asia. In 2023, the solar plant delivered 140.9 GWh of solar power, exceeding the target of 135 GWh, and avoided 115,623 tonnes of carbon dioxide equivalent emissions.

The national solar PV roadmap and the results of the National Solar Power Project have had a catalytic effect on the adoption of solar power in Cambodia. Alongside the ADB-funded projects, other projects have been announced and developed, with solar capacity at the end of 2024 reaching 827 MW (about 19% of power sources directly connected to national grid).

According to the reference scenario of Cambodia's Power Development Masterplan, 2022–2040, which was developed with ADB technical assistance, the share of solar PV is expected to reach 1,000 MW by 2030 and exceed 3,000 MW by 2040.

[a] ADB's early engagement in the project and expertise in project financing structures helped to catalyse long-term loans from BRED Bank, an international commercial bank using a 'B Loan' structure, which was not available from Cambodian banks before the project.

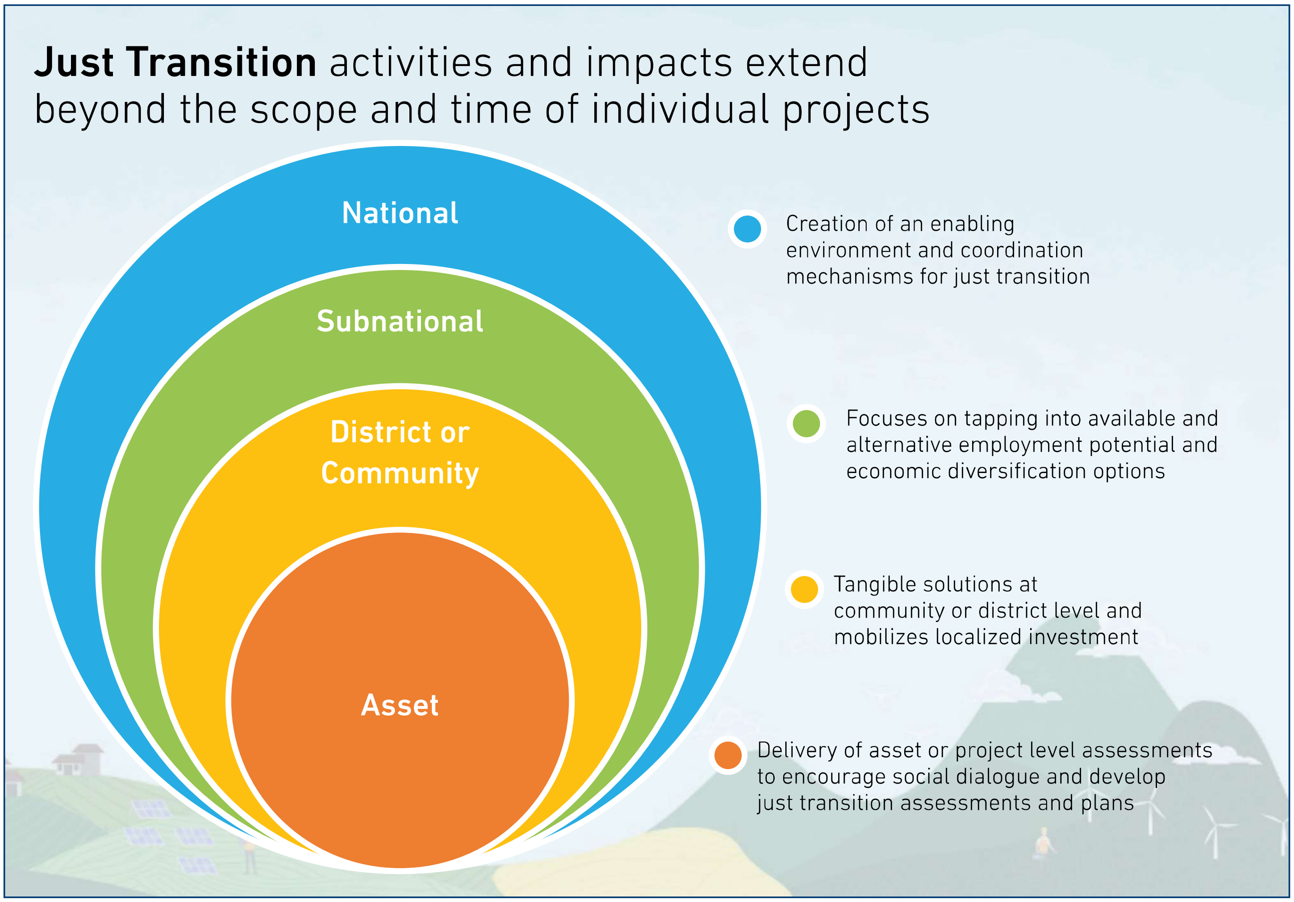
Sources: ADB. Cambodia: Cambodia Solar Power Project. https://www.adb.org/projects/50248-001/main; and ADB. Cambodia: Prime Road National Solar Park Project. https://www.adb.org/projects/52287-001/main

### 8. Building a just and inclusive energy transition

The transition to low-carbon and climate-resilient economies presents countries with a dual challenge: seizing the opportunity for economic transformation and green job creation, while managing the risks of disruption to industries and livelihoods. This is critical given that Southeast Asian economies not only continue to be reliant on fossil fuels and have a young coal fleet but also need to decarbonise the industrial sector – a key driver of emissions and economic activity in the region.

A just transition approach offers a strategic framework to ensure that the shift to a sustainable future is fair, inclusive, and socially responsible. Embedding just transition principles into national development strategies is essential for preserving socio-economic stability, reducing emissions, and strengthening resilience to climate shocks. This is already reflected in efforts such as Indonesia's Comprehensive Investment and Policy Plan (CIPP) and Viet Nam's Resource Mobilization Plan, both of which outline policy measures to support a just energy transition. By doing so, Southeast Asian economies can turn transition risks into opportunities and foster new employment pathways, enhance social protection systems, and build community-level resilience.

**Figure 1.15: Scaling a Just Transition – From Localised Solutions to National Strategies**




Source: Authors.

A well-designed just transition policy recognises the interconnectedness of policy, people, and place, going well beyond individual project boundaries (Figure 1.15). What distinguishes a just transition from any climate or economic transition is not just the scale of the impact, but the deliberate attention to how direct, indirect, and induced impacts are managed to ensure equity and inclusion. A national approach sets the direction for the transition by creating an enabling policy, regulatory, and institutional environment. This includes embedding just transition principles into national climate strategies, fiscal planning, labour policies, and industrial development programmes and diversification strategies. These actions have positive direct, indirect, and induced impacts on the economy. For example, large-scale investments in clean energy and infrastructure help generate employment and stimulate industrial demand. These lead to indirect benefits such as expansion of the supply chain linked to green sectors while having an induced impact such as an increase in income, consumption, and tax revenue. In a just transition context, these impacts are not just economic outputs, but are actively shaped through policies that protect workers, support vulnerable sectors, and redistribute opportunities.

Given the central role that fossil fuel industries play in fiscal and energy systems in Southeast Asia, just transition strategies must also account for public finance implications. Many governments in the region rely on royalties, taxes, and dividends from state-owned oil, gas, and coal companies to fund public services. Similarly, utilities often depend on revenue from coal- and gas-based electricity sales. Without clear fiscal transition plans, rapid decarbonisation could disrupt these revenue streams, leading to budget shortfalls or threatening utility solvency. To address these risks, policymakers must design fiscal buffers, diversify public revenue sources, and plan for long-term utility reform. These efforts should be grounded in detailed assessments of social, legal, and economic impacts and shaped through inclusive dialogue with affected stakeholders. Sector-specific strategies, particularly for energy and industry, must balance the urgency of emissions reductions with the need to protect livelihoods and regional development priorities.

At the subnational level, state and provincial governments are critical actors for adapting national policy frameworks to local industrial and labour market contexts. In many countries in the region, subnational governments have significant dependence on revenues from fossil fuels, and a transition away from such sources will have wide-ranging effects on areas from consumer behaviour to social protection. For example, regions like East Kalimantan and South Sumatra in Indonesia are likely to face significant direct, indirect, and induced impacts as a result of the transition. A just transition approach at the subnational level is necessary to coordinate cross-sectoral efforts to promote regional economic diversification, upgrade industries, generate employment, and manage regional supplier networks or service providers in fossil-intensive zones (Box 1.7).

At the district/community level, the transition impacts are more visible and personal. In this context, following a just transition framework helps in implementing reskilling programmes, small and medium-sized enterprise development initiatives, and expanded public services – enabling affected populations to participate in new economic pathways. It also addresses induced and indirect effects, such as reduced spending power and population outflows, by catalysing local investment and strengthening the social fabric. Most importantly, local governments can absorb shocks and shape new opportunities through inclusive planning and community engagement. At the asset level, just transition interventions, while site-specific, need to be aligned with district/community level interventions. This is because these assets are highly embedded in the local economy, and their closure has direct impacts not just on the stakeholders linked to the asset (e.g. workers vendors) but also the broader local economy. Therefore, just transition mechanisms need to start early to manage these impacts through stakeholder dialogue, retraining pathways, and planning for asset repurposing or new uses.

A just transition, when planned across all levels, has the potential to stabilise public finances, maintain business continuity, and create new sources of economic growth. It does this by balancing short-term fiscal risks such as loss of fossil revenues and increased public expenditure with long-term structural gains like resilient green jobs, a diversified tax base, and lower social and environmental costs. Through a coordinated, inclusive approach, the just transition becomes not only a social imperative but also an economic strategy for sustainable development.

**Box 1.7: Indonesia's Just Energy Transition**

Indonesia's commitment to a low-carbon future necessitates a comprehensive national just transition strategy that spans all sectors. With fossil fuels accounting for over 80% of the national energy mix and coal playing a central role in both domestic energy and export revenue, the shift towards decarbonisation carries deep economic and social implications. Indonesia's enhanced nationally determined contribution, submitted in 2022, not only raised the country's emission reduction targets to 31.89% (unconditional) and 43.20% (conditional), but also explicitly recognised the importance of a just transition. The enhanced nationally determined contribution emphasised supporting workers, communities, and regions affected by the transition, while promoting inclusive economic development through quality job creation, skills development, and social dialogue. This was reinforced by the National Long-Term Development Plan, 2025–2045, which identified a just energy transition as a priority pillar for achieving Indonesia's green economy vision under the broader 'Golden Indonesia 2045' agenda.

The Government of Indonesia launched the Just Energy Transition Partnership (JETP) on 16 November 2022, during the Group of Twenty (G20) Summit in Bali, in collaboration with the International Partners Group. With a pledged financing package of US$$20 billion, JETP Indonesia is the largest energy transition partnership globally and is focused on accelerating the decarbonisation of Indonesia's power sector. It aims to achieve peak emissions by 2030 and reach net zero in the power sector by 2050, with renewable energy contributing at least 44% of the power mix by 2030. Crucially, the JETP frames climate ambition within the broader objective of equity, seeking to ensure that regions reliant on coal – such as East Kalimantan and South Sumatra – are not left behind as Indonesia transitions to a cleaner energy system.

To guide this effort, the JETP Secretariat was established, working closely with key ministries and stakeholders to develop the Comprehensive Investment and Policy Plan (CIPP), which was launched on 21 November 2023. The CIPP sets out Indonesia's energy transition pathway and identifies policy reforms, investment priorities, and social safeguards under a dedicated just transition framework. The framework articulates nine safeguard domains – including labour rights, displacement, customary communities, and economic diversification – to ensure that transition measures are inclusive, equitable, and locally responsive. Designed as a living document, the CIPP is updated annually and functions as both a strategic and operational blueprint for channelling JETP funds, fostering stakeholder participation, and mitigating social and economic disruptions in transition-affected communities.

The institutional structure around the JETP also includes specialised working groups on a just transition, policy, finance, and technical design, with an Energy Efficiency and Electrification Working Group added in May 2024. These groups coordinate efforts across the government, business associations, trade unions, civil society, and development partners. This collaborative governance model is key to addressing the multi-sectoral and cross-cutting nature of a just transition. As the energy transition increasingly affects other sectors, such as agriculture through renewable irrigation, transport through electrification, and industrial processes through circular economy shifts, a focus on equity, job quality, and regional development will be essential. If effectively implemented, Indonesia's just transition efforts can serve as a model for harmonising climate ambition with economic resilience and social justice.

Source: Authors.

# Chapter 2

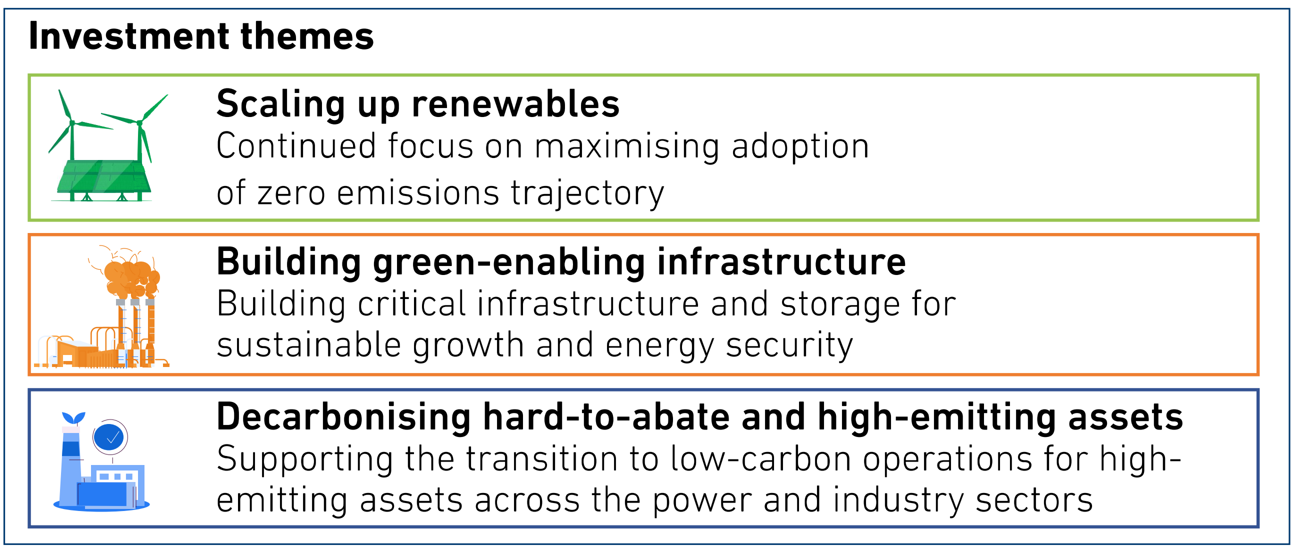
# Enabling the Energy Transition in Southeast Asia Today

# 2.1. Decarbonisation roadmap for Southeast Asia

Stand-alone green growth is insufficient to meet the region's real-world challenges. A 'one goal, various pathways' approach is required, focusing on three key investment themes (Figure 2.1). To deliver energy transition projects at scale across Southeast Asia, it is vital to deploy technologies across all three investment areas. Achieving this will require mobilising transition finance, accelerating technology adoption, and unlocking supportive policy and regulatory frameworks.

To guide these efforts and support informed dialogue amongst key stakeholders and contribute to decarbonisation efforts in Southeast Asia, this paper presents two high-level roadmaps: one focused on the power sector and another on the industrial sector. Each roadmap outlines potential technology adoption over three time horizons: near term (2026–2035), medium term (2035–2045), and long term (beyond 2045).

**Figure 2.1: A Holistic and Sustainable Approach to the Energy Transition for Southeast Asia**




Source: Authors.

The assessment draws on the Technology List and Perspectives for Transition Finance in Asia developed by the Economic Research Institute for ASEAN and East Asia (ERIA, 2025), which provided the foundation for identifying relevant technologies. These technologies were evaluated qualitatively based on key dimensions, including financing, the policy environment, and technical readiness (Figure 2.2). This evaluation was informed by a review of existing literature and consultations with experts across the region.

The roadmaps offer a strategic overview of technology options that could support the decarbonisation of power generation and key industrial sectors. They aim to align technological choices with development objectives and growing energy demand in Southeast Asia. Accelerating the deployment of these technologies could contribute to substantial emissions reductions and help guide the region towards alignment with the Paris Agreement.

The power sector roadmap addresses electricity generation technologies, while the industrial sector roadmap focuses on high-emission industries such as cement, chemicals, and steel. These industries collectively account for a significant share of global industrial emissions. In addition to energy-related emissions, they emit substantial volumes of process-related carbon dioxide ($CO_2$) due to inherent chemical reactions, making them particularly challenging to decarbonise. Given their emissions intensity and strategic importance, these sectors are central to industrial transition in Southeast Asia.

Based on the qualitative assessment, indicative adoption timelines have been proposed for key technologies relevant to the power generation, cement, chemicals, and steel sectors. These roadmaps are intended to serve as a strategic guide, recognising that multiple pathways may be pursued to achieve carbon neutrality across power and industrial sectors in the region.

**Figure 2.2: Sample Qualitative Assessment of Technologies in TLP**

| | Considerations | Priority Logic |
|---|---|---|
| Financing | **Abatement cost**[1]<br>Cost to reduce unit emission, measured in terms of cost per tonne of $CO_2$ equivalent (US$/t$CO_2$e) | Low (Prioritised) ← → High |
| Financing | **Funding efficiency**<br>Emission reduction per dollar invested, measured in terms of tonne $CO_2$ equivalent per unit cost (t$CO_2$e/US$) | High (Prioritised) ← → Low |
| Financing | **Included in mandate of existing energy transition programmes**<br>Mentioned as a priority technology in any of the existing energy transition programmes (e.g., ETM, FAST-P, GX League) | Yes (Prioritised) ← → No |
| Policy | **Classification in ASEAN taxonomy**<br>Colour-coding used in the ASEAN Taxonomy for Sustainable Finance to identify the degree to which a technology contributes to an environmental objective | Green (Prioritised) ← Amber → Red |
| Policy | **Included in national energy plans / decarbonisation strategy**<br>Mentioned as a priority technology in any of the country energy plans (e.g., RUPTL, PDP) | Yes (Prioritised) ← → No |
| Technology | **Technology maturity**<br>Upper limit of TRL in ERIA's Technology List and Perspective of Transition Finance in Asia | > = 8 (Prioritised) ← → < = 4 |
| Technology | **Prioritised for execution**<br>Identified for conducting feasibility studies, pilot-tests, and/or demonstrations | Ongoing / completed projects (Prioritised) ← → No plans |

ASEAN = Association of Southeast Asian Nations, $CO_2$ = carbon dioxide, ERIA = Economic Research Institute for ASEAN and East Asia, ETM = Energy Transition Mechanism, FAST-P = Financing Asia's Transition Partnership, GX = Green Transformation, PDP = Power Development Plan, RUPTL = Electricity Supply Business Plan (PLN, Indonesia), t$CO_2$e = tonne of carbon dioxide equivalent, TRL = technology readiness level, TLP = technology list and perspective.

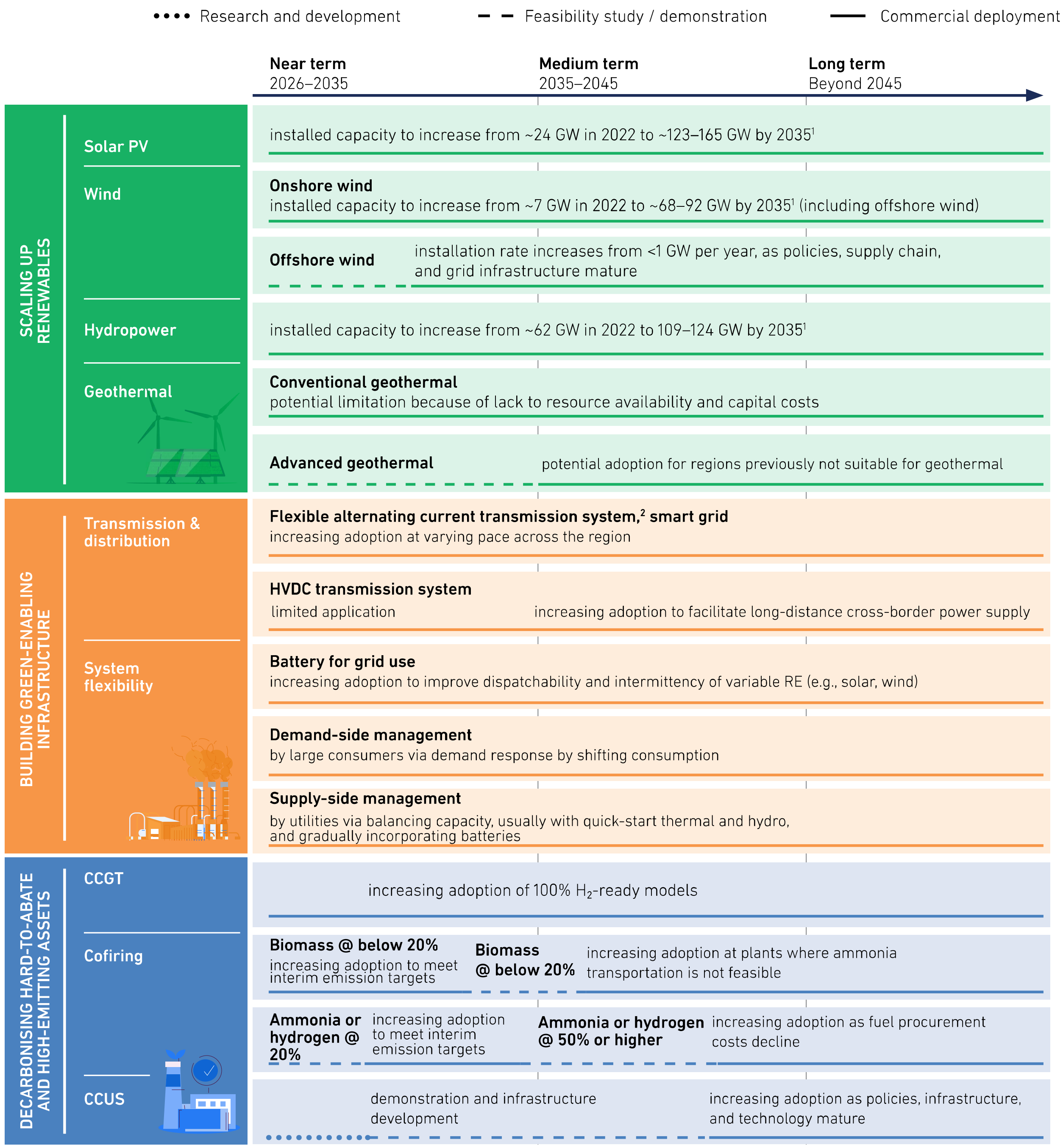
[1] While the value could differ significantly by project, estimates were made to calculate a representative average in US$ for the region.

Source: Authors.

## 2.1.1. Power sector decarbonisation roadmap

Southeast Asia is accelerating its renewable energy transition, with solar photovoltaic (PV) poised for rapid growth due to falling costs, while wind energy is expected to expand more gradually, especially offshore post-2030. Hydropower and geothermal remain underused despite their stability, hindered by environmental and financial barriers. To support this shift, Southeast Asia must upgrade its transmission infrastructure – deploying technologies like high-voltage direct current (HVDC) and smart grids – and enhance system flexibility through storage, demand-side management, and interconnections. Decarbonising high-emitting sectors involves scaling up gas-fired generation, biomass co-firing, and exploring hydrogen and ammonia co-firing. Carbon capture, utilisation, and storage (CCUS) is also seen as vital, with large-scale deployment anticipated in the 2040s. The roadmap presented aims to identify and map out a wide range of potential decarbonisation technologies across the power sector, reflecting all three key investment themes (Figure 2.3). While it provides a forward-looking view of available options, its application must be tailored to the specific contexts, plans, and targets of Southeast Asian countries. Alignment with appropriate decarbonisation strategies – national or corporate – will be critical to ensure effective and coordinated implementation while avoiding carbon lock-in.

## Figure 2.3: High-Level Transition Technology Adoption Roadmap for Southeast Asia's Power Sector




ATS = AMS Targets Scenario; CCGT = combined cycle gas turbine; CCUS = carbon capture, utilisation, and storage; CNS = Carbon Neutral Scenario; GW = gigawatt; $H_2$ = hydrogen; HVDC = high-voltage direct current; PV = photovoltaic.

[1] Based on 8th ASEAN Energy Outlook (ATS and CNS).

[2] Enhances grid efficiency and stability via active control of voltage, current, and power flow in real time, enabling better integration of renewables without new power lines.

Source: Authors.

**Scaling up renewables**

As of 2022, Southeast Asia's renewable energy capacity remains underused relative to its theoretical potential (Setyawati, 2023). Solar PV and wind capacity are still in their early stages, with solar energy growing rapidly due to the decreasing costs of solar modules. Projections suggest that solar PV could see a significant increase in capacity over the next decade, potentially growing by five to seven times by 2035 (ACE, 2024a). On the other hand, wind energy is expected to expand more slowly due to its higher capital costs compared with solar, though it will still see substantial growth by the mid-2030s, especially as offshore wind becomes commercially viable around 2030.

Hydropower and geothermal, while providing more stability and dispatchability than solar and wind, are facing slower growth. These energy sources are hindered by environmental concerns, complex engineering challenges, and high initial investment costs. Despite these hurdles, certain Southeast Asian countries have significant untapped potential in hydropower, with annual installations expected to increase in the coming years. Geothermal energy, which is abundant in countries like Indonesia and the Philippines, remains underdeveloped, with advanced geothermal systems expected to be available later in the 2030s.

**Building green-enabling infrastructure**

To support the growth of renewable energy and prevent curtailment, Southeast Asia's transmission and distribution infrastructure requires significant upgrades. Technologies such as the flexible alternating current transmission system (FACTS) are being deployed across the region to optimise electricity flow and reduce grid congestion. For long-distance transmission of clean electricity, HVDC systems are crucial, enabling power to flow from rural, renewable-rich areas to urban demand centres. While the adoption of HVDC is expected to increase over the coming years, this will require coordinated efforts from various stakeholders to address both technical and financial challenges.

System flexibility is crucial for maintaining grid stability. Most countries in Southeast Asia are at the early stage of their variable renewable energy (VRE) deployment, and VRE shares are minor compared with overall electricity demand. However, VRE plant development cannot be ignored – developers need clear information about where they can connect to the grid, and local infrastructure must be able to handle new connections. Key actions for evolving systems include adding VRE forecasting, updating operational rules to allow for more efficient energy management, and expanding the electricity grid to adapt to rising electrification. Storage technologies, such as pumped hydropower, batteries, and compressed air energy storage, will play a vital role in enhancing grid flexibility and maintaining system security when the share of VRE in the power mix is significantly higher than current levels.

As VRE volumes increase, delays in expanding grid capacity risk causing curtailment, disconnected plants, and missed decarbonisation targets. Power system operators must also ensure sufficient flexible resources within the power system as VRE penetration increases, such as dispatchable plants, demand-side management, interconnections with nearby grids, and storage capacities.

Flexibility can also extend beyond the electricity sector, involving heat and transport sectors through technologies like electric thermal storage and electric vehicles (EVs). Conventional power plants, designed to handle demand variability, are natural candidates for providing the initial flexibility needed due to increased VRE generation.

Given the long planning and development cycles for transmission infrastructure – often exceeding 10 years – it is critical to begin early. Early planning enables alignment between renewable deployment and grid readiness, ensuring that new capacity can be integrated efficiently. This requires coordinated action amongst regulators, grid operators, and policymakers, along with anticipatory modelling, clear permitting frameworks, and investment signals that account for future energy needs and spatial distribution of resources.

**Decarbonising high-emitting assets**

Combined-cycle gas turbine (CCGT) plants, which have significantly lower $CO_2$ emissions than coal-fired power plants, are becoming increasingly important in Southeast Asia's energy transition. Countries such as Indonesia and the Philippines are making notable shifts towards gas-fired power generation. Additionally, the region is expected to adopt increased percentages of hydrogen co-firing as they become commercially available, potentially within the next decade, marking a step towards cleaner power generation. At the same time, operational conversion should be considered. For example, the use of CCGT as peak load power plant[12] may be needed as a possible use of CCGT during the transition period to increase the penetration of renewables.

Biomass co-firing is gaining traction in Southeast Asia as a transitional strategy to reduce $CO_2$ emissions. Countries like Indonesia, Malaysia, and Singapore have been gradually implementing biomass co-firing not only at their coal plants but also in industrial thermal application, with continued efforts to scale this approach. While introducing higher levels of biomass co-firing is technically feasible, widespread implementation is expected to occur over the next decade, primarily due to challenges such as compatibility with existing infrastructure and sustainable supply of feedstock. In the longer term, widespread adoption of co-firing – whether with biomass, green ammonia, or hydrogen – will also depend on the affordability and availability of these low-carbon fuels, particularly as green ammonia and hydrogen are expected to become more viable later in the 2040s (ERIA, 2024).

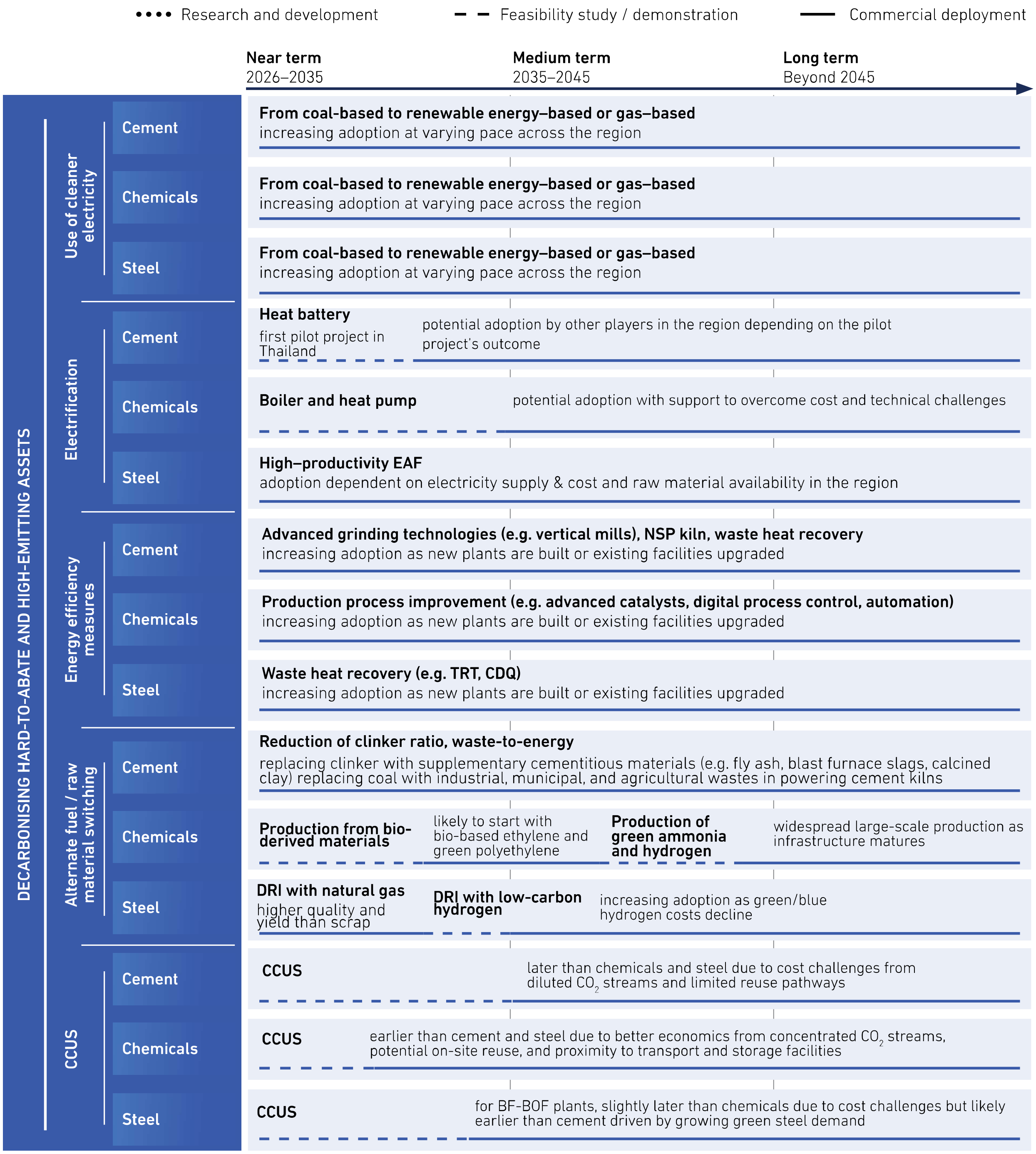
CCUS is another key technology for decarbonising high-emission power generation in Southeast Asia. As the region's electricity demand grows and many countries continue to operate young coal fleets, CCUS technologies are seen as essential for reducing emissions. Southeast Asia has substantial potential for $CO_2$ storage, and countries in the region are collaborating with industry and academic partners to create an environment conducive to CCUS development. While research and policy development are progressing positively, large-scale CCUS deployment is anticipated to occur in the 2040s, as significant infrastructure for $CO_2$ transport and storage, along with supportive policy frameworks, will take time to establish (ERIA, 2024).

[12] Power plants that generally run only when demand is high.

## 2.1.2. Industrial sector decarbonisation roadmap

The industrial sector in Southeast Asia faces a significant challenge in decarbonising high-emitting assets, as most $CO_2$ emissions from energy-intensive subsectors like cement, chemicals, and steel are directly linked to their operations. Despite the strategic importance of cement, chemicals, and steel, these sectors have received disproportionately low levels of mitigation-related development finance in emerging markets and developing economies, highlighting a critical gap in global decarbonisation efforts (OECD and Climate Club, 2025). To address these emissions, the sector is exploring several key strategies that are commonly discussed by industry experts and associations (Figure 2.4). Similar to the roadmap for the power sector, this roadmap outlines a set of potential decarbonisation technologies relevant to these hard-to-abate sectors and is intended as a reference point for identifying viable investment areas. However, the deployment of these technologies must be carefully aligned with each country's specific industrial decarbonisation plans, timelines, and national targets to ensure policy coherence and effective implementation.

**Figure 2.4: High-Level Transition Adoption Roadmap for Southeast Asia's Industrial Sector (Cement, Chemical, and Steel)**




BF-BOF = blast furnace–basic oxygen furnace; CCUS = carbon capture, utilisation, and storage; CDQ = coke dry quenching; DRI = direct reduced iron; EAF = electric arc furnace; NSP = new suspension preheater; TRT = top pressure recovery turbine.

Source: Authors.

**Decarbonising hard-to-abate assets**

One major lever is transitioning to cleaner electricity. Many companies in these industries rely on captive coal- or gas-fired power plants to meet both electricity and process heat needs. As part of their decarbonisation efforts, major manufacturers are increasing the share of renewable energy in their power mix, using on-site solar PV and long-term power purchase agreements (PPAs). Companies in coal-dependent regions are also considering switching to natural gas as a less carbon-intensive alternative, which serves as an interim solution until renewable energy becomes more widely available.

Another strategy is electrifying process heating, which typically requires high temperatures to process materials. For example, in the cement industry, Thailand is working on a pilot project involving the world's first commercial heat battery to store solar energy as heat for industrial use. In the chemicals sector, electrical boilers and heat pumps are being considered for low- to medium-temperature heating processes, though these solutions are expected to be adopted more widely in the medium term due to technical and cost challenges. Steelmaking, too, is transitioning towards more sustainable methods, with a focus on reducing reliance on traditional, carbon-intensive blast furnaces.

Energy efficiency improvements are being implemented across the industrial sectors, with initiatives ranging from advanced grinding technologies in cement production to innovative catalysts and digital solutions in chemicals. Steelmaking is also benefiting from mature waste heat recovery technologies, which help optimise energy use and reduce emissions.

Switching to alternative fuels and raw materials is another key decarbonisation strategy. In cement production, manufacturers are using less clinker, which is responsible for a significant portion of emissions, and increasing the use of substitute materials like fly ash and slag. In the chemical industry, bio-based alternatives to traditional raw materials are being explored, such as using renewable ethanol for plastics production. In steel, the adoption of cleaner technologies like DRI is still limited, but the development of hydrogen as a fuel for DRI and blast furnace processes is gaining attention as a long-term decarbonisation solution.

CCUS is widely considered as a suitable approach for industries where emissions cannot be fully eliminated. The chemicals sector may lead in CCUS adoption, given their potential to reuse $CO_2$ on-site and the proximity to key infrastructure. Recent experiences in Europe and the People's Republic of China (PRC) provide valuable lessons for CCUS implementation (Boxes 2.1 and 2.2).

### Box 2.1: Northern Lights CCUS Project

The Northern Lights project is a flagship carbon capture, utilisation, and storage (CCUS) initiative under Norway's Longship programme. It is a collaborative effort between Equinor, Shell, and TotalEnergies, supported by the Norwegian government. The project enables cross-border transport of captured carbon dioxide ($CO_2$) by ship to an onshore terminal at Øygarden, Norway, followed by permanent storage beneath the North Sea. Phase 1, launched in 2024, offers capacity of 1.5 million tonnes of $CO_2$ per year, with participation from emitters in Norway, the Netherlands, Sweden, and Denmark. Phase 2, planned for 2028, will raise capacity to at least 5 million tonnes annually and includes long-term contracts with Stockholm Exergi and other industrial clients.

Public funding has played a critical role. The Government of Norway covered about 80% of the Phase 1 cost, contributing NKr22 billion (US$2.2 billion) out of a total of NKr27 billion. For Phase 2, a further NKr7.5 billion (US$714 million) was mobilised, supported in part by a €131 million grant from the European Union's Connecting Europe Facility. These substantial public contributions illustrate strong government support for shared $CO_2$ storage infrastructure in Northern Europe.

Sources: Milne (2025); and Buli (2025).

### Box 2.2: Financial Case Study – The ChemChina Project

ChemChina, the largest state-owned enterprise in the chemical industry of the People's Republic of China (PRC), owns more than 100 industrial companies and 24 research and development institutes. The Asian Development Bank (ADB) supported ChemChina through the Chemical Industry Energy Efficiency and Emission Reduction Project, which aimed to enhance the environmental and ecological sustainability of the chemical industry in the PRC.

The project, approved on 30 October 2015 for a total loan amount of US$100 million (of which US$95 million was allocated for clean energy investment), includes the replacement of fossil fuels with renewable energy and other energy efficiency measures. The financial internal rate of return for the project was reevaluated at project completion as 6.8%, higher than the weighted average cost of capital of 5.9%, indicating financial viability.

In full operation since 2024, the project is expected to achieve significant energy savings and emission reductions. It is projected to save 7,322 terajoules of energy per year, reduce greenhouse gas emissions by almost 15 million tonnes of $CO_2$ equivalent annually, and avoid the use of 35 tonnes of mercury annually. The project has already demonstrated significant improvements in energy efficiency and emission reductions at ChemChina's plants. It contributes to the PRC's dual carbon goals of peaking carbon dioxide emissions before 2030 and achieving carbon neutrality by 2060.

Source: ADB (2022).

# 2.2 Paving the way towards the energy transition in Southeast Asia

Southeast Asia's energy transition hinges not only on scaling up renewables and building green enabling infrastructure, but also on accelerating the adoption of clean technologies across thermal assets and industrial systems. Technology adoption must be supported by robust research and development (R&D) ecosystems, regional innovation hubs, and cross-sector partnerships that bring emerging solutions from lab to market. Pilot projects, demonstration sites, and knowledge-sharing platforms will be essential to validate technologies and scale them across diverse geographies and industrial contexts.

Comprehensive policy and regulatory frameworks are critical to unlock technology deployment and ensure a just, inclusive transition. This includes project-level support such as streamlined permitting and concessional finance, programme-level tools like blended finance and standardised PPAs, and market-level reforms that enable flexible pricing, carbon markets, and regional harmonisation. Macro-level interventions – such as regional cooperation, infrastructure development, and green industrial strategies – must align economic, energy, and social policies to ensure that clean technologies are viable, competitive, and equitable. By embedding justice and inclusivity into its transition strategy, Southeast Asia can build resilient economies, create green jobs, and ensure no community is left behind.

## 2.2.1. Technology adoption

Accelerating clean technology development and adoption requires a multi-pronged strategy that aligns innovation, capacity building, and industrial policy. Key actions include strengthening R&D ecosystems through targeted investments and cross-sector partnerships, fostering regional innovation hubs tailored to Southeast Asia's unique climate and development needs, and enhancing knowledge sharing via structured platforms and training programmes. Localising technology and expanding domestic manufacturing capabilities – while avoiding premature local content mandates – can ensure cost-effective deployment and long-term competitiveness. Scaling up pilot and demonstration projects, particularly in hard-to-abate sectors, will validate emerging solutions and attract investment. Complementary efforts to facilitate international technology transfer, promote energy efficiency, and support industrial decarbonisation will further accelerate progress. Together, these strategies can help Southeast Asia leapfrog to a cleaner, more resilient energy future.

**Strengthen R&D ecosystems**

Strengthening R&D ecosystems across Southeast Asia could play a pivotal role in advancing clean energy technologies. National programmes that prioritise innovation in areas such as battery storage, carbon capture, and smart grid integration may help accelerate the journey from laboratory breakthroughs to market-ready solutions. Universities, start-ups, and private sector initiatives are likely to benefit from targeted funding that encourages experimentation and commercialisation. Collaborative efforts between governments, academic institutions, industry players, and international research bodies may offer a pathway to technologies that are not only technically viable but also contextually relevant. These partnerships often focus on pilot testing and training, and they may lead to the creation of regional testing centres, shared funding models, and joint research exchanges. Such initiatives could be particularly valuable in areas like industrial decarbonisation and off-grid renewable systems, especially for island and rural communities. Innovation hubs across Southeast Asia are already contributing to this momentum. In Singapore, the Energy Research Institute has been active in solar and storage R&D. In Malaysia, the Green Technology and Climate Change Corporation promotes research and innovation in energy-efficient technologies and sustainable manufacturing. Indonesia's Agency for the Assessment and Application of Technology has pilot tested renewable microgrid systems to support rural electrification, while Viet Nam's National Innovation Centre has launched clean tech accelerator programs that aim to boost start-ups in green energy and low-emission technologies. Connecting these hubs through regional networks may enhance knowledge exchange, enable co-development, and facilitate faster scaling of innovations through shared resources and aligned policy frameworks.

**Enhance knowledge sharing and capacity building**

Expanding knowledge exchange and capacity building across Southeast Asia may offer a powerful lever for accelerating the energy transition. Regional platforms that facilitate technical training and cross-border collaboration could build on successful initiatives such as the ASEAN Centre for Energy's ASEAN Energy Awards and the Renewable Energy Project Development Training series. Bringing together government agencies, energy utilities, academic institutions, and private sector players provides a platform for sharing practical insights and lessons learned from ongoing and completed projects. For example, the Philippines' National Energy Efficiency and Conservation Program has developed a strong national training programme for energy managers, which could be adapted regionally. Indonesia's work on microgrids and Malaysia's experience with solar leasing models are also valuable case studies that can be shared across borders. A regional digital knowledge hub could compile project case studies, policy tools, and technical resources to help accelerate the adoption of technologies and scale proven solutions across countries in the region.

Structured platforms that capture lessons from pilot and demonstration projects could help highlight technical outcomes, financial approaches, regulatory learnings, and stakeholder engagement strategies. Participation from engineers, utilities, technology developers, and policymakers could foster the co-creation of adaptable toolkits grounded in real-world experience. Viet Nam's rooftop solar rollout under the Vietnam Electricity (EVN)-led programme, Thailand's smart grid pilots in Chiang Mai, and Malaysia's biomass co-firing efforts offer examples of initiatives that could be shared and adapted across borders. Communities of practice – whether through workshops, regional learning labs, or digital forums – may help accelerate adoption, encourage local adaptation, and support continuous improvement in transition technologies.

**Support technology localisation and local manufacturing**

Adapting imported clean energy technologies to Southeast Asia's environmental and infrastructure conditions could enhance their durability and performance. Customising components for high humidity, salinity, and grid conditions may be more effective when local engineering institutions and manufacturers are engaged early in the process. Expanding domestic manufacturing across the clean energy value chain, including the production of solar PV modules, inverters, battery cells, efficient motors, and smart grid hardware, could strengthen regional supply resilience and industrial competitiveness. For instance, Thailand and Viet Nam are becoming regional hubs for solar component manufacturing, while Indonesia is developing its domestic capacity in battery materials processing. Indonesia's state electricity company (PLN) promotes local solar panel manufacturing in partnership with international companies. Public procurement programmes can prioritise locally made equipment, creating demand that supports industrial development.

Developing technical training programmes in collaboration with vocational schools, universities, and private companies may help build a skilled workforce capable of deploying and maintaining these technologies.

Reducing trade barriers for clean energy components and establishing regional quality certification bodies aligned with international standards could support supply chain integration. Regional centres of excellence may also serve as platforms for joint research, product testing, and policy coordination across countries in the region.

However, while local content policies can support industrial development, their effectiveness depends on alignment with actual supply chain readiness. When mandates are introduced before domestic capacity is in place, they risk slowing deployment, increasing costs, and undermining investor confidence. The International Energy Agency (IEA) has noted that overly rigid local content rules have, in some cases, delayed clean energy projects compared with more flexible approaches (IEA, 2021d).

For Southeast Asia, a rational approach may involve ramping up local content requirements in tandem with targeted support for industrial capacity development. Adaptive models demonstrate how foreign technology acquisition can be paired with local innovation to accelerate deployment while building long-term competitiveness. Lessons can be learned from experiences in other countries (Box 2.3).

**Box 2.3: India's PLI Scheme for Clean Energy Technologies**

The Production Linked Incentive (PLI) scheme is a flagship initiative by the Government of India aimed at boosting domestic manufacturing and reducing import dependency across 14 key sectors, including clean energy. Launched in 2020 under the broader vision of Atmanirbhar Bharat (Self-Reliant India), the scheme provides financial incentives to companies based on the incremental sales of goods manufactured in India. In the clean energy domain, the PLI scheme targets sectors such as solar photovoltaic (PV) modules, advanced chemistry cell (ACC) battery storage, and green hydrogen or ammonia production. The government aims to use the scheme to position India as a global hub for clean energy technologies, reduce carbon emissions, and support the country's transition to a low-carbon economy. As of the 2025–2026 budget, the government has significantly increased allocations to clean energy-related PLI schemes. For instance, the National Programme on ACC Battery Storage saw its budget rise from ₹154 million (US$1.73 million) to ₹1,557.6 million (US$ 17.5 million).

The scheme (i) attracted cumulative investments totalling about US$17 billion by August 2024 for all sectors; (ii) contributed to employment generation of over 1 million jobs for the clean energy sectors; (iii) strengthened high technology manufacturing in green sectors; (iv) strengthened India's export competitiveness by supporting globally competitive manufacturing capabilities through local value addition; and (v) aligned with India's climate commitments under the Paris Agreement and supports the goal of achieving net zero emissions by 2070.

Notwithstanding this success, some analysis has identified weaknesses and challenges of the scheme, including (i) delays in implementation experiences by several projects due to bureaucratic hurdles, land acquisition issues, and slow disbursement of funds; (ii) limited scope as the scheme does not include other important clean energy technology sectors such as green hydrogen electrolysers, and onshore and offshore wind; (iii) poor targeting as minimum investment thresholds and technical capabilities may exclude small and medium-sized enterprises from participating; and (iv) insufficient incentives as the scheme has not achieved the self-reliance of India since the country continues to rely heavily on imports for critical components like lithium, rare earths, and solar wafers, which could undermine long-term self-reliance.

While the PLI scheme aims to be a policy tool to enhance clean energy manufacturing, early results indicate that to unfold its effectivity, it would need to be complemented by measures for improving the general investment enabling environment, strengthening domestic skills development and other investment and competitiveness measures – including supporting the participation of small and medium-sized enterprises in the value chain.

Sources: Press Information Bureau Government of India (2025); Michael (2025); Ministry of New and Renewable Energy (n.d.); and Thaker (2025).

### Scale up pilot projects and demonstration sites

Accelerating the deployment of pilot projects across Southeast Asia may help validate next-generation clean technologies under real-world conditions. Technologies such as low-carbon hydrogen, carbon capture, ammonia co-firing, and sustainable aviation fuels could benefit from early testing in industry-relevant settings to generate insights that guide wider replication.

Industrial-scale demonstrations in hard-to-abate sectors – cement, steel, shipping, and refining – might be effectively hosted in existing industrial parks and special economic zones. Initiatives like Pertamina's pilot-scale hydrogen and carbon capture efforts within refining operations illustrate how national companies are already exploring these pathways. The long-standing support of the Asian Development Bank (ADB) for CCUS in Asia, including feasibility studies in Indonesia and the PRC, capacity building, and the creation of knowledge products and policy guidance, has laid important groundwork for scaling up CCUS hubs across the region (Box 2.4).

Clear policy signals and financial incentives could reduce barriers for early adopters. Matching funds, streamlined permitting, and risk-sharing mechanisms may encourage private sector participation. Regional innovation funds, competitions, and open calls could attract both international and local solution providers. Viet Nam's National Innovation Centre, for example, is collaborating with global partners to test renewable technologies alongside start-ups and academic labs. Indonesia's Cirata Floating Solar Photovoltaic Plant – Southeast Asia's largest of its kind – demonstrates how large-scale deployment can be achieved through strategic partnerships.[13]

[13] In January 2020, Masdar signed a PPA with PT PLN Nusantara Renewables, a subsidiary of Indonesia's state-owned electricity company (PLN), to build Southeast Asia's largest floating solar power plant (Masdar, n.d.).

Linking pilot projects with universities, vocational training centres, and small and medium-sized enterprises (SMEs) may support knowledge transfer and workforce development. Publishing results through regional platforms could build investor confidence and improve transparency. A shared ASEAN Clean Technology Demonstration Tracker could consolidate data and support replication across borders.

Accelerating low-carbon technologies in Southeast Asia can be achieved in several ways, such as (i) funding pilot projects that test the commercial and technical viability of low-carbon hydrogen, carbon capture, and bio-based fuels; (ii) supporting industrial-scale demonstrations in high-emitting sectors like steel, cement, and refining;[14] and (iii) organising innovation challenges and public–private partnerships (PPPs) to attract international technology providers.

**Box 2.4: ADB Support for CCUS in Asia**

The Asian Development Bank (ADB) has been supporting carbon capture, utilisation, and storage (CCUS) as a promising transition technology to decarbonise economies in Asia since 2009. Its activities include projects in the People's Republic of China (PRC) and Indonesia, where it worked closely with policymakers to draft national roadmaps, policies, and legislation.

The next steps involved carrying out project-specific feasibility studies at Tianjin (PRC) and Gundih (Indonesia). This helped ADB and its developing member countries (DMCs) to understand the complexities of the technology, the need for finance, and business models for future projects.

Empowering DMCs through capacity building is one of ADB's development objectives. Major activities in this area include:

- Providing assistance to the PRC and Indonesia in establishing Centres of Excellence for CCUS.
- Creating knowledge products such as technology compendiums, roadmaps, and studies on CCUS in the PRC and Indonesia.
- Developing industry-specific case studies on power, steel, petrochemicals, and cement.
- Conducting a study in Southeast Asia to fill information gaps and provide a foundation for long-term action on CCUS in Indonesia, the Philippines, Thailand, and Viet Nam.
- Co-authoring a CCUS handbook for policymakers, in partnership with the Government of the United States, offering guidance on creating effective CCUS policies.

These activities increased both the industrial and geographical coverage of CCUS. In addition to the PRC and Indonesia, ADB has supported CCUS in other parts of Asia including Bangladesh, India, Pakistan, and Viet Nam.

Over the years, ADB has established linkages with a number of multilateral and bilateral bodies, as well as industrial associations. It intends to create the enabling infrastructure for CCUS hubs with well-mapped sources and sinks so that CCUS can be scaled up to meet the challenge of decarbonising Asia.

Source: ADB (2024b).

[14] For example, Singapore's Tuas Power Plant is pilot testing carbon capture for thermal power. Similar projects could be rolled out across ASEAN.

### Facilitate technology transfer and international partnerships

Partnerships that support knowledge sharing and local market adaptation can accelerate decarbonisation in both the power generation and industrial sectors. For example, Thailand and Japan's collaboration on low-carbon hydrogen is a successful example of technology transfer.[15] Southeast Asian countries can further promote these agreements to introduce innovative solutions such as low-carbon hydrogen production, carbon capture, and energy storage.

PPPs that share risk and incentivise joint ventures, pilot projects, and technology demonstrations may foster collaboration, local adaptation, and scalability of clean technologies across Southeast Asia.

### Promote energy efficiency and industrial decarbonisation

Prioritising technologies that reduce energy losses by upgrading infrastructure, deploying smart grid technologies, and optimising system design may improve efficiency across Southeast Asia's power systems. Thermal power plants could benefit from modern turbines and control systems, while smart metres, fault detection, and high-efficiency transformers may help cut technical losses. On the consumption side, advanced load management, efficient lighting, and building insulation could support demand-side efficiency. Digital energy management systems may enable real-time monitoring and optimisation in industrial operations. High-efficiency motors and variable speed drives in sectors like manufacturing and food processing could reduce electricity use, while process optimisation tools may minimise waste. Countries such as Indonesia and Viet Nam have already seen notable improvements through these measures.

Cogeneration and trigeneration systems may offer efficient solutions for electricity, heating, and cooling in industrial parks. These systems are particularly suited to industries with consistent thermal loads, such as pulp and paper or petrochemicals, and could be supported by energy audits and targeted incentives. Waste heat recovery in manufacturing – using technologies like heat exchangers and organic Rankine cycle systems – could significantly lower emissions. Recovered heat may be reused for preheating, steam generation, or on-site electricity production, especially in the cement, steel, and glass industries. Efficient district heating and cooling networks, along with combined heat and power systems, may be valuable in dense urban and industrial areas. Policy support for retrofitting and integration of thermal energy solutions in new developments could enhance uptake.

Region-specific energy audits may help identify inefficiencies and guide investment towards high-impact areas. National programmes targeting commercial and industrial users – through performance contracting and mandatory audits – could replicate successful models seen in countries like Thailand. Promoting integrated thermal energy solutions across sectors such as glass, ceramics, and pulp and paper may strengthen waste heat recovery. Shared infrastructure in industrial parks could enable facilities to exchange excess thermal energy, supported by subsidies, low-interest financing, and inclusion in national efficiency standards.

[15] Japan and Thailand have worked towards fortifying their ties across various sectors, including defence, investments, and energy (Banerjee and Basu, 2024).

## 2.2.2. Policy and regulatory unlocks

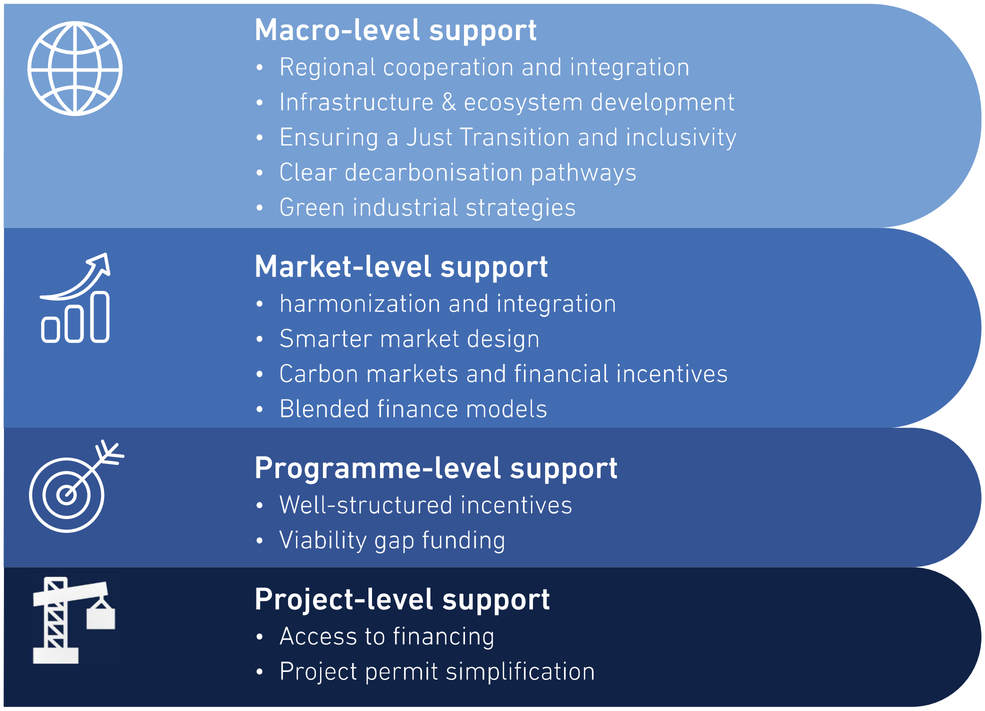
The shift to net zero is not only a technological transition but also a structural one. It will fundamentally reshape economies, labour markets, and regional development pathways. In this context, a just transition framework becomes essential to manage the distributional impacts – ensuring that workers, communities, and sectors most affected by the shift are not left behind. To decarbonise hard-to-abate and high-emitting sectors, governments must act to provide the right market signals. This requires a multi-layered policy approach that operates across different timeframes, offering long-term visibility through climate targets and regulatory certainty, while addressing immediate needs and integrating labour, social safeguards, and economic considerations into project-specific implementation. The financeability of energy transition projects improves markedly when policy frameworks address permitting, community acceptance, and long-term demand visibility – factors that reduce execution and political risks and attract institutional capital (GCCSI, 2023).

Renewable energy power plants and green industries do not function in a vacuum: they rely on a strong, supportive framework of rules, regulations, and policies. Just as fossil fuel-based solutions thrived for decades under favourable conditions – including subsidies, regulatory leeway, and infrastructure investment – clean technologies also require an enabling policy environment that supports their deployment and addresses potential social, economic, and financial consequences. This environment, guided by a just transition lens, should align economic, industrial, and energy policies in a way that makes sustainable solutions viable, inclusive, and competitive. Without this alignment, even the most promising green innovations risk stalling due to social resistance, regional disparities, or unmet worker needs.

At the heart of this transition is the justice dimension. Decarbonisation should be economically competitive and socially inclusive, generating decent jobs and reducing inequality. Green industries need the same kind of government support that traditional industries enjoyed, but with added attention to social outcomes: generating employment, reskilling programmes, access to low-cost capital; risk-sharing mechanisms for early-stage technologies; public procurement programmes; and infrastructure investment in areas like low-carbon hydrogen, carbon capture, and grid modernisation. Directing such investments towards fossil fuel-reliant or underdeveloped regions can support economic diversification and mitigate employment loss. Policy must also address demand-side dynamics, encouraging the uptake of sustainable goods and services through awareness campaigns, product labelling schemes, and carbon pricing mechanisms designed with a people-centred approach – ensuring affordability, access, and equity in the low-carbon transition. Incentivising consumer participation also builds public trust, which is an essential ingredient for long-term policy durability. Recent policy innovations such as the European Union (EU) Fit for 55 packages have demonstrated how stacking carbon pricing with production subsidies can yield effective carbon prices of US$90–US$200 per tonne, significantly improving the investment case for carbon capture and storage (CCS) applications (GCCSI, 2023).

Ultimately, deep decarbonisation is a coordination and governance challenge. This kind of systemic transformation does not happen by accident. It needs a clear societal vision, long-term political commitment, and an agile regulatory environment that evolves alongside technological progress and social priorities. Establishing multi-stakeholder platforms, transition commissions, and inclusive planning processes is key to ensuring that the shift to net zero enhances, rather than undermines, social cohesion and economic resilience. Figure 2.5 represents the kind of change needed to guide policymakers in understanding the size of the challenge. This is presented as a map to understand how to approach the challenge, with some selected policies as examples.

**Figure 2.5: Type of Policy Support Needed**




Source: Authors.

**1. Macro-level support**

Wider structural support, across borders and sectors, is essential for a just, inclusive, and lasting energy transition. Ultimately, macro-level support must be underpinned by strong governance and inclusive institutions. Establishing multi-stakeholder platforms, transition commissions, and participatory planning processes ensures that the shift to net zero enhances social cohesion and economic resilience. This systemic transformation requires not only technological innovation but also a shared societal vision and enduring political will.

- **Regional cooperation and integration:** Working together across countries can unlock huge potential. Initiatives like the ASEAN Power Grid help share renewable resources more efficiently and improve energy security at a regional level.

- **Infrastructure and ecosystem development:** Clean energy projects need the development of necessary infrastructure to thrive – from grid upgrades and transmission corridors to hydrogen pipelines and storage. PPPs can help build these systems and support long-term growth.

- **Ensuring a just transition and inclusivity:** As economies shift away from fossil fuels, it is vital to ensure that no one is left behind. Programmes to reskill workers and policies that support vulnerable communities are central to a fair and inclusive transition. The World Bank's Just Transition for All Initiative offers helpful guidance on a comprehensive and sustainable approach.

- **Clear decarbonisation pathways:** Strong, region-wide regulations can set the pace for industry. Carbon border adjustment mechanisms, emissions trading systems, and other policies send signals that help steer industries towards low-carbon technologies while maintaining a level playing field.

- **Green industrial strategies:** Green industrial policy can be adopted to drive the transition to a low-carbon economy by implementing measures like incentives for clean energy, support for green enabling infrastructure, and regulatory actions to phase out polluting sectors. Collaboration can be sought amongst stakeholders, including businesses and civil society, to create a sustainable and competitive industrial sector. The development of credible transition plans requires clear efficiency thresholds and sector-specific benchmarks to ensure alignment with long-term climate goals and financial viability (GFANZ, 2024).

**2. Market-level support**

Market-level support is critical to enabling the scale-up of clean energy solutions. Strong, well-designed markets can accelerate adoption by providing clear rules, effective price signals, and financial incentives. Harmonised standards, smarter market structures, and targeted partnerships create the enabling conditions for innovation, investment, and collaboration – ensuring that clean technologies are not only available but also accessible and competitive across regions and sectors.

- **Harmonisation and integration:** Unified standards for technology deployment, energy efficiency, and carbon reporting can build trust and promote collaboration across borders. Common certification systems and clear regulations support market transparency and help unlock regional synergies.

- **Smarter market design:** Energy markets must evolve with the technologies they host. Updating them to better accommodate renewables means ensuring flexible pricing structures, integrating decentralised systems, and giving appropriate price signals to both generators and flexibility providers.

- **Carbon markets and financial incentives:** Strong carbon pricing systems, like cap-and-trade or carbon taxes, create the financial incentives needed to drive emissions reductions. Singapore's carbon tax, for instance, encourages businesses to cut emissions or invest in sustainability measures like approved carbon credits or energy efficiency upgrades.

- **Blended finance models:** Combining public, private, and philanthropic capital can help share risks and bring more funding to the table. Guarantees, insurance, and concessional finance all play a role. Programmes like ADB's Energy Transition Mechanism, SDG Indonesia One (PT SMI, n.d.-b), and Singapore's Financing Asia's Transition Partnership (FAST-P) (Ministry of Sustainability and the Environment, n.d.) offer great examples of how blended finance can support clean energy investments.

**3. Programme-level support**

Programme-level support focuses on making individual investments and transactions more attractive and viable, especially in the early stages of project development. These measures are not designed as permanent policies but as targeted interventions to de-risk projects, improve bankability, and accelerate deployment. By offering structured incentives, bridging financial gaps, programme-level tools help kickstart clean energy initiatives and bring them to market faster.

- **Well-structured incentives:** Financial tools like feed-in tariffs, auctions, and standardised PPAs can provide the revenue certainty that investors and developers need. When these tools are well designed, they can encourage uptake of technologies like VRE while ensuring returns are predictable and bankable. India's solar PPA reforms offer a useful model.

- **Viability gap funding:** Viability gap funding (VGF) is a targeted tool used to make clean energy projects financially feasible when market returns alone are insufficient. It provides partial capital support to bridge the gap between project cost and expected revenue, helping attract private investment in early-stage or high-risk initiatives.

**4. Project-level support**

Project-level policies are designed specifically for energy transition projects, helping them move from concept to implementation. They focus on practical enablers like financing access, permitting, and land acquisition – critical steps that determine whether a project can proceed.

- **Access to financing:** Early-stage projects often face significant funding challenges. Improving access to grants, concessional finance, and government-backed capital – such as low-interest loans or loan guarantees – can make a big difference. These tools help de-risk investments and open doors for innovative but high-risk initiatives.

- **Project permit simplification:** Permitting and land acquisition are often major roadblocks. By simplifying these processes and aligning environmental and social impact criteria, governments can help projects move faster and with more clarity. Clear regulatory guidance can also ease uncertainty and keep timelines on track.

# 2.3. Transition finance to support a sustainable energy transition

To advance Southeast Asia's decarbonisation efforts, the concept of 'transition finance' has emerged as a pragmatic solution to address the investment gap required to achieve the region's sustainability and just transition goals. While the term has attracted considerable interest amongst global investors and policymakers, it lacks a universally accepted definition. Broadly, it refers to financial strategies and instruments that facilitate the shift from high-carbon to low-carbon economies, particularly within hard-to-abate and high-emitting sectors.

## 2.3.1. Understanding transition finance

Transition finance is an evolving and context-dependent concept, with multiple interpretations reflecting the diverse objectives of stakeholders.

The 2022 Group of Twenty (G20) Sustainable Finance Report defined transition finance as 'financial services supporting the whole-of-economy transition, in the context of the Sustainable Development Goals (SDGs), towards lower and net-zero emissions' (G20 Sustainable Finance Working Group, 2022: 5). In contrast, the Organisation for Economic Co-operation and Development (OECD) Guidance on Transition Finance emphasised 'the dynamic process of becoming sustainable, rather than providing a point-in-time assessment of what is already sustainable' (OECD, 2022: 11). From a financial market perspective, the Glasgow Financial Alliance for Net Zero described it as 'investment, financing, insurance, and related products and services that are necessary to support an orderly, real-economy transition to net zero' (GFANZ, 2022: 10).

From an investment standpoint, the International Capital Market Association (ICMA) positions transition as an investment theme that can be financed using existing frameworks for green, sustainability, and sustainability-linked bonds, while recognising the development of 'climate transition' labelled instruments. Based on evolving practices and interpretation amongst investors, ICMA (2024) categorised the overlapping interpretations of transition as:

- **Economy-wide transition:** encompassing wider sustainability goals or the SDGs
- **Climate transition:** specifically targeting the goals of the Paris Agreement
- **Hard-to-abate transitions:** focusing on high-emitting industrial sectors

In the Southeast Asian context, the ASEAN Capital Markets Forum (ACMF) issued the ASEAN Transition Finance Guidance (ATFG) Versions 1 and 2 (ACMF, 2023; 2024b) to provide a geographically contextualised approach to transition finance for the region. The ACMF maintains that the specific type of finance used for transitory activities or transitioning entities should not be the sole defining characteristic of transition finance, and that differentiating between the application of labelled and unlabelled transition finance in specific contexts can provide clarity to market participants. In particular, the ATFG Version 2 identifies three broad applications of transition finance:

- **Green finance:** for specific green activities or assets with low or zero emissions in alignment with the Paris Agreement
- **Asset-level transition finance:** for specific transitory assets or activities that contribute towards decarbonisation in the short term but are not fully green or long-term climate solutions
- **Entity-level transition finance:** for general-purpose finance provided to entities undergoing ambitious and credible transitions that are aligned with Paris Agreement

## 2.3.2. Differentiating green and transition finance

The concept of green finance is well developed and widely recognised by both market participants and policymakers. It refers to the allocation of capital to projects, assets, or activities that have already achieved low or zero carbon emissions, or that are deemed environmentally sustainable.[16] Such determinations are often guided by regulated technical screening criteria, as in the EU Green Taxonomy, or general market consensus, such as the ICMA Green Bond Principles or the ASEAN Green Bond Standards. This approach tends to categorise projects as either green or non-green (Table 2.1). This binary framework is conceptually simple and effective at channelling capital towards clearly defined green investments – such as renewable energy or electrified transport – that unambiguously align with globally recognised standards. However, it can inadvertently exclude or discourage financing for investments that do not fit neatly into these categories or lack current technological pathways to decarbonisation, regardless of other relevant economic, geographic, or social factors.

[16] Examples include renewable energy, such as transmission and battery storage; electrified personal transportation, such as EVs and charging infrastructure; green buildings; and resource circularity.

**Table 2.1: Characteristics and Examples of Brown, Transition, and Green Finance**

| Category | | Brown[a] | Transition | Green |
|---|---|---|---|---|
| ***Status*** | | Managed phaseout | Progressing or Aligning | Aligned |
| ***Concept*** | | No decarbonisation<br>No pathway | Rate of decarbonisation,<br>Multiple pathways,<br>Context dependent | State of decarbonisation<br>Single pathway<br>Context independent |
| ***Example Activities*** | | Unabated fossil fuel combustion<br><br>Unsustainable resource extraction | Fuel switching (Coal to Gas)<br><br>Efficiency improvements in high-emitting processes<br><br>Pollution reduction | Clean energy<br><br>Eco-efficient and circular economy<br><br>Pollution prevention and control |
| ***Example technologies*** | | Thermal coal<br>Internal combustion engine (ICE) vehicles | CCUS, CCGT, Co-firing<br>Hybrid electric vehicles,<br>Transmission systems | Solar, wind power, batteries<br>Electric vehicles, charging infrastructure |
| ***Example Sectors*** | ***Direct*** | Energy (fossil fuels) | Energy (low carbon)<br>Transport (aviation, marine)<br>Materials (steel, cement) | Energy (zero emission, clean)<br>Transport (electric vehicles)<br>Real Estate (green buildings) |
| | ***Enabling*** | | Manufacturing (batteries, transmission cables)<br>Chemicals (speciality chemicals for green energy, buildings, agriculture, etc)<br>ICT and Telecommunications (Smart mobility, efficiency-enabling, resource-use)<br>Materials (Copper and lithium mining and processing) | |

CCGT = combined cycle gas turbine; CCUS = carbon capture, utilisation, and storage; ICE = internal combustion engine; ICT = information and communication technology.

[a] In the context of sustainable finance, 'brown' sectors commonly refer to industries associated with intrinsically high levels of greenhouse gas emissions or other environmental damage (e.g. oil and gas extraction or coal mining), while 'brown finance' refers to financial flows or other investments into these industries.

Source: Author's Compilation

In contrast to green finance, transition finance refers to funding for entities, assets, and activities that are not yet green or partially green but are on a path to becoming more sustainable. It focuses on the process of improvement over time, rather than a single point-in-time assessment. This includes companies that disclose and actively implement credible transition plans, particularly those operating in high-emission sectors such as iron and steel, power, oil and gas, and aviation. Such sectors often require significant financial support to adopt more sustainable and environmentally friendly practices aimed at reducing their overall emissions. By financing transition at both the entity and activity levels, financiers and investors can incorporate forward-looking indicators into their analysis and focus on material risks and opportunities, rather than relying on backward-looking[17] indicators such as carbon footprints and financed emissions.

While transition finance is substantially aligned with and considered as a theme of green finance by the ICMA, it is also distinct in important ways. This distinction presents both opportunities and challenges for expanding finance to Southeast Asia's just and orderly transition to a low-carbon economy. With the proper safeguards, transition finance can support pathways to long-term decarbonisation that preserve near-term economic development and commercial viability by channelling capital to:

- **Companies** that disclose and implement credible transition plans over time
- **Companies** in hard-to-abate and high-emitting sectors – like chemicals, construction, marine transport, aviation, energy, materials, and oil and gas – that are seeking financial support to adopt greener practices and reduce emissions, and in some cases, undertake R&D to develop new technologies for decarbonisation
- **Transition activities** such as fuel switching or energy-efficiency improvements, subject to credible guardrails including transition taxonomies/sector pathways to avoid carbon lock-in

While market interest in the concept of transition finance is growing, practical challenges remain. To avoid greenwashing[18] or carbon lock-in, investors need ways to evaluate and monitor the credibility and progress of transitioning entities and to demonstrate that projects contribute to real-world transitions rather than business-as-usual activities. This is especially important when transition plans depend on future technologies and processes that shift operations from high- to lower-carbon intensity assets that still involve residual emissions in the medium term and are thus not 'green, today'.

It is difficult to comprehensively categorise the investment characteristics and full range of time- and context-dependent opportunities inherent in transition finance. Various approaches have emerged, each focusing on different aspects of transition finance (Table 2.2). These include guidelines for corporate transition plan disclosure and assessment at the entity level from the EU (EFRAG, 2025), transition technology roadmaps at the sector level from Japan (METI, n.d.-a), and sustainable finance taxonomies incorporating 'traffic-light'[19] distinctions for determining transition eligibility at the asset and activity level (ACMF, 2024a).

[17] Investors use forward-looking indicators to predict what they think will happen in the future, while backward-looking indicators explain performance or outcomes that occurred in the past. While both are relevant for financial analysis, forward-looking data – as an indicator of future outcomes – are considered more material to market participants, i.e. more likely to influence capital allocation decision-making and hence drive price discovery. On the other hand, in efficient markets, backward-looking data are already 'in the price' and should therefore be less relevant to investors. Corporate transition plans are considered forward-looking as they describe a future intended state and attendant actions, while carbon footprints are backward-looking because they describe a historical condition.

[18] Providing misleading information, labelling, or claims about the environmental benefits of a company, activity, or investment.

[19] 'Traffic light' taxonomies are a classification system incorporating multiple levels of assessment for an economic activity's alignment with climate sustainability objectives, with an intermediate or transitioning category. These categories are typically indicated by green, yellow, and red; hence, the name 'traffic light'. This approach contrasts with traditional taxonomies, which focus on already aligned (green) activities only.

**Table 2.2: Example Guidance and Frameworks for Developing Transition Finance Standards**

| Organisation | Resource | Target | Link |
|---|---|---|---|
| ASEAN Capital Markets Forum (ACMF) | ASEAN Transition Finance Guidance | Financial institutions, investors, issuers | https://www.theacmf.org/initiatives/sustainable-finance/asean-transition-finance-guidance-v2 |
| Ministry of Economy, Trade and Industry (METI, Japan) | METI Transition Finance Policy Resources | Financial institutions, investors, issuers | https://www.meti.go.jp/english/policy/energy_environment/transition_finance/index.html |
| Financial Services Agency (FSA, Japan) | Asia GXC Initiative and Working Paper | Regulators, financial institutions | https://www.fsa.go.jp/en/news/2024/20241002-01/20241002.html |
| International Financial Reporting Standards (IFRS) Foundation | UK Transition Plan Taskforce Resources | Issuers | https://www.ifrs.org/sustainability/knowledge-hub/transition-plan-taskforce-resources/ |
| International Capital Market Association (ICMA) | ICMA Climate Transition Finance Handbook | Financial institutions, investors, issuers | https://www.icmagroup.org/sustainable-finance/the-principles-guidelines-and-handbooks/climate-transition-finance-handbook/ |
| Climate Bonds Initiative (CBI) | Financing Credible Transitions White Paper | Investors | https://www.climatebonds.net/resources/reports/financing-credible-transitions-white-paper |
| G20 Sustainable Finance Working Group (SFWG) | Expectations for Real-Economy Transition Plans | Financial institutions | https://www.gfanzero.com/our-work/financial-institution-net-zero-transition-plans/#real-economy |
| Glasgow Financial Alliance for Net Zero (GFANZ) | 2022 G20 SFWG Transition Finance Framework | Regulators, financial institutions | https://g20sfwg.org/wp-content/uploads/2023/12/TFF-2-pager-digital.pdf |
| Organisation for Economic Co-operation and Development (OECD) | Guidance on Transition Finance | Policymakers, financial institutions, investors, issuers | https://www.oecd.org/en/publications/oecd-guidance-on-transition-finance_7c68a1ee-en.html |
| Asia Transition Finance Study Group (ATF SG) | ATF Activity Report and ATF Guidelines | Policymakers, Regulators, Financial Institutions | https://www.atfsg.org/uploads/report/files/645-1723430169.pdf |

GX = Green Transition.

Source: Authors' compilation.

## 2.3.3. Context dependency leads to product diversity

Transition finance is inherently context dependent. For market participants and policymakers, the term transition has various interpretations and exists simultaneously as a market theme, a financial product label, and a method of analysis. These generally fall into two categories: "Use of Proceeds" style bonds and loans that fund specific transition-related activities, projects, and assets such as Transition Bonds/Loans and Transition-Themed Green Bonds/Loans, and "Sustainability-Linked" Bonds/Loans that can be used to fund general corporate purposes by transitioning entities such as in hard-to-abate sectors (Table 2.3).

**Table 2.3: Sample Financial Market Instruments for Transition Finance**

| Financial Instrument | Description and Typical Sectors | Use of Proceeds / Structure | Global standards or principles? |
|---|---|---|---|
| Transition Bonds<br><br>Transition Loans | Bonds and loans for financing transition assets or projects that are not already net zero aligned but that credibly contribute to improving environmental performance over time<br><br>Often financing for companies in Hard-to-Abate and High-emitting sectors that do not have a sufficient pipeline of green assets and projects for green financing | **Use of Proceeds** for transition projects and assets<br><br>Typically reference official sector pathways or transition taxonomies | **No**<br>Alignment with national sectoral pathways and some transition taxonomies<br><br>ICMA Transition Finance Handbook financing for climate-transition mainly as a theme for Green Bonds and SLB, and recognises that some jurisdictions may opt to issue under a "Transition Bond" label[a] |
| Sustainability Linked Bonds (SLB) | Bonds where the financial or structural characteristics can vary depending on the issuer's achievement of predefined climate or sustainability goals, including Transition activities | **General corporate purpose**<br><br>Can provide more flexible fundraising for companies, particularly in hard-to-abate sectors or those that do not have large pipelines of green projects to finance. Often coupons feature step-up or step-down structures based on Climate and Sustainability performance | **Yes**<br><br>ICMA Sustainability-Linked Bond Principles (SLBP)[b] |
| Sustainability Linked Loans (SLL)<br><br>Sustainability Linked Loans financing Bonds (SLLB) | Loans (or bonds comprised of a portfolio of loans) that are linked to sustainability performance targets or other Green and Social (KPIs[c]), including Transition activities | | **Yes**<br><br>LSTA Sustainability-Linked Loan Principles (SLLP)[d]<br><br>ICMA Sustainability-Linked Loans financing Bonds Guidelines (SLLBG)[e] |

| Financial Instrument | Description and Typical Sectors | Use of Proceeds / Structure | Global standards or principles? |
|---|---|---|---|
| Transition-themed green bonds<br><br>Transition-themed green loans | Green bonds and loans with use of proceeds that may be considered transition-related in certain jurisdictions, such as nuclear power, emerging green technologies, and emissions avoidance or reduction-enabling activities, but that are not currently considered taxonomy-aligned.<br><br>In other cases, financing may be for achieving decarbonisation or significant improvements in resource efficiency for hard-to-abate industrial production processes, assuming no carbon lock-in, such as green steel or green cement, although these non-standardised cases are relatively rare. | **Use of Proceeds**<br><br>Projects and assets that are already aligned with global climate goals, typically based on ICMA principles or other taxonomy (e.g. European Union, Climate Bonds Initiative) but often not universally recognised as 'green' | **Yes**, but the ICMA has not defined a transition taxonomy, and transition-related use of proceeds is not universally accepted by sustainability investors as 'green'.<br><br>ICMA Green Bond Principles (GBP)[f] |

[a] ICMA (2023), 'Climate Transition Finance Handbook: Guidance for Issuers', Zurich: International Capital Market Association. https://www.icmagroup.org/sustainable-finance/the-principles-guidelines-and-handbooks/climate-transition-finance-handbook/

[b] ICMA (2024), 'Sustainability-Linked Bond Principles: Voluntary Process Guidelines', Zurich: International Capital Market Association. https://www.icmagroup.org/sustainable-finance/the-principles-guidelines-and-handbooks/sustainability-linked-bond-principles-slbp/

[c] KPIs are specific metrics or targets an SLB issuer commits to achieving as part of the SLB issuance process and are typically linked to changes in the bond's economic terms (e.g. coupon step-ups or step-downs) as an incentive to enhance interest alignment and accountability.

[d] Asia Pacific Loan Market Association, Loan Market Association, and LSTA (n.d.), 'Sustainability-Linked Loan Principles'. https://www.lsta.org/content/sustainability-linked-loan-principles-sllp/

[e] ICMA (2024), 'Guidelines for Sustainability-Linked Loans Financing Bonds', Zurich: International Capital Market Association. https://www.icmagroup.org/sustainable-finance/the-principles-guidelines-and-handbooks/sustainability-linked-loans-financing-bonds-guidelines-sllbg/

[f] ICMA (2025), 'Green Bond Principles: Voluntary Process Guidelines for Issuing Green Bonds', Zurich: International Capital Market Association. https://www.icmagroup.org/sustainable-finance/the-principles-guidelines-and-handbooks/green-bond-principles-gbp/

Source: Authors' compilation.

In the sustainable debt capital market, the main labelled instruments specifically used for transition finance are currently sustainability-linked bonds (SLBs) and transition bonds. However, most transition-aligned debt funding is still raised through green bonds and sustainability bonds. Additionally, there are a growing number of green bonds that include use-of-proceeds categories such as nuclear power or green-enabling projects[20] that some investors and jurisdictions consider as Green and Transition-aligned.

**Sustainability-linked bonds:** Unlike green and sustainability bonds, which follow a use-of-proceeds structure restricted to specific eligible project or asset categories, SLBs can be used for general corporate purposes. Distinct from use-of-proceeds bonds where issuers are required to publish allocation and impact reports, SLB issuers must set one or more key performance indicator (KPI) tied to the issuer's achievement of environmental, social, or other sustainability- and transition-related performance metrics. They should also report their performance against predefined sustainability performance targets, with results verified by an external party at least annually. Depending on whether these KPIs are met, the SLB's coupon rate may increase or decrease, providing issuers with a direct incentive to improve sustainability performance at the entity level. The flexible nature of SLBs makes them an attractive and inclusive financing option for issuers in hard-to-abate sectors that otherwise lack access to green financing. Investors also value SLBs for their potential to price in the probability that transition outcomes will be met, while directly incentivising issuers to fulfil their commitments.

Although SLBs are widely regarded by market practitioners as a solution for financing transitions, the market has faced challenges in practice. From the demand side, investors have raised greenwashing concerns over some issuers setting unambitious KPIs – sometimes with targets that have already been achieved at the point of issuance or that impose only marginal costs in case targets are missed. From the supply side, issuers argue that investors do not adequately reward ambitious KPIs with lower financing costs, and that the step-up coupon mechanism can penalise them for missing targets even for circumstances beyond the issuer's control. In terms of structural challenges, the variable coupon structure linked to KPIs can be difficult for even sophisticated investors to price accurately, leading some institutional investors to avoid SLBs due to the increased operational complexity and portfolio valuation challenges.

**Transition bonds:** Transition bonds are a type of labelled bond that, like green and sustainability bonds, typically follow a use-of-proceeds structure. The proceeds are allocated to projects and activities that enable a high-emitting issuer to transition towards lower greenhouse gas emissions. Eligible project categories are usually defined with reference to the issuer's transition plan, sector-specific decarbonization pathways, or official transition taxonomies, where available. These may include capital expenditures (CAPEX) to decarbonise existing infrastructure, reduce the carbon intensity of operations

[20] Footnote: ICMA has provided guidance on Green Enabling Projects that are not generally considered green per-se but are critical to the value chain of green projects. Examples include copper or lithium mining for electrification and electric vehicle batteries, and the manufacture of grid power cables for renewable energy capacity expansion and integration. Investment in such projects may be considered Transition finance, because they are key to achieving environmental goals but are not necessarily categorized as green due to significant harmful impacts or high life-cycle GHG emissions. See: https://www.icmagroup.org/sustainable-finance/the-principles-guidelines-and-handbooks/green-enabling-projects-guidance/

and assets, or fund R&D for innovative climate solutions, particularly in hard-to-abate sectors. Transition bond issuers are expected to disclose detailed transition plans or strategies outlining how and when they intend to reach their transition milestones, with sufficient CAPEX and business planning to allow investors to assess the credibility and likelihood of achieving these transition goals. While transition bonds are mainly relevant to issuers in high-emitting sectors, they can offer a unique source of financing for infrastructure, and project types typically fall outside the eligibility criteria of traditional green finance instruments.

An important distinction is that transition bonds aim to help issuers progress towards greener operations over time without requiring them to meet fully green criteria from the outset. The use of proceeds may still fund relatively carbon-intensive processes or certain fossil fuel-related activities, particularly in hard-to-abate sectors such as steel and power projects.

For investors, the primary challenge lies in understanding what transition bond issuers are transitioning to. In the absence of clear and context-specific criteria for what constitutes a credible transition, transition bonds may simply fund business-as-usual activities in high-carbon industries with only marginal improvements. Ambiguity stemming from the lack of widely recognised transition standards has led to criticism and slow uptake of transition bonds by green investors, who often express concerns about the potential reputational risks associated with financing 'brown' activities,[21] in addition to technological, commercial, and stranded asset risks.

## 2.3.4. Regional approaches to transition finance

In Europe and North America, 'transition' is often viewed as an analytical and investment theme, addressed through existing green and sustainable financial products. It typically refers to an issuer's transition plan or strategy for decarbonisation over time, along with the necessary capital expenditures and other actions required to align with global sustainability goals. European markets tend to focus on issuer-level objectives and strategies rather than asset- or project-level activities. This is evident in European preferences for SLBs and sustainability-linked loans (SLLs), which focus on issuer-level decarbonisation performance over time. Additionally, several transition-themed green bonds[22] based on the established use of proceeds structure have been issued in hard-to-abate sectors, as well as for financing green-enabling activities and clean energy technologies such as nuclear, which in certain contexts is considered green.

[21] In the context of sustainable finance, 'brown' sectors commonly refer to industries associated with intrinsically high levels of greenhouse gas emissions or other environmental damage (e.g. oil and gas extraction or coal mining), while 'brown finance' refers to financial flows or other investments into these industries.

[22] Examples include green bonds issued in France (EDF), Canada (Bruce Power), and the United States (Constellation Energy) for financing nuclear energy projects, a use of proceeds that is considered green, transition, or ineligible for green financing depending on the jurisdiction and investor preference. In Japan, similar bonds financing nuclear power-related projects have been issued as transition bonds (Kyushu Electric).

In Asia, the transition concept builds on global approaches, with a focus on technology- and sector transition criteria or roadmaps. In some cases, this results in distinct transition labels. Asian transition finance tends to incorporate issuer-level disclosures alongside a stronger emphasis on clearly defining transitional activities and supporting technological innovation. Policymakers in Asia have taken a particularly active stance in developing sectoral transition pathways and taxonomies that formally distinguish transition investments from green investments. This approach has led to a greater emphasis on transition bonds, particularly in Japan and, to a growing extent, the PRC. In Southeast Asia, transition-related issuance in these sectors often takes place in the form of SLBs or use-of-proceeds bonds aligned with the ASEAN Green Bond standards.

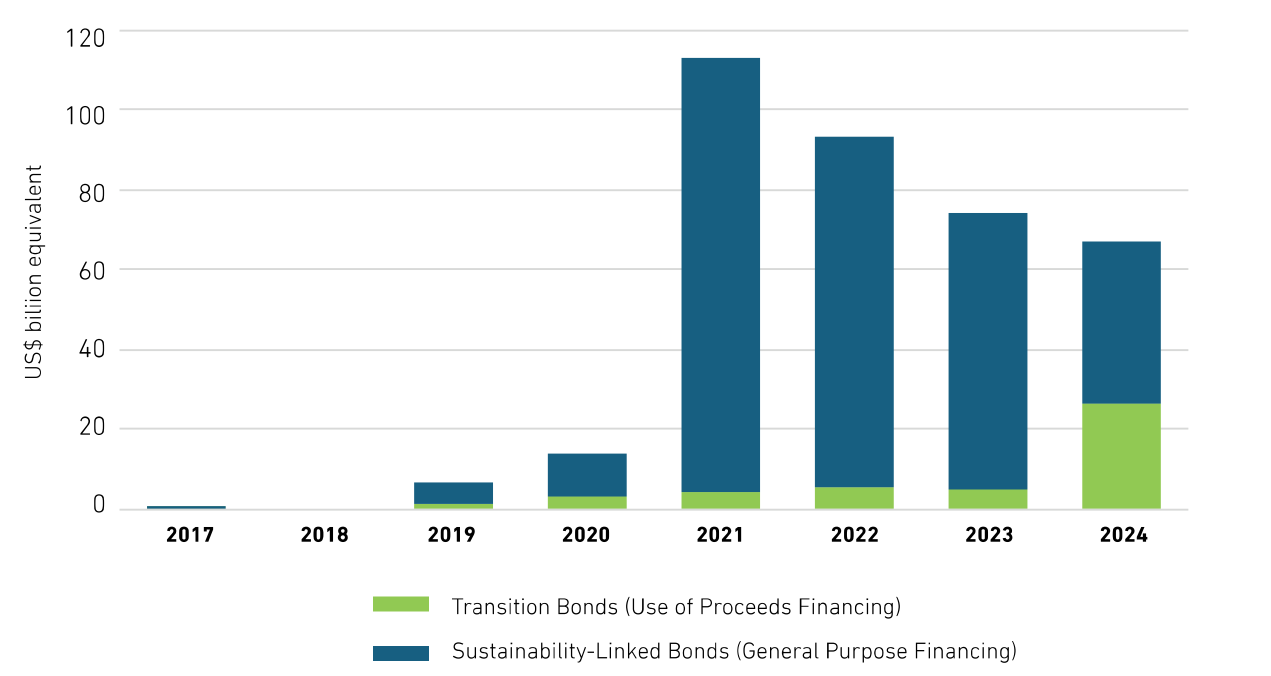
These regional differences reflect distinct economic structures, policy priorities, and levels of development. Europe's approach aligns with its advanced financial systems and regulatory frameworks, whereas Asia's focus on defining transitional activities responds to its continued increase in population and rapid economic growth, higher share of manufacturing, fossil fuel dependency, and more immediate just transition considerations. Ultimately, these variations underscore that there is no single, uniform pathway for financing transition – diverse approaches are necessary to accommodate regional realities while collectively advancing global climate goals.

## 2.3.4. Landscape of transition finance in the debt capital market

Transition finance encompasses both bank lending and public markets. In the debt capital market where information is publicly disclosed, the introduction of the ICMA's Sustainability-Linked Bond Principles in 2020 contributed to a surge in SLB issuance, which exceeded US$100 billion in 2021. However, annual volumes have since declined, partly due to concerns about greenwashing and the credibility of KPIs. While still a relatively large segment of the labelled finance market, SLBs and SLLs are not necessarily dedicated transition instruments: they are for general purpose financing and not tied to specific project types, may include KPIs unrelated to transition, and are not always issued with the sole intention of funding transition activities. These overlaps make it difficult to consistently track the development of the transition debt capital market based solely on sustainability-linked instrument issuance. Transition bonds,[23] while representing a smaller part of the market, are a growing and more directly observable form of transition debt capital markets with trackable use of proceeds and therefore form the basis of this analysis (Figure 2.6).

[23] The ICMA Climate Transition Finance Handbook (ICMA, 2023) noted that its guidance is intended for green, sustainability, or sustainability-linked instruments designated as a 'climate transition' bond, which may take the form of an additional 'climate transition' label.

**Figure 2.6: Global Issuance of SLBs and Transition Bonds, 2017–2024, Including Corporate and Sovereign Bonds**



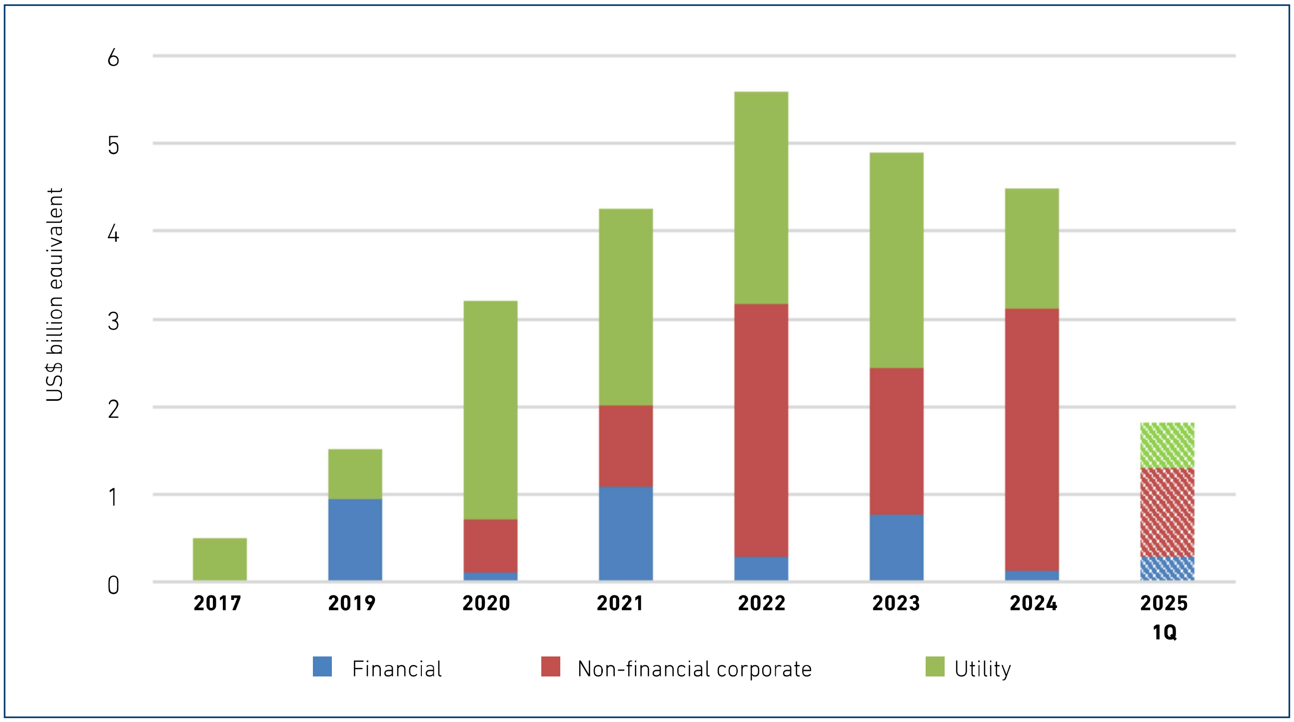

SLB = sustainability-linked bond.

Source: Bloomberg LP data based on issuance amounts as of 17 April 2025; authors' calculations and analysis.

Based on Bloomberg market data, the overall market for transition-labelled bonds grew at a moderate pace of US$3 billion–US$5 billion equivalent per year from 2017 to 2023, reflecting both the novelty of the transition label at the time and a lack of official guidance or standardisation. The first transition-labelled bond was issued in Asia by a subsidiary of an electric power company in Hong Kong, China in July 2017 to finance new combined-cycle gas turbine (CCGT) power plants for fuel switching. This was followed by a series of self-labelled transition bonds from Italian and United Kingdom (UK) natural gas utilities to upgrade pipeline infrastructure to hydrogen-ready standards, as well as PRC banks and industrial issuers in hard-to-abate sectors. Issuance during this period was often based on issuers' own bespoke transition frameworks for decarbonisation.

Standardisation in market practices improved with the introduction of the ICMA's guidance on transition-themed green instruments in 2020 and Japan's publication of transition sector pathways in 2021. Japanese non-financial corporate and utility issuers emerged as the main source of corporate transition-labelled bonds from 2022, resulting in a predominantly yen-denominated market representing 80% of issuance since 2023 (Figure 2.7). By 2024, annual issuance grew to more than US$26 billion equivalent as the Government of Japan began issuing Japan Climate Transition Bonds (Box 2.5). At the same time, European market preferences for transition finance in the debt capital markets shifted to SLBs, and all early European adopters of transition-labelled bonds have since switched to the ICMA-recognised SLB labelled format. On the other hand, in April 2025, the Government of Canada led by Mark Carney announced a policy commitment to issue transition bonds as part of its policy agenda, with the first issuance expected for 2027. Developments such as these indicate that the 'labelled' transition debt approach for high-emitting and hard-to-abate sectors remains relevant to issuers and investors outside Asia.

**Figure 2.7: Global Annual Issuance of Corporate Transition Bonds by Sector, 2017–Q1 2025 (excluding sovereign issuance)**



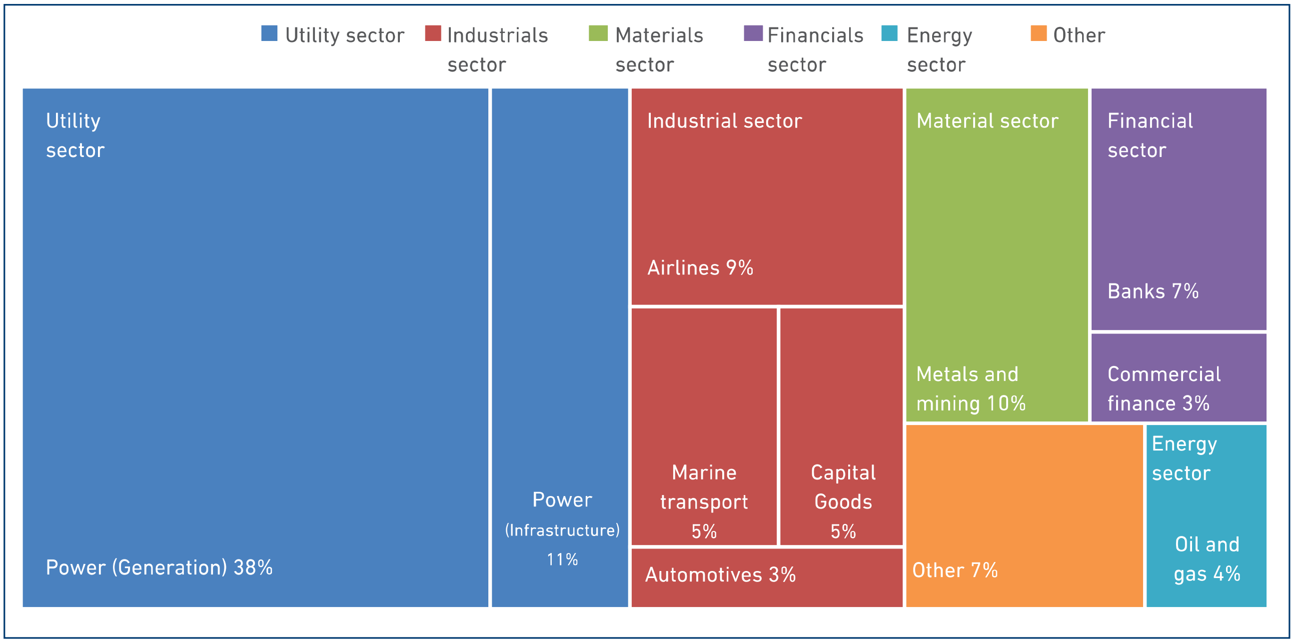

Q = quarter.

Source: Bloomberg LP data based on issuance amounts as of 31 March 2025; authors' calculations and analysis.

While transition-labelled bonds by issuance volume had only a small 2% share[24] of global green, social, sustainable, and other labelled (GSS+) bond issuance volume in 2024, they are more diversified across industrial non-financial sectors compared with traditional green bonds, which remain concentrated in financial sector issuance from banks and real estate (Figure 2.8). These sectors represent only 12% of transition bonds, which are almost entirely represented by non-financial sectors such as power generation and infrastructure utilities, steel and aluminium makers, airlines, marine transport, capital goods, and energy companies (Figure 2.9).

[24] United States dollar equivalent volume of transition-labelled bond issuance in 2024 as a percentage of total GSS+ labelled bond issuance. Source: Bloomberg LP data as of 31 March 2025, authors' calculations.

**Figure 2.8: Transition-Labelled Bonds' Cumulative Issuance by Corporate Sector, 2017–Q1 2025 (%, excluding sovereign issuance)**




Q = quarter.

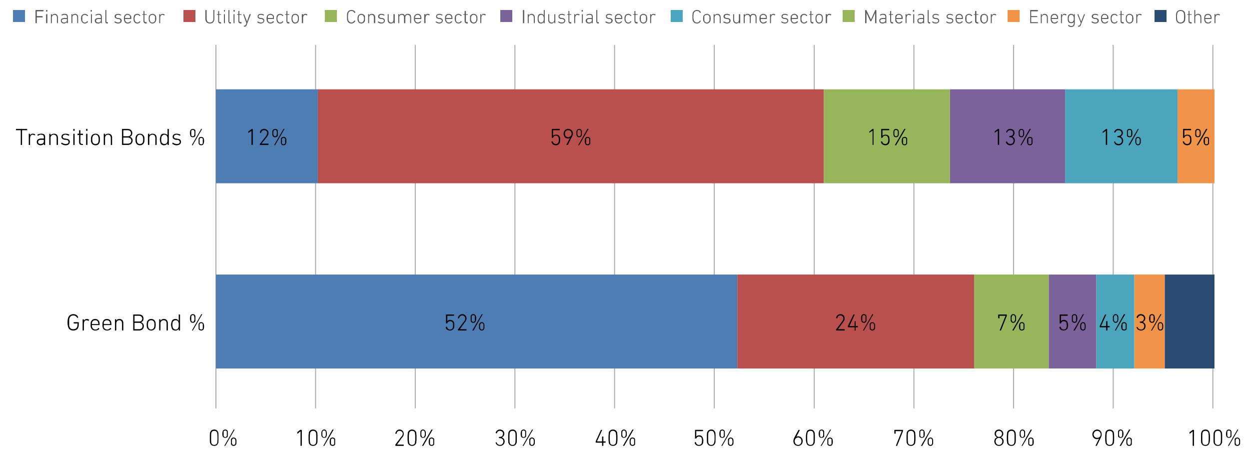
Note: 'Banks' include commercial banks and deposit-taking institutions. 'Commercial finance' includes non-bank entities providing business lending and other financing services such as leasing.

Source: Bloomberg LP data based on issuance amounts as of 31 March 2025; authors' calculations and analysis.

This stark difference demonstrates the potential for transition finance to diversify investor choices and channel capital to areas of the real economy that are typically excluded from green finance. At the same time, the relatively low number of financial sector transition bonds may represent an opportunity to grow the market through increased bank loan securitisation. Banks are already a crucial source of financing for transition sectors, and the development of a transition loan label by the Loan Market Association (LMA)[25] is under way (Hurley and Richardson, 2024). Several banks are already providing transition loans to high-emitting and hard-to-abate sectors in Japan. For example, Japan Airlines signed its first transition loan agreements with seven financial institutions in March 2023 to support the purchase of fuel-efficient aircraft. Meanwhile, the NYK Group secured its first transition syndicated loan in 2024, involving 21 financial institutions, including MUFG Bank, Ltd., to finance vessel upgrades and fuel conversion initiatives.

[25] The LMA and Asia Pacific Loan Markets Association updated the Sustainability-Linked Loan Principles in March 2025 to, amongst other things, distinguish the term 'transition' in the context of SLLs as 'supporting transition to more sustainable business practices', and therefore distinct from the concept of 'climate transition'. At the same time, the LMA is understood to be developing a distinct 'transition loan' label in 2025 in response to association member demand, although no formal announcement has yet been made.

### Figure 2.9: Global Issuance of Corporate Transition and Green Bonds by Sector, 2017–Q1 2025 (%, excluding-Sovereign issuance)




| | Green Bond % | Transition Bonds % |
|---|---|---|
| Financial sector | 52% | 12% |
| Utility sector | 24% | 59% |
| Consumer sector | 7% | 15% |
| Industrial sector | 5% | 13% |
| Materials sector | 4% | 13% |
| Energy sector | 3% | 5% |
| Other | 5% | 0% |

Q = quarter.

Source: Bloomberg LP data based on issuance amounts as of 31 March 2025; authors' calculations and analysis.

Developing an enabling regulatory environment with strategic policy frameworks will be key to creating capital market solutions for Southeast Asia's unique set of transition imperatives. Furthermore, much of Southeast Asia's borrowing activity occurs in the loan market, where global guidance on transition-labelled loans is at an advanced stage of development. The ASEAN Taxonomy for Sustainable Finance and the ATFG can also be applied to bank lending. Some regional banks have already begun incorporating the ATFG into their transition finance frameworks, and corporations have started developing their transition finance frameworks in accordance with the ATFG. Additionally, certain forms of financing instruments that align with transition objectives may qualify as transition finance, even if they are labelled differently, such as green bonds, SLBs, and SLLs, provided they share the common objective of promoting greenhouse gas emissions reductions.

## Box 2.5: Japan Climate Transition Bonds

First issued in 2024, Japan Climate Transition Bonds (JCTBs) are the world's first issuance of sovereign bonds for transition finance. Also known as green transition bonds or green transformation (GX) bonds, JCTB issuance is part of a 10-year plan for financing the country's transition to carbon neutrality by 2050 with ¥20 trillion of public funding for mobilising ¥150 trillion of private investment. GX bonds are an integral part of Japan's comprehensive GX strategy, a growth-oriented national plan for achieving economy-wide decarbonisation that emphasises economic resilience and energy supply diversification, reflecting the country's industrial structure and national circumstances.

A defining feature of Japan's approach is that, along with traditional investments in renewable energy and energy efficiency improvements, the strategy links Japan's carbon neutrality targets with industrial policy to emphasise the decarbonisation of hard-to-abate industrial sectors through technological innovation. The plan uses a phased-in approach to emissions regulation, with up-front disbursement of funds for industrial research and development and other early-stage inducements for Japan's high-emitting industrial sectors to achieve decarbonisation goals based on national transition sector roadmaps. This is to be followed by economy-wide emissions trading from FY2026 and fossil fuel surcharges beginning in FY2028.

Inaugural allocation reporting for the first JCTB issuance (Figure 2.10) shows that nearly half of the funding disbursements for cross-sector research and development (R&D) are through the Green Innovation (GI) Fund, followed by investments in ICMA Green Bond Principles categories such as energy efficiency and clean transportation (Financial Services Agency et al., 2024). The 2024 allocation report provides five case studies with analysis of the potential impact based on calculating emissions reduction potential at an economy-wide level from transition technology research and development funded by JCTBs.

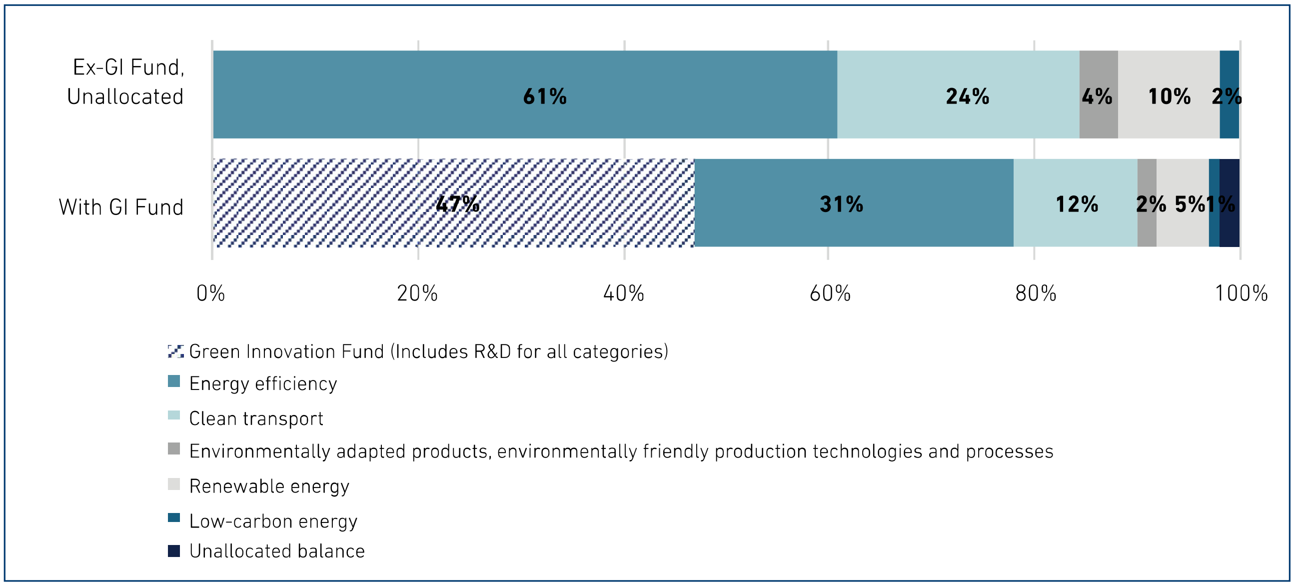
### Preliminary Five JCTB Impact Project Case Studies

| Research and Development | Capital Investment (including R&D) | Implementation Support |
|---|---|---|
| 1. Hydrogen Utilisation in Iron and Steelmaking processes | 3. Project for enhancing the resilience of Japan's power semiconductor supply chain | 5. Projects to promote the installation of advanced equipment and insulating windows to improve insulating performance and $CO_2$ emission reductions in the housing sector |
| 2. Decarbonisation of Thermal Processes in Manufacturing | 4. Project for enhancing the resilience of Japan's battery manufacturing supply chain | |

R&D = research and development.

Source: Financial Services Agency et al. (2024); authors' research.

**Figure 2.10: JCTB Allocation Report, FY2023 – Proceeds by Expenditure and ICMA Green Bond Principles Use-of-Proceeds Category**




GI = Green Innovation, ICMA = International Capital Market Association, JCTB = Japan Climate Transition Bond, R&D = research and development.

Source: Financial Services Agency et al. (2024); authors' calculations.

## 2.3.5. Why transition finance is needed in Southeast Asia

Southeast Asia is a rapidly growing region with increasing energy demand and a greenhouse gas–intensive industrial base that drives high-quality economic growth and employment. The region relies heavily on fossil fuels for about 80% of power generation, with 25%–35% of the economy in energy-intensive sectors (Bain & Company et al., 2025). Affordable and orderly decarbonisation of Southeast Asia's power sector is particularly challenging, as the region has a relatively young fleet of high-emitting coal-fired power plants, with an average age of less than 15 years, backed by long-term financial commitments with PPAs. The region faces challenges in accessing renewable energy due to its limitations in adequate areas with solar or wind resources, as well as mobilising finance for renewable energy and industry decarbonisation due to limited bankable projects, restrictive regulatory environments, and higher capital costs. Additionally, countries in Southeast Asia depend on fossil fuel resource extraction as a meaningful contributor to public finances and employment,[26] raising just transition concerns.

As a result, Southeast Asian economies face high exposure to carbon transition risks but lack the deep capital markets and technological access of advanced economies. Transition finance, through various types of financial market instruments, is well positioned to support an orderly decarbonisation pathway by funding gradual emissions reduction efforts while addressing the up-front costs and structural challenges unique to emerging markets.

[26] Direct job losses in ASEAN's coal, oil, and gas sectors could reach 3.4 million people by 2050 in an aggressive energy transition scenario (ACE, n.d.).

## 2.3.6. Benefits of transition finance for Southeast Asia

Expanding the market for green and transition finance can support Southeast Asian economies in achieving comprehensive and inclusive decarbonisation of the real economy, while simultaneously promoting sustainable growth and development. Transition finance offers several key benefits for Southeast Asian countries, particularly by supporting a just, inclusive, and pragmatic decarbonisation of hard-to-abate and high-emission sectors, which often require substantial up-front investment. The market for transition finance presents significant opportunities for the region in several ways:

**Addressing the region's financing gap:** IEA estimates of Southeast Asia's clean energy investment needs range from US$171 billion and US$185 billion per year from 2026 to 2030, and from US$208 billion and US$244 billion per year from 2031 to 2035 (IEA, 2023d). This transition from high-carbon to low-carbon energy systems will require significant funding for new and improved infrastructure to expand power supplies, decarbonise thermal power generation, and enhance the capacity and flexibility of renewable energy, particularly in the context of expected economic and energy demand growth in Southeast Asia. Encouraging transition finance can unlock additional financial resources for this development and growth.
Improving the competitiveness of industries: The region shares a large and growing component of the global supply chain. With many companies declaring to become carbon neutral, including their Scope 3 emissions, the companies and factories along their supply chain must also make the decarbonisation transition. To maintain and strengthen the region's economic competitiveness, it is crucial to support the decarbonisation of the industrial base as a whole, including hard-to-abate sectors.

**Achieving a just transition for workers:** The transition to a low-carbon economy will entail near-term costs and challenges for certain stakeholders. Additional investment will be needed for managing the social implications of this shift, including workforce retraining programmes, the creation of new jobs in the renewable energy sector, and support for communities and stakeholders affected by the shift – particularly in the context of phasing down fossil fuel extraction and power generation. A successful low-carbon transition will rely on holistic investment strategies that fund both technological advancements and innovations in social resilience for low-carbon growth and development.

**Supporting the transition to a low-carbon economy:** The global green finance market is relatively well developed, with funding allocated to projects that align with global sustainability goals. However, hard-to-abate and high-emitting industries are often neglected due to reputational concerns. With appropriate safeguards, transition finance can fill this gap and complement green finance by enabling informed investment decisions in these sectors, providing opportunities for all economic sectors to access funding, and ensuring that capital is directed towards projects with credible transition strategies to reduce greenwashing risks.

**Strengthening the role of the capital market:** Transition finance can support domestic capital market development through improved disclosure requirements. Financial market regulators in Southeast Asia, through the ASEAN Taxonomy Board (ATB) and the ACMF, have developed the ASEAN Taxonomy for Sustainable Finance and ASEAN Transition Finance Guidance, respectively, to enable gradual and credible transition over time that is relevant to each country's context while providing a framework for maximising interoperability with emerging global guidelines on transition. Adopting international sustainability disclosure standards, such as those developed by the International Sustainability Standards Board (ISSB), strengthens the role of capital markets as a key driver of economic transition. With better transparency and comparability, capital can be directed more effectively to projects that align with credible transition pathways, fostering investor confidence and supporting Southeast Asia's broader sustainability goals (Box 2.6).

**Box 2.6: Promoting Capital Markets for a Sustainable and Inclusive Southeast Asia**

Recognising the critical role of capital markets in addressing the transition financing gap in Southeast Asia – estimated at US$2.94 trillion by 2050 for the energy sector alone – it is essential to mobilise both public and private capital at scale. In this context, the Asian Development Bank (ADB) Green, Social, Sustainable, and Other Labelled (GSS+) Bonds Initiative for Southeast Asia, jointly implemented with the ASEAN Catalytic Green Finance Facility (ACGF) and the ASEAN+3 Asian Bond Markets Initiative, provides advisory support to catalyse flagship GSS+ bond issuances and foster an enabling ecosystem for sustainable finance across Southeast Asia.

To date, more than US$14 billion has been raised through local capital markets in the region. Notable examples include the pilot issuance of the Government of Thailand's sustainability-linked bond and the Electricity Generating Authority of Thailand's sustainability-linked bond, which targets reductions in greenhouse gas emissions to help meet national sustainability goals.

In parallel, ADB – supported by the ACGF – has been collaborating with the ASEAN Taxonomy Board (ATB) on the development of the ASEAN Taxonomy for Sustainable Finance, with version 4 expected to launch in 2025. The taxonomy serves as a common framework to guide and harmonise sustainable finance across Southeast Asian countries. It aims to direct capital towards climate-aligned investments and transition activities while accounting for national contexts and development needs. Importantly, it promotes interoperability and equivalence amongst national taxonomies and supports an orderly and just transition across the region.

Furthermore, ADB plays a pivotal role in promoting ASEAN capital market development and integration, positioning ASEAN as an asset class, and supporting capacity development for capital market regulators. Through its collaboration with the ASEAN Capital Markets Forum (ACMF), ADB supports the ACMF Action Plan in (i) strengthening ASEAN sustainable finance frameworks, including the green and sustainable finance taxonomy, transition finance guidance, voluntary carbon markets, and the ASEAN corporate governance scorecard initiative; (ii) promoting knowledge exchange and experience amongst capital market regulators to foster regional financial cooperation and cross-border capital market activities in Southeast Asia; and (iii) building capacity through dedicated trainings on various topics, such as the International Sustainability Standards Board (ISSB) Sustainability Disclosure Standards. In that context, the issuance of the ASEAN Transition Finance Guidance is a major recent achievement that complements the ASEAN Taxonomy for Sustainable Finance to provide a framework for assessing and demonstrating a credible transition within Southeast Asia to facilitate access to sustainable capital market financing.

Source: Authors (n.d.; 2019).

## 2.3.7. Addressing barriers to unlock the potential of transition finance

While transition finance can help channel additional investor capital to close climate finance gaps and diversify climate-related funding towards critical areas of the real economy – particularly hard-to-abate sectors – several challenges remain. These include varying levels of financial market development, differing national priorities, and diverse economic circumstances across Southeast Asian economies.

**Need for tailoring with contextually relevant official guidance:** No single transition pathway applies to all entities, as priorities, resources, and national circumstances vary significantly across regions and countries. This makes it difficult for market participants to assess the credibility of transition plans, which limits investor and issuer uptake. Given that different regions interpret the concept of 'transition' in varying ways, establishing a clear geographical and contextual basis – anchored in official guidance – is essential. Doing so can build market confidence in transition finance strategies, even as global convergence on standards and definitions remains limited.

To support this, there is a strong need for credible, science-based tools such as national and sectoral pathways, technology lists, and roadmaps with multiple options. These tools should be tailored to country-specific and industry-specific contexts, enabling investors and financial institutions to assess risks, opportunities, and impacts more effectively – while addressing concerns around greenwashing and transition-washing. The ASEAN Taxonomy for Sustainable Finance and the ASEAN Transition Finance Guidance are designed to fulfil this role, offering flexible, ambition-tiered frameworks aligned with the unique needs and development stages of Southeast Asian economies.

**Lack of scalable and bankable transition finance projects:** As transition finance covers a spectrum of activities and technologies leading to the goal of net zero, some projects may already be technologically and economically feasible and widely accepted as green on an asset level (e.g. deployment of renewables and EVs), whereas other projects may need more context regarding their timespan of development/deployment within the transition plan/strategy (e.g. hydrogen and fuel switching). These more nascent technologies may face challenges such as reputational risk in the near term and commercial feasibility/bankability risks in the long term.

While innovative transition technologies are critical for achieving economic decarbonisation across high-emission and hard-to-abate sectors, they often involve unproven technologies and complex supply chain investments with uncertain revenue models. These projects frequently face challenges in scaling up quickly, as investors perceive them as highly speculative and risky regarding financial returns, policy support, and technological development. Many transition technologies struggle to attract adequate support and financing at a reasonable cost due to the current lack of commercial viability and unproven business models, leading to ongoing difficulties in securing capital and investor backing. Regional cooperation and experience sharing, along with strategic, long-term policy commitments, could accelerate technological development, boost project bankability, and encourage large-scale deployment to break this cycle of underinvestment.

**Concerns about carbon lock-in:** As transition finance is by its nature a dynamic process, it is crucial to ensure that the endpoint of the investment does not lock in emissions. Therefore, government directions and roadmaps play a large role in providing clarity and predictability on how transition sectors such as power and other industries can progress towards decarbonisation. Where individual sectoral roadmaps are lacking, it may be useful to have a dialogue between the financing agencies and relevant government agencies to clarify the government's plans.

**Lack of forward-looking indicators:** A regulatory focus on 'backward-looking' indicators makes it challenging for investors and financiers to assess the full life cycle value of their climate investments. This can discourage investment in projects and assets that might temporarily raise an investor's reported financed emissions,[27] even if they contribute to long-term decarbonisation. Calculation methods that count emissions associated with transition finance separately, or other forward-looking metrics such as avoided emissions, should be considered.

**Need for forward-looking disclosure frameworks:** The existing frameworks for climate-related reporting, particularly in terms of performance, targets, and progress, do not fully address market needs. Although there is currently no global standard framework for reporting and assessment of transition activities and investments, several market-led initiatives have emerged to define approaches for evaluating the credibility of transition plans (Table 2.4). These may help shape future disclosure requirements for transition strategies, particularly the ISSB's ongoing work to integrate transition reporting in globally aligned sustainability disclosures through IFRS S1 and S2 standards.

**Table 2.4: Sample Guidance and Frameworks for Assessing Corporate Transition Plans**

| Publisher/Organisation | Guidance/Framework | Document link/reference |
|---|---|---|
| **World Benchmarking Alliance** | Assessing the Credibility of a Company's Transition Plan: Framework and Guidance | https://www.worldbenchmarkingalliance.org/research/assessing-the-credibility-of-a-companys-transition-plan-framework-and-guidance/ |
| **Climate Bonds Initiative** | Navigating Corporate Transitions | https://www.climatebonds.net/files/documents/publications/cbi_navcorptran_03b.pdf |
| **Institutional Investors Group on Climate Change** | Investor Expectations of Corporate Transition Plans | https://www.iigcc.org/resources/investor-expectations-of-corporate-transition-plans-from-a-to-zero |

Source: Authors' compilation.

[27] According to the Partnership for Carbon Accounting Financials, financed emissions are greenhouse gas emissions associated with the loans and investments made by financial institutions. These emissions are attributed to the financial institution based on its proportional share of the total financing provided to a company or project.

**Need for clearer policy framework to unlock transition finance:** Capital markets can mobilise finance quickly for a portfolio of projects over long payback periods, making bond investment particularly well suited as a complement to shorter-term bank financing for economy-wide transitions. However, the market for financial instruments, particularly transition or sustainability-linked bonds remains at an early stage of development due to the absence of clear national policies, sector-specific transition pathways, and well-defined eligibility criteria. While investor awareness and acceptance of transition finance as a necessary concept are growing, the market still lacks standardised and widely accepted financial products to channel such investments effectively.

Multilateral development banks and development finance institutions, in coordination with country regulators, can also play a role in pioneering and legitimising contextually relevant transition finance frameworks. These organisations can leverage their on-the-ground experience and technical expertise to assist in defining credible standards, providing technical assistance, and de-risking transition investments for local issuers and investors (Box 2.7). The involvement of these institutions can also signal credibility to market participants in regional transition finance markets, as investors may otherwise be discouraged from participating due to reputational or technical concerns.

### Box 2.7: Issuance of Asia's First Sovereign Sustainability-Linked Bond by the Government of Thailand and the First Sustainability Linked Bond by Thailand's State-Owned Power Generator

In November 2024, the Government of Thailand, through the Public Debt Management Office, issued the first sovereign sustainability-linked bond (SLB) in Asia and the Pacific and the third globally, with support from the Asian Development Bank (ADB) Green, Social, Sustainable, and Other Labelled (GSS+) Bonds Initiative for Southeast Asia.

The bond, with a 15-year maturity, raised B30 billion (US$880 million) and was more than 2.7 times oversubscribed by local and international institutional investors. SLBs are financial instruments whose characteristics can vary based on whether the issuer meets the predefined key performance indicators and sustainability performance targets. The bond aims to reduce the country's greenhouse gas emissions by 30% by 2030 compared with the business-as-usual level, according to the nationally determined contribution (NDC), and it targets an increase in Thailand's total zero-emission vehicles to 440,000 passenger cars and pickup trucks by 2030.

This transaction underscores the Government of Thailand's commitment to meeting international sustainability goals while balancing social and economic development. Thailand was the first country in Southeast Asia to issue a sovereign sustainability bond in 2020, and it has continued to demonstrate leadership by reopening the bond multiple times – bringing the total outstanding issuance to over US$12 billion in baht equivalent. The Public Debt Management Office has played a pioneering role in advancing Thailand's sustainable finance agenda, contributing significantly to the growth and credibility of the country's sustainable capital market. Its strategic issuance of sovereign sustainability and sustainability-linked bonds has not only mobilised substantial capital but has also set a strong precedent for other state-owned enterprises to follow.

Also supported by the GSS+ Initiative, one notable example is the Electricity Generating Authority of Thailand (EGAT), which is set to become the first state-owned enterprise in the country to issue an SLB. With support from ADB, EGAT has developed a sustainability-linked finance framework and plans to launch its inaugural SLB in September 2025.

By 2030, the bond's sustainability performance targets aim to reduce greenhouse gas emissions intensity for Scope 1 and 2 emissions by 30%. By linking its financial strategy with environmental performance, EGAT is accelerating investment in its transition efforts. This initiative contributes meaningfully to the country's sustainability goals, in alignment with Thailand's NDC, while ensuring energy security and affordability.[a]

[a] More information on ADB's GSS+ Initiative is available at ADB (n.d.).

Source: Authors

**Overly stringent selection criteria that constrain innovation:** The rigorous requirements set by the funds often make it difficult for many entities to qualify for transition finance, limiting access to much-needed capital for sustainable and low-carbon initiatives. Addressing this challenge is crucial to improving the uptake of transition finance and ensuring that a broader range of projects can contribute effectively to the region's sustainable development priorities.

## 2.3.8. Practical approaches to scale up transition finance in Southeast Asia

To ensure that the region can fully harness the potential of transition finance across both financial and capital markets, policymakers and financial market regulators should consider the following actions to address key barriers and accelerate progress:

**Introduce guidance and roadmaps tailored to the region:** Transition finance requires a deeper market understanding of the context of each fundraiser to effectively assess the risks and opportunities from corporate transition plans and investment in transition technologies. In Asia, the ASEAN Taxonomy for Sustainable Finance, ATFG, and Japan's approach to developing national sectoral technology roadmaps are good examples of context-specific guidance that promote a shared understanding of transition finance. To enhance market confidence and enable broader investor participation, financial market regulators should take the lead in developing additional country-level guidance to support greater interoperability and equivalence with the regional guidance and transition strategies.

With regulatory cover and common ground development, such guidance can help clarify expectations for financial institutions to support transitioning companies and for corporates to develop and disclose credible, forward-looking transition plans that are relevant and specific to local contexts. These plans should align with ambitious sustainability targets while considering each country's unique national circumstances, as well as the availability of financial and technological resources. It is important to note that while transition finance guidance and definitions should aim for interoperability across jurisdictions, the interim targets, metrics, and transition approaches will inevitably vary across sectors and countries. These differences reflect the diverse economic structures, development stages, and technological capacities within the region. As such, no single transition pathway or one-size-fits-all model applies universally. As recognised by the ATFG, transition strategies must be context-specific, allowing for flexibility while maintaining credibility and alignment with overarching net zero goals. To consider context specificity, it is crucial that financial institutions refer to the taxonomies/roadmaps applicable for the region they are financing, rather than climate-related regulations where the financial institution is based.

The development of such guidance has progressed but may still be nascent depending on countries or industries. In such cases, relevant national/regional roadmaps (e.g. government energy plans or long-term decarbonisation plans associated with nationally determined contributions (NDCs)) may also serve as interim references while the specific taxonomies/roadmaps are being developed.

### Box 2.8: ASEAN Transition Finance Guidance

The ASEAN Transition Finance Guidance was developed to address how entities may assess or demonstrate that transition initiatives are credible and bankable to obtain financing from capital markets in Southeast Asia, making use of relevant resources as needed. It aims to:

- Accelerate the efforts of financial institutions to direct finance to transitioning companies, as the tiering identifies which companies should be the focus of such efforts.
- Create incentives for real economy companies to develop more ambitious and credible transition plans by differentiating what commands a greater demand premium from investors.

The document does not aim to set a single standard for all Southeast Asian companies to transition. Instead, it provides a flexible framework that accommodates the diverse contexts and needs of different sectors and countries within the region through a tiered approach. This includes categories such as 'aligned and aligning 1.5°C', 'aligned and aligning well below 2°c', or 'progressing'. This flexibility ensures that companies at different stages of their transition journey can still access credible financing.

Source: Authors.

**Enhance data and sustainability disclosure standards tailored to the local context:** Companies require clear and comprehensive disclosures to illustrate their forward-looking transition pathways, and report their progress, including interim targets, to investors. Investors need substantial, forward-looking, and accurate information for investment analysis and capital allocation. Adopting global disclosure standards, such as the ISSB, aligned to local standards and along with comparable and high-quality emissions data and transition indicators, can enhance corporate reporting and improve market efficiency. Digital technology can greatly support the collection, monitoring, reporting, and verification of an entity's transition performance, which can then be reported to investors and policymakers consistently. This is especially critical for financial institutions in Southeast Asia in tracking the decarbonisation progress of their SME clients, many of whom are embedded in the supply chains of large corporations and publicly listed companies. These upstream firms, in turn, face growing expectations to disclose their climate strategies and achievements to investors. Leveraging digital solutions such as cloud-based data platforms can significantly improve the reliability and efficiency of transition-related disclosures.

### Box 2.9: Malaysia's Greening Value Chain Programme

At the 2022 United Nations Climate Change Conference (COP27), Bank Negara Malaysia, in partnership with financial institutions and strategic partners, introduced the Greening Value Chain Programme to assist Malaysian small and medium-sized enterprises (SMEs) in transitioning to greener operations. The programme provides technical guidance and on-site consulting services from participating organisations and transition financing through the Low Carbon Transition Facility. Participating SMEs will have the opportunity to measure, manage, and disclose their carbon emissions through a web-based climate technology platform. Corporate buyers and banks will be able to measure, track, and manage Scope 3 greenhouse gas emissions from the supply chain or financed emissions, preparing for environmental-related disclosure and regulations.

The programme will support banks in monitoring the climate performance of their sustainable financing activities and establishing credible and measurable key performance indicators for sustainability-linked financing. Bank Negara Malaysia will also require financial institutions listed on the Bursa Malaysia with market capitalisation (excluding treasury shares) of RM2 billion and above as of 31 December 2024 or as of the date of their listing to produce climate-related disclosures aligned with the International Sustainability Standards Board (ISSB) in phases starting in 2025.

Scope 3 emissions refer to all other indirect emissions that occur in the upstream and downstream activities within an organisation's value chain. These indirect emissions are not included in Scope 2, which covers indirect emissions from the generation of purchased energy, such as electricity, steam, heating, or cooling.

Source: Bank Negara Malaysia (2024).

**Promote innovative financing instruments for a sustainable and inclusive transition:** While the sustainable finance market in Southeast Asia, particularly the use of financial instruments like green, social, and sustainability bonds or loans, is relatively well developed, it remains insufficient to direct capital towards economy-wide decarbonisation efforts, especially for hard-to-abate and high-emitting sectors and SME borrowers through financial institutions. It is important for issuers and their advisers, where possible, to explore innovative approaches to label transactions according to international and/or regional standards, particularly the ICMA Green Bond Principles and Climate Transition Finance Handbook or the ASEAN Taxonomy for Sustainable Finance, which addresses hard-to-abate sectors, addresses the financing needs of SMEs, and incorporates flexibility through a multi-tiered 'traffic-light' system.

Furthermore, transition finance is also a critical tool for addressing both climate change mitigation and adaptation, particularly as entities develop their transition plans. Southeast Asia is highly vulnerable to physical climate risks like typhoons, floods, and sea-level rise, which directly threaten vital sectors such as agriculture, manufacturing, and tourism. Transition finance provides the capital needed to modernize infrastructure, relocate facilities, and build more resilient supply chains that can better withstand these climate shocks. By supporting high-emitting industries to decarbonize, it not only supports their long-term viability, but also helps them proactively prepare for future climate-related disruptions and contributes to a more sustainable and climate-resilient regional economy.

Policymakers can support the development of transition finance markets and innovative structures through sustainable market regulation reform and national strategies that recognise and define the role of transition based on national circumstances. Financial instruments that enhance capital flow to transition projects can include corporate and sovereign transition-labelled bonds, sustainability-linked bonds (SLBs), and sustainability-linked loans (SLLs). Early-stage tech start-ups focusing on R&D or product testing of new technologies to support industrial decarbonisation, which are not eligible for bank lending, should be able to access capital markets through crowdfunding platforms. Carbon credit markets, including high-integrity transition credits, can support the monetisation of carbon reductions in hard-to-abate sectors, such as initiatives for early coal-fired power plant retirement.[28]

### Box 2.10: Financing Climate Adaptation through Sustainability Bonds

The Provincial Electricity Authority (PEA) of Thailand was established in 1960 to procure and distribute electricity to consumers across 74 provinces, including underserved areas (except Bangkok, Nonthaburi, and Samut Prakan). It procures electricity from power producers, including the Electricity Generating Authority of Thailand and very small power producers.

Consistent with its overarching mandate, the PEA's strategic vision for 2024–2028 emphasises the digitalisation, modernisation, and greening of the grid. Concurrently, the PEA is developing a roadmap to attain carbon neutrality and net zero emissions, positioning itself as the infrastructure linchpin of a low-carbon economy and championing the proliferation of renewable electricity.

With support from the Asian Development Bank (ADB), the sustainability finance framework was developed to support the PEA's commitments to provide electricity access to rural areas, decarbonise its distribution network, provide solutions for greenhouse gas emissions reductions, and promote climate adaptation. Developed in alignment with the Association of Southeast Asian Nations (ASEAN) Taxonomy for Sustainable Finance – which provides opportunities to support projects that significantly contribute to environmental objectives 'beyond climate mitigation' – the framework includes the climate adaptation category. Under this category, the PEA will allocate proceeds for submarine cable extensions, supported by information and studies demonstrating how the projects can address climate risks by enhancing energy resilience on remote islands with the objective of increasing energy capacity and security for island systems, aiding in their adaptation to changing policies, and supporting economic growth and the well-being of residents and visitors amid climate change. A more stable electricity supply will support the operation of energy-intensive infrastructure, such as freshwater purification facilities, addressing remote islands' water crises and reducing dependency on fossil fuels for water transportation from the mainland.

Source: ADB (2024c).

[28] The Rockefeller Foundation and Global Energy Alliance for People and Planet announced the Coal to Clean Credit Initiative, which will set a comprehensive standard for the use of carbon finance to incentivise a just transition away from coal-fired power plants to renewable energy in emerging economies (The Rockefeller Foundation and Global Energy Alliance for People and Planet, 2023).

**Create fiscal and policy incentives for transition:** Policymakers can accelerate necessary market shifts through fiscal measures and policy support that give companies and relevant actors clear visibility on the national transition strategy and the motivation to contribute to its realisation through private investment.

Companies operating in hard-to-abate and high-emitting sectors should be given appropriate and practical guidelines to support the development and preparation of transition plans. A local governance platform similar to Japan's Task Force on Climate-related Financial Disclosures (TCFD) Consortium or regional initiatives like the Asia GX Consortium (AGXC), with support from the government, could be established to promote dialogue and experience sharing between the financial and non-financial sectors within and across countries to further discussion on effective and efficient corporate disclosure of climate-related information, transition strategies, and their use by financial institutions.

For early-stage companies developing transition technologies, government seed investments or grants can support R&D as well as the commercialisation of clean or transition technologies. For instance, Singapore's Start-Up SG Program provides grants and co-invests with private investors in start-ups, reducing financing costs and encouraging investment in transition technologies. Similarly, Japan's GX Acceleration Agency, established in 2024, offers financial support such as debt guarantees and equity investments to private companies undertaking GX investments, mitigating risks that private financial institutions are unable to fully cover. Expanding the role of carbon markets and carbon pricing can also support the commercial investment case for transition investments in hard-to-abate sectors.

**Implement blended finance and de-risking strategies:** Other financial instruments such as blended finance and concessional finance can mitigate risks, attract investment in sustainable projects, and help the region address the financing gap. One notable example is the Indonesia Just Energy Transition Partnership (JETP) and SDG Indonesia One, which aim to mobilise public and private financing to support energy transition infrastructure investment in Indonesia. To achieve scale, blended finance project design should focus on bankability, repeatability, and appropriate risk mitigation measures that appeal to private institutional investors.

**Strengthen technical and human capacity:** To facilitate the adoption of emerging regulatory requirements and address the complex challenges associated with transition finance – particularly the formulation of credible transition roadmaps and their effective communication to relevant stakeholders – it is essential to strengthen the capacity of key actors across the financial ecosystem. This includes financial market regulators, who play a critical role in setting standards and ensuring accountability; financial institutions, which must be equipped to assess, structure, and fund transition-aligned activities to all types of clients, including SMEs; corporates, which are responsible for developing and disclosing robust transition strategies; and users of transition-related information, such as institutional investors, which rely on transparent and consistent data to make informed investment decisions. Enhancing the capabilities of these stakeholders is critical to unlocking the full potential of transition finance in driving sustainable economic transformation.

**Encourage regional collaboration and partnership:** Regional collaboration and partnerships have shown substantial success in advancing transition finance within Southeast Asia. Various initiatives have been implemented and recognised by governments in the region, including the launch of the ASEAN Transition Finance Guidance and the establishment of the ASEAN Taxonomy for Sustainable Finance, both highlighted in the ministerial statement issued by the ASEAN Finance Ministers and Central Bank Governors (ASEAN, 2025). Moreover, collaborations with countries beyond the region, facilitated by forums like the Asia GX (Green Transformation) Consortium and the Asia Transition Finance Study Group (ATF SG), enable members to harness shared resources, knowledge, and expertise to further their sustainability objectives.

# Chapter 3

# The Energy Transition in Action

# 3.1. Illustrative examples

While several near-term technologies are in various stages of development – ranging from feasibility testing to successful commercial implementation – this report aims to highlight a select few that offer real-world opportunities and challenges. Additionally, it will provide a forward-looking perspective on the financial, technical, and policy-related factors that could help accelerate execution in Southeast Asia.

The technologies chosen (Figure 3.1) for this report represent a diverse mix of power and industrial solutions, spanning both fossil fuels and clean energy. They vary in the degree of challenges they present, addressing some of the most common issues that need to be overcome. While the list is not exhaustive, it is intended to serve as a representative sample that illustrates the current realities on the ground. This chapter focuses on the broader investment needs to support the energy transition in Southeast Asia, covering both green and transition-aligned technologies. Although transition finance is part of the picture, the discussion here is not limited to it. The aim is to present a representative set of technologies and investment needs that reflect real-world execution challenges and opportunities.

**Figure 3.1: Overview of Technologies and Case Studies**

| Investment theme | Technology | Illustrative example details: Sector | Country | Core challenge addressed: Financing | Technology | Policy-related | Project snapshot |
|---|---|---|---|---|---|---|---|
| Scaling-up Renewables | 1 Large Scale Solar | Power | Malaysia | √ | | √ | 2.26 GW project, commissioned from 2016 to 2021 |
| Building green-enabling infrastructure | 2 Grid connectivity & infrastructure | Power | ASEAN | √ | √ | √ | ASEAN Power Grid, existing ~7.7 GW, target ~17.6 GW by 2040 |
| Decarbonising hard-to-abate and high-emitting assets | 3 Thermal decarbonisation | Power | Indonesia Philippines | √ | | √ | Early retirement of CFPP of Cirebon and Mindanao CFPP |
| | | | Japan | √ | √ | √ | Trial of 20% ammonia co-firing at 1 GW Hekinan 4 plant |
| | 4 CCUS | Industry | Netherlands | √ | √ | √ | CCS hub to store 2.5 Mt $CO_2$ per year for 15 years, ongoing (2024-2026) |
| | | | Belgium Germany | √ | √ | √ | CCS in cement plants, LEILAC-1 and 2, the pilot plant |
| | | | Sweden | √ | | | Cost-bearing scheme for radioactive waste management |
| | | | United States | √ | | | US Tax Code on CCS improving the credit amount and scope |

| Investment theme | Technology | Illustrative example details | | | | | |
|---|---|---|---|---|---|---|---|
| | | Sector | Country | Core challenge addressed | | | Project snapshot |
| | | | | Financing | Technology | Policy-related | |
| | 5 Fuel switching | Industry | Japan | √ | | √ | Sumitomo Chemical Company switching to Gas for internal steam and electricity generation; intention to go 100% clean |
| | | | Sweden | √ | | √ | Stegra producing near-zero emission steel via H2-DRI, with production expected to start in 2026 |
| | 6 Green Mining | Industry | Mali | √ | √ | | Replaced legacy thermal power station with solar power (36MW), and lithium-ion battery energy storage (15.4 MWh) |

ASEAN = Association of Southeast Asian Nations; CCS = carbon capture and storage; CCUS = carbon capture, utilisation, and storage; CFPP = coal-fired power plant; $CO_2$ = carbon dioxide; H2-DRI = hydrogen-based direct reduced iron ; GW = gigawatt; LEILAC = Low Emissions Intensity Lime and Cement; MW = megawatt; MWh = megawatt-hour; US = United States.

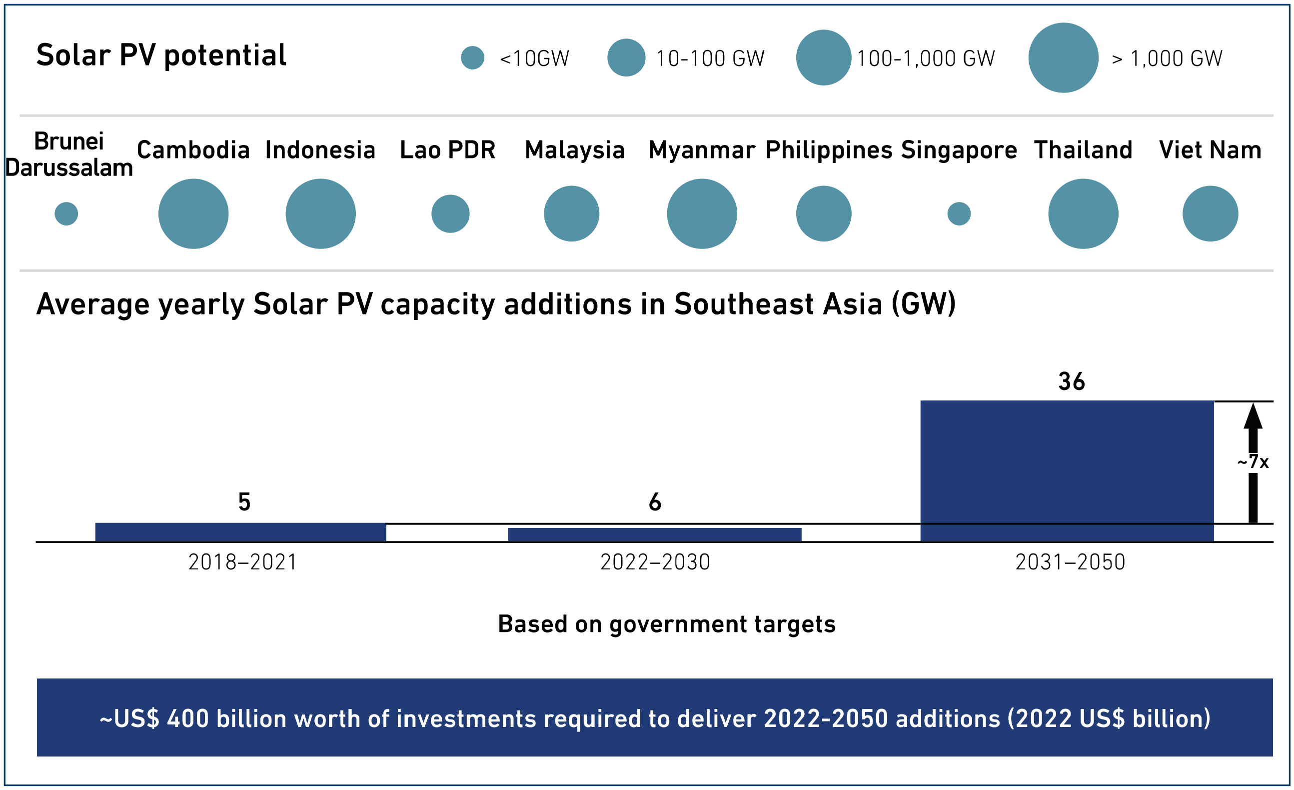
Source: Authors' compilation.

## 3.1.1. Large-scale solar PV

### The state of solar PV adoption

The solar energy potential in Southeast Asia far exceeds its current deployment. The region boasts an estimated 16 terawatts (TW) of solar energy potential (IRENA and ACE, 2022), yet as of 2023, only about 26 GW have been installed (Enerdata, 2023). Between 2016 and 2020, Southeast Asia has attracted one of the lowest levels of investment in solar photovoltaic (PV) and wind power, second only to Sub-Saharan Africa (IEA and Imperial College London, 2023). To meet net zero targets, it is estimated that annual renewable energy capacity additions must increase sevenfold for solar energy, from an average of 5 gigawatts (GW) per year between 2018 and 2021 to about 36 GW annually from 2030 to 2050 (Figure 3.2).

**Figure 3.2: Estimated Solar PV Potential and Average Annual Capacity Addition of Renewable Technologies in Southeast Asia (GW)**




GW = gigawatt, PV = photovoltaic.

Source: EDB (2024).

## Specific challenges of accelerating technology adoption

### Financing challenges

Renewable energy investments in Southeast Asia face significant financing constraints due to limited capital availability for early-stage projects, contractual and policy uncertainties, and grid capacity issues. These challenges, detailed in section 1.2.2 (Limited attractive investment and capital flow), hinder the mobilisation of capital from commercial and financial providers. Currency and inflation risk further complicate the investment climate.

### Country-specific examples

#### Indonesia

- **Policy-driven penalties:** The 'deliver or pay' scheme, where the state electricity company (PLN) pays independent power producers (IPPs) based on their availability to delivery electricity rather than the actual offtake, imposes penalties on IPPs if they fail to meet agreed availability or capacity requirements, which adds financial risk to projects (Yustika, 2024a).

- **Tariff and pricing issues:** The new ceiling tariff set by the government is considered too low, while the competitive bidding process, which rewards the lowest price, leads to unattractive tariffs, making it difficult to generate sufficient returns for investors (Yustika, 2024b; CPI, 2024a: 18).
- **State-owned enterprise financial constraint:** Electricity tariffs do not fully cover PLN's operating costs, requiring reliance on state capital injections. PLN is also mandated to purchase renewable power at higher prices than coal while supporting coal through a 25% domestic market obligation. With a majority coal-based fleet, PLN faces limited fiscal space to pursue power sector reforms or scale up clean energy investments, discouraging both PLN and IPPs from investing in renewables in the absence of direct subsidies.

**Viet Nam**

- **Cash flow instability:** The attractiveness of the renewable energy market is undermined by limited cash flow stability for developers, compounded by high curtailment risks. The shift from 20-year fixed feed-in tariffs to negotiation-based tariffs, which cannot exceed the ceiling announced by the government for the year, along with more variable calculation factors (e.g. solar radiation intensity) (Cooper and Nguyen, 2024), makes the financial outlook less predictable.
- **Grid and offtake issues:** The national electricity company, Vietnam Electricity (EVN), has the authority to curtail assets and only pay for the energy received, creating a further challenge for developers seeking reliable revenue. Additionally, the weak grid capacity in the country increases the curtailment risk (Le, 2022).
- **Currency risks:** Feed-in tariffs are denominated in the local currency, while financing often relies on the United States (US) dollar (Bo-yu, 2025), exposing them to exchange rate risks that could undermine profitability.

**Technical challenges**

Across several countries in Southeast Asia, technical challenges significantly impact the successful integration of renewable energy into the grid. As detailed in section 1.2.3 (Immature VRE integration system), these challenges include slow transmission infrastructure development, which delays renewable energy projects, and grid capacity limitations that lead to curtailment, reducing project profitability. A common challenge across this region is the delay in transmission infrastructure development, which affects renewable energy integration.
Country-specific examples

**Viet Nam**

- **Curtailment and grid congestion:** Viet Nam faces increasing curtailment issues, particularly in regions with high concentrations of solar and wind generation. This problem is more pronounced in the southern part of the country, where the density of solar farms is higher, leading to grid congestion (AMPERES, 2023).

**Policy challenges**

Across several Southeast Asian markets, investors and developers face substantial policy-related barriers that hinder the development of renewable energy projects. As detailed in Section 1.2.4 (Limited enabling policies), these challenges include complex and time-consuming permitting and licensing processes, unclear policy vision and governance, and uncertainty surrounding the terms of power purchase agreements (PPAs). Additionally, project developers must contend with challenges such as limited suitable land for project development and inconsistent policies, which increase investment risks and slow the development of bankable projects.

**Country-specific examples**

**Indonesia**

- **Regulatory complexity:** Current policies on renewable energy development, such as complex procurement procedures and overly restrictive local content requirements, often diminish investment attractiveness and hinder the acceleration of renewable energy deployment (Yustika, 2024b).
- **Implementation gaps:** While the government has set renewable energy targets, a clear and credible policy direction is lacking. State-owned utility PLN also faces resource constraints in accelerating renewable energy deployment, such as the lack of capital, internal budget limitations, and insufficient experienced personnel to handle renewable energy projects (Institute for Essential Services Reform, Climate Transparency, and Climate Emergency Collaboration Group, 2024).

**Philippines**

- **Land availability and conversion:** The country faces competition for limited suitable land for renewable energy projects as many potential sites are located near farmland or areas with established communities (G, 2025). In addition, land use conversion is a time-consuming process that involves multiple steps, such as barangay endorsements, public hearings, mayoral endorsements, and the issuance of development permits for civil works.
- **Development time lag:** The pre-feasibility study requirement adds significant delays (about 18 months), compounding issues with land consolidation involving local stakeholders (e.g. landowners, local government units, and the National Grid Corporation of the Philippines).[29]

**Thailand**

- **Inconsistent policy direction:** Renewable energy growth in Thailand is hindered by fluctuating government policies, including past bans on new renewables projects and recent suspensions (e.g. Phase 2 of the Renewable Energy Big Lot programme).[30]

## Case study: Large-Scale Solar (LSS) programme, Malaysia

The Large-Scale Solar (LSS) programme in Malaysia was introduced to accelerate solar capacity expansion. As the primary implementing agency, the Malaysian Energy Commission conducts competitive bidding for the projects. Under the programme, developers are required to build, own, and operate the plants, with a take-and-pay,[31] energy-only PPA for 21 years. The energy price is fixed throughout this period, and projects are connected to either the distribution network (for capacity under 30 MW t) or the transmission network (for capacity over 30 MW).

[29] Insights from expert interviews gathered in February 2025.

[30] Insights from expert interviews gathered in February 2025.

[31] The contracted capacity is fixed to that awarded in the auction, with increments or decrements not allowed under the PPA commercial structure. Under a build–own–operate concession scheme, energy contracts are take-and-pay, with the LSS developer paying an energy rate up to the LSS power plant's maximum annual allowable quantity.

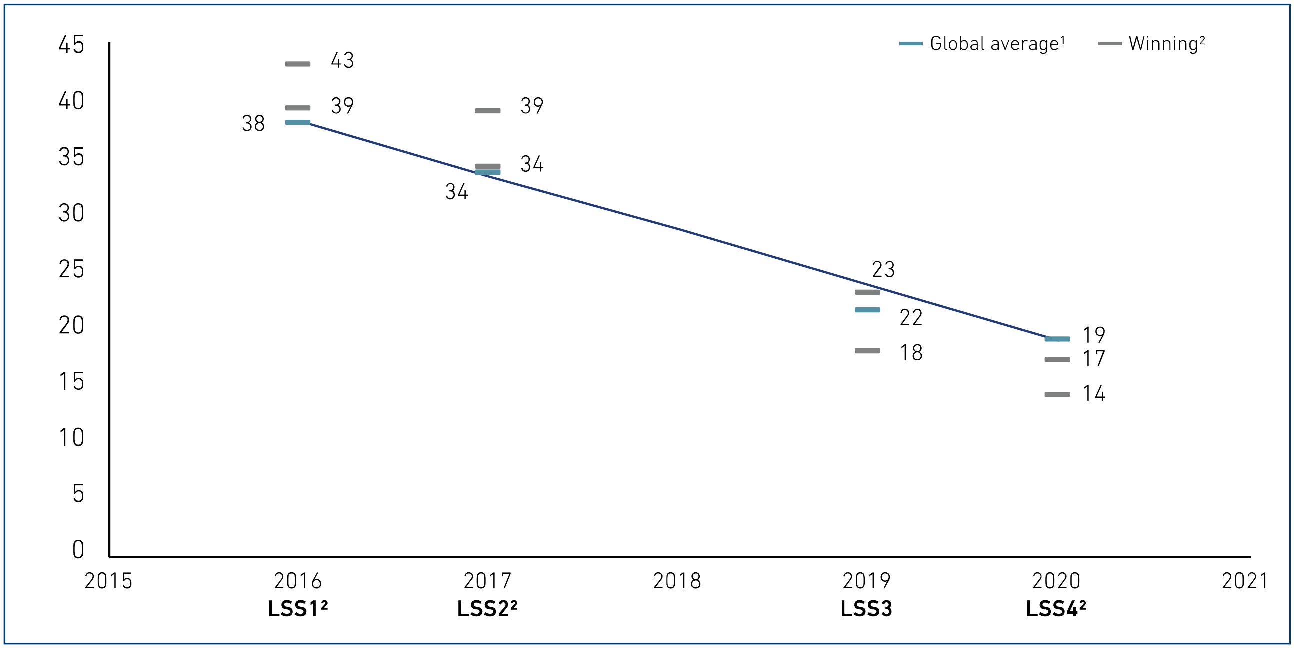
| Challenges | Solutions explored |
|---|---|
| Securing financing for renewable energy projects is challenging due to the high cost of capital and uncertainty on revenues, which affects their profitability and viability. | The programme has successfully attracted international investors, primarily due to the strong creditworthiness of Malaysian utilities.[32] The government has mitigated policy challenges by offering guaranteed 21-year offtake for projects. Developers are required to secure suitable land parcels for their solar plants, with the Malaysian Energy Commission overseeing the land acquisition process and ensuring compliance with regulations. |
| Land acquisition challenges include land availability, ownership and legal issues, regulatory hurdles, and lengthy approval and permit processes. | For solar plants under the LSS programme, the Energy Commission oversees the land acquisition process. Developers must secure suitable land parcels and ensure compliance with land use regulations and environmental impact assessments. Land ownership or a secured lease agreement is required to be eligible for project development.<br><br>The Energy Commission identifies specific 'connection nodes' in the transmission network where LSS projects can connect. Factors such as transmission line capacity and proximity to potential solar farm sites are considered. Developers are required to conduct technical studies to ensure their proposed connection point is feasible and meets grid requirements before submitting their projects for approval. |
| Malaysia's heavy reliance on fossil fuels (about 76% of installed capacity in 2016) made the transition to solar energy challenging. Solar power was initially less competitive and affordable compared with traditional fossil fuels. | The LSS programme has significantly increased the share of renewable energy in Malaysia's power generation mix, adding about 2 GW of solar capacity by 2023, up from just 300 MW in 2016. This has led to a notable reduction in the levelised cost of energy (LCOE) for solar PV, reaching about US$0.03 per kWh. This reduction aligns with global trends in solar PV auction prices. |

[32] Malaysian utilities are creditworthy. The country has three state-owned utilities – Tenaga Nasional Berhad, Sarawak Energy, and Sabah Electricity – which have monopolies in distribution and transmission in their concession areas. Tenaga Nasional Berhad has a local AAA credit rating issued by RAM Rating Services Ltd. and the Malaysian Rating Corporation. At the international level, it has a BBB+ rating issued by Standard & Poor's and an A3 rating issued by Moody's Investors Service.

## Impact

**Global competitiveness:** Malaysia's solar PV LCOE and its rate of decline have kept pace with global solar PV auction prices.

**Figure 3.3: LSS Programme Bid Prices (cents per kWh)**




kWh = kilowatt-hour, LSS = Large-Scale Solar, MW = megawatt.

Notes:

[1] Average auction value. Conversion based on the average United States dollar–Malaysian ringgit exchange rate of each year.

[2] Figures for 30–50 MW package in LSS 1, 10–30 MW package (Peninsular Malaysian) in LSS 2, and 30–50 MW package in LSS 4. Lower limits based on official reports. Upper limits based on industry expert input.

Sources: IRENA (2025a); Energy Commission of Malaysia (2025); and MIDF Research (2021).

**Manufacturing hub:** The country has become a major hub for solar PV manufacturing, with leading market players establishing a presence.

**Financial growth:** Malaysia has seen a tripling of sustainable debt issuance since 2022, reflecting a strong financial ecosystem and growing attractiveness for international investors. The power system and utilities are also on a solid financial footing.

## Recommendations for scaling adoption of solar PV

The key to scaling solar PV projects across Southeast Asian countries lies in leveraging well-structured policies, securing financing, enhancing grid infrastructure, and fostering local partnerships. As the region's market conditions vary due to differences in energy policies, economic development, the regulatory framework, and technical readiness, strategies need to be tailored to each market to fully realise the region's renewable energy potential.

**Policy and regulatory support**

- **Design well-structured auctions:** Implement auctions with guaranteed offtake to enhance investment security and create market confidence.
- **Streamline land acquisition:** Simplify permitting and land acquisition processes, with government support for securing land and conducting feasibility studies, to ensure a robust project pipeline.
- **Leverage local expertise:** Establish local teams and partnerships to improve foreign developers' ability to navigate market-specific challenges, such as land acquisition, permitting, and grid access, leading to more efficient and streamlined project development.
- **Engage in regulatory management:** Participate in policy discussions, public consultations, and regulatory forums to help shape policies that support renewable energy development and foster a more favourable investment environment.
- **Speed up permitting for transmission projects:** Expedite transmission permits and regulatory approvals to ensure timely integration of renewable energy projects. The Philippines provides a strong example through several reforms:
    - Certificate of Energy Projects of National Significance: grants priority processing and mandates simultaneous action by national and local permitting agencies for qualified renewable energy projects
    - Green Lanes for Strategic Investments: enhances ease of doing business by facilitating faster approvals, reducing bureaucratic delays, and improving coordination across government bodies
    - One-stop shops and permitting timelines: enable fast-track processing by setting time-bound approval windows and improving inter-agency collaboration
- **Expand offtaker base:** Enable direct PPAs between renewable energy developers and commercial and industrial consumers to reduce reliance on state utilities, which often face financial and grid capacity constraints.
- **Pursue bold, large-scale developments:** Support and incentivise large-scale projects that can attract significant capital, foster regional collaboration, and unlock new opportunities for the renewable energy sector.
- **Support distributed solutions:** Complement utility-scale projects with distributed renewable energy options such as solar-powered mini-grids, especially for remote or island communities.

**Technology support**

- **Target transmission buildout:** Focus on expanding and modernising transmission infrastructure to handle increasing variable renewable energy (VRE) generation.

**Financing support**

- **Expand financing mechanisms:** Introduce blended finance to reduce currency risks with local currency loans and make solar projects more attractive in less developed markets by sharing risks and increasing investor confidence through development bank involvement.

- **Narrow price gap between fossil fuels and solar PV:** Implement an appropriate carbon pricing scheme, especially in countries with high fossil fuel dependency (e.g. Indonesia and Thailand), to increase the cost of emitting carbon dioxide ($CO_2$) from fossil-based power generation, making solar a more cost-competitive alternative energy source, which enhances its attractiveness to investors.
- **Innovate financing and commercial structures:** Provide tailored financing options and commercial structures to suit various clients, from large corporations to industrial players.
- **Diversify investment portfolios:** Spread investments across different countries in the region to reduce risk exposure and enhance financial resilience, enabling sustained investor and developer presence to scale the deployment pipeline.
- **Develop risk mitigation strategies:** Build risk mitigation capabilities to address potential challenges, such as political instability, and explore innovative approaches to managing project risks.

## 3.1.2. Grid connectivity and infrastructure

### The state of grid connectivity in ASEAN

The ASEAN Power Grid (APG), a key programme of ASEAN Plan of Action for Energy Cooperation (APAEC) since 1999 (ASEAN, 1999), aims to integrate the region's power systems through cross-border interconnections, grid code harmonisation, and the establishment of regional institutions. It is expected to progress in three stages: (i) bilateral trade, (ii) subregional trade, and (iii) an integrated regional system.

The APG is divided into three geographic areas: the North System (Cambodia, the Lao People's Democratic Republic (Lao PDR), Myanmar, Thailand, and Viet Nam); the South System (Indonesia, Malaysia, and Singapore); and the East System (Brunei Darussalam, Indonesia, Malaysia, and the Philippines) (ACE, 2024a). According to the ASEAN Interconnection Masterplan Study (AIMS) III, 18 priority interconnection projects have been identified, aiming to increase the existing transmission capacity of 7.7 GW to 17.6 GW by 2040 (ACE, 2024c).

### Specific challenges of accelerating the development of the ASEAN Power Grid

#### Financing challenges

An estimated US$16 billion of capital investment is needed for the 18 cross-border grid interconnection projects (ADB, 2024a). Securing financing for these projects can be complex, especially for less developed ASEAN Member States (AMS). As mentioned in Section 1.2.2 (Limited attractive investment projects and capital flow), challenges include political uncertainties and perceived risks, which deter potential investors due to increased risk perception and financing costs. In most AMS, transmission infrastructure is primarily financed through the balance sheets of state-owned enterprises (SOEs), meaning financing capacity depends on the overall financial health of these entities rather than project-specific fundamentals. This structure also limits opportunities for private sector participation and project-based financing models (Kristiansen, 2022). Additionally, there is limited investment from private sector players and financial institutions, both domestically and internationally, in the development of APG projects.

**Country-specific examples**

**Cambodia**

- **Below investment grade rating:** Moody's Investors Service revised Cambodia's sovereign credit outlook from 'stable' to 'negative', while affirming its long-term issuer rating at B2 in April 2025 (Moody's Investors Service, 2025). The revision reflects Cambodia's high dependence on trade relations with the US and the downturn in its real estate and construction sectors. This could pose a potential barrier to attracting private capital for the grid interconnection projects.

**Lao PDR**

- **Below investment grade rating:** The Lao PDR holds a Caa3 credit rating from Moody's (as of 2024 (Cbonds, 2024), reflecting high external debt, limited foreign reserves, and currency depreciation (Ng and Yangsingkham, 2025), which necessitate significant multilateral and bilateral support to mitigate risks and attract private financing for projects.

**Thailand**

- **Financial vulnerability of SOE:** The Electricity Generating Authority of Thailand (EGAT), which operates Thailand's power transmission sector exclusively, accumulated substantial debt by the end of fiscal year 2022 due to the soaring cost of liquefied natural gas (LNG) used for power generation. This accumulation of debt could, in the long term, undermine its creditworthiness and hinder investments in expanding the transmission network leading to the APG project.

**Viet Nam**

- **Financial vulnerability of SOE:** Viet Nam's state-owned power corporation EVN, which exclusively operates the country's transmission network, recorded significant losses in 2022 and 2023. These losses were caused by rising fuel costs and fluctuations in exchange rates, which led to increased power generation expenses. This financial challenge may hinder the ability to secure funding for the grid interconnection projects.

**Countries with ongoing armed conflicts**

- **Ongoing armed conflicts:** Political instability has delayed energy projects and led to the exit of major energy companies, making it challenging for international financiers to assess risks and proceed with investments.

**Technical challenges**

Developing an integrated, multilateral power grid system that involves not only neighbouring regions or countries but also those separated by water bodies presents a myriad of technical challenges, which as mentioned in Section 1.2.3 fall under 'immature VRE integration' and 'limited technology advancement'. Developing an integrated, multilateral power grid system in Southeast Asia faces significant technical challenges, including grid code disparities, outdated infrastructure, and a lack of specialised knowledge for complex subsea cabling. Additionally, competition for high-voltage direct current (HVDC) cables from Europe and North America could delay APG projects. These issues highlight the need for coordinated efforts and investments to overcome technical barriers and integrate renewable energy into the grid.

**Country-specific examples**

**Lao PDR**
- **Limited, utility-led grid code:** The Lao PDR's grid code focuses on basic operational parameters and is primarily managed internally by Électricité du Laos (EDL) (Kiatgrajai, 2024), whereas detailed grid codes are approved and updated by regulatory bodies in other countries like Singapore and Thailand.

**Philippines**
- **Different system frequency:** The Philippines' system operates at 60 hertz, while other AMS use 50 hertz (Generator Source, n.d.). This necessitates frequency conversion infrastructure for future interconnections.

**Thailand**
- **Aging transmission line:** Thailand had to rehabilitate its aging transmission line to address lagging issues (Energy Commission of Malaysia, 2023) and ensure reliable power transfer for the Lao PDR–Thailand–Malaysia–Singapore Power Integration Project (LTMS-PIP).

**Policy challenges**

Stakeholders also face policy-related barriers to timely APG development. As mentioned in Section 1.2.4, the primary challenges fall under 'limited regional collaboration and interoperability' and 'limited enabling policies.' Differing energy priorities, the absence of a regional regulatory agency, and varying political will hinder cross-border energy trade. Additionally, regulatory and economic difficulties from different pricing mechanisms and the lack of a standardised wheeling charge complicate efforts. These challenges highlight the need for coordinated policies and regional collaboration.

## Case study: LTMS-PIP

The Lao PDR–Thailand–Malaysia–Singapore Power Integration Project (LTMS-PIP), which came into operation in 2022, is an arrangement that enables the Lao PDR to export up to 100 MW of hydropower to Singapore over a 2-year period using existing Thailand–Malaysia interconnections. It is the first multilateral cross-border power trading initiative in Southeast Asia across four countries and involves EDL, EGAT, Tenaga Nasional Berhad (TNB), and Keppel Electric. The LTMS-PIP serves as a pathfinder to enhance multilateral power trading beyond neighbouring countries towards realising the APG.

| Challenges | Solutions explored |
|---|---|
| The penalty for market participants under the rules of the Singapore Wholesale Electricity Market introduces unnecessary financial risks to wheeling countries. | Clearly define the roles and responsibilities of the seller, system operator, and importer of energy in the agreements.<br><br>Update the existing balancing mechanism and interconnections to cater for the new commercial energy flow under the LTMS-PIP.<br>Harmonise commercial settlement between participating countries. |

| Challenges | Solutions explored |
| --- | --- |
| The LTMS-PIP requires alignment and harmonisation with existing bilateral agreements that interconnect neighbouring countries under unique terms. | New agreements are made to supplement the existing bilateral interconnection agreement. |
| Singapore operates a liberalised power market, different from the single-buyer model in the Lao PDR, Thailand, and Malaysia. | A new web-based communication platform is developed to enable coordination between the market clearance in the Singapore Wholesale Electricity Market and system operators in the Lao PDR, Thailand, and Malaysia. The contract period is also kept short, at 2 years, to provide flexibility and reduce system and country risks (TNB, 2023). |
| EGAT transmission line began to lag due to ageing issues and needed to be rehabilitated. | Malaysia and Thailand share the rehabilitation costs of the transmission line (Energy Commission of Malaysia, 2023). |

## Impact

**Renewable energy growth:** The LTMS-PIP paves the way for the import and export of renewable electricity between AMS, driving the development and integration of renewables in the region.

**Energy security:** The cross-border renewable electricity trade diversifies Singapore's generation mix, reduces its reliance on fossil fuels, and builds resilience against fuel supply disruptions.

**Valuable experience for the broader APG initiative:** The success of the LTMS-PIP offers AMS valuable best practices and lessons learned in developing cross-border grid interconnections and multilateral power trade, laying the foundation for other APG projects.

## Recommendations for accelerating APG interconnection projects

### Financing and investment

- **Involve financial and commercial players:** Involve multilateral and national development banks, as well as international financial institutions, early in the process to enhance the viability and bankability of APG interconnection projects, since transmission projects in Southeast Asia are primarily financed through SOE balance sheets.

### Technology

- **Regulatory harmonisation:** Establish an institution that drives a regional regulatory framework covering elements like market rules and operational standards to enable efficient grid development and seamless energy trading amongst AMS.
- **Grid code harmonisation:** Consult national grid committees to define regional power trade requirements and update grid codes as more variable renewables are integrated to ensure the stability and reliability of cross-border grid systems.

- **Secure HVDC cable supply:** Pre-negotiate long-term procurement agreements with HVDC cable manufacturers to ensure production slots and explore joint procurement initiatives amongst AMS for better pricing and faster delivery.

**Policy and regulatory support**

- **Project of Common Interest designation:** Classify APG interconnection projects as Projects of Common Interest to signal stability, demonstrate long-term commitment, and reinforce regional priority, which will boost investor confidence and attract private sector funding.
- **Phased implementation:** Start with smaller or less complicated interconnection projects in neighbouring countries to build trust and expertise.
- **Standardised wheeling charge methodology:** Develop a common wheeling charge methodology based on four internationally recognised principles: promoting efficiency, recovering costs, ensuring transparency, and fairness and predictability.
- **Data-sharing platform:** Establish a standardised and reliable platform for real-time exchange of operational data across AMS to support regional power transactions and ensure coordination during system constraints.
- **Strengthen regional logistics and installation capabilities:** Invest in cable-laying equipment and workforce to reduce reliance on foreign contractors amid limited global availability.
- **Uniform mechanisms for settlement, payment, and dispute resolution:** Establish common rules and systems for pricing, payments, and conflict resolution to ensure fair transactions, reduce financial risks, and prevent power trade disruptions.

# 3.1.3. Thermal decarbonisation

## The state of thermal decarbonisation

In Southeast Asia, electricity generation remains heavily reliant on fossil fuels. Coal accounts for the largest share of the energy mix (30.5%), followed closely by oil (31.7%) and natural gas (19.7%). Despite the growing share of renewable energy in future projections, fossil fuels are expected to continue playing a significant role in meeting rising energy demand. According to the Baseline Scenario (BAS), fossil fuels are anticipated to remain the dominant source of energy in the region by 2050. However, the AMS Targets Scenario (ATS) presents a more optimistic outlook, suggesting that current policies could reduce the share of fossil fuels from 76.1% in the BAS to 63.4% by 2050. In more ambitious scenarios, such as the Regional Aspiration Scenario (RAS) and Carbon Neutral Scenario (CNS), the share of conventional fuels could decline further to 56.9% and 33.3%, respectively. In summary, while fossil fuels will continue to be a key energy source, it is essential to decarbonise these sources simultaneously alongside the growth of green renewable energy.

Thermal assets can be decarbonised via several potential pathways,[33] but many of these technologies remain economically unviable, technically untested in the region, and lacking sufficient policy guidance or financial support to enable widespread implementation. For example, combined-cycle gas turbines (CCGTs) emit 40%–50% less $CO_2$ than subcritical coal plants and, when compatible with hydrogen, align with Singapore's taxonomy for sustainable energy ('amber' rating). However, there is resistance to adopting gas as a transition fuel due to limited financing options for early coal plant retirement and concerns over the reputational risks associated with replacing coal with CCGT.[34]

**Figure 3.4: Decarbonisation Pathways for Thermal Assets**

| Decarbonisation pathways | | | Emission reduction potential (Low – High) |
|---|---|---|---|
| Retrofit | **CCGT + CCS** | Retrofit plant with CCS technology | |
| | **Coal + CCS** | | |
| | **CCGT + $H_2$ co-firing** | Retrofit plant to enable co-firing of hydrogen with existing fuel mix | |
| | **Coal + ammonia or biomass co-firing** | Retrofit plant to enable co-firing of ammonia or biomass with existing fuel mix | |
| Early retirement | **Replace with cleaner energy** | Early retirement of coal plant and replacement with cleaner energy (e.g. renewable energy, gas) | *High potential if replaced with RE |
| Coal avoidance | **Replace new build plan with gas** | Replace existing commissioned projects to build new coal with gas | |

RE = renewable energy, CCGT = combined-cycle gas turbine, CCS = carbon capture and storage, $H_2$ = hydrogen.

Source: ERIA (2022)

## Specific challenges of accelerating technology adoption

### Financing challenges

As mentioned in Section 1.2.2, the key financing challenge is 'limited attractive investment projects and capital flow':

- **Dependence on coal or gas as primary energy source:** Many AMS are heavily reliant on thermal fuels (coal, oil, and gas) for power generation. For instance, Indonesia, Malaysia, the Philippines, and Thailand have coal thermal power plants making up significant portions of their installed capacity. However, this trend is less pronounced in Cambodia, the Lao PDR, and Myanmar. This dependency makes the transition to renewables more challenging, both from technological and financial perspectives, as the transition requires substantial up-front investment in clean energy technologies.

[33] In addition to early retirement, retrofitting, and co-firing, the IEA highlights repurposing – such as reducing operations to focus on system adequacy or flexibility services – as a viable strategy to reduce emissions from coal-fired power plants. Converting coal plants into synchronous condensers or adapting them for industrial use can serve as a viable strategy to reduce emissions from coal-fired power (IEA, 2024a).

[34] A regional assessment from the ASEAN Centre for Energy highlighted that while coal-to-gas conversion is relatively straightforward, it 'requires huge investments in gas infrastructure' and faces barriers due to declining gas production and the abundance of domestic coal –making coal a preferred option in many AMS (ACE, 2024d).

- **Economic cost of early retirement of coal plants:** A major challenge in transitioning to cleaner energy is financing the early retirement of coal plants. Given the young age of coal assets in the region, early retirement of these assets is not yet economically viable. Many Southeast Asian countries incur high financial costs if they close coal plants prematurely, which are often still operating efficiently and generating significant revenue through long-term take-or-pay PPAs. The cost of decommissioning these plants stems from their outstanding debts and higher-than-expected returns.

**Financed emission concerns and reputation risk:** Despite project bankability (e.g. new build CCGT), transactions are not attractive for investors given the reputational risk and concerns over financed emissions given the high carbon footprint of thermal assets. Investor concerns should be addressed, highlighting the need to solve the energy trilemma while pursuing decarbonisation targets to support certain transactions.

**Country-Specific Financing Challenges**

**Indonesia**

- **High financial requirements for coal retirement:** Indonesia have a relatively young coal fleet, with an average age of 10 years (Figure 1.10). This is a challenge because younger plants typically have higher outstanding debts and more efficient technology, which makes early retirement more complicated. As a result, designing effective coal retirement schemes that balance financial, technological, and regulatory factors is crucial. Indonesia's Just Energy Transition Programme (JETP) has pledged US$20 billion in funding (JETP, 2023), but the Government of Indonesia estimates that US$600 billion is needed to retire 15 GW of coal capacity (Listiyorini and Dahrul, 2022) and replace it with renewables by 2050.

**Philippines**

- **Necessity of controlling electricity prices:** Electricity prices in the Philippines are higher than those of other AMS, making the refurbishment of power generation facilities – which could raise prices further – a significant challenge. This situation could hinder the adoption of new technologies that support the decarbonisation of power generation, which is generally associated with higher costs.

**Viet Nam**

- **High financial requirements for coal retirement:** In Viet Nam, many coal-fired power plants (CFPPs) are contracted under the build–operate–transfer scheme, with the government guaranteeing operational periods of 25–30 years. As a result, early retirement of these plants would require certain compensation. However, policy measures regarding such compensation have not yet been formulated. Future compensation policy measures could impose a significant fiscal burden depending on how the policy is structured, which could hinder the adoption of decarbonisation technologies for thermal assets.

**Technical challenges**

- To achieve a zero-emission future in power generation, several emerging technologies, such as ammonia and hydrogen as a fuel, must be developed and tested. As mentioned in Section 1.2, the key technical challenge is 'limited technology advancements':

- Emerging fuels like ammonia, hydrogen, and biofuels need rigorous feasibility tests and infrastructure development to ensure safe and efficient use in existing power systems. Establishing global supply chains and sustainable production methods is crucial for their integration. Since these fuels are more expensive than fossil fuels, advancements in production technologies and cost reductions are essential to make them economically competitive.
- Additionally, as solar PV, wind, and battery energy storage systems become more competitive and deployed, investments in cleaning coal production may not be repaid due to a lower revenue base from reduced coal energy consumption.

**Policy challenges**

Most AMS are still highly dependent on fossil fuels, especially coal, for power generation. With growing economies and rising electricity demand, governments face challenges in balancing thermal decarbonisation and the need to maintain energy security. Beyond funding for technical aspects of coal plant retirement, substantial efforts and resources are required to address the socio-economic consequences of this transition. As mentioned in Section 1.2.4, key areas of concern are around 'building a just and inclusive energy transition' and 'limited enabling policies':

- **Social impact of decommissioning coal plants:** Transitioning communities away from coal-based industries will require economic alternatives to coal mining and power generation. Local businesses and workers involved in coal-related supply chains (e.g. coal transportation, operation and maintenance, plant sub-suppliers, and electricity distribution) may face revenue losses and job cuts.
- **Energy affordability for vulnerable populations:** Governments must ensure that low-income households are shielded from disproportionate increases in energy costs as the shift to clean energy progresses.

**Country-specific examples**

**Indonesia**

- **Inconsistent policy signals:** Indonesia has committed to achieving net zero emissions by 2060 through its Long-Term Strategy for Low Carbon and Climate Resilience. However, the state utility PLN continues to prioritise CFPPs, especially mine-mouth CFPPs in regions with high coal reserves (ADB, 2021).
- **Regulatory barriers to early coal retirement:** While there is no formal prohibition against the early retirement of coal plants, the Ministry of Energy and Mineral Resources (MEMR) Regulation No. 5 of 2025 prevents ownership rights transfer before the commercial operation date (Situmorang and Mulia, 2025). Any share transfer after the commercial operation date will still be subjected to the PPA terms and conditions between the IPP and PLN, hindering the ability to repurpose coal assets to renewable energy facilities.
- **Lack of transparency and consistency:** While recent directives have aimed at increasing transparency, access to detailed plant-level carbon emissions data from CFPPs remains limited (Jong, 2024). Such inconsistent compliance poses a challenge to thermal decarbonisation as it slows policy implementation.
- **Inadequate carbon pricing:** Indonesia's carbon price is set at a minimum of Rp30,000 per tonne of carbon dioxide ($tCO_2e$) (Grant Thornton, 2024) or about US$2/$tCO_2e$, which is relatively low compared with other countries with similar schemes. Meanwhile, prices vary on Indonesia's carbon exchange (IDXCarbon) depending on the project type and credit origin (e.g. nature-based vs technology-based). Such price is contradictory to Indonesia's target for early retirement from coal.

- **Subsidies for fossil fuels:** Indonesia's Domestic Market Obligation (DMO) and Domestic Price Obligation (DPO) require 25% of domestic coal production to be sold within the country at a cap price of US$70/tonne set by the Ministry of Energy and Mineral Resources (JETP, n.d.). This policy creates artificially low prices for coal power plants during periods of high coal prices and is not aligned with the country's long-term sustainability goals.

## Case study 1: ADB's ETM

The Energy Transition Mechanism (ETM) is a blended finance mechanism designed by the Asian Development Bank (ADB) to incentivise the early retirement of CFPPs and other carbon-intensive power generation while accelerating the growth of renewable energy, grid modernisation, and energy storage. It uses concessional and commercial capital from various public and private sources, including governments, multilateral and bilateral development finance institutions, commercial banks, investors, the private sector, and philanthropies. In addition to its emphasis on the early retirement of high-emitting plants, the ETM also prioritises a just energy transition and the development of carbon markets to scale incentives for the accelerated retirement of coal-fired power generation assets.

At the 2021 United Nations Climate Change Conference (COP26), the governments of Indonesia and the Philippines and ADB announced a partnership to design and launch the ETM to accelerate the transition from coal to clean energy in Southeast Asia in a just and affordable manner. Work on pilot projects is ongoing in Indonesia and the Philippines, while initial activities in other countries are in various stages of progress, such as in Cambodia, India, Kazakhstan, Pakistan, and Viet Nam. This includes both asset level assessments as well as coordination on the national level feasibility study.

## Challenges and solutions

| Challenges | Solutions explored |
|---|---|
| **Energy security and affordability:** For any country, especially developing countries, energy security and affordability are paramount. A key challenge is to ensure the availability of clean energy that replaces retired coal plants, while keeping the replacement power affordable. | ADB typically begins with national feasibility studies to assess the cost-effectiveness of retiring CFPPs. At the asset level, grid impact studies are carried out to ensure that retiring a specific plant does not compromise the stability of the power supply in the region it serves.<br><br>Through the ETM and its regular financing programmes, ADB also supports the development of clean energy and the expansion of transmission infrastructure. |

| Challenges | Solutions explored |
|---|---|
| **Financing:** Retiring an operating, revenue-generating power plant early can be costly, and concessional financing to mobilise commercial capital for the ETM is limited. This must also address the risk of leakage, where early retirements are offset by new CFPPs elsewhere in the system – underscoring the need for robust policy safeguards and investment criteria that align with long-term decarbonisation goals. | ADB established a dedicated trust fund to pool concessional financing from governments and philanthropic sources in support of ETM transactions and technical assistance. To date, the ETM Partnership Trust Fund has received more than US$80 million in grant contributions from the governments of Germany, Japan, and New Zealand. The Global Energy Alliance for People and Planet has also provided financial commitments to support the ETM.<br><br>The ETM is pilot testing the use of carbon credits to help address financing gaps in early coal retirement transactions. ADB is developing a methodology for generating high-integrity carbon credits from such projects.<br><br>ADB is also exploring the establishment of an ETM funding vehicle – a blended finance, financial intermediary-like entity, designed to mobilise commercial capital and scale the ETM beyond ADB's own financial capacity. |

## Impact

Successful early retirement of CFPPs will demonstrate the feasibility of coal phaseout in Southeast Asia, a region that has the world's youngest coal fleet and faces rising energy demand driven by economic growth. It will also build momentum for other early coal plant retirements under ADB's ETM or similar mechanisms.

## Case study 2: Co-firing in Hekinan CFPP

IHI and JERA have conducted the world's first large-volume ammonia substitution demonstration test at JERA's 1 GW Hekinan No. 4 plant, replacing 20% of the heating value for coal with ammonia. For this trial, about 40,000 tonnes of grey ammonia were secured from the Japanese trading house Mitsui.

Building on the trial results, IHI plans to scale up the co-firing ratio to 50% and, eventually, develop a 100% ammonia burner. The necessary equipment for this process, including a large-scale ammonia fuel tank, has been under construction, installation, and testing since October 2022. JERA has also developed its own operational framework and safety protocols for the storage and use of ammonia on-site.

The trial focused on confirming the combustion characteristics of the ammonia-coal fuel blend, assessing the system's performance under fluctuating load conditions, and monitoring nitrogen oxides (NOx) emissions. Additionally, it aimed to observe the impact of the ammonia blend on fuel boilers and other equipment.

IHI and JERA plan to begin commercial operations with 20% ammonia co-firing at the Hekinan No. 4 unit as early as 2027, and to replace 50% of the heating value for coal with ammonia at the No. 5 unit targeted for the first half of 2030 (JERA, 2024).

## Challenges and solutions

| Challenges | Solutions explored |
|---|---|
| **Technology:** Ammonia is not currently used as a fuel for power generation. To realise a society where ammonia fuel can be used, various issues were addressed. | The project aims to develop high-ratio co-firing and single-fuel firing technologies to enable ammonia-based power generation. This will help meet the estimated domestic demand for ammonia, which is projected to reach 30 million tonnes per year by 2050.<br><br>As part of its ongoing efforts, JERA will conduct a comprehensive evaluation of the recent demonstration test's impact on the boiler and associated equipment. By March 2025, the company had completed the development of 20% of the ammonia co-firing technologies necessary to mainstream ammonia as a reliable and efficient fuel source in thermal power generation. |
| **Financing:** The high cost of ammonia production, transport, and storage makes it uncompetitive with conventional fuels, which could limit investor confidence in scaling the technology. | The project's primary goal is to reduce ammonia supply costs to about ¥10 per normal cubic metre ($Nm^3$) by 2030, aligning them with the calorific value of hydrogen. The government invests in import infrastructure at key ports (Shulman Advisory, 2024). |
| **Policy:** Investors need reassurance that ammonia co-firing will remain supported beyond 2030. | The Government of Japan positions ammonia co-firing as a transitional decarbonisation measure in its Basic Hydrogen Strategy, with the aim of shifting towards pure ammonia combustion in the longer term – a signal that helps reassure investors of the government's continued commitment to supporting the technology pathway beyond the pilot phase (METI, 2023). |

## Impact

This initiative resulted in positive environmental impacts. $CO_2$ emissions at the unit were reduced by about 20%. NOx emissions remained the same or were lower than the levels observed during coal mono-firing before the ammonia substitution. Sulphur oxides (SOx) emissions decreased by about 20%. Emissions of the potential greenhouse gas nitrous oxide ($N_2O$) were undetectable. Additionally, IHI and JERA confirmed that the unit's operability was maintained at the same level as before the transition to ammonia fuel.

## Recommendations for scaling the decarbonisation of thermal assets

### Financing support

- **Carbon credits:** Explore carbon credits as a funding mechanism for projects that enable the early retirement of CFPPs and their replacement with renewable energy, ensuring a just transition for workers and communities.[35] High-integrity carbon credits should be allocated to projects supporting coal plant retirement. The proceeds from credits can help mitigate forgone cash flows from retired plants, subsidise renewable energy replacement, and support the social and economic transition of affected communities.

[35] Verra approved a methodology in May 2025 that enables the quantification of climate benefits from the early phaseout of CFPPs, with provisions to support a just energy transition (Verra, 2025).

- **Blended financing options:** Engage donor countries and multilateral development banks to explore blended financing options for early coal plant retirement, following models like ADB's ETM.[36]

**Technology support**

- **Develop zero-emission fuel technologies:** Invest in the development of advanced technologies capable of utilising zero-emission fuels for power generation, such as ammonia, to support the decarbonisation of thermal power generation.

**Policy support**

- **Create conducive regulations for coal plant retirement:** Develop clear policies that support the early retirement of CFPPs and incentivise the transition to renewable energy. Indonesia recently issued MEMR Regulation No. 10 of 2025, which provides a regulatory basis for power sector decarbonisation by requiring PLN to assess the technical, legal, financial, and system reliability aspects of early retirement, with funding assurance as a prerequisite (UMBRA, 2025).
- **Carbon policies:** Implement a carbon market or tax system that encourages the removal of CFPPs and facilitates their replacement with renewable energy sources.
- **Address socio-economic impacts:** Policymakers and financiers should prioritise addressing the socio-economic concerns that arise from the transition, beyond technical aspects of coal retirement. This includes:
  - **Environmental restoration:** Provide funding for environmental restoration programmes to help affected communities find alternative economic opportunities to coal mining or power generation.
  - **Workforce training and subsidies:** Create mechanisms such as subsidies and workforce training programmes to ease the economic and social impacts on local businesses and supply chain workers (e.g. coal transportation and electricity delivery) who may experience job losses or revenue declines.
  - **Social service support:** Ensure continued funding for vital social services like healthcare, childcare, education, and small business support in regions impacted by coal plant closures.
  - **Affordable energy access:** As countries transition to cleaner energy, it is critical to protect low-income households and vulnerable populations from bearing an undue burden of rising energy costs during this period.

[36] Indonesia's ETM Country Platform facilitates these financing options (PT SMI, n.d.-a).

## 3.1.4. CCUS

### The state of CCUS

According to the International Energy Agency (IEA, 2021a), the region must deploy at least 200 $MtCO_2$ of capture capacity by 2050 to align with the Paris Agreement, requiring annual investments of about US$1 billion from 2025 to 2030. Indonesia and Malaysia are at the forefront of developing legal frameworks, financial incentives, and cost-reduction strategies, while other countries focus on research and development.

***At present, there are at least 24 carbon capture and storage (CCS) projects in Southeast Asia, 19 of which are led by Indonesia, with an estimated capture capacity of 9.84 million tonnes of carbon dioxide ($MtCO_2$)/year.***

**Table 3.1: Summary of Announced CCS Project in Southeast Asia**

| | Indonesia | Malaysia | Singapore | Thailand | Viet Nam |
|---|---|---|---|---|---|
| **Total Projects** | 19 | 2 | 1 | 1 | 1 |
| **Projects type** | 9 storages, 9 full chains, 1 capture | Full chains | Full chains | Full chains & storage | Offshore Oil and Gas |
| **Estimated Capacity** | 9.84 Mt $CO_2$/year | 3.3 Mt $CO_2$/year | 2.5 Mt $CO_2$/year | N/A | 71Gt $CO_2$ |
| **Announcement** | 2018–2024 | 2020–2022 | 2024 | N/A | N/A |
| **FID** | 2024–2025 | 2022 | N/A | N/A | N/A |
| **Operation** | 2025–2032 | 2025 | 2039 | N/A | N/A |
| **Industry** | 4 Storages; 2 Power Heats; 1 Other fuel transformations; Natural gas processing/LNG; | Natural Gas Processing/ LNG; | Hard-to-Abate sectors such as Energy & Chemicals, power and waste | Storage | Offshore Oil and Gas |
| **Fate of Carbon** | 9 Dedicated Storages; 5 EORs; 4 unspecified | Dedicated Storage | Storage, to be indentified | N/A | EOR |
| **Notable projects** | Gundih CCS, Sakakemang, Sukowati CCUS, Arun, Tangguh CCUS Hub | Kawasari, Lang Lebah, Shepherd | Establishment of S-Hub to develop cross-border CCS | PTTEP Arthit | RANG Dong |

CCS = carbon capture and storage; CCUS = carbon, capture, utilisation, and storage; EOR = enhanced oil recovery; FID = final investment decision; $GtCO_2$ = gigatonne of carbon dioxide; LNG = liquefied natural gas; $MtCO_2$ = million tonnes of carbon dioxide; PTTEP = Petroleum Authority of Thailand Exploration and Production Public Company Limited.

Source: ACE (2024b).

## Specific challenges of accelerating CCS adoption

### Financing challenges

For the countries in the region, financing availability is a serious challenge of CCS deployment in the region. As mentioned in Section 1.2, key challenges are mainly due to limited attractive investment projects and capital flow. High capital costs require significant up-front investment in capture facilities, transport infrastructure, and storage sites. The lack of a robust carbon pricing mechanism limits economic incentives for CCS, creating uncertain revenue streams and reducing investor appeal. Additionally, CCS cost projections for the coming decades are unlikely to be competitive, especially with the expected decline in renewable energy and storage costs.

### Country-specific examples

**Malaysia**

- **Lack of robust carbon pricing scheme:** Petronas has identified three definitive CCS hubs in Malaysia, including the Kasawari project in Sarawak (PETRONAS, 2023: 72–4). However, Malaysia has not yet implemented a comprehensive carbon pricing mechanism (Yeong, 2024).

**Indonesia**

- **Low carbon price:** Indonesia has a minimum carbon tax rate of Rp30,000/t$CO_2$e (Grant Thornton, 2024) or about US$2/t$CO_2$e, far below the projected CCS costs of US$50–US$130/t$CO_2$e for the power sector and US$19–US$105/t$CO_2$e for oil and gas projects (Pramesti, Abdullah, and Rakhiemah, 2025). This may shift early focus to low-cost, high-purity $CO_2$ sources like gas processing.

### Characteristics of Financing in Hard-to-Abate Sectors

The costs associated with CCS can be broadly divided into three stages: capture, transportation, and storage. While detailed comparative analyses by industry are limited, the capture stage is influenced by factors such as the concentration of $CO_2$ emissions and the characteristics of production and recovery processes. Accordingly, financing approaches may vary depending on these cost structures. In general, the higher the concentration of $CO_2$ at the emission source, the lower the cost of capture tends to be.

- **Cement industry:** The $CO_2$ concentration in cement production is about 15%–30% (IEA, 2019), which is lower than that in the chemical industry, making capture more costly. Amine-based liquid solvents are commonly used for $CO_2$ capture in cement manufacturing. Acidic components and fine particulates in the flue gas can reduce absorption efficiency, necessitating the installation of filters to condition the gas before capture – this increases capital expenditure (CAPEX). Additionally, high energy consumption and the need for solvent degradation and leakage management contribute to increased operational expenditure (OPEX). As a result, $CO_2$ capture costs in the cement industry range from about US$60 to US$120 per tonne (IEA, 2021b). Technologies are being developed to utilise captured CO2 as a raw material in cement production, which, if realised, could help reduce OPEX.
- **Steel industry:** The $CO_2$ concentration in steel production is about 21%–27% (IEA, 2019), which is lower than that of the chemical industry, resulting in higher capture costs. In integrated steel mills using blast furnaces and converters, $CO_2$ is emitted from multiple points in the production process. Capturing $CO_2$ from all these sources requires large-scale and complex equipment investments, increasing CAPEX. Consequently, $CO_2$ capture costs in the steel industry range from about US$40 to US$100 per tonne (IEA, 2021b). It is important to note that the steel industry faces intense price competition due to global oversupply, which constrains profitability and makes it difficult to pass additional CCUS-related costs on to product prices, thereby complicating cost recovery.

- **Chemical industry:** In major chemical production processes, $CO_2$ concentrations range from about 30% to 100% (IEA, 2019), making capture easier than in the cement and steel industries. However, chemical plants often have multiple emission points, each requiring its own capture units. Additionally, $CO_2$ purity may vary across equipment, necessitating the integration of specifications for transportation and storage infrastructure – this increases CAPEX. As a result, $CO_2$ capture costs in the chemical industry range from about US$15 to US$80 per tonne (IEA, 2021b). Technologies are being developed to utilise captured $CO_2$ as a feedstock for oxygen-containing compounds and other products, which, if realised, could help reduce OPEX.

As CCUS remains in the early stages of deployment across many industries, cost-related challenges are significant, and policy support is essential. For CAPEX, direct subsidies for equipment installation related to $CO_2$ capture and storage are one form of support. For OPEX, support mechanisms include price gap compensation between $CO_2$ processing costs and carbon prices, subsidies for transportation and storage fees, and tax credits based on the volume of $CO_2$ captured. These are examples from leading countries in CCUS policy development and can serve as references for other nations considering support frameworks for CCUS.

**Technical challenges**
Technical challenges significantly impact the successful adoption of CCS. As mentioned in Section 1.2.3, these challenges fall under 'limited technology advancement'. These include the complexity of developing large-scale transport, storage, and monitoring infrastructure, and the need for effective collaboration amongst emitters, transporters, and storage operators. Additionally, a robust measurement, reporting, and verification (MRV) methodology is essential to ensure $CO_2$ stays securely stored. Limited risk assessment strategies and a lack of pilot projects and technical expertise further slow adoption and increase costs.

**Country-specific examples**

**Indonesia**

- **Lack of CCS infrastructure:** Despite progress with its first full-chain CCS project at the Sukowati oil field (JAPEX, 2024), Indonesia's overall $CO_2$ transport and storage infrastructure remains in the early stages of development.
- **Underdeveloped MRV system:** A report on the Jepon-1 site at Gundih Field highlighted the need for a better MRV system to enhance both the quantity and quality of data, as the absence of such a system left a leakage incident unexplained (ACE, 2024b).

**Singapore**

- **Reliance on cross-border partnerships:** With no suitable domestic geological storage sites for CCS, Singapore will have to rely on cross-border partnerships (MTI, 2024) with neighbouring countries such as Indonesia and Malaysia, intensifying cross-chain coordination challenges for its emitters.

**Policy challenges**

Across several Southeast Asianmarkets, investors and developers face substantial policy-related barriers that hinder the development of CCS projects. As mentioned in Section 1.2.4, these challenges are primarily rooted in 'limited enabling policies.' These include the lack of a legal framework, insufficient support, and lack of social acceptance.

**Country-specific examples**

**Indonesia**

- **Regulatory gaps:** Indonesia's legal framework for CCS lacks clear $CO_2$ classification and purification standards, while its environmental impact assessment does not specify potential health considerations for humans and other organisms at storage sites (ACE, 2024b).
- **Lack of a comprehensive liability mechanism:** While Indonesia has signed agreements for the transport and storage of $CO_2$ from foreign sources, it has yet to fully align on liability allocation with partnering countries and companies.
- **Unclear incentives and labour constraints:** Presidential Regulation No. 14 of 2024 acknowledges the potential for tax and non-tax incentives to support CCS initiatives (Morgan, Ong, and Tan, 2024), though the exact details and rates of these incentives have not yet been finalised. Capacity constraints in skilled labour also pose implementation challenges.

**Malaysia**

- **Lack of a national framework:** The Land Code (Carbon Storage) Rules 2022, which regulate land use for $CO_2$ storage sites, only apply to the state of Sarawak, with no federal framework to supplement this regulation (ACE, 2024b).
- **Lack of a carbon pricing scheme:** Malaysia has no active carbon pricing mechanism but has plans to implement a carbon tax for the iron, steel, and energy industries by 2026 (Yeong, 2024).

**Singapore**

- **Limited grant coverage:** A US$55 million grant has been set up to fund eight feasibility study projects on CCS under the Low-Carbon Energy Research Funding Initiative (LCER-FI), but it only covers research, not up-front costs (ACE, 2024b).
- **Low carbon tax:** Singapore's carbon tax (S$25 in 2024 and 2025) (NEA, n.d.), the highest in ASEAN, remains low relative to most European countries (Mengden, 2025) and may not be sufficient to drive large-scale CCS investments without additional government support.

## Case study 1: Porthos, Port of Rotterdam

Porthos, the Netherlands' first large-scale CCS project, is financed by SOEs: Energie Beheer Nederland (EBN), Gasunie, and the Port of Rotterdam. Its infrastructure includes a collector pipeline running through the Port of Rotterdam, a compressor station for $CO_2$ pressurisation, and a pipeline to a North Sea platform, where $CO_2$ will be injected into a depleted gas field beneath the seabed. The project, serving Air Liquide, Air Products, ExxonMobil, and Shell, is set to begin $CO_2$ storage in 2026, capturing around 2.5 million tonnes annually and reaching a total capacity of about 37 million tonnes by 2042.

## Challenges and solutions

| Challenges | Solutions explored |
|---|---|
| The project cost has tripled since its inception due to delays from legal proceedings and inflation of raw materials prices. | The Government of the Netherlands will help Porthos' customers bridge the gap between the CCS cost and $CO_2$ price via the SDE++ scheme (Porthos, 2021). |
| Environmental groups challenged the project's exemption to bypass a full environmental assessment for nitrogen emissions during its build-up phase, leading to a court ruling that required a more detailed environmental assessment.<br><br>The project had to navigate the complex interplay of national and European environmental regulations governing CCS infrastructure. | Porthos conducted a more detailed nitrogen impact assessment while the government introduced new nitrogen reduction policies to support infrastructure projects.<br><br>The European Union (EU) and the government provided legal certainty for long-term $CO_2$ storage liability (European Commission, n.d.). |
| Designing and constructing a pipeline system capable of transporting liquefied $CO_2$ from the Port of Rotterdam to the offshore storage site poses significant technical challenges, e.g. navigating busy marine traffic and minimising environmental impacts on marine life and water quality. | Porthos conducted detailed spatial planning to address the complexities of constructing a large-scale pipeline system within the bustling port environment.<br><br>Environmental experts studied the potential impacts on marine ecosystems and developed risk mitigation strategies (Haskoning, n.d.).<br><br>Specialised pre-insulated piping solutions (Isoplus, n.d.) were deployed to ensure safe and efficient $CO_2$ transport. |

## Impact

**Boost for the Netherlands' climate goals:** Once operational, Porthos could contribute about 17% of the $CO_2$ reductions targeted for its industry in 2030.

**Foundation for future large-scale CCS initiatives:** As the first full-scale industrial CCS project in the Netherlands, Porthos sets a precedent for future CCS initiatives in Dutch industrial zones.

## Case study 2: Low Emissions Intensity Lime and Cement (LEILAC) Projects, Europe

LEILAC-1: A pilot-scale carbon capture project hosted by Heidelberg Cement in 2019 at one of its plants in Belgium. The project successfully separated 18,000 tonnes of $CO_2$ per year, demonstrating effective indirect calcination of limestone and raw meal, and direct separation of $CO_2$ process emissions (95% purity) without causing any negative impact on the host plant.

LEILAC-2: A demonstration carbon capture project to be hosted at Heidelberg Materials' Ennigerloh cement plant in Germany aiming to prove that its replicable module can efficiently capture up to 100,000 tonnes of $CO_2$ per year. Construction is scheduled to begin in 2025, with commissioning expected by mid-2026. Once commissioned, LEILAC-2 will be operated for up to 3 years to test and demonstrate the performance and operability of the technology.

## Challenges and solutions

| Challenges | Solutions explored |
|---|---|
| Difficult to secure funding in the early years of development | LEILAC received funding from the European Union's Horizon 2020 programme and collaborated with a consortium of industry and academic partners (Leilac, n.d.-a).<br><br>It also formed a joint venture with Heidelberg Materials for the LEILAC-2 project (Leilac, 2024). |
| Lack of harmonised legislative framework supporting CCUS markets across the EU | LEILAC engages in policy discussions and works with industry stakeholders and policymakers to push for a cohesive regulatory framework for CCUS deployment. |
| Carbon capture from industrial processes has not been widely adopted, mainly due to the low efficiency of traditional capture technologies, high technical complexity, and the need for plant-specific customisation. | LEILAC-2 will use a unique, indirectly heated calcination approach to keep unavoidable CO2 process emission separate from other exhaust gases, enabling direct capture at a higher concentration, reducing both capture cost and complexity. Its modular design will enable installations at new and existing cement plants without requiring major process changes (Leilac, n.d.-b). |

## Expected impact

Successful implementation of the LEILAC-2 project will achieve:

**Proof of concept:** Demonstration of a low-cost, replicable module that can efficiently capture up to 100,000 tonnes per year of unavoidable process $CO_2$ during cement and lime production.

**Scalability and transferability:** The LEILAC technology is designed to be delivered through a blueprint model for construction by local companies using local resources, enabling quick deployment at other operational cement plants.

## Case study 3: Sweden's Cost-Bearing Scheme for Radioactive Waste Management

A typical challenge in funding CCUS projects is to maintain and monitor stored $CO_2$ sites well beyond the $CO_2$ injection period. This shares similarities with the characteristics of radioactive waste management resulting from nuclear power generation. To maintain and monitor radioactive waste management over the long term, Sweden, for example, has developed a scheme that integrates the establishment and administration of a dedicated fund, periodic review of cost estimates, and the implementation of financial guarantees.

## Challenges and solutions

| Challenges | Solutions explored |
| --- | --- |
| It is necessary to establish a framework in which power producers bear the costs of radioactive waste management associated with nuclear power generation over the long term, without relying on future generations or taxpayers to bear these costs. | To ensure that future costs are covered, an independent account, the Nuclear Waste Fund, has been established.<br><br>Power producers contribute to the fund based on a predetermined fee per kWh of electricity generated. The fund is administered by an agency directly under the government.<br><br>The size of the fund's assets has grown over the years, reaching about SKr 82.9 billion (US$8.8 billion equivalent) at the end of 2024 (Swedish Nuclear Waste Fund, 2024).<br><br>Expenditures from the fund are strictly defined and limited to items stipulated by the government, such as waste management projects and power plant decommissioning.<br><br>Through this mechanism, the reserve has been used to implement radioactive waste management projects as planned. |
| Since the safe management of radioactive waste requires technology based on the latest knowledge and strict regulatory compliance, new costs may be incurred due to policy changes or tighter regulations. | The nuclear waste fee, which is the key element of the cost-bearing scheme, is subject to review according to changes in economic conditions and cost estimates.<br><br>The government reviews cost estimates every 3 years and revises the fee levels as necessary. In the latest review, the Swedish National Debt Office proposed a fee hike in response to an increase in the cost estimates of the Swedish Nuclear Fuel and Waste Management Company (SKB). As a result, the fee at Ringhals Nuclear Power Plant was raised significantly to about SKr0.09/kWh (US$0.9/kWh) in 2024 (MKG, 2023). |
| Since it will take many years to complete radioactive waste management, the risk of deterioration or bankruptcy of nuclear power plant operators during this period must be considered. If the nuclear power plant operators cannot continue to make stable contributions into the future, the sustainability of the cost-bearing framework could be undermined. | Each operator is obliged to post a deposit or collateral for the unpaid portion of future costs.<br><br>In cases where the amount of electricity generated is reduced due to earlier-than-expected reactor closure, resulting in a shortfall in contributions, or where the reserve fund is insufficient due to cost overruns or poor fund management, the deposit can be paid out to cover the shortfall. |

## Impact

The framework is designed to achieve both long-term safety and financial sustainability with respect to radioactive waste management.

## Case study 4: Amendment to Section 45Q of the US Tax Code

The US amended Section 45Q of the US tax code (Internal Revenue Code §45Q) in 2018 to promote CCS. Section 45Q, introduced in 2008, initially targeted the geological storage of $CO_2$. It was significantly expanded and revised under the Bipartisan Budget Act, 2018.

### Challenges and solutions

| Challenges | Solutions explored |
|---|---|
| The capture, compression, transportation, and storage of $CO_2$ require substantial capital investment and operational costs, making it difficult to recover investments under the previous credit levels of about US$10–US$20 per tonne. CCS at coal-fired power plants is estimated to cost tens of US dollars per tonne or more, and the lack of assistance has been an issue (Beck, 2020). | The 2018 amendment more than doubled the tax credit amount (Beck, 2020) and set a longer credit application period of 12 years (Internal Revenue Service, 2020), making it easier for private capital to recover its investment. |
| Prior to the amendment, eligibility was limited to large $CO_2$ emission sources that captured more than 500,000 $MtCO_2$ during a tax year (CRS, 2020).<br><br>This limited scope meant that $CO_2$ from medium-scale industrial facilities (e.g. ethanol plants, cement plants, and oil refineries) and DAC technology, which has been attracting attention in recent years, could not qualify for the credit, resulting in a narrow base for the expansion of CCS. | In the 2018 system design, the scope of application was broadened.<br><br>The revised thresholds allowed a wider range of facilities to qualify for the tax credit (CRS, 2020):<br>• Power plants are required to capture at least 0.5 Mt of $CO_2$ while other facilities can receive credits for capturing at least 25 kt of $CO_2$ per year.<br>• Direct air capture facilities qualify if they capture at least 0.1 Mt per year.<br><br>These adjustments have enabled a wide variety of facilities to participate in the CCS tax scheme. |

### Impact

The development of incentives has had the positive effect of giving new vitality to the stagnant US CCS industry and triggering a number of future projects.

### Recommendations for scaling CCS adoption

#### Financing support

- **Blended finance:** Scaling up CCUS and upgrading power infrastructure are both critical to Southeast Asia's energy transition. As renewable energy grows, investments in transmission systems, smart grids, and forecasting tools are needed to manage variability and avoid curtailment. These efforts, like CCUS, face financing challenges. Blended finance can help by reducing risks, attracting private capital, and supporting early-stage projects. Stronger collaboration with development and climate finance institutions will be essential to move these technologies forward and ensure reliable, low-carbon energy systems.

- **Revenue support:** Implement revenue support mechanisms such as carbon contracts for difference, tax credits, or fixed payments per tonne of $CO_2$ captured and stored. Domestic carbon pricing and markets can also complement these instruments by providing additional income streams that improve project bankability and attract private investment. In practice, stacking and combining multiple revenue streams – such as production tax credits, carbon pricing revenues, low-carbon fuel standard (LCFS) credits, and long-term offtake agreements – can significantly enhance financial returns and reduce perceived risks. This approach is increasingly used in markets like the US and Europe to strengthen the commercial case for CCUS and other emerging technologies (GCCSI, 2023).
- **Public–private partnerships:** Develop a clear public–private partnership framework to support large-scale CCS projects by sharing financial risks between governments and private investors. This approach can reduce costs for both sectors and make projects more viable (*Energy Industry Review*, 2024).

**Technology support**

- **Geological database:** Establish a geological data collection and sharing system amongst Southeast Asian countries to support the mapping of potential $CO_2$ sources and sinks.
- **Capacity building:** Leverage knowledge and best practices from experienced countries and global CCS networks to establish technical standards and develop effective risk assessment and management strategies.
- **Unified MRV system:** Agree on a common measurement unit and internationally recognised methodology for $CO_2$ accounting and tracking to ensure transparency, regulatory alignment, and carbon credit recognition in Southeast Asia's cross-border CCS projects.

**Policy support**

- **CCS regulatory framework:** Improve the CCS legal framework by defining and classifying $CO_2$; setting clear standards for environmental review, permitting, and responsibility allocation across the CCS chain; addressing transboundary challenges; and promoting harmonisation within Southeast Asia. Drawing on the United Kingdom (UK) model, this includes clarifying ownership of storage rights and instituting a regulated asset base approach for transport and storage infrastructure (UK Gov, 2020). The IEA also stresses the importance of policy coherence across ministries and jurisdictions, especially for cross-border $CO_2$ flows (IEA, 2023b).
- **CCS deployment targets:** Integrate CCS into national climate policy and long-term energy roadmaps while setting specific storage capacity targets to signal strong support for CCS development, provide investment predictability, boost confidence, and attract investors. The Global CCS Institute (GCCSI) highlighted that European CCS projects are increasingly linked to industrial decarbonisation strategies, with direct funding mechanisms (e.g. the EU Innovation Fund) and carbon pricing signals improving project viability (GCCSI, 2024). Southeast Asia can replicate this by aligning CCS with nationally determined contributions and embedding targets into energy transition pathways.
- **Public engagement:** Inform and educate the public about the applications and benefits of CCS technologies; address concerns about associated risks with evidence-based assessments and transparent communication.

# 3.1.5. Fuel switching

## Fuel Switching: Early Steps, Big Potential

Fuel switching is gaining attention across Southeast Asia as countries explore practical ways to reduce emissions, especially in energy-intensive sectors. The 8th ASEAN Energy Outlook (ACE, 2024a) highlighted the potential of emerging fuels such as hydrogen and ammonia in both the energy and transport sectors. While the report acknowledges their role in long-term decarbonisation, it does not present a clear roadmap or timeline for adoption.

Some countries in the region have begun to explore alternative fuels through pilot studies and feasibility assessments. These efforts include evaluating hydrogen and ammonia for power generation and industrial use, as well as expanding natural gas in sectors that are still heavily reliant on coal. For example, Singapore and Thailand have both outlined their interest in hydrogen as part of their broader energy strategies. Indonesia has also examined ammonia co-firing in coal plants as a transitional measure to lower emissions.

In hard-to-abate industrial sectors, several companies are considering a switch from coal to natural gas as a short-term solution. In the power sector, regional interest has been informed by international examples. Utilities in Japan and the Republic of Korea are already testing hydrogen and ammonia co-firing at existing CFPPs. Their experiences offer valuable insights, but actual implementation within Southeast Asia remains limited.

Progress is often constrained by a lack of policy direction, limited financial support, and uncertainties around fuel costs and infrastructure. In many cases, progress depends more on the climate goals and financial capacity of individual companies than on coordinated national strategies.

To scale up fuel switching in a meaningful way, countries in the region will need to develop clear national roadmaps. These should outline priority sectors, infrastructure needs, and supporting policies. Regional cooperation could also play an important role by harmonising technical standards, coordinating cross-border infrastructure, and improving access to affordable low-carbon fuels.

## Specific challenges of accelerating fuel switching

### Financing challenges

As mentioned in Section 1.2.2, key challenges are mainly due to ‘limited attractive investment projects and capital flow’. Financial institutions are reluctant to provide loans due to concerns over financed emissions and unclear classification of fuel switching in sustainable finance taxonomies. Additionally, transition projects often have lower returns than green projects.

**Country-specific examples**

**Singapore**

- **Forward-looking decarbonisation targets:** Singaporean financial institutions have a broader scope of emissions accounting, which considers not just financed emissions from lending and investment portfolios, but also facilitated emissions enabled through underwriting and advisory services (ARE, 2024).

**Malaysia**

- **Principle-based taxonomy:** Fuel switching is not explicitly defined as a stand-alone transition activity in Bank Negara Malaysia's Climate Change and Principle-based Taxonomy (BNM, 2021), which primarily uses qualitative assessments and lacks overarching quantitative thresholds for classifying transition activities.

**Technical challenges**

As mentioned in Section 1.2.3, technical challenges fall under 'limited technology advancement.' Most ammonia and hydrogen applications remain in pilot or demonstration phases, with limited operational data on efficiency and long-term performance, making power generators and industrial players hesitant to adopt them. Additionally, a lack of dedicated storage facilities and transport pipelines hinders the large-scale distribution of ammonia and hydrogen. Nearly all existing coal- and gas-fired power generation facilities require significant retrofitting to accommodate high percentages of ammonia and hydrogen co-firing. Furthermore, a lack of ammonia- and hydrogen-specific safety codes, coupled with a shortage of trained professionals, delays the transition to these alternative fuels.

**Country-specific examples**

**Indonesia**

- **Feasibility assessments with international support:** Indonesia is still in the early stages of ammonia and hydrogen co-firing, having signed memoranda of understanding with Japanese partners to conduct feasibility studies and pilot demonstrations at selected power plants (METI, 2024).

**Malaysia**

- **Lack of dedicated infrastructure:** Sarawak is developing its hydrogen infrastructure, including multi-fuel stations (Sanders, 2025) and hydrogen production facilities (ACE, 2023) for public transport. However, these developments are still underway, and comprehensive infrastructure for large-scale hydrogen distribution is not yet established.

**Policy challenges**

Investors and developers in the region also face substantial policy-related barriers that hinder the acceleration of fuel switching. As mentioned in Section 1.2.4, these challenges fall under 'limited enabling policies: most countries lack a robust emissions trading system (ETS) or sufficiently high carbon taxes to incentivise fuel switching, while government subsidies keep coal significantly cheaper than alternative fuels. Additionally, local content requirement policies significantly hinder alternative energy usage. Differences in scope and definition across taxonomies create confusion and uncertainty for potential developers and investors.

### Country-specific examples

**Indonesia**

- **Low carbon price and ongoing coal subsidy:** The current carbon price (Rp30,000/t$CO_2$e) (Grant Thornton, 2024) and continued coal subsidies (Erickson, 2024) provide little incentive for fuel users to transition to alternative energy sources

## Case study 1: Sumitomo Chemical Company

Sumitomo Chemical, a leading chemical manufacturer in Japan, decided to replace its power generation facilities in Ehime and Chiba, switching from oil and petroleum coke to natural gas, as part of the effort to achieve 50% reduction in Scope 1 and 2 emissions by 2030 compared with FY2013 levels. The upgrades are expected to reduce a total of 890,000 t$CO_2$ per year and pave the way for a future switch to low-carbon hydrogen. The company's efforts are in line with border sustainability goals to reduce greenhouse gas (GHG) emissions from the group's manufacturing processes to near zero and have set targets of a 50% reduction from the FY2013 level by FY2030 (Scope 1 and 2) and net zero by 2050 (METI, n.d.-b).

## Challenges and solutions

| Challenges | Solutions explored |
|---|---|
| Constructing new LNG-fired power generation facilities and related infrastructure is a huge financial undertaking.<br><br>Financial institutions under pressure to reduce financed emissions may avoid investing in any type of fossil fuel projects, including LNG. | Sumitomo Chemical secured transition loans of ¥18 billion to finance the two projects (METI, n.d.-b).<br><br>The company obtained METI's official recognition of the projects' support for Japan's carbon neutrality goal to validate eligibility for transition finance. |
| Japan enforces rigorous environmental impact assessments (EIAs) for new power plants, including lower-emission LNG-fired facilities. | Sumitomo Chemical incorporated high-efficiency gas turbines to meet strict environmental benchmarks. |

## Impact

**Model for effective utilisation of transition finance:** These projects are the first in Japan's chemical sector to be selected by METI as Climate Transition Finance Model Projects. They serve as a model for other companies in the industry, demonstrating how transition finance can be leveraged to support decarbonisation efforts in line with national and global climate goals.

**Significant $CO_2$ emission reduction:** The fuel switch at both sites contributes to an emission reduction of 890,000 t$CO_2$ per year, giving a huge boost to Sumitomo Chemical's energy transition progress.

## Case study 2: H2 Green Steel (H2GS), Sweden

H2 Green Steel (H2GS), now known as Stegra, is a Swedish industrial start-up founded in 2020 with the aim of producing near-zero emission steel via low-carbon hydrogen-based direct reduced iron (H2-DRI). Its first plant is under construction in Boden, with production expected to start in 2026.

### Challenges and solutions

| Challenges | Solutions explored |
|---|---|
| Establishing the world's first large-scale green steel plant requires significant capital investment.<br><br>The green steel market is still emerging, with uncertainties around demand and pricing, putting the company's revenue stream at risk.<br><br>The production of green hydrogen and steel requires a high and stable supply of renewable electricity, a shortage of which will disrupt operations and expose Stegra to volatile spot market prices, undermining cost predictability and sustainability claims. | Stegra pursued a combination of project financing, equity funding, and EU grants, successfully raising the €6.5 billion needed for the first-of-a-kind (FOAK) project (Reuters, 2024b).<br><br>Signed binding 5- to 7-year customer agreements for half of its initial 2.5 million tonnes (Mt) annual production (OECD, n.d.).<br><br>Secured long-term PPAs with leading renewable energy power producers such as Statkraft and Fortum to ensure reliable access to clean electricity at competitive prices for green steel production (Statkraft, 2022). |
| The European Commission's stringent criteria (e.g. additionality, temporal correlation, and geographical correlation) for renewable hydrogen production may have cost implications for Stegra. | Stegra participates in industry dialogue to advocate for practical regulatory frameworks and closely monitors policy developments. |
| H2-DRI requires high-grade iron ore pellets, which are limited in availability. Low-quality iron ores will reduce process efficiency and increase operational costs. | Stegra secured long-term supply agreements with Vale (Stegra, 2023a) and Rio Tinto (Stegra, 2023b) to ensure a steady supply of DRI-grade iron ore pellets. |

### Expected impact

**Proof of technology:** Successful production will prove an alternative steelmaking method with 95% less $CO_2$ emissions than that of coke-fired blast furnaces, paving the way to decarbonise one of the most hard-to-abate sectors.

**Reshaping the global supply chain:** Parts of steelmaking, such as DRI production, could shift to places where low-carbon hydrogen is abundant and available at a lower price.

### Recommendations for scaling fuel switching

#### Financing

- **Transition finance:** Leverage various transition finance instruments available in the region, such as transition bonds and green loans, to support the switch from coal to lower-carbon fuels.

#### Policy

- **Incentive policies:** Gradually remove coal subsidies and redirect funds towards cleaner fuels (e.g. LNG, biofuel, and low-carbon ammonia/hydrogen) to encourage a fuel switch across all sectors.
- **Taxonomy classification:** Develop a regional taxonomy with clear guidelines on the classification of low-carbon energy projects so that they are recognised for transition finance.

#### Technology

- **Capability building:** Grow a skilled workforce for ammonia/hydrogen handling by setting up technical training centres and partnering with universities to create specialised programmes.

## 3.1.6. Green mining

### Mining in ASEAN: A Snapshot

Southeast Asia is a global centre for nickel, tin, rare earth, copper, and other minerals reserve and productions (Table 3.2). Indonesia and the Philippines lead in nickel production, while Indonesia and Myanmar are major tin producers.

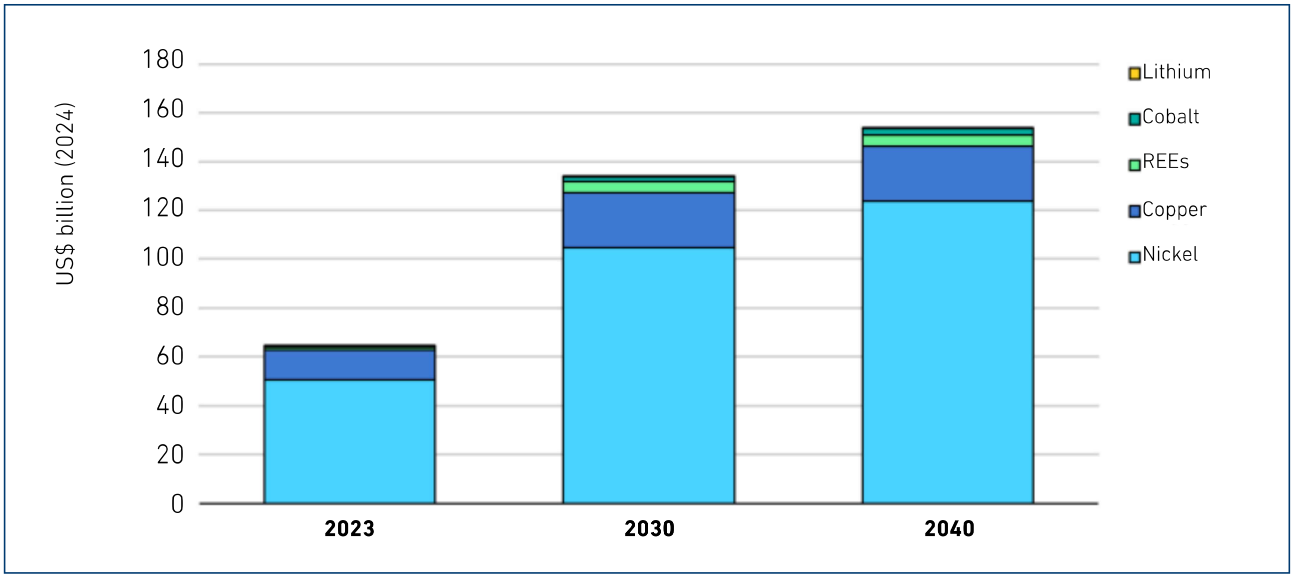
**Table 3.2: Global Mineral Reserves and Production Share in Southeast Asia**

| Mineral | World Reserves in ASEAN (%) | World production in ASEAN (%) |
|---|---|---|
| Nickel | 46.0 | 63.0 |
| Bauxite | 22.7 | n/a |
| Rare Earth Elements (REE) | 20.0 | 8.0 |
| Cobalt | 6.9 | n/a |
| Tin | n/a | 42.0 |
| Copper | 4.0 | 4.0 |
| Manganese | 3.0 | 3.0 |

Source: Wiratama Bhaskara (2025).

Although mineral exploration investment has declined recently, developing domestic value chains could more than double the market size for mining and refining to nearly US$154 billion by 2040. These minerals are vital for energy, electronics, and manufacturing industries.

**Figure 3.5: Market Size of Mining and Refining Production in Southeast Asia, 2023–2040**




REE = rare earth elements

Note: The market value is calculated by multiplying Southeast Asia's production volume in the base case in each year with today's market price for final products. The base case includes production from existing assets and those under construction, along with projects that have a high chance of moving ahead as they have obtained all necessary permits, secured financing, and/or established offtake contracts.

Source: IEA (2024). Global Critical Minerals Outlook 2024.

The decarbonisation challenge for mining value chains is substantial, especially as they scale up to meet the growing demand driven by the energy transition. To achieve net zero emissions by 2050, these value chains must reduce their absolute emissions by about 90% from 2020 levels and neutralise the remaining 10% with credible carbon removal offsets.

For example, for copper, this means reducing emissions from 85.0 $MtCO_2e$ per year to 8.5 $MtCO_2e$ per year, while for nickel, it means reducing emissions from 88.0 $MtCO_2e$ per year to 8.8 $MtCO_2e$ per year. These reductions must occur alongside a significant increase in supply to meet the growing demand. By 2050, the demand for copper is expected to increase by 156% to 59 Mt per year, and for nickel by 208% to 11.5 Mt per year (IFC, 2023).

Most GHG emissions from mining come from electricity used for ventilation, grinding, and refining. Fossil fuel consumption for haulage also contributes significantly. Emission intensity varies based on processing methods and mining types (open-pit vs underground). Solutions to decarbonise diesel and electricity exist, but important challenges lie ahead for mining sites.

## Specific challenges of accelerating technology adoption

### Financial Challenges

- **Significant capital investment** is required to scale up production and deploy low-carbon technologies. This includes investments in research, development, and deployment.
- **Access to sustainable finance instruments,** such as green bonds and loans, to fund the deployment of low-carbon technologies and just transition interventions. The economic viability of investment is often uncertain, making it difficult for companies to commit to long-term decarbonisation strategies.
- **Fluctuating prices of metals and minerals** can impact the financial stability of mining companies, making it challenging to allocate resources for decarbonisation efforts. The volatility in commodity markets can lead to unpredictable revenue streams, which in turn affects the ability of companies to invest in sustainable practices.

### Technical Challenges

- **The declining ore grades** necessitate more energy-intensive extraction processes, escalating energy consumption and operational expenses.
- **The off-grid integration of VRE** into existing mining operations can be complex and costly.
- **The commercialisation and widespread adoption of low-carbon hydrogen and large battery electric vehicles** are hindered by technical and financial constraints, as well as the need for extensive research and development.

### Political Challenges

- Small-scale miners face economic challenges due to **the high costs of certification** and compliance with environmental standards.
- **The lack of clear and consistent regulatory frameworks** can create uncertainty for mining companies, making it difficult to plan and invest in decarbonisation efforts.

## Case Study: Fekola Gold Mine, Mali

The Fekola Gold Mine, near Fadougou, Kenieba Cercle, Kayes Region, Mali, is owned by B2Gold Corporation, a Canadian mining company. The mine is 450 kilometres west of Bamako, the capital city of Mali. The mine requires a continuous electricity supply, operating 24/7 to support its operations.

Before 2019, the Fekola Gold Mine was solely powered by thermal generators using heavy fuel oil with capacity of 8 x 7.3 MW. To reduce CO2 emissions, B2Gold Corporation added 36 MW of solar power and 15.4 megawatt-hours (MWh) of lithium-ion battery energy storage. The battery energy storage system integrates and modulates energy supply using Energy Management System software. The company expanded the capacity again to a total of 61 MW of solar PV and 28 MWh of battery, which is enough to operate the mine with only renewable energy for extended periods.

## Challenges and solutions

| Challenges | Solutions explored |
| --- | --- |
| Investors and banks now prioritise decarbonisation and take environmental, social, and governance (ESG) factors seriously. | To demonstrate capacity for decarbonisation, creating an enabling environment with clear roadmaps is essential.<br><br>Starting with small, simple projects can prove the concept and pave the way for broader adoption of renewable energy. This can be done through self-production behind the metre or via PPAs. |
| Every mine is unique, with different aspects (on grid vs off grid, tariffs on electricity, gas connection) making it challenging to create a one-size-fits-all blueprint.<br><br>Additionally, the need for the electrification of diesel vehicles and legacy infrastructure can complicate decarbonisation efforts, especially given the limited lifetime of mines. | Conducting thorough assessments of resources and harnessing lessons learned from previous projects can minimise the need for extensive customisation and help upgrade existing infrastructure cost-effectively.<br><br>Electric-powered mining vehicles, including battery-electric and trolley-assist systems, were considered to decarbonise diesel consumption, which is the most difficult part of the decarbonisation of mines.<br><br>Depending on the ownership of the mines, a renewable energy power plant could continue to operate, selling electricity to the power utilities, or be operated by new companies to provide electricity to the local population. |

## Impact

The addition of the solar farm and the battery storage system allows the power station to rest the thermal generators during days with sufficient solar irradiation, covering up to 30% of the mine's annual electricity demand with renewable energy. This reduces the burning of over 20 million litres of heavy fuel oil annually, lowering the $CO_2$ footprint by 63,000 tonnes per year.

## Recommendations for scaling adoption of renewable energy in mining

### Policy and Regulatory Support

- **Strengthen data collection and reporting:** Enhance national statistics systems to collect reliable data on GHG emissions at the mine site level, disaggregated by activity. Require mining companies to submit detailed emissions data to inform national action plans.
- **Develop sector-specific roadmaps:** Collaborate with businesses to create a coherent sectoral approach to decarbonisation, including targets for production reduction and incentives for low-carbon investments.
- **Integrate adaptation and mitigation strategies:** Co-design decarbonisation plans that consider both adaptation and mitigation, accompanied by investments and incentive packages to secure resources and ensure implementation.
- **Mandate carbon pricing:** Implement carbon pricing or emissions trading schemes to create financial incentives for decarbonisation.

- **Leverage international commitments:** Use nationally determined contributions to set clear targets for the mining sector's GHG emissions reduction. Engage with international initiatives to support decarbonisation efforts.
- **Foster global collaboration:** Advocate for global collaboration and shared responsibilities between producer and buyer countries to ensure fair distribution of benefits and burdens from the energy transition.

### Financing and Investment

- **Promote sustainable finance:** Utilise sustainable finance instruments, such as green bonds and loans, to fund low-carbon technology interventions. Engage with sustainable finance providers to secure access to finance opportunities.
- **Expand financing mechanisms:** Introduce blended finance models that leverage both international funding and domestic resources to de-risk decarbonisation projects in the mining sector.

### Technological Innovation and Deployment

- **Enhance energy efficiency and renewable energy deployment:** Focus on continual improvement in energy efficiency and the full-scale deployment of renewable energy sources like solar and wind.
- **Develop and scale innovative technologies:** Invest in the development and commercialisation of low-carbon hydrogen, battery electric vehicles, and other innovative technologies essential for reducing emissions intensity.
- **Optimise processes and automation:** Evaluate and deploy commercially available process optimisation technologies and scale up automation for processes and systems relying on software controls.

### Social Inclusion and Just Transition

- **Ensure a just transition:** Foster inclusive collaboration between mining value chain actors, governments, suppliers, workers, labour, civil society, and local communities. Focus on employment impacts, environmental sustainability, and human well-being.
- **Develop a just transition strategy toolkit:** Create a toolkit to operationalise a just transition at the organisational level, addressing employment impacts and ensuring environmental and social sustainability.
- **Conduct environmental and social impact assessments and support certification:** Carry out robust assessments and leverage credible certification schemes to enhance transparency and accountability across operations.
- **Engage in public–private dialogue:** Build trust and share perspectives through public–private dialogue to design collective policy responses and support the decarbonisation of the mining sector.

# Chapter 4

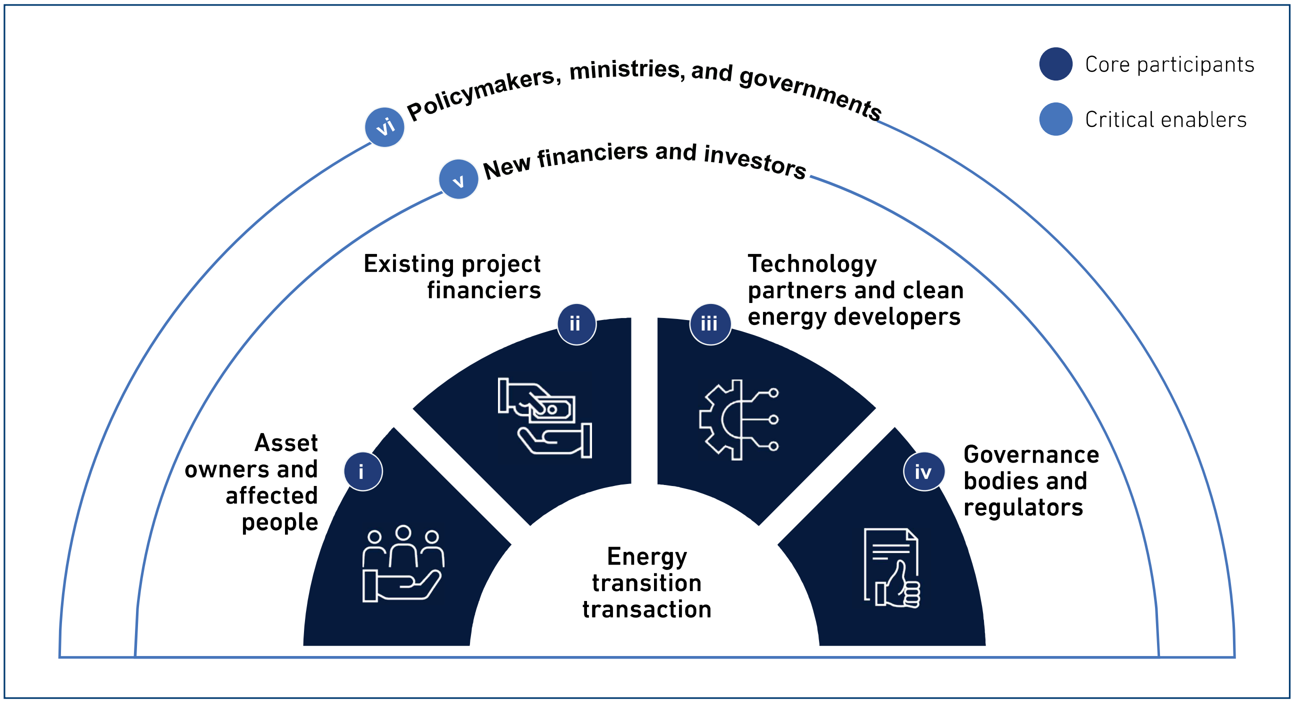
## Collaborative Efforts for Shaping the Future

The energy and industrial transition of Southeast Asia has reached a point where new strategies and policy frameworks alone are not enough. Progress will now be measured by the extent to which those ideas are translated into tangible investments and functioning infrastructure. This means allocating resources, committing to timelines, and delivering results in the form of operational projects. It requires governments and financial institutions to move from consultation to execution, and from signalling ambition to building systems that support real change. The opportunity lies in turning plans into projects that are financially viable, technically sound, and replicable across the region.

However, fragmented national efforts often result in inefficient allocation of resources and higher overall mitigation costs. By aligning policies and sharing technologies, countries in Southeast Asia can unlock cost-effective mitigation opportunities, particularly in lower-income economies. Coordinated action not only enhances efficiency but also ensures equitable burden-sharing, allowing the region to achieve its climate goals at significantly lower economic cost (ADB, 2023b).

Indeed, at the core of this transition is the ecosystem of stakeholders – comprising asset owners and operators, financiers, energy financial regulators, energy regulators, climate policy authority technology partners, and developers – all of whom are vital to driving the shift to cleaner energy solutions. To execute this transition effectively, they must rethink their sustainability goals and commitments and act to adopt new technologies, reskill the workforce, and ensure long-term, sustainable impact. However, for this ecosystem to function smoothly, they will need significant enabling support from policymakers, governments, and institutional investors. Such support is crucial to de-risk execution, foster market confidence, and provide the necessary financial, policy, and technical assistance to replicate and scale decarbonisation transactions. In addition, the power sector decarbonisation roadmap discussed in this report leaves room for future consideration of various power generation methods, including nuclear power generation, and it is important to note that the industrial decarbonisation roadmap will need to be elaborated further. Although cross-institutional models (e.g. the Transition Credits Coalition (TRACTION) and the Energy Transition Mechanism (ETM)) have shown success in pilot phases, actual transactions are still in nascent stages, and tangible impacts have yet to be realised. Furthermore, the next critical step would be to achieve scale by creating a stable pipeline of projects, moving beyond one-off initiatives. To this end, the role of enablers becomes even more pronounced. It is essential to codify lessons learned from these early pilot projects and formalise institutional support, whether in the form of financial or policy measures, so that other organisations can adopt and build upon these successes.

**Figure 4.1: Different Roles in an Energy Transition Transaction**




Source: Authors.

Each stakeholder within the transaction ecosystem has a distinct role to play in driving decarbonisation efforts. Key actions for each group are as follows:

**Asset owners:** Asset owners must assess their existing assets, identifying the highest-emitting ones that may be suitable for early closure, replacement, or retrofit to reduce emissions. Feasibility studies should be conducted to evaluate the technical and economic viability of various decarbonisation options. For example, ACEN, the energy arm of the Ayala Corporation in the Philippines, has made a commitment to transition away from coal. The company announced its intention to retire its last remaining coal-fired power plant and fully pivot to clean energy sources such as solar, wind, and geothermal. This aligns with ACEN's sustainability goals and their broader plan to reach net zero carbon emissions by 2050.

**Existing project financiers:** Financial institutions should support asset owners by assessing the economic viability of decarbonisation strategies. This includes conducting portfolio reviews to evaluate the highest-emitting assets and setting sector-specific internal targets for achieving portfolio-wide decarbonisation. Standard Chartered, for instance, has committed to ceasing support for clients that generate more than 10% of their earnings from thermal coal by 2030 (Standard Chartered, 2019).

**Technology partners and clean energy developers:** Technology providers and developers should collaborate with asset owners to explore decarbonisation pathways. This involves fostering cross-institutional dialogue to unlock the necessary capital, talent, and operational support. For example, companies like Siemens, ABB, and Ørsted seek partnerships with utility providers to explore innovative energy solutions or leverage advanced technologies to accelerate the transition.

**Governance bodies and regulators:** Governance and regulatory bodies play a critical role in removing administrative barriers that hinder the execution of decarbonisation projects. They should streamline processes for project and infrastructure development, fast-track approval procedures, and offer regulatory clarity to support energy planning efforts. Furthermore, they can take more proactive positions in leading change, advocating for policy changes and reform to incentivise clean energy.

**New financiers and investors:** Institutional investors (e.g. multilateral development banks (MDBs), development finance institutions, and philanthropies) must provide the financial support needed for early-stage transactions – including structuring deals, offering de-risk capital, guarantees, insurance, and other risk mitigation measures. By building market confidence, investors can catalyse a multiplier effect that mobilises future capital flows. Furthermore, innovative financing mechanisms and market-based solutions (e.g. carbon markets, climate funds, and sustainability-linked bonds) can help reduce dependency on concessional or grant-based capital, supporting the scaling of transactions. As most MDBs align their projects with the Paris Agreement, transition finance needs to be factored into the methodologies of Paris Alignment assessment.

**Policymakers, ministries, and governments:** Governments and policymakers should provide clear national commitments and guarantees, along with enabling policy frameworks, to encourage and facilitate energy transition transactions. Improving interoperability and regional coordination is essential to facilitate access to the necessary technology and talent across borders. Additionally, policymakers must safeguard vulnerable workers and communities affected by the shift away from fossil fuels. This includes minimising socio-economic disruptions through targeted measures such as job retraining, upskilling programmes, and inclusive social protection.

Collaboration between countries will also be essential to ensure that resources are pooled, knowledge is shared, and risks are managed effectively. The Asia Zero Emission Community (AZEC), spearheaded by Japan, advances regional decarbonisation through both bilateral and multilateral mechanisms designed to accelerate clean energy transitions across Southeast Asia. Rather than focusing on isolated projects, AZEC emphasises systems-level cooperation – aligning national strategies through shared infrastructure, policy frameworks, and cross-border technology deployment. Its bilateral engagements allow Japan to tailor support to each partner's technological readiness, sectoral priorities, and regulatory landscape, while multilateral dialogues foster regional policy harmonisation and interoperability in areas such as hydrogen, ammonia, and carbon capture. This hybrid structure enhances knowledge exchange and positions AZEC as a strategic platform for integrated, long-term industrial decarbonisation in the region.

By creating this shared platform, AZEC enables Southeast Asian countries to move more quickly from planning to implementation. It ensures that regional investments in decarbonisation are grounded in technical feasibility, supported by appropriate regulation, and structured to attract both concessional and commercial capital. By pooling resources, expertise, and policy efforts, initiatives like AZEC demonstrate how nations can tackle the complexities of clean energy transitions together.

## First-of-a-kind projects

To achieve the energy transition in Southeast Asia, together with 'traditional' energy transition technologies (solar photovoltaic, wind, and battery energy storage systems [BESS]), the role of first-of-a-kind (FOAK) projects becomes indispensable, given the large presence of young hard-to-abate and high-emitting assets. FOAK projects are those that apply new technologies or models in real-world conditions for the first time. Examples of such projects can be seen in Chapter 3.

They often involve processes or products that have not been deployed at commercial scale in a particular sector or region. In the context of Southeast Asia, this might mean a green hydrogen plant using locally sourced renewables, a blue ammonia facility in an emerging market, or a novel carbon capture installation tied to industrial output. Because there is no track record to draw from, these projects often face scepticism from investors, higher risk premiums, and regulatory gaps that slow progress.

The ammonia co-firing demonstration at Hekinan coal-fired power plant offers a replicable model for Southeast Asia's coal-dependent economies, especially those with young coal fleets (Chapter 3). This FOAK project shows how existing assets can be decarbonised without immediate retirement, reducing emissions while maintaining energy security. To scale such technologies across Southeast Asia, MDBs like the Asian Development Bank (ADB) can play a critical role by offering concessional finance, guarantees, and carbon credit mechanisms to de-risk investment. AZEC can further catalyse replication by harmonising technical standards, supporting infrastructure planning, and promoting regional cooperation on clean fuel deployment. By introducing technologies and business models that have not yet been proven on a large scale, these projects inherently carry significant risks. Securing financing can be an uphill battle, regulatory frameworks may be underdeveloped or absent, and the potential for commercial returns remains uncertain. Despite these obstacles, FOAK projects are critical to testing what works, identifying local adaptations, and building confidence for broader replication.

These projects often face overlapping challenges that make early-stage execution difficult. Investors hesitate to provide capital when there is no proven track record to demonstrate that the project can deliver financial returns. Developers struggle to secure bankable offtake agreements for products like hydrogen or ammonia, which are essential for project viability. In energy-focused projects, they may also encounter difficulties negotiating long-term PPAs, which are critical for financing renewable electricity generation. Regulatory systems tend to lag technology, with outdated permitting processes and unclear approval pathways that introduce delays and raise uncertainty. This mix of financial hesitation and regulatory fragmentation pushes up the cost of capital, making it harder for projects to advance even when the underlying value proposition is credible.

MDBs have a critical role to play here – not just in de-risking investments through concessional finance and guarantees, but also in anchoring blended finance structures that attract private capital. MDBs can help validate project design, support regulatory alignment, and ensure that environmental and social safeguards are met. Their involvement is often essential to move FOAKs from concept to execution, especially in markets where investor confidence is still maturing.

To turn the promise of these pioneering efforts into a tangible pathway towards net zero emissions, Southeast Asia must embrace a spirit of collective action. This means not only pushing the boundaries of technology and investment but also creating a support system that brings together the public and private sectors, regional policymakers, and technical experts.

AZEC can act as a catalyst by providing a regional framework for collaboration, knowledge sharing, and policy harmonisation. Through AZEC, countries in Southeast Asia can align on technology standards, financing criteria, and transition pathways, making it easier to replicate successful FOAK projects across borders. AZEC's convening power also helps bring together governments, MDBs, and private sector actors to co-develop solutions that are both ambitious and contex sensitive.

## Regional Standards and Trade Facilitation

Building regional supply chains for low-carbon fuels and technologies depends on more than infrastructure. It also requires a shared technical and regulatory foundation. Today, Southeast Asian countries operate with different standards for hydrogen purity, ammonia handling, emissions accounting, and infrastructure safety. This fragmentation creates friction for cross-border investment, adds complexity to project development, and slows down progress on regional integration.

Joint development of mutually recognised standards can reduce technical barriers to trade and improve investor confidence. For example, having a unified approach to measuring the carbon intensity of hydrogen or ammonia would make it easier for suppliers to tap into export markets and for buyers to verify compliance with their national climate targets.

Countries in Southeast Asia should work towards aligning their definitions and protocols for fuel quality, safety, and carbon accounting. This includes adopting consistent purity levels for hydrogen and ammonia, standardising the engineering requirements for storage and transport infrastructure, and defining a common approach to measuring, reporting, and verifying greenhouse gas (GHG) emissions. Without these elements in place, it becomes difficult to evaluate project performance across borders or ensure compatibility between national climate commitments and imported fuels. Aligning these standards will not only reduce uncertainty for developers and regulators, but it will also provide a foundation for credible regional carbon markets and enhance the traceability of traded decarbonised products.

To facilitate regional trade and investment in clean fuels, countries in the region should work together to develop shared standards for green ammonia and hydrogen. This includes agreeing on definitions of what constitutes 'green' based on emissions intensity, technology inputs, and life cycle boundaries. It also involves establishing consistent testing methods, quality certification protocols, and technical benchmarks for storage and transport. Without this kind of alignment, project developers face duplicated compliance efforts and inconsistent recognition across markets. Co-developing standards would provide clarity to buyers and sellers, reduce transaction costs, and help ensure the environmental integrity of traded products. Japan's experience in shaping hydrogen standards through domestic policy and international forums can serve as a strong foundation for this collaboration.

A regional framework for trade could also include harmonised measurement, reporting, and verification (MRV) systems and emissions reporting. This means adopting common methodologies for calculating emissions intensity, defining life cycle boundaries, and verifying data across jurisdictions. Standardised MRV protocols enable consistent tracking of emissions from production to delivery, reduce duplication in compliance, and support mutual recognition of carbon credentials. Without alignment, traded fuels risk inconsistent classification and limited market access. A shared MRV foundation is essential for credible carbon accounting, regional carbon markets, and ensuring the environmental integrity of cross-border clean fuel trade.

Actions in this direction are already being undertaken. The Partnership to Strengthen Transparency for co-Innovation (PaSTI) was created under the ASEAN–Japan Environmental Cooperation Initiative in 2017 to improve GHG emissions MRV systems in the ASEAN region. Based on PaSTI, the Ministry of the Environment Japan (MOEJ) has cooperated bilaterally with Southeast Asian countries such as Malaysia, the Philippines and Viet Nam by leveraging Japan's expertise since 2018. In Viet Nam, the MOEJ and the Japan International Cooperation Agency have supported the development of national GHG emissions policy in partnership with the Ministry of Agriculture and Environment (formerly the Ministry of Agriculture and Rural Development and the Ministry of Natural Resources and Environment), enhancing private sector involvement in the implementation of nationally determined contributions (Vietnam Investment Review, 2022). In Malaysia and the Philippines, the MOEJ supports the establishment of mandatory reporting of GHGs. Cooperation in Southeast Asia based on the Japan–ASEAN Integration Fund began in 2006, and the ASEAN Guidelines on Facility-level GHG Measurement and Reporting were developed in 2023. These frameworks may also support Scope 3 GHG emissions reporting (JAIF, 2019).

## Regional Financing Facility

A lack of accessible financing continues to delay the scale-up of industrial decarbonisation projects in Southeast Asia. While capital is not inherently scarce, many of the most critical investments fall outside the parameters of traditional financing. FOAK projects often involve high up-front costs, uncertain regulatory outlooks, and long payback periods. These characteristics make them less attractive to commercial lenders, especially when credit guarantees, offtake certainty, and currency risk mitigation are missing.

To address this gap, countries in the region should work together to design and launch a dedicated regional financing facility focused on industrial transition. This facility could offer concessional lending, early-stage grants, or guarantees tailored to the risk profile of decarbonisation projects in sectors like low-carbon hydrogen, clean ammonia, or CCUS.

Anchored by ADB, it would provide concessional capital and technical assistance to early-stage industrial transition projects, particularly those aligned with national and regional net zero strategies. An institution like AZEC could play a convening and coordination role, helping align national priorities, facilitate public–private dialogue, and promote interoperability of taxonomies and MRV systems. The facility could also draw on Japan's green transformation (GX) bond experience to structure long-term financing instruments with clear use-of-proceeds categories.

The regional financing facility (RFF) could offer a blend of instruments – such as interest-rate buydowns, partial risk guarantees, and milestone-based grants – tailored to the risk profile of FOAK projects. It would also support capacity building for domestic financial institutions, enabling them to assess and underwrite industrial decarbonisation investments. Over time, the facility could evolve into a regional platform for scaling clean industrial assets, integrating carbon markets, and supporting Southeast Asia's broader transition finance ecosystem. Eventually, this facility could also help align domestic financial institutions with regional goals by supporting taxonomy interoperability, improving project pipelines, and de-risking early commercial demonstrations. The goal is not simply to move more money, but to build confidence in a new class of clean industrial assets that can reshape the region's economy over the next decade. A new concessional fund or facility should be developed specifically to support early-stage industrial decarbonisation projects in Southeast Asia. This mechanism would address gaps in existing finance by offering terms that are tailored to the higher risk profile and longer development timelines of these projects.

Rather than duplicating existing efforts, it could build on structures already in place through institutions like ADB. The structure of this facility could build on relevant experience from Japan's GX bonds or ADB's ETM or ASEAN Catalytic Green Finance Facility (ACGF). GX bonds have been used by the Government of Japan to raise capital for industrial decarbonisation and low-carbon innovation, providing long-term finance backed by public credibility. These bonds are tied to clearly defined use-of-proceeds categories and are aligned with Japan's domestic net zero strategy. Meanwhile, ETM provides a blended finance approach designed to accelerate the retirement of high-emissions assets while funding their replacement with clean energy alternatives. It incorporates concessional funding, private co-investment, and technical assistance to manage the transition risks associated with early coal phaseout. Both tools reflect practical models for combining public policy direction with financial discipline and can be adapted to meet the needs of Southeast Asia's emerging transition priorities.

The ACGF is a regional blended finance platform launched in April 2019 by ASEAN Finance Ministers and administered by ADB. It is a country-owned initiative under the ASEAN Infrastructure Fund, with US$1.7 billion in co-financing pledged by partners including the Agence Française de Développement, the European Investment Bank, the European Union, the Green Climate Fund, Germany's KfW Development Bank, and the Republic of Korea. The ACGF provides loans and technical assistance to de-risk low-emission infrastructure projects and catalyse private capital. It offers a proven model for regional cooperation, financial innovation, and institutional alignment that could be scaled or adapted to support industrial decarbonisation in ASEAN.

## In conclusion

The next phase of Southeast Asia's energy transition must go beyond vision documents. FOAK projects must move from pilot projects to pipelines to implementation, backed by strong public–private collaboration. Through shared frameworks such as AZEC and joint facilities for green industry, countries in Southeast Asia can lead the region in realising the decarbonisation of hard-to-abate and high-emitting sectors at scale.

There is a narrow window of opportunity. Governments and development partners must treat energy transition projects not as isolated experiments but as a necessary first step in building the institutional, financial, and regulatory infrastructure for a low-carbon industrial future. Supporting them means investing in regional capabilities, de-risking innovation, and signalling clear policy intent to the private sector. The urgency lies in laying that groundwork now so that future investments can scale more efficiently.

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