Toward the Development of ASEAN and Japan Circular Economy Model

August 2026

Musashino Institute for Global Affairs (MIGA)

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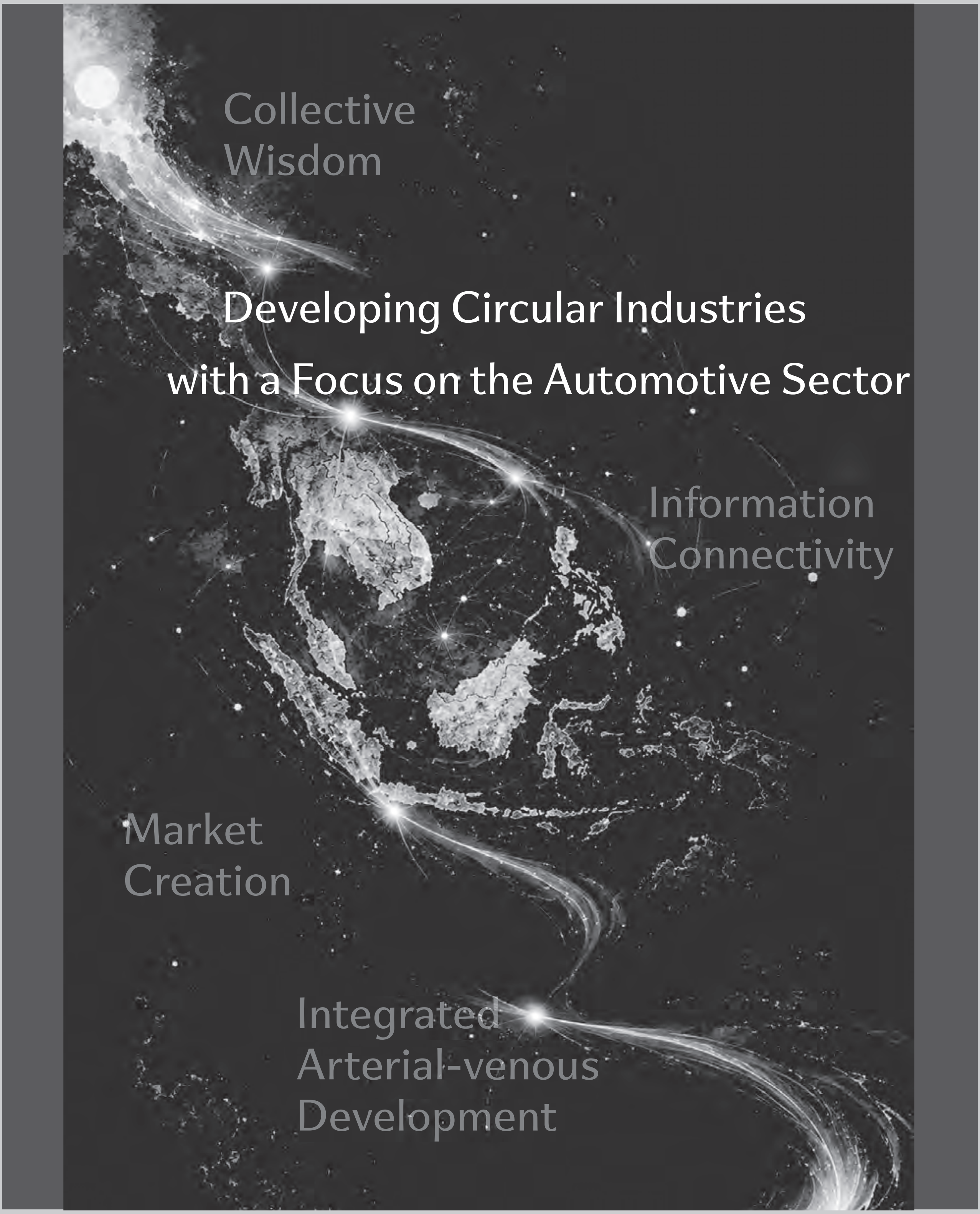
The cover illustration is inspired by this haiku. (いつもかすかな鳥のかたちをして氷る)
Being–/ ever-ambient/ birding, crystallizing, quickening. Yasuko Tsushima
The future of the circular industries envisioned by ASEAN and Japan has not yet fully emerged.
It is birding–revealing the icon of flight as a bird; crystallizing–gathering within itself the miracle of flight; and quickening–awakening the life that will one day take wing.

Toward the Development of ASEAN and Japan Circular Economy Model

Developing Circular Industries with a Focus on the Automotive Sector



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Chapter 1: General Overview: The Arterial (Manufacturing) and Venous (Circular) Integrated Industry Policy -Towards an Establishment of an ASEAN-Japan Circular Economy Model-

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1. The Achievements of ASEAN Industrialisation and New Policy Challenges

Since the fourth quarter of the 20th century, the Association of Southeast Asian Nations (ASEAN) region has achieved steady economic growth through a development strategy centred on regional integration and industrialisation. Through the attraction of foreign direct investment, export-led industrialisation and the promotion of intra-regional economic cooperation, ASEAN countries have built a manufacturing base and established their position as key production hubs within the global economy.

These achievements are symbolised by the launch of the ASEAN Community in 2015. Since then, the ASEAN Community has progressed beyond the milestone of 2025 to the point of celebrating its vision for 2045 (ASEAN Secretariat, 2025a). Through the formation of the ASEAN Economic Community (AEC) in ASEAN Community, ASEAN has aimed to develop as an economic community that transcends a mere free trade area, and has proceeded with the integration of the regional market, the advancement of production networks and the strengthening of intra-regional connectivity. Today, centred on the automotive, electrical and electronic equipment, and chemical products sectors, ASEAN has become one of the world's leading manufacturing hubs.

However, this success in industrialisation has given rise to new policy challenges. In recent years, rapid progress has been made in areas such as digitalisation, decarbonisation, the energy transition, the shift to electric vehicles (EVs) and the restructuring of supply chains; as a result, ASEAN member states are required to build more sustainable and resilient industrial structures whilst further developing their existing industrialisation policies. Furthermore, addressing the increase in resource consumption, the worsening waste problem and the growing environmental impact accompanying economic growth have also become key policy challenges.

Against this backdrop, the circular economy is attracting significant attention. Whilst the circular economy was initially discussed primarily in the context of environmental policy, in recent years it has come to be recognised as an issue deeply linked to improving resource efficiency, strengthening industrial competitiveness, enhancing supply chain resilience and ensuring economic security. Particularly in ASEAN, where manufacturing clusters are well-established, how to incorporate the circular economy into industrial and economic integration policies is becoming a key issue for consideration.

The industrial policy aspects of the circular economy are beginning to attract attention in ASEAN. In particular, we believe that a key role of this report is to examine new possibilities for industrial development and to provide a foundation for formulating industrial policy by refocusing on areas such as recovery, reuse, remanufacturing and recycling—areas that have traditionally received insufficient policy attention—and by re-framing them as targets for industrial development.

In the following section, drawing on these discussions on the circular economy, we shall outline the concept of ‘arterial–venous integrated industrial policy’ examined in this report.

2. The Circular Economy and the Arterial-Venous Integrated Industrial Policy

As mentioned in the previous section, the circular economy is increasingly recognised as a key policy issue that relates not only to environmental policy but also to industrial policy, trade policy and economic integration. The authors refer to the circular economy model examined throughout this report as ‘Arterial–Venous Integrated Industrial Policy’. This term draws on a framework for describing industry that has been predominantly used in Japan, which likens industry to the structure of the human body, referring to the process from manufacturing to sales as the ‘arterial’ and processes such as disposal and recycling as the ‘venous’.

Conventional industrial policy has been structured around the ‘arterial’ process—that is, the process of inputting resources, manufacturing products and supplying them to the market. Taking the automotive industry as an example, the core activities are resource extraction, raw material manufacturing, component production, assembly and sales. On the other hand, the ‘venous’ process—that is, how products are collected, reused, remanufactured and recycled after sale—has often been treated primarily as a matter for environmental policy or waste management, and has not necessarily been positioned as a central issue for the manufacturing sector or industrial policy.

However, from the perspective of the circular economy, the ‘venous’ process is not merely waste disposal. The collection, sorting, diagnosis, reuse, remanufacturing, repair and recycling of end-of-life products can, in themselves, constitute economic activities that generate new added value. Furthermore, these activities have the potential to contribute to improved resource efficiency, the strengthening of supply chains and the stable securing of critical resources.

On the other hand, there are many challenges to be overcome before these activities can be scaled up to an industrial level. For example, in ASEAN member states, much of this ‘venous economy’ is carried out by the so-called informal sector. The informal sector is a vital pillar supporting the ASEAN economy and plays a key role in maintaining employment and carrying out specific resource-recycling activities. However, it is difficult to fully capture these activities in economic statistics, and it is hard to say that access to finance, human resource development, technological development and quality control are thoroughly in place. As a result, although they possess potential as industries, there are many cases where their advancement and market formation have not progressed sufficiently. Therefore, the objective of "Arterial-Venous Integrated Industry Policy" is to establish circular value chains that integrate arterial and venous industries by the collaboration with ASEAN and Japan, through the formalisation (regularisation) of the informal sector, market development, human resource development, the development of information infrastructure, and integration with trade policy.

This perspective is increasingly being shared within the international community in recent years. The Policy Brief 'Embedding Circularity in Global Trade: A G20 Road Map for Catalysing Circular Value Chains', adopted at the 2025 T20 in South Africa, positions both 'arterial industries'—which underpin production activities—and 'venous industries'—which underpin circular activities—as subjects of industrial development, and raises the need for an 'integrative approach to production and circularity' that integrates production and circularity (Anbumozhi et al., 2025).

In particular, Anbumozhi et al., (2025) emphasises the importance of closing the circular loop by interconnecting arterial industries, venous industries and reverse logistics processes. It also highlights the need to enhance the efficiency of both arterial and venous industries by utilising *kaizen*, lean production, robotics, ICT and AI; to dynamically optimise circular value chains through open digital platforms; and to promote remanufacturing, refurbishing and repair process.

Consequently, the integrated industrial policy can be positioned as an analytical framework for specifically examining the concept of the integrated development of arterial and venous industries presented in the Policy Brief, within the context of ASEAN's industrial development and economic integration.

A similar direction is beginning to take shape as part of institutional discussions within ASEAN. The Framework for a Circular Economy for the ASEAN Economic Community (AEC), adopted in 2021, became a landmark policy document that positions the circular economy as a key policy issue for ASEAN economic integration (ASEAN Secretariat, 2021). Furthermore, the ATIGA Upgrade (Second Protocol to Amend the ASEAN Trade in Goods Agreement), signed in 2025, can be regarded as a significant institutional development for specifically examining the circular economy from the perspective of trade and industrial policy, by incorporating remanufactured products into the ATIGA (ASEAN Secretariat, 2025b).

This report examines the potential for implementing a circular economy in ASEAN, taking these international and regional policy trends into account. In this context, Japan's long-standing experience in developing circular economy, such as collection, reuse, remanufacturing, the distribution of second-hand parts, and the establishment of information-sharing systems is considered to provide valuable insights for future discussions within ASEAN.

Furthermore, the transition to a circular economy does not require all member states to follow the same path. The concept of 'Path Diversity', as advocated by MIGA in 2024 on the occasion of the Brazil T20, recognises this diversity and allows each country to choose its own unique development path; this is consistent with the principles of diversity and inclusivity that ASEAN prioritises (Anbumozhi et al., 2025; MIGA, 2024).

'Arterial–Venous Integrated Industrial Policy' is an attempt to re-examine the circular economy not only from the perspective of environmental policy but also from the perspectives of industrial policy and economic integration policy, whilst taking these diverse development pathways into account. In the following section, we will conduct an analysis focusing on the automotive industry to examine the feasibility of its concrete implementation.

3. Why Focus on the Automotive Industry? —As a Case Study on the Implementation of Circular Value Chains—

ASEAN is making progress in establishing an institutional framework to integrate the circular economy into regional economic integration. The Framework for a Circular Economy for the ASEAN Economic Community (AEC), adopted in 2021, sets out the basic direction for this, whilst the Second Protocol to Amend the ASEAN Trade in Goods Agreement (ATIGA Upgrade), signed in 2025, can be regarded as a significant institutional step towards its realisation (ASEAN Secretariat, 2021; ASEAN Secretariat, 2025b).

On the other hand, concrete consideration is still required regarding how to implement the circular economy as an actual industrial policy. In particular, how to link the policy issues newly emphasised in the ATIGA Upgrade—such as remanufactured goods, trade and the environment, and supply chain connectivity—to actual institutional design and industrial development strategies remains a key issue for future consideration.

To examine this issue, this study project focuses its analysis on the automotive industry. This is not to single out the automotive industry for special consideration, but rather because it is regarded as one of the sectors through which key policy issues relating to industrial policy can be observed in a relatively comprehensive manner.

Firstly, the automotive industry is a key sector representing ASEAN's industrialisation. It encompasses not only the manufacture of complete vehicles but also numerous related industries, such as steel, non-ferrous metals, chemicals, rubber, electronic components, logistics, finance and services. Furthermore, the automotive production network established within the ASEAN region is one of the prime examples illustrating the achievements of regional economic integration, a goal to which ATIGA has been committed.

Furthermore, the automotive industry has a long-life cycle that extends beyond the manufacturing stage to include maintenance, the distribution of used vehicles and used parts, dismantling, remanufacturing, repair, reuse and recycling. Consequently, by focusing on the Automotive industry, it is possible to examine in concrete terms the process of forming circular value chains, including 'arterial' industries, 'venous' industries and reverse logistics. In particular, the progress towards electric vehicles (EVs) makes this issue even more significant. Vehicle batteries contain critical minerals such as nickel, cobalt and lithium, and their recovery, reuse, and recycle are becoming increasingly important not only from the perspective of resource efficiency but also in terms of economic resilience and industrial competitiveness. The collection, diagnosis, 'second life' utilisation, remanufacturing and resource recovery of end-of-life vehicle batteries serve as a key litmus test for the implementation of the circular economy. Furthermore, the automotive industry is highly compatible with the institutional challenges associated with the ATIGA Upgrade. For example, issues such as how to classify remanufactured goods, how to evaluate materials recovered within the region, how to recognise the added value generated during the circular process for trade purposes, and how to develop supply chain connectivity into a circular economy can be examined in relatively concrete terms within the Automotive and vehicle battery sectors.

Furthermore, the automotive industry must take into account the utilisation of digitalisation within an achievement of a circular economy. It is also a prime candidate for examining the feasibility of implementing Open Digital Platforms and Digital Product Passports (DPPs). Vehicles, components and batteries can be individually identified, enabling the tracking of information throughout their lifecycle, from manufacture through to use, repair, reuse and recycling. Consequently, it serves as a key case study for examining the nature of the information infrastructure required to establish circular value chains.

From this perspective, this study positions the automotive industry as a case study for the implementation of a circular economy. In other words, by examining the potential for forming circular value chains within the automotive industry, the study aims to link the circular economy policies promoted by ASEAN and the direction of the ATIGA Upgrade to concrete institutional design and industrial policy.

However, the concept of forming circular value chains that integrate 'arterial' and 'venous' industries is not limited to the Automotive sector alone. Similar challenges exist in many other industrial sectors, such as electrical and electronic equipment, plastics, household appliances and construction materials. In this sense, this study is positioned as a pioneering case study focusing on the automotive industry, and it will be necessary to proceed with examining its applicability to other industries in the future.

4. Positioning of This Project and the Analytical Framework

Re-examining the circular economy from the perspectives of industrial policy and economic integration policy, and exploring the feasibility of forming circular value chains that integrate arterial and venous industries, has become an important policy issue in recent years both within the international community and in ASEAN. However, there remains considerable scope for further consideration regarding the specific methods for its implementation. This study was conducted against the backdrop of these concerns. The concept of 'arterial–venous integrated industrial policy' examined in this study was not derived incidentally from the current AMEICC project. Rather, it forms part of the ongoing research on the Global South, the circular economy and industrial upgrading that the Musashino University Institute for Global Affairs (MIGA) has been conducting.

In particular, the report Path Diversity for No One Left Behind, published by MIGA during Brazil's G20 presidency in 2024, highlighted the need for countries to achieve industrial upgrading whilst choosing different development paths (MIGA, 2024). Furthermore, the Policy Brief Embedding Circularity in Global Trade: A G20 Road Map for Catalysing Circular Value Chains, adopted at the 2025 T20 in South Africa, sets out an approach that places the circular economy at the core of trade and industrial development strategies (Anbumozhi et al., 2025). This study can be positioned as an attempt to examine these international policy discussions in concrete terms, in light of the realities within ASEAN. Furthermore, this study is closely linked to the discussions that have been taking place in recent years within the Musashino Reflection initiative. The Musashino Reflection views the circular economy, digital connectivity and leapfrogging as interrelated policy issues, and has been examining the potential for inclusive development through them. This study focuses specifically on the industrial policy aspects of the circular economy within this framework and conducts a detailed analysis of the automotive industry (MIGA, 2025).

To examine the potential of the circular economy from multiple perspectives, this study combined several analytical methods. Firstly, roundtable discussions were held with experts and industry representatives to identify key issues surrounding the circular economy, digitalisation and the automotive industry. Secondly, field surveys were conducted to assess the current state of institutions and industries in each ASEAN member state. Thirdly, an input-output analysis incorporating ESG perspectives was carried out to examine the potential economic and social effects of the circular economy. Fourthly, geographical simulation analysis (IDE-GSM) was utilised to analyse the impact of establishing circular supply chains on the ASEAN economy.

Based on these analytical findings, this report examines the potential for implementing a circular economy in ASEAN from multiple perspectives. It should be noted that the purpose of this report is not to unilaterally propose specific institutional frameworks or policies. Rather, it aims to examine the feasibility of concrete implementation, taking into account the circular economy policies already being pursued by ASEAN and the direction of the ATIGA Upgrade. This report is structured into a general overview and specific sections. The general overview outlines the significance of the circular economy, arterial-venous integrated industrial policy, and a case study focusing on the Automotive industry. The specific sections analyse individual themes such as the Automotive sector, vehicle batteries, plastics, ESG and digital connectivity, and examine the potential for establishing circular value chains within ASEAN.

The findings of this study will serve as a basis for discussions at the forthcoming Bangkok Symposium and for policy dialogue within the AEM-METI process. Furthermore, it is hoped that these discussions will lead to a deeper examination of the specific directions for the development of the circular economy and circular industries in ASEAN.

5. Structure of this report

This report is structured as follows.

- Chapter 2 (by Iwasaki) analyses the political and economic situation in ASEAN, explaining the challenges facing the circular economy in the context of ASEAN economic integration and providing an overview of the ATIGA upgrade.
- Chapter 3 (by Kojima) provides an overview of policies related to the circular economy implemented in ASEAN.
- Chapter 4 (by Kawamura) clarifies the differences between the concept of a 'Material-Cycle Society' in Japan and the circular economy, and examines how Japan's circular economy policies could be utilised in ASEAN.
- Chapter 5 (by Nakamura) addresses digitalisation, exploring the potential for achieving greater efficiency through the digitalisation of manufacturing processes and thereby contributing to the realisation of a circular economy.
- Chapter 6 (by Ueki and Iwasaki) presents the results of field research into the current status and challenges of the Automotive industry in ASEAN, examining the potential for resource efficiency and economic security arising from waste generated during manufacturing processes.
- Chapter 7 (by Oda) conducts a life-cycle assessment of electric vehicles from the perspective of ESG indicators and analyses the need for high-quality recycling.
- Chapter 8 (by Isono and Kumagai)utilises an geographical simulation model (IDE-GSM) to analyse the extent to which the efficiency gains achieved through the realisation of a circular economy contribute to regional CO_2 reduction and economic growth.
- Chapter 9 (by Maeda) conducts a civilisational analysis of the realisation of a circular economy, examining the impact of the transition from a linear to a circular economy on economic society and economic development.
- Chapter 10 provides the summary report on the Musashino University International Symposium held on July 2026 in Bangkok.

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Chapter 2: Overview of ASEAN's Political and Economic Situation: Challenges to ASEAN's Centrality and the Search for New Economic Partnerships

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1. Introduction

The Association of Southeast Asian Nations (ASEAN) is a major player in today's global economy. Founded in 1967 by five initial member states — Indonesia, Malaysia, Thailand, Singapore and the Philippines — this regional organisation has long maintained a structure of ten members following subsequent expansion. However, at the 47th ASEAN Summit on 26 October 2025, Timor-Leste was formally welcomed as the eleventh member state, marking the beginning of a new phase of integration (ASEAN Secretariat, 2025b). With a total population of around 690 million in 2024, ASEAN is the third-largest economic bloc in the world after China and India, accounting for over 8% of the global population (ASEANstats, 2025). Economically, its combined nominal GDP reached approximately US$3.9 trillion in 2024, forming the world's fifth-largest and Asia's third-largest economic zone. The value of goods exports reached approximately US$1.95 trillion in 2024, while foreign direct investment (FDI) inflows stood at US$226 billion in the same year, marking an 8.5% year-on-year increase (ASEANstats, 2025). The size of ASEAN's population, market, trade and investment gives its political decisions systemic implications that extend beyond regional significance. ASEAN's stance towards the outside world is no longer confined to South-East Asia but affects the future of the global balance of power.

Taking this scale into account, it becomes clear that international trends surrounding ASEAN are unfolding simultaneously on multiple fronts in recent years. Externally, ASEAN is facing various global policy shifts, including the ongoing US–China rivalry, the expansion of membership in organisations such as BRICS and the OECD, and the acceleration of supply chain restructuring resulting from the Trump administration's tariff policies in its second term from 2025 onwards. Furthermore, the crisis in the Strait of Hormuz is currently having a significant impact on the region due to energy issues. Despite these challenges, ASEAN's export destinations in 2024 were distributed as follows: the region (22.5%), China (14.9%), the US (16%), the EU (8.5%) and Japan (6.2%). While China (25.4%) remains the largest source of imports, the intra-ASEAN share (20.3%) is also significant, reflecting a diversified trade structure (ASEANstats, 2025). This multipolarity has ambivalent implications for groups of small and medium-sized states such as ASEAN. Some argue that Southeast Asian countries have distanced themselves from traditional balance-of-power politics, instead pursuing a more complex 'balance of influence' comprising multiple dimensions, including military, economic, institutional, and ideological factors (Ciorciari, 2010). A key feature of this strategy is 'inclusivity' — inviting competing great powers to participate in the region's economic and diplomatic activities, thereby ensuring that the great powers themselves have a stake in regional stability and prosperity (Ciorciari, 2010).

However, it should be noted that serious tensions within the region also emerged during this period. The armed conflict between Thailand and Cambodia that came to a head in July 2025 spread to multiple border points from 24 July onwards; five days of fighting resulted in at least 38 deaths and the displacement of over 300,000 people (Silobreaker, 2025). Fighting resumed in early December, and independent estimates suggest that this renewed round of hostilities in November and December resulted in a combined total of 101 deaths and the displacement of a further 500,000 or more people (Britannica, 2026). A temporary ceasefire was reached following a special meeting in Putrajaya on 28 July 2025, brokered by Malaysian Prime Minister Anwar (ASEAN Secretariat, 2025b, Chair's Statement: paragraph. 181), but fighting flared up again in early December. It was not until 27 December, following a meeting of defence ministers at a border post, that a second ceasefire agreement was signed (Quitzon & Poling, 2026). Meanwhile, while the military regime in Myanmar held 'phased elections' from late December 2025 to January 2026 (ACLED, 2025), ASEAN reviewed the implementation of the Five-Point Consensus, reiterating its call for an immediate end to the violence and ensuring access to humanitarian aid (ASEAN Secretariat, 2025b, Chair's Statement: paragraph. 171).

Turning to the institutional dimension of economic integration, ASEAN's trade framework has undergone significant change since the COVID-19 pandemic. Of particular note is the Second Amending Protocol to the ATIGA (ASEAN Trade in Goods Agreement), negotiations for which concluded in May 2025, and which was formally signed at the 47th ASEAN Summit in October 2025 (JETRO, 2025). Building on the First Amending Protocol of 2019, this latest amendment goes beyond merely deepening tariff liberalisation, entailing a substantive structural transformation to address contemporary trade challenges (JETRO, 2025). The amended ATIGA extends its scope to new areas such as trade in remanufactured goods, trade and the environment, supply chain connectivity, and trade in humanitarian crisis situations. In addition, the amendment gives consideration to MSMEs, introduces electronic and simplified certificate-of-origin procedures, and establishes alternative dispute resolution mechanisms — including good offices, conciliation, and mediation (JETRO, 2025; Shofa, 2025). The amended agreement is set to enter into force 18 months after all signature procedures are complete; during the transitional implementation phase, individual national circumstances regarding sensitive items such as sugar and rice will continue to be taken into account in order to protect existing domestic industries (JETRO, 2025). Set against the backdrop of external uncertainties, including the US tariff shock, this amendment can also be understood as a strategic response aimed at integrating regional supply chains and strengthening economic resilience.

During the 26th meeting of the ASEAN Economic Community Council (AECC) at the 47th ASEAN Summit, the third-generation upgrade to the ASEAN–China Free Trade Agreement (ACFTA) was signed (Lin et al., 2025). The simultaneous upgrade of the two most widely utilised free trade agreements in the region, ATIGA and ACFTA, has been noted as an attempt to strengthen supply chains by alleviating trade frictions caused by complex customs procedures and other factors. Both agreements have also incorporated new areas such as the environment and the digital economy (Lin et al., 2025). At the same time, the ASEAN Digital Economy Framework Agreement (DEFA), for which negotiations are in their final stages, is positioned as a key institutional development that complements this trend towards integration. The DEFA aims to be the world's first region-wide, legally binding digital economy governance agreement. It seeks to establish common regulations in areas such as cross-border data flows, e-commerce, cybersecurity, and digital payments (World Economic Forum, 2025a). ASEAN's digital economy is currently valued at around US$300 billion, projected to reach US$1 trillion by 2030 and US$2 trillion upon DEFA's full implementation. In particular, Indonesia accounted for US$90 billion as of 2024 and is expected to grow to US$360 billion by 2030 (World Economic Forum, 2025b). Although the DEFA is not expected to be signed or enter into force until 2026, its implementation has the potential to take substantive economic integration to the next level by removing non-tariff barriers and achieving regulatory convergence.

The deepening of trade and economic integration within ASEAN is inextricably linked to the cross-cutting issue of sustainability. At the heart of this lies policy development surrounding the circular economy. In 2021, the ASEAN Economic Community formulated the 'ASEAN Economic Community Framework on the Circular Economy', setting out priorities such as standardising and mutually recognising circular products and services, promoting sustainable finance and ESG investment, and efficiently using energy and resources (ASEAN Secretariat, 2021). From 2024 to 2025, institutional frameworks centred on Extended Producer Responsibility (EPR) in particular have been developed at an accelerated pace. The majority of ASEAN member states are introducing or expanding EPR regulations, primarily for packaging materials, shifting from voluntary approaches to legally binding, harmonised frameworks. Furthermore, the explicit inclusion of remanufactured products in the aforementioned ATIGA amendment indicates that circular economy policies are increasingly being integrated with trade regimes (JETRO, 2025). The circular economy is entering the implementation phase as a core policy area where trade, environmental, and industrial policies intersect (see Chapters 1 and 4).

The post-Cold War unipolar order led by the United States has been relativised, and economic and political power has diffused across multiple poles. This has fundamentally transformed the range of choices facing groups of small and medium-sized countries, such as ASEAN. On the one hand, the number of potential partners has increased, providing greater opportunities to avoid becoming dependent on a single major power (Sundram, 2025). However, if the United States and China were to put strong pressure on Southeast Asian nations to align with their respective camps, this could actually destabilise regional security. Conversely, ASEAN countries could hedge their bets by maintaining attractive economic relationships with both the United States and China (Gerstl, 2024). Multipolarisation presents ASEAN with opportunities for autonomy, as well as uncertainty.

ASEAN's diplomacy is defined by its ability to maintain 'ASEAN centrality' by engaging selectively with major powers rather than aligning itself with either side. Conversely, issues such as the situation in Myanmar and the dispute between Thailand and Cambodia can be viewed as challenges to 'ASEAN unity', which is considered essential for ASEAN's centrality.

Against this backdrop, this paper aims to provide a systematic overview of the political economy of ASEAN insofar as it relates to this report. Rather than being an empirical study designed to test a single hypothesis, it focuses on linking and analysing various aspects of external relations, intra-regional challenges, behavioural patterns, economic trends, and institutional integration. Section 2 examines the transformation of external relations, focusing on the US–China rivalry and the expansion of BRICS. Section 3 addresses remaining regional challenges, such as the situation in Myanmar, the South China Sea and the Thailand–Cambodia border. Section 4 examines the effects and limitations of the 'ASEAN Way' and centrality. Section 5 discusses the current state of the macroeconomy and prospects for regional economic integration. The conclusion synthesises these various aspects.

2. The Transformation of External Relations

2.1. The Trump Tariff Shock and ASEAN's Response

On 20 January 2025, the second Trump administration signed an executive order to address unfair trade practices (The White House, 2025a), imposing reciprocal tariffs on 2 April. As ASEAN member states had the third-largest trade surplus with the US in 2024, after China, Russia and the EU, they were targeted. Initially, Cambodia faced a 49% tariff, Vietnam a 46% tariff and Thailand a 36% tariff (The White House, 2025b). According to an analysis by the Institute of Developing Economies (IDE-JETRO), these high tariff rates are estimated to have negatively impacted GDP in these countries, particularly in the automotive, electrical equipment, and food processing sectors (Kumagai et al., 2025).

Between July and October, each country reached an individual agreement, with the final tariff rate generally converging at around 19%. Indonesia was the first to reach a settlement in July, removing 99% of its tariff barriers on US products in exchange for a fixed tariff rate of 19% (The White House, 2025c). Malaysia's agreement incorporated a 'poison pill clause' that allowed the US to terminate the deal if Malaysia cooperated with China (The White House, 2025d; Nikkei, 2025c). Meanwhile, due to the size of its trade surplus with the US, Vietnam settled on a tariff rate of 20% — higher than that of other countries (The White House, 2025e). Meanwhile, Chinese companies were hit with a 40% tariff on 'indirect exports' using ASEAN as a transit point (JETRO, 2026a), causing structural upheaval to ASEAN's 'assembly plant' model. By contrast, in October of the same year, China upgraded the ASEAN–China Free Trade Agreement (ACFTA), emphasising its position as a 'champion of free trade' (Nikkei, 2025b). On 20 February 2026, the US Supreme Court subsequently ruled that these 'reciprocal tariffs' were unconstitutional.

On the day of the ruling, the Trump administration introduced a 10% tariff under Section 122 of the Trade Act of 1974 as an alternative; however, on 7 May 2026, in a lawsuit brought by 24 states, including Oregon, and two importers, the US Court of International Trade (CIT) ruled that the measure was unlawful, on the grounds that it did not meet the requirement of a 'balance of payments deficit' stipulated in that section (Yomiuri Shimbun, 2026).

However, the injunction was limited to the direct parties involved, such as importers and distributors, and did not result in a nationwide suspension of the tariff (Yomiuri Shimbun, 2026). The administration is expected to appeal, and the dispute is likely to continue beyond the 24 July deadline; this is seen as a blow to the Trump administration ahead of this autumn's mid-term elections (Yomiuri Shimbun, 2026).

2.2. Expanded BRICS and Multilateral Engagement with ASEAN

At the Kazan summit in October 2024, the BRICS group established a new system of partner countries, welcoming ten new members, including Malaysia, Thailand, and Vietnam. In January 2025, Indonesia became a full member, the first country in Southeast Asia to do so (Strangio, 2025). The motivations for joining were cited as being the prospect of multilateral engagement beyond ASEAN and access to NDB funding (Sang & An, 2025). This is understood to be part of an 'omni-directional diplomacy' strategy running parallel to the process of joining the OECD (Nikkei, 2025a). While some have highlighted that this development raises questions about ASEAN's centrality and suggests that differences in levels of engagement within the bloc are prompting a redefinition of that centrality (Sundram, 2025), there are also concerns about the bloc's cohesion (Aun, 2025). In reality, however, this is not seen as choosing sides, but rather as a move to 'position itself in the centre rather than siding with either side' (Ryall, 2024). It has also been suggested that the US's reduced engagement with the Global South has paradoxically increased the appeal of BRICS (Parameswaran, 2025).

2.3. New Frontlines and the Search for Groupings

In addition to tariffs, ASEAN has become a battleground where US and Chinese regulations and investments clash in the areas of submarine cables (digital infrastructure), critical minerals and semiconductors. A symbolic example is Indonesia's nickel sector, where an export ban policy attracted an influx of Chinese capital, resulting in an asymmetric dependency structure in which Indonesia is effectively shut out of Western markets due to US FEOC regulations (Morikawa et al., 2025). Amid such pressures, ASEAN is also exploring new avenues of cooperation. In May 2025, the first ASEAN–GCC–China Summit was held (ASEAN, 2025a), with the intention of diversifying dependence on the US (Shoji, 2025). These developments indicate that the sustainability of 'role-separated hedging'—where 'security lies with the US and the economy with China'—is being called into question. Nevertheless, ASEAN is actively pursuing 'institutional hedging', which combines pragmatic concessions in bilateral negotiations with multilateral engagement with groups such as BRICS and the GCC.

While this can be understood as the practical application of Goh's (2007) concept of 'omnidirectional engagement', Cheng-Chwee (2008) points out that there are limits to reconciling the pursuit of benefits with the avoidance of risks. Some argue that Southeast Asian countries do not perceive Trump's transactional stance as a 'loss of values', but rather as a 'return to a familiar United States'. They continue to pursue a pragmatic approach of managing both the US and China simultaneously, rather than choosing between them (Kausikan, 2025). This dynamic will be a key factor in shaping the regional order in the 2030s.

3. Remaining Challenges within the Region

ASEAN's centrality is underpinned by its unity. While ASEAN has been working towards forming a community, there has been growing discord amongst its member states in recent years. This section provides an overview of these developments.

3.1. The Myanmar Crisis – The Prolonged Civil War and the Dysfunction of the ASEAN Five-Point Consensus

The February 2021 coup caused the protracted civil war with ethnic armed groups to spread to Bamar-inhabited areas. While estimates of the proportion of territory under the military regime's effective control vary between sources, as of September 2022 it was reported that only around 22% of all townships were under stable control (Freedom House, 2024). The military regime has since lost further control. At the Extraordinary Summit in Jakarta in April 2021, the Association of Southeast Asian Nations (ASEAN) adopted the 'Five-Point Consensus (5PC)', calling for an immediate cessation of violence and inclusive dialogue. However, the military regime's failure to comply has rendered the agreement effectively meaningless.

This failure is no longer just the military regime's problem, but is spreading throughout the region. The influx of refugees into Thailand and Malaysia, as well as cross-border crimes such as money laundering and cyber fraud originating from Myanmar, are casting a shadow over the domestic politics of neighbouring countries (Tin Shine Aung, 2025). The crisis in Myanmar is therefore transforming into a direct challenge to the region's security and public order. A symbolic example of this occurred in July 2025 when the military regime formally notified Malaysia, the ASEAN Chair for that year, of its opposition to Timor-Leste's accession to the organisation (Tin Shine Aung, 2025).

Vulnerabilities are also evident in the military regime's resource base. In October 2024, the Kachin Independence Army (KIA) seized control of rare-earth mining sites in the Pangwa and Chipwi townships of Kachin State; in response, China closed its border gate, which triggered a collapse of over three-quarters in Chinese imports of rare earths from Myanmar (Risk Advisory, 2025). Although Myanmar forms part of the global rare-earth supply chain, this episode illustrates, at the same time, the fact that the junta controls at best around 14 per cent of the country's territory (Green, 2025) and the instability of the junta's dependence on China. The military regime pressed ahead with a 'three-stage election' from 28 December 2025 to January 2026 (ACLED, 2025), but ASEAN declined to endorse the electoral plan, maintaining that an end to violence was a prerequisite. During 2025, the military regime regained some ground in northern Shan State and elsewhere, but it has not achieved full reunification of control, with almost the entirety of Rakhine State remaining under the control of the Arakan Army (ACLED, 2025; Mappr, 2026).

3.2. The South China Sea Dispute

At the heart of the dispute over the South China Sea lies China's claim to maritime rights based on the 'Nine-Dash Line'. Although the 2016 arbitration ruling determined that the Nine-Dash Line had no legal basis, China has consistently rejected this ruling and continues to construct artificial islands and employ grey-zone tactics. Against this backdrop, clashes between the Philippines and China occurred frequently throughout 2025. In September, vessels from both countries collided near Scarborough Shoal. A Filipino crew member was injured when a water cannon shattered a window (Al Jazeera, 2025a; Lariosa, 2025a). In December, near Sabina Reef, the China Coast Guard and maritime militia surrounded 20 Philippine fishing vessels. The Philippine Coast Guard described the actions as 'dangerous', including water cannon attacks and cutting anchor ropes. Three people were injured and two fishing vessels were damaged (Al Jazeera, 2025b; Lariosa, 2025b). The United States has reaffirmed that Article 4 of the US–Philippines Mutual Defense Treaty applies to attacks on Philippine government vessels (Lariosa, 2025b), and the South China Sea issue is increasingly serving as a litmus test for the effectiveness of the US–Philippines alliance.

There is a disparity of interest between countries directly involved in territorial disputes, such as the Philippines, Vietnam, Malaysia and Brunei, and those not directly involved. Countries with deep economic ties to China tend to be more cautious in their criticism of it. Negotiations on the Code of Conduct (COC) have been ongoing since the 2002 'Declaration of Conduct', but difficulties regarding its binding nature, scope of application, and the involvement of third countries continue to plague the process, leaving the path to an effective resolution unclear.

3.3. The Thailand–Cambodia Border Dispute

The border dispute between Thailand and Cambodia stems from ambiguities in the border demarcation dating back to the Franco-Siamese Treaties of 1904–1907. The dispute centres on Preah Vihear Temple, which was confirmed as Cambodian territory by the 1962 ICJ ruling and reaffirmed in 2013, and Ta Muen Thom Temple. Following a minor skirmish near Preah Vihear Temple on 28 May 2025, in which one Cambodian soldier was killed, tensions escalated and both countries exchanged accusations. This led to a series of tit-for-tat retaliatory measures: Cambodia imposed an embargo on Thai goods, while Thailand closed border checkpoints and restricted internet and electricity supplies (Britannica, 2026).

Tensions finally escalated into a full-scale armed conflict on 24 July. Gunfire, artillery fire and rocket attacks were exchanged at 12 locations along the border, while Thai Air Force F-16 fighter jets carried out cross-border air strikes (TWZ, 2025). Five days of fighting resulted in at least 38–48 deaths and the displacement of 200,000–300,000 people (Silobreaker, 2025; Natalegawa & Poling, 2025).

Resolving this crisis involved a complex interplay between ASEAN's institutional response and the influence of major powers. Prime Minister Anwar of Malaysia, who was holding the ASEAN chairmanship at the time, took the lead in mediation. Following talks in Putrajaya on 28 July, an unconditional ceasefire was agreed (Natalegawa & Poling, 2025).

However, direct pressure from President Trump also played a part in bringing about this ceasefire. It is believed that his warning to both countries that trade negotiations would be frozen 'until the fighting stops', coupled with his suggestion of a 36% tariff, was the decisive factor in persuading the initially reluctant Thai government to mediate (Silobreaker, 2025). On 31 July, just before the deadline for reciprocal tariffs to be imposed, the United States announced a deal with both countries to reduce tariffs. This suggests that the ceasefire and trade pressure were implemented as a single package.

The ceasefire was unstable from the outset. On 26 October, the ‘Kuala Lumpur Peace Agreement’ was signed in Kuala Lumpur in the presence of President Trump. It stipulated the withdrawal of heavy weapons and their return to regular military facilities, humanitarian demining and the implementation of confidence-building measures (The White House, 2025f). However, in November, Thailand declared a suspension of the agreement following a landmine explosion (Regan & Olarn, 2025; Quitzon & Poling, 2025). In December, fighting flared up again when the Thai military carried out air strikes on Cambodian military installations. It is reported that at least 100 people were killed and more than 500,000 were displaced that month (Britannica, 2026; Quitzon & Poling, 2026). On 27 December, the two countries agreed to a second ceasefire, stipulating a halt to troop movements and maintaining direct communication between defence ministers. It was also agreed to dispatch an ASEAN monitoring mission. However, this ceasefire differed from the July agreement in that China, rather than the United States, sought to position itself as the principal mediator (Quitzon & Poling, 2026).

3.4. Structural Commonalities in Regional Challenges

These three challenges act as a ‘strength of diversity’ when ASEAN responds to external pressures for multipolarisation through balanced diplomacy. However, they are perceived as a ‘lack of effectiveness’ when dealing with serious intra-regional conflicts.

The cases of Thailand and Cambodia, in particular, highlight that ASEAN’s institutional framework is insufficient for conflict resolution. Rather, achieving a substantive ceasefire depends on factors external to ASEAN, such as the chairperson’s diplomatic skills (Prime Minister Anwar’s ‘constructive engagement’) and the pressure and mediation exerted by extra-regional powers (the United States and China). The scenario in which US trade pressure determined the timing of the ceasefire shows that, as discussed in Chapter 1, tariff diplomacy exerts substantial influence even within ASEAN’s security sphere. This challenges ASEAN to adapt to the new reality of the interdependence of economics and security. This duality is directly linked to the ‘ASEAN Way’ and the effects and limitations of ASEAN centrality, discussed in Section 4.

4. The ‘ASEAN Way’ and ASEAN Centrality – Effects and Limitations

4.1. The Institutional Foundation of Centrality

From the mid-1990s to the early 2010s, ASEAN developed a comprehensive set of regional institutions, including the ARF, EAS and ADMM+. This established the most extensive regional architecture in both Southeast Asia and the wider Indo-Pacific region (Qiao-Franco et al., 2025). ASEAN has evolved from a subregional grouping focused on keeping major powers at bay into a driving force that actively manages power relations and steers multilateral cooperation, occupying a focal point for dialogue, cooperation, and strategic interaction (Qiao-Franco et al., 2025). At the 20th East Asia Summit in Kuala Lumpur on 27 October 2025, heads of state reaffirmed their support for ASEAN centrality and the ASEAN Outlook on the Indo-Pacific (AOIP). This institutional status remains intact, at least in form. From this perspective, 'ASEAN centrality' has multiple meanings: ASEAN not only occupies a geographical centre and serves as a venue for international conferences, but it also takes the lead in international negotiations and institutions (Fukunaga, 2015).

However, this centrality is inherently in a state of constant tension with the fluctuations of great power politics. As long as ASEAN remains in an asymmetrical relationship with the major powers in terms of size, resources, and capabilities, this framework will inevitably depend on their willingness to engage (Qiao-Franco et al., 2025). Indeed, there is an asymmetry whereby the major powers — China, the EU, India, Japan and the US — support the expansion of ASEAN's role in the economic sphere whilst not considering ASEAN-led mechanisms to be the 'first choice' in political and security cooperation (Qiao-Franco et al., 2025). Nevertheless, ASEAN has not been completely marginalised because it has used its 'in-between position' to ease tensions between the major powers. This ensures that these powers also have a stake in maintaining ASEAN's centrality (Qiao-Franco et al., 2025).

4.2. The Limits of Centrality

The response to the Myanmar crisis illustrates these limits most clearly. As discussed in Chapter 2, strict adherence to consensus and non-interference in internal affairs has led to ASEAN's inability to address cross-border challenges effectively (Tin Shine Aung, 2025). Even four years after the 2021 coup, virtually no progress has been made under the Five-Point Consensus, and this dysfunction is spilling over into neighbouring countries in the form of cross-border crimes such as the influx of refugees into Thailand and Malaysia, as well as money laundering and cyber fraud based in Myanmar. The July 2025 incident, in which the military regime (SAC) formally notified Malaysia, the chairing country, of its opposition to Timor-Leste's ASEAN accession, symbolises how the military regime can now exploit the core ASEAN norms of consensus and non-interference in internal affairs for internal political manoeuvring (Tin Shine Aung, 2025).

4.3. The Practical Exercise of Centrality: Chair Country Diplomacy in the Thailand–Cambodia Conflict

In contrast, the Thailand–Cambodia border conflict examined in Session 3 reveals a more nuanced situation, indicating that centrality did not entirely cease to function. Prime Minister Anwar of Malaysia, the ASEAN Chair, played a key role in the mediation process. He provided a neutral platform that led to the first ceasefire on 28 July and the signing of the Kuala Lumpur Peace Agreement on 26 October. This diplomatic manoeuvre is considered to have restored some trust in ASEAN (Natalegawa & Poling, 2025). However, the same case also demonstrates that trade pressure from the United States (in the form of a suggested freeze on 36% tariffs) was the decisive factor in bringing about the actual ceasefire (Silobreaker, 2025). The fact that the conflict was resolved only through a combination of the ASEAN

Chair's mediation capabilities and the coercive power of a non-regional great power also highlights the limitations of ASEAN's ability to resolve conflicts independently. The suspension of the agreement in November and the resumption of hostilities in December confirmed this vulnerability.

4.4. The Rise of the Argument for Institutional Reform

In order to overcome such dysfunction and maintain its effectiveness, it has been argued that ASEAN needs to adopt a more flexible decision-making model and establish a collective security mechanism capable of responding to crises that threaten its centrality (Tin Shine Aung, 2025). Specifically, proposals have been put forward to introduce a 'non-consensus' voting system for key security issues, rather than requiring strict unanimity, and to enhance ASEAN's capacity to respond amid competition between major powers by establishing an ASEAN Collective Security Mechanism (ACSM) (Tin Shine Aung, 2025). The 46th Summit in May 2025 was seen as a key moment to move beyond the limitations of a compartmentalised approach comprising a Political-Security Community, an Economic Community, and a Socio-Cultural Community, in light of the growing interconnection of economic and security matters, and to develop an integrated strategy (Tijaja & Dzakwan, 2025). However, these reforms face structural barriers in the form of resistance to altering the fundamental principles of consensus and non-interference in internal affairs, and their realisation requires a long-term shift in norms.

4.5. Centrality as Regional Pragmatism – Choices Beyond the US–China Axis

In this context, it is significant that ASEAN member states do not view the US–China rivalry as a 'binary opposition', but rather as a situation in which they manage their relations with both powers simultaneously (Kausikan, 2025). From this perspective, their engagement with BRICS, as discussed in Chapter 1, can be understood as a rational strategy to secure multiple institutional options at a time when the US is reducing its involvement as an offshore balancer, rather than as a shift towards anti-Americanism.

The 'ASEAN Way' and centrality cannot be assessed using the binary framework of 'effective' or 'ineffective'. In response to external pressures for multipolarisation, they act as a balancing mechanism, incorporating major powers into multi-layered institutions while maintaining a middle ground. However, when faced with serious intra-regional conflicts, the same norms — the principles of consensus and non-interference in internal affairs — are reversed and become dysfunctional. The Myanmar crisis illustrates this limitation, while the Thailand–Cambodia conflict highlights the limitations and partial effectiveness of ASEAN centrality. The latter, in particular, demonstrates the 'complex' nature of centrality, whereby the diplomacy of the ASEAN Chair only becomes effective when combined with pressure from extra-regional great powers. As examined in Section 5, the deepening of economic and institutional integration plays a role in supporting ASEAN's regional presence whilst compensating for these political constraints.

5. The Current State of the ASEAN Economy and Prospects for Regional Economic Integration

5.1. Current Macroeconomic Situation – Downward Revision Due to the Strait of Hormuz Crisis

In its December 2025 outlook, the ADB revised Southeast Asia's real GDP growth rates upwards to 4.5% for 2025 and 4.4% for 2026. This reflects the robust performance in the third quarter of Indonesia, Malaysia, Singapore and Vietnam (Asian Development Bank, 2025).

However, the crisis in the Strait of Hormuz—triggered by the US–Israeli attack on Iran on 28 February 2026—has forced a substantial downward revision to the economic outlook from the start of the new year onward. The Strait is a vital shipping route carrying around a quarter of the world's seaborne crude oil trade; as of 2024, 84 per cent of crude oil shipments and 83 per cent of LNG shipments through it were bound for Asian markets (Banerjee & Sharma, 2026). Average daily transits through the Strait, which stood at 129 vessels between 1 and 27 February, fell to an average of six vessels between 1 and 29 March—a decline of approximately 95 per cent (UNCTAD, 2026a). Crude oil prices (Brent) rose above US$90 per barrel as of 10 March (UNCTAD, 2026c), and to US$95 per barrel as of 4 March according to Banerjee and Sharma (2026).

This shock is having a direct impact on ASEAN countries that import energy. The structural vulnerability of these countries, which have long relied on oil and natural gas imports from the Gulf region, has been exposed, forcing each nation to respond individually. While negotiations with Iran regarding safe passage and the search for alternative suppliers are ongoing, Malaysia, Indonesia and Vietnam have entered into negotiations with Russia for long-term crude oil supply contracts, following the lifting of US sanctions on Russian crude oil (Banerjee & Sharma, 2026). While this will secure supplies in the short term, critics have pointed out that it will increase dependence on Russian energy and place ASEAN in an even more complex geopolitical position (Banerjee & Sharma, 2026).

UNCTAD forecasts that the growth rate of global trade in goods will slow sharply from around 4.7% in 2025 to between 1.5 and 2.5% in 2026. It also estimates that global GDP growth will slow from 2.9% in 2025 to 2.6% in 2026 (UNCTAD, 2026b).

Consequently, the region is facing a new challenge: how to strengthen its economic resilience in the face of soaring energy prices and a slowdown in trade. Following the US tariff shock (see Chapter 1), the fact that ASEAN is now facing a second external shock in the form of a geopolitical energy crisis highlights the need to extend the theme of 'multifaceted engagement within a multipolar world' — which forms the overarching tone of this paper — beyond trade to energy security.

5.2. Institutional Deepening of Regional Economic Integration

5.2.1. Second Protocol Amending ATIGA

Inheriting the spirit of its predecessors, the CEPT and the AFTA, the ATIGA was signed in Thailand in 2009 and came into force in 2010. It constitutes the fundamental legal framework for intra-ASEAN trade in goods. The agreement has virtually eliminated tariffs within the region and provided the legal basis for the 'competitive, efficient and seamless movement of goods' set out in the vision of the ASEAN Economic Community (AEC) (ASEAN Secretariat, n.d.). Following the First Amending Protocol of 2019, the Second Amending Protocol of 2025 represents a qualitative transformation that goes beyond merely deepening tariff liberalisation.

Negotiations on the amendment were concluded in May 2025. On the sidelines of the 47th Summit on 25–26 October, Indonesia, Brunei, the Philippines, Singapore and Thailand were the first to sign the protocol. The following day, a 'handover ceremony' was held, during which Malaysia's Minister of Investment, Trade and Industry, Tengku Zafrul—who was serving as Chair of the ASEAN Free Trade Area (AFTA) Council—presented the Protocol to ASEAN Secretary-General Kao Kim Hourn (ANTARA News, 2025; MOIT Vietnam, 2025). Cambodia and Lao PDR signed 'subject to domestic approval' (ad referendum), while Myanmar and Vietnam were expected to sign in November 2025 (ANTARA News, 2025). Timor-Leste, a new member state, is also set to participate in all trade agreements, including ATIGA (ASEAN Secretariat, n.d.). The amended protocol is expected to enter into force 18 months after all member states have signed it, which is anticipated to be around mid-2027 (JETRO, 2025).

According to JETRO (2025), the main changes to the revised ATIGA agreement are as follows: Firstly, the Product-Specific Rules (PSRs) have been relaxed for 458 tariff lines and the requirements for certificates of origin (CO Form D, including electronic forms) have been eased. Operational flexibility has been introduced, such as the acceptance of hard copies or scanned PDFs of COs in the event of system failures. Secondly, a post-import duty refund scheme has been introduced. Thirdly, seven new chapters have been added, covering micro, small, and medium-sized enterprises (MSMEs); supply chains; the environment; and trade facilitation.

Of particular note among these are the dispute settlement mechanism and the chapter on trade and the environment. Mr Satvinder Singh, Deputy Secretary General of ASEAN, explained that the organisational culture within ASEAN member states makes them reluctant to engage in arbitration against one another. He added that the revised ATIGA therefore introduces a mechanism that emphasises mediation as a form of 'alternative dispute resolution' (Shofa, 2025). This collaborative approach involves the parties sitting down to discuss and find a solution rather than determining a winner and a loser through arbitration. It is positioned as an institutional design suited to the ASEAN culture, which favours amicable resolutions (Shofa, 2025). Provisions have also been incorporated to enhance transparency and predictability. For example, deadlines have been set for responses and resolutions in technical consultations regarding non-tariff measures (60 and 180 days respectively), and 60 days' prior notice is now required when introducing new measures (JETRO, 2025). The 'Trade and Environment' chapter explicitly sets out a commitment to cooperation on the green and circular economy. It is also pioneering in that it is the first trade agreement to stipulate WTO-compatible measures to avoid supply chain disruptions in the event of a humanitarian crisis (JETRO, 2025).

The newly established provisions on remanufactured goods clarify their definition within the region (JETRO, 2025). This is significant as it links to the circular economy policy discussed in Section 4.4.

Previously, the legal status of remanufactured goods, which fell somewhere between new and second-hand goods, was unclear. This acted as a barrier to trade, but these provisions now provide a clear legal basis for the intra-regional circulation of remanufactured goods.

Mr Jatmiko Bris Witjaksono, Director General of International Trade Negotiations at the Indonesian Ministry of Trade, stated that Indonesia had succeeded in retaining special provisions regarding the trade of sugar and rice within the amended agreement. He explained that these provisions are essential for ensuring the stability of prices and supplies of both commodities (ANTARA News, 2025). He also expressed his expectation that the revised ATIGA would contribute to expanding market access within the region for Indonesia's small and medium-sized enterprises (ANTARA News, 2025). Intra-ASEAN trade reached US$823.1 billion in 2024, accounting for 21.4% of ASEAN's total trade (ANTARA News, 2025; Shofa, 2025). Institutional reforms covering trade on this scale are a key indicator of the ASEAN Economic Community's substantive deepening.

The amended protocol aims to strengthen intra-regional supply chain connectivity, promote green, inclusive and resilient trade, and support the integration of small and medium-sized enterprises within the region (MOIT Vietnam, 2025). This also serves as ASEAN's institutional response to the US tariff shock of 2025. Practical challenges identified during the 18-month preparation period prior to its coming into force that will affect Japanese companies include monitoring implementation progress in each relevant country, verifying the tariff-saving effects resulting from the relaxation of rules of origin and adapting to the transition to digitalisation (JETRO, 2025).

5.2.2. Expansion of Free Trade Areas

The Regional Comprehensive Economic Partnership (RCEP) entered into force in January 2022, forming the world's largest free trade area, encompassing the ten ASEAN member states along with China, Japan, South Korea, Australia and New Zealand, and accounting for approximately 30% of global GDP (World Economic Forum, 2025a). According to joint modelling by the East Asian Bureau of Economic Research (EABER) and the Centre for Strategic and International Studies (CSIS) in Indonesia, if ASEAN economies avoid retaliating against US tariffs and instead fully implement RCEP to deepen regional integration, they could achieve GDP growth of 1.9% and employment growth of 2.1%, whereas an escalating trade war involving 15% tariff increases could reduce GDP by 11.1% and employment by 25% — a 13-percentage-point difference in GDP outcomes between the two scenarios (Armstrong, 2025). The "Liberation Day" tariffs alone are estimated to reduce ASEAN's GDP by 2.3% and employment by 5.9% (Armstrong, 2025). RCEP can thus serve as a stabilising platform against this chain of protectionism (Armstrong, 2025).

The third-generation upgrade to the ASEAN–China Free Trade Area (ACFTA) had its negotiations announced at the 25th ASEAN–China Summit in November 2022; substantial conclusion was declared in October 2024, negotiations were completed in May 2025, and the agreement was signed at the 47th ASEAN Summit (ASEAN Secretariat, 2024). The upgraded agreement covers nine areas, including new fields such as the digital economy, the green economy, and supply chain connectivity (Diplomacy & Beyond Plus, 2025).

Furthermore, at the 10th Committee Meeting on 26 June 2026, it was announced that preparatory discussions would commence with the UAE (United Arab Emirates), the Philippines and Indonesia prior to formal accession negotiations (Mayger, 2026), regarding the CPTPP. As outlined above, free trade areas continue to expand, with each framework reflecting various strategic considerations.

5.2.3. DEFA – The Path to the World's First Regional Digital Economy Agreement

Negotiations on the DEFA began in September 2023, and after 14 rounds of negotiations, "substantial conclusion" was declared at the 26th AEC Council Meeting on 24 October 2025 (ASEAN Secretariat, 2025c). The provisions agreed by ASEAN as a whole amount to 24 articles and 98 paragraphs, equivalent to 73 per cent of the total (ASEAN Secretariat, 2025c). The next goal is to sign a fully concluded agreement in Manila, Philippines, in 2026, which is expected to be one of the priority deliverables under the Philippine Chairmanship (Tech For Good Institute, 2025). The DEFA is the world's first legally binding digital economy governance agreement to cover an entire region. It comprehensively addresses digital trade facilitation, cross-border data flows, e-commerce, data privacy, digital payments, cybersecurity, digital identity, competition policy, AI, and the mobility of digital talent (World Economic Forum, 2025a).

Without the DEFA, the region's digital GDP share is projected to remain at around 8.5% and the export growth rate of small and medium-sized enterprises is expected to be limited to 3.2% per annum. By contrast, the full implementation of the DEFA is projected to result in a digital economy worth US$2 trillion by 2030 (ITI, 2025). The annual costs incurred by regional enterprises due to fragmented digital regulation are currently estimated to be between US$15 and US$20 billion, meaning the benefits of regulatory convergence would be substantial (ITI, 2025). According to an OECD analysis, the full implementation of the DEFA could also boost intra-regional trade by 13–20% and total trade by 3–4%, depending on the level of ambition (OECD, 2026).

There are still challenges in terms of implementation. Significant disparities in digital infrastructure levels remain among member states, and differences of opinion regarding data sovereignty, privacy and security have not yet been fully resolved. Given that past ASEAN agreements have failed to translate ambitious principles into practice, sustained political will and technical support will be essential during the implementation phase (World Economic Forum, 2025b).

5.3. Electrification and Supply Chain Restructuring

By the end of 2025, EV adoption was expanding rapidly across ASEAN countries. The EV share of new car sales in Singapore and Vietnam reached around 40 per cent, surpassing levels seen in the EU and the UK. Thailand reached 21 per cent, having sold more EVs in the first three quarters of 2025 than Denmark, while Indonesia reached 15 per cent, surpassing the United States for the first time (Ember, 2025). Given that Vietnam's EV share stood at less than 0.05 per cent as recently as 2021, this represents a dramatic transformation achieved in under five years (Ember, 2025).

The dynamics driving this shift vary by country. In Vietnam, almost all EV sales are accounted for by the domestic manufacturer VinFast, whose VF3 model is now the highest-selling car in the country across all vehicle types (Ember, 2025). Indonesia recorded the second-largest growth in Chinese EV exports of any country in 2025, making it a major destination for expanding Chinese EV exports (Ember, 2025). BYD plans to bring its Indonesian production facility—a US$1.3 billion investment—online within 2025 (Mordor Intelligence, 2026).

This rapid expansion of EV adoption is having a twofold structural impact on the existing automotive industry. On the one hand, it creates opportunities for the development of new supply chains for electrification (batteries, electronic components, and charging infrastructure), with investment focusing on battery manufacturing that utilises Indonesia's nickel resources (Liahnson & Company, 2025). On the other hand, it poses a threat to the existing supply chain for internal combustion engines (ICE), which has long been centred on Japanese manufacturers and is now becoming increasingly difficult to maintain. While Japanese OEMs still hold a significant market share in ASEAN, Chinese brands secured around 5% in 2024, a trend that has persisted since 2025 (Infineum Insight, 2025). The speed at which component manufacturers adapt and undergo technological transformation has become a key factor determining the competitiveness of the ASEAN Automotive industry.

5.4. Development of Circular Economy Policies

Significant progress has been made in implementing circular economy policies in ASEAN, beginning with the formulation of the 'ASEAN Circular Economy Framework for the ASEAN Economic Community' in 2021 (ASEAN Secretariat, 2021). This transition was prompted by the observation that ASEAN member states are major sources of global marine plastic pollution, amongst other factors. It is estimated that six of the top ten countries contributing to this pollution are ASEAN member states (Landbell Group, 2026). This is part of a wider issue whereby the Southeast and East Asia region (ASEAN+3), accounting for around one-third of the region's GDP, is responsible for over one-third of global plastic leakage (OECD, 2025). In Malaysia, the Philippines, and Thailand alone, it is estimated that over 75% (equivalent to approximately US$6 billion annually) is lost each year due to leakage during the collection and sorting stages (Iwasaki & Kojima, 2026).

The ASEAN region has explicitly stipulated the development and implementation of Extended Producer Responsibility (EPR) policies in its 2019 'ASEAN Framework of Action on Marine Debris,' and the adoption of EPR principles for packaging products was also advocated in the 'Bangkok 3R Declaration' of the same year. In 2021, the 'ASEAN Regional Action Plan for Combating Marine Debris in the ASEAN Member States (2021 – 2025)' was adopted, proposing the establishment of a regional framework for regulatory harmonisation regarding EPR.

There are significant differences among member states in terms of the progress of EPR schemes (Iwasaki & Kojima, 2026). Under the Extended Producer Responsibility Act (Republic Act No. 11898), which was enacted in 2022, the Philippines has been gradually increasing the mandatory recovery rate for packaging waste, from 20% in 2023 to 80% in 2028. The country has already achieved the target for 2023. Meanwhile, Vietnam began enforcing EPR in January 2024, planning to expand coverage beyond the initial categories of packaging, batteries, and tyres to include electrical and electronic waste from

2025, as well as end-of-life automotive vehicles and motorcycles from 2027. In May 2025, Malaysia's National Circular Economy Council approved the EPR policy framework in principle, and preparations are underway to make the scheme mandatory from 2026. Meanwhile, Singapore has postponed the full implementation of its deposit-refund scheme for beverage containers from April 2025 to October 2026, while Thailand and Indonesia are preparing to transition to mandatory EPR. Brunei, Cambodia, Laos and Myanmar lag behind these six countries in terms of institutional development.

The aforementioned amendment to ATIGA (Section 4.2.1) explicitly stipulates cooperation on the green and circular economy in the 'Trade and Environment' chapter, and introduces new provisions concerning remanufactured products. This signifies that circular economy policies have been institutionally integrated with trade governance, transcending the realms of industrial and environmental policy (JETRO, 2025). Given the response to the amendment to the Basel Convention on plastic waste, and the fact that EPR was a key issue during the negotiations on the Plastics Treaty (INC5.2) in August 2025, it has been suggested that harmonising the definitions of 'recyclable' and 'producer', as well as reporting formats, within the ASEAN region would effectively align with future international legal frameworks while reducing the compliance burden on businesses (Iwasaki & Kojima, 2026).

The Japan–ASEAN Circular Economy Initiative (AJCEI), which was launched to celebrate the 50th anniversary of the friendship and cooperation between Japan and the ASEAN countries, aims to promote the transfer of technology and institutional frameworks for the circular economy. Cooperation is taking concrete form in various areas, including the recycling of end-of-life vehicles (ELVs) (Iwasaki et al., 2025). Although dismantling operations carried out by the informal sector and the improper handling of hazardous chemicals have been identified as challenges, the increasing use of lithium-ion batteries and electronic components in ELVs due to electrification is forcing ASEAN countries' EPR schemes to adapt. For example, Vietnam is set to expand the scope of its EPR scheme in 2027 (Iwasaki et al., 2025; Iwasaki & Kojima, 2026).

The circular economy is no longer an emerging policy area in ASEAN; rather, through the harmonisation of EPR schemes, integration with trade regimes and technical cooperation with external partners such as Japan, it is entering the implementation phase as a core policy area at the intersection of trade, environmental and industrial policies.

6. Conclusion

This paper has provided an overview of recent political and economic developments in ASEAN. The US–China rivalry and the expansion of BRICS are forcing ASEAN to rethink its traditional hedging strategy of 'security with the US, economy with China'. The simultaneous pursuit of individual responses to the Trump tariff shock and multilateral engagement with BRICS and the GCC demonstrates that ASEAN is not a passive entity, but is actively combining multiple institutional options to 'institutional hedging' by actively combining multiple institutional options (Goh, 2007; Kuik, 2008). The three intra-regional issues—Myanmar, the South China Sea, and Thailand–Cambodia—demonstrated that, in contrast to this external pluralism, the same norms of non-coercive consensus and non-interference in internal affairs are reversed within the region, leading to dysfunction. The fact that the ceasefire in the Thailand– the fact that the ceasefire in the Thailand–Cambodia conflict was brought about by US trade pressure symbolises that economics and security are now inseparable.

ASEAN-centrism was a concept that integrated the effectiveness of the organisation as a mechanism for external balance with the limitations of its capacity for intra-regional conflict resolution. Whilst ASEAN-centrism functions by incorporating major powers into a multi-layered institutional framework, its effectiveness has always depended on the willingness of major powers to engage and the diplomatic skills of the individual chairperson. Whilst initiatives such as the amendment of the ATIGA and the DEFA negotiations can be regarded as steps towards steady economic integration, the Strait of Hormuz crisis at the end of February 2026 revealed that ASEAN was simultaneously facing a second external shock— —an energy security shock—simultaneously. The response of member states, characterised by increased reliance on Russian crude oil, reaffirms the paradox underpinning this paper: that whilst multipolarisation broadens the range of options, it simultaneously gives rise to new risks of dependency.

Overall, ASEAN is seeking to secure its autonomy through pragmatism (Kausikan, 2025), utilising multiple institutions and partners in parallel rather than aligning itself with a single major power. However, the sustainability of this strategy cannot be maintained without an endogenous foundation of regional cohesion and economic resilience.

Amidst the simultaneous convergence of multi-layered pressures—namely, the US–China rivalry, the expansion of BRICS, intra-regional conflicts and the energy crisis—whether ASEAN can effectively maintain its central role will remain the most significant variable determining the regional order in the coming years.

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Chapter 3: Circular Economy and Trade on Recyclable Wastes in ASEAN and Japan

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1. Introduction

The circular economy is a concept that aims to transition from the linear economy—which is based on mass production, mass consumption and mass disposal—to an economic system that recycles resources as much as possible and balances economic growth with environmental conservation whilst maximising the retention of value. In recent years, it has come to be recognised not merely as a framework for waste management and recycling policies, but as a policy issue closely linked to resource security, climate change mitigation, the strengthening of industrial competitiveness, and even economic security.

Whilst the Asian region continues to develop as the centre of global manufacturing, it faces numerous challenges, such as the rapid expansion of demand for resources and a lack of waste treatment capacity. In the ASEAN countries, too, as economic growth and urbanisation progress, the volume of recyclable resources—such as scrap iron, non-ferrous metal scrap, waste plastics and waste paper—is increasing year on year, and how to recycle these materials appropriately and efficiently has become a key policy issue.

Against this backdrop, cross-border trade in recyclable resources has played a vital role in complementing the supply and demand for resources in each country, whilst also underpinning the competitiveness of the manufacturing sector. In East Asia in particular, China has long played a central role in the international resource cycle as the world's largest importer of recyclable resources, leading to the formation of a wide-ranging resource circulation network encompassing Japan and the ASEAN countries. However, from around 2015, the Chinese government gradually began to tighten import restrictions on recyclable resources with the aim of environmental conservation and industrial upgrading, and in 2018, it imposed a ban on the import of waste plastics.

China's import restrictions served as a catalyst for shifting the flow of recycled materials, which had previously been destined for China, towards ASEAN countries. Chinese recycling operators expanded into countries such as Thailand, Vietnam and Malaysia, where they began processing recycled materials to meet the standards required for import approval by the Chinese government before exporting them to China. For example, in the case of waste paper, it became possible to export it to China provided it was processed into waste paper pulp using the waste paper as raw material. Similarly, household electrical appliances could be exported if they were dismantled, sorted into copper and iron scrap, and had any hazardous waste removed.

However, as pollution arose during the recycling process carried out by Chinese recyclers operating in ASEAN countries, some nations (such as Thailand) began to impose restrictions on the import of recyclable resources. Environmental management systems and institutional frameworks in these countries were insufficient, which in turn became a factor in causing new environmental and social problems. Consequently, many countries have moved to review their import regulations and strengthen their recycling systems; in some cases, companies that imported recyclable resources and carried out proper recycling have been forced to close their factories. In order to position the circular economy as an industrial policy, it is important to implement measures to prevent environmental pollution during the recycling process.

Against the backdrop of these changes in the international resource circulation structure, this chapter summarises the impact of China's import restrictions on recycled resources on ASEAN countries and examines the current state of circular economy policies and trade in recycled resources within each ASEAN nation. Furthermore, based on the current status and challenges of cooperation between Japan and ASEAN, it explores future directions for building a sustainable circular economy.

China's restrictions on the import of recycled resources were not merely a policy to reduce import volumes; they also had an industrial policy dimension aimed at advancing the domestic resource circulation system and moving away from recycling practices with high environmental impacts. Traditionally, China has functioned as one of the world's largest resource recycling hubs by accepting large quantities of recycled materials from countries around the globe, processing them, and supplying them to the manufacturing sector. However, the increase in imports of waste plastics, waste paper and electronic waste contaminated with foreign matter caused serious environmental problems, such as air pollution, water pollution and the disposal of residues, leading to calls for a review of the very nature of the resource recycling system. For example, in Guiyu Town, Guangdong Province, in southern China, waste electrical and electronic equipment (WEEE) was collected from around the world, dismantled, and metals such as copper and iron were recycled. However, as lead solder was used at the time, lead leaked into the environment, and it has been reported that school playgrounds were also contaminated with lead and other substances (Walters and Santillo. (2008)).

As a result of China's ban on the import of recyclable materials, some of the materials previously processed within China began to be diverted to ASEAN countries such as Thailand, Malaysia, Vietnam and Indonesia. Although these countries already had established recycling industries, there was a rapid increase in the number of recycling operators relocating from China, leading to an influx of recyclable materials exceeding their processing and environmental management capacities.

Whilst recyclable materials are useful resources in themselves, if they are not adequately sorted or properly processed, they can lead to environmental problems such as the illegal dumping or incineration of residues, as well as air and water pollution. Consequently, national governments have been compelled to strike a balance between promoting resource circulation and protecting the environment.

Furthermore, this change had a significant impact on the resource circulation network in East Asia. Whilst a relatively simple flow of recyclable materials had previously been established, running 'from

Japan, Europe and the US to China', following the introduction of China's import restrictions, recyclable materials began to be sent from Japan, Europe and the US to ASEAN countries. There, after being processed and sorted, they were further processed to meet the standards permitted for import by the Chinese government before being exported to China. In the case of plastics, for example, recyclable materials imported from various regions were processed in Southeast Asian countries to a standard that met China's import requirements. Waste plastic is processed into pellets, whilst waste paper is processed into recycled pulp, thereby enabling these materials to be exported to China. Furthermore, diverse recycling pathways have emerged domestically, including the expanded use of recycled resources. In other words, rather than causing a contraction in the trade of recycled resources across East Asia as a whole, China's import restrictions can be seen as having provided an opportunity to reorganise these flows.

However, this reorganisation did not necessarily proceed smoothly. In countries and regions unable to cope with the rapid influx of resources, inappropriate recycling practices and inadequate environmental management became social issues; as a result, ASEAN countries in turn introduced or tightened their own regulations on the import of recycled materials. These developments highlight the importance, in promoting a circular economy, of not only the free movement of resources but also the establishment of appropriate institutional frameworks, environmental standards and monitoring systems.

2. China's Ban on the Import of Recyclable Materials and Its Impact on ASEAN

China, which had been importing large quantities of recyclable materials and recycling them, began gradually imposing restrictions on such imports from around 2012, with these restrictions being tightened in 2018 (Kojima, 2024). There was an increase in cases where various recyclable materials were loaded into containers and exported to China without adequate sorting or quality control, and the presence of foreign matter and waste mixed in with the imported recyclable materials became a major social issue (Photo 1).

Photo 1: Waste paper exported from the United States to China (at the customs office in Shenzhen, Guangdong Province, China)

This is a container of waste paper inspected by customs officials in Shenzhen, Guangdong Province, China. The waste paper, exported from the United States, contained foreign matter such as plastic. Photograph taken by the author in December 2011.

With the aim of addressing these environmental issues and advancing the domestic recycling industry, the Chinese government has gradually tightened restrictions on the import of recyclable materials. As a result, some of the recyclable materials previously processed within China have begun to flow into ASEAN countries such as Thailand, Malaysia and Vietnam. Chinese recycling operators have also shifted to a business model whereby they construct dismantling and sorting facilities in these countries, process the materials to a standard that meets China's import criteria, and then re-export them to China.

However, this rapid relocation of business activities has also created new challenges for ASEAN countries. Many of the imported recyclable materials had not been adequately sorted, leading to problems in various regions such as the improper disposal and illegal dumping of residues generated during the recycling process. Consequently, around 2019, ASEAN countries, including Thailand and Malaysia, began successively introducing import restrictions on waste plastics, electronic waste and other materials.

These import restrictions on recycled materials affected not only operators engaging in improper processing but also companies that had been promoting proper circular utilisation. For example, since 2004, Fuji Xerox has been dismantling, recycling, refurbishing parts and refilling toner cartridges from end-of-life photocopiers collected not only in Thailand but also in neighbouring countries, thereby establishing a practical model for the circular economy.

The company had established a circular production system that combined the reuse of parts, the utilisation of refurbished parts, and the recycling of components and materials, rather than simply collecting end-of-life products. Such operations not only enhanced resource efficiency throughout the entire product life cycle but also reduced the amount of new resources required and the volume of waste generated; they represented a pioneering initiative that put the principles of the circular economy into practice. However, as Southeast Asian countries such as Thailand and Vietnam began to impose restrictions on the import of recycled resources, it became difficult to continue operations at sites such as the Fuji Xerox factory in Thailand, and they were forced to close.

This series of changes demonstrates that China's import restrictions did not merely reduce the flow of recycled resources, but actually reorganised the resource circulation network across the whole of East Asia. In other words, the flow of recycled resources, which had previously been highly concentrated on China, was redirected to ASEAN countries—particularly Thailand, Malaysia and Vietnam—where the materials were processed to a certain extent (for example, waste plastics were turned into pellets and waste paper into recycled pulp) before being exported to China, with the final products being manufactured there. In regions within ASEAN where environmental regulations and institutional frameworks were inadequate, new environmental problems also came to the fore. Consequently, it has once again become clear that promoting resource circulation requires not only free trade but also appropriate environmental management, institutional design and international cooperation.

This demonstrates that, in promoting a circular economy, it is essential to design institutional frameworks that reconcile environmental conservation and the promotion of resource circulation, rather than viewing them as conflicting objectives. Whilst strict regulations are necessary to prevent illegal dumping and environmental pollution, it is also essential to establish an institutional framework that promotes the activities of businesses employing appropriate recycling technologies and engaging in resource circulation.

In recent years, drawing on these experiences, there has been a growing trend amongst ASEAN member states to position the circular economy as an industrial policy. They are not only strengthening the management of imports of recycled materials but are also fostering the domestic recycling industry, applying Extended Producer Responsibility (EPR) and developing legal frameworks for resource circulation. Furthermore, they are striving to shift towards policies that achieve both environmental conservation and industrial competitiveness, such as industrial standards for products using recycled materials and green public procurement. Such institutional reforms can be understood not only as a response to the challenges brought to light by China's import restrictions, but also as part of the process by which ASEAN is establishing its own circular economy system.

Thus, China's restrictions on the import of recycled resources have brought about a major shift in the trade of recycled resources in East Asia. This was not merely a change in the structure of trade; it served as a catalyst for a review of resource circulation policies, environmental regulations and industrial policies in each country, and has had a significant impact on the development of circular economy policies within

ASEAN. From this perspective, the following section examines the development of circular economy policies and the status of institutional frameworks in each ASEAN country.

3. The Development of Circular Economy Policies in ASEAN Member States

Prompted by China's restrictions on the import of recyclable materials, ASEAN countries have been forced to re-examine their management of such imports and the structure of their recycling industries. As waste that had not been adequately sorted began to be exported to Southeast Asian nations, import restrictions were tightened. However, the response from ASEAN member states has not been limited to merely tightening import restrictions; since 2020, initiatives have been launched to ensure that waste generated domestically is utilised and recycled appropriately. In Indonesia, whilst penalties could not be enforced, the 'Minister of Environment Regulation on the Roadmap for Waste Reduction by Producers' was issued in 2019. This initiative requires producers to report their efforts to the Minister of Environment and involves recognising companies that perform well.

In July 2022, the Philippines enacted the Extended Producer Responsibility Act (Republic Act No. 11898), setting progressively higher annual collection rate targets for plastic packaging—20 per cent by the end of 2023 and 40 per cent by the end of 2024, amongst others. The national recycling rate (diversion rate) has met its targets, standing at 33 per cent in 2024 and 56 per cent in 2025.

Vietnam has extended its Extended Producer Responsibility scheme to cover multiple types of packaging, including plastic, aluminium and glass. The 2020 Environmental Protection Law refers to responsibilities regarding recycling and the collection and treatment of waste. Articles 54 and 55 of the same law also refer to the recycling of waste products and packaging materials.

In 2026, Decree No. 110/2026/NĐ-CP was issued, setting out the recycling rates to be met.

Table 1. Recycling Rates for Bottles and Packaging in Viet Nam

Target	Required Recycling Rate
Cardboard Packaging	20%
Aluminium Packaging	22%
Iron and Other Metal Packaging	20%
Rigid PET Packaging	22%
Rigid HEPE, LDPE, PP, and PS Packaging	15%

Source: https://aneco.com.vn/news-events/vietnam-introduces-new-epr-recycling-targets-for-products-and-packaging.html

Developments are moving towards positioning the circular economy as a new foundation for sustainable economic growth. In other words, there is a growing trend towards viewing resource circulation not merely as part of environmental policy, but as a key policy underpinning industrial policy, investment policy and regional economic integration.

As the stages of economic development and industrial structures vary significantly across ASEAN member states, their approaches to the circular economy are not uniform. Whilst some member states, such as Singapore, are aiming for a highly developed urban circular economy, in countries such as Indonesia, Vietnam and the Philippines, improving waste management and fostering the recycling industry are key priorities. Furthermore, in Thailand and Malaysia, against the backdrop of clusters in the automotive, electrical and electronics industries, efforts are underway to advance resource circulation within the manufacturing sector. This diversity is a defining feature of ASEAN, and circular economy policies are being implemented in accordance with each country's institutional framework and industrial structure.

Against this backdrop, ASEAN has also been advancing initiatives to establish a common direction through regional cooperation. Having set out common objectives such as the proper management of recyclable resources, improving resource efficiency, promoting circular business models, and advancing sustainable consumption and production, it is fostering policy dialogue and cooperation on institutional development amongst its member states. Although the institutional frameworks of individual countries are still under development, the concept of leveraging the circular economy to enhance the competitiveness of the region as a whole is steadily gaining traction.

However, the realisation of a circular economy cannot be achieved through institutional development alone. Many challenges remain, including quality standards for recyclable materials, ensuring traceability, improving recycling technologies, human resource development, and the improvement of the investment environment. In ASEAN in particular, the informal sector accounts for a high proportion of the collection and sorting of recyclable materials; therefore, how to integrate these activities into a formal circular economy system has become a key challenge.

In the following sections, we will examine the characteristics and challenges of circular economy policies in each ASEAN member state on a country-by-country basis, whilst also exploring the potential for cooperation with Japan. Focusing primarily on Singapore, Malaysia, Thailand, Vietnam, Indonesia and the Philippines, we will analyse the current state of institutional development and its relationship with the trade in recycled materials.

Whilst the circular economy policies of ASEAN member states share common principles, there are significant differences in their content and areas of focus. These differences reflect each country's industrial structure, resource endowment, income levels and degree of urbanisation; consequently, rather than adopting a one-size-fits-all approach, policy-making is being driven by the specific circumstances of each member state.

Singapore, constrained by a scarcity of land and natural resources, has positioned the maximisation of resource efficiency as a national strategy. Alongside efforts to reduce waste generation, improve recycling rates and introduce advanced waste treatment technologies, it is promoting resource management utilising digital technology and fostering collaboration across industries. The National Environment

Agency (NEA) introduced an e-waste management system in July 2021 to ensure the proper collection and recycling of e-waste. The locations where bin bags for e-waste, such as fluorescent lamps and batteries, are available are published on the NEA's website. Furthermore, a 10 Singapore cent deposit-refund scheme has been launched for beverage containers (ranging from 150 ml to 3 litres). From 1 April to 30 September 2026, there will be a transition period during which both bottles eligible for the deposit-refund scheme and those not eligible will be on sale.

Vietnam is working towards implementing EPR. Decree No. 08/2022/ND-CP, issued in 2020, stipulates that manufacturers and importers will be subject to the scheme from 1 January 2024 for packaging, batteries, lubricants, tubes and tyres; from 1 January 2025 for electrical and electronic products; and from 1 January 2027 for means of transport. According to Decree No. 110/2026/ND-CP, which came into force on 25 May 2026, extended producer responsibility has been extended to cover product packaging, storage batteries and batteries, lubricants, tyres and inner tubes, electrical and electronic equipment, and road vehicles, in addition to the existing scope of extended producer responsibility.

The Philippines enacted the 'Extended Producer Responsibility Act of 2022' on 23 July 2022. This Act obliges businesses that generate plastic packaging to collect it. The initial collection targets were set at 20 per cent for 2023 and 30 per cent for 2024, with the target increasing by 10 per cent annually thereafter, reaching 80 per cent from 31 December 2028 onwards. Failure to meet these targets results in the imposition of fines. The targets achieved were 33.16 per cent in 2023 and 55.98 per cent in 2024.

In contrast, in Thailand and Malaysia, against the backdrop of a concentration of manufacturing industries centred on the automotive, electrical and electronics sectors, efforts are underway to advance the sophistication of resource circulation within manufacturing processes. By promoting the integrated recovery of end-of-life products, the reuse of components, remanufacturing and material recycling, these countries are seeking to achieve both improved resource utilisation efficiency and enhanced competitiveness in the manufacturing sector. Meanwhile, in response to the sharp increase in the inflow of recycled resources following China's import restrictions, regulations on the import of waste plastics and electronic waste have also been tightened, making it a challenge to strike a balance between environmental conservation and industrial promotion in policy management.

Furthermore, SIRIM, which certifies Malaysian industrial standards, has published an Eco-Labelling Scheme. For example, there are a total of 95 SIRIM Eco-Label certifications, including 'SIRIM ECO 018:2024 Recycled Plastic Products (Eco-labelling criteria – Recycled Plastic Products)', 'SIRIM Eco 001:2018 Eco-labelling criteria – Biodegradable and compostable plastic and bioplastic', and 'SIRIM Eco 029:2026 Eco-labelling criteria – Cement', with a total of 95 SIRIM Eco-labels currently certified (accessed 19 July 2026).

In Indonesia, the lack of waste management capacity resulting from urbanisation and population growth is a major challenge. Although efforts to establish waste management systems have been made in recent years, much of the resource recovery and sorting is carried out by the informal sector, and improving the efficiency of these operations and the environmental impact has become a key policy issue. To promote a circular economy, it is necessary to facilitate a smooth transition to formal systems whilst utilising the collection networks and knowledge accumulated by the informal sector. As used PET bottles are bought back, in cities such as Jakarta, waste pickers can be seen collecting discarded PET bottles on the streets. Meanwhile, at the community level, ‘Bank Sampah’ (waste banks) have been established; these buy back recyclable materials and then sell them to recycling operators.

In the Philippines, under the Ecological Solid Waste Management Act (RA 9003), which was passed by Parliament in December 2000 and approved on 26 January 2001, Material Recovery Facilities are being established in barangays (the smallest unit of local government) or across multiple barangays. Furthermore, it is not uncommon for the informal sector, including waste pickers, to be responsible for collection.

4. ASEAN’s Initiatives

Thus, whilst the circular economy policies of individual ASEAN member states differ in terms of their specific institutional arrangements and priorities, they are collectively evolving towards ‘policies that enhance industrial competitiveness whilst ensuring the circular flow of resources’. This development can be seen as indicative of a policy shift across the entire ASEAN region, moving beyond the traditional framework of environmental governance to position the circular economy as a new growth strategy.

However, for such a policy shift to be effective, institutional reforms within individual countries alone are not sufficient. There are numerous challenges that require a region-wide approach, including the harmonisation of quality standards and certification schemes for recycled materials, the establishment of rules governing cross-border movements, the advancement of recycling technologies, human resource development and the promotion of investment. Consequently, in addition to intra-ASEAN cooperation, collaboration with non-ASEAN countries, including Japan, is expected to become increasingly important in the future.

In October 2021, ASEAN published a document entitled ‘Framework for a Circular Economy for the ASEAN Economic Community’. It sets out three strategic objectives: a resilient economy, resource efficiency, and sustainable and inclusive growth.

Meanwhile, information on the ASEAN Socio-Cultural Community is available on the ‘ASEAN Knowledge Environment Hub’ website. The seven strategically prioritised areas are: ‘Chemicals and Waste’, ‘Climate Change’, ‘Coastal and Marine Environment’, ‘Environmental Education and Sustainable Consumption and Production’, ‘Environment and Sustainable Cities’, ‘Nature Conservation and Biodiversity’ and ‘Water Resources Management’. These working groups serve as effective points of contact when organisations outside ASEAN (such as JICA and the World Bank) propose projects targeting multiple ASEAN member states.

The development of circular economy policies within ASEAN cannot be achieved solely through individual countries establishing their own systems. The entire circular process—from the generation of recyclable resources through to collection, sorting, remanufacturing, recycling and reuse—transcends national borders; an efficient resource circulation system can only be established when the systems of each country are mutually coordinated. Consequently, it is essential to adopt a perspective that promotes the circular economy across the entire region through institutional harmonisation, technical cooperation and human resource development within the region.

Over many years, Japan has developed a diverse range of circular industries whilst advancing pollution prevention technologies, waste treatment technologies, recycling technologies and resource management systems. The Home Appliance Recycling Act, the Automobile Recycling Act and the Small Home Appliance Recycling Scheme are highly regarded internationally as systems that take the entire product life cycle into account. This experience can provide valuable insights for ASEAN countries as they progress towards a circular economy.

However, it is not simply a matter of introducing Japan's systems into ASEAN as they stand. ASEAN countries differ significantly in terms of their stage of economic development, industrial structure, administrative capacity and the role of the informal sector; therefore, institutional design tailored to each country's specific circumstances is required. The role expected of Japan is not to transfer its systems, but to support the formulation of systems and the development of human resources in line with each country's situation, and to encourage local businesses and governments to take the lead in developing a circular economy.

Furthermore, the promotion of a circular economy is closely linked not only to environmental policy but also to industrial and trade policies. To ensure the smooth circulation of recycled resources and recycled components, consistency with trade systems is also crucial, including the establishment of quality standards and certification schemes, the streamlining of customs procedures, and the assurance of appropriate traceability. In particular, against the backdrop of the deepening of the ASEAN Economic Community (AEC), the advancement of resource circulation within the region has the potential to become a new foundation supporting regional economic integration.

Furthermore, in recent years, the management of new recyclable resources—such as batteries for electric vehicles, solar panels and electronic devices—has become increasingly important. As these products contain critical minerals such as lithium, cobalt, nickel and rare earths, resource circulation is not only an environmental issue but also a matter of resource security. Going forward, ensuring a stable supply of critical minerals through the recycling of resources will become a key policy challenge for maintaining the industrial competitiveness of both ASEAN and Japan.

Whilst ASEAN member states are tightening restrictions on the import of recycled materials, they are also advancing initiatives to position the circular economy as a new foundation for sustainable economic growth. However, the specifics of these systems and policies vary according to each country's stage of economic development and industrial structure, making it difficult to introduce a one-size-fits-all system. Going forward, it is important to develop systems tailored to the specific circumstances of each country, whilst promoting the circular economy through regional cooperation.

Japan has accumulated a wealth of experience through the development of waste management and recycling systems, as well as the advancement of a circular manufacturing sector. Sharing this experience with ASEAN member states and promoting institutional development, human resource development and technical cooperation is considered to contribute to the development of the circular economy within ASEAN.

Furthermore, trade in recycled resources is closely linked not only to environmental policy but also to industrial and trade policies. To achieve proper resource circulation, it is necessary to advance quality control for recycled resources and the establishment of environmental standards, whilst also building an appropriate framework for international cooperation.

Thus, the circular economy in ASEAN is undergoing a significant shift in its positioning, moving away from conventional policies centred on waste management towards a development strategy that underpins industrial competitiveness, resource security and regional economic integration. To realise this, in addition to institutional reforms in each country, continuous cooperation with Japan, technological innovation by the private sector and international institutional coordination are indispensable; the circular economy is expected to develop further as a key policy area underpinning future Japan–ASEAN cooperation.

4.1. Initiatives of the ASEAN Economic Community

A distinctive feature of the circular economy in ASEAN is that it has not only originated from environmental policy but has also been shaped as an extension of the economic integration strategy of the ASEAN Economic Community (AEC). In the EU, the circular economy has developed on the basis of environmental and decarbonisation policies, whilst in China it has been promoted as part of policies aimed at resource security and industrial upgrading. In contrast, a key characteristic of the circular economy in ASEAN is that it has been positioned within the context of the development of the AEC, which aims to integrate the regional market and strengthen international competitiveness.

Since its launch in 2015, the AEC has aimed to create a single market in which people, goods, services and investment can move more freely. As a result, cross-border production networks (Regional Value Chains) have developed rapidly within the ASEAN region, centred on the automotive, electrical and electronic equipment, and chemical industries. However, as these production networks rely on the input of large quantities of resources, it is becoming increasingly difficult to maintain sustainable growth through a conventional linear economy alone in the current international environment, characterised by soaring global resource prices, supply risks for critical minerals, and the strengthening of climate change measures. Consequently, within the AEC, the transition to a circular economy—which views production, consumption, recovery, reuse and remanufacturing as an integrated whole—has come to be positioned as a policy for generating new regional competitiveness.

This approach was institutionalised in the Framework for a Circular Economy for the ASEAN Economic Community, adopted in 2021. This framework defines the circular economy not merely as an advancement in waste management, but as a new economic model that achieves ‘a balance between economic growth and resource efficiency’. It sets out the fundamental principles of ‘Resilient Economy’, ‘Resource Efficiency’ and ‘Sustainable and Inclusive Growth’, thereby charting a new phase of development for ASEAN economic integration.

A particularly noteworthy point is that this framework positions the circular economy as a policy for the upgrading of regional value chains. Conventional value chains have been structured around the procurement of raw materials, production, distribution and consumption. However, in the circular economy, it is necessary to go beyond this and establish a ‘Circular Value Chain’ that encompasses the collection of end-of-life products, the reuse and remanufacturing of components, material recycling, and the market for recycled resources. In other words, the AEC is seeking to transform the regional production networks that have been established to date into circular networks.

To this end, the framework identifies the harmonisation of standards for circular products and services, trade facilitation, the utilisation of digital technology, sustainable finance and ESG investment, and human resource development as key priorities. These are not isolated policies but are interlinked as the institutional infrastructure underpinning the regional market. For example, to realise the free circulation of recycled resources, quality standards alone are insufficient; institutional design is required that encompasses traceability through digital technology, certification schemes and financial systems. In this way, the AEC framework is characterised by its approach to the circular economy from the perspective of ‘market formation’ rather than ‘resource circulation’.

Furthermore, underlying this policy philosophy is the concept of ‘Connectivity’, which ASEAN has long promoted. ASEAN has advanced regional integration by strengthening not only physical connectivity—such as roads, ports and logistics networks—but also diverse forms of connectivity, including institutional, human resource, digital and financial linkages. The circular economy can be understood as an attempt to extend the scope of this ‘connectivity’ beyond mere products and services to include recyclable resources, recycled components and information on the circular economy. Consequently, the circular economy within the AEC is more accurately understood as a ‘policy to evolve regional economic integration towards a circular model’ rather than as resource circulation in its own right.

That said, there are significant disparities in stages of economic development and institutional capacity amongst member states. It is not realistic to introduce the same institutional framework in Singapore, which has a highly developed resource management system, as in countries where the informal sector plays a central role in resource recovery. For this reason, the AEC framework adopts the concept of the ‘ASEAN Way’, which focuses on sharing common goals whilst respecting each country’s diversity, rather than standardising institutions. It is precisely this flexibility that constitutes the most distinctive feature of ASEAN’s circular economy policy, and it can be regarded as forming a unique development model that differs from those of the EU or China.

As outlined above, circular economy policies within the ASEAN Economic Community are being implemented not as environmental policies centred on waste management, but as economic integration policies designed to further deepen regional market integration. The aim is not only to improve resource efficiency, but also to transform regional value chains into circular ones, thereby enhancing the industrial competitiveness and economic resilience of ASEAN as a whole. This perspective is the most crucial characteristic for understanding the ASEAN circular economy.

4.2. ASEAN Social and Cultural Community

Circular economy policies within ASEAN cannot be realised through economic integration promoted by the AEC alone. The circular economy requires a transformation of the entire social system—encompassing not only the circulation of resources and products, but also people's lifestyles, the urban environment, waste management, education and community participation. For this reason, within ASEAN, alongside the AEC, which is responsible for economic integration, the ASEAN Socio-Cultural Community (ASCC) plays a vital role in promoting the circular economy. This signifies that the circular economy is positioned not merely as an environmental policy, but as a comprehensive policy aimed at 'building a sustainable society'.

The ASCC upholds the formation of a people-centred community as its fundamental principle and oversees a diverse range of social policies, including environmental conservation, urban policy, public health, disaster management, education and the development of local communities. Within this framework, the circular economy is positioned not only as a means of reducing environmental impact through resource circulation, but also as a policy for improving people's quality of life and building sustainable local communities. This represents a unique role for the ASCC, distinct from that of the AEC, which prioritises economic efficiency.

Within the ASCC's environmental sector, several working groups are active, dealing with chemical and waste management, sustainable urban development and marine environmental conservation, amongst other areas. Whilst these organisations have traditionally addressed environmental issues independently, in recent years policy coordination between them has been advancing under the common principle of the circular economy. In other words, the approach of viewing waste management, resource recycling, urban policy and marine environmental conservation not as separate issues but as a single circular system is becoming firmly established.

The catalyst for this policy shift was the worsening problem of marine plastic litter. In the ASEAN region, whilst plastic consumption has surged in tandem with rapid economic growth and urbanisation, the development of waste collection and proper treatment systems has been inadequate, resulting in large quantities of plastic continuing to flow into rivers and the sea. Consequently, in 2019, ASEAN adopted the ASEAN Framework of Action on Marine Debris, positioning the issue of marine plastic pollution as a common challenge to be addressed by the entire ASEAN bloc. This policy served as a key catalyst not only for measures to combat marine pollution but also for the transition to a circular economy, encompassing product design, consumption, collection, reuse and recycling.

Furthermore, the ASCC places great emphasis on the development of the social infrastructure that underpins the circular economy. In many ASEAN countries, waste collection and resource sorting are supported by the informal sector. Although waste collectors and local communities are not fully recognised within the institutional framework, in practice they are key players underpinning the circular economy. Consequently, the ASCC recognises that, rather than simply excluding them, it is crucial to gradually integrate them into the formal circular economy system whilst improving safety and hygiene standards. This inclusive institutional design is one of the key characteristics of the ASEAN circular economy.

Furthermore, a change in public behaviour is essential for the realisation of a circular economy. No matter how advanced the recycling facilities or systems may be, the circular economy will not function without public understanding of waste separation and reuse. For this reason, the ASCC places emphasis on environmental education, Sustainable Consumption and Production (SCP), the participation of local communities and Corporate Social Responsibility (CSR), and is working to foster a shift in awareness across society as a whole. The policy is underpinned by the recognition that a circular economy is not achieved through technology alone, but only through a change in behaviour across society as a whole.

Furthermore, in recent years, the circular economy has become closely linked to measures to tackle climate change. As improving resource efficiency and reducing waste also lead to a reduction in greenhouse gas emissions, the ASCC is aligning the circular economy not only with the SDGs but also with each country's decarbonisation policies and green growth strategies. In this way, the circular economy is increasingly being positioned as a common foundation for integrating environmental, social and climate change policies.

Consequently, circular economy policies within the ASCC are evolving beyond traditional waste policies aimed at environmental conservation to become social policies designed to build a people-centred, sustainable society. Their role is not merely to complement the economic integration promoted by the AEC. Whilst the AEC aims to build a 'circular economy', the ASCC aims to form a 'society that supports the circular economy'. It is only through the mutual complementarity of these two elements that the circular economy envisaged by ASEAN can function as a regional development model that integrates economic, social and environmental dimensions. This very point constitutes the most significant characteristic of ASEAN's circular economy policy.

The circular economy cannot be realised through domestic policies alone. Recyclable resources move across borders, and these flows are significantly influenced by each country's resource prices, energy prices, environmental regulations and industrial structure. Consequently, promoting a circular economy requires not only the development of national institutional frameworks but also policy-making that takes into account the entire cross-border resource circulation system.

One example of this is the difference in electricity tariffs. In Cambodia, electricity tariffs are higher than in neighbouring countries, and in some cases it is more economically advantageous to export plastic and metal scrap to Vietnam, where electricity tariffs are lower, rather than recycling them domestically. In particular, as the recycling of plastics and the smelting of scrap iron consume large amounts of electricity, differences in electricity costs have a significant impact on the choice of location and the costs of recycling. This demonstrates that resource circulation is not determined by environmental policy alone, but is also closely linked to energy and industrial policies.

Furthermore, in the Taisen Puppet Special Economic Zone in Cambodia, costs are being reduced by sourcing electricity from Vietnam. This example demonstrates that not only are resources being recycled across borders, but the electricity infrastructure itself is also becoming regionally interconnected. In the circular economy of the future, it will be important to view the system not merely in terms of recyclable resources, but as a wide-area resource circulation network that encompasses electricity, logistics and industrial infrastructure.

Japan's trade in recyclable resources is also undergoing significant change. Whilst imports accounted for a large proportion of the trade in 1998, depending on the commodity, exports of waste paper, scrap iron and scrap aluminium have since increased substantially, and Japan has strengthened its role as a key supplier of recyclable resources. Meanwhile, the traditional structure of international resource circulation is changing significantly due to import restrictions in China and tighter import controls in ASEAN countries. Currently, there is a growing trend towards the international circulation of recycled resources that have undergone quality control and pre-processing, rather than simply exporting them.

Cross-border resource circulation is not shaped solely by market forces. These flows are shaped by the interplay of electricity tariffs, environmental regulations, logistics costs and the institutional frameworks of individual countries. Consequently, in order to ensure the sustainable development of the circular economy within ASEAN, it is necessary—in addition to the development of national institutional frameworks—to establish a wide-area resource circulation system that balances efficiency with environmental conservation through the standardisation of resource quality, the harmonisation of environmental standards and the strengthening of intra-regional cooperation.

5. Conclusion

Whilst institutional frameworks for the circular economy are making steady progress across ASEAN member states, the stage of development varies significantly from country to country. Some recycling facilities lack adequate environmental safeguards, and there are instances where the treatment process itself causes environmental pollution. Furthermore, whilst waste collection services are relatively well-established in urban areas, they are not sufficiently widespread in suburban and rural areas; as a result, there are still many regions where fly-tipping and open burning continue to occur. To ensure the sustainable development of the circular economy, it is important to establish a region-wide infrastructure for collection, sorting and recycling in parallel with the development of institutional frameworks.

Furthermore, the realisation of resource circulation cannot be achieved through large-scale institutional reform alone. In Japan, a system has become widespread whereby expanded polystyrene (EPS) materials, such as fish crates and food trays, are heat-compressed to improve transport efficiency and facilitate recycling. Conversely, in ASEAN member states, there are still regions where even similar resources are not being adequately collected and recycled. This demonstrates that promoting a circular economy requires not only advanced technology but also a combination of collection methods, logistics systems and cost-reduction technologies tailored to local circumstances. Sharing the practical experience accumulated in each country and rolling out best practices across the region will help to raise the overall standard of the circular economy.

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Chapter 4: Japan's Waste Management and the "Material-Cycle Society"

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1. Introduction

The "Circular Economy" is attracting worldwide attention as a new economic system (Agency for Natural Resources and Energy, 2024). The concept was originated and was developed in Europe. It was first raised as a government-level strategy in "Closing the Loop - An EU Action Plan for the Circular Economy" (COM(2015) 614 final), formulated by the European Commission in 2015 (Aoki, 2018). At the beginning of the action plan, a circular economy is defined as an economy "where the value of products, materials and resources is maintained in the economy for as long as possible, and the generation of waste is minimised."

Even before the EU's action plan, Japan had been promoting the formation of a "Material-Cycle Society" based on the "Basic Act on Establishing a Sound Material-Cycle Society" (Act No. 110 of 2000), which was enacted in 2000. Based on the provisions of this act, Japan promoted the "3Rs (Reduce, Reuse, Recycle)". In contrast, the circular economy is sometimes explained as promoting beyond the 3Rs, with the addition of the 9Rs (R0: Refuse, R1: Rethink, R2: Reuse, R3: Repair, R4: Refurbish, R5: Remanufacturing, R6: Repurposing, R7: Recycling, and R9: Recover) (CE Grow Circular, 2021).

This paper outlines the relationship between Japan's legal system and its policies regarding the concepts of a "Material-Cycle Society" and a "Circular Economy," while describing how the former was established in Japan and deployed internationally, mainly in Asian countries. It also touches upon the efforts of the Japanese government to achieve the international standardisation of the "Material-Cycle Society." And it should be noted that this paper partly overlaps with the author's previous work, namely, Chapter 21 of ERIA (2026).

2. Relationship between "Material-Cycle Society" and "Circular Economy" in Japan

As mentioned earlier, the concept of a "material-cycle society" originated in Japan, and its legal basis lies in the "Basic Act for Establishing a Sound Material-Cycle Society," enacted in 2000. Article 2 of the Act defines a Material-Cycle Society as 'a society in which the proper cyclical use of products and other items is promoted, the generation of waste is prevented or reduced, and the proper disposal of circulative resources not put into cyclical use is ensured, thereby conserving the consumption of natural resources and reducing the environmental load to the greatest extent possible'. In this context, 'disposal' refers to disposal as “waste,” and the definition of waste follows that in Article 2 of the “Act on Waste Management and Public Cleaning” (Act No. 137 of 1970).

While there are no Japanese laws or cabinet/ministerial ordinances that explicitly define “Circular Economy,” the government’s plan and policy package mentions the transition to a circular economy. This is exemplified by the “Fifth Fundamental Plan for Establishing a Sound Material-Cycle Society: Incorporating the Circular Economy into a National Strategy” (Cabinet Decision on 2 August 2024), which was developed based on the Basic Act. The “Package for Accelerating the Transition to a Circular Economy” (decision by the Ministerial Council on Circular Economy on 27 December 2024) was formulated to implement government-wide efforts to realise the circular economy set out in the Fifth Fundamental Plan.

The Fifth Fundamental Plan states that “the transition from a one-way linear economy, which leads to the economic and social patterns of mass production, mass consumption, and mass disposal, to a circular economy that efficiently and cyclically utilizes resources in a sustainable manner” is the key to “further strengthening efforts to increase resource productivity and the cyclical use rate toward the formation of a material-cycle society.”

The Acceleration Package states that “the transition to a circular economy utilises waste, etc., as a resource effectively, generates added value, and leads to new growth. Moreover, it contributes to regional revitalisation, the realisation of high-quality living, strengthened industrial competitiveness, and the ensuring of economic security, as well as addressing environmental challenges such as climate change and biodiversity conservation.”

Furthermore, Section 2, Chapter 2, Part 1 of the “White Paper on the Environment, the Sound Material-Cycle Society and Biodiversity 2025” states, “In order to further strengthen efforts to increase resource productivity and the cyclical use rate towards the formation of a material-cycle society, it is important to promote the transition to a circular economy that efficiently and cyclically utilises resources in a sustainable manner” (Ministry of the Environment, 2025: 34). This clearly specifies the relationship that the transition to a circular economy is intended to achieve a material-cycle society (see Figure 1).

Figure 1: Transition to a Circular Economy

Source: Ministry of the Environment (2025)

The White Paper also states that, "In international discussions, a circular economy is defined as an economic system that cyclically utilises resources (including renewable resources) and products by maintaining, restoring, or adding to their value" (Ibid.: 34). This clarifies the relationship between Japan's "Material-Cycle Society" and the "Circular Economy" within the context.

In other words, the concept of Japan's "Material-Cycle Society" is a concept that developed independently prior to the concept of a "Circular Economy," and the Japanese government aims to transition to the former (Circular Economy) in order to realise the latter (Material-Cycle Society).

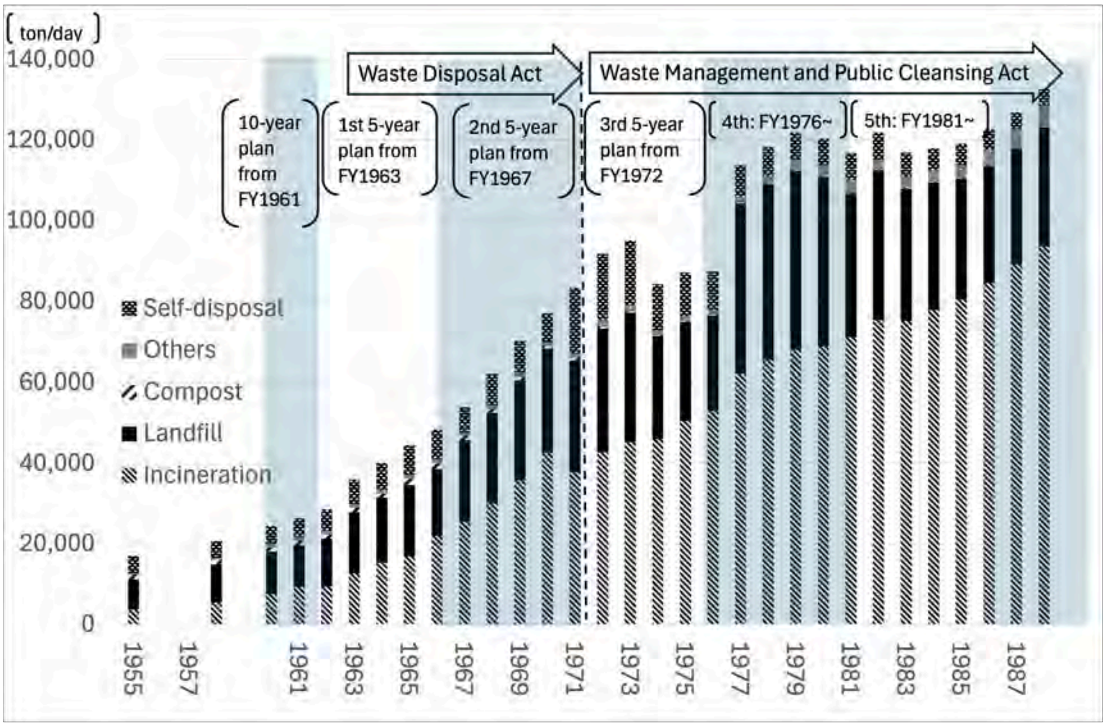
3. Background of the Emergence of the "Material-Cycle Society" Concept

To understand the origins of how the concept of a "Material-Cycle Society" was born, it is necessary to explore the history of waste management administration in Japan.

Prior to its transfer to the Ministry of the Environment in 2001 as a part of the reorganisation of ministries and agencies in 2001, Japan's waste management administration was handled by the Ministry of Public Health. The ministry publishes "White Paper on Public Health" annually to provide insight into the challenges faced by Japan's waste management administration and how these challenges have been overcome.

In the 1950s and 1960s, the White Papers on Public Health sequentially explained the background of how Japan began developing infrastructure for the treatment and disposal of human and other types of waste to solve public health issues. For example, the "White Paper on Public Health 1956" states that, "Looking at the current situation of public cleaning services in our country, both human waste and other types of waste are experiencing significant difficulties in disposal because, while the waste generation is increasing due to growth in urban populations, agricultural demand is decreasing due to increased production of chemical fertilisers" (Ministry of Public Health, 1956: 123). The paper also issues a strong warning about the negative impact of inadequate waste management on people's lives, stating, "Incomplete garbage disposal becomes a source of flies and foul odours, leading to the pollution of the people's living environments everywhere, adversely affecting their health" (Ibid.). However, the situation did not easily improve. Even the "White Paper on Public Health 1959," published in the year that Tokyo was chosen as the first Asian host city for the Olympics, noted, "… [t]he occurrence of mosquitoes and flies still remained at the level of underdeveloped countries, a truly regrettable situation," and pointed out that the cause lay in problems with the disposal of human waste and other waste as the cause (Ministry of Public Health, 1959: 10). According to the "White Paper on Public Health 1960," in response to these circumstances, the Ministry of Public Health formulated a new ten-year plan starting in FY1961 for the establishment of waste treatment facilities, as well as water supply and sewage treatment plants, to move forward with the development of waste management infrastructure (Ministry of Public Health, 1960). In response to the growing demand for infrastructure development, the ten-year plan was revised to a five-year plan from FY1963 onwards. Financial support from the national government was strengthened incrementally but sequentially. Passing through the fifth five-year plan starting in FY1981, by around 1988, waste treatment capacity had been strengthened to about seven times that of the 1950s, leading to the establishment of incineration and landfill infrastructure equivalent to that of the 2020s (Figure 2).

Figure 2: Historical Changes in Waste Disposal Volume by Treatment Method in Japan, 1955-1988



Source: Figure 21.1 of ERIA (2026)

In the 1970s, as the quantitative development of waste treatment infrastructure was becoming complete, new challenges emerged: the accumulation of plastic waste and the depletion of landfill capacity. Plastics were becoming increasingly prevalent in daily life. When they became waste, an increasing proportion of them were mixed into “flammable waste.” Taking Tokyo as an example, the mixture rate, which was 2.2% in 1963, reached 8.7% in 1968. According to the “White Paper on Public Health,” considering the performance of incinerators at that time, the allowable mixture rate was 10% (Ministry of Public Health, 1970). As a result of measures taken to prevent the mixture of “flammable waste,” the remaining lifespan of landfill sites for municipal waste that accept “non-flammable waste” dropped sharply. According to the “White Paper on Health and Welfare 1988,” the remaining lifespan of landfill sites for general waste in the Tokyo Metropolitan Area (i.e. Tokyo, Saitama, Chiba, and Kanagawa prefectures) was about 4 years as of 1988. (Ministry of Public Health, 1990).

To address this issue, the ‘White Paper on Public Health 1990’ recommended the establishment of a new socio-economic system. The description of this new system can be found in Section 4, Chapter 1, Part 1, Book 1 of the ‘White Paper on Health and Welfare’ (Ministry of Public Health, 1990b: 34).

> *“To reduce the total cost associated with waste, we must directly address processing costs and build a new socio-economic system that incorporates appropriate processing costs. To achieve this, it is necessary to clearly present the current state of waste processing costs to the*

public and to impose appropriate burdens on waste generation, thereby providing incentives for waste reduction at each stage of production, distribution, and consumption."

"As a reason why recycling activities are not actively carried out, it is often pointed out that recycling activities lack economic viability. However, if waste is reduced through recycling, processing costs can be reduced by that amount. Looking at the total cost including this reduction, there are considerable cases where economic viability is recognized in recycling activities. To activate recycling activities, it is necessary to appropriately allocate processing costs, strengthen regulations to prevent improper disposal, and give economic value to waste reduction."

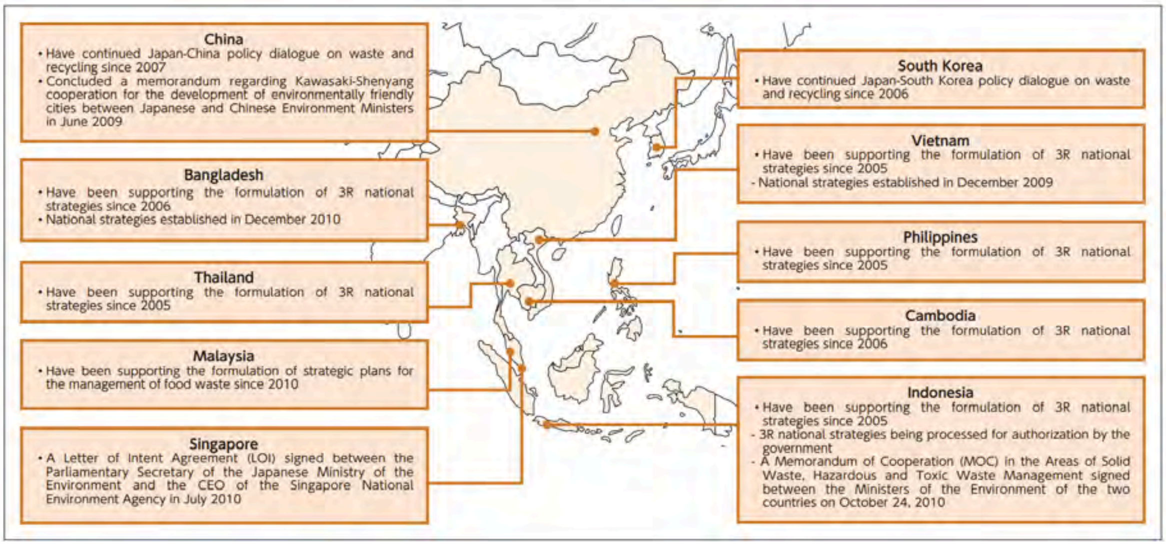
From the 1990s to the early 2000s, legal acts were sequentially enacted which defined the items subject to legal regulations, specified the appropriate burden of processing costs, and divided roles among stakeholders. These were spearheaded by the "Act on the Promotion of Effective Utilisation of Resources" of 1991, the "Containers and Packaging Recycling Act" of 1995, and the "Home Appliance Recycling Act" of 1998. The "Basic Act for Establishing a Sound Material-Cycle Society," the "Construction Recycling Act," and the "Food Recycling Act" were established in 2000, completing the core legal framework that contributed to the formation of a "Material-Cycle Society." The "End-of-Life Vehicle Recycling Act" was enacted in 2002, and other legislation promoting the utilisation of cyclical resources according to the characteristics of the items and the actual conditions of disposal has been established. In addition, around the same time, amendments to the Waste Management Act significantly strengthened penalties for improper waste disposal and illegal dumping, completing the requirements for the "new socio-economic system."

As a result, Japan's waste management performance improved significantly. The Containers and Packaging Recycling Act is a prime example of this; since its introduction, the recycling rate of general waste has increased from 9.8% in 1995 to 19.0% in 2005, while the remaining lifespan of landfill sites has increased from 9.9 years in 1996 to 14.8 years in 2005 (Ministry of the Environment, n.d.).

4. International Development of the "Material-Cycle Society"

By promoting the formation of a "Material-Cycle Society", Japan has successfully overcome the waste management problems that have been evident since the 1950s. Building on this success, Japan has expanded its waste and recycling policies, as well as its 'National 3R Strategy', to Asian countries (see Figure 3).

Figure 3: International Development of Waste Management and 3R Strategy



Source: Ministry of the Environment (2014)

Furthermore, in recent years, efforts have been made to utilise the experience accumulated in the process of promoting the formation of a "Material-Cycle Society" to promote the international adoption of a "Circular Economy." According to the "White Paper on the Environment, the Sound Material-Cycle Society and Biodiversity 2025," the "Circular Economy and Resource Efficiency Principles (CEREP)" were created and approved under Japan's leadership at the 2023 G7 Hiroshima Summit. These principles aim to enable value-chain-level monitoring based on circularity indicators and to encourage the disclosure of circularity-related information at the corporate level (Ministry of the Environment, 2025). At the G7 and B7 joint meeting on CEREP held in November 2023, the importance of developing infrastructure for indicators and information disclosure was shared. Furthermore, at the 2024 G7 Climate, Energy and Environment Ministers' Meeting, it was agreed in the communique to provide comparable indicators and information disclosure schemes (Ibid.).

Outside of the G7, the World Business Council for Sustainable Development (WBCSD) and the Ministry of the Environment have signed a memorandum of understanding on developing the Global Circularity Protocol. In May 2024, the International Organisation for Standardisation (ISO) issued standards, including guidance on the transition of business models and value networks (ISO 59010), which were proposed by Japan. Thus, Japan is actively involved in establishing international rules for a "Circular Economy" (Ibid.)

5. Conclusion

During its period of rapid economic growth, Japan successfully overcame waste management issues and concluded around the late 1980s that a "new socio-economic system" was necessary. From the 1990s to the 2000s, Japan developed a series of legal systems to promote the formation of a “Material-Cycle Society.” Building on its experience of improving waste management performance, Japan has since the 2000s expanded its policies and strategies for building a “Material-Cycle Society” to Asian countries.

The “Circular Economy,” which has attracted international attention in recent years, is positioned as a key way of promoting the development of a “Material-Cycle Society” under Japan’s legal system. In this context, the “Circular Economy” was established as a national strategy in the 2024 fundamental plan and the ministerial council decision.

Based on the knowledge and experience accumulated regarding a “Material-Cycle Society,” the Japanese government has also been contributing to the formation of international rules for a circular economy within the G7, WBCSD, and ISO since 2023.

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Chapter 5: Realising Knowledge-Driven Engineering in the AI Era: Collective Wisdom — A Practical Knowledge Ecosystem as the Foundation of the SEZ Vision —

Author

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Keywords: *Collective Wisdom, knowledge-driven manufacturing, cyber-physical systems, tacit knowledge, SEZ vision, Industry 4.0, human resource development, Digital Triplet*

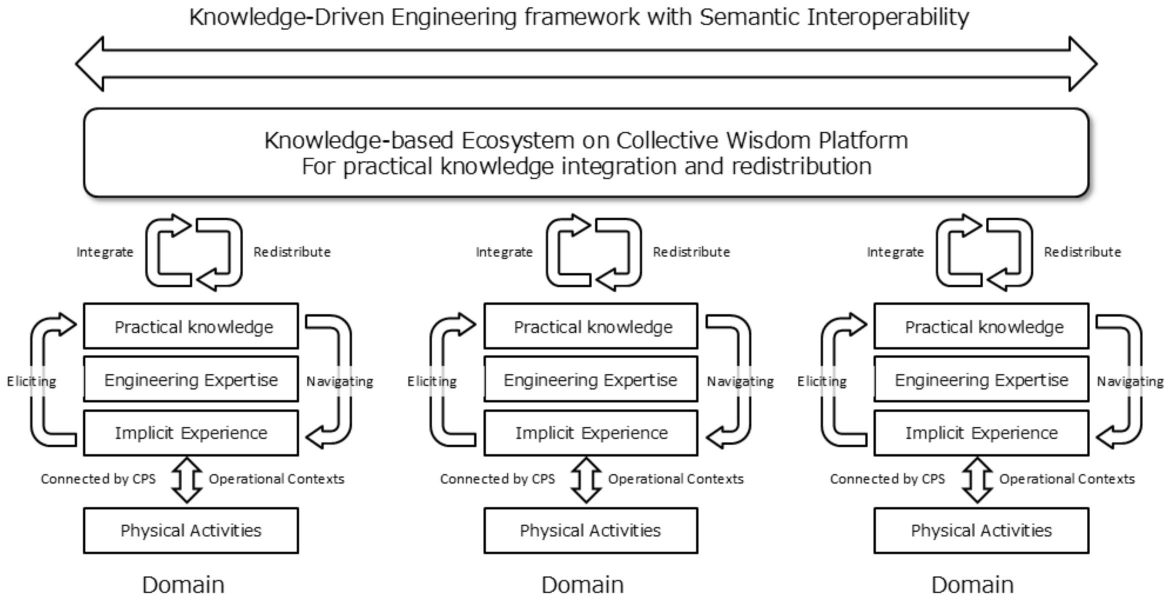
1. Introduction: The Collective Wisdom Concept Supporting the SEZ Vision

The Fourth Industrial Revolution is characterised by the convergence of digital technologies, cyber-physical systems and advanced automation. It is fundamentally transforming manufacturing paradigms worldwide. Within this transformation, product design, production systems engineering, manufacturing execution, quality management, logistics, maintenance, supply-chain coordination and human resource development are becoming increasingly interconnected through digital networks and cyber-physical systems (CPS). As these interconnected systems become more sophisticated, engineers and the organisations that manage them face unprecedented demands on their knowledge and judgement. It is in this context that the SEZ vision proposed in “Musashino Reflection” is particularly promising (Nakamura, 2025).

The SEZ vision targets value creation in a Global South strategy by penetrating data across heterogeneous domains connected by CPS (Nakamura, 2025). This can be achieved by defining the scope for combining heterogeneous information, thereby establishing epistemic relationships. Assigning special relationships to an intended scope enables the design of activities within that scope, where collaboration among members generates distinctive value. Furthermore, granting special functions and efficacy to a defined scope makes its uniqueness manifest — for example, by providing methods that generate significant business value or specialised knowledge that solves the current problems.

In this environment, knowledge-driven engineering grounded in accumulated practical expertise across multiple disciplines becomes both a critical approach and a strategic asset (Nonaka and Takeuchi, 1995; Polanyi, 1966). The objective is not merely to automate control systems or decision processes, but also to leverage the rich experiential wisdom organisations have built through years of practice and integrate it across functional boundaries to guide complex organisations towards system-wide optimisation. This approach aligns naturally with the smart manufacturing and intelligent factory visions at the heart of contemporary industrial policies in Germany (Industry 4.0) and Japan (Society 5.0)(Kagermann et al., 2013; Womack et al., 1990).

Figure 1: The AI Blind Spot: Engineering Transparency for Proprietary 'Operational Wisdom' and Bridging Knowledge to the Shop Floor

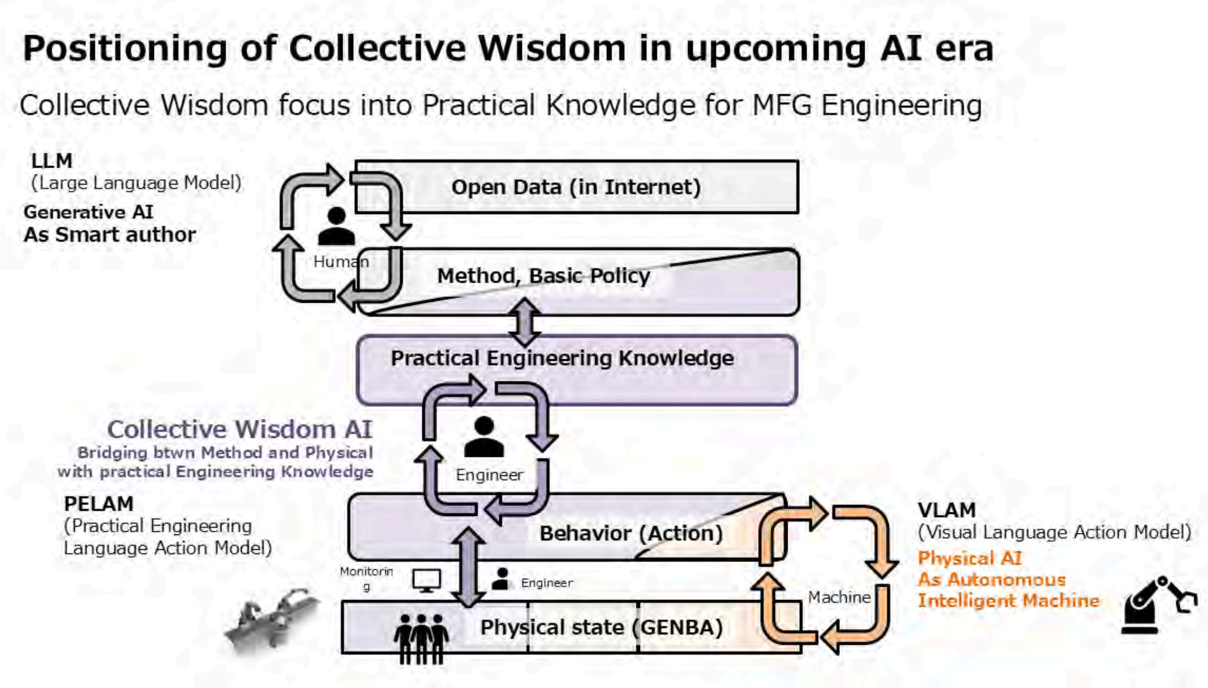


Source: by Author

Meanwhile, although the promise of generative AI and physical AI has grown substantially, important limitations have emerged in practice. Large language models (LLMs) trained on open internet data provide general conceptual knowledge but cannot capture the highly specific, context-dependent, and non-stationary realities of actual manufacturing floors (Nonaka and Takeuchi, 1995; Schwab, 2016). Real production environments are dynamic, evolving systems in which materials, equipment, operators, and process conditions change continuously — not static systems amenable to pattern recognition from historical datasets. Consequently, machine-learning-based approaches are fundamentally unable to fully address the practical challenges engineers face daily.

The gap between current AI capabilities and actual shop-floor demands highlights the indispensable importance of the implicit knowledge held by experienced engineers (Nonaka and Takeuchi, 1995; Polanyi, 1966). Accumulated through years of practical problem-solving, this knowledge is embedded in expert judgement rather than documented in formal procedures. Making it explicit, structured, and accessible across the organisation is therefore a central challenge in the advancement of manufacturing intelligence.

Figure 2: Concept of a Knowledge-Driven Engineering Network



Source: by Author

To address this challenge, the author has developed a new conceptual and technical concept, called 'Collective Wisdom (CW)'. The CW concept aims to systematically elicit, formalise, accumulate, and share the practical knowledge of domain experts across organisational and geographical boundaries. This builds a continuously growing knowledge-based ecosystem. The CW Platform facilitates societal implementation of this concept through a software architecture integrating knowledge management, interactive navigation for problem-solving, and real-time linkage with CPS-based physical production data (Grieves, 2024; Lee et al., 2015).

The remainder of this paper is organised as follows: Section 2 provides background on knowledge management in manufacturing and situates the CW concept within this field. Section 3 discusses knowledge-driven approaches for realising the SEZ vision. Section 4 introduces the relationship between the CW concept and the knowledge ecosystem. Section 5 describes the CW Platform architecture in detail. Section 6 presents the implementation methodology. Section 7 reports actual case studies. Section 8 presents the results and discussion. Section 9 offers conclusions and future directions.

2. Background: Knowledge Strategy in Smart Manufacturing

2.1. From Data-Driven to Knowledge-Driven Manufacturing

Contemporary discourse on smart manufacturing has largely assumed that data-driven approaches are sufficient. Technologies such as sensor fusion, big data analytics, and machine learning have attracted enormous research and investment (Lee et al., 2015; Wang et al., 2016). These approaches have delivered genuine value in domains where data are abundant, process conditions are stable, and optimisation targets are well-defined. When the full complexity of manufacturing operations is considered, however, structural limits on their applicability emerge.

Knowledge-driven approaches offer a complementary perspective. Rather than extracting knowledge solely from data, they begin with a structured representation of domain expertise and use data to instantiate and refine that knowledge within specific operational contexts (Nonaka and Takeuchi, 1995; Polanyi, 1966). This paradigm resonates with the traditional knowledge engineering tradition and with recent work on ontology-based manufacturing knowledge representation, model-based systems engineering, and knowledge graphs for industrial applications.

The specific challenge addressed here is not merely representing explicit, documented engineering knowledge, but also eliciting and formalising the tacit practical knowledge that skilled engineers exercise when diagnosing new quality problems on the shop floor or deciding how to reconfigure a production line in response to an unexpected failure (Polanyi, 1966; Umeda et al., 2020; Umeda et al., 2022). By definition, this knowledge is not fully contained in manuals or databases; rather, it is embedded in practitioners' experience and manifests in their problem-solving behaviour.

2.2. Tacit Knowledge and Its Organisational Significance

The distinction between tacit and explicit knowledge, first introduced by Polanyi and subsequently developed in organisational theory by Nonaka and Takeuchi, provides a fundamental framework for understanding the challenges of knowledge management in manufacturing (Nonaka and takeuchi, 1995; Polanyi, 1966). While explicit knowledge can be codified in documents, procedures, and databases, tacit knowledge, rooted in personal experience, sensory judgement, and intuitive pattern recognition, resists formalisation. In manufacturing, tacit knowledge is simultaneously a primary source of competitive advantage, but it is also one of the most vulnerable organisational assets and can easily be lost through ageing and retirement of the workforce, and staff turnover.

This challenge is especially acute in advanced manufacturing nations, where the ageing of skilled engineers is widely recognised as a structural concern. Decades of accumulated expertise in lean production, quality engineering and precision manufacturing are at risk of being lost as veteran technicians retire (Sato et al., 2024; Womack et al., 1990). The CW framework is expressly designed to address this challenge, with the explicit objective of enabling tacit expert knowledge to be shared and transmitted across generational and organisational boundaries.

Table 1: Comparison of Explicit and Tacit Knowledge

Attribute	Explicit Knowledge	Tacit Knowledge
Form of expression	Documents, formulas, procedures, databases	Experience, intuition, conjecture, judgment
Mode of transfer	Textbooks, manuals, digital data	Apprenticeship, on-the-job training
Standardizability	High	Low
Risk of loss	Low (preservable through documentation)	High (lost through workforce attrition)
Shop-floor example	Work standards, quality specifications	Skilled workers' sensory judgment and intuition
Handling in CW	Systematized as Basic KM with LLM and correction	Formalized through KX-led modeling

Source: by Author

2.3. Limitations of Current AI Approaches in Manufacturing

Recent advances in generative AI and physical AI have led to significant expectations for manufacturing applications. However, there are inherent limitations to applying LLMs to manufacturing problem-solving. Firstly, because LLMs are trained on general text data, they lack the deep, domain-specific causal models required for reliable manufacturing-engineering judgements (Schwab, 2016). Secondly, manufacturing environments are characterised by non-stationarity: process conditions, equipment states, and defect mechanisms change continuously in ways that historical training data cannot fully anticipate. Thirdly, and perhaps most fundamentally, manufacturing problem solving does not involve text generation. Instead, it requires grounded reasoning about physical phenomena, causal relationships, and operational consequences (Polanyi, 1966).

These constraints do not diminish the value of AI in manufacturing, but they underscore the importance of combining AI capabilities with structured domain knowledge (Nonaka and Takeuchi, 1995; Umeda et al., 2022). The CW Platform is designed as precisely such a hybrid: by using AI-assisted reasoning within a framework defined by expert-authored knowledge models, the reasoning process operates on validated causal understanding rather than statistical pattern matching alone.

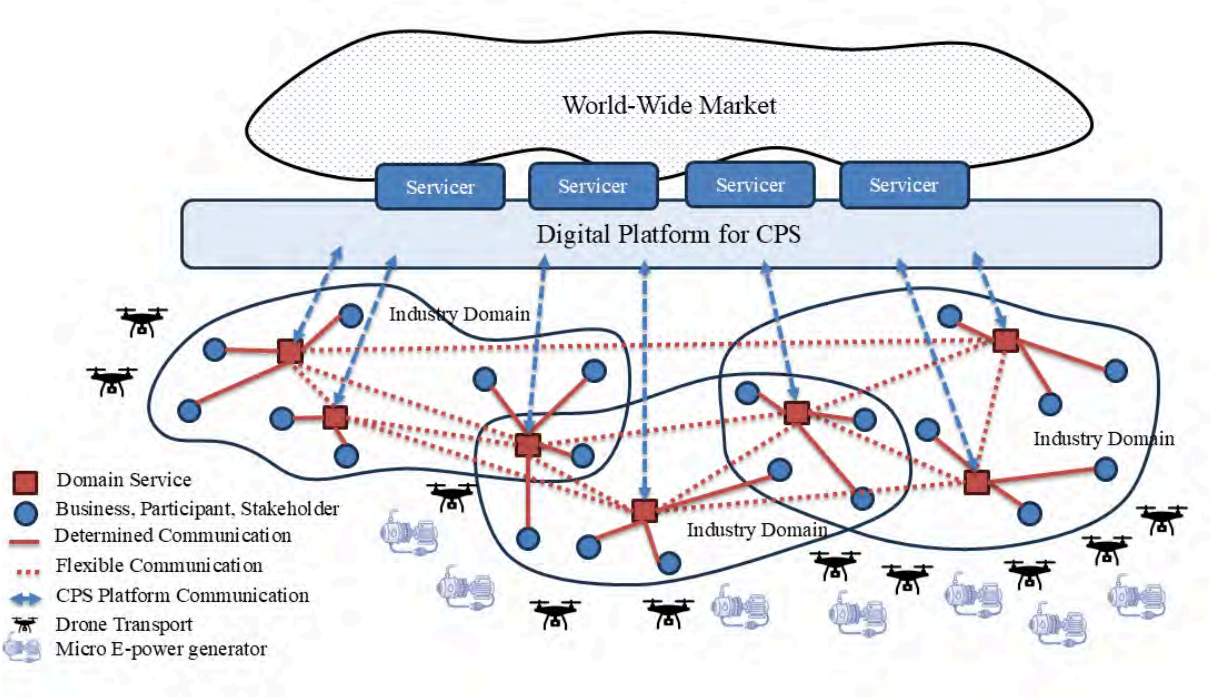
3. Knowledge-Driven Realisation of the SEZ Vision through Collective Wisdom

Building on the knowledge-driven manufacturing described above, we now consider the realisation of Special Epistemic Zone (SEZ) as an economic growth strategy (Nakamura, 2025). Through the integration of heterogeneous information enabled by knowledge-driven approaches, epistemic relationships — that is, societies — can be formed. The relationships today framed as 'supply chains', 'industry structures', or 'industrial ecosystems' generate economic value through the epistemic societies produced by their coupling. As economic value is generated through these relationships, the key to value creation lies in determining which entities to combine and how to establish epistemic relationships among them.

In the growth trajectory of the SEZ concept in the Global South, it is both foreseeable and inevitable that macroeconomic development policies will produce differential growth rates across regions (Nakamura, 2025). At the same time, consistent with the principle of 'leaving no one behind', it is essential to formulate economic policies that leverage the unique features of each region while achieving balanced development across the Global South as a whole. Data policies that assign epistemic relationships to defined scopes can simultaneously generate region-specific economic value while maintaining overall balance.

Epistemic scopes (societies) can be designed as data policies through Special Epistemic Zones (SEZs), with specialised knowledge services suited to each scope being deployed within them (see Figure 3) (Nakamura, 2025). A defining feature of SEZs is the ability to form hyper-distributed zones transcending geographic boundaries through digitally networked connections — rather than defining zones by conventional locality (Lee et al., 2015). Effective value generation is realised by strategically assembling effective pieces that transcend regional boundaries. Applying SEZ strategically atop a CPS-guaranteed environment in this way builds a knowledge-driven social system that advances economic growth in an organic, tree-like manner.

Figure 3: Epistemic Economic Scope Generated through Industrial-Space Penetration, Interoperability, and Knowledge Attribution



Source: by Author

4. The CW Concept: A Knowledge-Based CW Ecosystem

4.1. Conceptual Foundations

The CW concept is based on the fundamental conviction that the practical expertise accumulated by skilled engineers is the most valuable yet underutilised resource in contemporary manufacturing organisations (Nonaka and Takeuchi, 1995; Polanyi, 1966). By properly systematising and organising this expertise and making it accessible, it can become the driving force of organisational intelligence. This will guide diverse functional teams toward system-wide optimisation in ways that data analytics and conventional AI cannot replicate.

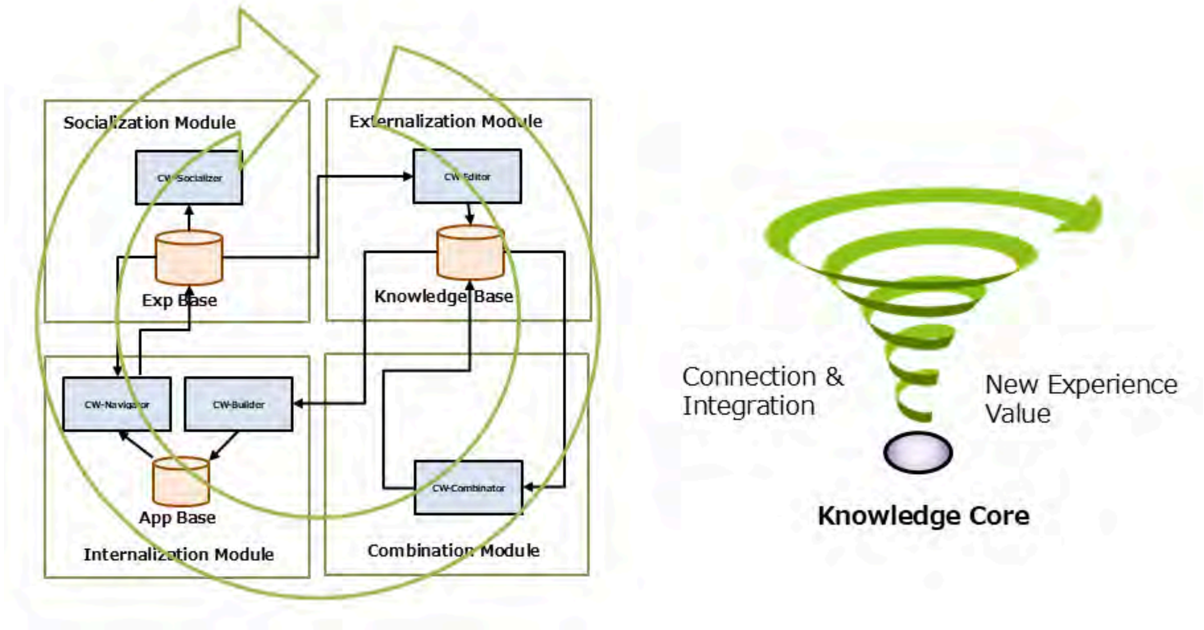
The CW concept constitutes a knowledge-based CW ecosystem that systematically collects, integrates, and redistributes the practical wisdom cultivated across diverse organisational functions such as product design, production systems engineering, manufacturing execution, quality management, logistics, maintenance, supply chain management, and human resource development (Nonaka and Takeuchi, 1995; Womack et al., 1990). This collective wisdom circulates continuously throughout the organisation (and across organisational boundaries within a supply chain ecosystem), growing richer and more refined with each cycle of application and feedback, rather than remaining locked in individual departments or the minds of individual experts. Within the CW framework, CPS serves as the data infrastructure for managing physical entities, providing real-time operational data that enables practical knowledge to be applied in specific shop-floor situations (Grieves, 2014; Lee et al., 2015).

4.2. CW Ecosystem Architecture for Epistemic Modality

The CW ecosystem is designed around three fundamental processes: knowledge extraction and formalisation, knowledge deployment and application, and knowledge refinement and growth (Nonaka and Takeuchi, 1995). These three processes form a continuous cycle that reflects the dynamics of biological evolution: knowledge is made explicit from expert practice, deployed in operational environments, and refined through the accumulation of application histories and the emergence of new insights from field experience.

A key design principle of the CW ecosystem is the integration of human judgement throughout the cycle (Figure 4). Rather than being designed for full automation, the CW Platform is designed to augment human cognition and judgement by providing relevant expertise as and when needed. This approach supports engineers' reasoning processes rather than bypassing them (Umeda et al., 2020; Umeda et al., 2022). This Human-In-The-Loop design philosophy reflects both a realistic recognition of the limitations of automated reasoning in complex manufacturing environments and a principled commitment to developing human capability as an organisational asset.

Figure 4: Collective Wisdom System Architecture for Epistemic Modality



Source: by Author

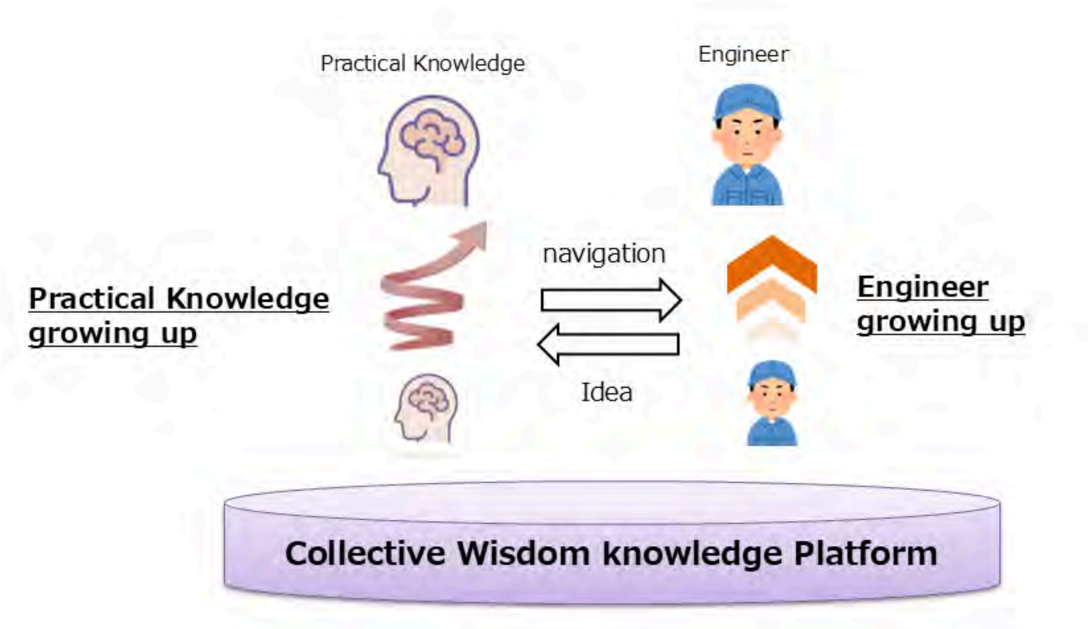
4.3. CW as a Framework for Human Development and Talent Cultivation

Beyond its operational role as a problem-solving support system, the CW framework embeds a clear philosophy of human development (Sato et al., 2024). When engineers engage with the CW Platform while working on real-world problems, they encounter the structured reasoning patterns of experienced domain experts simultaneously. Through repeated exposure to these models of expert knowledge in an operational environment, engineers gradually internalise advanced problem-solving frameworks that would otherwise take years of direct mentorship to acquire.

The platform is designed to facilitate what the author calls 'moments of realisation (kizuki)' — cognitive experiences in which new patterns of understanding suddenly crystallise, generating original insights and creative problem-solving approaches (Nonaka and Takeuchi, 1995; Polanyi, 1966). By systematically creating the conditions for such moments, the CW Platform serves as a vehicle for accelerating professional development in the deepest sense, cultivating practical wisdom through routine operational use, rather than merely acquiring information.

The author refers to this approach as a 'human development model for the digital era' — a fundamental innovation over traditional training paradigms (Nonaka and takeuchi, 1995; Sato et al., 2024). Traditional training has generally relied on classroom instruction supplemented by intermittent hands-on guidance from experts. The CW Platform aims to disseminate this cultivation model broadly, enabling organisations to accelerate engineering capability development while simultaneously enriching the shared knowledge base through the contributions of developing practitioners.

Figure 5: Human Development Model: Accelerating Capability Development through the CW Platform



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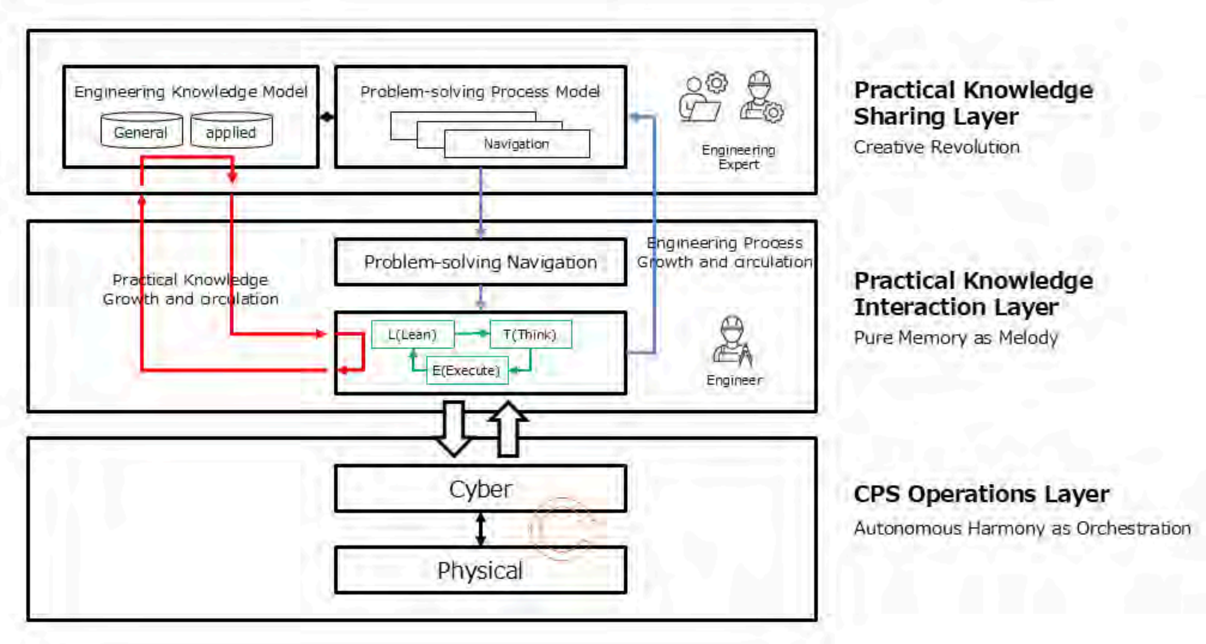
5. CW Platform Architecture

The CW Platform is the vehicle for socially realising the concept of collective wisdom. Its system structure comprises three clearly distinct yet tightly integrated layers (see Figure 6) (Nonaka and Takeuchi, 1995): the Practical Knowledge Sharing Layer (top layer), the Practical Knowledge Interaction Layer (middle layer), and the CPS Execution Layer (bottom layer). This three-layer architecture achieves a clear division of responsibilities: expert practical knowledge is digitised and accumulated in the top layer, applied to shop-floor problem-solving in the middle layer, and connected via data interfaces to manufacturing equipment and production lines in the bottom layer.

Figure 6: HCollective Wisdom (CW) Platform Architecture (Three-Layer Structure)



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5.1. Practical Knowledge Sharing Layer (Top Layer)

The Practical Knowledge Sharing Layer functions as the 'repository of practical knowledge' for the CW Platform. It is responsible for collecting, structuring, storing, and distributing expert knowledge in the form of knowledge models.

These knowledge models fall into two main categories. The first is the Problem Solving Process Model (PPM), which represents a structured methodology for addressing problems that arise in a specific manufacturing domain. A PPM captures the logical sequence of investigations and corrective actions that an expert follows when confronting a particular class of problem. It systematically presents the reasoning process so that less experienced engineers can handle analogous situations. The PPM adopts the Process Modelling Language for Digital Triplet (PD3) proposed by Professor Yasushi Umeda of the University of Tokyo as part of his Digital Triplet concept (Takeda et al., 2023; Umeda et al., 2022). The second type is the Knowledge Model (KM), which represents the causal relationships between phenomena and their root causes in a specific technical domain (Kondoh and Umeda, 2023).

Each model type is further subdivided into General Knowledge Models (GKMs), which encompass cross-industry general knowledge applicable across diverse manufacturing environments, and Applied Knowledge Models (AKMs), which capture knowledge specific to the causal relationships of particular technical domains or manufacturing processes (Kondoh and Umeda, 2023). This hierarchical structure enables the platform to achieve both universality and domain-specific accuracy.

- **Knowledge Development Organisation: CW Expert Center**

The knowledge models managed within this layer are developed by a dedicated organisational structure called the CW Expert Centre. The Expert Centre comprises personnel in two specialist role categories.

• **Knowledge Expert (KX)**

A practitioner in the relevant field who has accumulated rich practical knowledge through direct shop-floor experience and who can articulate the tacit knowledge embedded in their specialist work. KX serves as a source of knowledge, making visible and explicit the latent wisdom that has guided problem-solving through years of practice.

• **Knowledge Scientist (KS)**

A specialist in knowledge extraction and formalisation who works with KX to elicit, structure, encode, and convert tacit expert knowledge into the formal knowledge-model notation of the CW system. KS bridges the gap between domain expertise and computational representation, ensuring that expert knowledge is stored in a form that can be executed by the platform.

Knowledge models co-developed by KX-KS pairs are compiled into executable form by a tool called the CW Builder (Takeda et al., 2023; Umeda et al., 2022). This tool converts structured knowledge representations into platform-executable form deployable to the middle interaction layer. Completed models are distributed via the platform network from the cloud service infrastructure of the Practical-Knowledge Sharing Layer to operational users worldwide.

5.2. Practical Knowledge Interaction Layer (Middle Layer)

The Practical Knowledge Interaction Layer is the operational core of the CW Platform. It receives executable knowledge models from the top layer and deploys them to operational users via a network-accessible environment. Its primary function is to guide shop-floor engineers and operators through the problem-solving process, utilising practical knowledge to lead them toward effective solutions when they encounter challenges.

• **CW-LTE Manager**

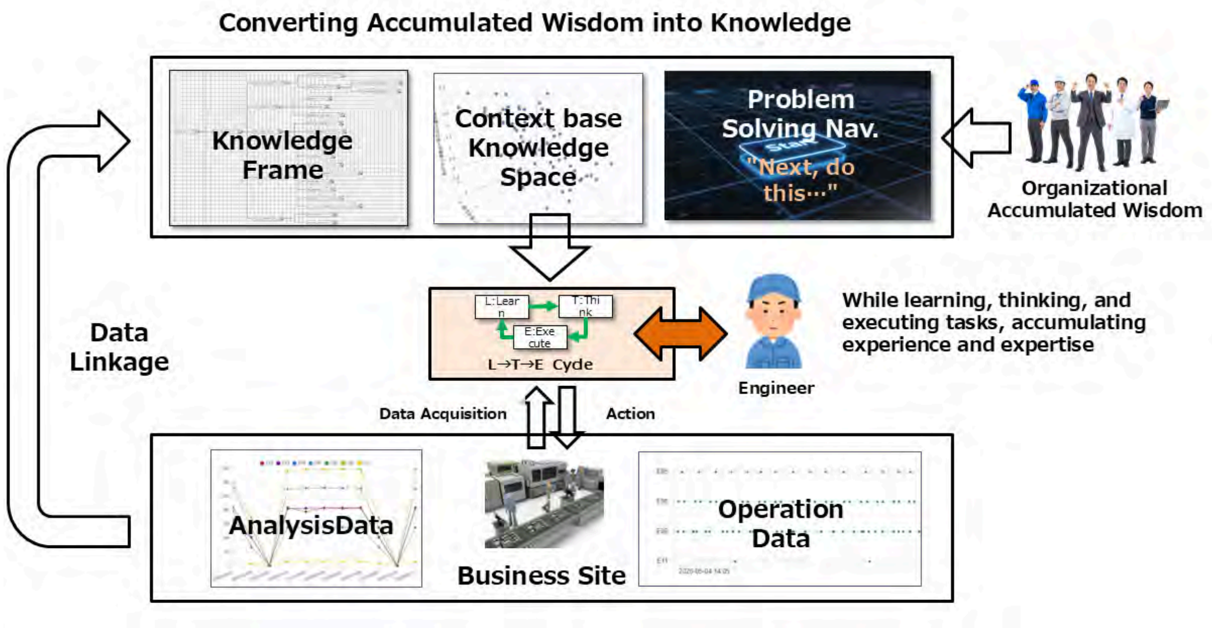
The central mechanism of the Practical-Knowledge Interaction Layer is the CW-LTE Manager, which guides problem-solving through a three-stage cycle: Learn (L) → Think (T) → Execute (E) (see Figure 7) (Nonaka and Takeuchi, 1995; Umeda et al., 2022). This LTE cycle constitutes the basic operational rhythm of the platform.

In the Learn (L) step, the current problem is clarified and organised through semantic reasoning based on knowledge models (Takeda et al., 2023; Umeda et al., 2022). This process is supplemented by reference to the ‘Experience Catalogue Service (Rekishi)’, which provides access to specific precedent cases. This step allows engineers to situate the current problem within the framework of accumulated expert experience and identify relevant practical knowledge and similar past cases.

In the Think (T) step, the engineer applies their acquired practical knowledge to the actual shop-floor situation — reflected in real-time data obtained through the CPS layer — and deliberates over potential solutions to reach a decision (Grieves, 2014; Lee et al., 2015). This step helps to structure and sharpen the engineer’s judgement by providing an expert-authored analytical framework while maintaining a focus on human judgement at the centre of the problem-solving process.

In the Execute (E) step, the engineer implements the selected solution as the primary execution agent and feeds the results back into the system (Sato et al., 2024; Umeda et al., 2020). The CW-LTE Manager accumulates the reasoning process of this execution as a historical record (rekishi) in the Practical Knowledge Sharing Layer. This enables practical knowledge within the system to mature autonomously over time.

Figure 7: Operations Support / Problem-Solving Navigation via the L→T→E Cycle



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5.3. CPS Execution Layer (Bottom Layer)

The CPS Execution Layer is the interface between the CW Platform and the physical manufacturing environment (Grieves, 2014; Lee et al., 2015). It collects digital data on the physical state of the shop floor — equipment operating status, production results, quality data, and other operational parameters — and provides this information to the Practical Knowledge Interaction Layer in real time.

Within this layer, autonomous agents embedded in the platform acquire data from IoT sensors and existing operational systems (such as manufacturing execution systems and enterprise resource planning systems). They restructure data in a standardised format and construct a digital twin of the shop floor within the CPS layer (Grieves, 2014; Wang et al., 2016). This mechanism enables the CW-LTE Manager to advance problem-solving based on accurate, up-to-date knowledge of actual shop floor conditions rather than historical averages or approximations. The CPS layer also receives and executes operational instructions from the interaction layer, translating the engineer's action decisions into concrete shop-floor tasks — providing the platform with architectural scalability for integration with future automated and autonomous systems.

6. CW Platform Implementation

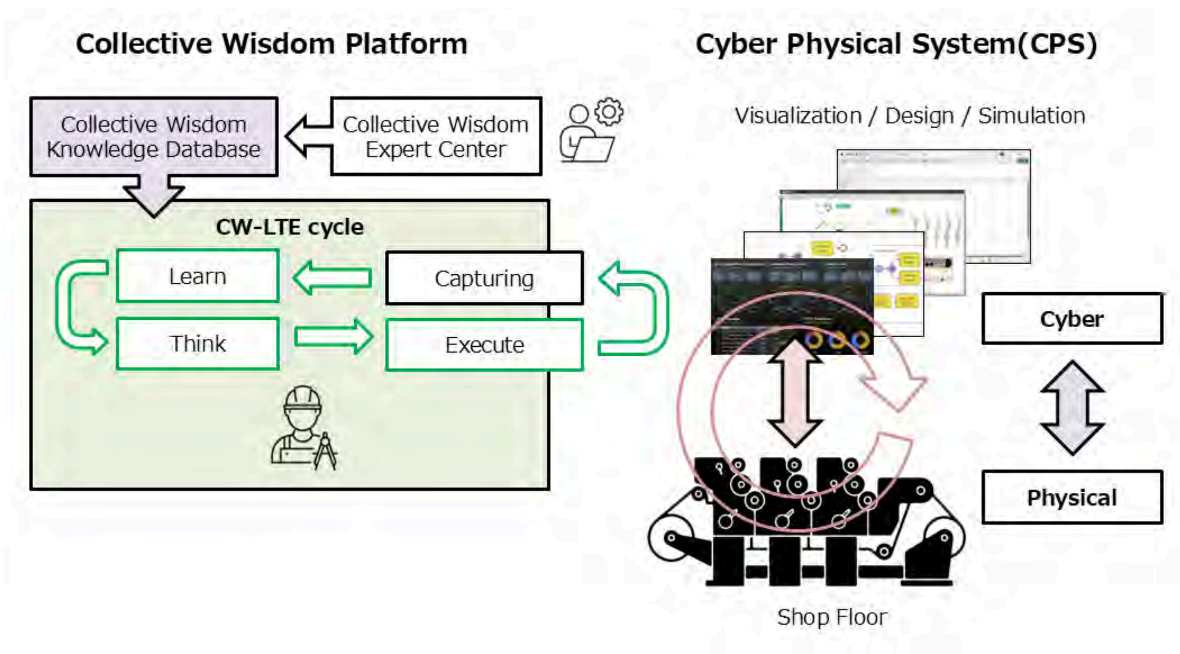
6.1. CW Platform-CPS Integration Mechanism

A critical aspect of the CW Platform's practical utility is its close operational relationship between the platform and the CPS systems (see Figure 8) (Grieves, 2014; Lee et al., 2015). The CW Platform operates in dynamic coordination with the CPS systems, creating a coherent environment in which knowledge-based decision-making is continuously grounded in actual physical operational data.

The CPS component of the architecture embodies the digital-twin paradigm (Grieves, 2014): the physical states and phenomena occurring in the actual production environment (physical) are implemented as a continuously updated digital representation (cyber). For example, production status and equipment state are captured as real-time data streams; conversely, target states defined in the cyber representation can be operationalized as commands and adjustment instructions directed at the physical shop floor.

The integration of the CW Platform and CPS thus realises two complementary functions: accurate real-time situational awareness of the physical environment through CPS data, and the generation of appropriate operational instructions based on the CW Platform's knowledge-guided analysis (Lee et al., 2015; Wang et al., 2016).

Figure 8: CW Implementation System Configuration



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6.2. Human-Centred Implementation Philosophy

The foundational principle that governs CW Platform implementation is the deliberate maintenance of human involvement in all critical analytical and decision-making processes (Nonaka and takeuchi, 1995;Polanyi, 1966). The platform is not designed for fully autonomous processing; rather, it aims to provide structured opportunities for human understanding, judgement, and decision-making at critical junctures in the problem-solving process.

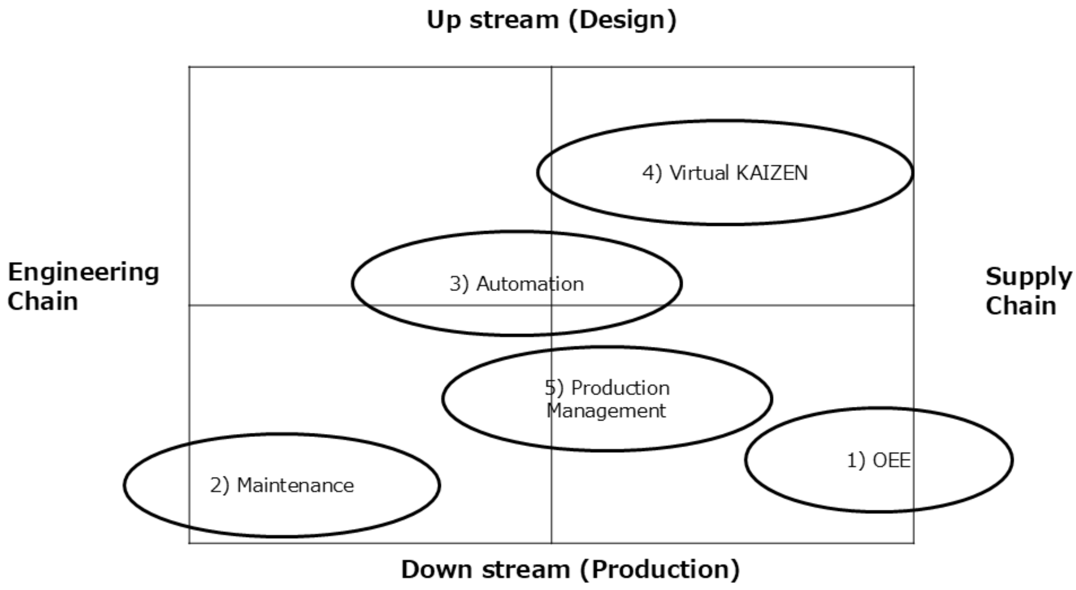
This design philosophy serves two purposes. Firstly, it ensures that expert knowledge and situational judgement — which current AI systems cannot fully replicate in manufacturing contexts — are always engaged in the decision-making process. Secondly, it ensures that engineers genuinely understand the problem-solving process they are working through, rather than merely accepting and executing system recommendations without comprehension. This understanding is the foundation of genuine professional development and the driving force of knowledge ecosystem growth.

6.3. CW Expert Centre

The practical implementation of the CW framework centres on the operation of the CW Expert Centre — the organisational unit responsible for developing and maintaining knowledge models (see Figure 9) (Kondoh and Umeda, 2023; Sato et al., 2024). The Expert Centre comprises Knowledge Experts (KX), who possess deep expertise in Japanese-style manufacturing practices such as lean production, Toyota Production System principles, precision engineering, and quality management, and Knowledge Scientists (KS), who convert that expertise into formal, executable knowledge models (Womack et al., 1990).

The collaborative knowledge extraction process between KX (knowledge transfer) and KS (knowledge structuring) practitioners is critical to the quality and practical utility of the resulting knowledge models (Kondoh and Umeda, 2023). This process involves structured interviews, observation of expert problem-solving, iterative model refinement, and validation against actual operational experience. The mission of the Expert Centre extends beyond initial model development to encompass the continuous curation and enrichment of the knowledge base.

Figure 9: Knowledge Model Development at the CW Expert Centre



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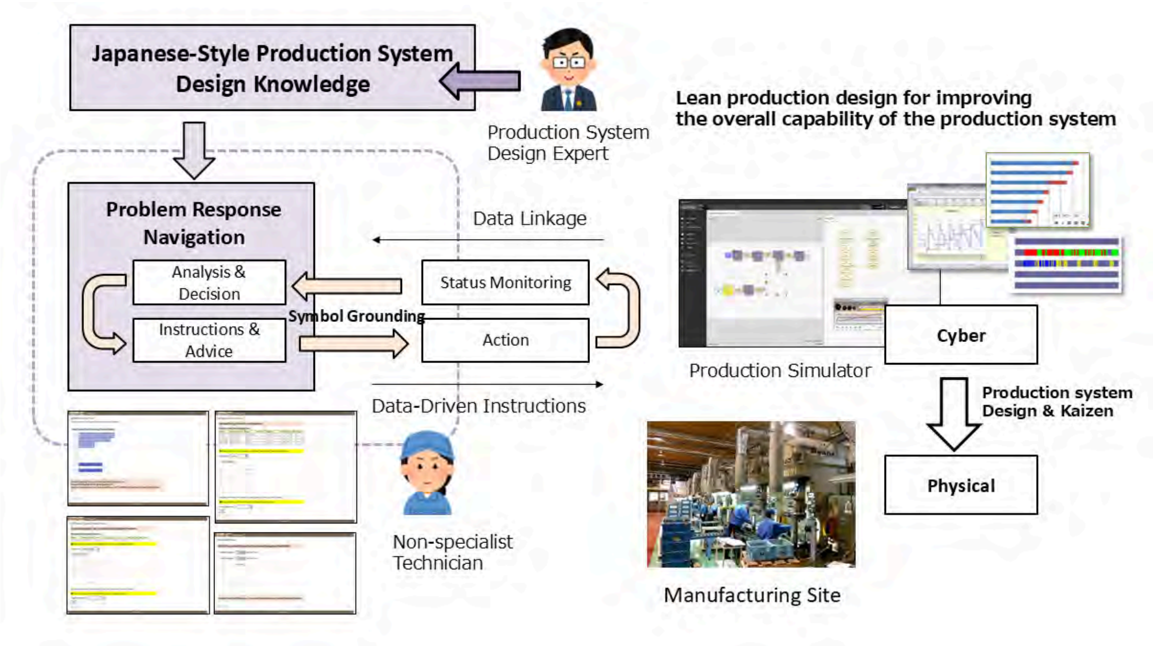
7. Case Studies

7.1. Application Contexts

To demonstrate the practical utility of the CW Platform, the author developed and deployed CW applications targeting problem-solving in manufacturing (Kondoh and Umeda, 2023; Sato et al., 2024). Three applications are presented here: production system design (see Figure 10), quality management (see Figure 11), and equipment maintenance (see Figure 12).

Production system design involves complex causal relationships among production process configurations, individual process parameters, plant layout, equipment capacity and staffing, production planning, manufacturing costs, and investment costs (Womack et al., 1990). Simply maximising productivity is not sufficient; investment costs, future demand forecasts, and other conflicting factors interact in complex ways. Effectively diagnosing these challenges requires the multi-factorial reasoning capability that experienced production system engineers cultivate through years of practice.

Figure 10: Production System Design Application



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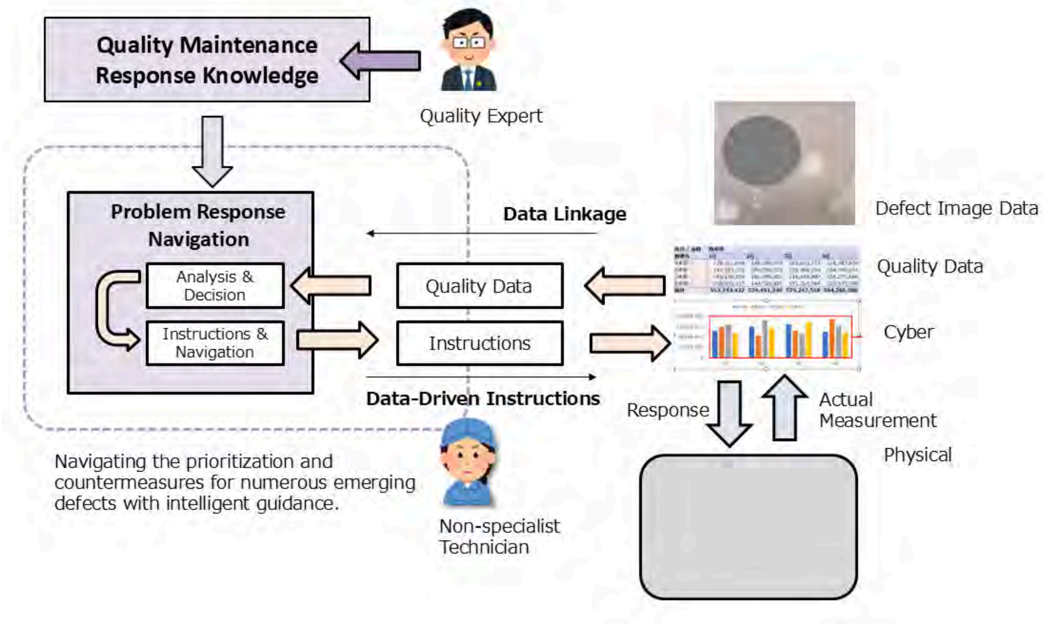
Quality management involves complex causal relationships among process parameters, tooling conditions, material properties, and the diverse defect phenomena occurring in processed parts (Kondoh and Umeda, 2023). For example, quality defects in manufacturing processes, such as burrs, dents, scratches, dimensional errors, etc., arise from the complex interaction of tool wear, material variation, lubrication state, press parameters, and production speed. Effectively diagnosing these defects requires knowledge cultivated by engineers through years of experience in the relevant process.

Figure 11: Quality Management Application



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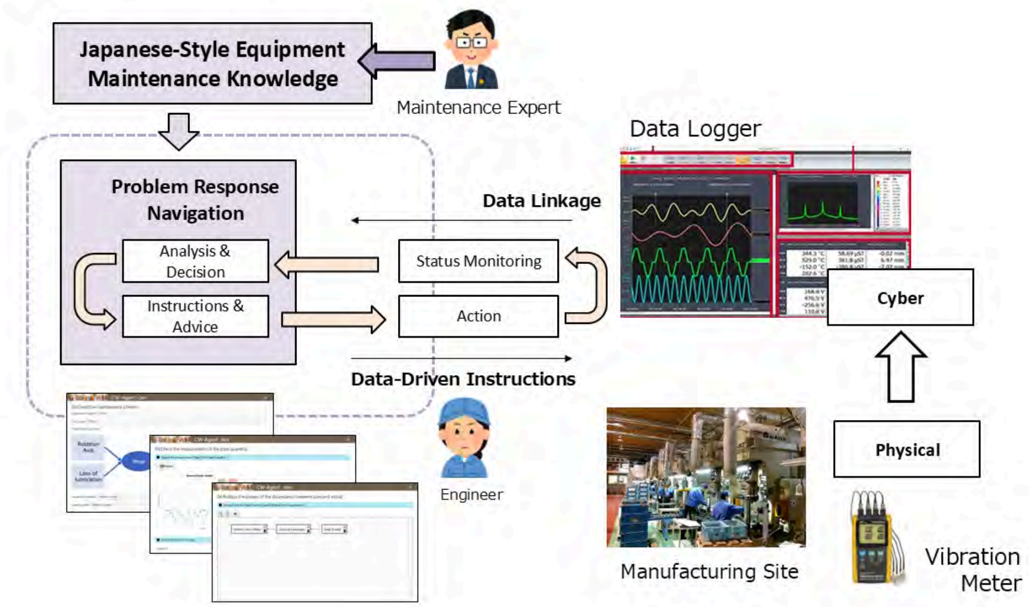
Equipment maintenance is similarly complex (Umeda et al., 2020). Accurately inferring equipment failures requires the knowledge of engineers familiar with the relevant process — particularly deep expertise in the structural knowledge of the target equipment. CW Platform applicability was verified in this domain using knowledge models corresponding to the relevant area.

Figure 12: Equipment Maintenance Application



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7.2. Pilot Evaluation

The cases presented above were implemented in manufacturing plants that were facing a common industry-wide challenge: a decline in the number of veteran engineers with in-depth problem-solving expertise, and the need to maintain quality management capabilities with relatively inexperienced staff (Sato et al., 2024; Womack et al., 1990).

The pilot evaluation showed that even less experienced engineers could handle the problems they encountered while working with the CW Platform (Kondoh and Umeda, 2023; Sato et al., 2024). They identified relevant causes, understood the logic linking defect phenomena to root causes, and carried out investigative and corrective activities more effectively than would have been possible through unaided judgement alone.

One important finding concerned the nature of the improvements realised. In problem responses across the applications, a recurring pattern emerged in which true root causes were not appropriately identified, leading to inefficient cycles of blind countermeasures that consumed resources without resolving the underlying problem. The CW Platform's semantic-reasoning capability — diagnosing based on expert-authored causal models — was found to be effective in helping engineers accurately grasp the essence of problems, reducing the occurrence of misguided activities and accelerating resolution (Kondoh and Umeda, 2023; Takeda et al., 2023).

Table 2: Summary of Pilot Evaluation Results

Evaluation Item	Conventional Approach (without CW)	With CW Platform
Root-cause identification	Experience-dependent, person-dependent	Systematic identification via causal models
Accuracy of initial response	Misguided actions frequent	Appropriate corrective actions selected
Lead time to resolution	Tendency to extend by Misguidence	Substantially shortened
Response capability of less-experienced engineers	Limited	Approaching experienced-engineer level
Knowledge accumulation/succession	Person-dependent, fragmented	Organizationally systematized via platform

Source: by Author

8. Results and Discussion

8.1. Demonstrated Capabilities and Strategic Value

The CW concept and the CW Platform developed to realise it address a fundamental challenge for Industry 4.0 manufacturing: how to maximise the value of accumulated practical expertise in an era of increasing system complexity and accelerating workforce transition (Kagermann et al., 2013; Schwab, 2016). The pilot results confirm that the platform's approach — making expert causal knowledge available to less experienced engineers through interactive navigation grounded in real-time CPS data — is both feasible and operationally effective.

The platform demonstrated its core function of enhancing human problem-solving capability through appropriate semantic reasoning, calibrated to the specific stage of the ongoing problem-solving process, based on knowledge models (Kondoh and Umeda, 2023; Takeda et al., 2023). The capability for engineers to recognise causal relationships between a problem and its root causes creates conditions that strengthen collaboration among technical systems, human practitioners, support systems, and organisational units, raising the collective intelligence of the manufacturing organisations.

From a strategic perspective, the CW Platform functions as an ecosystem engine (Nonaka and takeuchi, 1995). By continuously eliciting latent practical knowledge from experienced practitioners, structuring it into reusable knowledge models, and circulating it through diverse organisational environments, it simultaneously generates value and enriches knowledge. This circulation mechanism creates a positive feedback loop between knowledge use and growth, building sustained competitive advantage — the value of the knowledge increases over time rather than decreasing.

8.2. Knowledge Strategy Toward Smart Manufacturing

The CW Platform takes a unique approach to the issue of how knowledge should be developed in smart manufacturing. Rather than replacing human judgement with automated AI, the platform aims to enhance human judgement by providing access to the collective knowledge of experienced professionals when required. This approach recognises the vital role of human expertise in complex manufacturing environments and aims to ensure that this knowledge is not confined to individual practitioners, but rather becomes an organisational asset.

Its implications extend beyond individual enterprises to encompass supply-chain ecosystems and ultimately the arena of national and global manufacturing knowledge sharing (Lee et al., 2015; Wang et al., 2016). The CW framework is designed with the distribution of knowledge across organisational boundaries in mind, opening the possibility of shared knowledge ecosystems spanning multiple companies — a consideration particularly relevant in industries like the automotive sector, with its dense supplier networks and shared technical challenges.

Within the framework of Global South industrial policy, the CW Platform offers a perspective that complements the mainstream data-driven paradigm (Nakamura, 2025). The systemic formalisation of the knowledge cultivated on the shop floors of manufacturing-advanced regions like Japan over decades, and integrating it into a digital platform architecture, demonstrates the possibility of building hybrid human-AI systems that combine the analytical power of digital technology with the deep understanding of domain experts (Schwab, 2016; Womack et al., 1990).

9. Conclusion and Future Directions

This paper has introduced the CW concept and the CW Platform developed to implement it as a practical system for knowledge-driven manufacturing engineering in smart manufacturing.

The primary contributions of this research are threefold. First, a comprehensive conceptual framework — the 'CW ecosystem' — was presented, positioning the formalization and distribution of expert practical knowledge as the strategic foundation for organizational intelligence in complex manufacturing environments (Nonaka and takeuchi, 1995; Polanyi, 1966). This framework makes explicit that conventional knowledge-management approaches and current AI technologies alike have limitations in capturing and leveraging the domain-specific causal expertise required for manufacturing excellence.

Secondly, the implementation of the CW concept as an operational system was described using a three-layer platform architecture comprising a Practical Knowledge Sharing Layer, a Practical Knowledge Interaction Layer and a CPS Execution Layer (Takeda et al., 2023; Umeda et al., 2022). This architecture integrates expert-authored knowledge models, interactive navigation through the CW-LTE Manager's Learn–Think–Execute cycle, real-time CPS data linkage, and a continuous knowledge-growth mechanism, realising a coherent platform combining both operational efficiency and educational effect.

Thirdly, pilot test results for problem-solving applications across several manufacturing domains were reported, demonstrating the practical utility of the approach(Kondoh and Umeda, 2023; Sato et al., 2024). Less experienced engineers were shown to be able to conduct appropriate problem-solving under platform guidance, and the knowledge models' semantic reasoning capability was reported to be effective in guiding diagnosis toward accurate causal understanding.

The primary future research and development priorities are as follows: (1) the systematic expansion of the knowledge model library across all domains of manufacturing engineering (Kondoh and Umeda, 2023); (2) the development of rigorous methodologies for knowledge model quality validation and life-cycle management (Takeda et al., 2023); (3) the investigation of cross-enterprise knowledge ecosystem architectures enabling practical knowledge sharing across supply-chain boundaries (Lee et al., 2015; Wang et al., 2016); (4) the long-term evaluation of the CW Platform's impact on engineers' professional development and organizational knowledge capability(Sato et al., 2024).

The author believes that the CW framework and its vision of a human-centred knowledge ecosystem will make a productive and distinctive contribution to the continued development of intelligent manufacturing systems (Nakamura, 2025; Nonaka and takeuchi, 1995). It respects the depth of human expertise while harnessing the power of digital technology to make that expertise accessible, transferable, and continuously growing. In an era of accelerating technological change and workforce transition, the author believes that the systematic preservation and amplification of practical wisdom represents among the most valuable investments available to manufacturing organisations (Polanyi, 1966; Womack et al., 1990).

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Chapter 6: Efforts and challenges toward a circular economy in the automotive industry: A case study of four East Asian countries

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1. The business environment surrounding the automotive industry

The automotive industry plays a vital role in providing safe and environmentally friendly means of transport. This industry has faced a range of environmental challenges, including air pollution, global warming, noise and vibration issues, resource and energy concerns, and problems relating to waste and end-of-life vehicles (ELVs), as well as the need to ensure the safety of pedestrians and vehicle occupants.

Driven by growing social demands and the need to comply with regulations, the automotive industry has been working to implement environmental and safety measures. On the environmental front, as motorisation and car ownership have increased alongside economic growth, various environmental problems have come to the fore around the world. Starting with countries with advanced automotive industries, measures based on each nation's own policies and on international agreements concerning environmental issues have been introduced. As air pollution caused by exhaust emissions (nitrogen oxides, particulate matter, etc.) became more severe and emission standards were progressively tightened, the automotive industry developed and rolled out emission reduction technologies. When the Montreal Protocol, which regulates the production and consumption of ozone-depleting substances, came into force in 1989, the automotive industry proceeded with the switch to alternative refrigerants. From 1990 onwards, as global efforts to tackle climate change and global warming expanded, the automotive industry advanced the development and widespread adoption of vehicles with improved fuel efficiency and low-emission vehicles (such as natural gas vehicles, methanol vehicles, hybrid vehicles, fuel cell vehicles and battery electric vehicles). Since the adoption of the Paris Agreement in 2015, the automotive industry has been promoting electrification in response to the acceleration of policies aimed at decarbonisation. In terms of safety, in addition to the safety measures for vehicle drivers and passengers—comprising seat belts and airbags, which began to be widely adopted in the 1980s—measures to ensure the safety of pedestrians and occupants have been further enhanced in recent years, including the development of autonomous driving technology.

The evolution of environmental and safety measures in the automotive industry can be seen in newly launched vehicle models. However, this evolution will also have future implications for environmental measures (disposal and recycling) relating to end-of-life vehicles (ELVs). The automotive industry has, to date, established disposal and recycling systems for waste oil, chlorofluorocarbon (CFCs), airbags and Automobile Shredder Residue (ASR). In the future, it will be necessary to continue optimising the disposal systems for end-of-life vehicles in line with vehicle evolution and environmental regulations.

Among the future challenges in the field of environmental measures, the transition of the automotive industry to a circular economy is a priority requiring urgent action. This is against the backdrop of the agreement reached by the Council of the European Union and the European Parliament to introduce a new ELV Regulation as part of the EU Circular Economy Action Plan. The European ELV Directive (End-of-Life Vehicles Directive: 2000/53/EC), enacted in 2000, promoted the reuse, recycling and recovery of ELVs with the aim of preventing and limiting waste generated from ELVs and their components, and improving the environmental performance of all operators involved in the vehicle life cycle (EU, no date; IEA Policies database). Under the new ELV Regulation, car manufacturers are expected to be subject to Extended Producer Responsibility (EPR), requiring them to bear the burden of end-of-life vehicle disposal; they will also be obliged to increase the proportion of recycled plastic used in new car production to 25 per cent within ten years (of which 20 per cent must be derived from end-of-life vehicles, i.e. a closed-loop system) (EU, 12 December 2025). In response to efforts towards carbon neutrality and the intensification of various initiatives aimed at resource circulation both domestically and in Europe, the Japan Automobile Manufacturers Association formulated and published its 'The Japan Automobile Manufacturers Association's Initiatives to Promote the Use of Recycled Materials: 2050 Long-Term Vision and Medium- to Long-Term Roadmap (including Voluntary Targets)' in September 2024, with the aim of promoting the supply and utilisation of recycled materials (JAMA 2025). Within ASEAN, the 'Framework for a Circular Economy for the ASEAN Economic Community' was adopted in 2021 with the aim of promoting a circular economy within the ASEAN Economic Community (AEC). Consequently, the promotion of a circular economy has been established as a common objective for member states. In accordance with this framework agreement, ASEAN reached an agreement in 2025 to introduce new provisions on remanufactured products as part of the amendment to the ASEAN Trade in Goods Agreement (ATIGA).

In light of these changing circumstances both within and outside the ASEAN region, the ASEAN automotive industry is also being called upon to take measures towards the proper treatment of ELVs, the promotion of recycling, and the realisation of resource circulation. To achieve this, automotive manufacturers must engage in a wide range of activities—from vehicle design to identifying recyclers—to improve dismantlability and promote the use of recycled materials. Dismantling operators must also recover recyclable materials and secure supplies of recycled feedstock, whilst ensuring the proper treatment of ELVs in accordance with legislation. Automotive parts suppliers, too, will need to recover and recycle industrial waste, whilst collaborating with vehicle manufacturers and materials producers to develop technologies and invest in the utilisation of recycled materials.

This paper reports the findings of a survey on initiatives towards a circular economy in East Asian automobile-producing countries, as well as in Malaysia, Thailand, Vietnam and India, where automobile sales are expected to grow in the future. Section 2 introduces the situation in each country regarding the proper treatment of ELVs, based on a literature review and field surveys, and discusses the challenges involved. Section 3 reports the results of field surveys conducted with automotive parts suppliers. Section 4 clarifies the policy implications based on these survey findings.

It should be noted that this study addresses the informal sector for ELV dismantling and recycling. In countries without ELV regulations, all ELV-related businesses operate in what could be called an informal sector. However, in this study, operators who improperly process EVLs are referred to as the informal sector.

2. Initiatives for the proper treatment of end-of-life vehicles

The global vehicle fleet is expected to exceed 1.6 billion by the end of 2023, and car sales and fleet sizes are forecast to continue rising in line with economic growth in developing countries. In East Asia, too, Indonesia's fleet stands at 24.65 million vehicles and Thailand's at 19.39 million, already reaching the same level as Australia (19.74 million). India's vehicle stock stands at 82.65 million, exceeding Japan's 78.76 million (JAMA website). At the same time, with the spread of next-generation vehicles such as battery electric vehicles (BEVs) and hybrid electric vehicles (HEVs), measures for ELVs are facing a major turning point. Global sales of electric vehicles exceeded 20 million units in 2025, accounting for a quarter of new car sales (IEA, 2026).

In ASEAN member states, too, the volume of ELVs is expected to rise in line with increases in vehicle sales and the number of vehicles in use. Furthermore, the adoption of next-generation vehicles, such as BEVs and HEVs, is progressing rapidly. There is a need to establish systems for the proper management and treatment of batteries before those installed in vehicles currently on the market reach the end of their service life for automotive use. Although some analyses (e.g. Geslin et al., 2025) suggest that the service life of BEV batteries is longer than predicted in laboratory settings, batteries are still being discarded from vehicles involved in accidents and other sources, making urgent measures necessary.

However, whilst the automotive industry in major markets is transitioning towards a circular economy, the proper treatment of ELVs remains a challenge in developing countries. Numfor et al. (2021) identify the following common weaknesses across eight countries (India, South Africa, Brazil, Mexico, Turkey, China, Indonesia and Nigeria): inadequate waste regulatory frameworks; a lack of ELV collection systems; insufficient dismantling infrastructure; low technical capacity; deficient vehicle deregistration systems; and a lack of transparency regarding ELV information.

The severity of the challenges facing ASEAN member states in relation to the proper treatment of ELVs is particularly pronounced. The majority of ASEAN member states lack the formal recycling infrastructure, legal frameworks and institutional capacity that have enabled orderly ELV management in the EU, Japan and South Korea. Jamaluddin et al. (2022) conducted a comprehensive review of three major Southeast Asian countries (Indonesia, Malaysia and Thailand) and confirmed that none of the three countries has a formal ELV recycling policy.

In reality, in many ASEAN member states, ELV dismantling operations are still dominated by the informal sector, which operates outside regulatory oversight. Informal dismantlers earn their livelihood by extracting and reselling valuable items such as reusable parts, scrap metal and precious metals. At the same time, however, this practice gives rise to environmental problems such as the uncontrolled release of fluorocarbons, soil and groundwater contamination from waste oil, and occupational health hazards for workers handling hazardous substances (Kojima, 2018; Shrivastava et al., 2024). Consequently, informal dismantlers hold a cost advantage over formal dismantlers, hindering the stable procurement of ELVs and the financial stability of formal dismantling operators.

However, as outlined below, some countries have recently begun to establish institutional frameworks and are making progress with concrete initiatives (Iwasaki et al., 2025).

2.1. Malaysia

Under its National Automotive Policy, Malaysia is working to establish an ELV management system and improve recycling rates (MITI 2000; Sulaiman et al. 2023; Malay Mail 5 March 2025). In 2021, it launched a pilot project aimed at establishing Authorised Automotive Treatment Facilities (AATFs). As of June 2026, five operators, including Car Medic, have been authorised. The overwhelming majority of Malaysia's vehicle dismantling sector remains informal; to incentivise entry into the AATF scheme, preferential access to accident-damaged vehicles from insurance companies has been designed. Furthermore, the 'e-Dereg' electronic deregistration system has been introduced to reduce the number of abandoned vehicles and promote the proper disposal of ELVs through AATFs (Malay Mail, 21 March 2024). The Malaysian government is also working on the introduction of a battery passport (Malay Mail, 14 November 2025) and is developing infrastructure to ensure the traceability and proper disposal of EV batteries.

Furthermore, as part of its AATF-related policies, the government announced a subsidy scheme for vehicle replacement in January 2026, aimed at phasing out vehicles over 20 years old and promoting the transition to newer, safer and more environmentally friendly vehicles. Prior to this scheme, Proton (Geely Automobile) had introduced the Xchange Programme in May 2025 in collaboration with Car Medic. Through this programme, Car Medic has been able to source and dismantle vehicles traded in at Proton. Proton announced a trade-in scheme for older vehicles in line with the government's support scheme for the replacement of ageing vehicles, which was published on 29 January 2026. Under this new programme, which follows on from the Xchange Programme, Proton's trade-in support (up to 2,000 ringgit) will be supplemented by a government incentive of up to 2,000 ringgit (approximately 80,000 yen).

2.2. The Philippines

In the Philippines, small-scale informal operators known as 'junk shops' dismantle ELVs by hand, and the improper handling of pollutants such as waste oil has been a cause for concern. Against this backdrop, a locally owned company—supported by Japanese firms (Tsuruoka, Mitsui & Co., Toyota Motor Corporation and Toyota Metal) through a JICA project—has established En Tsumugi ELV Dismantler and is carrying out a demonstration project as a formal, compliant dismantling enterprise. En Tsumugi has partnered with taxi companies to ensure a stable supply of ELVs, thereby establishing a model for the proper recycling of ageing taxis. In April 2026, the company completed a Toyota-led training programme on xEV battery dismantling held in Aichi Prefecture, thereby strengthening its capacity for sustainable automotive recycling.

2.3. Thailand

Thailand has formed the largest automotive industry cluster within the ASEAN region and leads the region in both production volume and export volume. Whilst the country is maturing as a car-dependent society alongside urbanisation and rising incomes, its proper management system for ELVs remains underdeveloped, resulting in a striking gap between industrial maturity and institutional inadequacy. In particular, the fact that ELV dismantling is concentrated in the informal sector has long been identified as a structural challenge.

Informal operators carry out low-cost dismantling that relies heavily on manual labour, and there are frequent instances where hazardous materials, such as waste oil and CFCs, are released into the environment without being properly treated. Furthermore, the absence of an obligation to deregister vehicles, a vehicle inspection system that has become a mere formality, and a perverse incentive whereby the tax burden decreases as a vehicle ages encourage the prolongation of the service life of ageing vehicles. Consequently, older vehicles are kept in use for extended periods through repairs using second-hand parts, contributing to air pollution.

Efforts to develop institutional frameworks to address these challenges began with a demonstration project launched in 2016 by NEDO in collaboration with the Thai Ministry of Industry. This project identified technical and institutional challenges relating to the proper treatment and resource recovery of ELVs, and clarified fundamental issues such as the standardisation of dismantling processes and the streamlining of resource recovery. The findings were handed over to AOTS from 2021 onwards, and discussions regarding the legal framework necessary for institutional design, as well as the division of roles among relevant stakeholders, continued until 2023.

From 2024, JICA's 'Project for Establishment of Comprehensive End-of-Life Vehicles (ELVs) Management System in Thailand' commenced, taking on the implementation phase of institutional development whilst building on the achievements of NEDO and AOTS. Under the JICA project, efforts are underway to establish mechanisms for the collection, recycling, treatment and disposal of ELVs, and to verify feasibility through pilot projects; the project is expected to support the Thai government in formulating draft institutional frameworks and implementation plans.

Meanwhile, challenges remain regarding the current state of formal recycling facilities. Well-established operators, including Green Metals, which participated in the NEDO project, are struggling to secure ELVs. In Thailand, the procurement of ELVs relies on an auction system, creating a structure where formal and informal operators compete on the same platform. Consequently, formal operators, who bear the costs of environmental measures, are at a disadvantage in price competition, and there is no incentive for vehicle owners to take their vehicles to formal dismantlers. Consensus-building among the relevant government ministries is required to establish the necessary framework, and JICA is expected to play a coordinating role.

Furthermore, the rapid proliferation in recent years of BEVs manufactured by Chinese firms not only makes the establishment of a future battery recycling system an urgent priority but also risks highlighting the technical limitations of informal operators. The dismantling of BEVs, which contain high-voltage batteries, is difficult to manage using conventional, manual methods and poses significant safety and technical challenges. The proliferation of BEVs has the potential to trigger 'disruptive formalisation', rapidly transforming the existing industrial structure, which has been dominated by the informal sector; therefore, the acceleration of institutional development is required to ensure a smooth transition of the industrial structure.

2.4. Vietnam

In Vietnam, dismantlers and recyclers of ELVs have formed clusters in villages on the outskirts of Hanoi and Ho Chi Minh City. A notable feature is that commercial vehicles and heavy construction machinery are brought in more frequently than passenger cars. This is consistent with the Vietnamese government's imposition of service life regulations on commercial vehicles and construction equipment.

Small-scale informal operators are the main actors in these dismantling operations. Although Vietnam has an authoritarian administration, it has not introduced a certification system or institutional framework for formal operators involved in ELV dismantling. The dismantling processes carried out by informal operators mainly consist of manual work using inadequate equipment, and there have been reports of pollutants being released into the environment without being properly treated.

Meanwhile, independent of the traditional ELV dismantling system, the local BEV manufacturer VinFast has begun establishing a system for battery replacement and repurposing (conversion to industrial storage batteries). The VinFast case can be viewed as the nascent stage of 'disruptive formalisation', whereby the rise of next-generation vehicles is driving the development of such systems.

In terms of policy, Vietnam has introduced the first 'Extended Producer Responsibility (EPR)' scheme in ASEAN. EPR is a policy approach based on the principle that producers bear financial or physical responsibility for the handling and disposal of products after consumption (OECD 2001). The 2022 Environmental Protection Law (Decree 08/2022/ND-CP) stipulates that the scope of the EPR scheme will be gradually expanded from packaging materials, batteries, lubricants, tyres, electrical and electronic equipment, and motor vehicles. Consequently, whilst its effectiveness is currently limited, recycling obligations are scheduled to be imposed on vehicle manufacturers and importers from 2027 (Decree 110/2026/ND-CP).

2.5. India

Under the 2021 Vehicle Scrapping Policy, India has institutionalised Registered Vehicle Scrapping Facilities (RVSFs) and has been working to develop ELV dismantling facilities. In 2025, ELV regulations and EPR principles were introduced. As a result, car owners are now, in principle, required to send their vehicles for recycling once they reach a certain age. Car manufacturers have been made responsible for the collection and recycling of ELVs. Car manufacturers are also moving to establish RVSFs.

At dismantling facilities, manual dismantling and segregation enable used parts and most waste to be sold to industrial waste disposal operators for a better price. The dismantling facilities interviewed have achieved a resource recovery rate of over 90 per cent. However, it is not known exactly how much is disposed of as final waste by industrial waste disposal operators, nor how this is carried out.

Currently, around 200 dismantling operators nationwide, including Japanese companies, are certified as RVSFs. However, the vast majority of vehicle dismantling is still carried out by informal operators.

What these five countries have in common is that informal operators hold a dominant position. The establishment and implementation of systems aimed at ensuring the proper dismantling of ELVs will inevitably entail the formalisation of the informal sector. As many informal operators are small-scale and have limited capital, technical capabilities and capacity to deal with administrative requirements, an approach to their incremental formalisation is the most realistic course of action. Consequently, a transitional period during which informal and formal operators coexist will be unavoidable for some time after the institutional framework has been established.

However, if informal operators continue to maintain an advantage over formal operators in terms of costs and ELV procurement capacity during this transitional period, progress towards formalisation will be significantly hampered. The experience of the countries surveyed indicates that, as long as informal operators maintain market dominance backed by their low-cost structures and extensive procurement networks, it is difficult for formal operators to secure a stable supply of ELVs and operate in compliance with environmental standards. In other words, formalisation is not merely a natural consequence of economic growth, but can only be achieved through a combination of policy, economic and institutional measures (Aparcana 2017).

To achieve formalisation, it is essential to establish a funding mechanism for ELV recycling. The central issue here is the question of ‘who bears the cost of recycling?’. Taking Japan’s Automobile Recycling Law as a precedent, a prepayment system is adopted whereby purchasers of vehicles pay the recycling costs in advance. However, in many developing countries, the fact that ‘consumers are reluctant to pay additional costs’ constitutes a major barrier to the introduction of such a system, and governments tend to show strong resistance to adopting the prepayment system.

The burden of costs therefore falls on manufacturers. However, even under a manufacturer-funded system, consumers ultimately bear part of the cost through increases in vehicle prices. There is little fundamental difference from the prepayment system. Consequently, how the cost-sharing mechanism is designed and how social acceptance is secured become crucial policy challenges that will determine the success or failure of formalisation.

Looking at the status of EPR scheme implementation across ASEAN member states, there are significant differences between countries in terms of scope of application and scheme design. This situation stems from variations in each country's administrative capacity, waste management infrastructure, industrial structure and policy priorities, and highlights the difficulty of establishing a unified EPR scheme within the ASEAN region. In addition to Vietnam, as mentioned above, the Philippines also enacted the EPR Act in 2022, which applies to companies generating plastic packaging waste. In Malaysia, whilst EPR is currently a voluntary scheme, institutional reforms are underway to make it mandatory. In Thailand, deliberations on the relevant bill in the National Assembly are currently delayed, and it has not yet been enacted. The EU-ASEAN Business Council (2025) points out that gaps and ambiguities in national EPR regulations, weak waste infrastructure and uneven system coverage, misalignment with local realities, fragmented EPR regulations across ASEAN, and market barriers for recycled materials are major barriers to effective EPR implementation across many ASEAN countries (EU-ASEAN Business Council, 2025).

A key challenge in the design of EPR schemes specific to the automotive sector is the existence of large-scale secondary markets for used cars and used parts. Unlike general waste and electronic waste, motor vehicles are not products that are discarded immediately after use; rather, they circulate in the market over a long period, passing through multiple owners. In particular, as the value of reusing individual parts is extremely high, the period until a vehicle is finally disposed of as an ELV tends to be significantly longer in countries where the secondary market is well-developed.

Consequently, the more active the secondary market is, the more volatile the volume of vehicles entering formal dismantling facilities as ELVs tends to be. Whilst used parts are an important source of revenue for dismantlers, from an institutional perspective, its high market value acts as a factor delaying the 'final disposal' of ELVs, thereby reducing the predictability of the EPR scheme's operation. In other words, the existence of the secondary market serves as a structural factor that obscures the 'end of the product life cycle'—a premise upon which the EPR scheme is based—and makes the management of ELV flows difficult.

Furthermore, the handling of accident-damaged vehicles is a key issue concerning the stability of the ELV supply. Accident-damaged vehicles are considered one of the promising sources of ELVs for formal dismantling facilities and are regarded as a category that is relatively easy to secure under the current system. However, in practice, it is often more profitable for insurance companies to repair accident-damaged vehicles and resell them as used cars; consequently, it is common for such vehicles not to enter the dismantling process as ELVs.

As outlined above, in the design of EPR schemes for the automotive sector, the scale, structure and economic rationality of the secondary market are key factors that determine the effectiveness of the scheme. In the automotive industry, where the used car market, the used parts market and the market for accident-damaged vehicles are intricately intertwined, it is essential that the design of an EPR scheme takes into account the underlying principles governing the behaviour of the secondary market.

On the other hand, the most profitable business for ELV dismantlers is the trade in used parts. Used parts enjoy stable demand in markets with high repair demand; in particular, as there are many older vehicles in developing countries, they have high market value as replacement parts. Consequently, quality control, stock management and ensuring traceability of used parts are essential elements for the business continuity of dismantlers.

Against the backdrop of the development of this used parts market, Japanese dismantling operators have, over many years, been developing and improving information systems for the management and trading of used parts. These information systems are equipped with functions to centrally manage part quality information, vehicle identification numbers, mileage, accident history and stock levels, and play a vital role in ensuring the traceability of parts. Consequently, within Japan, multiple information systems coexist as de facto standards, and an industrial infrastructure has been established in which a diverse range of stakeholders—including dismantling operators, used parts dealers and repair workshops—utilise these systems.

Such information systems are not merely tools for improving operational efficiency; they are positioned as the foundational infrastructure for realising an international circular economy in the automotive industry, which is increasingly moving towards electrification. As the international circulation of used parts expands, an information infrastructure that can be utilised across national borders is essential to guarantee the quality and safety of parts and ensure compliance with environmental standards. In East Asia in particular, where the automotive industry is highly interdependent and the cross-border circulation of used parts is active, there is a need to establish a common information infrastructure for the region.

The establishment of such a common infrastructure will play a key role in promoting the formalisation of ELV management and in guaranteeing the safety, quality and environmental compliance of parts. Furthermore, the standardisation of information systems has the potential to serve as a policy tool to enhance the transparency of dismantling operators' businesses and to support the formalisation of informal operators.

3. Initiatives towards a circular economy in the automotive parts industry

Recycling in the automotive industry is primarily driven by actions taken by vehicle manufacturers and End-of-Life Vehicle (ELV) dismantlers. However, realising a circular economy in the automotive industry will require deeper involvement from automotive parts suppliers. In this section, we summarise the findings from interviews conducted by the authors between April and June 2026 with automotive parts suppliers—primarily major Tier 1 suppliers—in Thailand, Malaysia, Vietnam and India.

3.1. Initiatives by automotive parts suppliers

At some of the manufacturing plants of Japanese automotive parts suppliers visited, certain plastic materials and metals generated on the production line were being reintroduced into the production process. Several of the visited companies engaged in plastic moulding were re-pelletising the plastic generated during the moulding process within their factories and reintroducing it into the production lines. Companies with their own furnaces were also reprocessing metal scrap and defective products generated on-site into raw materials within their own facilities. During the recycling process, waste was sorted—including the destruction of defective products where necessary—to ensure the quality of the recycled materials. In addition to this in-house material recycling, we also identified cases where companies utilised aluminium containing scrap from other companies or other industries as raw material. However, some companies stated that even with copper, mixing automotive-grade copper with that from other industries would result in the material failing to meet quality requirements from car makers.

Waste materials that are not reused within the factory are properly managed and disposed of in accordance with the industrial waste disposal legislation of each country. Industrial waste includes defective products, machining swarf, plastic burr and offcuts and metal scrap; for suppliers, these are not merely waste but represent a dual cost factor comprising material costs and waste disposal costs. Consequently, regardless of the existence of legal regulations, suppliers are continuously striving to reduce defective products, segregate waste and recover valuable scrap, and minimise final waste.

Among the countries surveyed, in India, Malaysia and Thailand, suppliers collect industrial waste industrial waste disposal contractors to sell, and the incomes from the sale of scrap materials contribute to reducing production costs. As scrap materials hold value, companies have an incentive to improve the accuracy of waste segregation and maximise the recovery of resources.

Furthermore, among component manufacturers, there are examples of companies establishing their own governance systems; for instance, from the perspective of protecting intellectual property and preventing brand damage, they conduct on-site inspections of waste disposal operators to verify that the defective products handed over are indeed being destroyed. This demonstrates that waste management is not merely an environmental measure, but is positioned as part of corporate reputation management and supply chain risk management.

Thus, resource recycling activities within factories are being implemented on the premise of ensuring economic rationality. For companies, the transition to a circular economy—much like the transition towards decarbonisation—is driven primarily by the incentive to reduce costs. The motivation to reduce costs drives improvements in raw material utilisation efficiency and a reduction in defective products, thereby stimulating ‘upstream control’—a strategy aimed at curbing waste generation at its source. Such upstream control constitutes the practice of ‘waste prevention’, which forms the foundation of the circular economy; it is noteworthy that efforts to improve supplier productivity and the transition to a circular economy are progressing in a coordinated manner.

Regarding the international recycling of industrial waste, it was also noted that, in many cases, this is deemed economically and environmentally unsound when taking into account the increased logistics costs associated with international transport and the environmental impact from a carbon-neutral (CN) perspective (increased emissions in life-cycle assessments). As a specific example, a case was observed in which the Japanese head office, aiming for global internal circulation from a CSR perspective, proposed the re-import of offcuts from production processes to Japan; however, the foreign subsidiary rejected the head office's proposal on the grounds of 'the advantages of selling the materials locally for a profit' and 'the uneconomical nature of additional transport costs', opting instead for a resource circulation model optimised for the local context. This case demonstrates that the implementation of a circular economy is not merely a matter of principle, but that decisions are made following a comprehensive assessment of local market structures, cost structures and environmental impact. Consequently, it is believed that resource recycling is either carried out within the company's own factories or between domestic branch plants, or is limited to outsourcing to local recycling operators.

It should be noted that the implementation of the circular economy within factories is not limited to the manufacturing floor. Paper waste generated by administrative departments, office supplies, and wastewater and food waste from washrooms and canteens are also sorted, processed and managed in accordance with ISO 14000 and the company's own environmental management rules. Based on the results of the field survey, it is inferred that initiatives to implement the circular economy in such non-manufacturing activities tend to be influenced more by the company's overarching corporate policy than by the regulations of the country in which the factory operates.

As outlined above, it has been confirmed that the implementation of the circular economy by component suppliers depends to a greater extent on the company's business structure, internal governance structure and management philosophy than on differences between the countries where the factories operate, and that there are common principles of action that transcend national borders.

3.2. Challenges facing automotive parts suppliers in transitioning to a circular economy

3.2.1. Securing reliable waste disposal operators and recyclers

In the waste disposal and recycling processes that form the foundation of the circular economy, securing reliable waste disposal operators and recyclers is essential. Whilst parts suppliers hand over industrial waste to external contractors in accordance with regulations, institutional follow-up systems to precisely track the subsequent final disposal and recycling status remain underdeveloped in many countries.

If waste traceability is not ensured, defective products may find their way onto the second-hand market, leading to damage to the brand's reputation, or non-compliant offcuts recovered from unkown sources may be mixed in recycled raw materials, posing quality risks. To safeguard the credibility of Japanese companies, it is essential to select and develop reliable waste management operators and recyclers who can guarantee proper disposal right through to the downstream of the supply chain. However, in ASEAN countries, there is significant variation in the environmental management capabilities of waste management operators, and in some cases it is difficult to guarantee proper disposal unless companies conduct their own audits.

3.2.2. Technical and economic constraints on the transition to a circular economy

Closed-loop resource recycling—where resources are reintroduced from specific automotive parts into identical automotive parts—is often considered difficult from the dual perspectives of meeting quality requirements and ensuring cost-effectiveness. Attempts to reintroduce recycled raw materials into the manufacturing process face high technical barriers in meeting the strict quality standards and cost ceilings set by original equipment manufacturers. Consequently, the types and quantities of raw materials suitable for closed-loop recycling are likely to be limited.

On the other hand, 'Car-to-Car' resource recycling—where resources from waste materials of specific automotive components are reintroduced into different automotive components—appears to present lower technical and economic hurdles than closed-loop recycling. The reintroduction of waste materials from automotive components into products in other industries offers even greater technical and economic flexibility. Crucially, broadening the scope of such waste collection and recycling activities will ultimately lead to greater economic viability in the use of recycled materials in automotive component manufacturing.

3.2.3. The economic viability of capital investment and the dilemma of Kaizen activities

Capital investment is required to establish a fully-fledged resource recovery and recycling system. To maximise the return on investment, a certain minimum scale of operations must be achieved. However, this gives rise to the 'dilemma of continuous improvement (Kaizen) activities', whereby suppliers' productivity-enhancing efforts to 'minimise waste' reduce the absolute volume of recyclable materials (inputs), thereby undermining the economic viability of recycling. This expectation is dampening companies' motivation to make new capital investments in sorting and recycling system. This dilemma also highlights the difficulty of achieving a circular economy through the efforts of a single company alone and the necessity of inter-company cooperation.

3.2.4. Structural constraints arising from material specifications

Many component suppliers manufacture products in accordance with drawings provided by their customer companies, a business environment that is particularly pronounced among Tier 2 and lower-tier suppliers. These drawings specify in detail the type and grade of materials to be used, processing methods and quality standards, and suppliers are obliged to adhere strictly to these specifications.

It is common practice for suppliers to manufacture using materials specified by their customers, leaving them with little freedom in material selection. In some cases, drawings explicitly prohibit the use of recycled materials or set upper limits on the proportion of recycled content. This is because customer companies prioritise material homogeneity and product quality, making it virtually impossible for suppliers to introduce recycled materials on their own initiative.

Consequently, for component suppliers to promote the circular economy, initiatives confined to within their own factories alone have their limitations; involvement from the design and material selection stages of product development is essential. Specifically, collaboration in the upstream processes is required, such as working with vehicle manufacturers to jointly develop material specifications that meet quality requirements even when recycled materials are used, standardising or relaxing the permitted proportion of recycled materials, and formulating design specifications based on the premise of improved recyclability (Design for Recycling).

4. Challenges in transitioning the automotive industry to a circular economy

In this study, we have examined the situation in the five countries under study with regard to the transition of the automotive industry to a circular economy, focusing on two perspectives: ELVs and the proper collection of waste materials generated by automotive manufacturers and parts suppliers, alongside the use of recycled materials. The policy implications derived from the findings can be summarised as follows:

- Ensuring economic sustainability
- Establishing transparent supply chains and traceability
- Establishing regional resource circulation within East Asia
- Promoting education to drive behavioural change

As the survey results regarding automotive parts suppliers indicate, cost savings are a key motivator for companies to adopt environmental measures. At present, the use of recycled materials entails higher costs compared to virgin materials. To promote the use of recycled materials, it is necessary to improve the productivity of both the collection of recyclable waste and the production of recycled materials. Where economies of scale come into play and recycling is not economically viable based on the volume of waste generated by individual companies, it is necessary to establish mechanisms that enable resources to be efficiently collected and consolidated through collaboration with other companies or across different industries. Furthermore, the use of recycled materials often makes it difficult to meet the quality requirements of client companies. Whilst promoting technological development to meet customers' performance requirements, it is also necessary to facilitate the use of recycled materials by standardising specifications and durability criteria for such materials.

The informal sector plays a role in improving the economic viability of waste management for automotive parts suppliers. It is believed that industrial waste disposal operators accepting scrap collected by the informal sector—including unauthorised vehicle dismantlers—also include informal operators themselves. This supporting industry, which encompasses the informal sector, makes the recycling of scrap economically sustainable and generates demand for recycled materials. Part of this demand is met by high-quality scrap exported from Japan. It could even be said that Japanese automotive parts suppliers act as suppliers of 'Japanese-quality' scrap. Furthermore, thanks to the existence of this recycling industry ecosystem, Japanese automotive parts suppliers are able to sell disposed industrial waste, thereby achieving cost reductions.

However, the existence of the informal sector makes it difficult to formalise the ELV dismantling industry and to promote proper dismantling practices. The existence of an untransparent supply chain for recyclable waste materials is also a disadvantage for Japanese automotive parts suppliers, who are required to ensure the proper treatment of waste. It is necessary to establish a formal dismantling and recycling network subject to legal regulations—one that Japanese companies can use with confidence—in order to prevent the diversion of substandard products by waste disposal operators, as well as illegal dumping and the inclusion of recycled materials derived from stolen vehicles by informal dismantlers.

The development of systems enabling the traceability of vehicles and automotive parts, as well as management systems allowing tracking of waste through to its final disposal, will enhance the transparency of the recycled materials supply chain. By utilising these systems, dismantlers can increase their revenue from used parts and improve the efficiency of the proper disposal of ELVs. As these benefits are anticipated, the establishment of a highly transparent supply chain is also expected to promote the formalisation of the informal sector. Such systems are also considered applicable to battery management.

In this study, the competitiveness of ELV dismantlers has been discussed primarily through a comparison between the informal and formal sectors. However, whilst heavy machinery—symbolised by the ‘nibbler’ in Japan—is widely used in the ELV dismantling process in Japan, manual labour is employed in a greater number of stages in ASEAN and India. Whilst the use of the nibbler allows for an increase in the number of vehicles dismantled per hour, manual dismantling enables the recovery of more valuable materials than dismantling using the nibbler. By combining these approaches, each with their own distinct advantages, it is possible to enhance the economic efficiency of recovering waste materials generated by ELVs, as well as from automotive manufacturing and parts suppliers.

This industrial structure surrounding recycling demonstrates that the transition to a circular economy cannot be easily achieved through the efforts of individual companies, the automotive industry alone, or individual nations. These findings also highlight the need for cooperation between nations and between companies. However, the transition to a circular economy has the potential to alter the current balance of supply and demand for recyclable materials in East Asia. A quantitative assessment is required to determine what economic, social and environmental impacts the transition to a circular economy will have.

The transition of the automotive industry to a circular economy can be achieved through fundamental lifestyle changes that view waste as a resource, the thorough segregation of recyclable waste materials within factories, and the fostering of consumer awareness that places a value on environmental benefits; educational and awareness-raising activities are therefore essential. Many automotive suppliers pointed out that the use of recycled materials by car manufacturers is unlikely to become widespread unless consumers actively choose vehicles made from recycled materials. They also mentioned that whilst employees follow sorting procedures on the production line as standard practice, it is difficult to ensure thorough compliance in places such as canteens. It can be said that the transition of the automotive industry to a circular economy must be promoted in tandem with the transition of society as a whole to a circular economy.

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Chapter 7: Towards A Responsible Circular Economy: Assessing Regional Variations in the ESG Impacts of Battery Recycling in ASEAN Region

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1. Background and Objectives

1.1. Rapid Electrification in ASEAN and the Manifestation of ESG Issues

The automotive industry in the Association of Southeast Asian Nations (ASEAN) is undergoing a rapid transition towards electrification. In Thailand, the electric vehicle (EV) sales share reached 21% of the market in 2025, while in Indonesia, EV sales surged three-fold year-on-year in 2024, recording a market share of over 7% (IEA, 2025; Ember, 2025). National governments position EVs as a strategic measure for job creation, reducing imported crude oil dependence, and improving air quality. Representative examples include Thailand's "30@30 policy," Indonesia's nickel downstream industry strategy, and Malaysia's National Energy Transition Roadmap (Iwasaki et al., 2025). This rapid acceleration of EV adoption has generated multi-layered environmental, social, and governance (ESG) challenges spanning from the upstream supply chain to the end-of-life (EOL) phase.

In the upstream phase, issues surrounding nickel, which is indispensable for EV batteries, are particularly severe. In Indonesia, the world's largest nickel producer, the domestic smelting industry has expanded rapidly since the 2020 ban on the export of unprocessed ores. However, over 90% of the smelters in the country employ pyrometallurgical processing, and 97% of their electricity is supplied by captive coal-fired power generation. Consequently, approximately 99,000 kg-CO_2 is emitted per ton of ferronickel produced (Wahyono et al., 2024). This creates a structural paradox where the widespread adoption of EVs promotes the expansion of upstream industries characterized by high carbon emissions and high environmental burdens.

Challenges in the EOL phase are equally significant. The typical lifespan of an EV battery is 8 to 10 years, meaning that the initial cohort of EVs popularized between 2015 and 2020 will reach the mass disposal phase in the near future. The Economic Research Institute for ASEAN and East Asia (ERIA, 2024) estimates that the cumulative generation of EOL EV batteries in ASEAN will reach up to 2,166 GWh by 2040. However, according to field surveys conducted by Iwasaki et al. (2025) targeting six ASEAN countries (Indonesia, Malaysia, the Philippines, Singapore, Thailand, and Vietnam), even in the three major automotive production hubs—Indonesia, Malaysia, and Thailand—there is virtually an absence of official policies regarding end-of-life vehicle (ELV) recycling. As a result, a large portion of used vehicles, including EOL batteries, are left to inappropriate dismantling and disposal by the informal sector. As of 2022, less than 25% of global e-waste was adequately recycled (Baldé et al., 2024), and the situation wherein the recycling rate of lithium remains below 1% is a common challenge shared across the ASEAN region.

Pressure for ESG compliance is also intensifying in terms of international regulations. The EU Battery Regulation (EU 2023/1542) mandates carbon footprint declarations for EV batteries starting in February 2025, and by 2027, the Digital Battery Passport (DBP), which requires transparency across the entire supply chain, will become mandatory. Furthermore, recycled content thresholds (12% for cobalt, 4% for lithium, and 4% for nickel) will be established in 2030, which will subsequently increase to 20%, 10%, and 12%, respectively, by 2035 (European Parliament, 2023). Battery materials produced in ASEAN are highly likely to fall short of these standards under current conditions, presenting an urgent compliance challenge for the entire EV supply chain in the region (Walker and Palaon, 2024).

1.2. Achievements of Previous Studies and Remaining Gaps

Life cycle assessment (LCA) studies of EV batteries have accumulated rapidly, primarily focusing on Europe, China, and North America. Hawkins et al. (2013) established a comprehensive LCA comparing conventional vehicles and EVs, demonstrating that EVs have a EVs the environmental impact during the manufacturing phase, and that the electricity mix and driving distance are pivotal parameters. Through a review of lithium-ion battery (LIB) LCA studies, Peters et al. (2017) identified the electricity mix, battery chemistry, and driving distance as key parameters, while Ellingsen et al. (2014) refined a component-level LCA for NMC battery packs.

Regarding previous studies within the ASEAN region, Chayutthanabun et al. (2025) compared four EOL scenarios (landfill, remanufacturing, repurposing, and recycling) for an NMC battery pack (366 kg) in Thailand, revealing that remanufacturing yielded the greatest greenhouse gas (GHG) reduction (−1,193 kg CO_2eq). Additionally, Sirithan (2023) partially evaluated Thailand's EOL management using process LCA, and Kosai (2022) conducted a fuel comparison LCA focusing on Malaysia. Nevertheless, quantitative comparative LCAs encompassing the broader ASEAN region remain exceedingly limited.

Based on the achievements of these previous studies, two significant methodological gaps emerge. The first gap is the lack of comparative LCAs that reflect regional differences, such as the electricity mix, waste management infrastructure, and regulatory environments. While the electricity mix is a dominant parameter determining 65 to 70% of GHG emissions during the use phase (Aryan, 2025; Kosai, 2022), the power generation compositions in Thailand and Indonesia differ vastly, meaning that identical findings cannot be applied directly. Nevertheless, most existing literature is confined to single-country and single-scenario analyses, and no studies have systematically quantified the impact of country-specific conditions within the ASEAN region on LCA results.

The second gap is the absence of a social life cycle assessment (S-LCA) that elevates human rights risks throughout the entire life cycle. The extraction phase of battery raw materials, such as cobalt, lithium, and nickel, inherently involves forced labour, child labour, and poor occupational health and safety environments. As Jose et al. (2025) demonstrated in their S-LCA of NMC battery raw materials, the mining and refining stages constitute the largest source of social risk. However, in the ASEAN context, there is a complete absence of research integrating E-LCA and S-LCA from the same inventory, meaning that evaluating only GHGs completely overlooks the critical ESG dimensions such as human rights and labour risks.

1.3. Objectives of the Study

Given the aforementioned background and the gaps in prior research, this study sets the following three objectives:

(1) To quantitatively evaluate the impact of a scenario upgrading the recycling rate from current levels to target levels on environmental indicators for EV batteries in Indonesia and Thailand, utilising a hybrid LCA framework (an integration of process-based and input-output analyses).

(2) To simultaneously evaluate the trade-offs that the recycling rate improvement scenario imposes on social ESG indicators throughout the entire life cycle by incorporating human rights risk indicators into the environmentally extended input-output analysis described in (1).

(3) To systematically demonstrate, for the first time, how regional differences within ASEAN influence both environmental and social LCA outcomes by comparing Indonesia and Thailand—two countries with contrasting characteristics in terms of nickel production structures and reliance on battery cell procurement—thereby providing quantitative evidence for formulating country-specific circular economy policies.

The academic contribution of this study lies in simultaneously bridging the two aforementioned gaps. Specifically, it conducts the first integrated assessment in Indonesia and Thailand that combines (a) a comparative LCA reflecting regional differences in ASEAN, such as the electricity mix, and (b) an integrated E-LCA and S-LCA spanning from the mining phase to the manufacturing phase. Furthermore, as a practical contribution, this study provides policymakers, automotive OEMs, and suppliers—who are seeking to address EU regulations, reduce Scope 3 emissions, and formulate circular economy policies —with quantitative evidence regarding the ESG benefits and trade-offs resulting from enhanced battery recycling rates in ASEAN.

2. Methodology

2.1. Problem Formulation and Approach Overview

This study addresses two primary methodological challenges. Challenge 1 (Diversity of Indicators): The evaluation indicators span a wide range, including climate change (GHG), mineral resources, fossil resources, water resources, biomass consumption, and human rights risks (such as forced labour, child labour, and excessive working hours). Consequently, assessments based on a single indicator risk overlooking the critical trade-offs associated with increasing recycling rates. Challenge 2 (Comprehensiveness of Upstream Scope 3 Emissions): Although the majority of the environmental and social burdens of EV batteries reside in the raw material procurement stage (upstream Scope 3), it is practically impossible to comprehensively cover Tier 2 and subsequent tiers using process data alone.

To address these challenges, this study adopts a hybrid life cycle assessment (LCA) approach that integrates environmentally extended input-output analysis (EEIOA) and process LCA. Primary manufacturing processes are analysed using process data from ecoinvent v3.11, while indirect processes from Tier 2 onward are supplemented with multi-region input-output (MRIO) data. This MRIO-based analytical framework follows on from the work of Lenzen et al. (2013) and Stadler et al. (2018).

2.2. Environmentally Extended Input-Output Analysis (EEIOA)

EEIOA is a framework for collectively calculating the indirect burdens triggered by the final demand for a product across the entire supply chain by multiplying the input-output tables by the environmental burdens or social indicators per unit of production activity in each industrial sector (intensity) (Miller & Blair, 2009). By utilising multi-regional input-output (MRIO) tables, the cross-border supply chains of industrial activities in different countries can be handled within a single model.

In addition to environmental extension variables (GHG, mineral and fossil resources, water use, and biomass consumption), human rights extension variables (forced labour, child labour, and excessive working hour risks) are calculated using a working-hour model that integrates MRIO and working-hour data. In this model, the working hours of each industrial sector in each country are multiplied by country- and sector-specific human rights risk factors (Jose et al., 2025; Benoît Norris et al., 2020). However, since EEIOA utilises sector averages, it has a limitation in directly reflecting differences in battery chemistry (e.g., NMC111 vs. LFP). To compensate for this limitation, the hybrid LCA described in the next section is required.

2.3. Hybrid LCA

2.3.1. Definition of Method and System Boundary

Hybrid LCA is an approach that integrates the process-based method and the input-output method (Suh & Huppes, 2005; Majeau-Bettez et al., 2011). This study adopts a tiered hybrid method. Process data from ecoinvent v3.11 are applied to the primary manufacturing processes (battery cell production, pack assembly, and the production of recycled secondary raw materials), while upstream and peripheral processes are supplemented with MRIO intensities. This ensures the accuracy of the major processes while eliminating cut-off errors.

The system boundary is defined as cradle-to-gate, encompassing the stages from raw material extraction and refining to battery manufacturing (cell manufacturing and pack assembly). The functional unit is defined as “a battery pack for one passenger EV.” The study targets an Indonesian NMC111 battery pack (510 kg) and a Thai LFP battery pack (480 kg).

2.3.2. Scenario Definition

The difference between the baseline (current) and future scenarios lies in the proportion of secondary raw materials derived from recycling among the precious metal materials input into battery manufacturing.

In the future scenario, it is assumed that 30% of the target metals are replaced from primary extracted raw materials to recycled secondary raw materials (Table 1). The recycling process in the future scenario is positioned not as a waste treatment process but as a manufacturing process for secondary raw materials produced through recycling, adhering to the closed-loop evaluation approach adopted in the EverBatt model (Dai et al., 2019).

Table 1: Scenario Settings: Target Metals and Recycling Rates (Baseline vs. Future)

	NMC111 Target Metal	LFP Target Metal	Baseline Recycling Rate	Future Recycling Rate
Battery chemistry-specific metals	Li, Co, Ni, Mn	Li, Fe, P	0%	30%
Metals common to both chemistries	Al, Cu	Al, Cu	0%	30%

Source: by Author

2.3.3. Evaluation Indicators

The analysis covers 14 indicators encompassing both environmental and human rights domains (Table 2). However, in accordance with the Water Footprint Network (WFN) definitions, water use in this study is evaluated by distinguishing it into two categories: green water (water originating from precipitation that is held in the soil and utilized for the growth of crops and plants) and blue water (water abstracted from surface or groundwater resources, such as rivers, lakes, and aquifers, and consumed in irrigated agriculture or industrial processes)

Table 2: List of Main Evaluation Indicators

Category	Indicator Name	Unit	Main Reference Source
Environ-mental	Climate change (GWP100)	kg CO_2-eq	Gütschow and Pflüger (2022)
	Fossil Resource Use	MJ	Krausmann et al. (2015)
	Mineral Resource Use	kg Cu-eq(ReCiPe)	Krausmann et al. (2015)
	Water Use (Green Water)	L	Hoekstra and Mekonnen (2012)
	Water Use (Blue Water)	L	Hoekstra and Mekonnen (2012)
	Biomass Use	kg	Krausmann et al. (2015)
Human Rights	GII (Gender Inequality)	Risk Hours	United Nations Development Programme (2022)
	Excessive Working Hours Risk		U.S. Department of State, Bureau of Democracy, Human Rights, and Labor (2020)
	Child Labor Risk		United Nations Children's Fund (2019)
	Forced Labor Risk		U.S. Department of Labor, Bureau of International Labor Affairs (2020)
	Corruption Risk		Kaufmann et al. (2010)
	Legal System Risk		Kaufmann et al. (2010)
	Occupational Toxics and Hazardous Substances		GBD 2016 Occupational Carcinogens Collaborators (2020)
	Low-Wage Labor Risk		International Labour Organization (2019)

2.4. Selection of Batteries for Analysis

An NMC111 battery for Indonesia and an LFP battery for Thailand were selected to represent typical vehicle models. Comparing different battery chemistries, namely NMC111 and LFP, allows for the effects of regional differences to be isolated from those of chemical variations.

2.5. Battery Inventory

2.5.1. LFP Battery (Thailand)

The LFP battery pack consists of 480 kg (349 kg for cells and 131 kg for the pack structure). It uses lithium iron phosphate ($LiFePO_4$) as the cathode material. Since it does not contain cobalt, its human rights risks during the extraction phase are relatively low. Conversely, it faces challenges in the EOL phase due to the technical difficulty of lithium recovery (Table 3).

Table 3: LFP Battery Pack Inventory (Thailand)

Component	Weight (kg)	Ratio (%)	Primary Sourcing Origin
Battery Pack Total	480	100	China (Cells) -> Thailand assembly
$LiFePO_4$ Cathode Material	145	30.2	China (Phosphorus/Iron raw materials: China/ South America)
Graphite Anode Material	100	20.8	China (Natural/Synthetic Graphite)
Electrolyte ($LiPF_6$-based)	78	16.3	China (Petrochemical origin)
Separator, Current Collector, etc.	26	5.4	China, South Korea, Chile, Peru
Pack Structure	131	27.3	China, Domestic Thailand, South Korea

Source: by Author

2.5.2. NMC111 Battery (Indonesia)

The NMC111 battery pack consists of 510 kg (77.4 kWh) (371 kg for cells and 139 kg for the pack structure). Nickel (approximately 58 kg in the cells) is mined and refined at domestic mines in Indonesia, processed into pCAM (precursor cathode active material) in South Korea, and subsequently integrated into the battery cells. The ESG challenges in Indonesia's nickel refining phase (dependence on coal-fired power, ecosystem destruction, and labour rights violations) directly affect the life cycle burdens of this battery (Table 4).

Table 4: NMC111 Battery Pack Inventory (Hyundai Ioniq 5, Indonesia)

Component	Weight (kg)	Ratio (%)	Primary Sourcing Origin
Battery Pack Total	510	100	South Korea (Cells) -> Indonesia assembly
NMC111 Cathode Material	118	23.1	Ni: Indonesia; Co: DRC; Mn: South Africa -> South Korea pCAM
Graphite Anode Material	106	20.8	China (Natural/Synthetic Graphite)
Electrolyte ($LiPF_6$-based)	82	16.1	China (Petrochemical origin)
Separator, Current Collector, etc.	29	5.7	South Korea, China, Chile, Peru
Pack Structure	139	27.3	Indonesia, South Korea

Source: by Author

2.6. List of Foreground Processes and Process Flow

Foreground process data were obtained from ecoinvent v3.11 and Dai et al. (2019) (Table 5). "Battery Cell Production" is an overarching process that encompasses the individual anode, cathode, and electrolyte processes. Isolating these constituent processes enables adaptation to the recycling scenarios.

Table 5: List of Foreground Processes Obtained from ecoinvent v3.11 (Secondary-Material Production Obtained from Dai et al.)

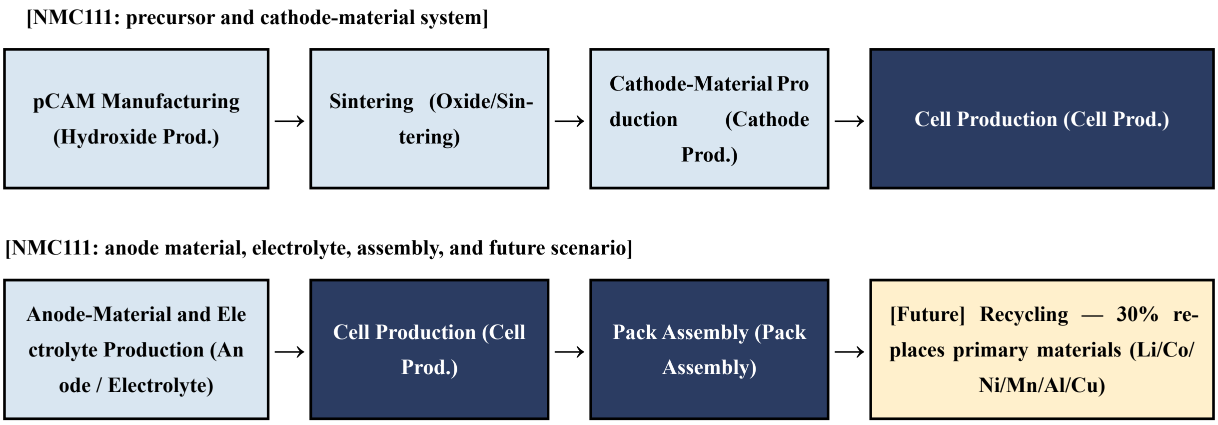
Stage	NMC111	LFP	Notes
Precursor Refining	NMC111 Hydroxide (pCAM) Production	–	Ni, Co, Mn Precursor
Sintering	NMC111 Oxide Production (Sintering)	–	pCAM -> NMC Oxide
Cathode Material	NMC111 Cathode Production	LFP Cathode Production	NMC111 vs $LiFePO_4$
Anode Material	NMC111 Anode (Graphite) Production	LFP Anode Production (Graphite)	Both graphite-based
Electrolyte	NMC111 Electrolyte Production	LFP Electrolyte Production	$LiPF_6$-based
Cell Manufacturing	NMC111 Battery Cell Production	LFP Battery Cell Production	Overarching process integrating the above steps
Pack Assembly	NMC111 Battery Pack Assembly	LFP Battery Pack Assembly	BMS, including cooling
Secondary Material Production	EOL – NMC111 Battery Recycling (Hydromet)	EOL – LFP Battery Recycling	Future scenario only; substitutes 30% of primary raw materials

Source: by Author

The NMC111 chemistry involves a three-stage precursor process (pCAM production, sintering, cathode material production), whereas the LFP chemistry requires 6 processes in total as these stages are unnecessary. While the NMC111 recycling process (hydrometallurgy) enables the recovery of all target metals (Li, Ni, Co, Mn, Al, and Cu), uncertainties remain regarding the recovery efficiency of lithium in the LFP recycling process.

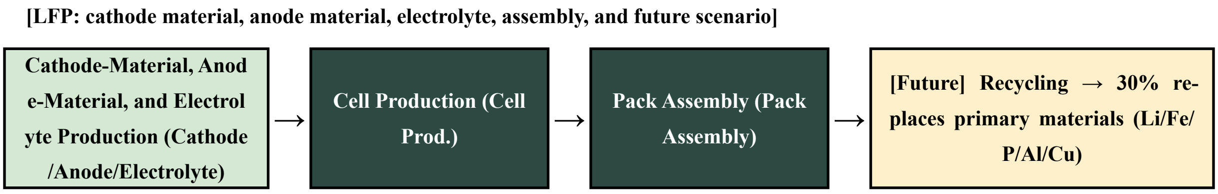
Figures 1 and 2 illustrate the process flows for NMC111 and LFP, respectively. The background system (upstream inputs, electricity, transportation, etc., for each process) is supplemented with the input-output coefficients of the MRIO model, and indirect burdens are calculated by multiplying these by the environmental and human rights risk factors.

Figure 1: Foreground Process Flow of the NMC111 Battery (ecoinvent v3.11)



Source: by Author

Figure 2: Foreground Process Flow of the LFP Battery (ecoinvent v3.11)



Source: by Author

3. Results and Discussion

This chapter presents the impacts of a future scenario—wherein the end-of-life (EOL) recycling rates of critical metals, Al, and Cu are increased from the baseline (0%) to 30%—on 14 environmental and human rights indicators for the Indonesian NMC111 battery and the Thai LFP battery.

3.1. Environmental Indicators

Table 6 presents the evaluation results for the six environmental indicators, while Figures 3 through 8 illustrate the material-specific contributions to each indicator.

Table 6: Evaluation Results of Environmental Indicators (▲: worsening, ▼: improvement)

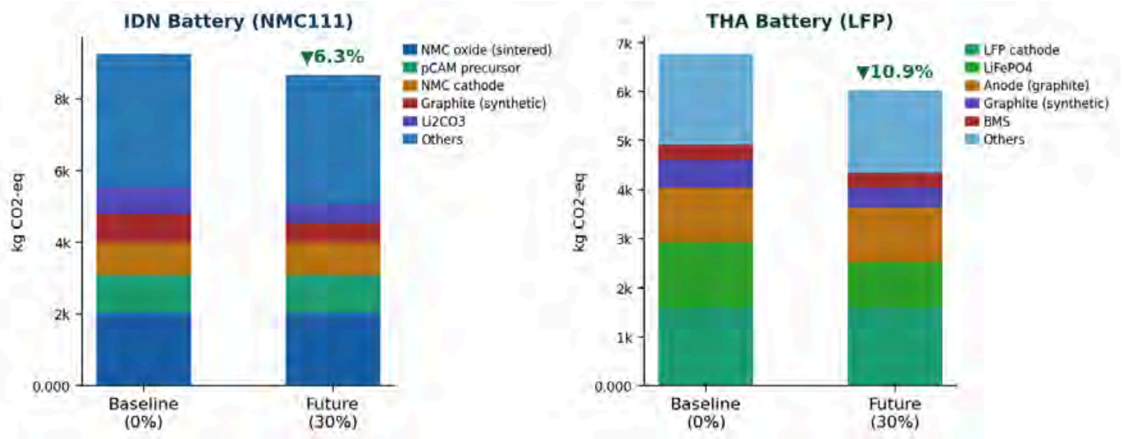
Environmental Indicators	NMC111 (Indonesia)			LFP (Thailand)			Unit
Indicator	Baseline	Future	Rate of Change	Baseline	Future	Rate of Change	
GHG Emissions	9,253	8,666	▼6.3%	6,774	6,039	▼10.9%	kg CO_2-eq
Biomass Consumption	0.316	0.377	▲19.4%	0.187	0.293	▲57.1%	t
Fossil Fuel Consumption	10.5	8.62	▼17.8%	2.95	2.69	▼8.9%	t
Water Use (Green Water)	95.3k	94.2k	▼1.1%	55.5k	100.4k	▲81.0%	L
Water Use (Blue Water)	15.7k	15.1k	▼4.0%	10.4k	12.0k	▲15.8%	L
Mineral Resource Use	6.88	5.35	▼22.3%	1.75	1.46	▼17.0%	t

Source: by Author

3.1.1. GHG Emissions

The baseline values for the NMC111 and LFP batteries are 9,253 and 6,774 kg CO_2-eq, respectively, with the NMC111 exceeding the LFP by approximately 37%. For the NMC111, three precursor stages—NMC oxide (sintering), pCAM precursor, and NMC cathode material—account for approximately 43% of the total emissions, primarily driven by the heavy reliance of the Indonesian HPAL process on coal-fired power. In the future scenario, emissions improve in both cases, decreasing by −6.3% for the NMC111 and −10.9% for the LFP, with the LFP exhibiting a larger margin of improvement. This is because the emission reduction effect per unit weight through recycling substitution is more pronounced in the LFP than in the NMC111, which contains cobalt and nickel.

Figure 3: Material-specific contributions to GHG emissions (kg CO_2-eq): Baseline vs. Future

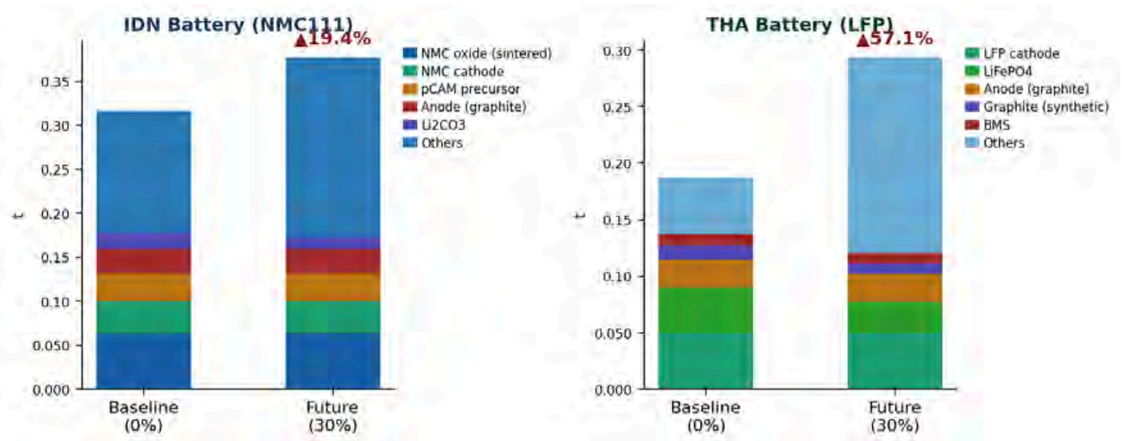


Source: by Author

3.1.2. Biomass Use

The baseline values are 0.316 t for the NMC111 and 0.187 t for the LFP. In the future scenario, biomass consumption deteriorates in both cases, increasing by 19.4% for the NMC111 and 57.1% for the LFP. This counterintuitive increase is attributable to the fact that the upstream manufacturing chain of chemical solvents, such as NMP used in the battery recycling process, relies on the agricultural sector (secondary supply chain trade-off). This effect, captured for the first time through MRIO background supplementation, would be overlooked by process LCA alone. The reason the deterioration of the LFP (+57.1%) significantly exceeds that of the NMC111 lies in the strong dependence of the upstream supply chain of Thailand's LFP recycling solvents on the agricultural sectors of Myanmar and Lao PDR.

Figure 4: Material-specific contributions to biomass consumption (t): Baseline vs. Future

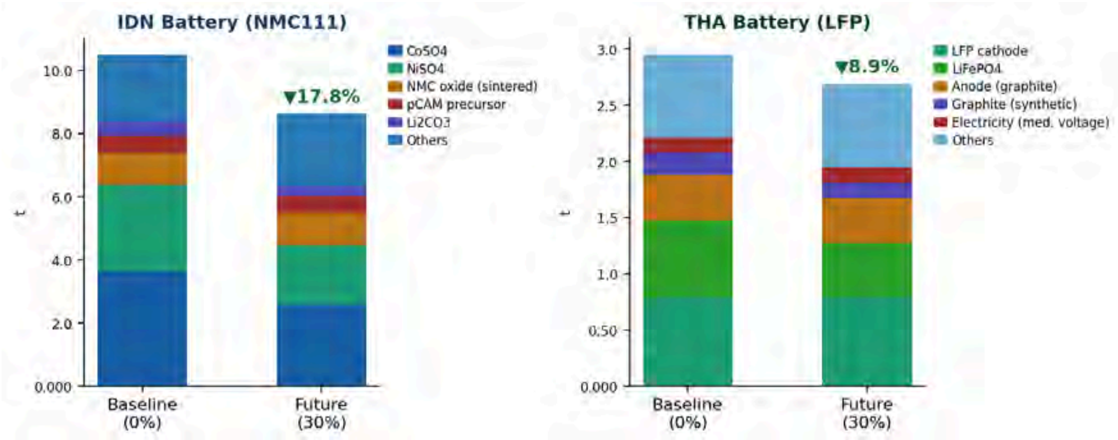


Source: by Author

3.1.3. Fossil Fuel Consumption

The baseline values are 10.5 t for the NMC111 and 2.95 t for the LFP, with the NMC111 reaching approximately 3.6 times that of the LFP. For the NMC111, the coal-dependent refining of cobalt sulfate (3.6 t) and nickel sulfate (2.7 t) in Indonesia constitutes the largest contribution (Figure 5, left). In the future scenario, both show improvements, with a decrease of −17.8% for the NMC111 and −8.9% for the LFP, with the NMC111 showing a larger improvement. This is due to the reduction in coal-derived fossil fuel consumption achieved by substituting 30% of the HPAL process with recycled materials.

Figure 5: Material-specific contributions to fossil fuel consumption (t): Baseline vs. Future

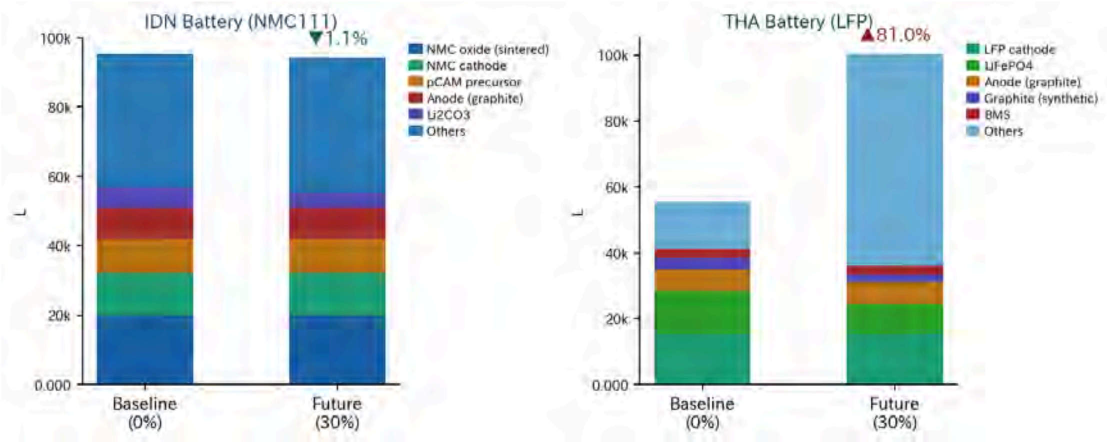


Source: by Author

3.1.4. Total Water Consumption: Green Water

The baseline values are 95,278 L for the NMC111 and 55,479 L for the LFP. In the future scenario, while the NMC111 decreases by −1.1%, the LFP experiences a substantial deterioration of 81.0% (reaching 100,390 L) (Figure 6, right), representing one of the core findings of this study. In the future scenario for the LFP, hydrometallurgical recycling reagents such as sulfuric acid (for leaching), sodium carbonate, and sodium hydroxide are newly required in large quantities, causing the “Other” material category to surge approximately 4.4 times, from the baseline of 14,455 L to 64,313 L. This deterioration is directly caused by the massive water consumption entailed by the upstream manufacturing in the agricultural and chemical sectors, which is an original finding quantified for the first time through MRIO background supplementation.

Figure 6: Material-specific contributions to total water consumption (Green water, L): Baseline vs. Future

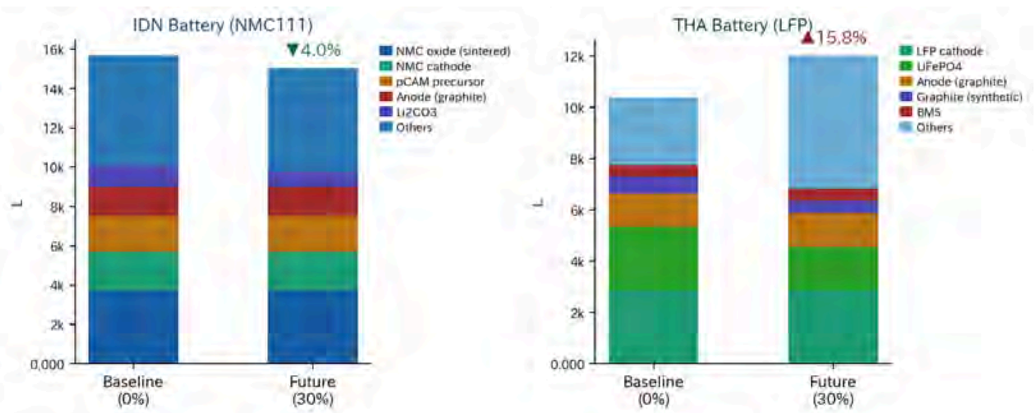


Source: by Author

3.1.5. Total Water Consumption: Blue Water

The baseline values for blue water (irrigated water) are 15,688 L for the NMC111 and 10,383 L for the LFP. In the future scenario, while the NMC111 improves by −4.0% (15,065 L), the LFP deteriorates by +15.8% (12,025 L) (Figure 7, right). In Indonesia, NMC oxide (sintering) (24%), NMC cathode material (13%), pCAM precursor (12%), anode material (9%), and lithium carbonate (7%) constitute the top contributors, and the total value improves by −4.0% primarily due to the substitution of lithium carbonate. In Thailand, hydrometallurgical recycling reagents such as sulfuric acid (leaching), sodium carbonate, and sodium hydroxide are newly introduced in the future scenario, doubling the "Other" material group from 2,622 L to 5,201 L. This deterioration stems from the same second-tier supply chain trade-off observed for green water (Thailand: +81.0%), although the magnitude of deterioration is more limited compared to green water.

Figure 7: Material-specific contributions to total water consumption (Blue water, L): Baseline vs. Future

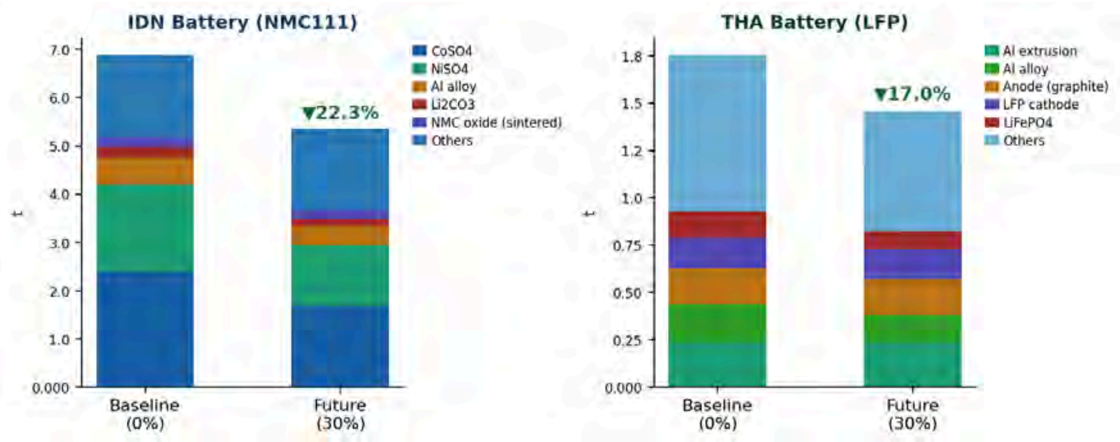


Source: by Author

3.1.6. Mineral Resource Use

The baseline values are 6.88 t for the NMC111 and 1.75 t for the LFP. In the future scenario, the NMC111 decreases by −22.3% (the greatest improvement) and the LFP by −17.0%, demonstrating the highest rate of improvement among all 14 indicators. For the NMC111, this is primarily driven by the primary mining substitution of cobalt sulfate (−40%) and nickel sulfate (−40%), whereas for the LFP, the recycling substitution of Al extrusion processing and aluminium alloys contributes to the reduction (Figure 8, right).

Figure 8: Material-specific contributions to mineral resource use (t): Baseline vs. Future



Source: by Author

3.2. Human Rights Indicators

Table 7 presents the results for the eight human rights indicators, while Figures 9 through 16 illustrate the material-specific contributions to each indicator. The human rights indicators were quantified as risk hours using the MRIO and working-hour model.

Table 7 Evaluation Results of Human-Rights Indicators (▲: worsening, ▼: improvement)

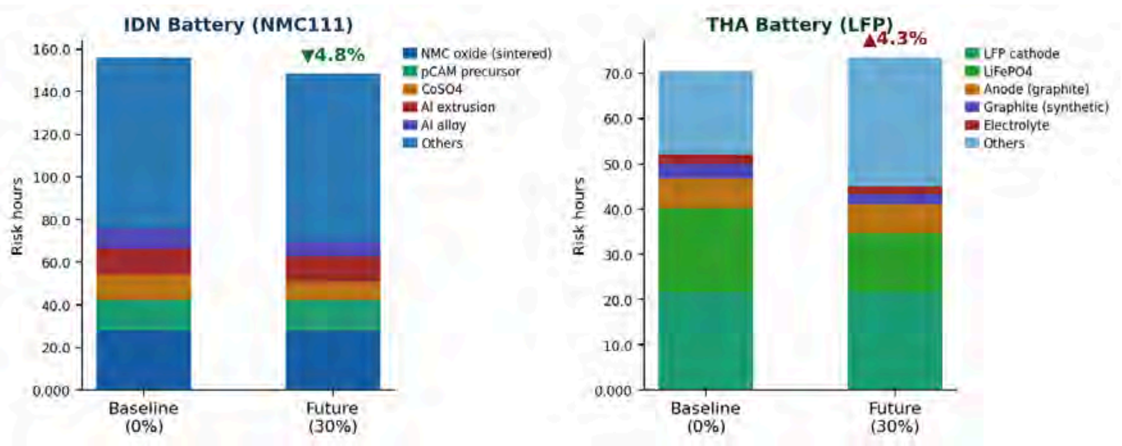
Human Rights Indicators	NMC111 (Indonesia)			LFP (Thailand)			Unit
Indicator	Baseline	Future	Rate of Change	Baseline	Future	Rate of Change	
GII (Gender Inequality Index)	156.1	148.6	▼4.8%	70.4	73.5	▲4.3%	Risk Hours
Excessive Working Hours Risk	315.0	297.9	▼5.4%	208.9	196.5	▼5.9%	Risk Hours
Child Labor Risk	70.1	66.6	▼5.1%	52.6	52.8	▲0.4%	Risk Hours
Forced Labor Risk	158.6	149.8	▼5.5%	107.6	113.8	▲5.7%	Risk Hours
Corruption Risk	113.0	107.0	▼5.3%	80.9	82.2	▲1.7%	Risk Hours
Legal System Risk	311.9	295.0	▼5.4%	210.1	204.3	▼2.8%	Risk Hours
Occupational Toxics and Hazards	384.1	362.8	▼5.5%	278.8	259.8	▼6.8%	Risk Hours
Low Wage Labor Risk	228.5	217.2	▼5.0%	133.4	122.6	▼8.1%	Risk Hours

Source: by Author

3.2.1. GII (Gender Inequality Index)

The baseline values are 156.1 for the NMC111 and 70.4 risk hours for the LFP, with Indonesia's value being approximately 2.2 times higher. For the NMC111, the precursor manufacturing group and cobalt sulfate dominate the upper tier, reflecting the low female employment ratio in the Indonesian nickel industry. In the future scenario, the NMC111 improves by −4.8%, whereas the LFP deteriorates by 4.3%. The deterioration of the LFP is attributable to the new involvement of sectors with low female labour participation rates in the upstream supply chain of recycled secondary raw material manufacturing.

Figure 9 Material-specific contributions to Gender Inequality Index (GII, risk hours): Baseline vs. Future

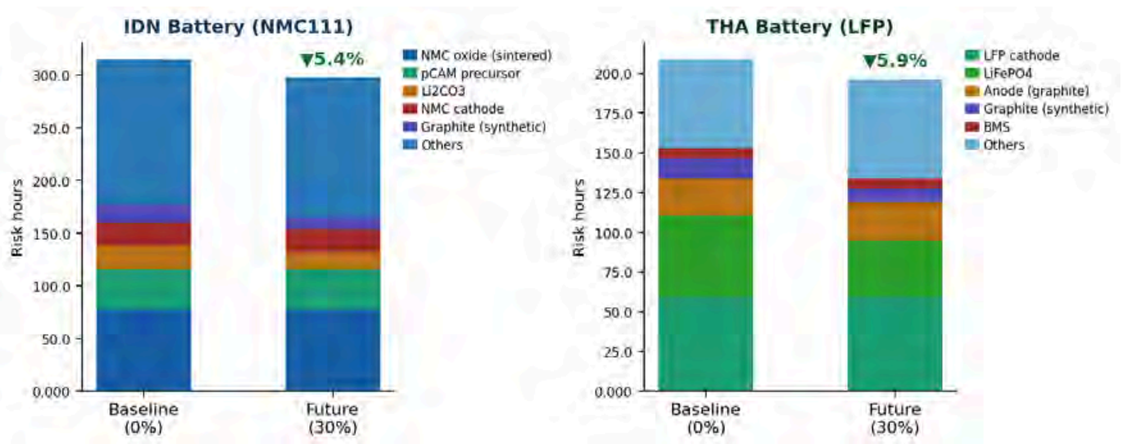


Source: by Author

3.2.2. Excessive Working Hours Risk

The baseline values are 315.0 risk hours for the NMC111 and 208.9 risk hours for the LFP. For the NMC111, NMC oxide (sintering) (77.1) and pCAM precursor (38.7) rank highest. In the future scenario, both show improvements of nearly identical magnitudes, with a decrease of −5.4% for the NMC111 and −5.9% for the LFP. This is because recycling substitution mitigates the risk of excessive working hours associated with primary mining and refining.

Figure 10: Material-specific contributions to excessive working hours risk (risk hours): Baseline vs. Future

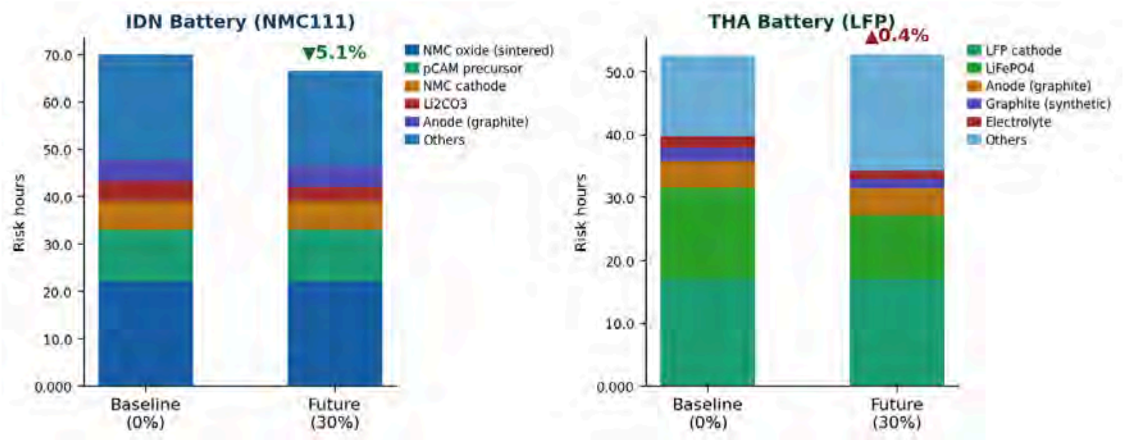


Source: by Author

3.2.3. Child Labour Risk

The baseline values are 70.1 risk hours for the NMC111 and 52.6 risk hours for the LFP. For the NMC111, NMC oxide (sintering) (22.1) and pCAM precursor (11.1) constitute the primary contributors, reflecting the risk of cobalt mining originating from the DRC. In the future scenario, the NMC111 improves by −5.1%, while the LFP remains virtually unchanged at 0.4%. Since LFP does not contain cobalt, its potential for improvement through recycling substitution is limited.

Figure 11: Material-specific contributions to child labour risk (risk hours): Baseline vs. Future

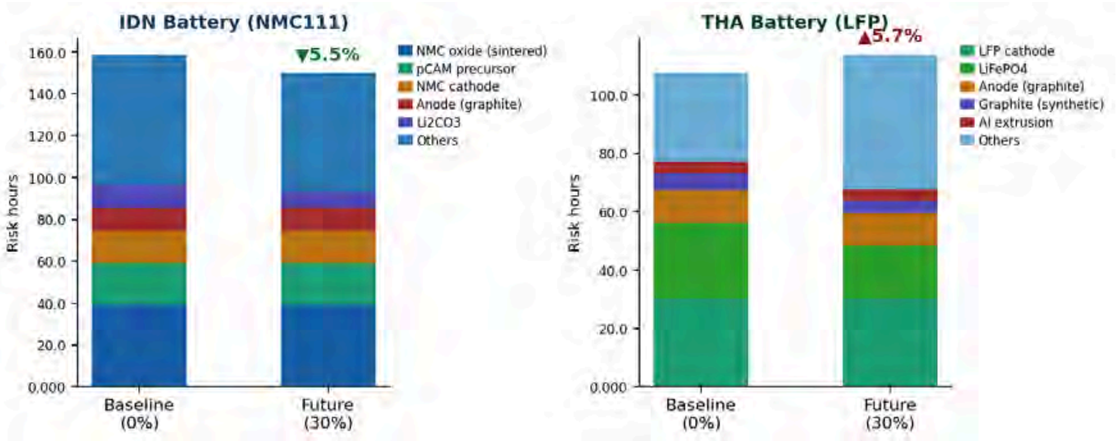


Source: by Author

3.2.4. Forced Labour Risk

The baseline values are 158.6 risk hours for the NMC111 and 107.6 risk hours for the LFP, with NMC oxide (sintering) (39.2) yielding the largest contribution to the NMC111. In the future scenario, while the NMC111 improves by −5.5%, the LFP deteriorates by +5.7% (reaching 113.8 risk hours). New inputs required for the recycling process, such as battery collection logistics (+6.6 risk hours), sulfuric acid (+5.9), sodium carbonate (+3.9), and sodium hydroxide (+2.9), increase forced labour risks, forming a structure that results in a net increase that outweighs the reduction achieved from primary raw materials (such as $LiFePO_4$: −7.8). This represents one of the key insights of this study, demonstrating that increasing recycling rates does not necessarily lead to comprehensive improvements in human rights risks.

Figure 12: Material-specific contributions to forced labour risk (risk hours): Baseline vs. Future

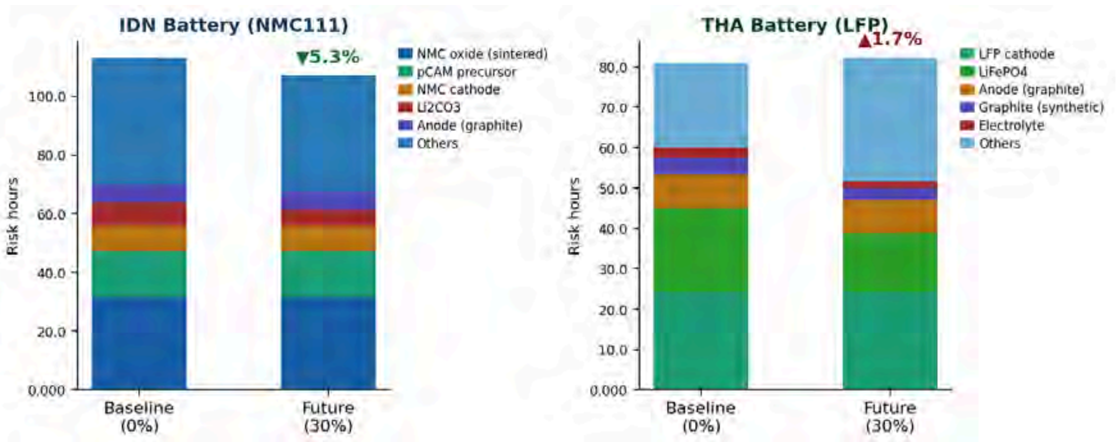


Source: by Author

3.2.5. Corruption Risk

The baseline values are 113.0 risk hours for the NMC111 and 80.9 risk hours for the LFP. In the future scenario, the NMC111 improves by −5.3%, while the LFP deteriorates slightly by 1.7%. The improvement in the NMC111 is due to a reduced dependence on countries characterized by high corruption risks associated with primary nickel and cobalt mining. Conversely, the slight increase in the LFP is attributable to the inclusion of sectors from high-corruption-risk countries within the procurement chain for recycled secondary raw materials.

Figure 13: Material-specific contributions to corruption risk (risk hours): Baseline vs. Future

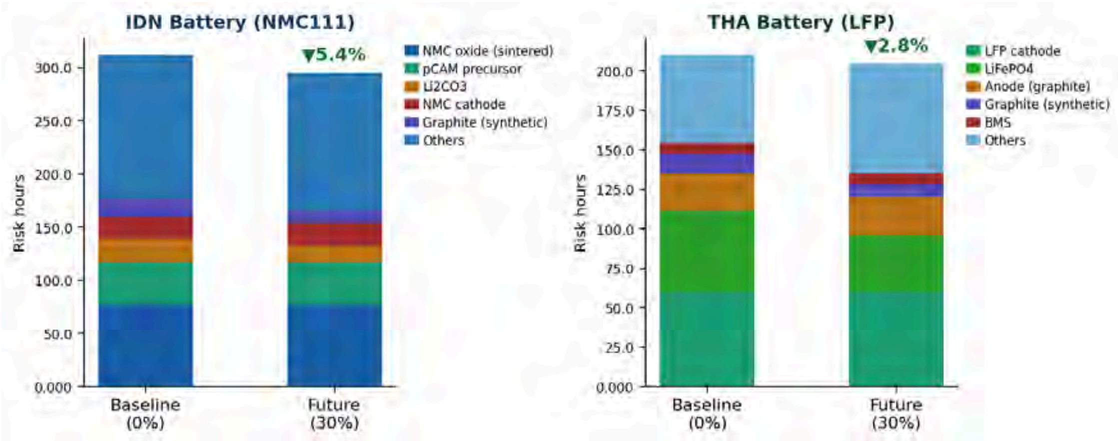


Source: by Author

3.2.6. Legal System Risk

The baseline values are 311.9 risk hours for the NMC111 and 210.1 risk hours for the LFP. In the future scenario, both countries exhibit improvements, with a reduction of −5.4% for the NMC111 and −2.8% for the LFP. However, the margin of improvement for the LFP is only half of that for Indonesia, indicating that the rule-of-law risk reduction effect through recycling substitution in the LFP battery supply chain is less pronounced than that in the NMC111.

Figure 14: Material-specific contributions to legal system risk (risk hours): Baseline vs. Future

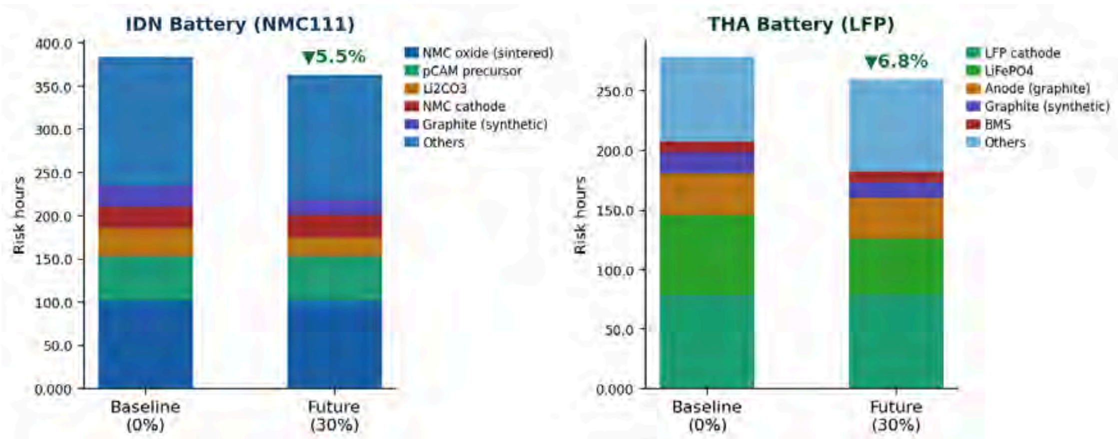


Source: by Author

3.2.7. Occupational Toxics and Hazards Risk

The baseline values are 384.1 risk hours for the NMC111 and 278.8 risk hours for the LFP, representing the highest absolute values among the eight human rights indicators. For the NMC111, the nickel and cobalt refining processes, which entail a high risk of exposure to hazardous chemical substances, stand out prominently. In the future scenario, improvements are observed in both cases, decreasing by −5.5% for the NMC111 and −6.8% for the LFP, with the LFP showing a slightly larger improvement margin.

Figure 15: Material-specific contributions to occupational toxics and hazards risk (risk hours): Baseline vs. Future

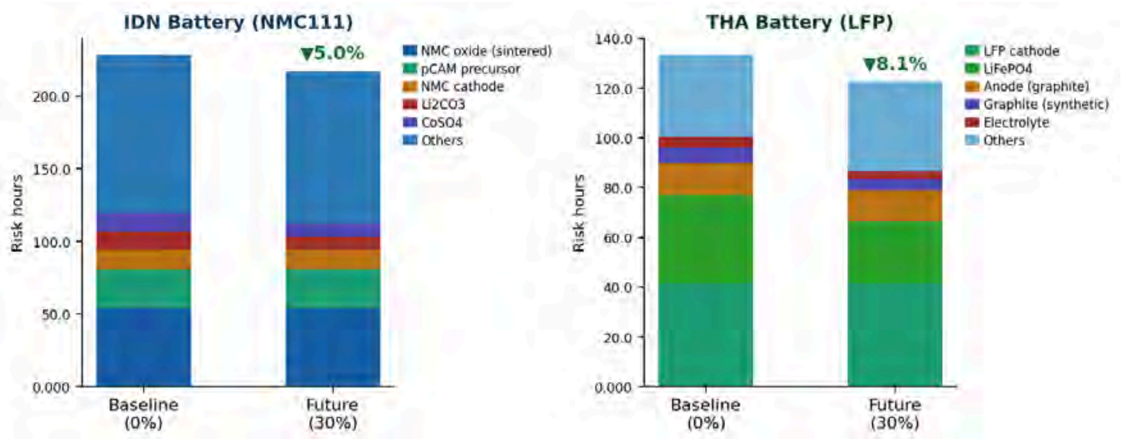


Source: by Author

3.2.8. Low Wage Labour Risk

The baseline values are 228.5 risk hours for the NMC111 and 133.4 risk hours for the LFP. In the future scenario, both exhibit improvements, dropping by −5.0% for the NMC111 and −8.1% for the LFP, with the LFP showing a larger reduction. This demonstrates that the effect of mitigating the low-wage labor risk associated with the primary manufacturing of LFP cathode materials and $LiFePO_4$ through recycling substitution is manifested to a corresponding degree.

Figure 16: Material-specific contributions to low wage labour risk (risk hours): Baseline vs. Future



Source: by Author

3.3. Discussion

3.3.1. Three Categoriesof Variations in ESG Indicators

A cross-cutting synthesis of the results across the 14 indicators reveals that the effects of raising recycling rates can be classified into the following three categories:

- Category 1 "Consistent Improvement in Both Countries": This includes six indicators: GHG emissions, fossil fuel use, mineral resource use, excessive working hours risk, occupational toxins and hazards risk, and low-wage labour risk. The benefits of enhanced recycling rates were confirmed for both the NMC111 and the LFP.
- Category 2 "Improvement in NMC111 and Deterioration or Stagnation in LFP": This encompasses four indicators: forced labour risk (NMC111: −5.5% vs. LFP: +5.7%), GII (NMC111: −4.8% vs. LFP: +4.3%), corruption risk (NMC111: −5.3% vs. LFP: +1.7%), and child labour risk (NMC111: −5.1% vs. LFP: +0.4%). Due to differences in battery chemistry, the impacts of recycling substitution became asymmetrical between the two countries.
- Category 3 "Secondary Trade-offs Arising from Upstream Recycling Solvents": This includes three indicators: biomass consumption (NMC111: +19.4%, LFP: +57.1%), green water (LFP: +81.0%), and blue water (LFP: +15.8%). This represents a "secondary supply chain trade-off" resulting from the

dependence of the upstream manufacturing chain of chemical solvents (such as NMP) used in the recycling process on the agricultural and chemical sectors.

3.3.2. Analysis of Factors by Categories

The consistent improvements observed in Category 1 are due to the environmental and social burdens of primary mining and refining processes being substituted through recycling, outweighing the new burdens introduced by manufacturing the secondary raw materials. In particular, mineral resource use exhibits the most significant improvement rate among all 14 indicators, with a decrease of −22.3% for the NMC111 and −17.0% for the LFP, clearly demonstrating that recycling substitution directly contributes to the conservation of mineral resources. Regarding GHG emissions, the margin of improvement for the LFP (−10.9%) batteries is greater than that of NMC111 (−6.3%); this is due to the fact that the primary materials targeted for recycling substitution in LFP batteries (LFP cathode active materials and $LiFePO_4$) possess relatively carbon-intensive primary manufacturing processes, thereby amplifying the substitution effect.

The asymmetry identified in Category 2 is rooted in structural differences regarding the target metals and manufacturing processes for recycling substitution across different battery chemistries. In the case of NMC111, the materials being substituted are cobalt (originating from the DRC) and nickel (originating from Indonesian HPAL), which are high-risk mining sources where forced labour, GII, and corruption risks are concentrated; thus, recycling substitution directly translates to a reduction in human rights risks. Conversely, because LFP is a cobalt-free design, the substituted components are the LFP cathode active material and $LiFePO_4$, whose secondary raw material manufacturing supply chains also encompass regions and sectors with corresponding human rights risks. Consequently, the effects of the substitutions cancel each other out, resulting in a +5.7% increase in forced labour risk for LFP. This highlights that the idea that 'cobalt-free equals human rights risk-free' is not true.

The factors underlying Category 3 lie in the manufacturing supply chain of the chemical solvents (e.g. N-methyl-2-pyrrolidone, or NMP) used in the recycling process. In the hydrometallurgical processing of lithium iron phosphate (LFP) batteries, large volumes of organic solvents are used to dissolve, separate and refine the cathode active materials. Tracing the manufacturing supply chain of these synthetic raw materials back through the input-output tables reveals that the agricultural sectors of Myanmar and Laos are the primary upstream inputs in the case of Thailand. As the agricultural sector is water-intensive, a future scenario with a 30% recycling rate would lead to a significant increase in upstream agricultural water use due to increased solvent demand, resulting in a +81.0% increase in green water consumption for LFP. Blue water (irrigated water) deteriorates by +15.8% through the same mechanism. This 'second-tier supply chain burden' falls outside the systemic boundary of process-based LCA and has thus been overlooked in conventional literature. It is a novel finding of this study, which is the first to quantify it via MRIO background supplementation. Although biomass consumption in Indonesia increases by 19.4% through a similar mechanism, its green water consumption changes by only −1.1% because the reduction from primary mining substitution and the increase in upstream agriculture virtually offset each other, while blue water consumption improves by −4.0%. This disparity reflects the structural differences in the geographical reliance of the two nations on upstream solvent components. It shows that outcomes can diverge significantly depending on the country and battery chemistry, even when identical evaluation methodologies are applied.

3.3.3. Policy Implications

In interpreting the results of this study, it must first be acknowledged that the comparison between the NMC111 (Indonesia) and the LFP (Thailand) represents a paired comparison that simultaneously incorporates two variables: differences in battery chemistry and variations in national/regional supply chain structures (MRIO background coefficients). Consequently, it is impossible to deduce a single-variable superiority from this study, such as “NMC111 is superior to LFP in ESG performance” or “recycling in Indonesia is superior to that in Thailand”. The following policy implications should be understood as conditional insights indicating what an enhanced recycling rate entails within specific combinations of chemistry and regional conditions.

The findings of this study offer several practical implications for circular economy policies surrounding EV batteries in ASEAN. First, regarding the “consistent improvement in both countries” indicators such as GHG emissions, mineral resource use, and fossil fuel consumption, it was confirmed that complying with the recycled content thresholds set by the EU Regulation (2023/1542) for 2030–2035 (Li: 4→10%, Ni: 4→12%, Co: 12→20%) directly translates into ESG improvements within ASEAN. The GHG reduction margin for the LFP battery in Thailand (−10.9%) exceeds that for the NMC111 in Indonesia (−6.3%), establishing the development of EOL battery collection and recycling frameworks as a priority climate mitigation agenda in Thailand, where LFP is predominant. However, these improvement effects can only be realised if the premise of the future scenario — a 30% recycling rate — is met. As indicated by Iwasaki et al. (2025), official policies regarding EOL EV batteries are virtually non-existent in Thailand and Indonesia, leaving the majority of processing to the informal sector. Nations at more advanced stages of industrial agglomeration exhibit a higher demand for establishing formal facilities, certified operator systems, and waste tracking databases; gradual formalisation constitutes the political precondition for extracting the improvement effects demonstrated in this study.

Second, the deterioration of green water (+81.0%) and blue water (+15.8%) in Thailand demonstrates that the technological choices and procurement sources for chemical solvents used in the recycling process heavily dictate the water footprint. Critical technological solutions include transitioning to alternative solvents with lower water intensity (e.g. dimethyl sulfoxide [DMSO] or ionic liquid systems) and enhancing solvent recovery rates. Both require investment in research and development (R&D) and policy guidance. It should be noted that this study evaluates a single scenario with a 30% recycling rate, and sensitivity analyses incorporating varying recycling levels or alternative solvent technologies remain a subject for future research.

Third, the increase in forced labour risk (+5.7%) for the Thai LFP batteries indicates that improving recycling rates does not automatically bring about improvements in human rights risks. Applying human rights risk assessment, mandated by the European CSRD and the due diligence clauses of the EU Battery Regulation, to the selection and auditing of recycling operators is necessary; that is, the institutionalisation of “social auditing of the recycling supply chain” based on S-LCA is required. Particularly in ASEAN, major automotive OEMs are accelerating efforts to roll out Scope 3 reduction targets to suppliers, and the trend toward including human rights risks in the disposal phase within disclosure requirements is expected to intensify in the future.

These three policy implications are mutually complementary. While developing EOL battery collection frameworks (the first implication) expands recycling volumes, an integrated approach that simultaneously pursues solvent technology selection and recycler due diligence is indispensable to prevent this from triggering deteriorations in green and blue water (the second implication) or increases in human rights risks (the third implication). The circular economy for EV batteries in ASEAN should look beyond merely achieving quantitative recycling rate targets; it must strive to realise “responsible recycling” that comprehensively manages both environmental and human rights ESG indicators, maximising benefits such as GHG reduction while minimising trade-offs. Rather than uniform recycling targets, these insights demonstrate that differentiated policy designs tailored to battery chemistry and regional supply chain structures are what will bring efficacy to recycling promotion within the ASEAN region.

4. Discussion

4.1. Comparison with Previous Studies

Chayutthanabun et al. (2025) demonstrated a maximum reduction of −1,193 kg CO_2equivalent through the remanufacturing of an NMC battery pack (366 kg). In contrast, the reduction achieved in the NMC111 battery (510 kg) recycling scenario in this study is −587 kg CO_2eq. This discrepancy can be rationalised by the operational differences in end-of-life (EOL) processing between the two studies. Remanufacturing involves dismantling, inspecting, and reassembling the entire battery pack for reuse, thereby entirely avoiding the full burden of manufacturing a new battery (encompassing pCAM precursor production, sintering, cathode material production, cell manufacturing, and pack assembly). In contrast, the recycling scenario in this study is designed so that 30% of the primary extracted raw materials are substituted by metals recovered via hydrometallurgical processing; thus, the avoided burden is confined to a specific portion of the raw material procurement stage. Furthermore, the inputs required for the hydrometallurgical process itself, such as electricity and reagents (e.g., sulfuric acid and lime), are deducted from the recovery credits, resulting in a net reduction significantly lower than that of remanufacturing.

Notably, the recycling of the Thai LFP battery (480 kg) in this study yields a reduction of −735 kg CO_2eq (−10.9%). This greater mitigation effect compared to the Indonesian NMC111 is due to the relatively carbon-intensive nature of the primary manufacturing process for the LFP cathode active material and $LiFePO_4$. Additionally, the aforementioned study evaluated GHGs exclusively, failing to capture the substantial increase in green water (+81.0%), the deterioration of blue water (+15.8%), and the increase in biomass consumption (+57.1%) identified in this study. To capture such trade-offs, a comprehensive evaluation utilising a diverse set of indicators on the identical inventory, as performed in this study, is indispensable.

In terms of human rights indicators, the findings of this study align with those of Jose et al. (2025), who, in their social life cycle assessment (S-LCA) of NMC raw materials, identified the mining and refining stages as the primary sources of risk. The observed improvement in human rights indicators, such as forced labour, GII and corruption, in the Indonesian battery under the recycling scenario, is due to the reduced reliance on high-risk mining sources in Indonesia through substitution. This aligns with the mining-centric risk thesis proposed by Jose et al. (2025).

Conversely, the novelty of this study lies in the fact that it is the first to quantify, within the ASEAN context, the non-trivial trade-off where increasing recycling rates do not necessarily improve human rights indicators for LFP batteries but rather deteriorate the forced labour risk by +5.7%. Although cobalt-free LFPs have conventionally been regarded as having relatively low human rights risks during the extraction phase, this study demonstrates that corresponding human rights risks are also present within the procurement supply chain of recycled secondary raw materials. This presents an important caveat to the simplistic understanding that “cobalt-free equals human rights risk-free.”

In terms of water consumption, no previous studies are directly comparable to this research, which uses the Water Footprint Network’s (WFN) definition of green and blue water in volumetric terms (Hoekstra et al., 2011). As a reference for scale, Kim et al. (2016) estimated the total life cycle water consumption of a Ford Focus BEV at 170 m^3/vehicle. Given that the use phase accounts for 85% of total consumption, the allocation to the manufacturing stage (encompassing all processes for the vehicle body and battery) is roughly approximated at 25 m^3/vehicle. The baseline blue water value for the NMC111 battery pack alone in this study (15.7 m^3/vehicle) corresponds to approximately 63% of this reference value, consistent with the structural reality that the battery pack constitutes the majority of water consumption in the vehicle manufacturing stage.

Although the system boundaries (this study: cradle-to-gate for the battery pack alone; Kim et al.: cradle-to-grave for the entire vehicle) and indicator definitions differ, making this reference useful only for confirming the order of magnitude, the absolute increase in blue water in the future LFP scenario (+1.6 m^3/vehicle) is limited. However, its summation with the concurrent increase in green water (+44.9 m^3/vehicle) yields a total increase of +46.5 m^3/vehicle, which significantly exceeds the aforementioned reference value for the entire manufacturing stage (approx. 25 m^3/vehicle). This demonstrates that the choice of recycling solvents can become a dominant determinant of the total water footprint.

4.2. Methodological Significance and Limitations

The primary methodological contribution of this study lies in the application of a hybrid LCA that incorporates multi-region input-output (MRIO) background supplementation. The Category 3 insight —wherein the upstream manufacturing of chemical solvents (such as NMP) utilised in the recycling process involves the agricultural sector, thereby increasing water use (green and blue water) and biomass consumption—represents a second-tier supply chain burden that falls outside the systemic boundary of process LCA alone and cannot be quantified without MRIO. In this regard, this study empirically demonstrates that hybrid LCA is indispensable for the ESG evaluation of battery recycling.

(1) Limitations of the system boundary (cradle-to-gate): This study defines its system boundary from raw material extraction to manufacturing, excluding both the use and disposal stages. Literature confirms that GHG emissions originating from charging electricity during the use phase constitute a major portion of the total EV burden (Aryan, 2025; Kosai, 2022). Including the transportation, dismantling, and hazardous waste treatment in the disposal stage could potentially alter the results. A full life cycle comparison requires extending the boundary to a cradle-to-grave framework.

(2) The scope of influence of the electricity mix: The electricity mix influences not only the use phase but also the battery manufacturing stage (factory electricity for cell manufacturing and pack assembly) and the disposal/recycling stage (electricity for EOL processes). While this study fixes the electricity mix at current values, the deployment of renewable energy is progressing in ASEAN, and future shifts in the electricity mix will affect GHG outcomes in both the manufacturing and EOL stages. Thailand heavily relies on natural gas (61%), and Indonesia's NMC battery exhibits an extreme dependence on fossil-fuel power during the refining stage. Consequently, advancements in future decarbonization policies could substantially alter the findings of this study.

(3) Technological level of EOL recycling processes: The types and recovery rates of materials reclaimed in the EOL recycling process in this study rely on Dai et al. (2019). However, because that model is calibrated to US technological conditions, discrepancies may exist regarding the actual technological level and recovery efficiency of recycling facilities in ASEAN. Thailand, in particular, has virtually no domestic recycling capacity for LFPs, which significantly differs from the recycling conditions assumed by Dai et al. A recycling inventory that reflects the current situation in ASEAN is necessary for a realistic evaluation of future scenarios.

(4) Modelling of cross-border waste flows: In reality, some ASEAN member states currently implement a flow where EOL batteries are converted into black mass and exported to Japan or South Korea for advanced recycling processing. However, this study simplifies this process by assuming domestic processing rather than explicitly modelling such cross-border flows. If cross-border flows were explicitly modelled, the electricity mixes and advanced hydrometallurgical technologies of the processing nations would be applied, which could alter the GHG emissions, human rights indicators, and metal recovery rates of the recycling process. This aligns with the direction needed to address the lack of cross-border EOL evaluations identified as a research gap by Chayutthanabun et al. (2025).

(5) Modelling of the informal sector: In Indonesia, approximately 41% of waste plastics rely on open burning and illegal dumping by the informal sector (Iwasaki et al., 2025), and a significant portion of EOL batteries may similarly flow into informal processing routes. This study approximates informal processing using formal recycling flows, thereby failing to capture the impacts on ecotoxicity and human toxicity indicators caused by hazardous gas and heavy metal emissions from open burning. Explicit modelling of the informal sector requires the development of local emission factor data, which remains highly limited within the ASEAN region.

(6) Confounding of battery chemistry and regional conditions: This study compares the specific pairs of NMC111 (Indonesia) and LFP (Thailand). This means that variations in the battery chemistry and background MRIO country-specific coefficients jointly influence the outcomes. Therefore, the superiority of either the chemistry or the region cannot be evaluated independently from the results of this study. To isolate the effects of both variables, sensitivity analyses evaluating a single chemistry across multiple regional conditions, or additional analyses evaluating multiple chemistries under a single regional condition, are required as a task for future research.

5. Conclusion

This study quantitatively evaluated the ESG impacts of a future scenario—wherein the recycling rates of critical metals, Al, and Cu are increased from the baseline (0%) to 30%—on a total of 14 indicators (six environmental and eight human rights indicators) for an Indonesian NMC111 battery (510 kg) and a Thai LFP battery (480 kg), utilising a hybrid LCA framework (ecoinvent v3.11 foreground and MRIO background).

Regarding the environmental indicators, three metrics showed improvement in both countries: GHG emissions (Indonesia: −6.3%, Thailand: −10.9%), fossil fuel consumption (Indonesia: −17.8%, Thailand: −8.9%), and mineral resource use (Indonesia: −22.3%, Thailand: −17.0%). In particular, mineral resource use exhibited the highest rate of improvement among all 14 indicators, quantitatively demonstrating that recycling substitution directly translates to the conservation of critical metal resources. Conversely, biomass consumption (Indonesia: +19.4%, Thailand: +57.1%), green water (Thailand: +81.0%), and blue water (Thailand: +15.8%) exhibited counterintuitive deteriorations. This second-tier supply chain burden stems from the involvement of the agricultural sectors of Myanmar and Laos in the upstream manufacturing chain of chemical solvents (such as NMP) utilised in the recycling process, representing an original insight of this study quantified for the first time via MRIO background supplementation.

In terms of human rights indicators, the Indonesian NMC111 battery showed improvements in seven out of the eight metrics, including forced labour, GII, corruption, and child labour. In contrast, the Thai LFP battery deteriorated across four indicators: forced labour risk (+5.7%), GII (+4.3%), corruption (+1.7%), and child labour (+0.4%). This asymmetry is attributable to the fact that while the recycling of the NMC111 yields a substitution effect for high-risk mining sources (cobalt from the DRC and nickel from Indonesia), the recycling of the LFP—owing to its cobalt-free design—faces corresponding human rights risks within the procurement supply chain of secondary raw materials targeted for substitution, causing the substitution effects and newly introduced risks to offset or invert. This insight provides the first quantitative evidence within the ASEAN context to empirically demonstrate that the simplistic notion of “cobalt-free equals human rights risk-free” does not hold true.

The most crucial message conveyed by this study is the quantitative demonstration of the fact that the magnitude and direction of the ESG impacts resulting from enhanced recycling rates depend on the specific combination of battery chemistry and supply chain structures. While recycling has a greater impact on the substitution of metals with higher extraction burdens, the introduction of new reagents in the recycling process affects regional supply chain structures differently. This insight underscores the importance of independently evaluating battery chemistry and regional conditions when designing recycling policies, suggesting that differentiated policy designs tailored to specific conditions will bring greater efficacy to the circular economy in ASEAN than uniform recycling rate targets. Balancing the expansion of recycling volumes with ESG quality—namely, “responsible recycling”—is an achievable objective through evidence-based policy design as demonstrated in this study.

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Chapter 8: Impact Analysis of the Circular Economy and GHG Reduction in ASEAN

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1. Introduction

The Association of Southeast Asian Nations (ASEAN) is now at a juncture where both a shift in its stage of economic development and the maturation of its institutional architecture necessitate a transformation of its growth model. The region has witnessed deepening fragmentation within production networks and increasing integration into global value chains (GVCs), while the institutional framework for market integration, centred on tariff elimination, has reached an almost complete stage. The further deepening of economic integration will therefore depend less on traditional trade liberalisation measures such as tariff reductions, and more on qualitative enhancements to competitiveness, including the reduction of non-tariff measures (NTMs), the promotion of digitalisation, and industrial upgrading.

Against this backdrop, greenhouse gas (GHG) emission reduction should not be viewed merely as an environmental constraint; it has the potential to serve as a critical trigger for advancing ASEAN's economic upgrading strategy. Industrial structures premised on energy intensive and resource consuming growth patterns risk not only increasing environmental burdens but also constraining long term growth through declining international competitiveness and heightened exposure to external regulatory risks. For this reason, GHG reduction ought not to be treated as an isolated policy objective. Rather, it must be understood as an integral component of sustaining economic growth and facilitating structural transformation.

The circular economy represents a promising option for ASEAN in addressing this challenge. By improving resource efficiency, promoting reuse, and expanding recycling, the development of a circular economy can reduce environmental burdens while simultaneously enabling value creation and the emergence of new industries. Although attention often gravitates towards new technologies such as CCUS and hydrogen as primary GHG mitigation tools, this paper emphasises an approach that does not rely solely on technological breakthroughs. Instead, it highlights the importance of introducing circular economy practices in ways that align with existing economic integration, supply chains, and the behavioural patterns of firms and consumers. The circular economy is significant not only because it contributes to reducing GHGs, but also because it leverages ongoing economic activity within the ASEAN region to reconcile environmental objectives with sustained economic growth. On the other hand, the effects of such developments differ substantially across countries, industrial structures, and trade relationships, making it difficult to derive policy implications solely from qualitative discussion. It is therefore essential to evaluate, in an integrated and quantitative manner, how the progress in the circular economy influences economic activity and GHG emissions in each ASEAN member state.

This paper employs the Geographical Simulation Model (IDE-GSM), an applied general equilibrium model grounded in spatial economics, to conduct a scenario-based quantitative assessment of how progress in the circular economy affects GHG emission reduction and economic activity in ASEAN. The first advantage of the IDE-GSM is that economic agents, firms and consumers, are explicitly incorporated within the model, allowing changes in economic structure to be captured endogenously through behavioural responses to price changes and policy constraints. Under scenarios that introduce GHG emission constraints or assume improvements in emission efficiency, firms adjust their location and production choices, while consumers alter their consumption patterns, resulting in the emergence of different industrial structures and spatial distributions. Moreover, IDE-GSM contains data at the district level, enabling the tracking of changes in GHG emissions and economic indicators not only at the national or sectoral level but also across regions. This feature is particularly valuable when analysing ASEAN, a region characterised by substantial heterogeneity both between and within countries.

The analysis presented in this paper demonstrates that progress in the circular economy can achieve substantial GHG reductions, particularly in the power and heat supply sectors, while improving resource efficiency in ways that do not undermine economic growth. It shows that a decoupling of growth from environmental burdens is attainable. The reduction effects spread widely across the ASEAN region and are especially pronounced in areas of industrial agglomeration. At the same time, the sectoral contributions and economic impacts differ markedly depending on each country's industrial structure and position within international production networks.

The structure of this paper is as follows. Section 2 reviews the position of the circular economy within ASEAN's economic structure and economic integration context, together with relevant existing studies. Section 3 outlines the IDE-GSM framework, the analytical approach adopted in this paper, the method for deriving GHG emissions, the scenario design, and the results. Section 4 examines the relationship between GHG reduction and economic impact and discusses the policy role of the circular economy. Section 5 concludes and identifies avenues for future research.

2. ASEAN's Economic Structure, Economic Integration, and the Circular Economy

Debates evaluating the circular economy as a strategy capable of reconciling GHG reduction with economic growth have expanded rapidly in recent years across both international organisations and academic research. As highlighted in UNEP's *Global Resources Outlook 2024*, the extraction, processing, and use of natural resources account for more than half of global GHG emissions, making it clear that energy transition alone is insufficient (UNEP, 2024). Within this context, the circular economy is positioned as a complementary element of climate policy, offering a means of reducing emissions by improving resource efficiency and extending product lifetimes.

Nevertheless, mainstream climate policy research remains predominantly technology-centred, with discussions focusing on the feasibility and cost-effectiveness of individual technologies such as CCUS and hydrogen. While such studies are important for clarifying technological options for decarbonisation, they often refrain from examining the compatibility of these technologies with existing economic structures and firm behaviour. CCUS and hydrogen typically require significant upfront investment and substantial operating costs, meaning that commercial viability frequently depends on public subsidies, price support, or implicit public risk sharing.

Indeed, research by ERIA examining CCUS deployment in Southeast Asia finds that market mechanisms alone are insufficient to support CCUS introduction in the region, and that stable policy support and new financial schemes, similar to those in advanced economies, are indispensable (ERIA & GCCSI, 2024). Analysis by IEEFA similarly notes that ASEAN lacks carbon price signals strong enough to sustain the economics of CCUS, and that without subsidies or public support, CCUS, particularly in the power sector, is likely to remain uncompetitive (IEEFA, 2022).

A comparable situation applies to hydrogen. According to the ASEAN Centre for Energy, low-carbon hydrogen has significant technical potential, but its production costs, infrastructure requirements, and the need to stimulate demand all entail significant upfront requirements. At present, financial incentives such as subsidies, tax credits, concessional loans, and direct support, as well as government-backed de-risking strategies, are considered necessary (ACE, 2024).

For many ASEAN member states, which have limited fiscal space, relying on such high-cost technologies as the central pillar of decarbonisation strategies is unlikely to be sustainable, either politically or economically. Moreover, GHG reduction measures based on high-cost technologies risk imposing excessive burdens on supply chains through rising costs and disrupted trading relationships, thereby undermining the foundations of economic growth. ASEAN is also characterised by a large share of SMEs and informal sector activity, alongside significant variation in regulatory enforcement capacity across countries. Under these conditions, behavioural change driven solely by mandatory technology adoption or regulatory pressure faces inherent limitations.

In practice, Japan’s Asia Zero Emission Community (AZEC) initiative is conceived as a framework that seeks to reconcile decarbonisation with economic growth, while emphasising feasibility grounded in each country’s stage of development and institutional constraints. AZEC goes beyond the articulation of principles: it has launched concrete pilot projects and cooperation initiatives centred on hydrogen, ammonia, CCUS, and next-generation biofuels through public–private partnerships in ASEAN member states. AZEC’s distinguishing feature lies in pursuing emission reductions through a phased transition that builds upon existing energy and industrial systems. However, insofar as its core instruments continue to rely on technologies with inherently high-cost structures, there remain clear limits to achieving transformative, widespread emission reductions in ASEAN countries, many of which face constraints in fiscal capacity and administrative capability.

Much of the existing research on the circular economy has been developed from environmental or resource management perspectives. Emami et al. (2025), through an economy-wide material flow analysis of ASEAN, quantitatively demonstrate the scale of resource use, low circularity rates, and the structure of emissions, thereby highlighting the need for policy intervention. Ramli and Kasih (2024) and the ASEAN Secretariat (2021) similarly position the circular economy as a response to resource constraints and environmental degradation, while noting economic benefits such as job creation and new growth opportunities. Yet even within these studies and policy documents, the circular economy is often treated primarily as an extension of environmental policy or resource management. Insufficient attention is paid to how circular economy practices can be connected to existing market behaviour with the central objective of GHG reduction.

A key feature of the circular economy is its ability to encourage behavioural changes within firms by reducing costs and mitigating risks within existing production, distribution and consumption systems, without necessarily requiring large upfront investment or permanent public subsidies. Reductions in raw material demand, lower waste management costs, and more stable procurement conditions can generate direct economic benefits for firms. Consequently, reducing greenhouse gas emissions can be seen as an economically rational outcome rather than a compliance burden. In this respect, the circular economy is comparatively more feasible to implement in ASEAN.

Sometimes, concerns are raised that promoting the circular economy, including recycling, may incur additional costs. However, such concerns must be evaluated in relative and comprehensive terms. Firstly, while recycling involves costs associated with processing, collection and sorting, it often requires less energy and fewer resources than extracting and refining virgin materials. Therefore, it can be relatively low-cost. Secondly, recycling is not merely an additional expenditure; it simultaneously reduces other cost factors, including waste disposal expenses, exposure to raw material price volatility, and procurement risks. For firms, the net cost should thus be assessed by weighing the direct expenses of recycling against these cost-saving effects. Overall, recycling can be economically rational, and even if certain processes entail higher costs, the efficiency of the economy as a whole may nonetheless improve.

Thus, climate policy research has tended to be technology-driven, while circular economy research has largely been rooted in environmental and resource considerations. As a result, the intersection between the two, namely, the perspective of implementing the circular economy as a GHG reduction strategy in ways aligned with existing firm and consumer behaviour, has remained relatively underdeveloped. To establish the circular economy as a feasible strategy that supports both GHG reduction and economic growth in ASEAN, it is essential not merely to wait for new technologies capable of dramatically reducing costs, but to consider its compatibility with economic structures and the economic incentives of firms and consumers. This approach is consistent with the international trend identified in UNEP's *Global Environment Outlook 7* (UNEP, 2025), which asserts that climate change, biodiversity loss, and pollution, the triple planetary crisis, should be addressed as interconnected systemic challenges, necessitating integrated policy solutions that transcend economic, social, and resource domains.

For example, in many ASEAN member states, the informal sector plays a major role in waste collection and recycling. Operating outside regulatory frameworks, these activities can give rise to problems such as illegal dumping and transboundary leakage. Promoting the circular economy therefore requires institutional mechanisms that correct and complement such informal activities and integrate them into the formal economy. Even if current circular practices are incomplete, there remains scope to develop them into a sustainable and well functioning circular economy by harnessing market forces.

In the ASEAN context, the link between circular economy implementation and economic integration is also crucial. ASEAN's economic integration has historically advanced through firm behaviour before institutional harmonisation. Production networks that connect multinational and local firms form the core of intra-regional trade and investment, with much economic activity occurring within cross-border supply chains. Implementing the circular economy as a GHG reduction strategy within this reality requires institutional design that aligns with existing firm and consumer behaviour and with established production networks. The ASEAN Circular Economy Framework itself explicitly states that circular economy measures must "function within the realities of international production networks", recognising the need to ensure compatibility with regional economic integration (ASEAN Secretariat, 2021).

3. IDE-GSM Analysis

3.1. Geographical Simulation Model

The IDE-GSM is an applied computable general equilibrium (CGE) model grounded in spatial economics, enabling integrated evaluation of how policy interventions affect economic structures and interregional relationships by endogenously incorporating the behavioural responses of firms and consumers. The model was initially developed as a joint research effort between the Institute of Developing Economies (IDE) and the Economic Research Institute for ASEAN and East Asia (ERIA), and has since been widely used to analyse the economic impacts of international infrastructure development and improvements in regional connectivity.

One of the distinctive features of the IDE-GSM is its ability to conduct analysis not only at the national level but also at more detailed state and district levels. This allows the model to capture spatial disparities in development and differences in industrial agglomeration observed across ASEAN, and to trace the spatial distribution of economic activity and GHG emissions, as well as changes therein, with considerable precision. The model incorporates industrial sectors including agriculture, mining, automotive, electrical and electronics, textiles, food processing, other manufacturing, and services, alongside data on population, cultivated land, and transport infrastructure (such as roads, railways, maritime transport, and aviation).

In terms of trade and transport, the model treats transport costs in a broad sense, incorporating not only physical distance but also transport costs, time costs, tariffs, non-tariff barriers, and even social and cultural factors. This enables analysis that reflects realistic economic mechanisms such as changes in supply chains and the reorganisation of industrial locations.

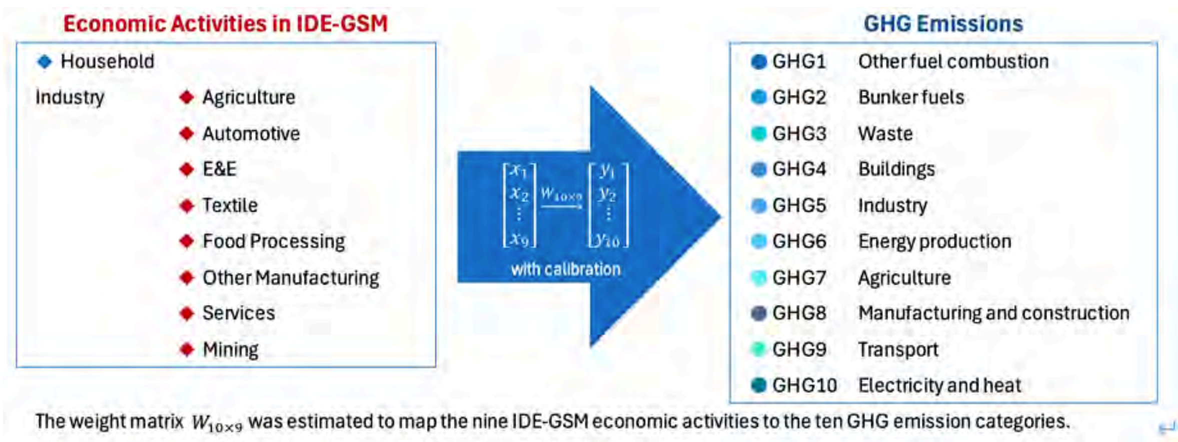
For the construction of regional data, official statistics are used where available, while economic censuses and land use data are employed where official statistics are incomplete. In regions lacking census data, night time light data are used to estimate GDP by region and sector, thereby establishing a global scale regional database. This data foundation allows IDE-GSM to capture the spatial relationship between economic activity and GHG emissions and to conduct a comprehensive analysis of how decarbonisation policies and the introduction of the circular economy affect economic growth and industrial structure.

3.2. Deriving GHG Emissions

In the analysis, a baseline scenario (BAU) and multiple policy scenarios are constructed to compare changes in economic indicators (GDP and regional GDP) and emission related indicators up to 2050. Specifically, the scenarios combine GHG reduction targets with additional improvements in emission efficiency (emission intensity), allowing for a structured examination of growth, emissions, sectoral contributions, and regional variation.

GHG emissions are derived from IDE-GSM's economic activity using the approach developed in Kumagai (2026) (Figure 1). Emissions are classified into ten categories (GHG1–GHG10), and total emissions are calculated by applying a conversion matrix obtained through estimation, supplemented by calibration procedures.

Figure 1: Conversion from IDE-GSM Economic Activity to GHG Emissions



Source: Prepared by the authors using the conceptual description in Kumagai (2026).

GHG1: Other Fuel Combustion

- Small scale enterprises and household sectors. A highly decentralised domain in which regulatory oversight is difficult.

GHG2: Bunker Fuels

- International aviation and maritime transport. Falls outside the jurisdiction of any single state and requires international governance.

GHG3: Waste

- Increases with rising income levels. A sector in which circular economy policies can directly and effectively curb emissions.

GHG4: Buildings

- Residential and commercial buildings. Strongly influenced by long lived capital stock such as insulation and water heating systems.

GHG5: Heavy Industry

- Metals, cement, and similar sectors. Characterised by substantial process related emissions; a hard to abate sector requiring advanced technologies such as CCS.

GHG6: Fugitive Emissions

- Leakage during energy production. Highly dependent on infrastructure quality and regulatory enforcement capacity.

GHG7: Agriculture

- Emissions from livestock and soils. Driven by biological processes; technological innovation is more important than carbon pricing.

GHG8: Manufacturing and Construction

- Fuel consumption by machinery. Closely linked to economic cycles, with significant potential for energy efficiency improvements.

GHG9: Transport

- Road, rail, and other modes. Strongly correlated with income levels and urban structure. EV adoption and investment in public transport are key.

GHG10: Electricity and Heat Supply

- The largest source of emissions. Highly capital intensive. Requires renewable energy deployment and a fundamental shift in the power generation mix.

3.3. Scenarios

In the simulation analysis, a Business as Usual (BAU) scenario, which assumes that the current trend of improvements in GHG emission efficiency continues, is compared with four policy scenarios. The policy scenarios combine GHG reduction targets[1] (20% and 30% reductions by 2050) with additional improvements in emission efficiency attributable to the progress in the circular economy (+1.0% and +2.0% above the BAU rate), yielding four distinct patterns for comparison.

BAU Scenario

Business as Usual (BAU)

- The simulation is extended to 2050. GHG emission efficiency improves at an annual rate of 2.3%.

Policy Scenarios

GHG −20%, Efficiency +1.0

- Each ASEAN member state reduces GHG emissions by 20% by 2050. Emission efficiency improves by an additional 1.0% annually on top of the BAU rate of 2.3%.

GHG −20%, Efficiency +2.0

- Each ASEAN member state reduces GHG emissions by 20% by 2050. Emission efficiency improves by an additional 2.0% annually on top of the BAU rate of 2.3%.

GHG −30%, Efficiency +1.0

- Each ASEAN member state reduces GHG emissions by 30% by 2050. Emission efficiency improves by an additional 1.0% annually on top of the BAU rate of 2.3%.

GHG −30%, Efficiency +2.0

- Each ASEAN member state reduces GHG emissions by 30% by 2050. Emission efficiency improves by an additional 2.0% annually on top of the BAU rate of 2.3%.

3.4. Results

Table 1 presents the relationship between emission reduction targets, improvements in emission efficiency, and the resulting impacts on GDP across countries when the simulation is implemented. A clear trade off is observed between emission reduction targets and GDP outcomes. In general, the stricter the emission reduction target, the stronger the constraints imposed on economic activity, and the more pronounced the negative impact on GDP.

However, this trade off is substantially mitigated in cases when there is a significant improvement in emission efficiency. As emission efficiency improves, emissions per unit of energy use decline signifi-

[1]The 20% and 30% GHG reduction targets set in this paper are not intended to represent the achievement of carbon neutrality by 2050. Given that ASEAN member states are expected to continue experiencing upward pressure on energy demand and emissions due to ongoing economic growth, industrialisation, and urbanisation, a scenario in which countries reduce absolute emissions by 20% or 30% by 2050 would require substantial policy effort and structural transformation. Accordingly, this paper positions these targets as realistic yet ambitious policy scenarios that take into account ASEAN's stage of development.

cantly, reducing the extent of restrictive measures required to meet a given reduction target. This, in turn, offsets the negative impact on GDP. As a result, it becomes feasible to maintain stringent reduction targets without undermining economic growth, making the simultaneous pursuit of growth and decarbonisation a realistic policy option.

Notably, in the scenario where emission efficiency improves by an additional 2.0% annually, and the GHG reduction target is set at 20%, and the rate of economic growth exceeds that of the BAU scenario by a substantial margin.

Table 1: GDP Effects under Each Scenario (Relative to BAU, 2050)

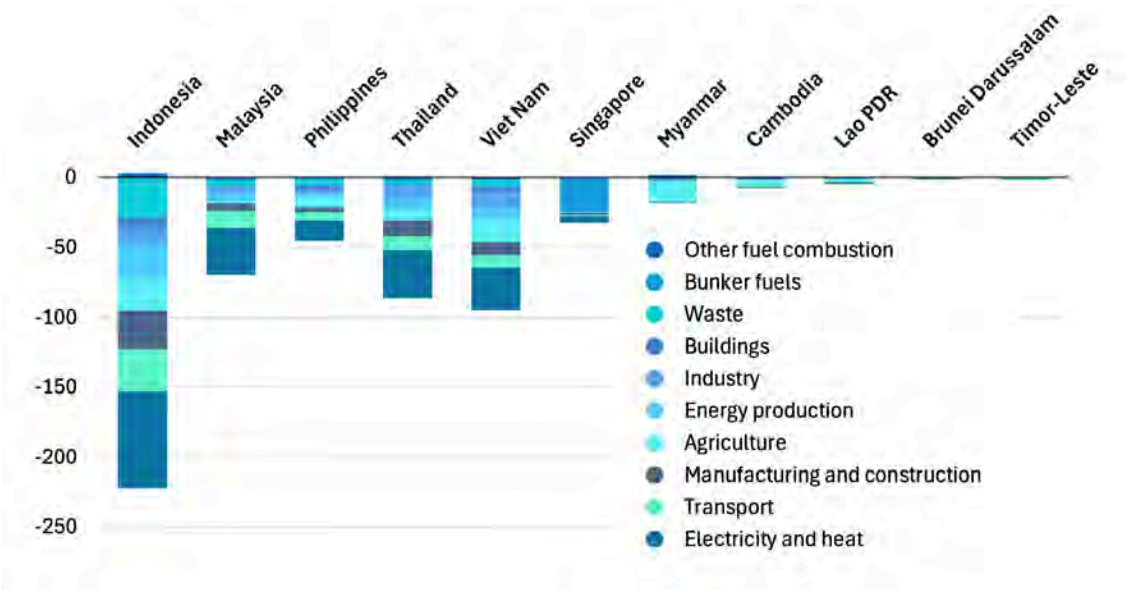
		Efficiency +1.0%/yr	Efficiency +2.0%/yr
GHG -20%	IDN	-2.9%	25.0%
	MYS	-2.8%	22.0%
	PHL	-4.2%	26.9%
	THA	-3.7%	25.5%
	VNM	-2.1%	21.9%
	SGP	-2.7%	20.8%
	MMR	-7.6%	40.1%
	KHM	-3.9%	27.4%
	LAO	-2.3%	22.2%
	BRN	-1.7%	19.0%
	TLS	0.0%	0.2%
	ASEAN	-3.1%	24.5%
GHG -30%	IDN	-18.2%	5.2%
	MYS	-15.8%	3.9%
	PHL	-19.4%	5.5%
	THA	-18.9%	5.1%
	VNM	-18.6%	5.1%
	SGP	-15.8%	5.1%
	MMR	-34.3%	8.0%
	KHM	-23.0%	5.1%
	LAO	-16.7%	3.7%
	BRN	-14.8%	3.0%
	TLS	-0.2%	0.0%
	ASEAN	-18.3%	5.1%

Source: IDE-GSM simulation results.

Figure 2 presents the breakdown of GHG reductions by country and sector under the GHG −20%, Efficiency +2.0 scenario. The figure shows that GHG10 (electricity and heat supply) has the largest reduction potential, while other sectors also account for substantial shares of total reductions. Countries are ordered by GDP size in the BAU 2050 scenario, and among them, Indonesia, Thailand, and Viet Nam exhibit particularly large reductions. This is partly attributable to the significant contribution of the "other manufacturing" sector in IDE GSM, which includes industries such as steel production.

By contrast, in Cambodia, Lao PDR, and Myanmar, the agricultural sector accounts for a large proportion of total reductions, indicating clear differences in reduction structures across countries.

Figure 2: GHG Reductions and Sectoral Contributions under the GHG −20%, Efficiency +2.0 Scenario (Relative to BAU, 2050)

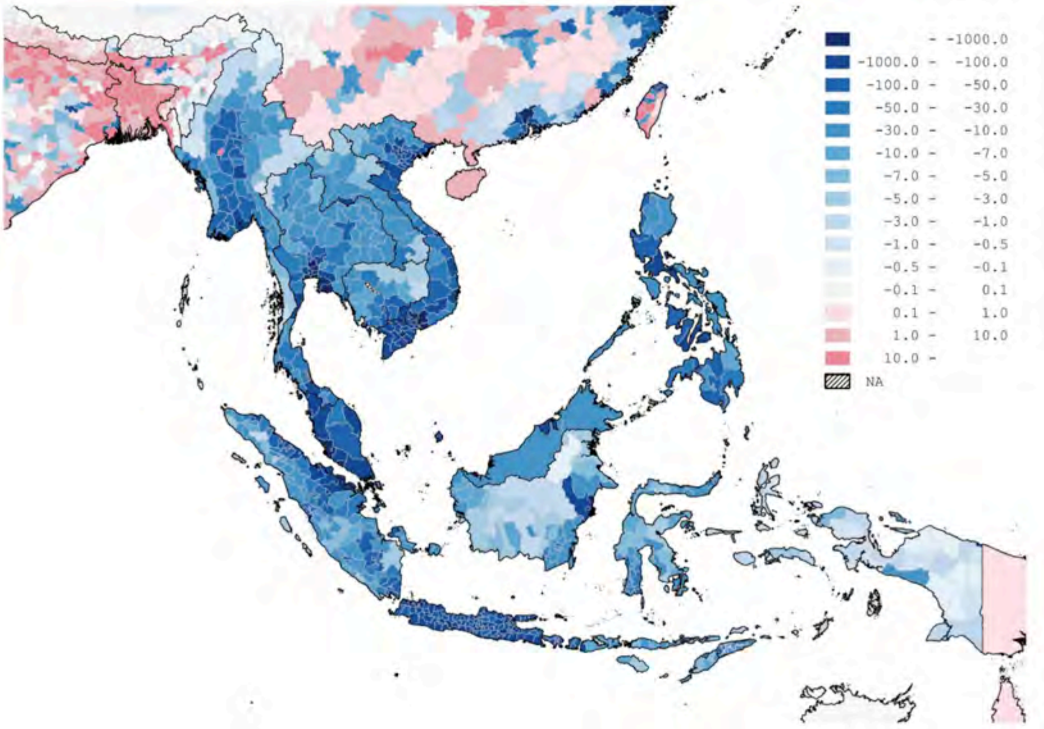


Source: IDE-GSM simulation results.

Figure 3 illustrates the spatial spillover effects of GHG reductions under the GHG −20%, Efficiency +2.0 scenario. In almost all ASEAN member states, substantial reductions are achieved relative to the BAU scenario (shown in blue), with particularly pronounced effects in densely populated areas and in manufacturing hubs where improvements in resource efficiency and reuse are more advanced. In these locations, reductions are driven largely by suppressed electricity demand.

Specifically, the effects are most evident around Bangkok, in southern Viet Nam, and across Java, where industrial activity is concentrated and efficiency gains translate into significant reductions in power consumption.

Figure 3: GHG Reductions under the GHG −20%, Efficiency +2.0 Scenario (Relative to BAU, Mt/km², 2050))



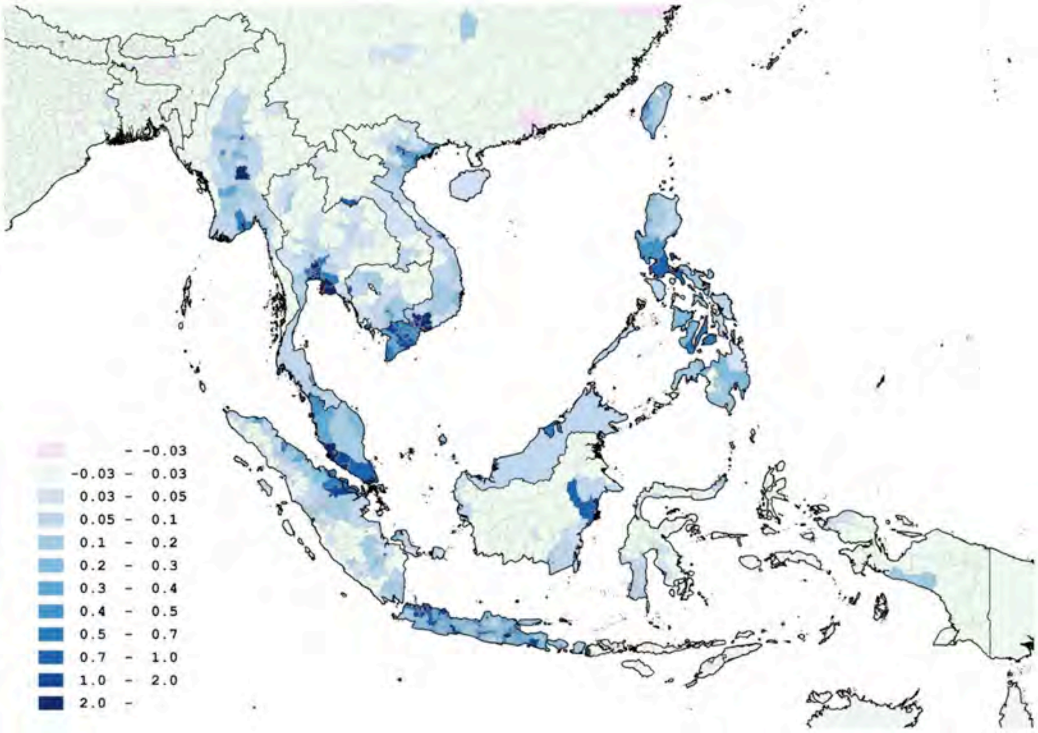
Source: IDE-GSM simulation results.

By contrast, in regions outside ASEAN, such as China, GHG emissions increase relative to the BAU scenario. This occurs because, under this scenario, ASEAN's GDP grows more rapidly than in the BAU case, thereby stimulating economic activity in other regions through supply chain linkages and production and consumption behaviour. As these external regions are not assumed to undertake efficiency improvements for GHG reduction, emissions generally rise in line with GDP growth. Conversely, in regions with relatively strong automotive industry agglomeration, regional GDP tends to decline due to competitive pressures from ASEAN, resulting in lower GHG emissions (as discussed later in Table 2).

Figure 4 shows the impact on regional GDP under the GHG −20%, Efficiency +2.0 scenario. The figure illustrates both the potential for decoupling economic growth from emissions and the pronounced positive economic effects observed in industrial agglomeration areas. In other words, industrial clusters that actively advance emission reduction efforts experience substantial economic benefits alongside GHG reductions, creating a virtuous cycle. Moreover, these effects extend beyond major cities and core industrial clusters, spreading to surrounding areas located along supply chain linkages. This generates broad based GDP gains across wider regions.

Such dynamics suggest that ASEAN may become a more attractive, cleaner, and more efficient production base within global value chains (GVCs), indicating that the simultaneous pursuit of decarbonisation and economic growth can constitute a realistic strategic pathway.

Figure 4: Regional GDP Effects under the GHG −20%, Efficiency +2.0 Scenario (Relative to BAU, Million USD/km², 2050)



Source: IDE-GSM simulation results.

Table 2 summarises the impacts of the GHG −20%, Efficiency +2.0 scenario across countries and industries. Notably, there is substantial variation in the direction and magnitude of economic effects across sectors and regions. Within ASEAN, for example, many industries exhibit increases in GDP, indicating that efficiency gains and expanding demand associated with decarbonisation contribute positively to economic growth.

By contrast, the effects are more heterogeneous in regions outside ASEAN. Differences in industrial structure and international competitive relationships mean that some industries experience negative GDP impacts, reflecting the uneven nature of adjustment across the global economy.

Table 2: GDP Effects for Major Countries and Regions under the GHG −20%, Efficiency +2.0 Scenario (Relative to BAU, 2050)

	Agriculture	Automotive	E&E	Textile	Food Proc.	Oth. Mfg.	Services	Mining	GDP
ASEAN10	14.2%	28.7%	25.3%	27.5%	34.5%	23.1%	26.3%	7.2%	24.5%
Indonesia	14.0%	29.5%	29.6%	28.9%	35.9%	26.1%	26.9%	6.7%	25.0%
Malaysia	7.0%	26.5%	22.4%	27.1%	26.4%	20.9%	23.2%	8.9%	22.0%
Philippines	14.9%	32.6%	27.9%	27.6%	34.4%	25.6%	27.9%	9.8%	26.9%
Thailand	13.8%	27.3%	26.1%	27.2%	35.5%	22.2%	28.1%	5.8%	25.5%
Viet Nam	8.8%	30.8%	26.4%	25.1%	25.6%	20.2%	24.6%	6.6%	21.9%
Singapore	6.7%	24.7%	22.6%	25.2%	28.2%	17.0%	22.6%	6.1%	20.8%
Myanmar	23.7%	59.4%	56.7%	53.4%	42.6%	49.8%	43.8%	9.2%	40.1%
Cambodia	15.8%	37.2%	36.3%	27.4%	33.0%	32.3%	28.5%	8.9%	27.4%
Lao PDR	13.2%	32.4%	35.2%	27.9%	27.5%	30.9%	23.2%	11.9%	22.2%
Brunei Darussalam	16.3%	31.3%	27.0%	25.6%	31.3%	24.0%	21.9%	13.3%	19.0%
Timor-Leste	-0.2%	0.2%	0.0%	0.1%	0.3%	0.3%	0.3%	0.1%	0.2%
Japan	6.9%	-1.2%	0.7%	0.2%	9.1%	1.3%	0.5%	0.6%	0.7%
Korea	2.1%	-0.7%	0.2%	-0.2%	1.3%	0.2%	0.1%	0.6%	0.1%
China	4.9%	-0.4%	0.1%	-0.2%	1.1%	-0.3%	-0.2%	0.4%	-0.1%
Australia	-0.8%	-2.1%	0.3%	0.1%	5.9%	0.6%	0.6%	0.3%	0.6%
New Zealand	-0.5%	-3.3%	-0.4%	0.4%	5.1%	-0.1%	0.4%	1.4%	0.8%
Taiwan	21.4%	-3.3%	-0.9%	0.1%	7.2%	1.0%	0.6%	0.1%	0.9%
India	5.6%	-2.0%	0.6%	-1.0%	1.4%	-1.1%	-0.6%	0.1%	-0.4%
United States	-1.5%	0.0%	0.4%	0.3%	1.2%	0.1%	0.2%	0.0%	0.2%
EU	-3.9%	-0.2%	0.8%	0.4%	1.4%	0.2%	0.1%	0.0%	0.1%
World	2.1%	1.3%	2.3%	1.4%	4.6%	1.0%	0.9%	0.5%	1.1%

Source: IDE-GSM simulation results.

In the automotive sector, negative impacts are observed in countries outside ASEAN, including Japan. This suggests that, given the sector's strong emphasis on geographical proximity, the advancement of decarbonisation enhances ASEAN's competitive position, leading to a greater concentration of automotive parts and vehicle production within the region. As a result, the relative competitiveness of production bases outside ASEAN declines, appearing as negative GDP effects.

It is important to note, however, that the results presented here refer to sector level trends within each country and do not directly evaluate the performance of multinational enterprises from Japan, Korea, or China. If these firms strengthen their production and supply systems within ASEAN and establish a solid local presence, it is entirely plausible that their global business performance could improve rather than deteriorate.

4. Measures for Achieving GHG Reduction and the Role of the Circular Economy

For ASEAN to achieve GHG reductions while maintaining economic growth, multiple policy measures are required, including energy transition, industrial upgrading, and improvements in the efficiency of urban and transport systems. Among these, the circular economy constitutes a foundational element that structurally lowers emission intensity. Through reduced resource inputs, expanded use of recycled materials, extended product lifetimes, and the promotion of industrial symbiosis (sustainable linkages whereby waste from one firm becomes an input for another), the circular economy simultaneously suppresses energy demand and emissions in major sectors such as manufacturing, logistics, and construction. ERIA's circular economy report (Ramli and Kasih, 2024) similarly notes that the introduction of circular economy practices in ASEAN contributes both to improved resource efficiency and to reductions in environmental burdens and emissions. This analysis demonstrates that the circular economy extends beyond waste management and constitutes a core policy instrument for GHG reduction.

The simulation results indicate that the electricity and heat sector (GHG10) provides the largest contribution to emission reductions. In this regard, the circular economy plays a central role in both reducing electricity demand and facilitating power sector decarbonisation, thereby underpinning improvements in emission efficiency and the broader energy transition.

Firstly, the circular economy establishes the preconditions necessary for decarbonising the power sector. Resource savings, longer product lifetimes, and reuse significantly reduce energy demand in manufacturing. The International Energy Agency (IEA) shows that in key material industries such as steel, aluminium, and cement, reductions in material inputs and expanded reuse (material efficiency) substantially lower energy demand, with recycling processes requiring markedly less energy than primary production (International Energy Agency, 2020). As manufacturing energy demand declines, the burden on the power sector, specifically the scale of renewable energy deployment and grid expansion required for decarbonisation, is reduced, making emission reductions in the electricity sector easier to achieve.

Secondly, the use of recycled materials and industrial symbiosis, such as the sharing of waste heat and by products, lowers both the manufacturing and operational costs of renewable energy equipment, thereby easing bottlenecks to renewable energy expansion. IRENA estimates that more than 17.7 million tonnes of materials could be recovered from discarded solar panels by 2050, generating economic value by reducing the manufacturing costs of renewable energy technologies (International Renewable Energy Agency, 2025). Moreover, improved material circularity and waste management efficiency for renewable energy equipment enhance the sustainability and cost structure of renewable energy deployment, ultimately contributing to improvements in emission intensity in the power sector. Taken together, these points position the circular economy as a foundational enabler of power sector decarbonisation.

Moreover, the emission reduction effects of the circular economy become larger as decarbonisation of the power sector progresses. Material Economics (2019) notes that the recycling of steel and plastics can be carried out with substantially less energy than primary production, and that these processes can be powered by renewable electricity. Similarly, the Ellen MacArthur Foundation (2019) shows that core circular economy activities, such as recycling and remanufacturing, can be operated using renewable electricity, emphasising their complementarity with power sector decarbonisation. Accordingly, circular economy activities with high dependence on electricity, such as recycling facilities, digital optimisation, and EV charging, achieve greater emission reduction effects as the power sector becomes cleaner.

EVs constitute a technology that links these dynamics. Powered by renewable electricity, EVs reduce emissions in the transport sector; battery recycling promotes resource circularity; and vehicle to grid (V2G) systems contribute to balancing electricity supply and demand. Song et al. (2024) demonstrate that the emission reduction effects of EVs are maximised when the expansion of renewable energy generation is combined with circular use of batteries. Zhang et al. (2025) likewise highlight the importance of coordinated deployment of EVs and renewable energy, noting that regions with rapid expansion of wind and solar power experienced larger reductions in energy related CO_2 emission intensity and faster EV adoption.

In ASEAN member states, particularly in countries such as Indonesia, where dependence on fossil fuels in the power sector remains high, it is important to recognise that EV diffusion does not automatically lead to GHG reductions. In these countries, most electricity is supplied by coal fired power plants, resulting in high emission intensity for the electricity used to charge EVs. Consequently, even if emissions decline on the vehicle side, emissions in the power sector may increase or remain elevated. Furthermore, power plants are long lived infrastructure assets that typically operate for several decades, creating carbon lock in when existing or newly built fossil fuel facilities remain in operation. For these reasons, decarbonisation of the power generation mix is a critical condition for realising the environmental benefits of EV deployment.

To enable the circular economy to function as a central component of GHG reduction efforts, the roles of governments, firms, regional cooperation, and Japan must operate in a mutually reinforcing manner. Governments provide the regulatory framework necessary to promote circular economy practices and electrification, including waste management regulations, extended producer responsibility (EPR) schemes, energy efficiency standards, and zero-emission vehicle (ZEV) regulations. They also stimulate technological innovation by providing subsidies and research and development support for EV manufacturing, recycling infrastructure, and renewable energy deployment. Firms advance the implementation of the circular economy through voluntary initiatives such as decarbonising supply chains, expanding the use of recycled materials, establishing industrial symbiosis, and adopting digital technologies.

Within ASEAN, regional cooperation, such as the ASEAN Circular Economy Framework (ASEAN Secretariat, 2021) and initiatives like the ASEAN Power Grid, provides the foundation for standardisation, cross-border resource circulation, and wider power system interconnection. These mechanisms support the scaling of circular economy practices across national boundaries.

Japan is well positioned to support both the circular economy and power sector decarbonisation in ASEAN through policy research collaboration under AEM-METI, assistance in introducing EPR systems and circular economy legislation, the provision of high efficiency manufacturing and recycling technologies, and cooperation in the EV and battery industries. When these roles operate in concert, the circular economy becomes a central driver of improvements in emission efficiency, forming a realistic pathway for ASEAN to achieve GHG reductions while sustaining economic growth.

5. Conclusion

This study has sought to demonstrate that the circular economy offers ASEAN member states a realistic, economically grounded pathway for achieving GHG reductions without sacrificing economic growth. To this end, it contrasted conventional decarbonisation policies with the structural transformation implied by a circular economy approach and examined their implications through simulation analysis.

Firstly, the analysis highlights that, unlike traditional decarbonisation approaches centred on supply side clean technologies, the circular economy pathway focuses on transforming the underlying economic structure. Supply side technologies such as CCUS and hydrogen often entail high-cost structures and face limits to widespread diffusion without substantial public subsidies. By contrast, the circular economy transformation emphasised in this study, centred on improvements in resource efficiency, can generate direct cost reduction effects for firms and thereby encourage voluntary behavioural change based on economic rationality. This has important implications for ASEAN, suggesting a growth strategy that is less dependent on continuous policy support and more aligned with market incentives.

Secondly, the simulation results indicate the potential to achieve what may be termed "double decoupling". Under conditions where emission efficiency improves by around 2% annually (Efficiency +2.0), the negative GDP impacts associated with GHG reduction constraints are fully offset. This implies that both "the decoupling of resource consumption from human welfare" and "the decoupling of economic growth from environmental pressure" can be achieved simultaneously. These findings suggest that the circular economy constitutes an industrial upgrading strategy that can enhance ASEAN's international competitiveness and is not merely an environmental measure.

Thirdly, the study provides important insights into the spatial dimensions of circular economy implementation. In existing industrial agglomeration areas, such as Thailand's Eastern Economic Corridor (EEC), southern Viet Nam, and Java in Indonesia, GDP gains and GHG reduction effects are simultaneously maximised. This offers useful guidance for concrete policy design, including the strategic placement of recycling hubs within established production networks and the development of battery storage infrastructure for EVs.

Nevertheless, the simulation analysis conducted in this study does not explicitly endogenise the micro level processes of the circular economy, such as post consumption disposal, recycling decisions by economic agents, or the market mechanisms that coordinate these activities. By focusing on the macro structural transformation of the economy, the study has prioritised a panoramic understanding of the circular economy's significance; this represents an intentional limitation of the analytical scope. However, the results obtained here clearly indicate that constructing models which incorporate these micro level circular processes constitutes an important task for the next stage of research. Endogenising firm and household behaviour related to waste generation and recycling, as well as the formation of associated markets, within a dynamic general equilibrium framework would allow for a more precise assessment of the growth and environmental effects of the circular economy. This can be positioned as a frontier for theoretical and empirical research aimed at advancing and operationalising circular economy policies in ASEAN member states.

This study represents a first stage analysis that demonstrates, from a macroeconomic perspective, that the circular economy is a promising strategy for achieving both economic growth and GHG reduction in ASEAN. Future research that incorporates micro level circular processes will enable the insights of this study to be connected more directly to concrete policy design.

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Chapter 9: The Civilisational Significance of the ASEAN Circular Economy

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1. A Civilisational Framework for Analysing the Circular Economy

1.1. Introduction

Musashino Institute for Global Affairs (MIGA) is conducting various surveys and research with the aim of establishing a new circular industry based on an integrated "arterial-venous" supply chain on a global scale and specifically to build pilot projects within the Association of Southeast Asian Nations (ASEAN) (see Chapter 1). This chapter organises the philosophical background of this initiative within the framework of the history of civilisational evolution. MIGA does not view the establishment of a circular industry merely from the perspective of building a new industry; rather, it posits that the resulting changes to the entire social system will bring about a certain evolution of modern civilisation. The establishment of a circular industry will bring about structural changes to the entire social system, thereby driving the evolution of the modern civilisation, which today finds itself at an impasse in many respects.

Global environmental problems, the extreme wealth disparity resulting from global capitalism, and the military conflicts erupting around the world all have their root causes in the fundamental architecture of modern civilisation today. Superficial stopgap measures are ineffective in resolving these issues; it is necessary to focus on the evolution of modern civilisation itself. These issues represent systemic risks to modern civilisation.

Looking back, the numerous civilisations that have emerged throughout human history were not all highly developed at the time of their inception; rather, they have repeatedly undergone unique evolutions to overcome the various systemic risks that arose within them, and the modern civilisation is no exception. As we will see later, modern civilisation has undergone fundamental structural changes every few centuries since its establishment in the mid-16th century. What is required today is a new evolution of the modern civilisation that follows this lineage, and the series of initiatives beginning with the establishment of a circular economy is expected to provide a crucial catalyst for this.

First, let us organise a theoretical framework for understanding the evolution of civilisations.

A methodology that views many challenges arising worldwide as systemic risks of modern civilisation and employs the concept of civilisational evolution to resolve them is being developed in various parts of the world. Notably, the research conducted by the University of Tokyo's Faculty of Liberal Arts since the 1970s has garnered significant attention. In 1970s Japan, many researchers were keenly aware of the country's unique position in world history as having achieved the most successful modernisation among non-European societies. Consequently, they felt a strong sense of mission to construct a unique path for the evolution of the modern civilisation, serving as a bridge between Europe and the non-European world. Against this backdrop, researchers at the University of Tokyo's Faculty of Liberal Arts have promoted a framework for independent civilisational analysis based on a multidirectional view of civilisational evolution, developing it into the "Komaba School" (named after the location of the Faculty of Liberal Arts campus in Komaba). It was established as Infosocionomics in 2000, and the component of civilisational analysis within it became independent as Applied Infosocionomics in 2020. In addition to providing cutting-edge insights into models of civilisational evolution, this research is recognised for its significance as an intellectual contribution that Japan shares with the world; therefore, this chapter will essentially follow this research framework.

If one seeks to evaluate a wide variety of civilisations as neutrally as possible, focusing solely on physical structures or institutions is not entirely sufficient. On the other hand, since every civilisation inevitably possesses its own unique social philosophy, viewing civilisations through this lens is considered a highly neutral methodology.

If we define civilisation from this perspective, it can be understood as a combination of institutions and physical structures built upon a specific social philosophy.

1.2. Civilisation as Social Philosophy

According to Kumon and Maeda (2021), Applied Infosocionomics defines civilisation by the social philosophy that underpins the governance of social systems. Thus, civilisation is understood as a social philosophy before it is understood as physical structures such as palaces or institutional systems such as legal frameworks. It is this unique social philosophy that constitutes the essence of civilisation; both physical structures and institutional systems are merely consequences of that social philosophy. Using the framework of social systems theory, social philosophy is the genotype of civilisation, and the phenotypes —institutional systems and physical structures—are derived from it.

In this context, social philosophy refers to the fundamental way of thinking held by the people living within a social system. It becomes the most critical factor in constituting a civilisation because it determines the basic methodology of governance for that social system. The governance of a social system involves establishing and maintaining the order necessary to enable a large population to live within a defined scope. In the Brain Functional Analysis of Civilisations (B-FAC), we adopt a narrower definition by drawing on Edward O. Wilson's ideas in sociobiology (Wilson, 2012). Specifically, the governance of a social system is the philosophical framework designed to encourage its inhabitants to voluntarily restrain selfish behaviour and reinforce altruistic behaviour.

Conversely, the governance of a social system is not solely philosophical; to implement it, institutions — typically represented by a legal system — and corresponding physical structures are necessary. In other words, the governance of a social system can be viewed as being implemented through a combination of specific philosophy, the institutions (such as a legal system), as well as specific physical structures.

Thus, the characteristic feature of civilisational analysis in Applied Infosocionomics is the understanding of civilisation through three layers: social philosophy as the genotype, and institutions and physical structures as the phenotype. Incidentally, this three-layer framework of social philosophy, institutions, and physical structures resonates with the concept of connectivity, which is the fundamental principle of ASEAN integration. Connectivity within ASEAN is a concept understood in three layers: physical connectivity (corresponding to physical structures), institutional connectivity (corresponding to institutions), and people-to-people connectivity (corresponding to social philosophy).

The perspective of understanding civilisation through social philosophy may seem incongruous when viewed from the standpoint of conventional notions of civilisation. Generally, civilisations are understood either through the physical structures they have left behind, such as massive cities, or through their institutional frameworks, such as extensive legal systems. However, as research on civilisations in Applied Infosocionomics demonstrates, there is a wide variety of civilisations that have emerged on Earth; some invest vast resources in constructing massive physical structures, while others deliberately choose not to build such structures. Furthermore, while some civilisations invest vast resources in establishing and maintaining extensive legal systems, others deliberately avoid constructing complex institutional frameworks. Therefore, if one seeks to evaluate the diverse array of civilisations as neutrally as possible, focusing on physical structures or institutions is not an appropriate approach. On the other hand, since every civilisation possesses its own unique social philosophy, defining civilisation through this lens constitutes a highly neutral methodological approach.

From this perspective, civilisation can be defined as a combination of institutions and physical structures built upon a specific social philosophy. Among these elements, social philosophy serves as the most fundamental foundation.

1.3. Civilisation and the Structure of the World System

The nature of the dominant civilisation on Earth exerts a significant influence on the entire planet during that period. In particular, since each civilisation constructs its own unique world-system structure, fundamentally, all of humanity on Earth is strongly influenced by the civilisation that dominates the planet at any given time.

According to the classification of civilisation analysis in Applied Infosocionomics, from the perspective of world-system structure, civilisations can be broadly divided into two types: globalising civilisations and non-globalising civilisations. Using the terminology of Kinji Imanishi’s theory of compartmentalisation, these correspond to non-segregated civilisations and segregated civilisations. Applied Infosocionomics’ analysis of civilisations posits that globalisation (non-segregated civilisations) is a major characteristic of central civilisations, whereas non-globalisation (segregated civilisations) is a trait generally observed in peripheral civilisations.

Globalisation is the process by which a civilisation established in a particular region of the globe successively includes other regions beyond its region of origin. “Inclusion” refers to the process whereby governance of the social system in a region—previously governed by a civilisation distinct from the one in question—begins to be carried out according to the methods of that civilisation.

A non-segregated civilisation is one in which the act of encompassing other regions beyond its region of origin is embedded in the civilisational principle. This means that continuing the governance of the social system based on that social philosophy inherently possesses a fundamental driving force that leads to the encompassing of other regions. Conversely, a segregated civilisation does not possess this principle. Even if its social system is governed by its social philosophy, no driving force to incorporate other regions.

2. The Process of the Modern Civilisation’s Evolution and the Circular Civilisation

2.1. Renewal of the Modern Civilisation’s Social Philosophy Through Circular Thought

The most distinctive feature of civilisation analysis in Applied Infosocionomics is its emphasis on the “evolution” of civilisation and its detailed study of the dynamics of that evolution. In summary, the evolution of civilisation consists of the renewal of social philosophy while inheriting existing institutions and physical structures. If social philosophy is renewed and existing institutions and physical structures are abandoned in favour of rebuilding them from scratch, this constitutes not the evolution of civilisation, but rather a transition to a new civilisation based on a new social philosophy.

In accordance with this model of civilisational evolution in Applied Infosocionomics, this chapter examines the nature of the evolution of the modern civilisation.

As researchers have demonstrated, modern civilisation has undergone major updates to its fundamental social philosophy several times over the centuries since its emergence in the mid-16th century. Despite these updates, the physical structures and institutions of modern civilisation have been preserved and continue to this day. The following classification has been proposed regarding these renewals of social philosophy (Yamauchi, 2026). According to this classification, the social philosophy that initially underpinned the modern civilisation (the Modern Civilisation Social Philosophy I) was a Western epistemology based on Christian theological foundations, characterised by clear and distinct reason and the absolute identity of existence. This was the era of the so-called Enlightenment. Representative philosophers who articulated this social philosophy include Descartes, Locke, Hume, and Kant. This social philosophy generally persisted until the latter half of the 18th century. On the other hand, by the latter half of the 18th century, criticism of the Christian theological foundation and the socialisation of ideas through materialism progressed, and social philosophy shifted toward a Western epistemology based on the theological and materialistic identity of reason and existence (the Revised Modern Civilisation Social Philosophy I). This is the era known as the so-called Romantic Modernity. Representative philosophers who articulated this social philosophy include Fichte, Hegel, Feuerbach, Marx, and Lenin. This social philosophy generally persisted throughout the 19th century. The situation changed significantly at the beginning of the 20th century. While traditional social philosophy had been grounded in Christian theology, it was replaced by a foundation in modern science, leading to the rise of logical empiricism, falsificationism, and historicism. Social philosophy thus evolved into a globalised epistemology (the Modern Civilisation Social Philosophy II) based on historicist reason and the naturalistic identity of existence. This is what is known as "reflexive modernity." This has been the situation since the 20th century and continues essentially to this day. Furthermore, with the remarkable development of AI today, the possibility has emerged that a complete, data-driven identity between reason and existence could be realised, raising the prospect of a new social philosophy (the Revised Modern Civilisation Social Philosophy II?) being constructed on this basis.

Based on the above framework, the evolution of modern civilisation in the near future will occur through the following process.

The greatest challenge lies in constructing a new social philosophy of modern civilisation—one that fully incorporates the perspectives of regions outside Europe, particularly the Global South—by updating the social philosophy of modern civilisation that has evolved in Europe from the Modern Civilisation Social Philosophy I to the Revised Modern Civilization Social Philosophy I, and further to the Modern Civilization Social Philosophy II. Since the social philosophy of modern civilisation already shifted course significantly in the 20th century, moving away from Christian theological foundations toward a global foundation, the conditions are ripe for the construction of a new social philosophy that fully incorporates the perspectives of the Global South within a relatively short period.

In this context, how we respond to digital technologies, particularly AI, is likely to be the key factor. Several ideas for a new social philosophy, premised on fully leveraging the potential of digital technology, have already been proposed. For example, Harari advocates for a "Data Religion," arguing that governance methods for social systems should be determined by processing big data with AI (Harari, 2018).

Furthermore, Shumpei Kumon, the founder of Infosocionomics, argues that the development of digital technology has the potential to bring about a new civilisation entirely different from both modern civilisation and the entire history of human civilisation, which he refers to as a 'super-intelligent civilisation' (Kumon, 2017).

Indeed, given the current pace of AI development and its immense impact on society, it seems reasonable to conclude that the idea that AI will become the primary driving force of future civilisation is becoming increasingly persuasive.

On the other hand, we believe that the wisdom humanity has painstakingly cultivated since the dawn of civilisation is not so trivial that it can be so easily replaced by AI. Perhaps these commentators are only seeing one aspect of the wisdom that humanity has produced. In building and managing civilisation, has humanity not cultivated a profound wisdom that we, living in modern civilisation, have been unable to grasp due to our technological limitations? Has that profound wisdom not been overlooked within the social systems of the Global South, which have not been regarded as the primary drivers of modern civilisation throughout history? If that is the case, then the challenge we should tackle today is to uncover the multilayered and profound wisdom latent within those social systems of the Global South, to organise it as part of the lineage of social philosophy that underpins world civilisation, and thereby drive the further evolution of modern civilisation.

I believe that our approach to AI should be developed within the context of such initiatives. In other words, when considering the lineage of social philosophy underpinning modern civilisation—from the aforementioned "the Modern Civilisation Social Philosophy I" to "the Revised Modern Civilisation Social Philosophy I," and further to "the Modern Civilisation Social Philosophy II"—the wisdom employed therein cannot help but command our attention in light of AI's development. On the other hand, if we can reconstruct the multi-layered and profound wisdom latent within the social systems of the Global South as the social philosophy of modern civilisation, it is conceivable that humanity will be able to truly master AI as a tool for the evolution of civilisation.

Some researchers have already proposed strategies for constructing a new social philosophy of modern civilisation by reconstructing the multi-layered and profound wisdom latent within the social systems of the Global South. The first example is the concept of "adapteering," which Shumpei Kumon has advocated since the 1970s. Based on this concept, Kumon outlines the direction of adaptive evolution for the modern civilisation, positing that after achieving this evolution, the modern civilisation will transition into the Wisdom Civilisation.

The second example is the "Second Type Civilisation," namely the "Whole-Brain Civilisation," as proposed by Mitsuhiro Maeda in his analysis of Brain Functional Analysis of Civilisations (B-FAC) (Maeda, 2022).

The common ground between the concept of Adapteering and that of the Whole-Brain Civilisation lies in the manipulation of the human inner self. Adapteering is a technology by which humans manipulate their own inner selves to alter their desires (utility functions). A Whole-Brain Civilisation (Type 2 Civilisation) is a civilisation that governs its social system based on procedures (Cultural Element Embedding Measures) designed to embed in humans a mode of thinking that spontaneously drives them toward altruistic behaviour through special rituals experienced during religious events, community festivals, and performing arts.

If such Adapteering or Cultural Element Embedding Measures are appropriately integrated into modern civilisation, there is a possibility that many of the systemic risks currently facing modern civilisation could be overcome. On the other hand, their content differs significantly from the social philosophy that underpins modern civilisation as understood within the aforementioned lineage. While it is possible that the systemic risks of modern civilisation could be overcome, it is unrealistic to suddenly adopt Adapteering or Cultural Element Embedding Measures as the social philosophy of modern civilisation, which has developed over the past few centuries within the aforementioned lineage, while maintaining the existing physical structures and institutions.

As comparative institutional analysis suggests, 'institutions cannot be grafted'.

Given this situation, a realistic approach would be to embed within the social philosophy of modern civilisation mechanisms that, as a result, lead to consideration of the manipulation of the human psyche.

We believe that the current social philosophy of modern civilisation is not structured in a way that sufficiently addresses the manipulation of the human psyche.

A key factor behind this can be discerned from the above description of the genealogy of modern civilisation's social philosophy.

Yasusuke Murakami, founder of the "Komaba School," identifies the essence of the social philosophy of modern civilisation as "instrumental activism." That is, human actions consist of "instrumental actions"—means aimed at a specific goal—and "consummatory or expressive actions"—actions in which the act itself is the goal. The value system of industrialisation is a composite of "activism" and "instrumentalism"—that is, "instrumental activism." (In the case of Europe, individualism is further added to this.) The circumstances leading to the emergence of such a value complex vary. In the early European examples, a religious background in the broad sense appears to have played a major role, whereas in later societies, tangible and intangible threats from the early nations served as the catalyst (Murakami et al., 1979).

In instrumental activism, the objects of manipulation are limited, and the sole pursuit is for the state of those objects to change in a way that enhances one's own utility. Conversely, all phenomena in the world exist within an interconnected network, regardless of whether the Buddhist concept of Auspiciousness is invoked. Consequently, when the state of a particular object changes, the impact extends to various other domains. However, in instrumental activism, a bias operates that tends to disregard impacts arising in domains other than the object being manipulated. The concept of "externalities" in economics clearly illustrates this attitude. Regardless of the nature of the effects arising in other areas, they can simply be dismissed as (negative) externalities. Needless to say, this attitude was the direct cause of the environmental pollution problems stemming from industrial activity in the 1960s through the 1980s, and it is also the cause of today's global environmental issues.

Therefore, today's approach must guide modern civilised people, whose behaviour is characterised by instrumental activism and justified and reinforced by social philosophy, towards paying appropriate attention to fields beyond their immediate sphere of control. Those involved in Buddhism might think that, in that case, we should simply preach the doctrine of Auspiciousness; however, as we saw earlier in the genealogy of modern civilisation's social philosophy, it is not realistic to directly "graft" Buddhist philosophy onto that lineage.

We propose "circularity" as a concept that can be naturally developed within the genealogy of modern civilisation's social philosophy and that serves as a catalyst to guide modern civilised people toward giving appropriate consideration to areas beyond the objects of manipulation. We believe that the concept of circularity can be relatively easily reconstructed as a social philosophy underpinning the modern civilisation by passing through the following stages, and that this will make it possible to guide an evolution that overcomes the significant systemic risks facing modern civilisation.

2.1.1. The Industrialisation Stage

The first stage is industrialisation. Since the success of the industrial sector is one of the primary concerns for people in modern civilisation today, the effects of appropriately introducing the concept of circularity in the industrial sector are significant.

MIGA has proposed the concept of an "arterial-venous integrated industry," which incorporates recycling, recovery, and reuse as indispensable components of the supply chain. Conventional supply chains can be viewed as having focused solely on the "arterial" portion. However, it goes without saying that manufactured industrial products do not simply disappear naturally once their useful life ends; rather, they remain on Earth as waste. If we stand on the typical foundation of instrumental activism, waste remaining on Earth is treated as an external (dis)economy and, as such, excluded from the scope of economic activity and ignored. On the other hand, if we introduce the concept of the circular economy (or Auspiciousness), since this waste represents a change generated in other sectors by instrumental activist economic activities focused on the arterial phase, it is inappropriate to ignore it.

In this case, attempting to persuade people that such behaviour is ideologically impermissible constitutes a religious approach. As I have repeatedly noted, this approach is incompatible with the social philosophy of modern civilisation, which has followed its own distinct lineage of renewal; consequently, its effectiveness can only be expected to be limited.

In contrast, we argue that the waste management sector, which is part of the "arterial industry," was not considered part of the "commercially viable sphere" (i.e., the domain of industrial activity)—should be transformed into a commercially viable sphere by reforming the current legal framework and other institutional structures, while simultaneously introducing various new technologies. Once incorporated into the commercially viable sphere, the "venous industry" can be expected to develop through normal industrial activities.

The commercially viable sphere fluctuates significantly depending on the technologies introduced into industry and the nature of institutional frameworks such as the legal system. It goes without saying that the introduction of new, superior technologies enables industrial activity in areas where commercialisation was previously impossible. Furthermore, implementing support systems such as subsidies for these activities, or regulating rival sectors that pose major obstacles to commercialisation in the relevant field, will significantly advance commercialisation in that sector. Thus, transforming areas where commercialisation was previously unfeasible into viable commercial sectors through institutional reforms grounded in sovereign power can be viewed as a form of Public-Private Partnership (PPP). Furthermore, transforming areas where commercialisation was previously unfeasible into viable commercial sectors through support for technological development or institutional reforms can be termed "Commercially Viable Sphere Enhancement Measures."

Given the current situation surrounding the recycling industry, we can expect these Commercially Viable Sphere Enhancement Measures to be highly effective. In particular, the recycling sector in the Global South is overwhelmingly operated as part of the informal sector, and the technologies employed are generally of a low standard. Formalising such sectors by reforming legal frameworks and other institutional structures, while simultaneously improving technological standards through various forms of support, constitutes a classic example of Commercially Viable Sphere Enhancement Measures—that is, the creation of new industries. This should be positioned as one of the key industrial policies in the Global South.

In other words, given the current situation in the Global South, promoting the recycling industry through measures to expand the commercialisation sphere and building an integrated arterial-venous industrial system is technically and institutionally feasible. Furthermore, because the resulting benefits to society are extremely significant, it is highly likely to receive strong support from all sectors of society. Consequently, if an arterial-venous integrated industrial system becomes firmly established in society, it is expected that the value of “circularity” will be strongly ingrained in people’s mindsets.

2.1.2. Institutional Stage

The second stage of the methodology for embedding the value of circularity as a social philosophy that constitutes civilisation pertains to the institutional sphere. In the current social system of modern civilisation, a wide variety of institutions are in operation, and it is not uncommon for these institutions to be seen as failing to adequately address the value of circularity.

As previously mentioned, within instrumental activism, which forms the foundation of modern civilisation’s social philosophy, attention is focused “solely” on altering the state of the target domain to increase one’s own utility. Consequently, it is undeniable that a tendency easily arises to ignore the changes and impacts that result in domains outside the target area. The most striking consequences of this are environmental pollution problems and global environmental issues.

In the contemporary modern civilisation, it can be observed that a certain kind of stopgap response is being adopted toward these problems. The basic structure of this response involves leaving the various key institutions that form the foundation of modern civilisation untouched, while addressing environmental pollution and global environmental issues by establishing them as “new” policy response areas. The approach taken toward these newly established policy response areas is to proceed with measures based on instrumental activism, just as before. In other words, our concern is that, although environmental pollution and global environmental issues are systemic risks of modern civilisation that have emerged as logical consequences of the fundamental social philosophy of modern civilisation, by adopting a method that addresses these new policy areas using conventional response methods, the conventional social philosophy of modern civilisation is actually being reinforced.

In response to this, we propose reviewing the major institutions that have traditionally supported modern civilisation and restructuring them into new ones that incorporate the concept of circularity. We have taken the international trade system as a concrete example of the major institutions that have supported modern civilisation and are advancing this initiative.

While we are fully aware that the definitions of “national” and “international” vary greatly depending on the civilisation in question, we will deliberately set these definitions aside for the sake of argument. International trade in goods and services is an activity that constitutes the machinery of the world system based on modern civilisation, and the various rules governing it are indeed the major institutions that underpin modern civilisation. MIGA identified the absence of a circular perspective within this international trade system as a problem and participated in the compilation of the official G20 policy brief in 2025, titled “Embedding Circularity in Global Trade: A G20 Road Map for Catalysing Circular Value Chains” (Anbumozhi et al., 2025). The main argument is that the international trade system, which traditionally focused only on the movement of goods and services between nations, should be restructured to include provisions that hold countries accountable for the final disposal of exported products. This policy brief was formally adopted after undergoing the prescribed T20 review and peer-review process and was published on the official T20–G20 website.

Although this is just one example, we plan to continue our efforts to reexamine the major institutions that underpin modern civilisation—institutions currently constructed without incorporating the concept of circularity, a concept that modern civilised people do not question at this point—and to reconstruct them to incorporate this concept of circularity. Such initiatives can be said to lead directly to the renewal of the social philosophy underpinning modern civilisation based on the concept of circularity.

2.2. Reconfiguring the World System

Another challenge in promoting the evolution of modern civilisation is reorganising the world system that has been constructed as a result of modern civilisation’s operation.

There is no doubt that a firmly established two-tiered world system has been constructed within modern civilisation. Modern civilisation is characterised by the steadfast maintenance of a concept that distinguishes Western Europe — the birthplace of modern civilisation — from the rest of the world. Although the specifics vary somewhat depending on the era, to use Wallerstein’s terminology, this involves a clear distinction between the “core” and the “periphery” of the world-system. Essentially, the former determines the nature of the world-system’s governance and operates it, while the latter complies with that governance.

If we view the core and the periphery as a basic framework, the history of modern civilisation has progressed through the following three stages. The first stage was an era in which it was believed that only Europe—specifically Western Europe, the birthplace of modern civilisation—could modernise; this can be referred to as the First Modernity. Since characteristics such as the white race and the Christian religion were seen as attributes associated with Western Europe, they were often regarded as essential factors for modernisation. The second stage was an era in which, while modernisation was considered possible outside of Europe, it was believed that only non-European regions (Asia and Africa)—acting as “model students” who faithfully studied European teachings and implemented them under European guidance—could successfully achieve modernisation. This can be termed the Second Modernity. This represents an extension of the two-tiered conceptual framework that views Europe alone as the core, or the primary agent of governance within the world system. In contrast, the third stage is an era in which it is believed that all nations and peoples on Earth can modernise, regardless of race, religion, culture, or historical background; this can be called the Third New Modernity.

The concept of the First Modernity served as a central dogma during the era of imperialism. The core was the suzerain states, and the periphery was regarded as the colonies. Furthermore, it can be said that the concept of the Second Modernity continues to exert a significant influence on today's international society. Although the suzerain–colony relationship ended with imperialism, the developed–developing nation framework has become the prevailing trend since the latter half of the 20th century. Within the OECD's DAC-based international development finance regime, developed countries are defined as providers of international development finance, while developing countries are defined as recipients.

On the other hand, given the current situation in the 21st century, it can be concluded that governance is becoming impossible under this two-tiered view of the world system for the following reasons. The first reason is that all regions of the Global South—including Sub-Saharan Africa, which was viewed as a region left behind in the 20th century—have achieved rapid economic growth in the 21st century. Given this situation, it is impossible to construct a rational argument that limits the qualification for successful modernisation to specific nations alone.

Secondly, due to changes in the nature of international development finance, the structure of the world system based on the concept of the Second Modernity has effectively collapsed. Specifically, not only are the world's major donors now developing countries listed as recipients on the DAC list (particularly China and India), but various forms of financing other than concessional loans have emerged as central modalities of international development finance, expanding their scope of application.

3. Conclusion

In summary, given the current situation, it is considered impossible to achieve appropriate global system governance without reexamining the two-tiered structure of the world system that modern civilisation has maintained until now.

One possible alternative to the current two-tier structure is for the middle powers to collaborate and assume important governance functions between the core and the periphery, thereby creating a three-tier world system.

Several initiatives aimed at fostering cooperation among middle powers are already underway globally. The most prominent example is the G20. This group was formed by adding major emerging economies to the G7 — the main group of core states — based on the recognition that, throughout the 20th century, the G7 had become increasingly unable to adequately address critical issues arising within the international community.

However, the G20 is not the sole bearer of governance in the new world system, and various possibilities for cooperation should continue to be explored.

As detailed in another paper in this volume, MIGA is currently preparing to establish a new solidarity organisation in which Japan will collaborate with the four Global South countries—Indonesia (G20 Chair in 2022), India (G20 Chair in 2023), Brazil (G20 Chair in 2024) and South Africa (G20 Chair in 2025)-

and Japan. Once established, it is anticipated that this solidarity organisation will contribute positively to the governance of the world system within the framework of modern civilisation. This will solidify the three-tier structure of the world system and drive the evolution of modern civilisation in terms of its structure.

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Chapter 10: Musashino University International Symposium: 'Towards the Creation of a Japan–ASEAN Circular Economy Model' – Event Report

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1. Introduction

The Musashino University International Symposium, 'Towards the Creation of a Japan–ASEAN Circular Economy Model', was held on 17 July 2026 at the Pullman Bangkok King Power Hotel. It was co-organised by the AEM-METI Economic and Industrial Cooperation Committee (AMEICC), JETRO Bangkok Office, and with the support of the Embassy of Japan in Thailand and NEDO. The event was attended by approximately 200 participants, including Mr Seferino S. Rodolfo, Undersecretary of the Department of Trade and Industry (DTI) of the Philippines; Mr Pasakorn Chaiarat, Assistant Secretary of the Ministry of Industry (MOI) of Thailand; Mr Pasakorn Chai-rat, Director-General of the JETRO Bangkok Office, Mr Ichiro Abe, and Mr Masayoshi Tamura, Representative of the AMEICC Secretariat, amongst others.

The theme of this symposium was to discuss the path forward for Japan and ASEAN to strengthen international resource circulation and enhance economic security capabilities through necessary cooperation. The symposium focused on the automotive industry's supply chains (including batteries and plastics) as a core element, and discussed the significance and feasibility of developing ASEAN as a 'circular economy hub' that consolidates and reuses resources recovered from the wider Global South.

2. Musashino University International Symposium

2.1. Symposium Agenda

- Date and time: Friday 17 July 2026, 8.30 am – 2.00 pm
- Venue: Pullman Bangkok King Power Hotel (hybrid conference)
- Theme: Towards the Development of a Circular Economy Model for ASEAN and Japan

Time	Agenda
08:00 - 08:30	**Registration Open** Moderated by Prof. Masamu Kamaga, Visiting Professor, Asian Institute of Technology (AIT), Thailand
08:30 - 09:00	**Opening Remarks** • Mr. Ceferino S. Rodolfo, Undersecretary, Department of Trade and Industry (DTI), The Philippines (Video Letter) • Mr Pasakorn Chaiarat, Deputy Parmanent Secretary of the Ministry of Industry (MOI) in Thailand • Mr. Ichiro Abe, President of JETRO Bangkok • Mr. Masayoshi Tamura, Chief Representative of AMEICC Secretariat
09:00 - 09:10	**Photo Session**
09:10 - 09:30	**Scene Setting** • Prof. Hidetoshi Nishimura, Director of the Musashino Institute for Global Affairs (MIGA)
09:30 - 11:00	**Session 1: Explanation of the Report** • Dr. Yasushi Ueki, President of the Bangkok Research Centre, IDE-JETRO. • Mr. Takahiro Oda, Analyst, aiESG Inc. • Mr. Ikumo Isono, Senior Research Fellow, IDE JETRO. • Prof. Dr. Masahiro Nakamura, Professor, Tokyo City University; CEO, LEXER RESEARCH Inc. Q&A
11:00 - 11:15	Coffee Break
11:15 - 12:30	**Session 2: Roundtable Discussion, challenges and opportunities of the development of circular economy system in the ASEAN** Moderator: Prof. Fusanori Iwasaki, Consulting Fellow of RIETI • Mr. Cuong Ba Tran, Assistant Director, and the Head of the Trade Facilitation Division, ASEAN Secretariat. • Mr. Jen-nio Gabinete Hung, En Tsumugi Inc. • Mrs. Nuchanat Suphansri, Management and Treatment Technology, Department of Industrial Works (DIW) • Dr. Lai Van Manh, Head of the Department of Natural Resources and Environmental Economics, Institute of Strategy and Policy on Agriculture and Environment (ISPAE). Q&A
12:30 - 13:45	**Session 3: Roundtable Discussion, towards the human resource development for developing circular industry in the ASEAN**

	Moderator: Prof. Mitsuhiro Maeda, Professor of Advanced Institute of Industrial Technology (AIIT) • Prof. Alvin B. Culaba, Distinguished Professor and University Fellow, De La Salle University • Prof. Nita Yuanita, Dean, Faculty of Civil and Environmental Engineering, Institut Teknologi Bandung • Prof. Mohd Naz'ri Mahrin, Dean, Faculty of Artificial Intelligence, Universiti Teknologi Malaysia • Prof. Masamu Kamaga, Visiting Professor, Asian Institute of Technology (AIT) Q&A
13:45 - 14:00	**Closing Session** • Prof. Hidetoshi Nishimura, Director of the MIGA
14:00 - 15:00	Networking

3. Opening Remarks

3.1. Mr Ceferino S. Rodolfo, Under-Secretary of the Department of Trade and Industry (DTI) of the Philippines

At the outset, he expressed his heartfelt gratitude to all the organisers—including the Musashino Institute for Global Affairs (MIGA), the Japan External Trade Organisation (JETRO) and AMEICC—for providing this extremely timely forum for dialogue. He also began his remarks by paying special tribute to Professor Nishimura, a good friend, and Mr Tamura, Chief Representative of AMEICC Secretariat, and expressing his respect for them.

Currently, the uptake of hybrid electric vehicles (HEVs) and battery electric vehicles (BEVs) is advancing rapidly across the ASEAN region as a whole. Whilst this trend presents significant industrial opportunities, it also necessitates addressing new challenges relating to the collection of end-of-life batteries, the establishment of recycling systems, resource security and the creation of sustainable supply chains. Against this backdrop, the Philippines has clearly expressed its strong support for further cooperation between Japan and ASEAN to build a resilient and circular industrial ecosystem.

As economies around the world continue to advance industrialisation and pursue decarbonisation targets, the circular economy is recognised not merely as an environmental necessity, but as a crucial economic and industrial strategy for strengthening industrial competitiveness, improving resource efficiency and creating new investment opportunities.

In particular, he expressed his expectation for the initiatives being promoted under the AMEICC framework. Specifically, these included research into battery recycling, the formulation of quality standards for recycled materials, and discussions aimed at enhancing the commercial viability of the circular economy across the ASEAN region. Within the Philippines, the circular economy initiative is closely linked to the broader industrial development agenda, and significant opportunities are being identified for building local capacity in areas such as advanced manufacturing, automotive production, the battery value chain, recycling technologies and human resource development. It was therefore welcomed that emphasis is being placed on both the physical and institutional infrastructure essential to supporting this transition, and it was emphasised that this includes the development of specialist skills and the training of circular economy experts.

Finally, it was emphasised that, as ASEAN and Japan continue to deepen their close cooperation, the transition to a circular economy must go beyond the mere pursuit of environmental benefits; it is vital that it ensures the creation of economic value, the provision of high-quality employment, technological advancement, and inclusive growth across industries and local communities as a whole. The opening address concluded by expressing strong hopes that the discussions at this symposium would lead to the identification of specific areas of cooperation to accelerate the development of the region's circular economy ecosystem.

3.2. Mr Pasakorn Chaiarat, Deputy Parmanent Secretary of the Ministry of Industry (MOI) in Thailand

He expressed his welcome and gratitude to the guests, speakers and participants, including Professor Hidetoshi Nishimura, Mr Ceferino S. Rodolfo, Mr Ichirō Abe and Mr Masayoshi Tamura.

He stated that the introduction and development of the circular economy is currently a matter of utmost importance for both ASEAN and Japan, and that, based on the discussions at the ASEAN-Japan Senior Economic Officials' Meeting (SEOM-METI) held in late May, the aim is to incorporate these discussions into the drafting of policy recommendations for this year's meeting. He mentioned that, at this symposium, the findings of the 'Japan–ASEAN Circular Economy Model Study', conducted by MIGA under the AMEICC framework, were presented. Approaches involving batteries and plastics—applied in accordance with the BCG economic model and ESG principles—were outlined for the automotive industry, including electric vehicles (EVs) and related supply chains, he said.

Japan is regarded as a model nation leading the way in recycling and the circular economy through technology and innovation, legislative frameworks, the promotion of participation by various sectors and local communities, Extended Producer Responsibility (EPR), green procurement and the integration of waste management systems. In Thailand, too, the Ministry of Industry has identified the promotion of the circular economy across a wide range of sectors—including plastics, tyres, construction materials, steel and metals, electronic components, solar cells and EV batteries—as a top priority.

1. The Department of Primary Industries and Minerals (DPIM) is currently spearheading efforts to maximise resource efficiency and stabilise supply by promoting the following five initiatives.
2. Business development, enhancement and facility development incorporating the principles of 'Design for Circular Economy'

3. Establishment of the Circular Economy Performance Assessment System (CEPAS)
4. Conducting audits of industrial facilities and recognising outstanding companies
5. Supporting research and development and facilitating knowledge transfer through the establishment of a ‘Recycling Technology Research and Development Centre’ in Samut Prakan’s Prapra Deang District
6. Promoting ‘urban mining’ with the aim of securing alternative raw material supplies

Finally, he expressed his gratitude for the selection of Thailand—a major automotive manufacturing hub—as the host country of this symposium, whilst strong hopes were expressed that, through the presentation of the survey findings and the round-table discussions, this event would serve as a new and important framework for realising a circular economy and achieving sustainable growth across various industries in ASEAN and Japan.

3.3. Mr Ichiro Abe, President of the JETRO Bangkok Office

He began by expressing his sincere condolences on the passing of Her Royal Highness Princess Pacharakitiyapha, and his heartfelt sympathies to the Thai Royal Family and the people of Thailand. He then expressed his gratitude to the participants from a wide range of sectors, including government officials, industry representatives and research institutions.

In his opening remarks, Mr Abe noted that the importance of resource circulation is growing internationally, particularly in light of recent efforts towards decarbonisation and the strengthening of supply chains. He pointed out that whilst institutional frameworks for promoting the circular economy—particularly in relation to the circulation of automotive resources, including batteries and plastics—are being developed in ASEAN member states, the actual implementation and corporate responses remain unclear in some respects; consequently, companies are required to consider concrete measures and identify the challenges they face in their day-to-day operations.

He also noted that, as JETRO Bangkok supports the business activities of Japanese companies within the ASEAN region, issues such as securing a stable supply of recycled raw materials, adapting to differing regulations across countries, and balancing environmental considerations with cost-effectiveness have come to be recognised as key challenges. He emphasised that, in addition to initiatives by individual companies, cross-cutting measures—such as the harmonisation of rules and standards within the region, human resource development and infrastructure development—are essential to address these challenges, and that today’s discussion on ‘making ASEAN a hub for the circular economy’ holds significant importance as a means of building the foundations to support corporate activities. Furthermore, he spoke of the importance, within the diverse ASEAN region, of utilising these differences to enhance the competitiveness of the region as a whole.

In conclusion, he expressed his expectation that this symposium would bridge the perspectives of policy, research and business, and serve as a catalyst for new collaboration and co-creation. JETRO also stated its intention to act as a facilitator between the parties involved and to support these initiatives, whilst taking into account the realities on the ground.

3.4. Mr Masayoshi Tamura, Chief Representative of the AMEICC Secretariat

He expressed his heartfelt condolences to the Royal Family. He then expressed his gratitude to Under-Secretary Seferino S. Rodolfo, representing the ASEAN Chair, and to Deputy Parmanent Secretary Pasakorn Chaiarat, representing the host country.

In his opening remarks, Mr Tamura referred to the role of AMEICC, which was established in 1998 with the endorsement of the ASEAN-Japan Summit. To promote economic cooperation between ASEAN and Japan, AMEICC has been engaged in organising public-private policy dialogues, providing support to Japanese companies for technology demonstration and human resource development, and conducting research on future themes for economic cooperation. These activities are linked to the discussions at the annual ASEAN Economic Ministers and METI Consultation. Mr Tamura highlighted that, in addition to efforts to strengthen supply chain resilience in light of recent changes in the international situation, there is growing interest in resource recycling due to the need for decarbonisation and constraints on resource supply.

As an example of this trend, it was noted that new provisions concerning remanufactured products were included in the amendments to the ASEAN Trade in Goods Agreement (ATIGA), which were agreed last year. Against this backdrop, the AMEICC Secretariat has launched initiatives—including the research project that led to this symposium—aimed at promoting the establishment of circular economy models across multiple sectors, including the automotive industry.

He pointed out that whilst ASEAN countries, led by Thailand, are home to a concentration of Japanese corporate supply chains centred on the manufacturing sector and possess significant potential to become hubs for the circular economy. There are numerous challenges to be overcome—including institutional, infrastructural and social issues—in order to establish and operate the entire process of resource recovery, sorting, reprocessing and reuse in a way that ensures economic viability and competitiveness across both the 'venous (circular)' and 'arterial (manufacturing)' sectors of the economy.

Finally, it was noted that the report on the survey results from Musashino University, together with the discussions among leaders and experts from industry, government and academia, provided numerous insights for the development of a circular economy model in ASEAN, and strong expectations were expressed that these would lead to concrete initiatives. The AMEICC Secretariat also stated its intention to incorporate the insights and ideas gained from today's discussions into future public-private policy dialogues and to support the efforts of stakeholders from industry, government and academia in Japan and ASEAN from multiple angles, thereby driving these efforts towards tangible results in economic cooperation.

4. Scene Setting

4.1. Professor Hidetoshi Nishimura, Director of the Musashino Institute for Global Affairs (MIGA)

He began by reflecting on his history, including his posting to Bangkok in 1993 as Head of the Secretariat of the JODC—the predecessor organisation to AMEICC—and his time as President of ERIA (Economic Research Institute for ASEAN and East Asia), a role he held for 15 years until 2023, whilst also referring to the progress made to date through forums such as the East Asia Summit.

Professor Nishimura spoke about ASEAN's rapid development over the past 30 years, noting that, when comparing 1992 with 2022, GDP had increased tenfold, trade volume fivefold and direct investment twentyfold; he added that Japan, AMEICC and ERIA had all contributed to this export-led industrialisation, often referred to as the 'Asian Miracle'. However, he noted that the world is currently undergoing major structural changes, such as GX, DX, AI, economic development strategies and the reorganisation of supply chains. He introduced the recent MIGA report as an examination of 'measures to link the circular economy to industrial development' as a perspective for advancing ASEAN's industrialisation to the next stage of development.

Referring to the Framework of the Circular Economy for ASEAN Economic Community adopted at the 2021 ASEAN Summit as the background to the report's preparation, he praised ASEAN's foresight in proactively positioning the circular economy not merely as an environmental policy but as an industrial policy and economic growth strategy. Furthermore, he explained that, building on the spirit of the 2025 G20 Policy Brief, which proposed the circular economy from the perspective of new industrial development, the report made practical policy recommendations by linking ASEAN policies, policies proposed by Japan, and the AEM-METI policy dialogue.

Professor Nishimura highlighted the following points as the most important proposals in this report.

- Fostering a 'circular industry': As industries cannot be developed through targets alone, it is necessary to foster a 'circular industry' in which collection, sorting, repair, reuse, remanufacturing and recycling work in unison to create new value.
- Integration of 'arterial' and 'venous' industries: Rather than considering them separately, integrating them into a single circular value chain will generate new investment, employment and markets, thereby facilitating a shift from the 'value through manufacturing' of the industrialisation era to 'value through the circular economy'.
- Reasons for focusing on the automotive industry: The automotive industry is a key sector underpinning ASEAN's industrialisation. As the ATIGA upgrade provides the most concrete opportunity to examine new policy issues—such as remanufactured products, trade and the environment—it serves as a model case for rolling out circular industry policies more broadly.

Finally, he concluded his remarks by highlighting four key points for discussion at today's symposium: (1) how to foster the circular economy as a new growth strategy for ASEAN; (2) the establishment of a circular value chain centred on the automotive industry; (3) the implementation of the ATIGA upgrade in institutional and business contexts; and (4) the joint development of institutional frameworks, human resources and knowledge bases by Japan and ASEAN. He expressed strong expectations for lively debate and the identification of specific areas for cooperation.

5. Session 1: Explanation of the Report

5.1. Dr Yasushi Ueki, President and Senior Research Fellow at the IDE-JETRO Bangkok Research Centre

Dr Yasushi Ueki presented a report on the current status and challenges of circular economy initiatives within ASEAN, based on his field research.

1. Background and Objectives of the Survey: Dr Ueki visited three ASEAN member states, primarily Thailand, as well as India, and conducted interviews—focusing in particular on parts suppliers—regarding the state of the circular economy in the automotive industry (specifically, the reuse and recycling of parts and materials generated from vehicle dismantling, and the recycling of waste generated by the automotive parts industry). He explained the international context, noting that the European Union (EU) had enacted new EV regulations making resource circularity mandatory from the design stage (including the introduction of numerical targets for the use of recycled materials and extended producer responsibility), and stated that momentum towards a circular economy is gaining traction in ASEAN as well, with the introduction of frameworks for the circular economy and provisions regarding remanufactured products in the revision of the ATIGA. In light of this, it was explained that the automotive industry and its suppliers must promote the collection and sorting of waste at source, as well as its recycling and proper disposal.
2. Current Status of National Policies and Initiatives Regarding ELVs: The current situation regarding the proper treatment of ELVs in the countries surveyed is as follows.
   - Thailand: Whilst the country has a major industrial cluster for motor vehicle production, the development of ELV-related systems has lagged behind, and the vast majority of the numerous dismantling operators are in the informal sector. Even when formal enterprises attempt to procure vehicles through auctions and similar channels, they are outbid by informal firms and struggle to secure a stable supply (the establishment of a framework supported by JICA is eagerly awaited).
   - Malaysia: Although the country has introduced the government-certified dismantling facility (AATF) scheme in ASEAN and is moving towards formalisation, the informal sector remains significant, and discussions on ensuring a stable supply are ongoing.
   - Vietnam: Although its effectiveness is limited, Vietnam was the first country in ASEAN to introduce the EPR principle. The requirements imposed on manufacturers are not yet stringent, but the policy is to promote a circular economy whilst exercising control in the future.
   - Philippines: A Japanese private-sector dismantling operator (En Tsumugi), supported by JICA, has been established, and capacity-building is also progressing.

- India: The EPR principle and a government-certified automotive dismantling facility (RVSF) scheme have already been introduced, with approximately 200 RVSFs in operation. Manufacturers are also working to improve their dismantling capacity.

3. Current Status and Reality of Waste Management at Automotive Parts Suppliers: The methods of waste management employed by suppliers can broadly be categorised into the following three types.
   - Reconstruction and recycling of materials generated on production lines: Further recycling of in-house waste. Some companies re-pelletise plastic waste within their factories, whilst those with smelting furnaces remelt metals and reintroduce them into production lines. However, the automotive industry has extremely stringent quality requirements, necessitating technical measures to prevent the contamination of materials—such as copper used in electrical wiring—with foreign substances, as well as strict quality control when aluminium ingots contain scrap originating from other industries.
   - Handover to industrial waste contractors: Waste is processed in accordance with each country's industrial waste disposal laws. Waste materials collected for a fee contribute to cost reduction, whilst defective products are also recycled through processes such as shredding. To maintain brand reputation and value, it is essential to verify the reliability of industrial waste disposal contractors and to confirm that the material has been properly shredded.
   - Waste management from non-manufacturing departments (offices, etc.): Paper waste and similar materials are generated and managed in accordance with the company's own internal rules, such as ISO 14000.
4. Challenges and Dilemmas in Promoting the Circular Economy The following structural and economic challenges exist in promoting recycling and the circular economy.
   - The cost and quality barrier: The use of recycled materials and the need to ensure strict sorting and traceability incur costs; in a market where they compete with low-cost car manufacturers, this becomes a factor driving up costs and puts them at a competitive disadvantage.
   - The Dilemma of Continuous Improvement and Capital Investment: As suppliers are constantly engaged in day-to-day improvement activities—such as 'reducing defective products', 'reducing material usage' and 'reducing waste'—it is not guaranteed that a consistent volume of recyclable waste will be generated. Consequently, there is a dilemma whereby even if capital investment is made to facilitate waste reuse, the payback period may be delayed if waste volumes decrease in the future.
   - Structural constraints (challenges in the engineering chain): Suppliers (particularly Tier 2 and below) often do not have their own design departments and, as they lack the authority to specify materials, find it difficult to independently promote the use of recycled materials. Collaboration across the entire value chain, including design departments, is essential.
   - Impact of the informal sector: In developing countries, labour costs are relatively low and a significant amount of valuable materials can be recovered through manual sorting, resulting in a strong

informal sector. This indirectly affects suppliers' resource intensity and economies of scale to some extent.

5. Future Policy Implications and Directions Finally, the following were identified as essential elements for the future promotion of the circular economy.
   - Ensuring economic sustainability: This requires business decisions based on local market structures and cost structures, rather than mere idealism.
   - Development of highly transparent supply chains and digital infrastructure: A digital infrastructure is required to ensure traceability and enable appropriate operation.
   - Changing consumer behaviour and establishing rules: To enable consumers to choose products made from recycled materials and second-hand parts and use them with confidence, it is necessary to formulate quality control standards, establish reliable rules, and educate consumers.

5.2. Mr. Takahiro Oda, Analyst, aiESG Inc.

Mr Oda presented a research report entitled 'Towards Responsible Resource Circulation: An Assessment of the ESG Impacts of Battery Recycling in ASEAN and Regional Variations'.

1. Background to the Presentation and Issue Definition: The adoption of EVs is advancing rapidly across the ASEAN region (e.g. EVs are projected to account for 21 per cent of vehicle sales in Thailand by 2025, and EV sales in Indonesia are set to triple by 2024); whilst this is bringing about desirable changes, it is also giving rise to new challenges.
   - The nickel paradox: Much of Indonesia's nickel smelting relies on coal-fired power (97 per cent), creating a contradiction whereby the uptake of EVs drives an increase in GHG emissions in upstream industries.
   - Concerns over mass battery disposal: As early-generation EVs reach the end of their lifespans, ERIA estimates that up to 2,166 GWh of used batteries will be generated across ASEAN by 2040; however, the current lithium recovery rate across the region is less than 1 per cent.
   - Pressure from EU regulatory developments: These include mandatory carbon footprint disclosure under the EU Battery Regulation, the digital battery passport, and the gradual increase in targets for the content of recycled materials; delays in resource circulation policies are becoming an issue for supply chain competitiveness.
   - Previous research has been characterised by a lack of comparative LCA studies reflecting regional differences, as well as the absence of studies integrating environmental LCA with human rights risk assessment (social LCA). This study therefore aims to: (1) quantitatively evaluate scenarios for improving battery recycling rates in Indonesia; (2) conduct an integrated assessment of environmental and human rights indicators; and (3) demonstrate the impact of differences in chemical composition and regional structures on ESG outcomes.
2. Analytical Methodology (Hybrid LCA)
   - Methodology: Secondary data, such as ecoinvent, was used for key processes including battery cell manufacturing, pack assembly and recycling, whilst multi-regional input-output tables were

employed for upstream processes to cover the entire supply chain whilst reflecting regional differences.

- Scope: NMC (nickel-manganese-cobalt) batteries in Indonesia and LFP (lithium iron phosphate) batteries in Thailand.
- Scenarios: Baseline (0% recycling rate) and future scenario (30% of key metals substituted with secondary raw materials).
- Evaluation indicators: A total of 14 indicators. In addition to six environmental indicators (GHG, fossil resources, mineral resources, water use, biomass use, etc.), human rights and governance aspects (forced labour, child labour, gender inequality, corruption, legal systems, etc.) were quantified as 'risk working hours'.

3. Analysis Results and Key Findings
   - Overall Trends: The results are not uniform; for example, whilst GHG emissions improved by 6.3 per cent in Indonesia and 10.9 per cent in Thailand, water use remained largely unchanged in Indonesia and deteriorated by 15.8 per cent in Thailand, illustrating complex trade-offs.
   - Environmental findings (trade-offs between resource conservation and water): Mineral resource consumption was reduced by 22.3 per cent in Indonesia and 17.0 per cent in Thailand, directly contributing to resource conservation. Meanwhile, an investigation into the cause of increased water consumption in Thailand's LFP batteries revealed that the production of organic solvents used in the recycling process relies on water-intensive agricultural sectors in upstream countries such as Myanmar and Laos. It is essential to give due consideration to technology selection (such as improving solvent recovery rates).
   - Findings regarding human rights (asymmetry based on chemical composition): Results showed that for LFP batteries in Thailand, a recycling rate of 30 per cent led to a 5.7 per cent increase in the risk of forced labour. Whilst NMC contributes to reducing human rights risks (a 5.5 per cent improvement in Indonesia) by substituting primary mined resources (such as cobalt and nickel), cobalt-free LFP batteries present corresponding risks in the supply chains for secondary raw materials used as substitutes, thereby offsetting or reversing these benefits. This is the first time in the ASEAN context that human rights impacts have been demonstrated to vary depending on battery chemical composition.
4. Policy Implications and Recommendations: The direction of resource circulation policies and the shift towards electric vehicles is unwavering; trade-offs are not a reason to halt resource circulation, but rather side effects that should be managed through appropriate technologies and institutional frameworks. The following specific measures were proposed to this end.
   - Institutional framework: Establishment of a formal collection system for used batteries, a certified operator scheme, and a waste tracking database (an urgent priority given the current situation where informal processing is the norm).

- Technology selection and capacity building: Fundamentally reduce dependence on and the burden on upstream water resources by improving the recovery rate of organic solvents, amongst other measures.
- Addressing human rights risks: Tackling human rights risks through measures such as the institutionalisation of social audits of recycling operators based on social LCA.

Furthermore, the importance of designing differentiated policies based on the combination of chemical composition and region, rather than setting uniform targets, was highlighted. For example, it was argued that in Thailand, where LFP batteries are prevalent, priority should be given to establishing a collection system that emphasises GHG reduction, whilst in Indonesia, a nickel-producing country, priority should be given to strengthening measures to reduce human rights risks (such as risk audits).

5. Limitations of the study
   - Restrictions on the system boundaries (emissions during the use and disposal stages, such as those arising from charging power, are not covered).
   - As US data has been adapted for the recycling rate figures, this presupposes that local data in ASEAN countries is properly organised.
   - The informal sector has not been modelled; therefore, the actual risks may be more severe than indicated by these results (underpinning the urgency of establishing an official collection network).

Finally, as a message to government officials, the report concluded that whilst there is no need to hesitate in advancing resource circulation policies, 'responsible resource circulation' can only be achieved by designing institutional frameworks, technology selection and human rights measures as an integrated whole.

5.3. Mr. Ikumo Isono, Senior Research Fellow, IDE JETRO.

Mr Isono presented the results of an economic geographical simulation analysis using the spatial economics model (IDE-GSM).

1. Background to the Research and the Need for this Approach: In the ASEAN region, traditional trade liberalisation—centred on the elimination of tariffs—has reached its final stages, and the region is now entering a phase of enhancing qualitative competitiveness through the reduction of non-tariff measures (NTMs), digitalisation and industrial upgrading. Conventional energy-intensive and resource-consumptive growth patterns are unsustainable; therefore, the reduction of greenhouse gas (GHG) emissions must be regarded not merely as an environmental constraint or a cost, but as a strategic catalyst for the upgrading of the economic structure. Next-generation technologies such as CCUS (carbon capture, utilisation and storage) and hydrogen require enormous initial investment and operational costs; consequently, there are limits to their widespread adoption across the ASEAN region, where fiscal capacity is limited and small and medium-sized enterprises (SMEs) and the informal sector are prevalent. On the other hand, the circular economy can encourage voluntary behavioural changes rooted in corporate economic rationality through the reduction of raw material demand and waste disposal costs, thereby providing a realistic approach to reconciling environmental

goals with economic growth. It was pointed out that the circular economy is the sole driving force behind achieving ‘double decoupling’ (the decoupling of resource use from well-being, and of economic growth from environmental impact), as advocated by UNEP.

2. Overview and Analytical Framework of the Spatial Economics Model (IDE-GSM): In order to go beyond qualitative discussions and conduct a quantitative assessment, we utilised the Spatial Economics Model (IDE-GSM), which captures changes in the economic structure resulting from the price and policy responses of firms and consumers. IDE-GSM is a highly reliable model that has been developed since 2007 as a joint research project between the IDE-JETRO and ERIA, and has been widely utilised by organisations such as the World Bank and the Asian Development Bank (ADB) for analysing the economic effects of international infrastructure development and other initiatives. To compensate for data gaps, we utilised satellite night-time light data and agricultural data, amongst other sources, and converted detailed regional and sector-specific economic activity into GHG emissions (across 10 individual sectors) for analysis. In terms of scenario design, the study covered the period up to 2050 and examined four policy scenarios: a Business-as-Usual (BAU) scenario (with an annual improvement in emission efficiency of 2.3 per cent), combined with GHG reduction targets (–20 per cent or –30 per cent) and an additional efficiency improvement (plus 1.0 per cent or 2.0 per cent per annum) resulting from the advancement of the circular economy.
3. Results and Findings of the Simulation Analysis
   - Balancing economic growth and emissions reduction (mitigating trade-offs): Whilst stringent reduction targets typically have a negative impact on GDP, in cases where efficiency improvements through the circular economy are substantial (Efficiency +2.0), these trade-offs are significantly mitigated or offset. In particular, the ‘GHG −20%, Efficiency +2.0’ scenario confirmed that economic growth significantly exceeding the Business-As-Usual (BAU) scenario would be achieved across ASEAN as a whole.
   - Regional Impacts: A broad-based boost to GDP was observed, particularly in existing industrial clusters such as the Bangkok metropolitan area, southern Vietnam, Java, Malaysia and Singapore. This demonstrates the potential for ASEAN to be selected globally as a clean and efficient production hub.
   - Contributions by sector: Whilst the ‘electricity and heat supply’ sector—the largest source of emissions—offers the greatest reduction potential, the contribution of ‘other manufacturing (e.g. steel)’ is also significant. Furthermore, as the ‘agriculture’ sector accounts for a large proportion in countries such as Cambodia, Laos and Myanmar, the analysis highlighted the need for approaches tailored to the industrial structures of individual countries and regions. Furthermore, resource conservation and reuse through a circular economy will structurally reduce energy demand, thereby alleviating the burden on the roll-out of renewable energy and grid development.
4. Policy Recommendations and Conclusions: Based on the analysis, the following policy recommendations were put forward.

- Government and regional cooperation: Establishing waste regulations and an EPR scheme; creating mechanisms to integrate the informal sector into the formal sector; and strengthening wide-area power interconnections, such as the ASEAN Power Grid.
- Businesses: Optimising resource utilisation through digital technologies and establishing 'inter-industrial symbiosis' whereby waste is exchanged between industries.
- Support from Japan: Comprehensive support, including policy research assistance via AEM-METI, sharing of know-how on building a circular economy, provision of efficient recycling technologies, and public-private partnerships in the battery industry.

In conclusion, it was stated that the circular economy represents a 'realistic and sustainable pathway' for ASEAN countries to achieve GHG reductions without sacrificing economic growth; by delivering direct cost savings to businesses, it encourages voluntary behavioural change and serves as a powerful engine enabling dual decoupling.

5.4. Prof. Dr. Masahiro Nakamura, Professor, Tokyo City University; CEO, LEXER Research Inc.

Dr Nakamura delivered a presentation entitled 'Knowledge-Driven Engineering Based on Collective Wisdom and the Social Implementation of the Circular Economy'.

1. The Background to the Need for Knowledge-Driven Engineering and Industrial Structural Transformation: The aim of industrial structural transformation should not be merely the digitalisation of business processes, but rather a transformation of the very structure through which industries are organised to create value. It is necessary to reshape this into a new social system that integrates digital technology, cyber-physical systems (CPS), Industry 4.0 and AI. This ties in with the vision of 'SEZ (Special Epistemic Zone / the concept of data policy)' outlined in the Musashino Reflection 2025; it is an approach that involves strategically and policy-wise designing the scope within which information is integrated to generate unique value. This approach, which has the potential to become a hyper-decentralised ecosystem transcending geographical boundaries, is positioned at the core of the ASEAN and global strategies aimed at achieving balanced growth whilst respecting the characteristics of each region.
2. A Three-Tier Structure and Stakeholder Network for Realising a Circular Economy: As an international strategy for the societal implementation of a circular economy, an architecture comprising the following three tiers (layers) was proposed.
   - Layer 1 (Top Layer): Industrial design for the circular economy
   - Layer 2: Stakeholder, business and social networks (design and implementation of an ecosystem of business players supporting the circular economy)
   - Layer 3 (Physical Layer): Operations via physical networks

To realise the circular economy, the 'circulation of knowledge'—which leads stakeholders to practical action—is the key to overcoming bottlenecks.

3. The blind spots of generative AI and the need for 'collective wisdom': Whilst generative AI (large language models / LLMs), which are currently gaining popularity worldwide, provide general knowl-

edge, they have 'blind spots' in that they are unable to capture the specific and unpredictable nature of business environments, nor the tacit knowledge and operational strengths unique to individual organisations. As generative AI and physical AI alone cannot replace all aspects of work, a 'knowledge strategy'—that is, 'Collective Wisdom (CW)'—which serves as a bridge between methodology, knowledge and operational execution, becomes of paramount importance. The CW ecosystem is a mechanism that systematically extracts, formalises and accumulates the practical knowledge of experts, facilitates cross-border networking, and circulates knowledge throughout the organisation. This is not intended to delegate decision-making to AI and replace human capabilities, but rather to extend and enhance human judgement. It accelerates the maturation of knowledge and the development of talent through practical work, and fosters 'insights' among engineers on the front line.

4. CW Platform Technology and Implementation: The CW platform consists of the following three layers and a feedback loop.
   - Practical Knowledge Sharing Layer: Accumulates experts' knowledge as a 'world model'
   - Interaction Layer: Provides knowledge to support problem-solving by engineers and operators on the shop floor
   - CPS Layer: Links data from physical activities to knowledge
   - LTE Loop (Learning, Thinking, Execution): A mechanism for accumulating experience within the knowledge system, rather than within individuals, through a process of learning, executing and then learning again.

In implementing this global model, we are incorporating the concepts of 'Kaizen' and the 'Lean Production System' (a philosophy of manufacturing efficiently and without waste) that Japan has cultivated, and are working to establish a 'Knowledge Bank' to share the insights of Japanese experts with people around the world, including those in ASEAN. In practical trials applying these concepts to manufacturing sites—such as quality control, production line design and equipment maintenance—significant results have been achieved; for instance, even engineers with little experience (those in their first to third year) have been able to solve problems at a level approaching that of seasoned professionals (with ten years' experience).

5. Summary and Conclusions: Dr Nakamura concluded his presentation by emphasising the following three points regarding knowledge strategy.
   - An ecosystem that transforms industrial structures: The value of data and knowledge assets does not diminish over time but increases, and they should be utilised within an ecosystem that realises new industrial structures.
   - The need for a new knowledge approach: Current AI is incapable of understanding complex manufacturing environments or the intentions of experts; therefore, a new knowledge approach (CW) to replace it is essential.
   - Social knowledge that transcends national borders: The framework of the CW ecosystem itself constitutes social knowledge, and its social implementation will be advanced as an effective means of realising a circular economy through knowledge transfer to supply chains and the Global South.

5.5. Q&A

The panellists (Dr Ueki, Mr Oda, Mr Isono and Dr Nakamura) each responded to questions from the audience and those submitted online.

- Profitability as a business and the development of a circular model (Dr Ueki and Mr Oda) Whilst 'profitability (the economy first)' is essential for realising a circular economy, there are limits to what individual companies can achieve on their own. To secure sufficient volume and ensure the sector's viability, it is necessary to centre efforts on the Automotive and battery sectors whilst involving players from existing 'reverse logistics' industries, such as those dealing in second-hand parts and vehicle dismantling. Furthermore, there is a need to design incentives to promote the formalisation of the informal sector and to review supply chains from a global perspective.
- An Economic Perspective and Balance (Mr Isono) The circular economy is a classic example of an externality problem, and it may appear costly for individual companies. To resolve this, it is important to strike a balanced combination of four elements: regulation, incentives, market formation and information (digitalisation). Furthermore, by utilising a spatial economics model (IDE-GSM), it is possible to quantitatively assess dynamic changes in the behaviour of businesses and consumers, regional disparities at prefectural and state levels, and the effects in industrial clusters (such as the simultaneous increase in GDP and reduction in GHG emissions in areas around Bangkok and on the island of Java), thereby enabling the prioritisation of efficient policy interventions.
- Stakeholder Networks and Knowledge Strategy (Dr Nakamura) To implement the circular economy in society, it is essential to design an ecosystem involving stakeholders, rather than simply accumulating 'as-is' elements. Rather than leaving everything to AI, it is vital to utilise 'collective wisdom'—which systematises the 'Kaizen' and practical knowledge cultivated in Japan—and to establish mechanisms for circulating and sharing knowledge across national borders.
- Policies and Common Standards at the National and ASEAN Levels (Dr Ueki) The discussions on issues such as the utilisation of ATIGA in Thailand, national planning, and the establishment of common standards and traceability for the cross-border movement of resources were highly insightful. It is necessary to deepen these discussions as part of public-private policy dialogue and practical measures between Japan and ASEAN through forums such as AMEICC.

6. Session 2: Roundtable Discussion, challenges and opportunities of the development of circular economy system in the ASEAN (Moderator: Prof. Fusanori Iwasaki, Consulting Fellow of RIETI)

6.1. Mr. Cuong Ba Tran, Assistant Director, and the Head of the Trade Facilitation Division, ASEAN Secretariat.

Mr Tran gave a presentation on the circular economy and 'remanufacturing'.

1. Background to the Publication and Policy Timing: The publication of the findings of this study is extremely timely. Currently, the revised ATIGA has been signed and is scheduled to come into force at the end of this year; furthermore, an agreement in principle has been reached to conduct negotiations next year towards the upgrading of the ASEAN-Japan EPA, making it extremely important to incorporate the findings of this study into those negotiations. Against this backdrop, we will share the key issues concerning ‘remanufactured products’ and the ‘circular economy’ as highlights of the RCEP (Regional Comprehensive Economic Partnership), which is due to be upgraded this year and come into force at the end of the year.
2. Private-sector demand and the reality of the remanufacturing business New free trade agreements (FTAs), such as the RCEP, incorporate issues such as remanufactured products, trade and the environment, supply chain connectivity and the circular economy as ‘next-generation challenges’. As a concrete example of business demand, the case of ‘Fujifilm Optics’, which has established a presence in the Philippines, was cited. The company imports ‘used multifunction printers’ and other equipment for reuse in the Asia-Pacific region; it then dismantles, cleans and repairs them, replacing irreparable parts with new ones to transform them into new multifunction printers, and exports 70 per cent of these to other countries. In the ASEAN region, companies such as HP from the US and Caterpillar from Indonesia (construction machinery and heavy goods vehicles) are also engaged in similar remanufacturing businesses. Remanufacturing business models are indispensable for realising a circular economy. In light of developments in Europe, where recycling and remanufacturing are being promoted from the perspectives of environmental and economic security, now is the optimal time to embrace new models with a view to establishing global standards.
3. Legal frameworks in FTAs and progress under the RCEP: In order to adopt such models, it is necessary to amend the legal frameworks and provisions within FTA agreements (such as the upgraded RCEP and the ASEAN-Plus-1 FTA). At last year’s workshop in Manila, the business community strongly advocated for the incorporation of the concept of ‘remanufacturing’ into the upgraded RCEP, and this year, remanufacturing was finally successfully incorporated into the upgraded RCEP. At present, three member states have accepted this rule; however, the remaining seven countries intend to monitor developments closely over the next five years and consider adoption once they have assessed the results. Professor Nishimura and his colleagues were asked to raise this issue with leaders at the summit in November this year and to advocate for its formal inclusion in next year’s EPA negotiations.
4. Definition, benefits and distribution challenges of remanufactured products
   - Positioning and definition: Remanufactured products are not ‘second-hand goods’ but ‘as good as new’. They are remanufactured in factories to meet the same technical and safety standards as new products, and come with a manufacturer’s warranty card. This is based on standardised definitions already adopted in agreements such as the CPTPP and the FTA with the EU.
   - Benefits: They align with the SDGs, contributing to the conservation of natural resources, waste reduction, the abatement of CO_2 emissions, significant cost savings and the creation of domestic jobs.

- Process: They undergo a series of processes comprising dismantling, thorough cleaning, repair of worn or damaged parts, reassembly and the issuance of a warranty certificate.
- Trade treatment: Import bans or restrictions on second-hand goods (such as those under the Basel Convention) do not apply to remanufactured goods; they are permitted to circulate freely without barriers amongst certain ASEAN member states, as they are treated as equivalent to new goods (duty-free due to the 0% tariff on industrial products within ASEAN).

5. Requests from the private sector and future prospects: The private sector has expressed a keen interest in ensuring thorough awareness of the upgraded provisions (including explanations of key provisions, technical guidance and the setting of parameters). Finally, it was emphasised that, in order to establish a common circular economy market across the region, common standards and traceability are essential—rather than simply moving waste across borders—and expectations were expressed that today's discussions would lead to further cooperation.

6.2. Mr. Jen-nio Gabinete Hung, En Tsumugi Inc.

Mr Hung gave a presentation on initiatives and challenges relating to automotive dismantling and recycling from a business perspective.

1. Company Overview and Background to Establishment En Tsumugi is the Philippines' first ELV dismantling operator to meet Japanese standards, and the first company to be certified and standardised by Toyota Motor Corporation. The following three organisations are cited as key partners on the Japanese side:
   - 'Tsuruoka', a Japanese ELV dismantling operator with a 100-year history
   - 'JARC (Japan Automotive Recycling Centre)', which provided financial support for safe surveys and research to launch the project
   - 'Mitsui & Co.', a long-standing and influential domestic trader. In addition to these, the company was established in line with the vision of Toyota's 'Environmental Challenge 2050'. The circular economy in the Automotive industry involves minimising waste through the collection and safe dismantling of ELVs, the proper sorting of materials, and material recycling; as electrification progresses, appropriate dismantling forms the foundation of the Automotive economy.
2. Three Challenges Faced in Business Operations: Since commencing operations in September 2024, the company has faced the following challenges.
   - Lack of a comprehensive ELV policy: Whilst environmental regulations exist, a unified legal framework clearly governing the proper collection, dismantling, recycling and disposal of ELVs has not yet been established.
   - High compliance costs: Operating facilities to Japanese standards requires substantial investment, specialised equipment, environmental protection measures and staff training, which drive up costs but are essential for responsible recycling.
   - Unfair competition from informal operators: Informal operators, who do not necessarily adhere to environmental and safety standards, are able to keep costs low, creating an unfair competitive

environment for the company, which complies fully with regulations. The company cites 'traceability' as its greatest strength in countering this. As the Philippines lacks a JARC-centred recycling law similar to Japan's, the company ensures that, within its vehicle purchase model, all parts are thoroughly recorded in ledgers, enabling the proper disposal of hazardous substances and the safe recovery of reusable parts.

3. Market Opportunities and Case Studies in the Philippines With the Philippine population growing and the electrification of vehicles progressing rapidly (according to figures released by CAMPI and VPA, sales rose by 130 per cent in the first five months of 2026), there are immense opportunities in the ELV dismantling sector. Given the rapid growth of EVs and PHEVs, it is essential to prepare for the future management of end-of-life vehicles. Establishing an appropriate ELV system will lead to the recovery of resources such as steel and non-ferrous metals, a reduction in the need for new mining and environmental damage, and the creation of a sustainable ecosystem. The following case studies were presented as concrete examples of achievements:
   - Suzuki Motor Philippines: Received approval for the ELV dismantling of vehicles that had previously posed handling difficulties.
   - MG Philippines (fire incident response): In 2025, when a fire in the neighbourhood threatened to completely destroy more than 190 brand-new vehicles—including ICE vehicles, hybrid vehicles and EVs—En Tsumugi safely transported all the vehicles to its facility without incident, whilst other companies without specialist knowledge of EVs and similar vehicles shied away from the task. A key factor in the successful and safe completion of this operation was that, prior to the incident, I had personally visited 'Toyota Metal' in Nagoya to receive appropriate training on the handling of EV batteries and PHEVs, as well as to learn about Japanese standards, alongside Toyota personnel from Thailand and Japan.
4. Expectations of the Government and the Academic Community, and Conclusions
   - Expectations of the Government: The establishment of ELV-related legislation, the enforcement of laws, and the introduction of incentives (equivalent to subsidies provided by Japan's JARC, for example) for recycling operators who comply with regulations.
   - Expectations of the Academic Community: Data policies, institutional development, and the continuation of symposia and forums for academic discussion.

Finally, it was emphasised that building a circular Automotive industry is a responsibility shared not only by individual nations but by the ASEAN region as a whole, and a commitment was expressed to establish a sustainable ELV ecosystem through cooperation between industry, government and academia, as well as knowledge sharing between ASEAN and Japan. It was emphasised that En Tsumugi's Japanese-standard practices would serve as a model for building a resilient and sustainable Automotive industry for the future of the entire region, in line with ASEAN's motto of 'One Vision, One Identity, One Community'.

6.3. Mrs. Nuchanat Suphansri, Management and Treatment Technology, Department of Industrial Works (DIW)

Mrs Spancy presented the findings of a study on ‘Establishing a Comprehensive Management System for ELVs in Thailand’, carried out as part of a collaborative project with JICA.

1. Background and Current Challenges Since 2000, automotive sales in Thailand have grown steadily at an annual rate of approximately 800,000 to 1 million units, and in recent years there has been an increase in the use of alternative energy sources and EVs. Furthermore, whilst there is a large-scale second-hand parts market comprising salvaged and imported parts, hazardous waste such as refrigerants, waste oil, batteries and lithium-ion batteries are not integrated into an efficient management system, and there is a lack of a comprehensive tracking system covering the entire process from dismantling to final disposal. Furthermore, as automotive vehicles are expensive in Thailand, there is a tendency for them to be used for long periods; the system whereby annual tax (automotive tax) decreases for older vehicles does not serve as an incentive to purchase new ones. The lack of accurate figures on the number of end-of-life vehicles (ELVs) and tracking data also poses obstacles to research and management.
2. Collaborative Project with JICA and Research Methodology: As a model case to address these challenges and promote a circular economy, a collaborative project with JICA was launched in August 2024. The project has set out six deliverables, including the development of a management system, an ELV tracking mechanism, and proposals for recovery and reuse guidelines, and is advancing its operational plan in collaboration with the Industrial Bureau of the Ministry of Industry, the Land Transport Bureau, the Pollution Control Department (PCD), and relevant government agencies and private sector companies. Between April and July, in addition to a desktop review of existing data, interviews were conducted with insurance companies, auction houses and dismantling contractors to map material circulation flows and identify policy gaps.
3. Results of the data analysis
   - Vehicle numbers: According to forecasts for the end of 2024, the number of registered motor vehicles in Thailand is expected to reach approximately 45 million, of which more than 6.5 million will be vehicles that have been in use for 15 years or more. However, only around 26,000 vehicles per year are officially and completely deregistered (under a system whereby vehicles are automatically deregistered after three consecutive years of unpaid tax).
   - ELV Flow: Approximately 90 per cent of ELVs originate from insurance companies and are channelled through auctions or sold for scrap.
   - Proportion of Parts: It has been found that approximately 60 per cent of ELV parts are reusable.
4. Identified Policy Gaps and Conclusions: Thailand has not yet introduced an EPR system, nor does it have any financial mechanisms in place to support the management of low-value materials and hazardous waste. Furthermore, there is a lack of tracking of various components within the system. In order to establish an environmentally sound end-of-life automotive management system, clear regulations, the accountability of vehicle owners and manufacturers, a tracking system, data integration

with deregistration procedures, and the development of financial mechanisms are essential. The report concluded by stating the aim to raise the standard of ELV management in Thailand and establish it as a model case capable of creating and applying a balance between economic value, safety and the environment.

6.4. Dr. Lai Van Manh, Head of the Department of Natural Resources and Environmental Economics, Institute of Strategy and Policy on Agriculture and Environment (ISPAE).

Dr Manh gave a presentation on policy and regulatory developments relating to the circular economy in Vietnam, focusing in particular on the current situation and challenges in the electric vehicle battery sector.

1. The Evolution and Positioning of Circular Economy Policy in Vietnam
   - Phase 1 (2016–2020): The concept of the ‘circular economy’ was introduced to Vietnam through the World Economic Forum (WEF) and Japanese experts, amongst others, and provisions relating to the circular economy were incorporated into the Environmental Protection Law for the first time.
   - Phase 2 (2021–2025): The circular economy was positioned as a key priority for environmental protection and climate change adaptation within the National Socio-Economic Strategy, and detailed guidelines—including standards, the responsibilities of various ministries, agencies and local authorities, and preferential policies—were established under the Law on Environmental Protection.
   - Next Phase (Policy looking ahead to the 14th Party Congress and beyond): The circular economy is positioned not merely as a ‘solution for environmental protection’ but as a fully-fledged ‘eco-economic model (economic and industrial model)’, and work is underway to formulate detailed standards and incentives, as well as to revise regulations (such as the development of a circular taxonomy and amendments to the Environmental Protection Law).
2. Definition of the Circular Economy and Legal and Policy Incentives: The Circular Economy is defined in Vietnam’s Environmental Protection Law as ‘an economic model aimed at reducing the extraction of raw materials, extending the life cycle of products, reducing waste generation, and minimising the adverse environmental impacts of economic activities through design, production, consumption and service activities’. The government is implementing preferential policies relating to taxation, fees, land and capital, in addition to investing in data, building platforms and conducting research and development. Furthermore, it has submitted a ‘National Action Plan on the Circular Economy’ with a target date of 2035 and is updating standards and regulations to align with the ASEAN’s Circular Economy Framework.
3. Current Situation and Challenges in the EV Battery Sector: Vietnam was one of the first countries in ASEAN to introduce the EPR principle, and Automotive batteries and cells are also covered by EPR. Whilst the government requires companies to meet statutory recycling targets, unlike with plastics or steel, the battery sector faces the following major challenges:

- Shortage of recycling operators: There are still very few commercial-scale EV battery recycling facilities or established reuse businesses within Vietnam; the country is currently in the stage of promoting pilot projects and initiatives.
- Concerns for the future: With the transition to green transport and the promotion of the shift to EVs in pursuit of net-zero targets, it is anticipated that large volumes of EV waste and battery-related challenges will arise in the future, necessitating the development of urgent national solutions.

Finally, it was concluded that promoting battery recycling through cooperation with Japan and other Asian countries is in line with Vietnam's policies and regulations and represents an important direction for the future.

7. Session 3: Roundtable Discussion, towards the human resource development for developing circular industry in the ASEAN Moderator: Prof. Mitsuhiro Maeda, Professor of Advanced Institute of Industrial Technology (AIIT)

During 'Session 3, Pror Mitsuhiro Maeda acted as moderator, and a discussion took place with panellists from leading engineering universities and other institutions representing ASEAN.

Prof. Maeda emphasised that promoting a circular economy is not merely a matter of recycling or environmental consideration, but rather an initiative to cultivate from scratch an entirely new and vast industrial network known as the 'circular industry' (the 'venous industry' as opposed to the 'arterial industry'). Industrial policy aimed at fostering this new industry requires three essential elements: (1) funding, (2) technology (including quality standardisation), and (3) 'human resources'. Drawing on the history of MIT's 1980s study on the 'Lean Production System'—which highlighted the presence of 'highly skilled industrial personnel (middle management)' possessing leadership and communication skills to guide workers, in addition to advanced technology and managerial capabilities, as a key strength of the Japanese Automotive industry—he pointed out that the development of 'highly skilled circular industry personnel' is of critical importance in supporting the new circular industry. It was explained that the purpose of this session was to serve as a forum for discussing whether higher education institutions —which are responsible for developing such highly skilled professionals—within ASEAN have the necessary systems in place, and whether human resource development is acting as a bottleneck.

7.1. Prof. Alvin B. Culaba, Distinguished Professor and University Fellow, De La Salle University

Prof. Culaba delivered a presentation entitled 'Transforming Higher Education in the Philippines towards a Circular Economy and Sustainable Industrialisation'.

1. The Current Situation in the Philippines and the Need for a Circular Economy: Whilst the Philippines possesses a young and abundant demographic dividend, growth in the higher education sector driven by free education, and strengths in key supply chains such as semiconductors, electronics and

automotive components, it also faces challenges including a concentration on low- to medium-value-added activities such as assembly and processing; dependence on imports of advanced technologies; limited investment in research and development; high energy costs; and logistical challenges specific to an archipelagic nation. Circular industrialisation presents significant opportunities for improving resource productivity, reducing dependence on imports, minimising waste and creating high-value-added employment; however, this will require a new type of specialist workforce different from that of the past.

2. The Role and Challenges Facing Higher Education Institutions: Whilst there are over 2,000 universities in the Philippines, industrial competitiveness is not determined by the number of graduates alone. There remains a mismatch between 'what is learnt in the classroom' and 'what is required in the workplace', and whilst academic staff may be engaged in research, there is often a lack of pilot plants and sustainable partnerships with industry. Higher education must be closely linked to national industrial policy and must address not only the question of 'what courses should be offered', but also 'which industries should be developed and who are the highly specialised professionals to lead them'.
3. The 'Three Integrated Competencies' Required of Professionals in the Circular Economy: Prof. Culaba identified the following three competencies as those that should be developed simultaneously, rather than in separate domains.
    - Competencies in technology and high-tech: In addition to adapting to advanced manufacturing, this involves understanding circular economy tools such as LCA (Life Cycle Assessment) and material flow analysis, and learning new methods for designing and managing existing industries such as electronics. The ability not merely to operate imported technologies, but to adapt and refine them to local conditions and create suitable technologies.
    - Management and leadership skills: Managing the transition from research to application (including project management, supply chains, intellectual property and technology commercialisation). Furthermore, the 'ability to build coalitions'—which involves reconciling conflicting interests and managing cross-disciplinary teams—as well as ethical leadership that underpins environmental justice, worker safety and inclusive regional development.
    - Communication and stakeholder engagement skills: The ability to engage with a diverse range of stakeholders, including communities, businesses, policymakers, workers, investors and informal waste workers. Skills in evidence-based, honest communication and the preparation of various reports and proposals to prevent greenwashing and safeguard social trust.
4. Five Proposals and Future Approaches: The following five points were proposed as specific methodologies to be pursued by the Philippines and ASEAN.
    - Development of a national circular economy competency framework
    - Roll-out of cross-disciplinary and stackable educational programmes (a combination of degrees, micro-credentials, professional certificates, etc.)
    - Establishment of shared regional laboratories and pilot facilities
    - Promotion of institutionalised industry-embedded learning

- Strengthening ASEAN–Japan cooperation in higher education (joint degrees, academic staff exchanges, scholarships, technology transfer, etc.)
- Furthermore, the importance of supporting 'regional specialisation'—tailored to each region's economic strengths and ecological resources—was emphasised as a means of avoiding excessive concentration in Metro Manila.

5. Conclusion: The future of the circular economy in the Philippines will be determined not only by the technologies it acquires, but also by the calibre of the people it nurtures and the opportunities they are given to take the lead. It was concluded that an integrated system linking education, research, industrial leadership and national development is required to cultivate Filipino professionals capable of spearheading industrial transformation, generating technology and building a resilient and sustainable national economy.

7.2. Prof. Nita Yuanita, Dean, Faculty of Civil and Environmental Engineering, Institut Teknologi Bandung

Prof Yuanita delivered a presentation entitled 'The Role of ITB in the Development of the Circular Economy'.

1. Overview of the Institut Teknologi Bandung (ITB): Founded in 1920, ITB is Indonesia's oldest and most prestigious university of technology, currently ranked first in Indonesia and 287th in the world in the QS World University Rankings. It comprises 12 faculties covering engineering, the arts, and business and management, and contributes to the development of the circular economy in Asia through education, research and collaboration with the local community.
2. The role of higher education and a shift in mindset within the circular economy: It was noted that the greatest barrier to a circular society lies in 'mindset (awareness)', and that higher education plays a crucial role in embedding sustainability into the curriculum and promoting innovation through research and social contribution. Compared to traditional higher education, circular education emphasises not only economic growth but also sustainable growth achieved through waste reduction, resilience, innovation, and partnerships involving governments and local communities. ITB proposes the following four roles:
   - Curriculum and skills development
   - Activities related to transforming mindsets and culture
   - Research, social contribution and innovation
   - Contributions to policy and industry partnerships
3. Specific Approaches to Education and the Curriculum: ITB offers the following three types of classes and courses.
   - University-level compulsory core modules: We offer 'Introduction to the Principles of Sustainability' and 'Introduction to Engineering', enabling students to consider not only technical challenges but also the implications of sustainability by learning the principles of the circular economy and circular industries.

    - Compulsory core modules common to all programmes
    - Elective modules
4. Research, Social Contribution and Industry-Academia Collaboration Initiatives: ITB's research aligns with the UN's Sustainable Development Goals (SDGs) – in particular Goal 9 on industry, innovation and infrastructure, and Goal 4 on quality education – and the following specific initiatives are being implemented:
    - Circular Dago: A community-led initiative in which students and local residents collaboratively co-create solutions for waste management, transforming waste into a source of wellbeing.

- Eco-educational tourism and art festivals: Initiatives such as 'Eling Earth' and 'Surga Hijau'.
    - ▸ PISCES Living Lab: Supported by organisations such as UK Research and Innovation (UKRI), this initiative conducts research on waste management and provides education for students and the local community.
    - ▸ Joint research laboratory partnerships with private companies: We collaborate with companies in the recycling sector to provide scholarships for Master's and PhD programmes and to facilitate mutual research exchanges.
    - ▸ Triple Helix Sustainability Event: We organise events inviting representatives from government, ministries and the private sector to discuss topics relating to sustainability and the circular economy.
    - ▸ International Summer School: We promote collaboration amongst students from Japan and overseas (including Indonesia, Malaysia and Japan).

5. Conclusion: ITB's progress in developing human resources for the circular economy has been achieved through a combination of curricular innovation, outstanding research, community empowerment and international cooperation. It was concluded that we can build a future in which sustainability is viewed not merely as a matter of compliance but as a commitment on the part of the university, and that ASEAN and Japan can work together to pave the way for the creation of a resilient and inclusive circular economy model.

7.3. Prof. Mohd Naz'ri Mahrin, Dean, Faculty of Artificial Intelligence, Universiti Teknologi Malaysia

Prof Mahrin delivered a presentation entitled 'Artificial Intelligence (AI) and its Role in the Circular Economy (CE)'.

1. Opportunities and the skills gap in the circular economy: Whilst the introduction of a circular economy at the ASEAN level presents a significant opportunity to generate approximately US$324 billion in potential economic growth and create 1.5 million new jobs, it is facing a severe skills shortage (a gap in green and circular economy skills). Whilst the growth rate of green job vacancies within the ASEAN region stands at 30 per cent, the workforce possessing the relevant skills is growing by only 6 per cent annually. The following points were identified as structural barriers to preventing this skills gap:
    - A mismatch between industry needs and university curricula

- A shortage of sufficient manpower
- Fragmentation of training provision (proliferation of similar initiatives across multiple ministries and a lack of coordination)
- Low levels of AI and data literacy

2. The framework required for professionals supporting the circular economy: Prof Mahrin proposed the following elements as competencies for the development of future professionals.
   - Technical and material skills: Life Cycle Assessment (LCA), eco-design, reverse logistics, and re-manufacturing materials science. Additionally, technologies utilising AI to discover new composite materials and other materials.
   - Digital and AI literacy: Operation of IoT sensors; the use of AI to analyse big data; computer vision and sorting for waste management and separation; predictive maintenance; integrated monitoring systems; and expertise in data interpretation.
   - Systems thinking and sustainability thinking: Mastery of industrial ecosystems (industrial symbiosis), the design of circular business models, and carbon and resource accounting.
   - Entrepreneurship and collaboration skills: The ability to build cross-regional cooperation, including the Quadruple Helix (industry, academia, government and civil society), and to break down silos (isolation).
3. Examples of AI usage to accelerate circularity: AI serves as a powerful support tool at every stage of the circular economy ecosystem.
   - Design stage: Development of new materials utilising generative AI and 'Large Material Models'.
   - Production and utilisation stage: Improving on-site efficiency through the use of IoT, computer vision and predictive maintenance.
   - Recovery stage: AI-powered robotics, sensors, sorting and grading. This includes the automatic identification, classification and extraction of high-value components using computer vision on Automotive dismantling lines, as well as the intelligent separation of critical minerals and resources, such as those found in sodium-ion batteries.
4. New job roles (employment) required in the circular economy: It has been pointed out that the convergence of AI and the circular economy will create a need for the following new job roles in the future.
   - AI sorting technician
   - Circular data analyst
   - Industrial ecosystem broker (a professional who manages matching algorithms to reduce waste by connecting suppliers and demand)
   - Predictive maintenance engineer
5. Summary and Five Key Points: Finally, five key recommendations for human resource development and policy implementation were put forward.
   - Focus on curriculum development: Collaborate with industry to ensure that programmes meet students' needs.

- Unlock circular finance: Secure investment and funding.
- Establishing an inter-regional credential mobility scheme: Enhancing professional mobility across the entire ASEAN region.
- Targeting workers transitioning from or being displaced by the linear economy: Providing existing workers with opportunities to engage with the circular economy (the measure that should be prioritised).
- Scaling up circular innovation amongst young people: instilling the right mindset in young talent.

The report concluded by emphasising that, ultimately, however many policies or technologies there may be, it is 'people' who put them into action, and that human resources are the number one factor underpinning the initiative.

7.4. Prof. Masamu Kamaga, Visiting Professor, Asian Institute of Technology (AIT)

Mr Kamaga delivered a presentation entitled 'Human Resource Development to Bridge the Circular Economy and Reality (the Circular Industry)'.

1. The need for human resource development to realise a circular industry: In order to transition the circular economy from a concept to an actual 'circular industry' (reality), it is necessary to cultivate a new industrial network from scratch, including the integration of 'arterial' and 'venous' industries and the incorporation of the informal sector into the formal sector. Whilst primary and secondary education and vocational training institutions play their respective roles, higher education institutions (particularly at postgraduate level) are responsible for developing human resources with a broad range of practical skills and the ability to implement solutions in society. The following three requirements have been defined for the 'highly skilled circular industry professionals' necessary to build a circular industry:
   - Implementation skills: The ability to apply new policies and technologies in the field and bring them to fruition.
   - Coordination skills: Communication skills and teamwork that enable mutual understanding and the formation of consensus amongst diverse stakeholders.
   - Strategic leadership: The ability to pioneer a new, uncertain world and lead people forward.
2. Insights from the Japanese Higher Education Model (Case Study: Advanced Institute of Industrial Technology: AIIT): As universities across ASEAN continue to transition towards Outcome-Based Education (OBE), the educational model of Japan's 'AIIT', which implements a rigorous competency-based education programme, was presented. At AIIT, competencies are defined as communication, consensus-building, project management, continuous learning, teamwork and problem-solving skills. Through a one-year programme of Project-Based Learning (PBL), students undertake a cycle ranging from problem definition to analysis, design, social implementation and evaluation in collaboration with industry, thereby developing practical skills relevant to the workplace. It is argued that introducing this model to ASEAN would create an ecosystem capable of producing, in a timely manner

and in line with industry needs, cross-disciplinary professionals with the practical skills required to build circular value chains.

3. A phased approach in ASEAN and future prospects: As establishing a new postgraduate programme from scratch presents a significant challenge, it was proposed to begin by introducing 'short courses' comprising one or two credits, based on a defined concept, at universities in ASEAN countries (such as the Philippines, Indonesia and Malaysia). It was suggested that an effective approach would involve gradually gathering insights tailored to the varying educational and industrial contexts in each country, whilst having Japanese companies (such as Denso and other industry partners) share their practical expertise and challenges with students, thereby fostering a mechanism for joint talent development and the generation of new ideas. Ultimately, a strong commitment was expressed to building an ecosystem that transforms the concept of the circular economy into a tangible industrial reality by strengthening collaboration between universities within the ASEAN region, as well as partnerships between industry, academia and government, through the development of highly skilled professionals for the circular economy.

7.5. Q&A

During the question-and-answer session, Prof Maeda, the moderator, posed the following question: 'In order to cultivate highly skilled professionals for the circular economy, can this be achieved whilst retaining the existing university structures, or will it require the reorganisation or establishment of new faculties, and to what extent would this be difficult?' The panellists (representatives from the respective universities serving as APEN board members) then expressed their respective views.

- Prof Culaba's response

Prof Culaba emphasised the importance of accurately analysing strengths, constraints and opportunities within one's own country's industrial context. Whilst the Philippines possesses a talent pool of young, highly motivated individuals (a strength), there are also constraints such as a reliance on imported technology and the fact that maintenance personnel are struggling to keep pace with new technological developments, such as electric vehicles. He also noted that, as older members of the academic community can sometimes be resistant to change, it is necessary to assess the country's actual circumstances before determining where to focus appropriate training for professionals.

- Prof Yuanita's response

Prof Yuanita pointed out that, as the industrial implementation of the circular economy involves diverse aspects, students require both strong technical competencies and strong soft skills such as project management, leadership and communication. She addressed the challenge of whether new faculties or programmes should be created from scratch—given that existing programmes tend to be biased towards technology and engineering—or whether existing foundational frameworks should be utilised to blend and strengthen soft skills and the circular economy dimension.

- Prof Mahrin's response

Prof Mahrin stated that the first step in developing professional talent is to 'instil the right values'. He emphasised the importance of value-based education (VBE)—which emphasises integrity and sustainability and is currently being implemented in Malaysia—and ESD education based on the SDGs. He stressed that, as complex challenges cannot be addressed by a single academic discipline, there is a need for transdisciplinary programmes in which experts from fields such as economics, manufacturing and AI work together. He also argued that in today's world, where technology is changing at the speed of light, a system of 'lifelong learning'—where learning becomes a way of life—is indispensable.

- Prof Kamaga's response

Prof Kamaga pointed out that, as a general rule, there is always a structural gap between universities and industry, as there is inevitably a time lag before innovations arising in industry are reflected in university education via research, journals and textbooks. He concluded by stating that, in order to bridge this gap and develop practical talent tailored to the needs of industry, it is of the utmost importance for the government and industry to actively support universities and to build an ecosystem and collaborative framework in which academia and industry work as one.

7.6. Conclusion

The three clear concluding messages summarised by Prof Maeda, who acted as moderator, are as follows.

- First message: The need for highly skilled professionals in the circular economy. To foster the circular economy, it is essential to develop 'highly skilled professionals in the circular economy' with specialised abilities, and only higher education can fulfil this role. Whilst there were slight differences amongst the panellists in how they described and categorised the required skills (such as technical, managerial, leadership, communication, AI literacy and systems thinking), the overall direction and the essence of the specialised skills required were consistent.
- Second Message: The Need for New Higher Education Institutions and an International Foundation. Whilst existing university structures are capable of addressing this to a considerable extent, given Japan's history of establishing specialised higher education institutions—such as the National Colleges of Technology (*Kosen*) and professional graduate schools—to promote manufacturing in the past, it is also desirable to create new higher education institutions specialised in the circular economy. Furthermore, as the circular economy is not confined to a single country, it would be ideal to establish these new institutions with an 'international foundation', if possible.
- Third message: The establishment of new higher education institutions and the development of highly skilled personnel for the circular economy are new and uncharted challenges for the higher education sector; they cannot be achieved easily or overnight. Therefore, higher education institutions must also strive and make every effort to accumulate knowledge and adapt through a process of trial and error —starting, for instance, with the implementation of short-term courses—and continue to evolve.

8. Closing Session

Prof Nishimura's closing remarks and summary, as well as the details regarding the conclusion of the entire programme, are as follows.

1. Closing Remarks and Review of Today's Discussions: On behalf of the organisers, Prof Nishimura delivered the following closing remarks and address.
   - Outcomes of the Discussions and Key Takeaways: Today's symposium began with the unveiling of the report prepared by MIGA, followed by in-depth discussions on regulatory and policy trends in ASEAN member states, the current state of the industry, the relationship between the ASEAN-wide trade structure and the circular economy, and methods for implementing the circular economy. In particular, there was a shared conviction that starting with the Automotive industry can generate significant value, and that within ASEAN—where industrial clustering has progressed over the past 30 years—value chains can be further enhanced by linking 'arterial' industries with existing 'venous' industries.
   - Positioning within international agreements and trade: It was emphasised that ASEAN should vigorously implement the global trend of 'incorporating the circular economy into trade'—as highlighted in MIGA's policy recommendations to the G20 and the importance of upgrading ATIGA —and that Japan should also provide further cooperation in this regard.
2. Nine key issues summarised in the form of policy recommendations: Prof Nishimura summarised the major issues for the future in the form of policy recommendations as follows.
   1. Upgrading hardware and software: To realise a high-quality circular economy, upgrades will be implemented in relation to physical infrastructure, institutional frameworks and human resources.
   2. Creation of New Circular Industries: We will aim to implement new circular industry policies in order to create new circular industries that will serve as key drivers of a high-quality circular economy.
   3. Utilisation of International Resource Circulation and Trade Order: We will promote international resource circulation between ASEAN and Japan to achieve greater resilience in supply chains and the economy across the entire region. To this end, the public and private sectors will work together to upgrade ATIGA and the Japan–ASEAN EPA.
   4. Building supply networks: We will establish supply networks for traceable, highly transparent and reliable recyclable waste materials, second-hand parts and ELVs.
   5. Standardisation and digitalisation: We will achieve the development of standards that enable the integration of 'arterial' and 'venous' streams through the construction of a digital information infrastructure.
   6. Establishing a new higher education system: We will establish a new higher education system to cultivate 'highly skilled circular industry professionals' who will spearhead the circular economy.
   7. Promotion of Competency-Based Education: Promote competency-based education aimed at implementing the circular economy.

8. Promotion of Phased Development: Promote a phased transition from the implementation of short courses and similar initiatives to competency-based education.
9. Design of an East Asian Circular Economy Mechanism: Promote ASEAN-Japan cooperation towards the design of an economically sustainable East Asian circular economy mechanism based on the above-mentioned 8 recommendations.

Furthermore, it was announced that the aim is to build on today's progress and continue striving for an agreement at a higher level, whilst further refining the discussions with a view to formulating recommendations for the ASEAN Economic Ministers and METI Consultation and the ASEAN-Japan Summit. Finally, sincere thanks were extended to the co-organisers, speakers, relevant organisations and all those who had participated throughout the event.

Authors' Profile List

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Graduated from the Faculty of Law, the University of Tokyo and obtained a Master's Degree in International Development and Economics from Yale University. Joined the Ministry of International Trade and Industry in 1976. Has assumed numerous positions, Vice Governor for International Affairs of Ehime Prefecture, Director-General of the Business Support Department of the Small and Medium Enterprise Agency, Executive Managing Director of the Japan-China Economic Association. Assumed position of founding ERIA Executive Director in 2008 and subsequently was appointed as ERIA's first President in 2015, and was reappointed as President of ERIA until 2023. Haiku Poet as Gania Nishimura. Editor of The Matsuyama Declaration1999.Representative of Haiku Magazine *TEN I*.

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Born in 1962. Graduating from Department of Law, University of Tokyo, Prof. Maeda has stepped up so-called ' a Revolving Door Career Path' between the Government and Academia. In the Government of Japan, he served as Director for International Finance, and Director of Financial Cooperation Division, Ministry of Economy, Trade and Industry. In Academia, he served as Associate Professor of University of Saitama, Visiting Professor of Graduate Institute of Policy Studies (GRIPS), Visiting Fellow of the Royal Institute of International Affairs (Chatham House, UK), Visiting Fellow of Johns Hopkins University School of Advanced International Studies (SAIS, USA) and Visiting Fellow of University of Cambridge. He is now serving as Professor of Advanced Institute of Industrial Technology (AIIT), President of ERISE (Epistemic Research Institute of Social Ethics), Vice President of the Global Society of Applied Infosocionomics (GloSAI), and Visiting Professor of Musashino University.

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Graduated from the Faculty of Law at Kokugakuin University in 2005. Joined Misawa Home Co., Ltd. in 2005. Joined Aichi Co., Ltd. in 2008 and worked as a preschool teacher at Ishigami Kindergarten, affiliated with the Kenchu Welfare Association, a social welfare corporation, from 2019. October 2023: started to serve as a secretary to the Supreme Advisor of the Economic Research Institute for ASEAN and East Asia (ERIA), supporting various research projects including the Global South Research Caucus.December 2024: Became a Visiting Researcher at MIGA. Supported the establishment of the Global South Research Caucus and engaged in network-building activities. Participated in the research project "Urban Development to Strengthen Water Ecosystems," jointly promoted by MIGA and the Japan Disaster Risk Reduction Platform (a general incorporated association).April 2024: Presented at the "Global Environmental Issues Countermeasure Seminar" at Dong A University (Da Nang) on the topic "Enhancing Urban Development through Water Ecosystems" (co-presented with Professor Mitsuhiro Maeda of the AIIT). November 2024: Supported the presentation of the Global South Research Caucus's policy package "Path Diversity" at the T20 Brazil Side Event themed "No One Left Behind." December 2024: Contributed to the signing of a contract for the "Master Plan for Strengthening Resource Circulation through Enhanced Digital Connectivity in Logistics in Africa" under the Ministry of Economy, Trade and Industry (METI)'s "2023 Supplementary Budget 'Global South Future-Oriented Cooperation Project (Formulation of a Strategy to Strengthen Economic Partnerships with Africa and Promotion of Overseas Expansion of Japanese Companies, etc.)'."

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Michikazu Kojima is an economist specialising in environmental policies, especially, waste management and recycling in Asian countries. Prior to joining ERIA in March 2018, he was a chief senior researcher at Institute of Developing Economies (IDE) in Japan from 2015. He has also contributed in the field of international cooperation, as a member of Expert Working Group of Environmentally Sound Management under the Basel Convention, a member of Technical Expert Committee for Green Industry Platform by UNIDO and the course leader on JICA training courses on recycling policy. He holds Master of Science on Agricultural and Resource Economics from University of California, Berkeley.

Mr. Reo KAWAMURA, Former Director for Environment Policy, Economic Research Institute for ASEAN and East Asia (ERIA) (Chapter 4)

Reo Kawamura has spent over 20 years as a government official in Japan's Ministry of the Environment (MOE). During his tenure, he focused on various environmental policies, particularly in areas such as climate change mitigation, biodiversity, and promotion of sustainable fashion. Recently, he worked on the consideration of a new statutory plan for Japan's environmental policy, aiming to enhance its environment, economy, and society by aligning it with contemporary trends such as carbon neutrality, the circular economy, and nature-positive initiatives. Kawamura also had international assignments, including working with the OECD in France and serving in roles within the Ministry of Finance and the Nuclear Regulation Agency. After serving as the Director of the Office of Environmental Education and concurrently as Senior Planning Officer of the General Policy Division, starting in July 2023, Kawamura has taken the helm of the Environment Unit and the Regional Knowledge Centre for Marine Plastic Debris (RKC-MPD) at the Economic Research Institute for ASEAN and East Asia (ERIA).

Prof. Dr. Masahiro NAKAMURA, President & CEO, LEXER RESEARCH Inc.; Representative Director, Green CPS Council, Japan; Professor, Tokyo City University Graduate School, Japan (Chapter 5)

Doctor in Engineering from the Graduate School of Engineering, Osaka University.1982 joined Komatsu Ltd. and conducted research and development of spatial understanding and cognitive technology at the Production Technology Research Laboratory, and promoted the development of applications for automation systems, etc. In 1993, he established LEXER RESEARCH Inc. and became its president and CEO. In 2022, he founded the Green CPS Consortium, which promotes GX/DX activities for a carbon-neutral society. In 2016, the company announced the "CPPS Technology Concept and 2040 Manufacturing Vision (Japan Society of Mechanical Engineers)," which sets out guidelines for manufacturing in Japan, and was featured in the Ministry of Economy, Trade and Industry's Manufacturing White Paper. In 2022, he established the Green CPS Consortium, an incorporated association promoting GX/DX activities towards a carbon-neutral society, and became its representative director. In addition to promoting proposals for new social systems with members from industry and academia, he has been focusing on GX/DX human resource development, and has developed human resource development courses not only in Japan but also in collaboration with industry, academia and government in ASEAN countries, focusing on activities to enhance Japan's international appeal.

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Mr. Kumagai holds an MSc in Global Market Economics from the London School of Economics and Political Science and a Master in Media and Governance from Keio University. Most significantly, Mr. Kumagai was awarded the prestigious 40th Masayoshi Ohira Memorial Prize in 2024 for his groundbreaking work with Dr. Nakamura on Malaysia's economic development strategy, specifically addressing solutions for overcoming the middleincome trap. This recognition underscores the significant impact of his research on understanding economic development in Asia.

His major publications on Malaysia include:

- "Economic Development Strategy Learning from Malaysia: Hints for Overcoming the MiddleIncome Trap" (with M. Nakamura, Sakuhinsha, Nov 2023);
- "How Politics and Economy Changed in Post-Mahathir Malaysia" (with M. Nakamura, IDEJETRO, 2018);
- "The Middle-Income Trap from the Viewpoint of Trade Structures: Are the Geese Trapped or Still Flying?" (Journal of International Commerce, Economics and Policy, 6(3), 2015).

His other influential works on Asian economic integration and development include:

- "The Economics of East Asian Integration: A Comprehensive Introduction to Regional Issues" (with M. Fujita and I. Kuroiwa, Edward Elgar, 2011);
- "Economic Integration in East Asia: Perspectives from Spatial and Neoclassical Economics" (with M. Fujita and K. Nishikimi, Edward Elgar, 2008)
- "Economic Impacts of the US-China Trade War on the Asian Economy: An Applied Analysis of IDE-GSM" (with T. Gokan, K. Tsubota, et al., Journal of Asian Economic Integration, Jul 2021)

His research uniquely combines theoretical frameworks with practical policy implications, making it valuable for both academic researchers and policymakers. Mr. Kumagai's expertise in using the IDE Geographical Simulation Model (IDE-GSM) has provided crucial insights into regional economic development and integration patterns across Asia.