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Economic Research Institute
for ASEAN and East Asia

Masterplan for ASEAN–Japan Next-Generation Automotive Industry

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Foreword

On behalf of the Economic Research Institute for ASEAN and East Asia (ERIA), I am honoured to present the ASEAN–Japan Next-Generation Automotive Industry Masterplan.

Formulated in response to the strategic agreement reached at the 2023 ASEAN–Japan 50th Anniversary Commemorative Summit, this Masterplan establishes a comprehensive policy roadmap to strengthen the region's automotive competitiveness through 2035 while accelerating decarbonisation.

The ASEAN automotive sector is at a critical turning point, marked by shifting consumer demand, intensifying international competition, and growing pressure to decarbonise.

The strength of our region's automotive industry is built on a substantial internal combustion engine (ICE) manufacturing base that produces vehicles tailored to local demand and supplies markets within and beyond ASEAN

To navigate market uncertainties and maintain regional trade competitiveness, ASEAN must move beyond business-as-usual trajectories by pursuing industry transformation through decarbonisation, digitalisation, and servitisation.

ERIA's research highlights the importance of a varied-pathway approach that reflects the diverse levels of development and consumer needs across ASEAN Member States.

This approach supports the continued use of efficient, low-emission ICE and hybrid electric vehicles (HEVs) powered by biofuels and e-fuels in the near term, while systematically developing the human capital, digital infrastructure, and regulatory foundations required for the wider adoption of electrified vehicles (xEVs) beyond 2035.

To address the structural gaps between current trends and our 2035 vision, the Masterplan sets out targeted recommendations across five priority areas:

First, upgrading supplier competitiveness: Addressing digital and green talent shortages through regional upskilling programmes, developing green industrial energy parks, and establishing carbon-tracking infrastructure connected to interoperable data platforms.

Second, strengthening regional supply chains: Integrating ASEAN Member States into a more connected production network by leveraging their distinct national strengths, industrial capabilities, and development needs.

Third, amplifying regional strengths and advancing circularity: Establishing end-to-end traceability for vehicles and materials, from assembly to end-of-life scrap, to enable rare metals and battery components to be reintegrated into manufacturing processes, while expanding regional biofuel adoption.

Fourth, harmonising mobility and climate action: Modernising urban transport through Mobility-as-a-Service (MaaS) and diverse servitisation models, supported by harmonised, region-wide inspection and maintenance regulatory frameworks.

Finally, translating this policy framework into practice: Achieving implementation will require close co-operation amongst ASEAN governments, Japanese partners, and private- sector stakeholders. ERIA remains committed to supporting the next phase of this initiative through targeted in-country consultations and collaboration with relevant operational bodies to advance these strategic measures.

Through joint commitment and co-creation, ASEAN and Japan can help ensure that the region's automotive ecosystem remains resilient, sustainable, and globally competitive for generations to come.

Tetsuya Watanabe
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List of Abbreviations

2G	second generation
5G	fifth generation
AATF	Authorised Automotive Treatment Facility
AC	alternating current
ADAS	advanced driver assistance system
ADB	Asian Development Bank
AFA	ASEAN Federation of Accountants
AI	artificial intelligence
AMEICC	ASEAN Economic Ministers–METI Economic and Industrial Cooperation Committee
AMS	ASEAN Member State
API	application programming interface
APN	Asosiasi Penambang Nikel Indonesia (Indonesian Nickel Miners Association)
APS	ASEAN Plan of Action for Energy Cooperation Target Scenario
ASEAN	Association of Southeast Asian Nations
ATIGA	ASEAN Trade in Goods Agreement
ATP	assembly, testing, and packaging
ATS	ASEAN Member States Target Scenario
AV	autonomous vehicle
AVIP	ASEAN Vehicle Inspection Protocol
ASW	ASEAN Single Window
BAU	business-as-usual
BEV	battery electric vehicle
bpd	barrels per day
CAGR	compound annual growth rate
CASE	connected–autonomous–shared–electric
CATL	Contemporary Amperex Technology Co., Limited
CBAM	Carbon Border Adjustment Mechanism
CBU	completely built-up
CCS2	Combined Charging System
CDP	Carbon Disclosure Project
CHAdeMO	Charge de Move
CKD	completely knocked down
CO_2	carbon dioxide
CPA Australia	Certified Practising Accountants Australia
CPO	crude palm oil
DC	direct current
DPP	Digital Product Passport (EU)
DVX	domestic value-added
DX	digital transformation
E/E	electrical and electronic
EIA	Energy Information Administration
EIP	eco-industrial park

EIU	Economist Intelligence Unit
ELV	end-of-life vehicle
EPR	extended producer responsibility
ESCO	European Skills, Competences, Qualifications and Occupations
ESG	environmental, social, and governance
EU	European Union
EV	electric vehicle
FCEV	fuel cell electric vehicle
FDI	foreign direct investment
FTA	free trade agreement
FVA	foreign value added
GAPKI	Gabungan Pengusaha Kelapa Sawit Indonesia (Indonesian Palm Oil Association)
GB/T	Guobiao/Tuijian
GDP	gross domestic product
GEIPP	Global Eco-Industrial Parks Programme
GHG	greenhouse gas
GVC	global value chain
GX	green transformation
HEV	hybrid electric vehicle
HICE	hydrogen internal combustion engine
HICEV	hydrogen internal combustion engine vehicle
HKTDC	Hong Kong Trade Development Council
HPAL	high-pressure acid leaching
IBC	Indonesia Battery Corporation
ICCT	International Council on Clean Transportation
ICE	internal combustion engine
ICEV	internal combustion engine vehicle
IFR	International Federation of Robotics
IGES	Institute for Global Environmental Strategies
ILO	International Labour Organization
IMV	Innovative International Multi-Purpose Vehicle
IoT	Internet of Things
IP	intellectual property
ISO	International Organization for Standardization
ITC	International Trade Centre
JAMA	Japan Automobile Manufacturers Association
JICA	Japan International Cooperation Agency
KPI	key performance indicator
kt	kilotonne
kW	kilowatt
Lao PDR	Lao People's Democratic Republic
LCA	life-cycle assessment
LULUCF	land-use, land-use change, forestry
MaaS	mobility-as-a-service
METI	Ministry of Economy, Trade and Industry (Japan)
MIDA	Malaysian Investment Development Authority
MoFA	Ministry of Foreign Affairs (Japan)

MPOC	Malaysian Palm Oil Council
MPV	multi-purpose vehicle
MRA	mutual recognition arrangement
MRV	monitoring, reporting, and verification
MSRP	manufacturer's suggested retail price
Mt	megatonne
NEDO	New Energy and Industrial Technology Development Organization
NGV	new-generation vehicle
NSW	national single window
NTM	non-tariff measure
NZE	net-zero emissions
OBD	onboard diagnostics
OEC	Observatory of Economic Complexity
OECD	Organisation for Economic Co-operation and Development
OEM	original equipment manufacturer
OTA	over-the-air
PCE	passenger car equivalent
PCF	product carbon footprint
PHEV	plug-in hybrid electric vehicle
PLN	Perusahaan Listrik Negara (State Electricity Company)
PPA	power purchase agreement
ppm	parts per million
PUSPAKOM	Pusat Pemeriksaan Kenderaan Berkomputer (Computerised Vehicle Inspection Centre, Malaysia)
R&D	research and development
RCA	revealed comparative advantage
RDS	regional data service
REE	rare earth element
RFID	radio-frequency identification
SDV	software-defined vehicle
SMEs	small and medium-sized enterprises
STEPS	Stated Policies Scenario
SUV	sport utility vehicle
t	tonne
TCO	total cost of ownership
TVET	technical and vocational education and training
UIO	units in operation
UK	United Kingdom
ULSD	ultra-low-sulphur diesel
UNDP	United Nations Development Programme
UNECE	United Nations Economic Commission for Europe
UNIDO	United Nations Industrial Development Organization
US	United States
USDA	US Department of Agriculture
VKT	vehicle–kilometre travelled
WEF	World Economic Forum
xEV	electrified vehicle
yr	year

Executive Summary

The ASEAN Automotive Industry is at a pivotal turning point. Automotive has long been a crucial anchor of the Southeast Asian economy, contributing approximately 6.3% to the region's GDP. Over the past decade, vehicle sales in ASEAN have remained stable at around 3 million units annually, implying a resilient base, even as markets globally have faced volatility. Beneath this steadfastness, however, the region's automotive landscape is becoming increasingly complex. Consumer preferences are rapidly diversifying, both in terms of powertrain technologies and vehicle body types, reflecting ASEAN's economic heterogeneity and rich demographic mix. The region's powertrain mix, based on units of sales, currently comprises of 85% internal combustion engine (ICE), 9% hybrid electric vehicle (HEV), and 6% plug-in electrified vehicles, consisting of battery electric vehicle (BEV), plug-in hybrid electric vehicle (PHEV), and fuel cell electric vehicle (FCEV) – together referred to as xEV. In parallel, body type preferences are shifting as well. In 2024, a notable demand split between conventional models (33%), sport utility vehicles (SUVs) (33%), multi-purpose vehicles (MPVs) (20%), pickups (11%), and others (3%) were observed, evolving from Conventional's dominance of 45% in 2014.

At the same time, regional competitiveness is facing new challenges. Neighbouring countries with large domestic markets and focused industrial strategies are intensifying competition for investment, talent, and export markets. Increasingly, competitiveness is being defined not just by cost or scale, but by progress in decarbonisation and digitalisation, two areas where ASEAN is under growing pressure to catch up. Decarbonisation is not only an environmental imperative but also a competitiveness strategy; ASEAN's ability to integrate into the global xEV component supply chain depends on its capacity to meet increasingly strict carbon standards.

Further compounding this pressure is the growing demand from key export markets such as the EU for stricter decarbonisation standards, which ASEAN must respond to. Many of ASEAN's collective climate commitments, reaffirmed at COP28, can be seen as a response to these evolving global expectations. These commitments vary across the region, with net-zero or carbon neutrality targets ranging from 2040 to 2065 among the member states. While this variation reflects differing national circumstances, it also highlights the need for a coordinated regional approach to decarbonising the sector, which remains one of the highest emitting in ASEAN.

Given the sector's central role in the region's economic development, ASEAN must not only preserve its automotive industry but also actively future-proof it by evolving, decarbonising, and embracing digitalisation. In response to the industry's need, the ASEAN Next-Generation Automotive Masterplan has been developed as a strategic guide for policymakers, industry players, and other stakeholders. The Masterplan sets out a shared vision for transforming ASEAN's automotive sector in light of global shifts toward electrification, digital integration, and sustainability.

The development of this Masterplan is grounded in inclusive dialogue and collaboration among ASEAN Member States (AMS), industry leaders, and international partners, including the Government of Japan through Ministry of Economy, Trade, and Industry (METI), Japan Automobile Manufacturers Association (JAMA), and AEM-METI Economic and Industrial Cooperation Committee (AMEICC). More importantly, The Masterplan also builds on the shared vision reaffirmed during the December 2023 Japan-ASEAN 50th Year Anniversary Commemorative Summit, which highlighted the importance of deepening economic cooperation and advancing sustainable development across the region. Through a series of consultations, workshops, and technical discussions, the process ensured that the Masterplan accurately reflects both current industry trends and the direction in which the sector is headed. Beyond desk research and survey inputs, this approach allowed the team to directly incorporate the views of key industry players and government officials, aligning the vision with real-world needs and priorities.

The Masterplan defines a clear To-Be vision for ASEAN's automotive industry by 2035, acknowledging four primary themes. First is to boost manufacturing competitiveness, envisioning a state where ASEAN becomes a region with factories that surpass competitors, featuring green-powered operations, carbon-audited systems, and real-time data-verified manufacturing practices. Second, to fortify the regional supply chain. In this state, ASEAN is expected to function as ten markets operating as one, with supply chains including rare metals, chips, and e-fuels flowing seamlessly across borders through a shared customs window. Third, to amplify region-specific competitiveness. The aim is to establish a region with low-emission ICE, HEV, or xEV vehicles with robust traceability systems, enabling lifecycle monitoring from production through to end-of-life treatment (i.e., disposal). For instance, scrap metals and used batteries would be reintegrated into production cycles, enabling circular value creation that supports both environmental sustainability and material sufficiency for future manufacturing. Fourth, to harmonise climate action with mobility options, implying a region that reduces congestion and emissions through mobility-as-a-service, with shared, connected, and regularly inspected systems. Such a set of visions are proposed to reinforce ASEAN's positioning as a key global production hub, particularly for vehicles serving the needs of emerging economies, while simultaneously building a resilient and sustainable future for the region.

While the Masterplan sets out an ambitious vision for 2035, it also recognises the current gaps that must be addressed to realise the region's ambitions. Despite ASEAN's growing automotive base, the current landscape reflects significant disparities between vision and ground reality. The first observation highlighted that while urban areas have seen progress in vehicle adoption and mobility options, the needs of rural populations and the middle class remain largely unaddressed. Unaffordable vehicle prices are a key factor behind the stagnating demand in the region, limiting broader uptake even in rapidly expanding economies. Unlike in developed economies, annual incomes in Thailand and Indonesia fall below the price points of both ICE and xEV vehicles, highlighting a critical mismatch between policy ambition and consumer affordability.

Secondly, many AMS, at the national level, have introduced advanced policy tools such as

xEV incentives, but these often target technologies that exceed domestic industrial capacity. Countries are, in some cases, pursuing goals that may not align with their current level of capability, especially in pushing for high-end electrification without first addressing foundational readiness (such as charging infrastructure, power supply, skilled workforce, and local component manufacturing capability), as noted in policy critiques and stakeholder feedback. This fragmented approach across countries results in regional incoherence, with varying degrees of progress and limited opportunities for economies of scale or knowledge sharing.

Third, ASEAN is lagging behind neighbouring countries in decarbonisation and digitalisation efforts, which are increasingly central to global industrial competitiveness. ASEAN auto players show limited awareness of the need to decarbonise and digitalise their operations, further impeding transformation. This was echoed in the project's primary survey results, which revealed a systemic mindset gap, where many respondents stated that 'management does not understand the need for investment in this area,' particularly concerning supply chain decarbonisation, greenhouse gas (GHG) emissions calculations, environmental, social, and governance (ESG) reporting, and the upgrading of outdated manufacturing facilities.

Following the identified challenges above, this Masterplan outlines three strategic directions. The first direction is to deploy a Varied Pathway approach, which calls for initially focusing on the largest demand segment (ICE and HEV), while gradually preparing for a transition to xEVs over time. This approach responds to the region's economic realities, where mass electrification remains premature and unaffordable for most households. In practice, the Deloitte Global Automotive Consumer Survey revealed that ICE remains the top choice for ASEAN consumers, with over 50% still preferring ICEs over HEVs and xEVs. The skewness towards ICE is further supported by an industry forecast from GlobalData, which estimates that by 2035, ICE and HEV will remain the majority of ASEAN automotive sales, with ICE accounting for 54%, HEV 31%, and xEVs only 15%. Nonetheless, there is significant uncertainty around these projections. The trajectory of xEV adoption will be heavily influenced by trade developments and policy changes, particularly as shifts in government administrations can reshape incentives, regulations, and investment priorities. Stronger policy support could accelerate xEV uptake, while weaker or inconsistent policies may reinforce ASEAN's reliance on ICE and HEVs.

Moreover, the survey conducted as part of the Masterplan's development also found that xEV cost remains a major barrier, as fuel savings account for less than 10% of the xEV-ICE price gap. Therefore, prioritising ICE/HEV models tailored to ASEAN's needs allows the region to deliver more inclusive and scalable solutions, especially for rural and middle-income populations, while building capacity for future electrification.

The second strategic direction of this Masterplan is Regional Harmonisation, recognising that ASEAN member states cannot compete effectively in isolation. To attract meaningful investment and establish a resilient automotive base, ASEAN must collaborate as a regional market rather than a collection of fragmented national efforts. Global vehicle

sales remain heavily concentrated in a few dominant markets. In 2024, ASEAN accounted for only 3.2 million units out of the 88.7 million total vehicles sold worldwide (including ICE, HEVs, and xEVs), equivalent to just 4% of global volume. At the individual country level, this contribution is even less significant, making it difficult to achieve the scale or predictability needed to attract long-term industry players. By harmonising standards and coordinating policies across borders, particularly in the ICE and HEV segments where regional demand is strongest, ASEAN can improve market coherence and present a more attractive investment landscape. Examples of standards that could be harmonised include vehicle data monitoring frameworks to support dismantling and resource circulation, as well as data interoperability protocols to enable seamless tracking of vehicles across borders.

The third strategic direction of the Masterplan is to upgrade ASEAN's automotive industry through three key efforts: decarbonising while maintaining a majority ICE and HEV line-up – particularly through the promotion of sustainable fuels such as biofuels, enhancing the digital competitiveness of the industry, and developing servitisation models suited to emerging market conditions. The study revealed that rising decarbonisation requirements and intensifying regional competition have exposed deep structural challenges, with local suppliers often lacking access to digital infrastructure, green investment, and skilled talent, making transformation difficult. For that reason, this Masterplan envisions an upgraded industrial base where renewable energy powers connected green parks, cross-supply-chain digital systems support carbon tracking, and digital and green know-how is embedded across the value chain. Additionally, it is suggested that ASEAN must unlock new models of value creation through servitisation, building offerings beyond traditional vehicle sales to meet evolving consumer and market needs.

The Masterplan delivers clear value to ASEAN member states by offering a structured framework that allows every country to participate meaningfully in the region's automotive transformation. Acknowledging the diverse characteristics and unique strengths of each nation is fundamental to the masterplan, as it allows for every country to make a distinct contribution. To note, this study emphasises that this grouping is dynamic and may change over time as supply chains progress. Rather than a one-size-fits-all approach, it leverages the diversity of ASEAN by assigning differentiated roles aligned with each country's current strengths and future potential:

- Group 1 – Leading Export Hubs to safeguard CBU and component exports, establishing manufacturing and export capacity for complete vehicles and components
- Group 2 – Emerging Manufacturing Hubs to deepen supply chains to reach export scale, focusing on domestic demand with continued supply chains development, mainly through CBU (Complete Built-Up) units' assembly and scaling up towards export expansion

- Group 3 – Strategic Supporting Hubs to contribute niche resources and logistics in renewable energy, circular economy, and high employment potential, positioning them as integral partners in the region's diversified value chain
- Group 4 – Tech and Mobility Hub to become the region's backbone and innovation leader positioned to support regional data platforms, mobility services, and servitisation enablement

To realise the region's ambition for a next-generation automotive ecosystem, the Masterplan proposes a set of co-creation areas with Japan positioned as a key strategic partner. Four key areas of Japan-ASEAN co-creation are: (i) data platform development, (ii) human resource development, (iii) biofuel collaboration, and (iv) effective policy creation and enactment. Looking ahead, ASEAN aims to become a key hub for ICE and HEV production and export, particularly in auto parts and components, while gradually shifting its supply chain towards xEV manufacturing. Japan's strength in HEV technologies is well aligned with this vision, offering a strategic bridge toward deeper electrification, as many HEV components share technological foundations with xEVs. In this context, Japan's collaboration, especially through METI's support for automotive suppliers, reinforces ASEAN's ability to strengthen current industrial capacity while preparing for future market shifts. Japan's earlier experience and expertise are considered valuable in strengthening ASEAN's positioning in the above strategic areas, enabling the region to expand its role in the global automotive landscape.

First, Japan's expertise in data platform of the Ouranos ecosystem can be leveraged to support the creation of a similar regional platform in ASEAN. Such platform would enable secure, interoperable data flows for traceability, carbon tracking, and digital service integration across ASEAN's automotive value chains. Second, the proposed co-creation area emphasises a collaborative approach in which Japan supports education and training initiatives to build a skilled workforce aligned with the future needs of the ASEAN automotive sector. This includes the dispatch of Japanese technical experts to ASEAN institutions such as technical and vocational education and trainings (TVETs), and the placement of ASEAN talent in Japan for hands-on learning and skills acquisition. Third, the potential collaboration in biofuels and e-fuels involves establishing an ASEAN–Japan co-working group in AMEICC to develop a regional fuel economy that secures long-term supply for the automotive industry. Japan can contribute through technology transfer mechanisms and joint manufacturing capabilities, while ASEAN can leverage its biomass potential, particularly for second-generation (2G) or advanced biofuels. Fourth, Japan can provide ongoing support for policy formulation and institutional capacity building across ASEAN. This includes cooperation on regulatory planning, technical advisory, and policymaking processes, drawing on Japan's long-standing track record in development-oriented policy assistance and institutional expertise.

Ultimately, at the core of realising this Masterplan is the need to translate strategic recommendations into clear, structured, and coordinated implementation across ASEAN. To support this recommendation, it is proposed that a dedicated ASEAN–Japan forum or working group be established as a permanent coordination platform for follow-up and

execution in AMEICC. This mechanism would facilitate ongoing dialogue, enable information and knowledge exchange, and monitor progress across the identified co-creation areas. By involving key stakeholders from government, institutions, and industry players, this platform would help ensure that the Masterplan delivers measurable outcomes and effectively positions ASEAN as a next-generation automotive hub.

The Masterplan consists of nine chapters, each presenting a distinct purpose and progressing logically from introduction to implementation, as outlined below.

Chapter 1: Introduction

The first chapter provides a background and contextualises the importance of the Masterplan. This chapter identifies that ASEAN's vehicle industry sectors have found themselves at the intersection of multiple forces, particularly shifting market trends and rising decarbonisation objectives. Therefore, the main research question guiding the Masterplan is as follows: *How can ASEAN strengthen the competitiveness of its automotive industry amidst decarbonisation and electrification?*

The chapter highlights that, over the past two decades, several ASEAN countries, notably Thailand, Indonesia, and Viet Nam, have emerged as key automotive production bases, with increasing integration into global value chains and significant inflows of foreign direct investment. Thailand remains the region's lead exporter of automotive components, recording US$77.1 billion in exports, though it is also the only country to maintain a trade surplus in this category. In contrast, other ASEAN Member States run persistent trade deficits, while non-ASEAN countries such as Japan exhibit more diversified and resilient trade competitiveness, particularly in passenger vehicles. Technological progress is also narrowing the gap in the total cost of ownership (TCO) between ICE vehicles xEVs with several tipping points for xEV affordability projected between 2025 and 2030.

Based on the initial findings, Chapter 1 emphasises the growing urgency of regional direction. The Masterplan is developed in response to regional policy ambitions, notably former Prime Minister Kishida's call for ASEAN–Japan 'co-creation' to drive future development. The overarching objective of the study is to establish a theoretical base for policymaking in ASEAN, enabling each country to develop stronger, more competitive automotive sectors. Ultimately, the effort is geared towards positioning ASEAN as a regional hub for diversified automobile models, aligned with global market dynamics and technological trends, while accounting for the growing imperative to decarbonise.

Chapter 2: An Academic Perspective of the Future of ASEAN's Automotive Industry

Chapter 2 lays out the theoretical framework for analysing the automotive industry in a broader sense, including the perspective of sustainable transportation and mobility from an academic lens. This chapter offers insights on how academic thinking can inform the development of strategic masterplans within ASEAN countries, while highlighting the existing challenges faced in both automotive production and consumption across the ASEAN market. It also provides an important discussion on production-related issues and elaborates on Japan's perspectives regarding automotive manufacturing and market

dynamics.

In relation to the Masterplan, the chapter offers early indications of the strategic direction elaborated in subsequent chapters. From the transport supply-demand view, Indonesia and the Philippines show the highest ratio of registered vehicles (PCE), ranging from 350 to 400 PCE per km, reflecting a heavily loaded or congested road network. Countries such as Singapore, Malaysia, Brunei, Thailand, Myanmar, and Lao PDR record a medium range of 150 to 250 PCE per km, while the lowest ratios are seen in Cambodia and Viet Nam at less than 50 PCE per km. Notably, Singapore experiences traffic congestion despite strict regulations on car ownership. In Vietnam, although there is a high volume of two-wheelers, the overall PCE remains low, which may explain relatively lighter congestion when adjusted for vehicle equivalency.

With ongoing global economic growth, the automotive industry is not only presented with the opportunity to develop the Next Generation Automotive Industry, but also entrusted with the responsibility to support a more sustainable transportation system. There is a growing potential to expand into innovative mobility services, such as car sharing and ride-hailing, by deploying low-emission vehicles that improve overall vehicle utilisation.

The chapter also highlights that combustion engines, with their more horizontal structure and greater number of components, may pose disadvantages when compared to non-combustion engines, which tend to have a more vertical structure and fewer components. The non-combustion engine model may allow for higher value creation in logistics and value chains, potentially giving rise to more production hubs across the ASEAN region. These two contrasting production models should serve as foundational considerations for the Next Generation Automotive Industry, especially in the context of cost-effective manufacturing and distribution.

To realise the region's future visions, governments are called to craft policies that effectively stimulate the development of Next Generation Vehicles and mobility services. This includes market segmentation and tailored strategies for specific user groups. Fiscal instruments, such as targeted tax policies, will be essential to increase the affordability and adoption of vehicles with new technologies. In parallel, carbon trading mechanisms may offer alternative pathways to lower the effective selling price of these vehicles.

Ultimately, Chapter 2 emphasises that the shift towards Next Generation Vehicles cannot stand alone. It requires the emergence of a new, environmentally sustainable vehicle industry, one that is deeply interconnected with adjacent sectors such as renewable energy, digital infrastructure, raw materials and mining, clean fuels, and artificial intelligence.

Chapter 3: Summary and Overview of the Questionnaires

Chapter 3 presents the results of the Masterplan's survey conducted in Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Viet Nam, which aimed to capture respondents' perspectives on the current state and strategic direction of the automotive sector across selected ASEAN countries. The sample

size comprised a total of 2,133 respondents, consisting of 2,106 suppliers and 27 original equipment manufacturers (OEMs).

The survey revealed several notable findings for the ASEAN automotive industry moving forward. First, ASEAN countries vary widely in terms of the powertrain types of focus, with the majority of respondents reporting ambiguity about their strategic direction. Second, regarding market distribution, the data indicate that firms in Indonesia, Malaysia, the Philippines, Singapore, and Thailand are predominantly oriented toward their domestic markets, both currently and in their future plans. The outlook for BEV and PHEV penetration is cautiously optimistic, with over 80% of respondents forecasting an increase in market share to 13%, supported by advancements in vehicle functionality and the development of adequate supporting infrastructure. However, hesitation remains due to concerns over the high upfront costs of xEVs.

Supply chain efficiency is further challenged by factors such as material costs and procurement difficulties, compounded by short-term disruptions including low productivity, insufficient process reviews, limited adoption of digital technologies, and restricted investment decision-making authority. Efforts toward supply chain decarbonisation also face significant hurdles, notably a shortage of qualified personnel with the necessary expertise.

From the above findings, the survey infers that prevailing uncertainty emphasises a critical need for clearer policy signals and stronger strategic alignment within these markets. To enhance the future competitiveness of ASEAN suppliers, it may be beneficial to group countries according to their respective production specialisations, allowing for more focused and complementary roles across the region. As Southeast Asian countries tend to concentrate primarily on their domestic markets for distribution, exports remain limited. Therefore, positioning the region as a competitive export hub for ICE and HEV vehicles to emerging markets will require significant improvements in supply chain efficiency and integration, enabling firms to meet global standards and capture new growth opportunities.

Chapter 4: Current and Future State of the Global Automotive Market

Chapter 4 assesses the current and future state of the global automotive market, focusing on both the larger, more established players and the rising powers within the industry. Globally, China, the US, and EU dominate automotive sales, accounting for 29%, 18%, and 17% of the total market respectively. Meanwhile, emerging regions such as ASEAN and India represent just 4% and 6% respectively. Despite this minority share, India's automotive market is expected to grow at a rate that outpaces the global average in the coming years.

The study reveals that the transition from ICE and HEVs to xEVs is now irreversible due to global decarbonisation efforts. The continued shift toward xEVs, which include BEVs and PHEVs, is largely driven by national-level decarbonisation targets, with BEVs and PHEVs currently seen as the most viable options. However, the pace of xEV adoption is becoming increasingly unpredictable due to factors such as policy revisions in the US, including

potential withdrawal of EV targets and ZEV regulations and reviews of the IRA, as well as ongoing assessments of CO_2 regulations in Europe. Additionally, international reports, such as the IEA's market outlook, are undergoing updates, further contributing to projection uncertainties.

In the demand frontier, xEV sales for the United States, European Union, and China stood at 10%, 20%, and 40% respectively in 2024. By 2035, the EU is expected to lead in terms of xEV share relative to total vehicle sales, with 98% of vehicle sales projected to be BEVs and PHEVs, followed by China at 72%, and the US at 60%. The EU's leadership is driven by government mandates to completely phase out ICE vehicle sales by 2035. In the case of China, xEV adoption is largely government-driven, supported by strong industrial policy, subsidies, and state-led planning, whereas in the US, adoption rates are more influenced by factors such as oil prices and government incentives including subsidies and tax breaks. In ASEAN, the proportion of BEVs and PHEVs is not expected to rise as sharply, but HEVs will play a significant role in 2035, with a projected 31% share.

Based on multiple projections and government targets, global penetration of BEVs and PHEVs is expected to continue increasing over time. However, ICEs and HEVs are likely to remain dominant globally. The future of the global powertrain mix is fraught with uncertainty, as these projections can be influenced by socio-economic factors, including oil prices, infrastructure development, and the availability of products and ecosystem support.

The global xEV transition has been shaped by three main factors: (1) infrastructure readiness, (2) product lineup, and (3) total cost of ownership (TCO). In terms of infrastructure, charging networks, particularly fast chargers, have grown considerably in quantities. Fast charging is expected to expand further, with ultra-fast charging capacity more than doubling in Europe since 2022. China remains the global leader in fast-charging deployment, contributing approximately 80% of global growth over the past year. In general, several countries have made progress in expanding their public charging infrastructure.

In terms of product lineup, automakers continue to prioritise model development in markets with strong demand, primarily in leading xEV-adopting countries. As a result, China and the US benefit from a wider variety of xEV models compared to developing markets such as ASEAN and India.

On TCO, developed countries such as China, Germany, the UK, and Japan are ahead in narrowing the cost gap between ICE and xEVs. This disparity is further widened by aggressive government support in developed markets. For example, Germany offers a US$10,000 subsidy for xEVs, where buyers of electric cars costing less than €40,000 receive a total discount of up to €9,000 (around US$10,000), including €6,000 in direct government subsidy. These incentives are planned to be gradually reduced in line with the pace of BEV transition. In China, the government provided a total of US$690,000 in subsidies for New Energy Vehicles (NEV) until 2023, and a 10% tax reduction remains in place through 2027. In mature markets mentioned earlier, ICE-to-BEV TCO ratios vary

widely, particularly due to electricity cost differences. For instance, China demonstrates the largest gap, with ICE fuel expenses nearly nine times higher than BEV electricity costs, driven by historically low electricity prices previously supported by subsidies of up to $29,000 per vehicle in 2018 (now phased out). Japan and the UK each show a ratio of around three, while Germany is close to parity with a ratio of one. These variations highlight the significant role of local market conditions and policy measures in shaping TCO outcomes.

Globally, both developed and developing countries are undergoing significant powertrain diversification. However, the pace of this transition varies widely depending on several factors, including government policies, subsidies, infrastructure development, consumer readiness, and the anticipated future of oil prices. In developed countries, where government support is relatively strong, infrastructure is more advanced, and consumer purchasing power is higher, the shift towards BEVs and PHEVs may happen more rapidly.

Conversely, in developing nations, the transition may be slower, often hampered by lower purchasing power, limited charging infrastructure, and a greater reliance on traditional ICE vehicles. Additionally, the future trajectory of oil prices will play a crucial role, as higher prices may accelerate the shift to xEVs, whilst lower prices could slow the adoption of greener alternatives. This varying pace underscores the complex and multifaceted nature of the global automotive landscape as it moves towards more sustainable powertrain options.

Chapter 4 concludes by recognising that the outlook for powertrains remains uncertain, influenced by potential policy shifts and ongoing technological developments. A singular focus on any one powertrain or technology may constrain industry progress, reinforcing the need for a flexible and diversified approach. To navigate this uncertainty, the study suggests that policymakers develop sustainable, well-targeted strategies that support multiple vehicle technologies while remaining mindful of fiscal limitations. These policies should span areas such as technological innovation, decarbonisation at both the vehicle and supply chain levels, and new business models such as servitisation.

Ultimately, by drawing lessons from global leaders such as the EU and China, the chapter emphasises the importance of Southeast Asia building enabling technologies within its supply chains to create a competitive automotive manufacturing base for ICE and HEV vehicles. Such efforts will advance the creation of an efficient and integrated production network, which can help strengthen ASEAN's position in the global automotive landscape.

Chapter 5: Current and Future State of the ASEAN Automotive Market

Chapter 5 provides an in-depth analysis of the current trends and outlook of the ASEAN automotive market. The focus of this chapter is on the trend of the powertrain transition, which is expected to be slower than in major leading global auto markets, with ASEAN remaining an ICE/HEV-majority market until 2035. It highlights the challenges ASEAN faces during the global powertrain transition and how these may impact the region's position in the automotive industry. The analysis presented in this chapter bears crucial inferences for identifying the necessary steps for ASEAN to sustain and advance its

automotive market collectively as a region.

The chapter begins by examining the demand landscape, noting that ASEAN has shown a relatively stable trend for over a decade. The ASEAN market first reached sales of 3.4 million units in 2012, led by Indonesia and Thailand, and as of 2024, sales stood at 3.2 million units. Growth is projected to slow down to a compound annual growth rate (CAGR) of 3.6% from 2024 through 2035. A key observation is the significant drop in Thailand's contribution to the automotive market, decreasing by about 5 percentage points from 23% to just 18% in 2024. This decline is due to weak consumer purchasing power, sluggish economic growth, and stricter auto loan criteria imposed by banks and financing companies in response to high household debt.

For the region as a whole, affordability has been a major barrier to vehicle sales. Findings show that, compared to developed countries, car prices in ASEAN are relatively higher than annual household income, reaching up to 54% and 64% higher in Thailand and Indonesia, respectively. In the US, 89.5% of households earn more than the average price of the best-selling car model. This figure is 92.0% in Canada, 77.5% in Germany, and 88.9% in Japan. By contrast, only 41.7% and 21.3% of households in Thailand and Indonesia respectively earn more than the average price of the best-selling model.

Beyond purchasing power, current levels of vehicle ownership also shape automotive sales. Compared to emerging markets such as China and India, the growth of vehicle stock (measured as cars per 1,000 population) in ASEAN countries has been relatively slower. Over an 18-year period, China is projected to grow at a CAGR of 9.0% and India at 6.0%. In contrast, the fastest growth in ASEAN is expected from Viet Nam at 4.4%, followed by Indonesia at 2.7%, the Philippines at 2.1%, and both Thailand and Malaysia at 1.3%. This comparatively slower pace highlights underlying stagnation in sales, with key provinces that historically drove growth now showing signs of saturation.

In terms of powertrain transition, a gradual shift toward HEVs and xEVs has become more apparent as the shares of the two powertrains continue to rise. In 2024, ICE accounted for 82% of new cars sold, followed by HEVs at 9%, and BEVs and PHEVs at 6%. HEV is expected to make up of 31% of new cars sold (up by 22 percentage points), while BEV and PHEV contributing to 15% (up by 9 percentage points) in 2035. Thailand's xEV market is forecasted to lead the region, accounting for 31.6% of total sales by 2035, based on one scenario from the dataset used in this study. Other ASEAN nations are expected to transition more slowly, with xEV shares below 10% in each member state.

Nevertheless, regional transition as a whole is expected to be slower than that in mature markets, as outlined in Chapter 4, for several reasons. First, current xEV offerings do not fully cater to ASEAN consumers, who prefer larger payload vehicles such as seven-seater MPVs and pickups. This mismatch is partly due to the global unification of vehicle platforms, which limits manufacturers' incentive to customise products for regional needs. Additionally, the assumption that xEVs offer lower total cost of ownership due to fuel savings does not hold in ASEAN. Fuel cost savings make up less than 10% of the total additional price of xEVs compared to ICEs. While governments actively promote xEVs

through favourable policies, adoption remains slow as consumers become more cost-conscious, and the price gap between electricity and fuel is insufficient to offset the higher upfront costs.

Rather than shifting entirely to xEV after 2035, options such as HEV and biofuels will also be further promoted. Encompassing not only HEVs, the diversified offering of vehicles from ASEAN would include biofuels, for which ASEAN has the potential to become a hub. Countries like Indonesia and Malaysia have experience with biofuel production but need to scale up, facing challenges like costs and land use. Efficient biofuel production could improve trade balances by reducing fossil fuel imports, enhancing self-sufficiency, and boosting local industries. Establishing ASEAN as a biofuel centre would attract R&D and talent, increasing the region's competitive advantage in sustainability. This dual focus on HEVs and biofuels would strengthen ASEAN's automotive sector, promote economic growth, and support environmental sustainability. Beyond 2035, ASEAN can play a role in supplying low-emission ICEs, HEVs, and vehicles compatible with biofuels and e-fuels, addressing the needs of growing ICE-centric markets pursuing decarbonisation. Simultaneously, ASEAN should strategically invest in developing and producing BEVs and other xEVs with a long-term perspective. This approach will allow ASEAN to capitalise on its current strengths whilst positioning itself for a future of increasing demand for xEVs.

Based on the findings, the chapter concludes by identifying the need to pursue a unique pathway for the ASEAN auto industry going forward. Given the pace of transition and the challenges encountered, solely focusing on accelerating the powertrain shift, while mirroring the strategies of leading global markets may exacerbate stagnation in the ASEAN auto market. Therefore, two key interplays are proposed: ASEAN must sustain its sizeable ICE market while gradually cultivating the nascent stage of HEV development as a transitional step. Simultaneously, ASEAN should strategically invest in biofuel-compatible vehicles and maintain ICE/HEV production to serve growing low-emission ICE-centric markets, while preparing for BEV and PHEV adoption over the longer term.

Chapter 6: Current State and Pathway for the Future of Global and ASEAN Automotive Industry

Chapter 6 provides an overview of the current and future state of the global and ASEAN automotive industries. It first examines global production and powertrain trends, emphasising the dominance of China, the US, and the EU, the emergence of India, and the growing importance of decarbonisation and digitalisation through software-defined vehicles and autonomous technologies. This is followed by an analysis of ASEAN's competitive positioning, highlighting both existing strengths and notable challenges.

The chapter studies how these global shifts are reshaping not only the vehicle but also the supply chain that supports it. Decarbonisation requirements are compelling manufacturers and suppliers to reconfigure production processes, while digital innovations are redefining vehicle design, functionality, and integration. At the same time, servitisation is emerging as a new revenue stream, further transforming industry dynamics. To remain competitive, ASEAN must adapt and upgrade its capabilities to keep

pace with changes in the global supply chain. Accordingly, this chapter examines the automotive industry through three lenses: the transformation of the vehicle, the evolution of the supply chain, and the rise of servitisation as a business model.

The Chapter first assessed the global production landscape. In the vehicle production landscape, China, the EU, and the US remain dominant in absolute volume, with India and ASEAN gaining strategic relevance as OEMs diversify their manufacturing footprint. ASEAN's importance has grown not only due to industrial policies in the West but also because it sits at the intersection of two global forces: China's surging automotive exports and Western efforts to de-risk supply chains. Additionally, the global powertrain transition is accelerating. Germany, China, and South Korea led BEV exports, with shipments valued at $40.3 billion, US$32.2 billion, and $13.7 billion respectively, showcasing both production strength and value chain positioning. The United States, despite its production capacity, was the largest BEV importer at $19.1 billion, highlighting the gap between domestic output and rising demand. These trade patterns reveal the uneven global pace of powertrain adoption.

Building on the current production landscape, the chapter outlines the key global manufacturing and technology trends reshaping the automotive sector. In the vehicle space, Chapter 6 identified 2 core trends: Software-Defined Vehicles (SDVs) as a New Idea of Vehicle Development and Autonomous Driving Gaining Traction. This section explores the transformative trends in vehicle technology that are reshaping the global automotive landscape. It focuses on the rise of software-defined vehicles (SDVs), which marks a shift from traditional hardware-centric design to vehicles increasingly driven by software capabilities. This transition enables new features such as advanced driver assistance systems, connected services, and autonomous driving, fundamentally changing how vehicles operate and deliver value. These developments reflect a broader industry move towards integrating vehicles into digital ecosystems, where software plays a central role in enhancing user experience, safety, and sustainability.

In the supply chain front, Chapter 6 also examined key trends by value chain – at the upstream, midstream, up to downstream level accordingly. At the upstream, the growing importance of securing critical materials in the automotive upstream supply chain is identified. With the rise of xEVs, access to rare metals has become essential for battery production and overall vehicle performance. At the same time, the emergence of SDVs has increased demand for advanced semiconductors, which are vital for powering new digital features and autonomous capabilities.

At the midstream, key changes in the midstream automotive supply chain driven by the shift towards xEVs are observed. Component requirements are evolving, often leading to a reduction in the number of parts needed. Meanwhile, emerging brands are increasingly adopting vertically integrated production models to strengthen control and efficiency. The decoupling of hardware and software is advancing, placing greater emphasis on software development. Additionally, manufacturing innovations such as giga casting, artificial intelligence, and full automation are transforming production processes to enhance

scalability and flexibility.

The downstream section highlights the push toward circularity – through battery recycling, remanufacturing, and secondary materials – is gaining traction as a hedge against supply chain shocks, price volatility, and geopolitical risk. Finally, the cross-cutting theme across the entire value chains highlighted carbon emission calculation and tracking are increasingly driven by carbon neutrality commitments, creating new expectations for transparency and accountability. At the same time, integration and collaboration of data across the entire supply chain are advancing, enabling greater efficiency, resilience, and alignment with sustainability goals.

In the servitisation front, globally, leading OEMs are re-architecting cars as 'rolling operating systems,' turning one-off transactions into multi-year service relationships that bundle connectivity, on-demand performance, insurance or even ridesharing into an app-centric experience. A growing share of industry profit pools is migrating to recurring, software-enabled services – from over-the-air (OTA) feature unlocks and predictive-maintenance packages to subscription-based insurance, infotainment and even vehicle-on-demand plans.

The chapter also turns to ASEAN's own production landscape, identifying both strengths and challenges. Several structural advantages have shaped the region's global role. First is a robust and extensive ICE supply chain, particularly concentrated in Thailand, often referred to as the 'Detroit of Asia'. Second, ASEAN demonstrates a strong market focus on ICE light vehicles, supported by a comprehensive regional supply chain that includes parts suppliers and vehicle assembly capabilities. Third is ASEAN's ability to produce unique vehicle models tailored to regional needs. Demand across the region has shaped the development of vehicles that are compact yet spacious, well-suited to varied infrastructure and climate conditions. Fourth, ASEAN has built a strong history of ICE vehicle exports, reaching over 120 countries. This resilience is rooted in demand similarities, as manufacturers focus on durable segments like pickups, frame-based SUVs, and MPVs that perform well in infrastructure-constrained environments. These combined strengths underscore ASEAN's position as a leading ICE supplier for markets with similar demand levels and emerging markets.

Yet, despite these strengths, ASEAN faces a range of structural and emerging challenges. The region as a whole accounts for just 4% of global vehicle sales, and no single member state is large enough to command global influence on its own. This fragmentation hinders the region's ability to consolidate investments or present a coordinated regional positioning in the xEV transition. Additionally, ASEAN's long-standing advantage in low-cost labour is eroding. In 2024, monthly manufacturing wages ranged from $192 in Indonesia to $766 in Malaysia, compared to India's $248. While still cheaper than China ($1,240) and high-income economies like Singapore ($3,149), the narrowing gap with India is a growing concern for OEMs seeking cost-efficient hubs. Compounding this, competitiveness is being impacted by aging infrastructure and slow tech adoption. The study's survey showed that 47.5% of respondents see aging equipment as a major barrier

to efficiency by 2035. Furthermore, ASEAN's automotive production is still primarily ICE- and HEV-based, with BEV manufacturing mostly limited to Thailand. Given these realities, ASEAN must carefully manage the pace of the EV transition to protect the industrial advantage it has cultivated over decades. A sudden shift could disrupt well-established supply chains, manufacturing processes, and labour markets, creating economic and industrial challenges. As such, ASEAN's transition strategy should be phased, leveraging existing production capabilities to meet current ICE and HEV demand while progressively preparing for BEV and PHEV adoption. Without accelerated investment in localised battery supply, component production, policy coordination, and infrastructure, ASEAN risks missing out on its share of the realigned global xEV supply chain.

Most importantly, ASEAN must carefully weigh the risks associated with a rapid transition to xEVs, as it could undermine the automotive industry advantage that the region has cultivated over decades. A sudden shift could disrupt the well-established supply chains, manufacturing processes, and labour markets that are currently centred around ICE vehicles, potentially leading to significant economic and industrial challenges for the region.

ASEAN's strength as a leading ICE supplier to markets with similar demand levels and emerging markets, coupled with the ongoing global automotive transformation, necessitates a diverse transition strategy to sustain its current position and expand its production capabilities.

Given this premise, ASEAN should pursue a phased industrial transformation, capitalising on its existing production capabilities and technologies to meet the current demand for ICEs and HEVs whilst simultaneously preparing for the future transition to BEVs and PHEVs.

Chapter 7: Cradle-to-Cradle Aspects of Automotive Industry in ASEAN

Chapter 7 applies a cradle-to-grave approach to analyse the environmental, economic, and social impacts of automotive transitions across AMS. Drawing on a multi-dimensional and balanced perspective, it synthesises findings from multiple ERIA studies to assess how new technologies, shifting global value chains (GVCs), and evolving consumer and policy priorities are redefining the automotive sector in Southeast Asia.

Building on these foundations, the chapter presents key findings that demonstrate the potential, though conditional, environmental and economic benefits of xEV adoption in ASEAN. First, the Lifecycle Assessment (LCA) results show that xEVs, particularly BEVs and PHEVs, can offer significant reductions in GHG emissions over their lifecycle. However, these benefits are most apparent in countries with cleaner electricity systems and well-developed circular supply chains. It was also found that BEVs' advantage will grow as ASEAN continues to decarbonise its power sector. For instance, in a scenario where renewable energy share increases to 50%, BEVs could emit less than 60 gCO_2/km, compared to over 150 gCO_2/km for ICEs.

As part of understanding the supply chain landscape of the ASEAN automotive industry,

the Chapter finds that weaknesses compound the region's overreliance on primary mining and hinder its ability to build secure and sustainable supply chains. While mineral extraction brings clear economic benefits, overdependence on it, especially in environmentally sensitive areas, risks undermining ASEAN's long-term goals for decarbonisation and industrial resilience. The study also reveals that contrasting strategies among ASEAN countries reflect different comparative advantages and policy orientations, but simultaneously underscore the absence of a coherent regional industrial strategy. Currently, ASEAN risks becoming a patchwork of competing investment zones, each vying for a piece of the EV value chain, often at the expense of collaborative efficiency. To date, ASEAN has not yet established a unified Critical Minerals Alliance, standardized environmental and labour regulations for mineral supply chains, or joint infrastructure for recycling and reverse logistics.

Furthermore, TCO analysis finds that xEVs are reaching, and in some cases have already achieved, economic competitiveness with ICEs in ASEAN markets. These advantages are likely to increase as battery costs decline, energy sources become greener, and supportive policies are implemented. However, despite this momentum, most countries still lack binding regulatory frameworks for battery take-back and recycling. In several AMS, batteries and e-waste continue to be processed through informal scrap economies, posing serious health and environmental risks due to unsafe dismantling and disposal practices.

Chapter 7 also highlights the importance of building resilience in digital talent for the automotive industry, where digitalisation can help local firms leapfrog legacy technologies and position themselves more competitively in the global market. AMS have moved at different paces in this transition. For instance, Indonesia and Cambodia are still at early stages, focused on attracting foreign investment and raising awareness among industry players. Meanwhile, Malaysia has introduced strategic policy frameworks such as the National Automotive Policy 2020 (NAP 2020) and the New Industrial Master Plan (NIMP 2030) to guide the sector's future development. In Thailand, the demand for digital talent in the automotive industry is rising rapidly.

Furthermore, to manage industry wastes, the chapter recommends that ASEAN countries adopt a multi-faceted approach to establish sustainable end-of-life vehicle (ELV) recycling systems. First, all AMS should establish legislation or systems to ensure appropriate ELV dismantling and recycling, tailored to their respective economic conditions and national capacities. Second, vehicle owners should be encouraged to replace ageing, high-emission vehicles with newer, cleaner models. Finally, existing initiatives to develop recycler licensing schemes with proper environmental and operational standards (such as those seen in Malaysia, the Philippines, and Viet Nam) should be promoted and further strengthened.

Finally, the chapter proposes a set of strategic shifts to develop a resilient ecosystem for semiconductors in the automotive sector. To move from comparative advantage in low-cost manufacturing to competitive advantage in innovation, ASEAN must prioritise three

strategic directions:

- Build design and fabrication capabilities: Singapore has taken the lead, hosting global fabs (e.g., GlobalFoundries) and electronic design automation hubs. There is potential to expand this model into Malaysia and Viet Nam
- Invest in critical mineral refining and recycling
- Develop integrated innovation zones: SEZs in Cambodia, Viet Nam, and Laos offer potential for cross-border EV and semiconductor ecosystems

All in all, Chapter 7 calls for a holistic rethinking of how vehicles are designed, produced, used, and retired, as ASEAN accelerates its shift toward sustainable and inclusive mobility.

Chapter 8: Transition Strategies and Policy Recommendations

Chapter 8 aims to visualise the 'To-Be' state of ASEAN's automotive industry and assess the gap between this desired future and the current Business-as-Usual (BAU) trajectory. By systematically analysing this gap and root causes, the chapter provides policy recommendations designed to close it, supporting ASEAN's transition toward a more competitive, sustainable, and future-ready automotive ecosystem.

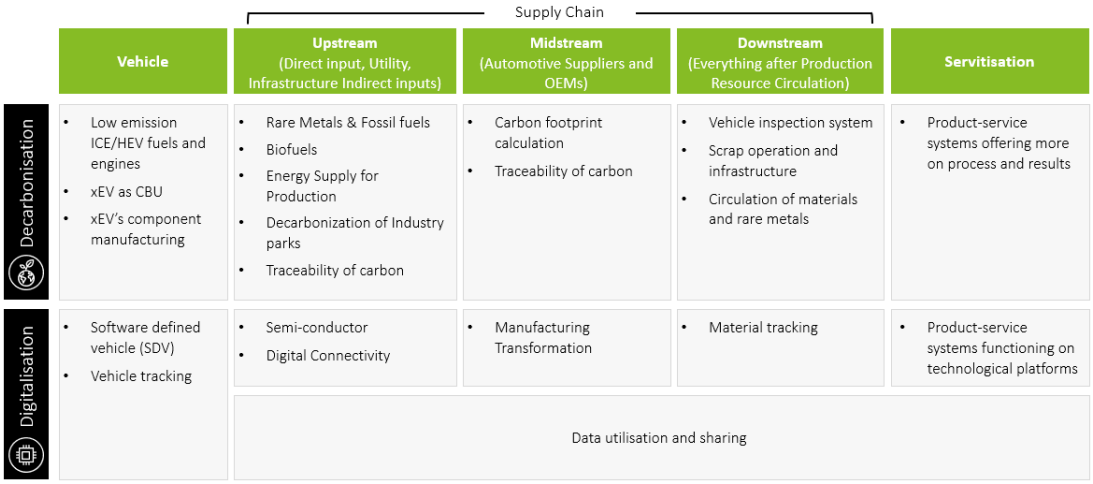
Studies from prior chapters highlighted the importance of ASEAN pursuing a varied pathway, as the region must navigate both structural constraints at home and evolving demands abroad. While ASEAN continues to dominate in ICE and HEV vehicles, still expected to make up 87% of regional sales by 2035, global pressures toward electrification, combined with uncertainty around BEV penetration and future powertrain trajectories require the region to invest in xEV readiness without undermining its existing strengths in ICE/HEV manufacturing. In other words, such a multi-pathway approach will ASEAN to sustain its competitiveness in ICE/HEV exports while progressively preparing for a region-tailored transition to electrification.

In doing so, Chapter 8 suggested that varied pathway will be sustained by five To-Be vision pillars: (i) Establishing ASEAN as a competitive ICE/HEV export hub, (ii) Fostering an advanced, cost-competitive and integrated supply chain network, (iii) Gradually integrating into the xEV component supply chain, (iv) Decarbonising the automotive supply chain, and (v) Developing innovative mobility services that match the needs of ASEAN market.

To translate these vision pillars into a structured transformation pathway, this chapter introduces an integrated framework grounded in two interlinked imperatives: decarbonisation and digitalisation. It segments the automotive value chain into three key domains (upstream, midstream, and downstream) to enable precise diagnosis and targeted policy formulation. A fourth domain, servitisation, overlays this structure to reflect the sector's pivot toward lifecycle value creation through digitally enabled services. Together, these interconnected domains form the basis for ASEAN's transition to a competitive, sustainable, and future-ready automotive ecosystem.

The To-Be states are later explored in greater depth, covering the following topics:

To-Be State Deep Dives



Source: Authors (2025).

Digitalisation acts as the connective tissue that accelerates transformation across all domains. In the vehicle space, the rise of software-defined vehicles (SDVs) and advanced telematics allows ASEAN to compete on intelligence and user experience, not just cost. Within the supply chain, digitalisation enables enhanced connectivity, data-driven manufacturing, and real-time traceability. These capabilities are critical for building a resilient, cost-efficient, and regionally integrated production base.

Meanwhile, Decarbonisation is not only an environmental imperative but also a competitiveness strategy. ASEAN's ability to integrate into the global xEV component supply chain depends on its capacity to meet increasingly strict carbon standards. In the vehicle domain, this translates into investment in low-emission ICE and HEV platforms, as well as the localisation of xEV component production. Across the supply chain, it requires a coordinated push toward green energy adoption, emissions traceability, and the creation of regional recycling ecosystems.

Most importantly, the framework positions servitisation as a fundamental shift in how value is created. As mobility preferences evolve and ownership models diversify, ASEAN must move beyond vehicle production to deliver integrated mobility solutions. This involves developing product-service systems that are both results-driven and process-oriented, supported by digital platforms and lifecycle analytics.

Following a deeper assessment of the To-Be states against the BAUs, the chapter examines the root causes behind the gaps that emerged in each assessed domain. In total, 11 root causes have been identified as foundational challenges to ASEAN's automotive industry, including the following:

1. Unclear vision of regional automotive industry and market direction, spurring a lack of clarity on market growth, powertrain transition, and fuel transition timelines
2. Insufficient Support for Fuel and xEV Material Manufacturing, resulting in limited accessibility to essential fuels and raw materials

3. Unfocused Vehicle Registration and Inspection Regulation to Optimise UIO (Units in Operation) Replacement, subsequently leading to a low share of connected and intelligent vehicle units on the road
4. Insufficient Infrastructure for Carbon Neutral Activities of Manufacturing, leading to low economic viability for decarbonisation efforts, particularly among Small and Medium-Sized Enterprises (SMEs)
5. Limited Experience and Know-How Within the Region, giving rise to talent and capability gaps in driving decarbonisation and advanced manufacturing initiatives
6. Limited Regional Alignment on Scrapping, Disposal, and Tracing for Resource Circulation, resulting in ineffective end-of-life vehicle systems and poor recycling and scrapping traceability
7. Insufficient Support for Regional Semiconductor Manufacturing, causing a persistent shortfall in the region's semiconductor supply
8. Lack of Regional Direction and Infrastructure for Optimised Supply Chain and Information Sharing on Traceability and Circulation, resulting in fragmented efforts to align with global trends and inadequate digital infrastructure for traceability and circularity
9. Conventional Regulations Prevent New Mobility Business Models, restricting consumer options for flexible vehicle access, purchase, and usage
10. Unfocused Vehicle Registration and Inspection Regulation to Optimise UIO Condition, leading to weak enforcement of vehicle maintenance standards as part of UIO requirements
11. Unattractive and Regionally Unharmonised Open Innovative Investment Environment, contributing to talent shortages in R&D, limited support for innovation in new mobility services, and constrained market scalability at member state level

Chapter 8 wraps up by providing policy recommendations to address the gaps and root causes identified for ASEAN to achieve its desired states of the automotive industry. The recommendations are structured around a four-layer policy stack: Strategy & Policy, Schemes & Regulations, Resources, and Operations & Infrastructure. They specify the key levers ASEAN must activate to shift from today's Business-as-Usual trajectory toward a low-carbon, digitally enabled, and service-oriented automotive ecosystem. The policy recommendations at each layer are as follows:

- Layer 1 – Strategy and Policy: The masterplan itself is the Layer 1 instrument. One key root cause surfaced is the unclear vision of the regional automotive industry and market direction. This is precisely where Layer 1 plays a critical role by setting a unified direction to remove that ambiguity once and for all
- Layer 2 – Schemes & Regulations, through:
    - Regional biofuel and e-fuel usage and circulation enhancement

- Regional support for DX/GX actions
- Revision of Vehicle inspection system
- Development of regional recycle and scrap regulation
- Development of regulation for various vehicle ownership/usage options
- Regionally harmonised regulations for open innovation investment life cycle

- Layer 3 – Resources, through:
  - Fiscal incentive for biofuel, e-fuel, semiconductor manufacturing
  - To bring DX/GX/Open Innovative human resource/know-how from outside of the region and develop internally
  - Regional information connection and sharing
  - Fiscal support for innovative investment
- Layer 4 – Operations and Infrastructure, through:
  - Green Energy Industry Park Programme
  - Material and Carbon Footprint Tracing Platform
  - Human Resource Database and Education System
  - Trade and Sustainability Enhancement through the ASEAN Single Window 2.0
  - Reduce Tariff and Non-Tariff Barriers

Ultimately, ASEAN's policy mix is recommended to advance along three mutually reinforcing arcs. First, to fortify current cash flows by deep-decarbonising the ICE/HEV complex, using bio and e-fuels, high-efficiency powertrains, digital inspection systems, and age-based surcharges that fund scrappage. Second, to secure future competitiveness by scaling xEV enablers such as critical-mineral refining, regional semiconductor fabs, hydrometallurgical recycling, and renewable-powered green parks. And third, to unlock new value pools by legalising and nurturing connected, autonomous, and shared services through cross-border data-flow compacts, mobility sandboxes, outcome-based insurance, and dynamic road pricing.

The linked approach to policy direction is expected to preserve ASEAN's role as a resilient export hub for ICE and HEV by improving supply chain efficiency. At the same time, it enables gradual integration into the global xEV supply chain through targeted investments, while aligning with the decarbonisation demands of global OEMs and evolving trade policies. By building on its existing strengths, including robust ICE/HEV supplier networks, localised models, and an export footprint spanning more than 120 countries, ASEAN can remain competitive while advancing toward a greener, more sustainable future.

Chapter 9: Co-Creation Areas

Chapter 9 presents a set of proposals on Japan-ASEAN co-creation activities to accelerate

the transformation of ASEAN's automotive industry. To realise the policy recommendations defined in Chapter 8, this section outlines potential areas of collaboration to be jointly pursued. These pathways aim to deepen partnership and advance the region's automotive ambitions. ASEAN's long-term vision includes becoming a production and export hub for ICE and HEV vehicles, while gradually shifting its supply chains toward xEV component manufacturing to meet future demand. Japan's established expertise in HEV technologies aligns closely with this trajectory and provides a strategic basis for collaboration, given the technological commonalities between HEV and xEV components.

In particular, the collaboration can support ASEAN's efforts to enhance industrial capabilities, particularly among suppliers, and expand the region's capacity for automotive parts production and export. Such cooperation contributes to reinforcing ASEAN's position within the global supply chain, especially as the region transitions toward more advanced technologies.

Subsequently, the chapter also identifies ten co-creation areas, focusing on domains where mutual strengths and strategic priorities are best positioned to deliver practical and regionally meaningful impact, as outlined below.

1. Platform or forum of stakeholders. To translate high-level policy recommendations into tangible actions, it is proposed that ASEAN and Japan co-create a dedicated stakeholder platform or forum to serve as a mechanism for implementation follow-up and policy coordination. Establishing a forum is one of the most practical and immediately actionable steps under the Masterplan. Its role would extend beyond progress monitoring to include surfacing implementation challenges, supporting mid-course adjustments, and ensuring structured, transparent, and outcome-driven co-creation between ASEAN and Japan.
2. Bilateral Collaboration for Biofuel and E-Fuel Economy Development: The potential collaboration area would be to establish an ASEAN–Japan co-working group to develop a biofuel and e-fuel economy in the region to secure supply for the automotive industry. Japan's active role in developing sustainable biofuel models positions it well for this partnership. This collaboration can help both sides scale the regional use of low-carbon fuels and accelerate the automotive sector's clean energy transition. As a case in point, Japan and Brazil launched the Initiative for Sustainable Fuel and Mobility (ISFM), combining Brazil's decarbonised fuel potential with Japan's high-performance hybrid technologies.
3. Human Resources Development Through Education System Development, Exchange and Dispatchment: The proposed co-creation area emphasises a collaborative approach in which Japan supports education and training initiatives to build a skilled workforce aligned with the future needs of the ASEAN automotive sector. This includes dispatching Japanese technical experts to ASEAN institutions such as TVET, and enabling ASEAN talents to train in Japan through skills-based placements. Japan has implemented relevant initiatives such as the Dispatch of

Roving Automotive Experts to several ASEAN countries and provided roadmap development support through technical assistance.

4. Automotive Related Regulations Commonalisation: The proposed co-creation area focuses on aligning key regulatory frameworks in ASEAN with established Japanese practices, particularly in vehicle inspection and automotive maintenance certification, to support both environmental and safety outcomes. Two key areas of collaboration include introducing a vehicle inspection system modelled after Japan's to support timely vehicle replacement, and adopting Japan's maintenance certification framework to build technical capacity and mobility of skilled professionals. Japan's early efforts in Cambodia and Myanmar already offer foundational examples of this kind of institutional support.
5. Recycle and Circulation Rules Development Support: The proposed co-creation area involves supporting the development of automotive recycling regulations, modelled after Japan's system, to help establish an effective resource circulation framework across the region. Japan's previous support in developing End-of-Life-Vehicle regulations in the Philippines, including a structured disposal system, reinforces the practicality of this approach.
6. Biofuel and E-Fuel Manufacturing and Technical Support: The potential co-creation area lies in deploying technology transfer mechanisms and joint manufacturing capabilities from Japan, while leveraging ASEAN's biomass resources for 2nd Generation (2G) biofuel production. The feasibility of this approach is supported by use cases such as NEDO's activities in the promotion of biofuel development in Southeast Asia. Since 2023, NEDO has been studying the feasibility of 2G biofuel production, particularly through the utilisation of palm oil residues in Indonesia that has followed into a taskforce proposal in 2024, and a Business and Technology Introduction and Exchange Meeting on Non-Edible Biomass-Based Biofuels for a demonstration project in February 2025.
7. Information and Data Standardisation Development: The proposed co-creation area centres on the joint development of institutional and regulatory foundations to operationalise the ASEAN Automotive Data Space and considers the potential utilisation of Japan's Ouranos Ecosystem as a cost-effective and immediately scalable foundation. One of the Ouranos Ecosystem's key applications is the Automotive and Battery Traceability Centre (ABtC), which plays a central role in material and carbon footprint tracking. By leveraging Japan's experience with the Ouranos Ecosystem, particularly in data standardisation, real-time traceability, and cross-border data governance, ASEAN and Japan can co-develop a regional framework that supports decarbonisation, supply chain integrity, and digital integration.
8. Green Energy Industry Park Model Case Development: The proposed co-creation area focuses on the development of a Green Energy Industry Park model to support the decarbonisation of SMEs in ASEAN. By aggregating energy demand and enabling shared infrastructure, the model can offer tailored support to SMEs facing scale and

resource limitations. The feasibility of this co-creation area is reinforced by Japan's involvement in the development of the Patimban Port Green Corridor in Indonesia. Through METI, an MOU was signed between Pertamina and Toyota Tsusho Indonesia to jointly explore carbon-neutral fuel solutions for the Eastern GX Corridor, an initiative aimed at decarbonising logistics and industrial zones in eastern Jakarta.

9. ASEAN Single Window (ASW) Strengthening Support: The proposed co-creation area involves Japan's support for the further technical and institutional enhancement of the ASW, aimed at enabling more seamless cross-border goods transfer across the region. Japan's long-standing contributions include technical support to Vietnam's VNACCS/VCIS system and broader engagement in ASEAN's digital integration since 2015, particularly through customs streamlining and single-window platforms.
10. Policy and Regulation Making Support: the proposed co-creation area involves Japan's continued support for policymaking processes in ASEAN through capacity building, regulatory planning, and advisory cooperation, drawing on Japan's institutional experience and long-standing track record in policy-oriented development assistance. For example, JICA's advisory role in the Philippines on preferential tax systems illustrates how Japan can help shape responsive, evidence-based policies aligned with ASEAN's regional goals.

In conclusion, building on the ASEAN–Japan Commemorative Summit and its shared vision for 'Co-Creation for the Future,' the proposed collaborative areas offer a coherent set of actionable pathways to advance the ASEAN–Japan Co-Creation Initiative. These efforts reaffirm Japan's role as a long-standing, forward-looking partner and reflect a shared commitment to transform strategic alignment into concrete, regionally significant progress for ASEAN's next-generation automotive industry.

Chapter 1
Introduction

The automotive industry is a major player in the global economy, closely tied to the manufacturing and services sectors. It serves as the primary consumer of iron, steel, petrochemicals, and tyres, drives technological advancements across these sectors, and fosters a multi-tiered supplier network characterised by extensive outsourcing (Mohamad and Songthaveephol, 2020). Its high value-added output, substantial employment generation, and strong multiplier effect on technological advancement make it a strategic driver of economic and technological progress (Cinicioglu et al., 2012). Population growth and the consequent rise in vehicle demand have intensified competition, strengthened the industry's global influence (Mohammad Nazir and Shavarebi, 2018), and promoted transnational interdependence (Pichler et al., 2021). Beyond its economic impact, the automotive industry has shaped global lifestyles, serving as a centre for innovative management practices and a continuous source of advanced technologies. Consequently, changes within the industry exert profound effects on the wider economy and the socio-technical system (Mohamad and Songthaveephol, 2020).

The ongoing electrification of motorised vehicles underscores the need for agility across the automotive industry in Southeast Asia. Historically, the automotive industry has served as a backbone of the Association of Southeast Asian Nations (ASEAN) industrialisation and regional economic integration. Leveraging its strategic geography, relatively low production costs, and preferential trade regimes, ASEAN has evolved into a global automotive production hub, ranking sixth globally in vehicle output and fifth in vehicle exports by volume in 2022.

Compared with internal combustion engine vehicle (ICEV) production, electric vehicle (EV) manufacturing differs significantly in production structures and supply chains, material requirements, end-of-life treatment, the labour needs in both quantitative and qualitative terms, and the configuration of global value chains (GVCs) within the industry.

On the latter, a study conducted by Kohpaiboon (2025) observed that battery electric vehicle (BEV) manufacturers have largely adopted export-platform business strategies similar to those of ICEV producers, whereby manufacturers select a country as a production hub to serve both domestic and neighbouring markets. The study highlighted two main findings.

First, the gains from industrial agglomeration, i.e. the formation of ICEV GVCs characterised by industrial clustering, with vehicle assembly at the geographical centre surrounded by parts suppliers, do not always outweigh the benefits of international fragmentation. As a result, replacing ICEV GVCs with those of BEVs could adversely affect backward linkages to

the rest of the economy. Considering the limited overlap in parts between ICEVs and BEVs, existing ICEV GVCs are unlikely to significantly benefit the formation of BEV GVCs.

Second, abrupt policy changes that introduce the disruptive effects of BEVs must be approached with caution in production hubs within developing countries. Positioning these countries as BEV production hubs may entail costs to their current roles as ICEV production hubs. Any strategy to enable developing countries to leapfrog towards becoming technological leaders, such as BEV development hubs, requires accurate technology foresight and conducive institutional environments.

ASEAN's automotive industry derives its strength from its deeply embedded position within GVCs, particularly those coordinated by Japanese original equipment manufacturers (OEMs). These vertically coordinated supply networks have enabled ASEAN countries to specialise in component manufacturing, vehicle assembly, and regional distribution. However, the rapid emergence of electric mobility, digitalisation, and decarbonisation is driving structural shifts in GVC configurations. These changes challenge ASEAN's traditional comparative advantages and call for adaptive and forward-looking policy responses.

At the same time, most ASEAN countries have committed to achieving net-zero emissions by the middle of the century. This commitment not only accelerates the electrification of transport and mobility across the region but also imposes an imperative on the automotive sector itself to decarbonise and to embrace the principles of circular economy. This implies that automotive activities and related sectors, whether in EV or ICEV production, must decarbonise and implement circularity across all supply chains throughout all life-cycle phases, from cradle to grave.

ASEAN's vehicle industry sectors therefore find themselves at the intersection of multiple forces, most notably market dynamics and decarbonisation objectives. This raises a central question: how can the ASEAN automotive industry strengthen its competitiveness amid accelerating electrification and decarbonisation?

Before addressing how this research responds to that question, the following sections establish the conceptual foundation underpinning it. The chapter starts with a discussion of how competitiveness is defined, perceived, and structured. It then examines competitiveness as reflected through key trade-related indicators and concludes by discussing the importance of industry-wide decarbonisation.

1.1. Automotive Industry Competitiveness

As in other industries, automakers, auto-part producers, and other automotive industry players seek, to some extent, to exert market power: the ability to generate profits by capturing market segments willing to purchase products or services at prices above their corresponding costs of production. However, this market power is constrained by the need to preserve consumer surplus. As with suppliers in other industries, automotive industry players must therefore consider two types of substitutability: demand-side and supply-side

substitutability (Mota, 2004).

Demand substitutability refers to the possibility of substitution amongst different products and services. Vehicles with similar characteristics have competed in markets since the inception of the automotive industry. Market outcomes have been shaped by factors such as purchase price, fuel economy, model range, suitability for urban and non-urban use, durability, brand reliability, and other determinants of total cost of ownership, as well as broader user preferences. As in other parts of the world, EVs in their various forms represent new automotive products entering ASEAN markets. ICEVs are therefore in direct sales competition with EVs. Current market trends in ASEAN indicate that EVs, usually benefiting from government incentive schemes, are gaining market share, whilst ICEV producers and sellers are increasingly required to adopt strategies to maintain their competitive positions.

Substitutability amongst players has also become more complicated. The entry of EVs has brought new automotive industry players, many of which are relatively new to the industry. To overcome market barriers, these players are developing not only distribution networks, sales outlets, and charging infrastructure (often in coordination with different developer actors), but also new EV components, particularly in relation to the production or procurement of EV batteries. This expansion extends to supporting industries, including mineral extraction, processing, and refining.

1.1.1. Definition of Competitiveness

The World Economic Forum has, for many years, applied a consistent definition of competitiveness in its annual country competitiveness reports: competitiveness is defined as the set of institutions, policies, and factors that determine a country's level of productivity (Porter et al., 2007; Schwab and Sala-i-Martín, 2012).

This definition is characterised by its conciseness, its exclusion of the outcomes of competitiveness, and its close alignment with an economist's interpretation, whereby productivity ultimately determines competitive advantage. This definition provides the basis for the present analysis, with one modification. Although it appears comprehensive, the first two determinants – institutions and policies – can be subsumed under the third determinant, namely 'factors', which is treated here as a catch-all category.

Purwanto et al. (2017) define competitiveness as the extent to which firms in a particular region can compete with firms elsewhere. In this context, critical factors of competitiveness are those that determine the level of productivity in a region relative to other regions.

In this definition, 'competing with firms elsewhere' can be understood as producing goods and services that meet the test of international markets. Key elements of the definition include firms, regions, and productivity. Firms and other individual units, such as entrepreneurs and employees, are the key actors of competitiveness. Regions, by contrast, are not actors in themselves but analytical constructs; accordingly, the definition explicitly refers to 'firms in a region'.

Competitiveness can be examined at multiple spatial scales, including national, supranational (such as ASEAN or the European Union), and subnational levels. As institutions are generally assumed to play a role in regional competitiveness (Rodrik et al., 2004), spatial levels without governmental institutions may be less appropriate for analysis. Nevertheless, any spatial grouping of firms can, in principle, be analysed.

1.1.1.1. Firm-level competitiveness: Definition and factors

Firm-level competitiveness can be defined as the ability to produce and sell products or services that attract customers relative to competitors, whilst consistently meeting market demands in terms of quality and price, thereby benefiting both consumers and business owners (Nagy and Jambor, 2018). The factors influencing firm-level competitiveness include internal company dynamics, demand conditions, related and supporting industries, global competitiveness, government influence, and human resource capabilities. Table 1.1 provides further details on the factors of firm-level competitiveness.

Table 1.1. Firm-level Competitiveness Factors

No.	Factors
Internal Company	
1	Company plans for entry into overseas markets [1]
2	Research and development investment in technical knowledge and product development [1] [2] [3]
3	Access to logistics and infrastructure [1] [4]
4	Availability of new and updated products [1]
5	Company's financial situation [1]
6	Business sophistication (production process sophistication, availability of scientists and engineers, capacity for innovation) [2]
7	Organisational competences and strategic alliances [1] [3] [5]
8	Interaction with government [4]
Human Resource	
1	Labour cost, flexibility, and productivity [4]
2	Availability of skilled labour [1] [4]
3	Health and primary education [2]
4	Higher education and training [2]
5	Labour market efficiency [2]
Demand Condition	
1	Customers' purchasing power [1]
2	Size and distribution of markets (domestic and overseas) [1] [2]

No.	Factors
3	Global share of vehicle production, sales volume, and vehicle exports [4] [6] [7]
4	Cost leadership [4]
5	Variety and choice, diversification, and customisation [3] [4]
Related and Supporting Industries	
1	Technological maturity and level of innovation [1]
2	Conditions of related industries within the supply chain and OEMs [1]
3	Availability and quality of local suppliers [2] [4]
4	Market access for foreign producers [8]
5	Supply chain flexibility and effective logistics system [3] [9]
6	Infrastructure [2]
7	Technological readiness (firm-level technology absorption and availability of advanced technologies) [2]
Government	
1	Macroeconomic risks, investment risks, and fluctuations [1] [2]
2	Taxes and tariffs [1] [4]
3	Governmental subsidies and fiscal incentives [4] [11] [12]
4	Interaction with government [4]
5	Financial market development (ease of access to loans) [1] [2] [8]
International Competitiveness	
1	Foreign direct investment [1] [10]
2	Perception of new technologies [1]
3	Global perception of the country [1]
Environmental	
1	Integration of environmental goals into industrial policy [4] [13]

Sources: Author's research based on [1]Fathi and Ahmadian (2016), [2]WEF Report (2011), [3]Nazir and Shavarebi (2018), [4]Holweg et al. (2009), [5]Muhamad and Songthaveephol (2020), [6]Konrad et al. (2018), [7]Meckling and Nahm (2019), [8]Winston (1987), [9]Delic and Eyers (2020), [10]Heneric, Licht, and Sofka (2005), [11]Sakuramoto et al. (2018), [12]Lee (2017), [13]Pichler et al. (2021).

1.1.1.2. National competitiveness: Definition and factors

Nagy and Jambor (2018) define national competitiveness as a country's ability to sustain economic growth and improve citizens' well-being by enhancing productivity. This involves fostering an environment in which businesses and institutions can develop and produce goods and services that meet global competitive standards and evolving social expectations. It is closely related to international trade theory, which explains why countries engage in trade.

National competitiveness factors are typically analysed in terms of factor conditions, demand conditions, related and supporting industries, and firm strategy, structure, and rivalry, as summarised in Table 1.2. The significant overlap between firm and national competitiveness factors suggests a close relationship between the two.

Table 1.2. National Competitiveness Factors

Factor Conditions	Demand Conditions	Related and Supporting Industries	Firm Strategy, Structure, and Rivalry
• Labour pool • Local raw material sources • Other factors that are important for effective production	Characteristics of domestic market demand, whereby sophisticated consumer needs drive higher standards	Globally competitive industries that provide a strong foundation for downstream sectors	

Source: Authors, based on Nagy and Jambor (2018).

Within the automotive industry, Meckling and Nahm (2019) categorised countries according to their industrial capabilities and regulatory approaches. The first category comprises countries that pursue export-focused EV industries as a strategic means of accelerating industrial upgrading. Efforts to leapfrog conventional automotive technologies have intensified global competition in green industrial policies, accelerating technological change and compelling established automotive producers to adapt. Countries in this category include China, India, the Netherlands, and Scotland. In ASEAN, Viet Nam falls within this category, following the establishment of VinFast in 2017 and its subsequent EV exports to various markets.

The second category consists of countries with well-established, export-oriented automotive industries that face the challenge of maintaining global competitiveness amid structural change and increasing environmental requirements, including the transition to low-carbon technologies. These countries are pursuing industrial renewal to remain competitive. This category includes Japan, France, Germany, the United Kingdom, and the Republic of Korea (henceforth, Korea) (Meckling and Nahm, 2019). Within ASEAN, Malaysia is similarly seeking to adapt its existing automotive sector to the EV transition.

The third category includes countries that are primarily importers of vehicles and that pursue low-carbon and energy transition goals mainly for environmental reasons, despite lacking a domestic automotive industry. Examples include Norway and Ireland, as well as most ASEAN countries other than Viet Nam and Malaysia. This typology reflects the diversity of competitive strategies adopted across countries.

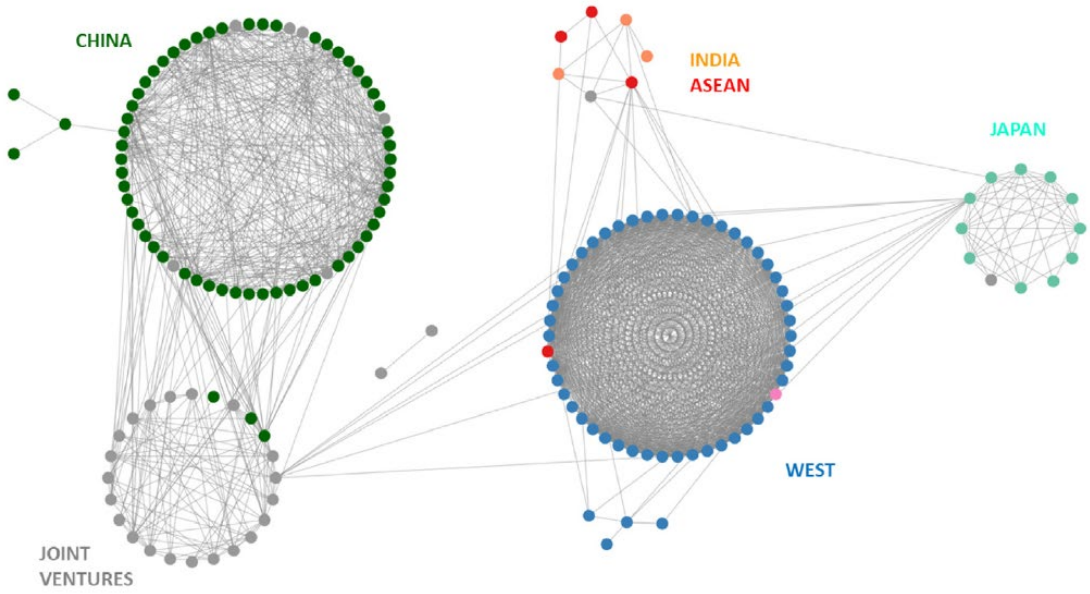
1.1.1.3 Regional competitiveness

Nagy and Jambor (2018) define regional competitiveness as the success of regions and cities in competing with one another across various dimensions. Other studies describe it as the ability to offer an attractive and sustainable environment for businesses and residents to live and work. Purwanto et al. (2016) approach regional competitiveness across multiple scales, including national, supranational bodies (such as the European Union), and subnational levels. Subnational competitiveness is often assessed on the basis of factors such as infrastructure investment.

Overall, the factors shaping regional competitiveness include economic structure, innovative activity, regional accessibility, workforce skills, environmental conditions, decision centres, social and regional structures, research and technological development, the development of small and medium-sized enterprises, foreign direct investment activity, infrastructure and human capital, and institutions and social capital.

Fessina et al. (2024) show that production networks in the automotive sector are structured through 'functional' relationships, indicating both complementarity and competition amongst firms. A significant number of suppliers are shared across manufacturer pairs, suggesting that competition persists even amongst firms that are strongly connected through common partners. These network structures, or clusters, are influenced by both geographical proximity and industrial similarity.

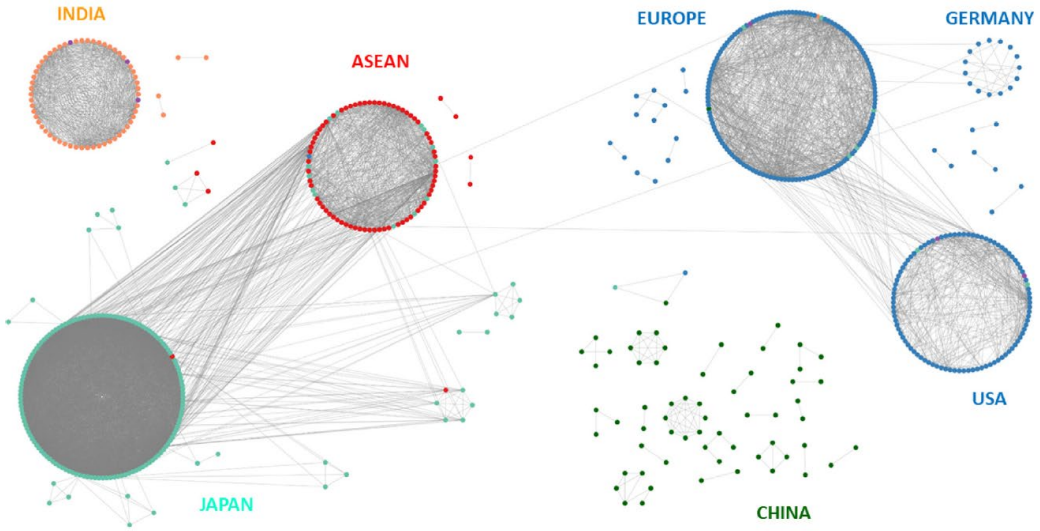
Figure 1.1. A Validated Projection onto the Manufacturer Layer, with Links Indicating the Sharing of a Significantly Large Number of Suppliers



ASEAN = Association of Southeast Asian Nations.
Source: Fessina et al. (2024).

Figure 1.1 illustrates that Chinese manufacturers do not share a significantly large number of suppliers with other manufacturers. The Chinese cluster is linked only to the joint venture cluster, which in turn links to the Western cluster through the BMW Brilliance partnership. By contrast, the Western cluster is connected with manufacturers in ASEAN, India, and Japan, making it the most centralised manufacturers' network.

Figure 1.2. A Validated Projection onto the Supplier Layer, with Links Indicating the Sharing of a Significantly Large Number of Manufacturers



ASEAN = Association of Southeast Asian Nations, USA = United States of America.
Source: Fessina et al. (2024).

Figure 1.2 shows that Chinese suppliers are relatively isolated and internally fragmented. This pattern suggests a more decentralised industrial structure compared with Western economies, potentially reflecting a strategy to promote balanced economic development across provinces and to enhance national competitiveness. Meanwhile, the largest components in the global network comprise two interconnected clusters: ASEAN–Japan and Europe–United States (US).

Taken together, the various definitions and factors associated with firm, national, and regional competitiveness reveal substantial overlap across these analytical levels. The boundaries between firm, national, and regional competition are increasingly blurred and are best understood through a historical and structural perspective.

1.1.2. Blurred Lines of Firm, National, and Regional Competition

Holweg (2008) comprehensively explains the major evolution of production systems by categorising them into three models: Ford, Sloan, and Toyota. The Ford model pioneered mass production through the standardisation of interchangeable components and the use of the assembly line as a central production tool. This innovation significantly streamlined manufacturing processes, increased efficiency, and reduced costs. Ford focused on maximising production volume to achieve profitability by lowering unit costs. A prime example is the Model T, whose price dropped by almost half, from US$1,200 in 1909 to US$690 in 1914.

Over time, however, consumer preferences shifted towards greater variety rather than the uniform and limited options offered by the Model T, which was available only in black. Recognising this change, Alfred P. Sloan of General Motors (GM) introduced a new approach in the 1920s. The Sloan model emphasised variety and brand differentiation, offering a brand hierarchy ranging from mass-market Chevrolet models to high-end Cadillac vehicles, encapsulated in the idea of 'a car for every purse and purpose'. Sloan also popularised flexible payment methods, including both cash and credit, making GM vehicles accessible to a wider range of consumers (Holweg, 2008; Pietrusza, n.d.).

By the mid-1920s, GM's ability to integrate mass production with consumer choice, coupled with Ford's failure to adapt to evolving market demand, led to a shift in consumer preferences. As a result, GM gained market dominance, whilst Ford voluntarily closed its factories in 1927 to retool for the Model A, which was introduced a year later with more variety and enhanced features to compete with GM (Holweg, 2008). However, combining mass production with a wider range of choices led to higher inventory levels, tying up significant capital costs and warehouse space. In addition, the reliance on large production batches to achieve economies of scale led to higher defect rates (Holweg, 2006).

By recognising the flaws inherent in both the Ford and Sloan models, Ohno Taichi, who underpinned the Just-in-Time (JIT) manufacturing philosophy of the Toyota Production System (TPS), expanded the concept of small-lot production. This approach reduced costs by minimising waste through smaller production batches. Ohno also introduced *jidoka,* or

humanised automation, which ensured quality by detecting defects and stopping production when they occurred. He also implemented a JIT replenishment system inspired by *kanban*, a production and workflow management system used to control the flow of materials and information. With additional input from Shigeo Shingo, Toyota further improved efficiency through the development of Single-Minute Exchange of Dies, which significantly reduced machine changeover times. As a result, JIT manufacturing allowed for greater model variety, smaller batch sizes, and improved quality with minimal defects (Holweg, 2006).

The JIT manufacturing system began to attract attention in Western economies during the late 1980s, coinciding with the so-called 'Economic Pearl Harbor', which referred to the sharp increase in Japanese car imports. In response, the US and Japan negotiated a 3-year Voluntary Export Restraint agreement in 1981 to protect domestic markets by limiting Japanese car exports to the US. However, this agreement proved contradictory. Japanese automakers shifted towards selling higher-end vehicles and established transplant factories in North America to bypass import restrictions and maintain market expansion, beginning in 1982 (Holweg, 2006; Clemens, 1987; Russo et al., 2023).

From the 1980s to the 1990s, the global automotive industry became increasingly integrated, driven by accelerating cross-border trade encouraged by the World Trade Organization through trade and investment liberalisation. These developments fundamentally reshaped automotive competitiveness (Sturgeon et al., 2008). As the industry globalised, competitiveness could no longer be defined solely by individual manufacturing phases or by national origin, leading to increasingly blurred boundaries. Several factors contributed to this blurring of competitive lines within the automotive industry.

1) Global mergers and acquisitions

Since the 1990s, major disruptions have occurred across industries as globalisation accelerated following recovery from the 1990–1991 economic recession. The reduction of trade barriers facilitated international trade and investment, reinforcing a shift towards free-market economies. As markets became increasingly globalised and competitive, the fifth wave of mergers spread worldwide, driven by firms seeking to meet growing demand, including in the automotive industry (Açyta and Kaya, 2016).

Mergers and acquisitions (M&A), together with equity-based alliances, surged in the automotive sector during the 1990s, strengthening the global dominance of already concentrated lead firms, primarily from Japan, Germany, and the US (Sturgeon et al., 2008). Key drivers of M&A activity (Holweg, 2008; Kuznetsova, 2016; Warter and Warter, 2016) included

a. gaining access to emerging markets and new consumer bases;
b. enhancing economies of scale in procurement and technological development, necessitating continuous upgrades in production capabilities;
c. building global brand portfolios; and

d. sharing technological and financial risks.

Table 1.3 shows selected automotive mergers and acquisitions from the 1990s to the 2000s.

Table 1.3. Automotive Producer Mergers and Acquisitions, 1990s–2000s

Year	Type	Merger and Acquisition Parties
1989	Acquisition	Ford acquired Jaguar
1998	Merger	Daimler-Benz and Chrysler formed DaimlerChrysler
1998	Acquisition	Volkswagen acquired Bentley, Bugatti, and Lamborghini
1999	Acquisition	Renault acquired a controlling stake in Nissan
1999	Acquisition	Ford acquired Volvo Cars
2000	Acquisition	General Motors acquired 20% of Fuji Heavy Industries (Subaru's parent company)

Source: Minadeo (2024).

2) Lean manufacturing production beyond Japanese producers

Holweg (2006) provides an extensive genealogy of lean manufacturing. The JIT concept, derived from the Toyota production system, also referred to as the Japanese manufacturing technique, had already been recognised in Western economies since the early 1980s, as documented by authors such as Schonberger (1982), Hall (1983), and Monden (1983). However, the publication of *The Machine That Changed the World* by Womack et al. in 1990 played a decisive role in popularising lean manufacturing in the West. Several additional factors also contributed to its widespread adoption:

a. Japanese car manufacturers were not perceived as major competitors until the oil crisis of 1973, which triggered public and industrial reassessment of automotive competitiveness.
b. The success of Japanese transplant manufacturers in North America from 1982 onwards, which facilitated the transfer of JIT knowledge and strengthened the capabilities of local suppliers.

These developments demonstrated that JIT was not culturally bound to Japan, but rather transferable and adaptable across countries and organisational contexts (Holweg, 2006). As lean manufacturing practices diffused globally, Japanese car manufacturers gradually lost their exclusive competitive advantage in this production approach.

3) Outsourcing and modularisation

Globalisation has reshaped the automotive industry by opening emerging markets such as China, India, and Brazil. In contrast, mature markets in Europe, North America, and Japan initially struggled to offer models that matched the preferences of these new

markets (Camuffo, 2002). As cross-border trade accelerated in the late 1980s, governments in emerging markets introduced trade restrictions and investment incentives to limit imports and attract foreign direct investment (FDI) (Camuffo, 2002; Sturgeon et al., 2008). In response, multinational carmakers adopted global outsourcing strategies, shifting production towards local suppliers and implementing a 'build where you sell' strategy by locating manufacturing facilities closer to consumers. This relocation reduced costs through access to skilled and lower-cost labour, whilst also optimising marketing, sales, and logistics through shorter communication lines, and faster product introduction (Camuffo, 2002; Collins et al., 1997)

As outsourcing expanded, relationships between OEMs and suppliers evolved, with local suppliers increasingly involved in the co-design of components and systems (Lung, 2001; Sturgeon et al., 2008; Camuffo, 2002). Modularisation emerged as a key strategy for reducing complexity and establishing clear boundaries in both design and production (Pandremenos et al., 2008). Modularisation also facilitates the integration of external innovation sources. Cabigiosu et al. (2012) define modularity through three key features: separability, isolability, and recombinability.

Approaches to modularity differ between Western and Japanese automotive systems. In Western contexts, automakers increasingly outsource modules, shifting from integral architectures towards more vertically structured production systems and transferring greater responsibility to suppliers (Pandremenos et al., 2008; Holweg, 2008). As a result, carmakers reduce direct manufacturing involvement and focus on managing overall design and production networks (Lung, 2001; Sturgeon et al., 2008). This shift may create relational or market-based linkages that can prove unstable. Frequent supplier switching may undermine product quality, whilst inadequate compensation for design work can expose suppliers to financial distress or bankruptcy (Sturgeon et al., 2008).

In contrast, modularity in the Japanese automotive industry relies more heavily on in-house co-design and long-term relationships with a limited group of suppliers, primarily domestic firms. These trust-based and captive partnerships support stability, coordination, and consistency in production (Sturgeon et al., 2008).

4) Expanded product spectrum and shorter product life cycles

Holweg (2008) highlights how globalisation has driven dynamic expansion in both model variety and product life cycles. Early automotive markets offered a limited range of vehicle categories, such as small, mid-size, and sports cars. Over time, this spectrum expanded to include supermini, compact, executive, multi-purpose, sport utility, and urban activity vehicles. This diversification, driven by shifting consumer preferences, technological advancements, and production innovations, has been accompanied by a reduction in product life cycles. In developed economies, the average product life cycle declined from 8 to 4 years (Sabadka et al., 2019).

The combined increase in model variety and reduction in product lifespan has lowered sales volumes per model, forcing carmakers to rationalise production to maintain

efficiency. Platform-based production emerged as a response, enabling manufacturers to offer diverse models whilst containing development costs. Brands within the same corporate group increasingly share common platforms to reduce design effort and achieve economies of scale, as seen in the case of Ford and Jaguar. Platform production generally includes shared rolling chassis, braking systems, suspensions, engines, and transmission (Danilovic et al., 2007; Sturgeon et al., 2008).

However, platform strategies have also attracted criticism. As brands arising from successive mergers increasingly share components, brand differentiation may weaken, potentially leading to internal competition and cannibalisation (Sturgeon et al., 2008; Ramos and Ruiz-Gálvez, 2024). Overall, globalisation has reshaped the competitive landscape of the automotive industry, but it has not produced a fully unified global market. Instead, the industry has shifted from nationally rooted production systems towards regionally oriented structures. Several factors explain the persistence of regionalisation (Jetin, 2018; Sturgeon et al., 2008; Lung, 2001):

a. the high cost of transporting parts, components, and completely built-up vehicles, particularly due to their weight and, in some cases, fragility;
b. high import tariffs, especially between countries lacking free trade agreements;
c. local content requirements and political pressures to protect domestic manufacturers and labour when import shares exceed domestic production;
d. modular production strategies that favour regional proximity to reduce lead time, inventory levels, and logistics risks, given the bulky nature of automotive modules and the limitations of air freight; and
e. market-specific regulatory differences, including driving orientation, environmental standards, and other compliance requirements, which limit the viability of truly 'global cars' to luxury or niche segments.

As regional integration deepens, cross-regional trade has also intensified. Russo et al. (2023) identify three major clusters in the global automotive parts and components trade, led by Germany, the US, and China and Japan. Their analysis of trade flows from 1993 to 2017 shows that intra-cluster exports consistently accounted for more than half of total exports, declining from 82.7% in 1993 to 66.6% in 2017. Over the same period, cross-cluster trade nearly doubled, increasing from 15.1% in 1993 to 32% in 2017.

Whilst production and supply-chain management continue to evolve, technological change within the automotive industry has historically been incremental. In contrast, propulsion systems represent a disruptive and radical shift, driven by increasingly stringent global carbon dioxide emission targets. Rather than converging on a single 'best' technological solution, the industry is pursuing multiple pathways, including BEVs, hydrogen fuel cells, and biofuel-based systems (Holweg, 2008; Russo et al. 2023).

The transition from ICE to non-fossil-fuel propulsion systems is restructuring competition and GVCs. EVs comprise about 200 parts, compared with about 1,400 parts in ICEVs, reflecting a much simpler product architecture. Consequently, suppliers of ICE-related

components, such as engines, gearboxes, exhaust systems, mufflers, and fuel pumps, are in decline, whilst demand is rising for batteries, electric motors, and advanced transmission systems. This shift also affects employment, as modular and platform-based EV production reduces labour requirements. The EV battery market exhibits an oligopolistic structure dominated by Asian suppliers, particularly from China, Korea, and Japan. Consequently, leading automotive companies increasingly form alliances or joint ventures with battery manufacturers to secure technological expertise and strengthen their competitive positions in the EV value chain (Ramos and Ruiz-Gálvez, 2024).

1.1.3. Perspective of Competition Theory

Automotive industry players naturally seek to increase their profits. When prices increase, the resulting growth in profits does not compensate for the reduction in consumer surplus. When prices reach their highest possible level, i.e. the monopoly price, overall welfare reaches its lowest level.

Welfare is maximised when price equals marginal production cost. However, marginal production cost also represents the lowest possible price. Under such conditions, firms would be reluctant to invest, as they would anticipate earning no profit and being unable to recover fixed costs associated with investment. In this hypothetical situation, future welfare would decline, as firms would stop introducing new products, undertaking innovation, and improving the quality of their goods and services.

The goal of making profits motivates automotive industry players to improve existing products, introduce new ones, and decrease prices to capture market share from rivals. Intervening to reduce or limit profits may increase consumer surplus in the short run, but it is likely to have a stronger negative effect in the long run.

In practice, firms require some degree of market power. Market power is defined by Motta (2004) as the difference between the price charged by a firm and its marginal cost of production. Setting prices above marginal cost triggers welfare losses in the form of deadweight loss, which increases as the gap between price and marginal cost widens. Consequently, welfare declines as market power increases.

Motta (2004) argues that market power decreases productive efficiency for two main reasons. First, competition, by lowering market power, forces firms to exert greater effort and improve productivity, for example, by adopting the most efficient available technologies. Second, competition selects more efficient firms, which should result in lower market prices. From a dynamic perspective, a monopolistic industry player may have weaker incentives to innovate and is unlikely to invest unless it expects to appropriate the returns from such investments.

Market power should therefore exist somewhere between perfect competition and monopoly. Collaboration amongst automotive industry players in ASEAN Member States (AMSs) could help maintain and optimise market power without falling into collusion. Motta (2004) defines collusion as a situation in which firms' prices exceed a competitive

benchmark or are set sufficiently close to monopoly prices.

Such collaboration may take the form of horizontal agreements, including joint ventures, research joint ventures, and other forms of technological co-operation. According to Motta (2004), joint ventures are agreements between competitors that create a new entity to carry out certain activities instead of the parent firms. These activities may include research, production, marketing, and sales. Research joint ventures, for example, involve two or more partners ceasing independent research and development and conducting it jointly through a newly established entity. These arrangements are often characterised by spillovers – flows of technology and know-how between firms through imitation or labour mobility – and non-rivalry, whereby outputs such as knowledge can be used by others without diminishing their value.

The net effects of joint ventures can be assessed in terms of market power and efficiency gain, and these effects may be either pro-competitive or anti-competitive. The main concern with this form of horizontal agreement is the need for caution to prevent ancillary clauses that could distort competition.

Another form of technological cooperation that is particularly relevant to the automotive industry in ASEAN is cooperative standard-setting. This occurs when firms competing in the development of new technologies agree on common standards. Such standards can benefit consumers by enabling a single network, reducing the risk of being locked into obsolete technologies, and expanding choice within a common standard. Nevertheless, careful safeguards are required to ensure that cooperative standard-setting enhances welfare rather than undermines competition. In this context, both ex-ante and ex-post analyses are important, for example, to minimise the risk that the adopted standard is not the most efficient one.

1.2. Driving Interdependence: Trade, Investment, and Cooperation in the ASEAN and East Asian Automotive Sector

The automotive sector has attracted significant attention in the industrial policy discussion of various AMSs. Policymakers recognise its potential to drive structural transformation and stimulate value-added manufacturing. Beyond its direct contributions to gross domestic product and exports, the sector generates considerable spillover effects through inter-industry linkages, supporting related activities in metals, electronics, chemicals, and logistics, whilst promoting technology transfer and skills development. As countries seek to strengthen their positions in regional and global value chains, the automotive sector serves as a crucial entry point for economic upgrading and diversification.

Governments across the region, most notably in Thailand, Indonesia, Malaysia, the Philippines, and, more recently, Viet Nam, have introduced targeted measures to attract investment, build domestic capabilities, and enhance competitiveness in both traditional vehicles and emerging segments such as EVs. Southeast Asian countries have introduced various initiatives under the ASEAN framework and ASEAN Plus free trade agreements to

facilitate trade, including targeted efforts to enhance regional integration in the automotive sector.

Despite these efforts, the region faces critical challenges. Persistent non-tariff measures (NTMs), fragmented regulatory frameworks, and uneven infrastructure readiness pose barriers to investment and regional production integration. Heavy reliance on imported intermediate inputs presents a significant risk of being trapped in low-value-added stages of production and restricts the potential for positive spillovers. Smaller markets struggle with limited economies of scale, whilst competition from more established producers outside ASEAN remains strong. The global shift towards green and smart mobility requires ASEAN countries to rapidly adapt their policy and investment environments to remain competitive in a rapidly evolving technological landscape.

These challenges underscore the urgency of deepening regional cooperation and improving the overall coherence of industrial and trade policies across ASEAN. In this context, enhanced regional value chain (RVC) development emerges not only as a means of overcoming structural constraints but also as a strategic response to external competitive pressures and technological shifts. A well-integrated RVC enables member states to capitalise on their respective comparative advantages, whether in upstream inputs, components, or final assembly, thereby promoting production efficiency, achieving economies of scale, and expanding intra-regional trade. Regional integration also facilitates the diffusion of technology, the harmonisation of technical standards, and capacity-building efforts, all of which are crucial for enhancing the region's participation in higher-value-added activities. Countries with smaller domestic markets or nascent industrial bases, in particular, benefit from access to regional production networks and coordinated infrastructure and investment strategies. As the global automotive industry undergoes rapid transformation driven by electrification, automation, and digitalisation, ASEAN's collective ability to adapt and compete can be significantly enhanced through deeper regional coordination and connectivity.

Although this study focuses primarily on the ASEAN region, it situates the analysis within a broader East Asian context by including key regional partners: Japan, China, Korea, and India. These countries play a critical role in both the upstream and downstream segments of the automotive value chain, serving as major suppliers of technology-intensive inputs such as machinery, electronics, and advanced materials, as well as important end markets for vehicles and components. They also host leading automotive companies that are key players in regional and global production networks. Linkages with these firms facilitate technology transfer, the diffusion of managerial expertise, and integration into GVCs, resulting in spillover effects that are vital for ASEAN's industrial upgrading. China and India, in particular, with their large consumer bases and increasing automotive demand, represent significant export markets and investment destinations. Strengthening cooperation and interdependence with these economies would not only enhance ASEAN's competitiveness and innovation capacity but also deepen its integration into global production networks. In a time of heightened geopolitical uncertainty and realignment of

global supply chains, such regional collaboration is increasingly important for bolstering economic resilience and sustaining growth.

Against this backdrop, this introductory section presents an updated analysis of the GVC landscape in the ASEAN and East Asian automotive sector, structured in two parts. The first part examines GVC participation, with a detailed analysis of trade along the value chain and trends and patterns in FDI. The second part evaluates the policy landscape influencing the sector's competitiveness and integration, looking at tariffs, NTMs, and related commitments under trade agreements. Based on the analysis, the report outlines policy implications for developing ASEAN's automotive value chain.

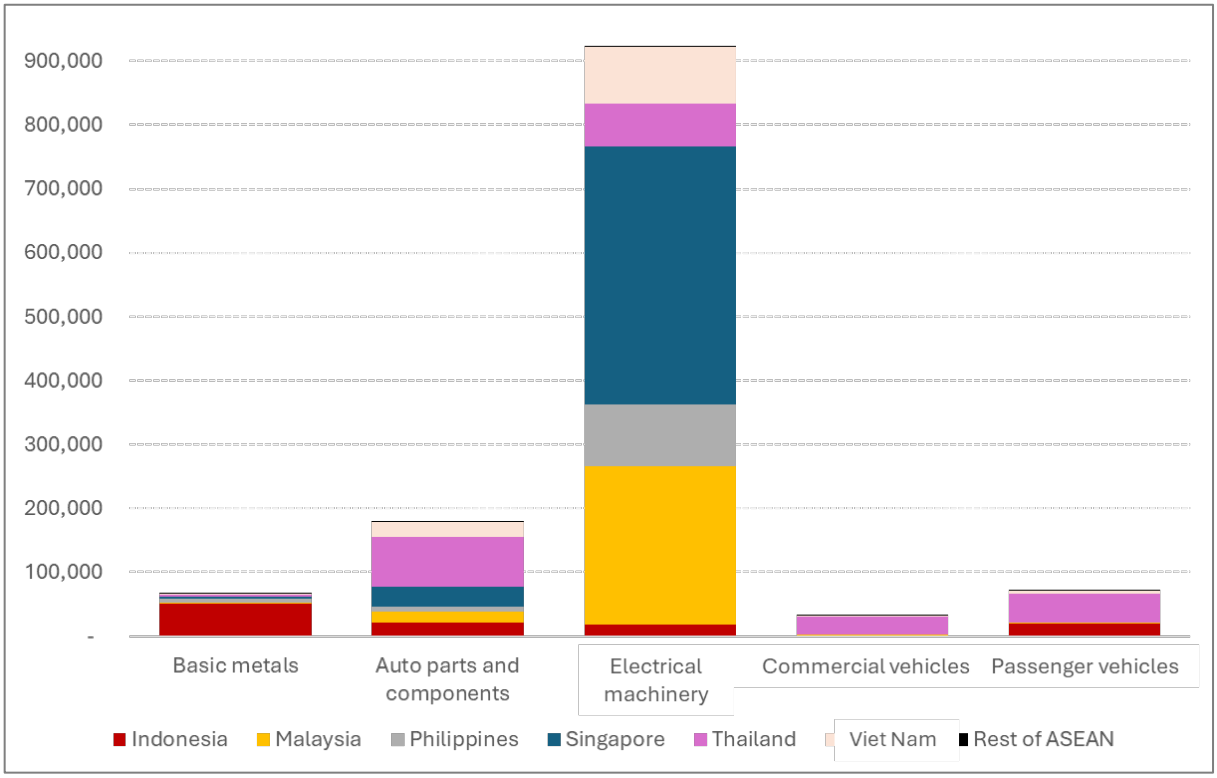
1.2.1 Automotive Sector in ASEAN and Key Trading Partners: Trade and Investment Landscape

1.2.1.1. Trade

Over the past 2 decades, several ASEAN countries, notably Thailand, Indonesia, and Viet Nam, have emerged as major automotive production hubs in the region. They have attracted significant FDI and have become increasingly integrated into GVCs. Whilst production remains geographically concentrated, cross-border trade in parts and components has strong potential to deepen intra-ASEAN integration by enabling member states to specialise vertically. The automotive sector is also closely linked with key Asian partners, particularly Japan, China, and Korea, and, to a lesser extent, India, through trade and investment flows. This section reviews trade and FDI in the automotive sectors within the region and with selected partners, noting emerging shifts and patterns of strategic complementation.

Figure 1.3 and Figure 1.4 illustrate the structure of the automotive trade in ASEAN countries, whilst Table 1.4 shows trade balances across five product groups between 2021 and 2023.

Figure 1.3. Export Structure of Automotive Products in ASEAN, 2021–2023

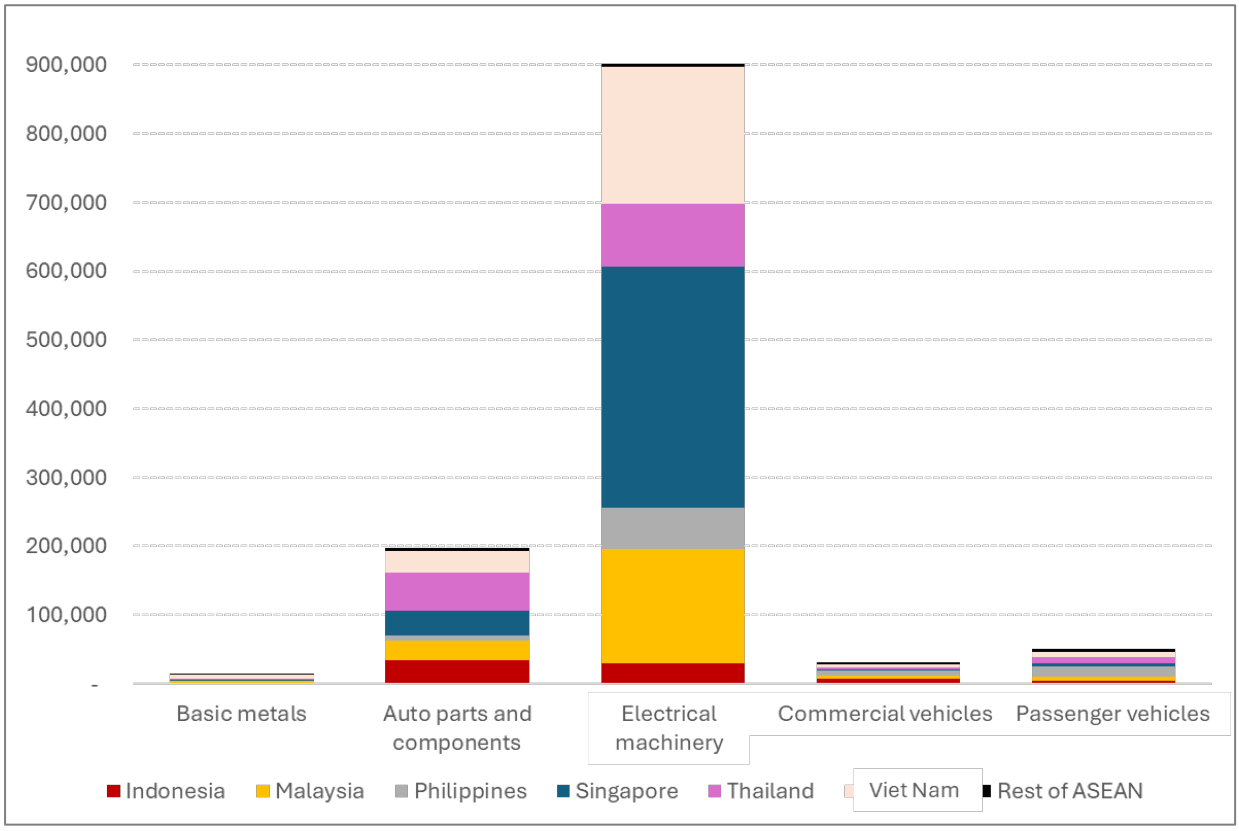


ASEAN = Association of Southeast Asian Nations.

Notes: i) Data are expressed in million US dollars and represent total exports from each country to the world over 2021–2023; ii) data values are world's exports in real prices; iii) 'rest of ASEAN' includes Brunei Darussalam, Cambodia, Lao People's Democratic Republic, and Myanmar; and iv) values in the brackets indicate negative figures.

Source: Authors, based on World Integrated Trade Solution (2025) and Census and Economic Information Centre (2025).

Figure 1.4. Import Structure of Automotive Products in ASEAN, 2021–2023



ASEAN = Association of Southeast Asian Nations.
Notes: i) Data are expressed in million US dollars and represent total exports from each country to the world over 2021–2023; ii) data values are world's exports in real prices; iii) 'rest of ASEAN' includes Brunei Darussalam, Cambodia, Lao People's Democratic Republic, and Myanmar; and iv) values in brackets indicate negative figures.
Source: Authors, based on World Integrated Trade Solution (2025) and Census and Economic Information Centre (2025).

Table 1.4. Trade Balance of Automotive Products in ASEAN, 2021–2023

Country	Basic Metals	Automotive Parts and Components	Electrical Machinery	Commercial Vehicles	Passenger Vehicles
Indonesia	49,331	(13,663)	(11,237)	(6,006)	14,745
Malaysia	(1,924)	(10,114)	81,006	(3,476)	(3,980)
Philippines	6,233	(829)	37,446	(7,446)	(15,961)
Singapore	1,871	(4,643)	51,132	(1,199)	(2,891)
Thailand	2,403	21,875	(23,531)	24,030	35,465
Viet Nam	(5,937)	(7,125)	(111,085)	(3,011)	(3,007)
Rest of ASEAN	503	(2,701)	(1,378)	(782)	(4,086)

Notes: i) Data are expressed in million US dollars and represent total exports from each country to the world over 2021–2023; ii) data values are world's exports in real prices; iii) 'rest of ASEAN' includes Brunei Darussalam, Cambodia, Lao People's Democratic Republic, and Myanmar; and iv) values in brackets indicate negative figures.
Sources: World Integrated Trade Solution (2025) and Census and Economic Information Centre (2025).

In basic metals, Indonesia leads the region. Its exports reached US$51.3 billion, generating a surplus of US$49.3 billion. This performance reflects Indonesia's resource endowments, particularly nickel and other raw materials critical to EV production. The Philippines and Thailand also recorded modest surpluses. By contrast, Viet Nam and Malaysia posted deficits, indicating a continued dependence on imports of metal-based intermediate goods.

Thailand leads regional exports of automotive parts and components, with exports totalling US$77.1 billion, followed by Singapore with US$31.5 billion, Viet Nam with US$23.8 billion, and Indonesia with US$20.9 billion. Thailand is the only ASEAN country to record a trade surplus in this category. All others ran deficits, with Indonesia recording a particularly large gap of US$13.7 billion and Viet Nam US$7.1 billion. These results suggest a strong reliance on imported components for vehicle assembly or domestic consumption.

In electrical machinery, Malaysia and Singapore are the leading exporters. Both recorded substantial trade surpluses, amounting to US$81 billion for Malaysia and US$51.1 billion for Singapore. The Philippines also achieved a significant surplus. Viet Nam, however, recorded a substantial deficit of over US$111 billion. Despite its large export volumes, the high import value reflects its role as a major electronics assembly and re-export hub. Thailand and Indonesia likewise recorded deficits in this category.

Thailand is the most competitive exporter in the commercial vehicle sector, with exports of US$27.1 billion and a surplus of US$24 billion. This reinforces its position as a regional manufacturing hub for trucks and other utility vehicles. All other ASEAN countries recorded trade deficits in this segment, suggesting either limited production capacity or domestic demand exceeding local supply.

A similar pattern emerges in passenger vehicles; Thailand again leads, with exports of US$44.1 billion and a surplus of US$35.5 billion. Indonesia is the only other country to record a surplus in this category. Other ASEAN members, including Viet Nam, Malaysia, and the Philippines, remain heavily dependent on imports. The Philippines recorded the largest deficit, at US$16 billion, highlighting its limited domestic production base for passenger cars.

Overall, Thailand stands out as the most well-rounded exporter across vehicle types and components. Indonesia excels in raw material exports, especially basic metals, and is increasingly involved in the passenger vehicle market. Malaysia and Singapore retain a comparative advantage in electronics-related segments. Viet Nam and the Philippines show growing participation in regional automotive value chains but remain dependent on imports in several key segments.

1.2.1.2. Revealed comparative advantage

Table 1.5 illustrates the evolution of trade competitiveness in automotive-related sectors amongst ASEAN and its regional partners over the past decade, using revealed comparative

advantage (RCA) as a proxy.[1] RCA complements trade value analysis by considering the relative importance of a country's automotive exports within its overall export portfolio and comparing this with the global export structure of automotive products.

Table 1.5. Revealed Comparative Advantage in Automotive-related Product Groups

	Basic Metals		Automotive Parts and Components		Electrical Machinery		Final Commercial		Final Passenger	
	2013	2023	2013	2023	2013	2023	2013	2023	2013	2023
Brunei Darussalam	0.12	0.08	0.04	0.03	0.03	0.01	0.04	0.02	0	0
Cambodia	0.03	0.01	0.01	0.46	0.29	0.47	3.66	1.27	0.14	0.09
Indonesia	4.07	17.89	0.51	0.5	0.44	0.31	0.19	0.15	0.3	0.62
Lao PDR	0.01	0.04	0.02	0.01	0.1	0.07	0.31	0.02	0.02	0.01
Malaysia	0.1	0.18	0.27	0.33	2.92	3.23	0.07	0.05	0.03	0.03
Myanmar	0.08	1.28	0	0.04	0.01	0.08	0.02	0.04	0	
Philippines		5.5		0.74		5.26		0.02		0.02
Singapore	0.51	0.33	0.51	0.41	4.58	3.18	0.07	0.04	0.03	0.02
Thailand	0.69	1	1.36	1.65	1.36	1	3.6	2.4	0.86	1.23
Viet Nam	0.05	0.08	0.3	0.45	1.02	0.99	0.03	0.07	0.07	0.1
China	0	0.01	0.7	0.89	1.56	1.27	0.76	0.85	0.11	0.58
India	0.06	0.1	0.59	0.83	0.22	0.25	0.24	0.31	0.53	0.48
Japan	1.72	1.6	2.24	1.85	1.67	1.12	1.57	1.2	3.41	3.82
Republic of Korea	0.19	0.34	1.3	1.17	2.4	2.14	0.54	0.28	1.94	2.39

Lao PDR = Lao People's Democratic Republic.
Source: Authors, based on World Integrated Trade Solutions (2025).

Within ASEAN, the data present a fragmented and uneven landscape. Thailand continues to stand out as the region's de facto automotive hub, recording RCA values above 1 in several key segments in 2023, including automotive parts and components (1.65), commercial vehicles (2.4), and passenger vehicles (1.23). This pattern suggests strong trade specialisation across multiple stages of the automotive value chain. Indonesia shows a

[1] Whilst RCA offers useful insights into trade specialisation, it has notable limitations. As a relative measure, it does not account for domestic consumption, production scale, or the actual value-added contribution of each country within the automotive value chain. For instance, countries with large domestic markets, such as Indonesia, may exhibit a low RCA in final vehicles despite possessing substantial production capacity oriented towards domestic demand. RCA is sensitive to the overall structure of a country's exports. Smaller economies with narrow export baskets may appear more competitive than they are in absolute terms. RCA should therefore be interpreted as only one dimension of competitiveness and should ideally be complemented by other indicators, such as value-added trade measures, production data, or firm-level performance metrics, to provide a more comprehensive assessment of a country's role in the automotive sector

particularly sharp rise in RCA for basic metals, rising from 4.07 in 2013 to 17.89 in 2023, driven largely by the surge in iron and steel exports since 2021. However, its RCA values for both commercial and passenger vehicles remain below 1, pointing to a relatively weaker export orientation in downstream assembly despite growing domestic production. Supported by its rich nickel reserves and other resources, the Philippines also demonstrates high trade competitiveness in basic metals.

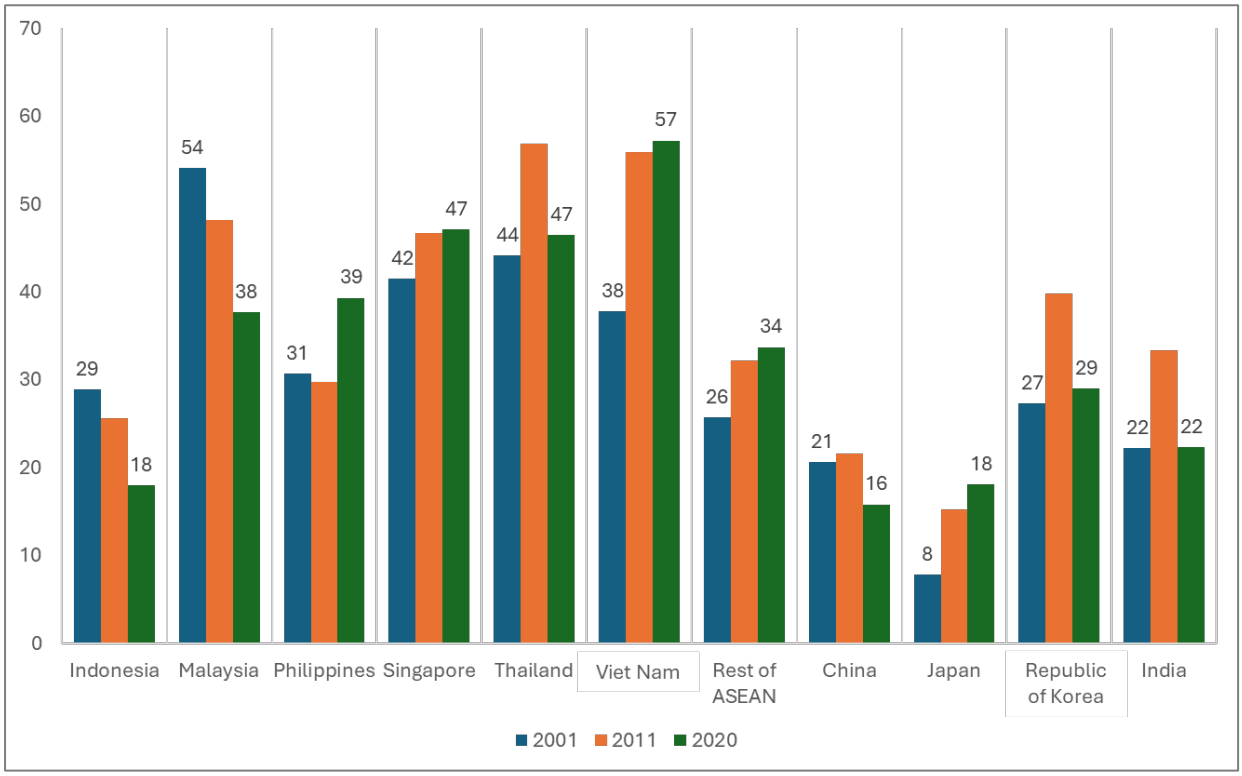
In terms of intermediate inputs, Viet Nam and the Philippines show modest improvements. For example, Viet Nam's RCA in automotive parts and components rose from 0.30 to 0.45, indicating gradual integration into regional supply chains. Nonetheless, these values remain below 1, indicating that both countries have yet to achieve global competitiveness in these areas. Malaysia and Singapore retain a strong comparative advantage in electrical machinery, with RCA values exceeding 3, a sector that is increasingly vital for EV production. Cambodia, Myanmar, and the Lao People's Democratic Republic (Lao PDR) continue to play marginal roles in the automotive value chain, as reflected by RCA values below 1 across most categories.

In contrast, non-ASEAN economies demonstrate more diversified patterns of trade competitiveness. Japan remains particularly strong in passenger vehicles, with its RCA increasing from 3.41 in 2013 to 3.82 in 2023. Both Japan and Korea maintain RCA values above 1 in automotive parts and electrical machinery, reflecting the maturity and export-orientation of their automotive industries. China, whilst not yet exhibiting a comparative advantage in final vehicles, shows a strong position in electrical machinery. India remains more domestically oriented, with relatively low RCA values across all five product groups.

As shown in Figures 1.3 and 1.4, intermediate inputs, such as automotive parts, components, and electrical machinery, account for the largest share of traded products in the sector, indicating deep engagement in automotive value chains. To better understand these value-chain linkages within ASEAN and between ASEAN and its key regional partners, the following section analyses patterns of GVC participation.[2] Figure 1.5 compares backward GVC participation across ASEAN and key regional partners.

[2] It is important to note that electrical machinery is used across multiple sectors, whereas automotive parts and components are specific to the automotive industry. As a result, in value chain analysis, the share of automotive parts and components is expected to be significantly larger than that of electrical machinery when capturing automotive-specific activities.

Figure 1.5. Backward Global Value Chain Participation in the Automotive Sector



Note: Backward participation in global value chains in the automotive sector, measured as the share of foreign value added (FVA) in gross exports, offers insights into countries' reliance on imported intermediate inputs. FVA reflects both integration into global production networks and potential gaps in domestic supporting industries
Source: Authors, based on Organisation for Economic Co-operation and Development (2023b).

From 2001 to 2020, ASEAN's average backward participation remained relatively constant at about 40%, suggesting sustained engagement in cross-border production. This aggregate stability, however, masks remarkable cross-country variation. Amongst ASEAN countries, Viet Nam experienced the most notable increase, with FVA rising from 38% in 2001 to 57% in 2020, implying growing dependence on imported inputs. Whilst this trend reflects deeper integration into regional production hubs, it may also expose structural weaknesses in Viet Nam's domestic supporting industries.

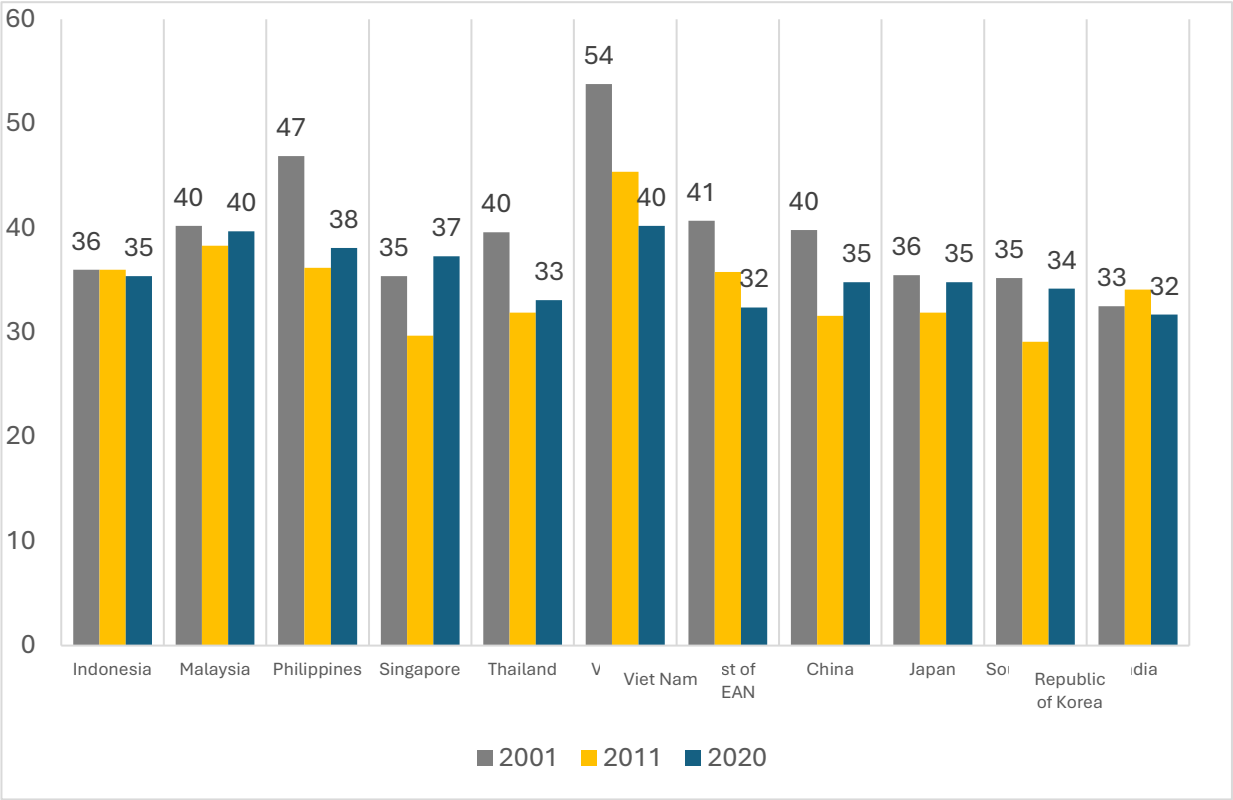
In contrast, some ASEAN economies recorded declining levels of FVA. Indonesia's FVA share dropped from 29% in 2001 to 18% in 2020, whilst Malaysia's declined from 54% to 38%. These shifts suggest either improved domestic supply capabilities or a relative decline in participation in more complex GVCs. Thailand, as a regional automotive hub, maintained a high level of backward participation, peaking at 57% in 2011 before falling to 47% in 2020. This pattern indicates a continued but reduced dependence on foreign inputs, potentially reflecting the maturation of domestic supplier bases.

Compared with ASEAN, non-ASEAN partners rely less on imported intermediate inputs and display distinct temporal trends. Japan's backward participation remains amongst the lowest, but it increased from 8% in 2001 to 18% in 2020, indicating a gradual shift towards

offshore sourcing in response to regional production fragmentation. Conversely, China experienced a modest decline in FVA from 21% to 16%, which may be attributed to policies promoting domestic input production and reducing dependence on imports. Korea and India both exhibit non-linear trajectories, with backward participation peaking in the early 2010s before returning to levels closer to those observed at the beginning of the period.

As shown in Figure 1.6, ASEAN's average forward participation in the automotive sector remained relatively stable, declining only marginally from 46% in 2001 to 45% in 2020, with a slight dip in 2011. Again, this aggregate trend conceals divergent national experiences. Viet Nam, for example, recorded a notable decline in forward participation, from 54% in 2001 to 40% in 2020, indicating a reduced role as a supplier of upstream inputs. This decline mirrors the earlier increase in FVA, reinforcing evidence of limited development in domestic intermediate industries. The Philippines and Malaysia, by contrast, maintained relatively stable domestic value-added (DVX) ratios of about 40% throughout the period.

Figure 1.6. Forward Participation in the Automotive Sector



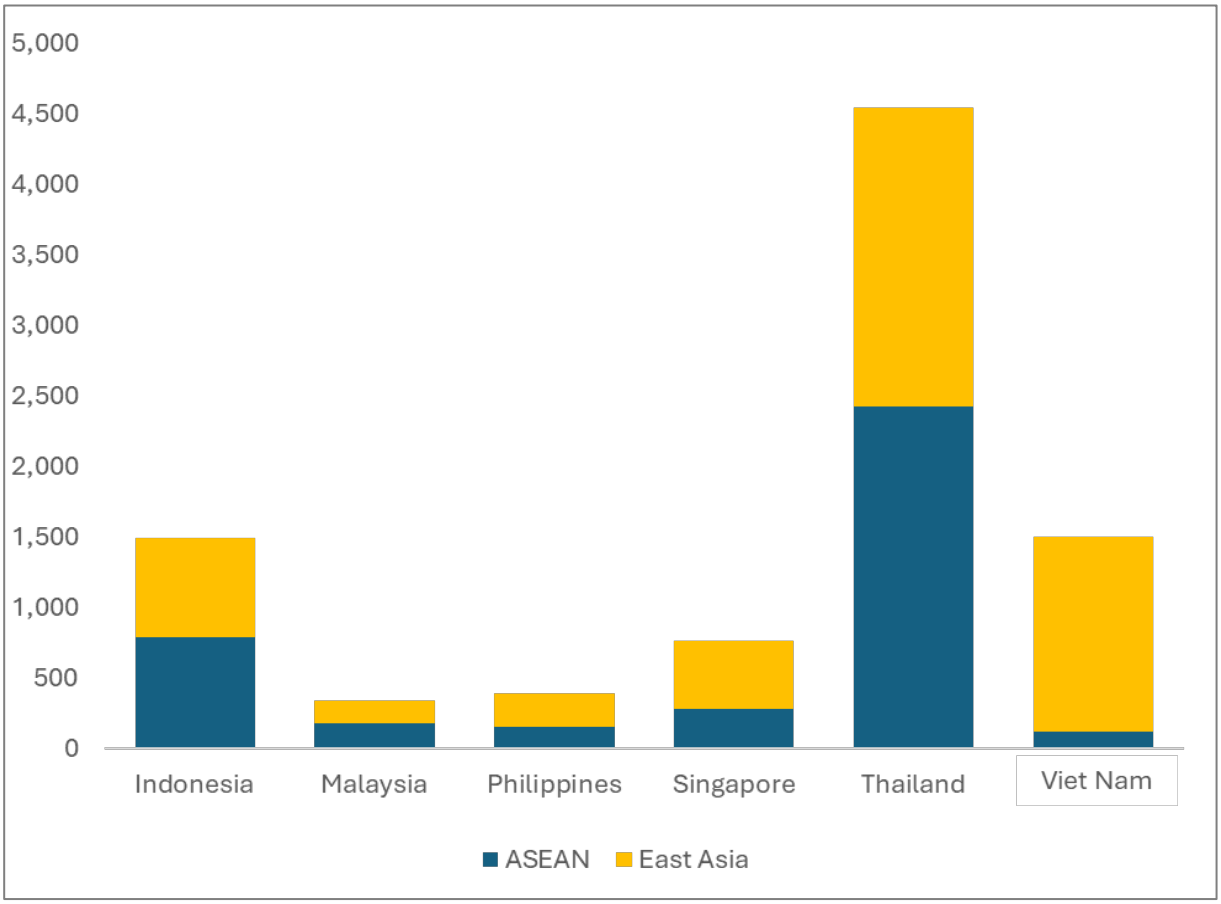
ASEAN = Association of Southeast Asian Nations.
Note: Forward participation in global value chains, measured as domestic value added embedded in other countries' exports, reflects a country's role in supplying intermediate inputs to global markets. These inputs include not only materials, parts, and components, but also higher value-added upstream services, such as research and development, software development, and systems integration.
Source: Authors, based on Organisation for Economic Co-operation and Development (2023a).

Singapore's forward participation remains high, although with some fluctuations. Its DVX share dropped from 35% to 30% in 2011 before partially recovering to 37% in 2020. Given Singapore's limited manufacturing base, this pattern suggests specialisation in upstream, knowledge-intensive services rather than physical production.

Amongst non-ASEAN partners, Japan and Korea, both traditionally strong in upstream activities, show moderately declining trends, although forward participation rates for both remained above 30% in 2020. China's forward GVC share also decreased, from 40% in 2001 to 35% in 2020, consistent with its strategic shift towards higher value-added and final assembly activities in the global automotive value chain. India's DVX ratio also remained stable at just over 30%.

Figure 1.7 further disaggregates the destinations of DVX, illustrating the extent of intra-regional forward linkages. Overall, ASEAN and East Asia remain important trade partners, accounting for 30% and 26% of DVX, respectively. However, this distribution varies significantly across individual AMSs.

Figure 1.7. Domestic Value Added Embedded in Exports, by Destination



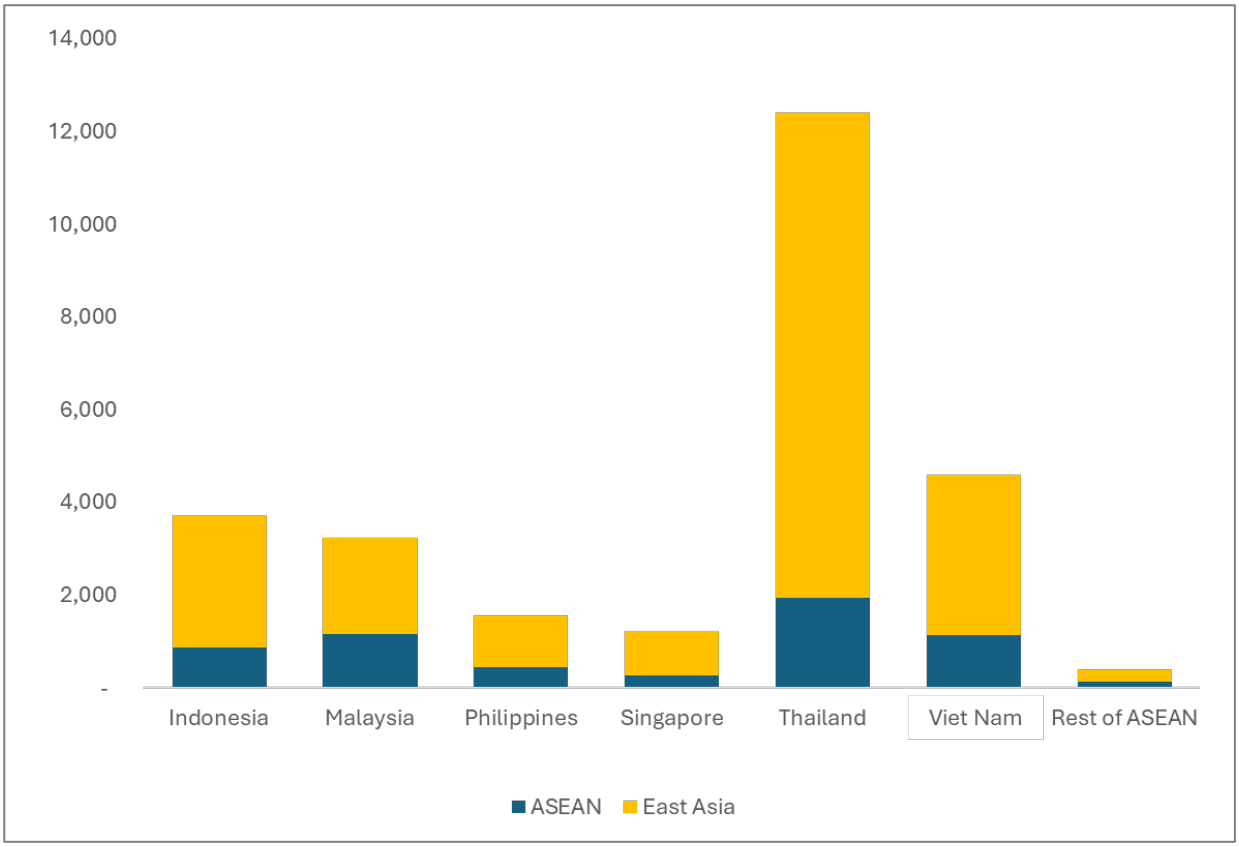
ASEAN = Association of Southeast Asian Nations.
Notes: i) Data are expressed in million US dollars; ii) figures for Brunei Darussalam, Cambodia, Lao People's Democratic Republic, and Myanmar are omitted because their combined values are small relative to other ASEAN countries.
Source: Authors, based on Organisation for Economic Co-operation and Development (2023a).

Indonesia and Malaysia each direct about 35% of their DVX to exports within ASEAN and East Asia. The Philippines and Thailand follow, with about 25% of their value added destined for each of these regions. In contrast, Singapore exports around 10% of its DVX to ASEAN and 16% to East Asia.

Viet Nam exhibits a distinct pattern, characterised by limited forward engagement with ASEAN but strong dependence on East Asian markets. It is noteworthy that Singapore and Viet Nam are amongst the most open economies in ASEAN, each having concluded a large number of free trade agreements (FTAs) outside the region.

On the input side, East Asian economies supply up to half of ASEAN's FVA, with most AMSs sourcing 40%–60% of their imported intermediate inputs from East Asia. Singapore is an exception, sourcing only about 15%, reflecting the service-oriented nature of its automotive-related activities. ASEAN supplies only about 20% of intermediate inputs used by its members.

Figure 1.8. Foreign Value Added Embedded in Exports, by Source



Notes: i) Data are expressed in million US dollars; ii) 'rest of ASEAN' includes Brunei Darussalam, Cambodia, Lao People's Democratic Republic, and Myanmar.
Source: Authors, based on Organisation for Economic Co-operation and Development (2023a).

Overall, the GVC indicators reveal diverse patterns of ASEAN engagement in global automotive value chains. Thailand and Malaysia hold relatively balanced positions, with strong participation in both upstream and downstream segments. Viet Nam is more deeply

integrated into assembly stages, marked by high dependence on foreign inputs and a limited upstream role. Indonesia and the Philippines occupy intermediate positions, with moderate and stable participation across both dimensions. Singapore maintains a strong upstream role as a supplier of knowledge-intensive inputs and services. These contrasts underscore the need for tailored national strategies and enhanced regional collaboration to foster domestic value creation.

By comparison, regional partners such as Japan, Korea, and China retain stronger upstream capabilities, supplying high-value inputs and services to ASEAN. Strengthening linkages with these partners, alongside upgrading domestic supply networks, will be crucial for ASEAN economies seeking to move up the value chain and capture a larger share of value added within the regional automotive ecosystem.

1.2.2.3. Foreign direct investment

FDI plays a crucial role in shaping automotive trade patterns amongst ASEAN countries. Figure 1.9 and Figure 1.10 present the number of projects and the capital intensity of greenfield FDI inflows, as well as the expansion of existing FDI, into ASEAN's automotive components and OEM sectors from 2003 to 2024. Thailand clearly stands out as the leading destination, accounting for around 40% of the 945 projects, alongside significant capital investment. This performance reflects its position as ASEAN's main automotive hub.

Viet Nam, Indonesia, and Malaysia comprise the second group, collectively securing about 430 projects with varying levels of capital intensity. Viet Nam's FDI has increased steadily, shifting from labour-intensive investments towards more capital-deepening production, supported by regulatory reforms and infrastructure improvements. Indonesia's large domestic market, together with the introduction of the Low-Cost Green Car programme in 2013, has helped attract OEM assembly and capital-intensive investments as local capabilities have grown. Malaysia, whilst attracting fewer projects, continues to maintain a capital-intensive focus. This is supported by the National Automotive Policy and a skilled labour force, which is oriented towards higher value-added supply chain activities.

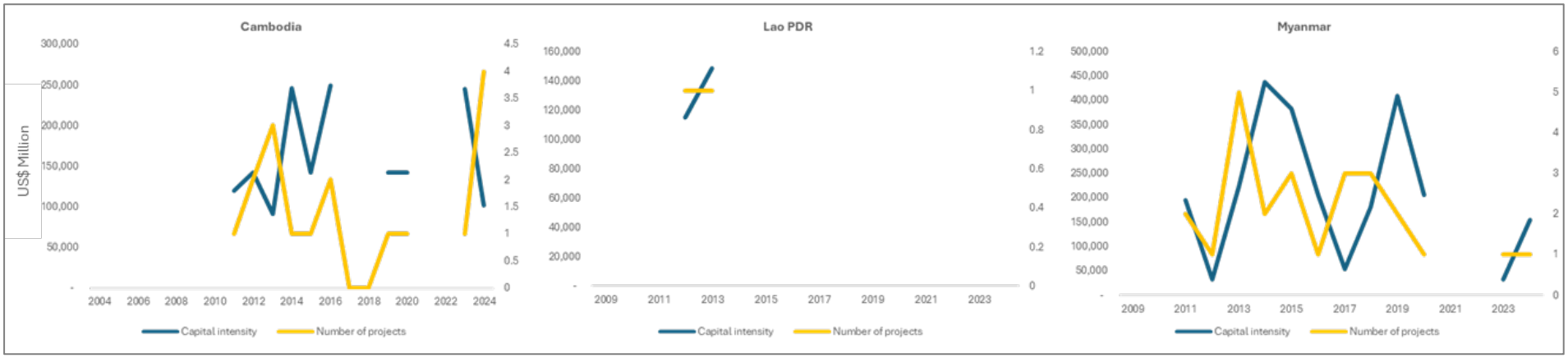
The Philippines recorded 61 projects and Singapore 50. Although new capital investments fluctuate significantly over time, the average project size in the Philippines, measured by both capital investment and job creation, shows a declining trend. Conversely, Singapore, despite its limited manufacturing base, attracts highly capital-intensive projects, especially in the automotive OEM sector.

Amongst the less developed ASEAN members, Myanmar briefly attracted several low- to moderate-capital projects focused on assembly and special economic zone operations in the late 2010s. However, political instability subsequently disrupted this momentum. Cambodia and Lao PDR remain marginal players, drawing only a handful of low-capital, labour-intensive projects. Structural constraints, including inadequate infrastructure and limited workforce capacity, continue to hinder their competitiveness.

Figure 1.9. Foreign Direct Investment Inflows in the Automotive Sector (Part 1)

Source: Authors, based on fDi Markets (2025).

Figure 1.10. Foreign Direct Investment Inflows in the Automotive Sector (Part 2)



Source: Authors, based on fDi Markets (2025).

Table 1.6 shows the leading source economies of FDI into ASEAN's automotive sector. Japan stands out as the dominant investor, contributing nearly US$32 billion, far exceeding other countries. This investment leadership is also reflected in the highest number of projects and jobs created.

Table 1.3. Top 10 Investing Economies in ASEAN's Automotive Sector, 2003–2024

Country	Capital Investment	Number of Projects	Number of Jobs
Japan	31,864	505	269,289
Germany	4,756	150	46,874
China	20,936	79	79,769
United States	4,645	62	30,214
Republic of Korea	6,134	34	25,889
India	1,360	23	11,548
France	1,374	22	10,486
Malaysia	405	18	3,722
Sweden	544	18	4,659

ASEAN = Association of Southeast Asian Nations.
Notes: i) Capital investment is expressed in million US dollars; ii) the number of projects and the number of jobs are expressed in units.
Source: fDi Markets (2025).

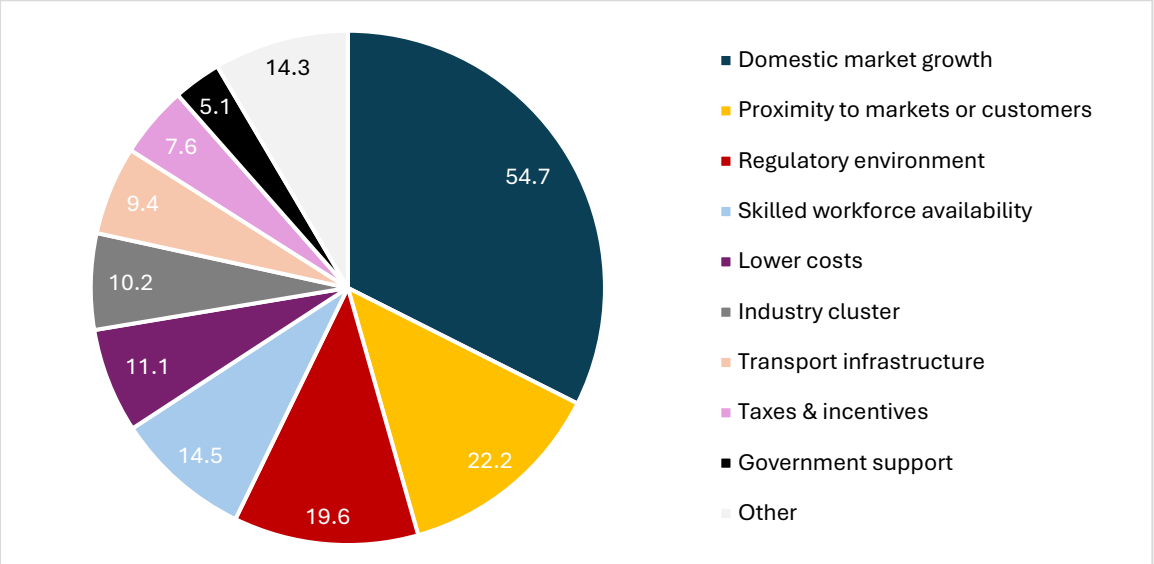
A small number of major investors – Japan, China, and Germany – account for the bulk of capital inflows and employment. Although China records fewer projects than Japan or Germany, its investments are substantial in both capital scale and job creation.

Other economies, including the US, Korea, and India, remain active but operate at a smaller scale, contributing between US$1 billion and US$6 billion each. Several small investors, such as France, Malaysia, and Sweden participate with more limited capital and job creation, often below US$1 billion.

Overall, ASEAN's automotive sector benefits from a concentrated yet diverse FDI base, with Japan maintaining a leading role and China emerging as a strong and increasingly significant investor.

Figure 1.11 illustrates the main determinants of FDI inflows into ASEAN's automotive sector. Market-oriented motives dominate. Domestic market growth, cited by 55% of projects, highlights the strong pull of the region's expanding consumer base. Proximity to markets or customers ranks second, at 22%, emphasising the importance of market access.

Figure 1.11. Motives and Location Determinants



Source: Authors, based on fDi Markets (2025).

An enabling investment environment plays an important role. Investors place value on a stable regulatory framework (20%) and the availability of a skilled workforce (15%). Cost considerations (11%) and industry clustering (10%) influence location decisions to a lesser extent. By contrast, infrastructure-related motives, including transport and information and communication technology, as well as taxes, incentives, and government support, are of secondary importance. Factors such as technology, innovation, language skills, and natural resources are rarely mentioned.

In summary, FDI decisions in ASEAN's automotive sector are driven primarily by market potential and supportive regulatory and human capital conditions, whilst traditional resource-based factors exert only a limited influence.

1.2.2. Policy Environment

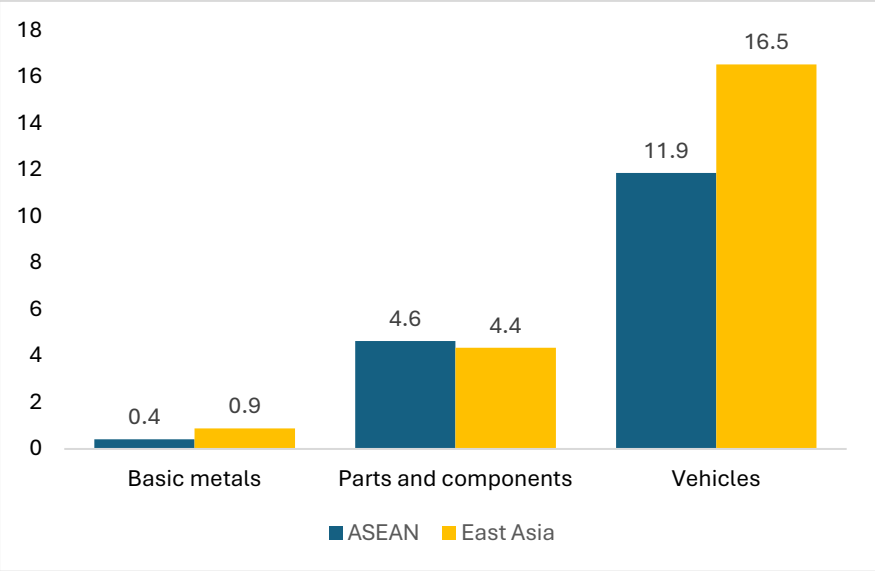
1.2.2.1. Tariffs and non-tariff measures

Building on the preceding discussion of trade and investment flows in ASEAN's automotive sector, this section examines the regional policy environment that shapes those flows. Specifically, it focuses on tariff structures and NTMs. Whilst tariff rates have generally declined under FTAs, a wide range of NTMs continues to influence market access, compliance costs, and competitiveness. Understanding the nature and prevalence of these measures is therefore critical for assessing the regulatory landscape and its implications for automotive manufacturing and trade in the region.

Figure 1.12 illustrates a noticeable pattern of tariff escalation, whereby tariffs on raw materials are substantially lower than those on final products. Overall, vehicle tariffs are the highest across both ASEAN and East Asia, whilst tariffs on intermediate inputs generally remain below 5%. This pattern reflects countries' efforts to facilitate value chain

integration by providing relatively better access to intermediate inputs.

Figure 1.12. Effectively Applied Tariffs in the Automotive Sector



ASEAN = Association of Southeast Asian Nations.
Note: The effectively applied tariff is calculated as the simple average of tariff lines.
Source: Authors, based on World Integrated Trade Solution (2025).

By contrast, the imposition of NTMs, some of which may function as hidden trade barriers, raises concerns about the effective degree of trade openness. Table 1.7 shows the number of NTMs applied by each country to automotive-related products.

Table 1.7. Non-tariff Measures Count by Product Category

Country	Total	Basic Metals	Automotive Parts and Components	Electrical Machinery	Commercial Vehicles	Passenger Vehicles
Brunei Darussalam	35	2	4	25	2	0
Cambodia	69	1	5	26	1	1
Indonesia	176	60	94	55	38	6
Lao PDR	45	7	13	23	15	11
Malaysia	62	1	16	29	5	0
Myanmar	63	17	19	19	14	9
Philippines	126	6	51	83	25	4
Singapore	76	0	36	45	3	1
Thailand	122	0	45	39	7	17
Viet Nam	109	0	10	32	6	12
China	411	57	165	144	94	56
Japan	99	10	50	47	37	5

Country	Total	Basic Metals	Automotive Parts and Components	Electrical Machinery	Commercial Vehicles	Passenger Vehicles
Republic of Korea	88	0	33	32	14	6
India	68	22	15	39	3	2

Lao PDR = Lao People's Democratic Republic.
Source: Trade Analysis and Information System, United Nations Conference on Trade and Development (2025).

The data show noticeable cross-country differences in the prevalence of NTMs, reflecting variations in regulatory capacities, policy priorities, and institutional frameworks.

In the basic metals sector, most countries impose relatively few NTMs, typically fewer than 10. Indonesia is a notable exception, with 60 measures, a level comparable to China's. Given that both China and Indonesia are rich in natural resources, a higher number of regulations may reflect greater emphasis on quality control, industrial safety, and environmental protection.

For automotive parts and components, regulatory intensity is higher outside ASEAN. China applies 165 NTMs in this category, whilst Japan applies 50 measures and Korea 33. Within ASEAN, Indonesia, the Philippines, and Thailand have comparatively more regulations, whereas Brunei Darussalam, Cambodia, and Viet Nam show more limited regulatory coverage. This variation may reflect differences in technical capacity and in the complexity and maturity of national automotive sectors.

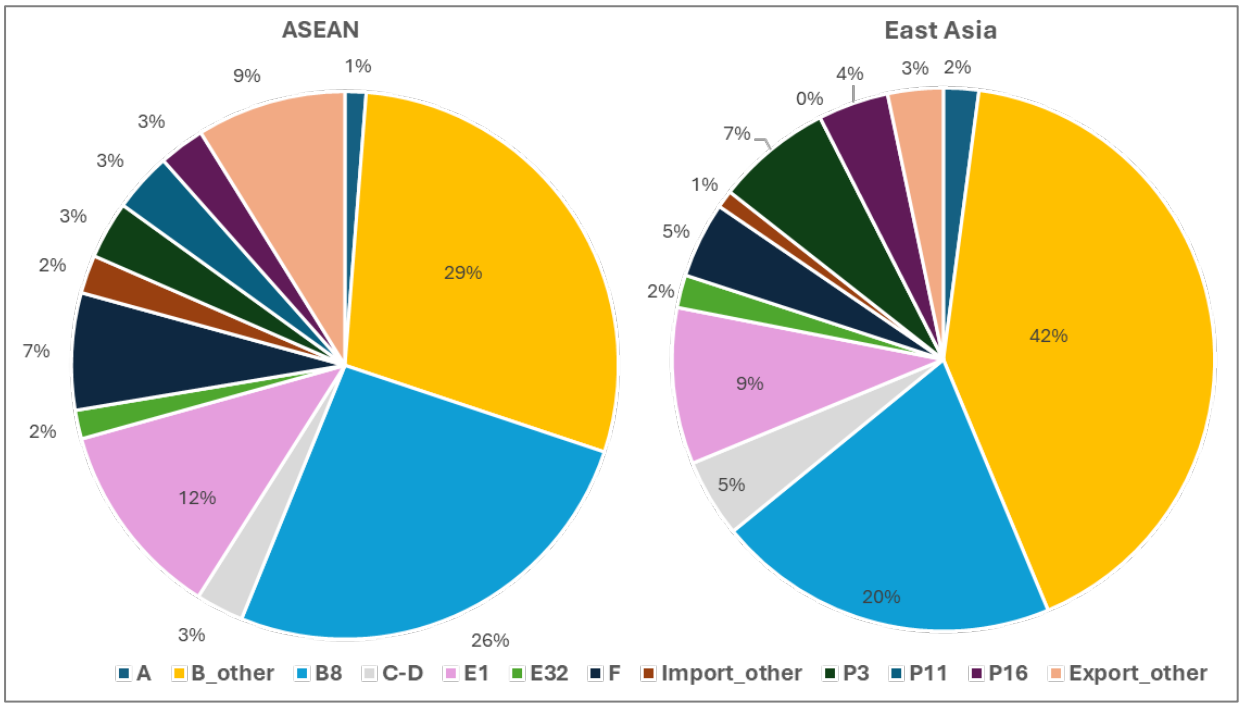
In electrical machinery, which is crucial for EVs, China again leads with 144 NTMs. The Philippines follows with 83 measures, whilst Japan applies 47. These requirements are likely linked to quality assurance and environmental performance. Within ASEAN, Brunei Darussalam, Cambodia, and Lao PDR maintain fewer regulatory requirements in this category.

For vehicles, China has the most extensive regulatory framework, with 94 NTMs for commercial vehicles and 56 for passenger vehicles. Amongst ASEAN countries, Indonesia, Viet Nam, Thailand, and Myanmar apply relatively more NTMs, likely to ensure safety and regulatory compliance. Japan and Korea maintain a moderate level of regulation in both segments.

In summary, non-ASEAN countries tend to have more comprehensive regulatory frameworks, with China emerging as the most regulated market. Within ASEAN, regulatory intensity varies considerably: countries such as Indonesia, the Philippines, Thailand, and Viet Nam are relatively more active, whilst other members maintain a lighter regulatory environment. Although NTMs can serve legitimate policy purposes, compliance with them can impose significant trade costs. This variation underscores the need for enhanced coordination and capacity-building within ASEAN to support effective regulatory measures and to promote deeper regional integration in automotive value chains.

While NTM counts provide a useful overview, they do not indicate how trade-restrictive these measures may be in practice. Figure 1.13 illustrates the distribution of NTMs by type, noticing potentially restrictive measures across ASEAN and its regional trading partners.

Figure 1.13. Non-tariff Measures Count by Type



ASEAN = Association of Southeast Asian Nations.
Note: A: sanitary and phytosanitary measures; B: technical barriers to trade; B8: conformity assessment procedures, C-D: pre-shipment inspection and other formalities; contingent trade-protective measures; E1: non-automatic import licensing procedures other than authorisations under Chapters A and B; E32: prohibitions for non-economic reasons; F: price-control measures, including additional taxes and charges; Import Other: other import-related measures; P3: export licences, export quotas, export prohibitions, and other restrictions; P11: export authorisation or permit requirements for technical reasons; P16: export conformity assessment; Export other: other export-related measures.
Source: Authors, based on Trade Analysis and Information System, United Nations Conference on Trade and Development (2025).

Overall, ASEAN and East Asian countries exhibit similar aggregate patterns of NTM use. Technical trade barriers (Chapter B) account for about 55% of total NTMs in ASEAN and about 60% in East Asia. These measures include requirements related to product standards, labelling, testing, and certification. Their prevalence indicates that regulatory compliance and safety are primary concerns in the automotive sector. Although such measures are generally transparent and aligned with international norms, they can pose challenges when requirements are complex, lack a clear scientific basis, or vary significantly across countries. Within this category, conformity assessment procedures (B8) are particularly significant, accounting for about half of ASEAN's technical barriers to trade and one-third of those in East Asia, and can impose significant procedural costs.

The second-largest category, representing 14%–18.5% of NTMs, comprises export-related

measures (Chapter P), including licensing requirements (P11), conformity assessments (P16), and export prohibitions (P3). Whilst these measures may aim to safeguard quality or domestic supply chains, their prevalence may also signal constraints on outward trade, particularly in strategic or input-sensitive industries. This is notable in a region aiming to deepen its integration into GVCs.

Non-automatic import licensing and quantitative restrictions (Chapter E), together with price-control measures (Chapter F), also feature prominently. These measures can be particularly burdensome due to their administrative nature and limited predictability. Price controls, in particular, may distort pricing and, depending on their implementation, delay imports or limit foreign competition under the guise of regulatory oversight. Although often legitimate, such measures may act as hidden trade barriers if applied selectively.

Other NTM categories are less prevalent but remain relevant. Pre-shipment inspections (Chapter C) account for about 3% of measures, indicating additional procedural burdens for exporters. Other import-related measures covering finance (Chapter G), competition (Chapter H), and investment (Chapter I) are minimal, together accounting for less than 2% of NTMs. Nevertheless, even a single requirement in these categories, such as a local content requirement, can be substantially trade-restrictive. Sanitary and phytosanitary measures (Chapter A) account for only about 2% of cases, which is expected given their primary relevance to agricultural products.

Overall, whilst most NTMs affecting ASEAN's automotive sector consist of standard technical regulations, a substantial share, estimated at 39.3%, falls under more ambiguous or potentially trade-restrictive categories in Chapters E, F, and P. The prevalence of conformity assessment procedures amongst technical barriers further suggests high procedural costs where these measures are not well-designed or implemented. These issues deserve greater scrutiny in the context of ASEAN's regional integration agenda and its participation in GVCs. Policymakers may therefore consider improving transparency, streamlining procedures, strengthening technical assistance, and promoting regulatory alignment to ensure that NTMs do not unintentionally hinder trade or investment.

1.2.2.2. Regional initiatives

ASEAN has engaged in various FTAs. Whilst most commitments are of a general nature, several include sector-relevant provisions, particularly in tariff reductions, rules of origin design, and emerging areas of cooperation for the automotive industry.

The ASEAN Trade in Goods Agreement has contributed significantly to reducing tariff barriers. At the same time, the ASEAN Framework Agreement on the Facilitation of Goods in Transit and the ASEAN Single Window aim to streamline customs procedures. The ASEAN Automotive Product Working Group, together with the ASEAN Consultative Committee for Standards and Quality, serves as a coordination platform to harmonise automotive technical regulations and standards, thereby supporting mutual recognition and reducing regulatory fragmentation. More recently, regional discussions have expanded

to include cooperation on EV development and supply chains, aligning with sustainability and energy transition goals.

Beyond intra-ASEAN integration efforts, regional trade agreements such as the Regional Comprehensive Economic Partnership (RCEP) and various ASEAN+1 FTAs, create additional opportunities to access both input and output markets. RCEP, for example, offers significant opportunities by simplifying and harmonising rules of origin across multiple partner countries. This is particularly relevant for the automotive industry, which relies on complex supply chains that span national borders. The agreement facilitates the accumulation of value added across member states, supporting regional production networks and encouraging firms to source inputs from within the RCEP bloc. Tariff liberalisation under RCEP and ASEAN+1 FTAs (with Japan, China, Korea, and India) has also enhanced market access for automotive parts and vehicles.

Sector-specific initiatives have also emerged under certain FTAs. For example, the ASEAN–Japan Comprehensive Economic Partnership has supported technical cooperation on automotive standards and environmental regulations, including joint initiatives to develop fuel efficiency benchmarks and safety standards. Similarly, Japan has provided capacity-building and investment support for automotive development in individual countries under the Japan–ASEAN Integration Fund. Discussions within ASEAN and amongst its dialogue partners have increasingly focused on the future of mobility, including the development of EV ecosystems and battery supply chains, although more formalised cooperation mechanisms in this area are still evolving.

Table 1.8. Summary of Selected Regional Initiatives Related to the Automotive Sector

Agreements	Tariff Reduction	Non-tariff Measures	Rules of Origin	Customs and Trade Facilitation
RCEP	Yes	Elimination of quantitative restrictions; transparency; mutual recognition in conformity assessment; technical cooperation and assistance	Regional value content of 40%; non-originating materials must originate from a different Harmonised System 4-digit subheading; verification of origin by exporters	Advance rulings; defined time periods for customs clearance; streamlined import, export, or transit formalities; authorised operators; risk management
ATIGA	Yes	Elimination of non-tariff barriers; transparency; notification	ASEAN cumulation	ASEAN tariff and non-tariff measure finders; ASEAN Single Window

Agreements	Tariff Reduction	Non-tariff Measures	Rules of Origin	Customs and Trade Facilitation
AJCEP	Yes	Harmonised technical regulations; mutual recognition; simplified conformity assessments	Regional value content of 40% plus tariff shift rules; regional cumulation; streamlined certification	Digital customs procedures; risk-based clearance; exchange of certificates across parties
Mutual recognition arrangements on type approval for automotive products	Not applicable	Harmonised technical safety and environmental standards; single conformity test. Fourth Protocol prohibits forced localisation, export or import mandates, and restricted sales, benefiting global automotive investors.	Not applicable	Boosting testing infrastructure; laboratory capabilities; research and development; accreditation systems
ASEAN Declaration on Developing Regional EV Ecosystem	Standards harmonisation; strengthening regional value chains for EVs; interoperability and seamless cross-border mobility			

AJCEP = ASEAN–Japan Comprehensive Economic Partnership, ASEAN = Association of Southeast Asian Nations, ATIGA = ASEAN Trade in Goods Agreement, EV = electric vehicle, RCEP = Regional Comprehensive Economic Partnership.
Source: Authors (2025).

Overall, ASEAN's various regional commitments, at least on paper, indicate a shift towards deeper integration and a broadening of the scope of commitments and cooperation. However, their effectiveness remains uncertain, as it largely depends on consistent and effective implementation. Rather than introducing new mechanisms, priority should be given to strengthening the implementation of existing commitments. Indeed, the ASEAN Economic Community Strategic Plan for 2026–2030 places strong emphasis on advancing trade facilitation to support deeper regional integration. Accelerating the harmonisation of standards, technical regulations, and conformity assessment procedures is therefore critical. This can be facilitated by operationalising mutual recognition arrangements, improving the use of digital tools for customs and trade, and ensuring transparency in regulatory processes.

Given the mutual benefits, targeted technical assistance and capacity building from more advanced economies, such as Japan, would be particularly vital. Such support may include

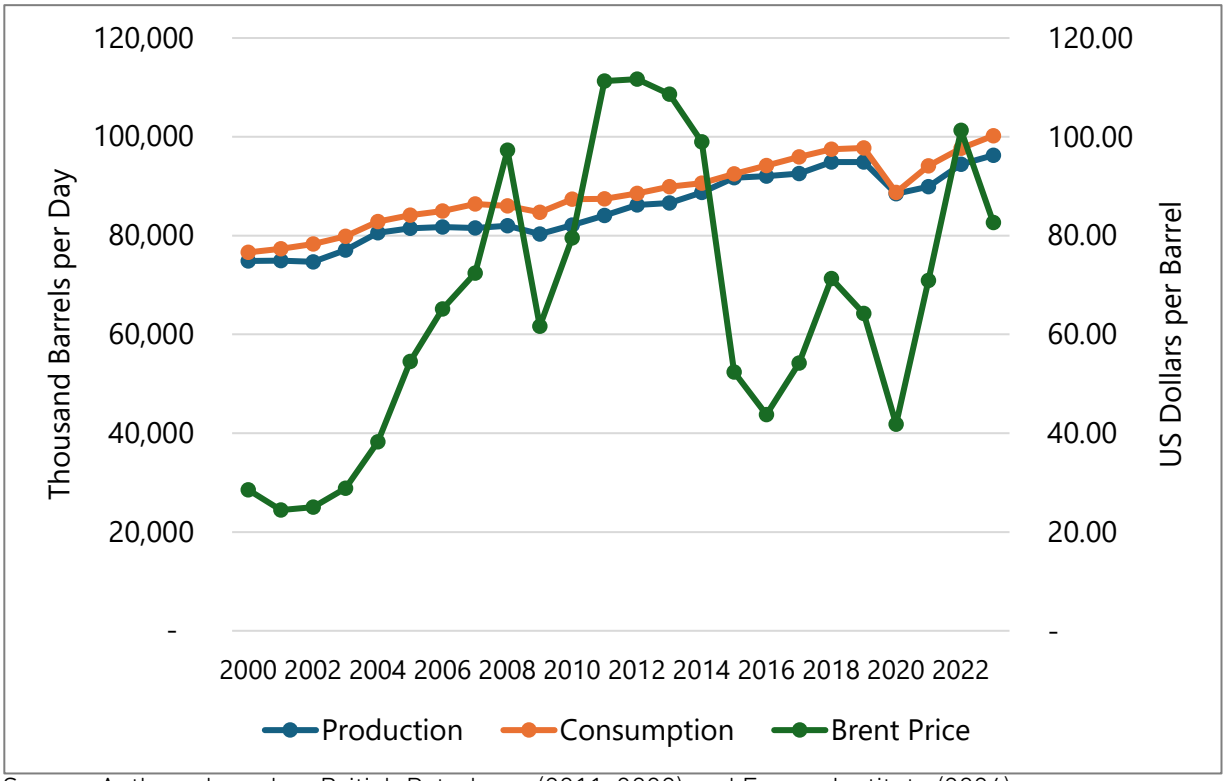
enhancing national testing and certification infrastructure, improving regulatory alignment with international norms, especially for green and digital technologies, and facilitating knowledge sharing on best practices in digital trade facilitation. Such cooperation would not only help AMSs close implementation gaps but also ensure that trade facilitation contributes meaningfully to broader goals, including sustainable development, low-carbon transitions, and inclusive economic growth.

1.3. Decarbonisation in the Automotive Industry

1.3.1. The Imperative for Decarbonisation in the Automotive Industry

The imperative for decarbonisation in the automotive sector is driven by three converging global pressures: declining oil reserves, escalating geopolitical instability in fossil fuel-producing regions, and intensifying climate change concerns. Historically, vehicles have relied on oil as their primary source of fuel. However, oil has long been characterised by volatility. Changes in its price, production levels, consumption trends, and availability (Figure 1.14) are often shaped by geopolitical variables, including conflicts in oil-producing regions, political instability, trade restrictions, and strategic decisions by major oil-exporting nations.

Figure 1.14. Historical Oil Production, Consumption, and Prices Worldwide



Source: Authors, based on British Petroleum (2011, 2022) and Energy Institute (2024).

From a long-term planning perspective, oil represents an unpredictable energy source due to its inherent instability, especially for the transport sector, which remains highly dependent on it. The oil price shocks of the 1970s, triggered by conflicts in the Middle East, disrupted the global economy on a large scale. More recent events have again demonstrated the sensitivity of the world's oil markets to political developments, including sanctions imposed on key oil producers such as Russia.

According to the International Energy Agency (2024), energy demand in the transport sector increased by about 4% in 2023, broadly matching the pace observed in 2022. Within this sector, road transport played a significant role, contributing to an increase in oil demand of 4.2 million barrels per day, accounting for over 45% of total growth in global oil demand. Additionally, road transport is responsible for around 16% of global greenhouse gas emissions. In ASEAN, road transport alone accounts for approximately one-fourth of the region's final energy consumption (Kimura et al., 2023).

Achieving net-zero emissions by mid-century requires ASEAN's transport sector to reduce energy use by nearly 28% relative to the business-as-usual scenario by 2050 (Kimura et al., 2023). This will necessitate a rapid shift away from ICEVs towards lower-emission alternatives, including hybrid electric vehicles (HEVs), BEVs, and plug-in HEVs (PHEVs), alongside the use of sustainable biofuels. As a result, decarbonisation across the entire vehicle life cycle, from manufacturing and operation to end-of-life management, has become a central pillar of the ASEAN–Japan automotive transformation.

1.3.2. Multi-pathway Transition and Global Competitiveness

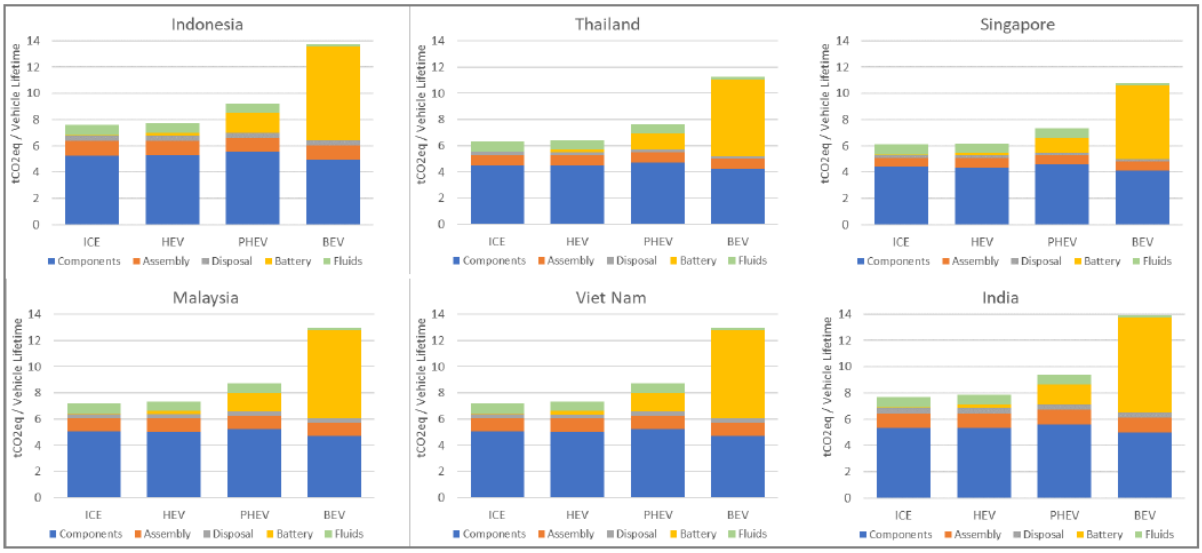
Decarbonisation has catalysed innovation and diversification across multiple technological pathways. Rather than a one-size-fits-all transition, the shift involves an evolving mix of powertrains – BEVs, HEVs, PHEVs, and sustainable ICEVs – adapted to regional energy contexts and industrial capabilities (Doi et al., 2024). Each of these vehicle types introduces distinct challenges and opportunities in terms of energy sources, supply chains, production systems, and life-cycle emissions.

Well-to-wheel and life-cycle assessment analyses conducted by the Economic Research Institute for ASEAN and East Asia and the Institute of Energy Economics, Japan (2024) reveal important trade-offs. Whilst BEVs generate lower emissions during operation, their production, especially battery manufacturing, results in higher upfront emissions due to energy-intensive processes, particularly in countries with carbon-intensive electricity grids . Notably, global greenhouse gas emissions from battery production represent the largest single source of emissions for BEVs, whereas ICEVs and HEVs generate the greatest emissions from iron and steel components (Doi et al., 2024). These findings imply that decarbonisation strategies must be coupled with the expansion of clean power generation and the adoption of green manufacturing practices.

As electrified vehicle (xEV) production scales up, it is driving fundamental changes in global trade patterns and supply chains. ASEAN, with its rich endowment of nickel and other

critical minerals, is becoming increasingly integrated into global xEV battery supply networks. At the same time, this integration exposes regional industries to new dependencies and competitive pressures. For instance, the expansion of xEV battery production is significantly reshaping mineral trade flows, shifting from oil-dominated logistics towards the extraction and processing of lithium, cobalt, and nickel.

Figure 1.15. Greenhouse Gas Emissions in Six ASEAN Countries, 2019



BEV = battery electric vehicle, HEV = hybrid electric vehicle, ICE = internal combustion engine, PHEV = plug-in hybrid electric, tCO2eq stands for tonnes of carbon dioxide equivalent.
Source: Doi et al. (2024).

This structural shift is reshaping global automotive competitiveness. Leading economies are striving for technological leadership and supply chain resilience, whilst emerging markets such as ASEAN are positioning themselves as production and export hubs. Over the longer term, ASEAN's competitiveness will hinge on its ability to build circular supply chains, including battery recycling and reuse, attract foreign investment, and develop low-emission vehicle technologies tailored to local market needs.

1.3.3 From Transition to Transformation

Looking ahead, the region faces a delicate balance between accelerating decarbonisation and maintaining economic competitiveness. The total cost of ownership for EVs is approaching parity with ICEVs in several ASEAN countries, with affordability tipping points projected from 2025 to 2030 (Doi et al., 2022). However, this convergence depends heavily on battery cost trajectories and energy pricing structures.

By 2040, ASEAN is projected to generate from 325 GWh to 2,166 GWh of used EV batteries, depending on the electrification scenario. This projection underscores the urgent need to establish circular economy mechanisms, including second-life applications for batteries in stationary energy storage systems (Doi et al., 2023).

In conclusion, decarbonisation in the automotive industry is not only a climate imperative but also a catalyst for economic restructuring, industrial innovation, and deeper regional integration. ASEAN must therefore leverage this transition by adopting multi-technology pathways, enhancing regional cooperation, and fostering policies that promote life cycle sustainability, technological neutrality, and equitable growth.

1.4. Scope of the Study

Former Japan Prime Minister Fumio Kishida (Nikkei Asia, 2023) proposed a clear road map for future cooperation between Japan and ASEAN countries, centred on the concept of 'co-creation' to advance economies and societies, whilst supporting peace and stability. By mid-December 2023, in the automotive sector, Japan and ASEAN countries launched the ASEAN–Japan Co-Creation Initiative for the Next-Generation Automotive Industry. An agreed implementation pathway calls for the joint development of an industry 'master plan', policy coordination to decarbonise the entire value chain, and the construction of resilient and reliable supply chains.

Against this backdrop, the objective of this study is to provide a theoretical base for policies in each ASEAN country to strengthen competitiveness and to support development as a production and export hub for diversified automobile models, considering the global market situation.

Competitiveness is defined as the extent to which firms in a particular region can compete with firms elsewhere. Critical factors for competitiveness are those that determine the level of productivity in a region relative to other regions (Purwanto, et al., 2017).

In this study, competitiveness refers specifically to road vehicle and automotive firms operating in ASEAN countries. The critical factors of competitiveness are those that determine the performance of ASEAN-based firms relative to firms outside the region.

In other words, the main goal of this study is to provide a theoretical policy foundation to support ASEAN countries in strengthening their automotive industries, enhancing their competitive position, and developing as export hubs for diversified automobile models. This assessment is undertaken in light of the evolving global market situation, technological trends, and the imperative to decarbonise.

The master plan should ideally be grounded in a comprehensive analysis of the current global and ASEAN automotive markets, including domestic sales, vehicle stock, production, imports, and exports, as well as future market developments. It should also identify the critical factors shaping regional industrial competitiveness and propose a coherent set of policy recommendations.

1.5. How to Read This Report?

The study on the ASEAN–Japan next-generation vehicle industry master plan adopts an integrated research approach that brings together diverse theoretical perspectives and

research methods to address the core research questions. The approach moves from broad theoretical frameworks to specific, actionable insights by combining multiple data collection and analytical techniques.

Chapter 2 sets out the theoretical framework for analysing the automotive industry in a broader context, incorporating perspectives on sustainable transport and mobility.

Chapter 3 presents the results of a survey conducted across 10 ASEAN countries. The survey is designed to comprehensively capture how OEMs and suppliers across ASEAN perceive recent shifts in the business environment, including evolving market dynamics, technological advancements, and policy changes. It also seeks to understand the transformations these companies aspire to achieve in response to such changes, as well as to identify the critical challenges they currently face in pursuing those transformations. The survey targeted suppliers, with the aim of collecting 2,133 responses, alongside participation from about 27 OEMs to ensure a comprehensive industry perspective.

Chapter 4 and Chapter 5, respectively, discuss the current and future states of the global and ASEAN automotive markets. Together, these chapters provide an in-depth analysis of prevailing trends and market outlooks at both the global and regional levels. Drawing on insights from the global assessment presented in Chapter 4, Chapter 5 highlights the challenges ASEAN faces during the global powertrain transition and assesses how these developments may affect the region's position in the automotive industry. The analysis in Chapter 5 yields critical insights into the steps required for ASEAN to sustain and collectively advance its automotive market.

Chapter 6 provides an overview of the current and future states of the global and ASEAN automotive industries. It begins by examining global production patterns and powertrain trends, followed by an assessment of ASEAN's competitive positioning, highlighting both existing strengths and emerging challenges. This analysis lays the groundwork for proposing a multi-pathway strategy to enable ASEAN to sustain and expand its role within the global automotive value chain.

Whilst Chapter 3 to Chapter 6 provide a comprehensive review of the current and future market landscape and competitive dynamics, Chapter 7 offers a focused discussion on life cycle impact assessment in the automotive industry and related sectors. This chapter highlights the need for decarbonisation, reinforcing the rationale for transformative change within the industry.

Chapter 8 visualises the 'to be' state of ASEAN's automotive industry and assesses the gap between this desired future and the current business-as-usual trajectory. Through a systematic analysis of this gap, the chapter provides policy recommendations designed to close it and support ASEAN's transition towards a more competitive, sustainable, and future-ready automotive ecosystem.

Finally, Chapter 9 outlines proposed co-creation activities between Japan and ASEAN in the automotive industry, intending to accelerate the transformation of ASEAN's automotive industry.

Chapter 2
Future of ASEAN's Automotive Industry: An Academic Perspective

2.1. Rationale

Amid the growing scarcity of fossil-based energy resources, the world population continues to grow at an annual rate of about 0.91% (2024), reaching an estimated 8.1 billion people. Within this global context, the Association of Southeast Asian Nations (ASEAN), comprising 10 member countries, has a population of about 663.9 million, making it the world's third-largest population grouping and accounting for around 8.4% of the world population (2021). This substantial population is spatially distributed across multiple countries and territories, generating significant demand for transport systems to facilitate the movement of people and goods in support of both daily and non-daily socio-economic activities. Whilst each ASEAN Member State (AMS) adopts different policies to manage transport demand, national vehicle stock figures provide useful indications of demand trends and the extent to which this demand is being met. At the same time, the global transport sector is undergoing rapid technological change in response to energy scarcity, environmental pressures, and the need to deliver transport services more efficiently and effectively. These changes are not limited to a transition away from fossil-based fuels towards renewable and more environmentally friendly energy sources, but also encompass the intelligent operation of transport systems to improve service quality and performance. Together, these dual drivers are key determinants of the future of vehicles and will shape how ASEAN's automotive industries formulate production strategies and compete for market share within the region and beyond.

This chapter aims to provide academic perspectives to support automotive industries in developing strategic masterplans within ASEAN countries. ASEAN and Japan, through a co-creation approach, jointly assess the existing challenges related to both automotive production and consumption in ASEAN markets. The subsequent sections are structured as follows. Section 2.2. highlights ASEAN's automotive growth. Section 2.3 discusses emerging technologies in automotive operation and services, focusing on the sector's ongoing transition. Section 2.4 examines market conditions for next-generation vehicles, whilst Section 2.5 elaborates on the technological landscape of future vehicles and the associated automotive value chains. Section 2.6 addresses production-related issues, and Section 2.7 presents Japan's perspectives on automotive production and markets. The chapter concludes in Section 2.8 with key considerations for the ASEAN–Japan next-generation vehicle masterplan strategy.

2.2. Supply and Demand in ASEAN Road Transport

In the specific context of road-based passenger transport, growth in the automotive sector is

fundamentally determined by the mobility needs of individuals and communities. Transport demand is therefore derived demand, arising from the spatial separation of socio-economic activities that necessitates the movement of people. Several modes of road transport are available for passenger movement, especially in urban areas, where individuals may choose between private vehicles and public transport. However, the scope of this automotive masterplan focuses primarily on private vehicles: four-wheelers (cars) and, where relevant, two-wheelers (motorcycles), which may function as competitive and/or complementary modes of transport.

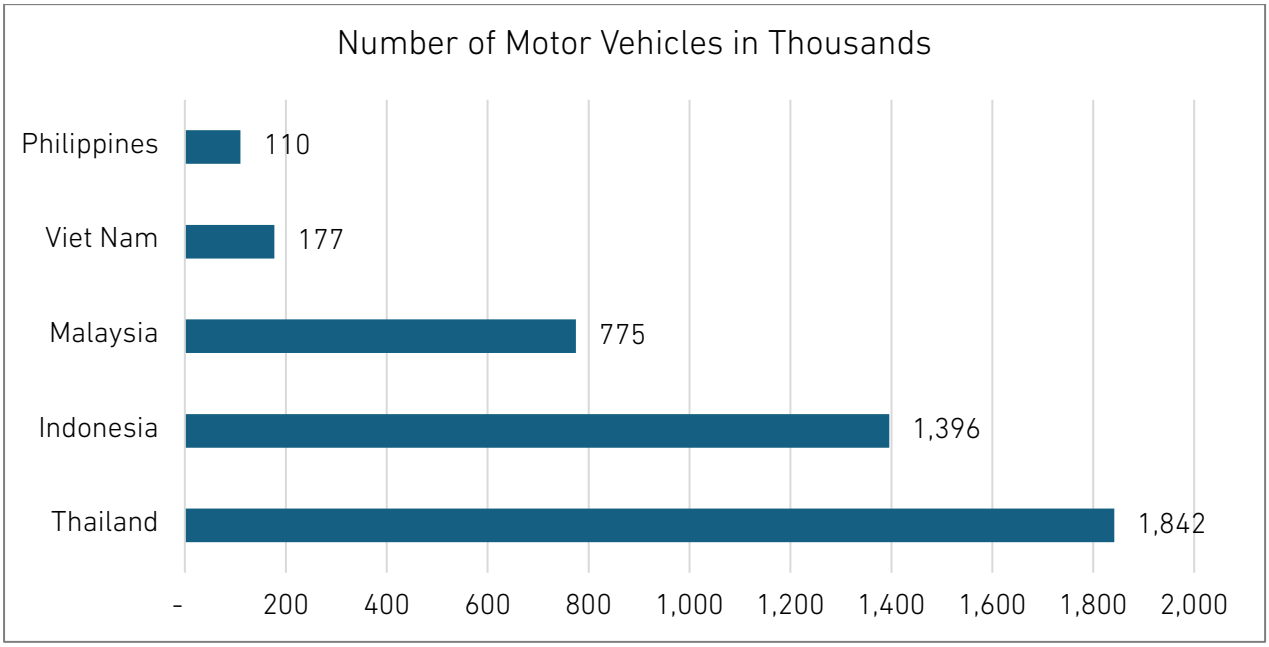
2.2.1. Supply and Demand Perspectives

Road-based vehicles, including two-wheelers and four-wheelers, are typically used as private transport in urban or metropolitan areas across ASEAN countries. As a result, national vehicle statistics can be considered a useful aggregate representation of underlying supply and demand dynamics. To some extent, these figures reflect the balance between automotive demand and supply, shaped by several structural conditions.

Most ASEAN countries are developing economies, and their cities commonly experience imbalances between transport supply and demand. In many cases, transport demand exceeds supply, particularly with respect to road infrastructure. For example, in Jakarta, vehicle growth on the demand side is estimated at 10% per year, whilst the expansion of road length on the supply side is less than 0.01% per year. Such disparities are often attributed to insufficient road infrastructure and limited availability of mass or public transport systems, which compel individuals to rely on private vehicles to meet their mobility needs.

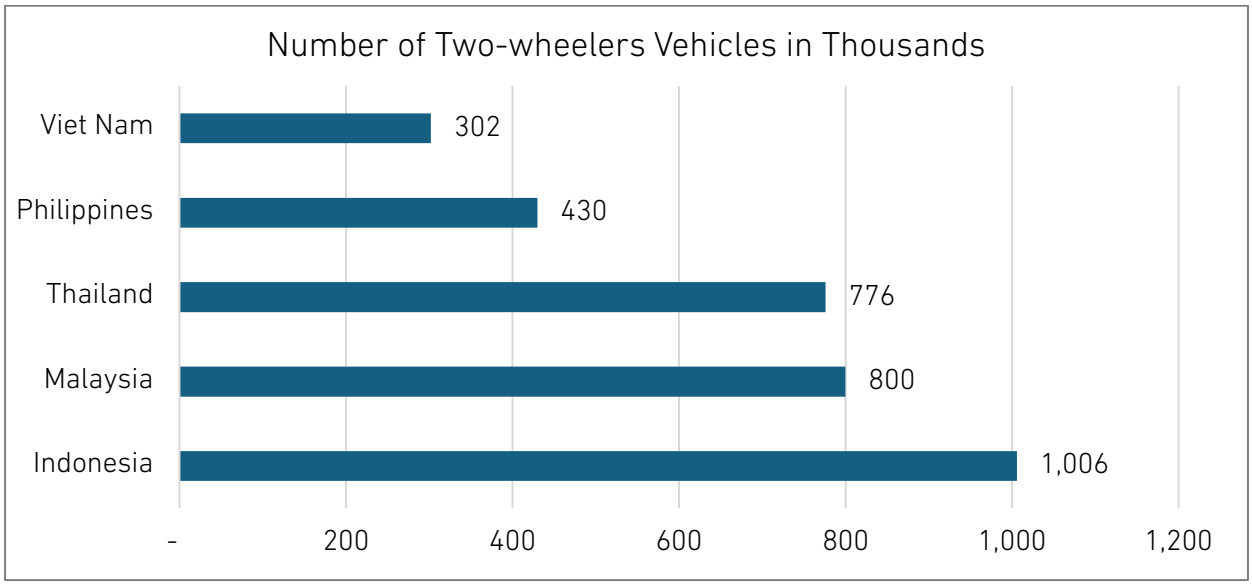
Figure 2.1 shows vehicle growth in five ASEAN countries: Thailand, Indonesia, Malaysia, Viet Nam and the Philippines. The major cities represented include Bangkok (Thailand); Jakarta, Medan, Surabaya, Makassar, Semarang, Palembang, Samarinda, and Pekanbaru (Indonesia); Kuala Lumpur and George Town (Malaysia); Manila, Davao, and Cebu (Philippines); and Ho Chi Minh City, Hanoi, and Da Nang (Viet Nam). As shown in Figure 2.1, Thailand ranks highest in terms of total vehicle growth, followed by Indonesia. In contrast, Figure 2.2 shows that Indonesia records the highest growth in two-wheelers (motorcycles), exceeding that of Thailand. Overall, these five ASEAN countries exhibit significant growth in vehicle fleets, indicating a strong and expanding automotive market.

Figure 2.1. Growth of Vehicles in Five ASEAN Countries, 2023



ASEAN = Association of Southeast Asian Nations.
Source: Authors, based on Statista (2025a).

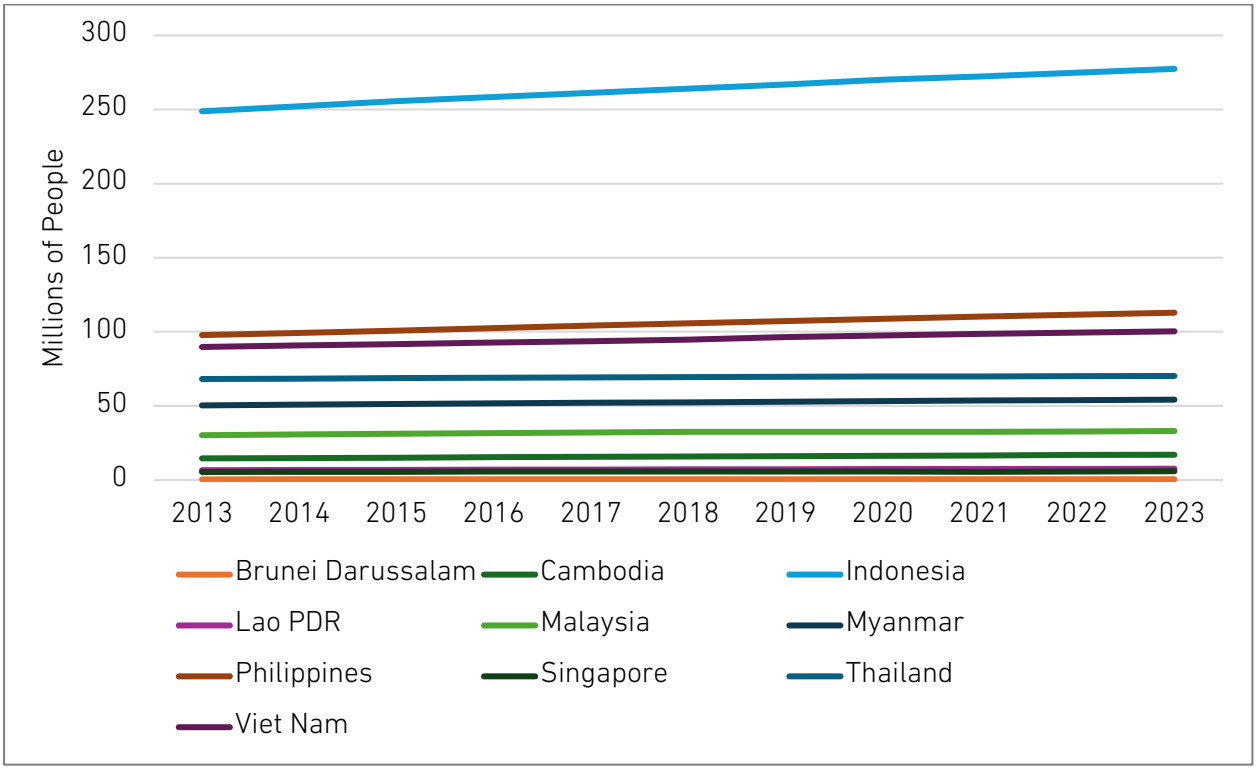
Figure 2.2. Growth of Two-Wheelers in Five ASEAN Countries, 2023



ASEAN = Association of Southeast Asian Nations.
Source: Authors, based on Statista (2025a).

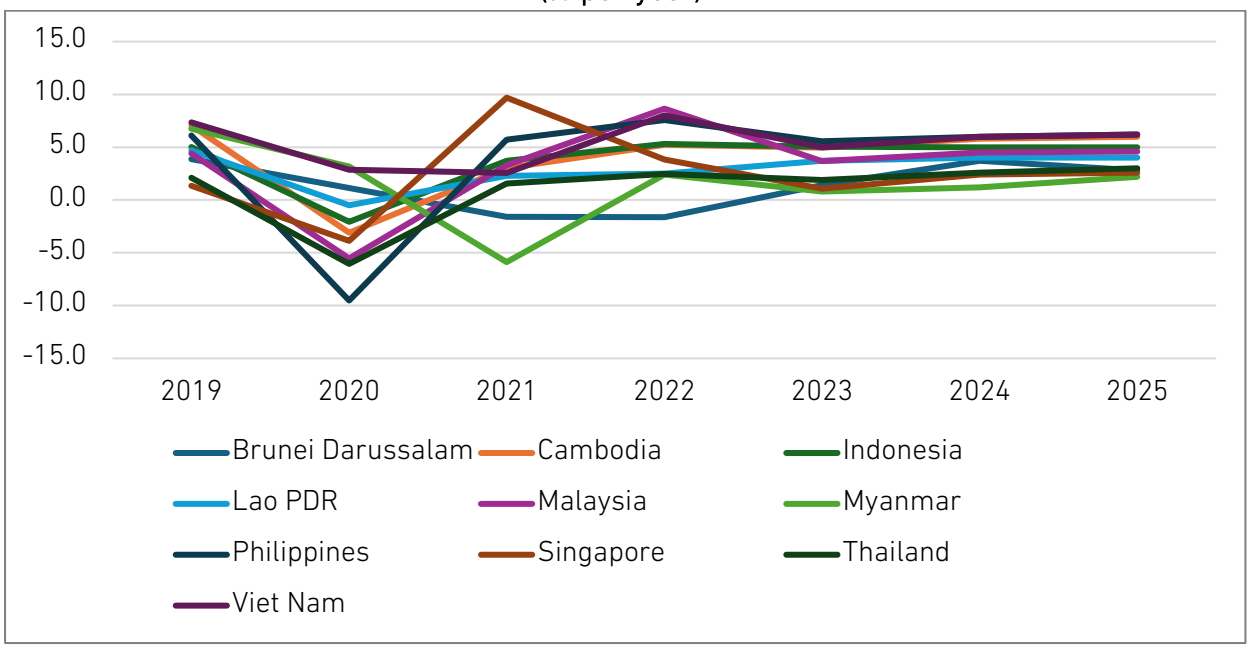
From a comparative perspective, the trends shown in Figure 2.1 and Figure 2.2 should be interpreted alongside factors such as population size, road network density, availability of public transport, and transport policy frameworks. Despite these moderating factors, population size (Figure 2.3) and gross domestic product (GDP) (Figure 2.4) demonstrate a strong correlation with vehicle growth across most of ASEAN countries, suggesting that they are amongst the most influential drivers of automotive demand.

Figure 2.3. Population of ASEAN Member Countries



ASEAN = Association of Southeast Asian Nations, Lao PDR = Lao People's Democratic Republic.
Source: Authors, adapted from International Monetary Fund (2024).

Figure 2.4. Gross Domestic Product Growth Rates of ASEAN Member Countries (% per year)

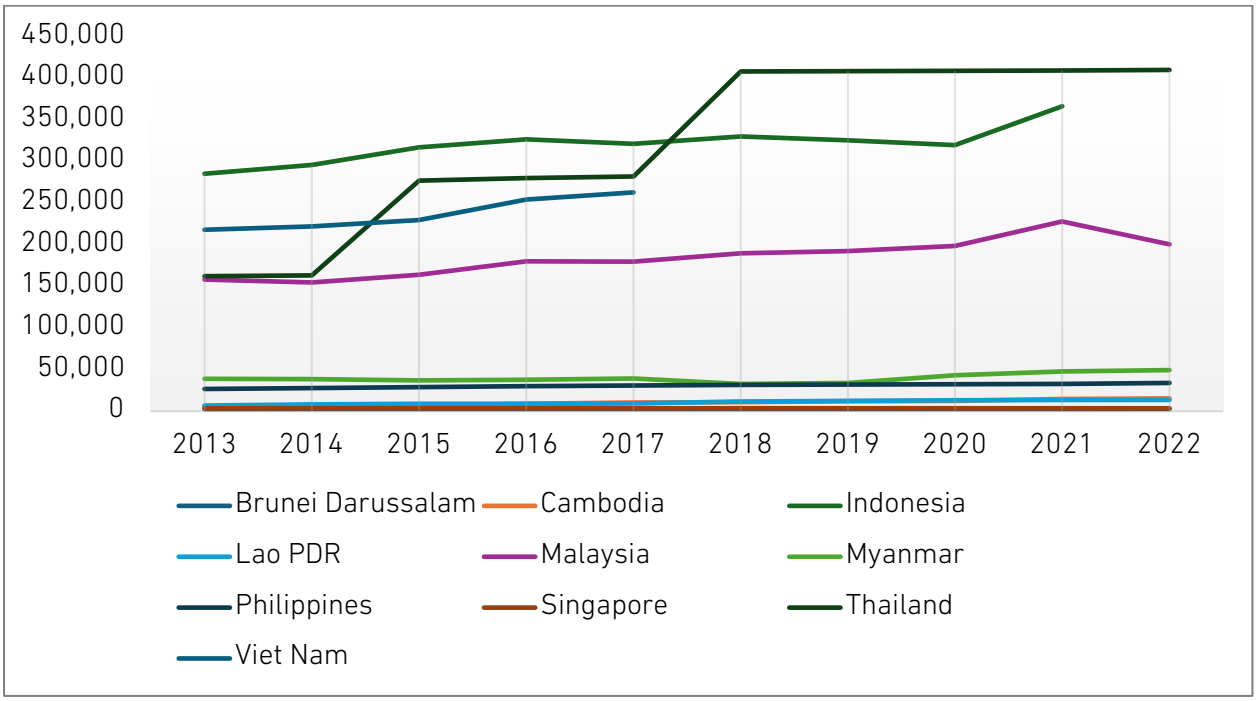


ASEAN = Association of Southeast Asian Nations, Lao PDR = Lao People's Democratic Republic.
Source: Authors, adapted from Asian Development Bank (2024).

2.2.2. Transport Supply–Demand and Its Determinant Factors

On the supply side, regardless of differences in geographical size and population, road infrastructure growth across almost all AMSs has remained largely stagnant since 2018. Thailand has the longest paved road network, at about 400,000 kilometres (km), followed by Indonesia with about 375,000 km, Viet Nam with about 350,00 km, and Malaysia with about 170,000 km (Figure 2.5). The remaining AMSs have substantially shorter paved road networks, generally below 50,000 km.

Figure 2.5. Length of Paved Roads in ASEAN Member States



ASEAN = Association of Southeast Asian Nations, Lao PDR = Lao People's Democratic Republic.
Source: Authors, adapted from ASEAN (2024a).

Transport demand is commonly represented by indicators such as gross domestic product (GDP), population size, and car ownership ratios. Almost all AMSs exhibit steady population growth of about 1% year-on-year, projected through to 2029 (Figure 2.3). GDP growth across ASEAN experienced a sharp downturn from 2019 to 2022 due to the coronavirus disease (COVID-19) pandemic. Since 2023, however, economic activity has rebounded, with GDP growth stabilising at about 2%–6% per year across the region.

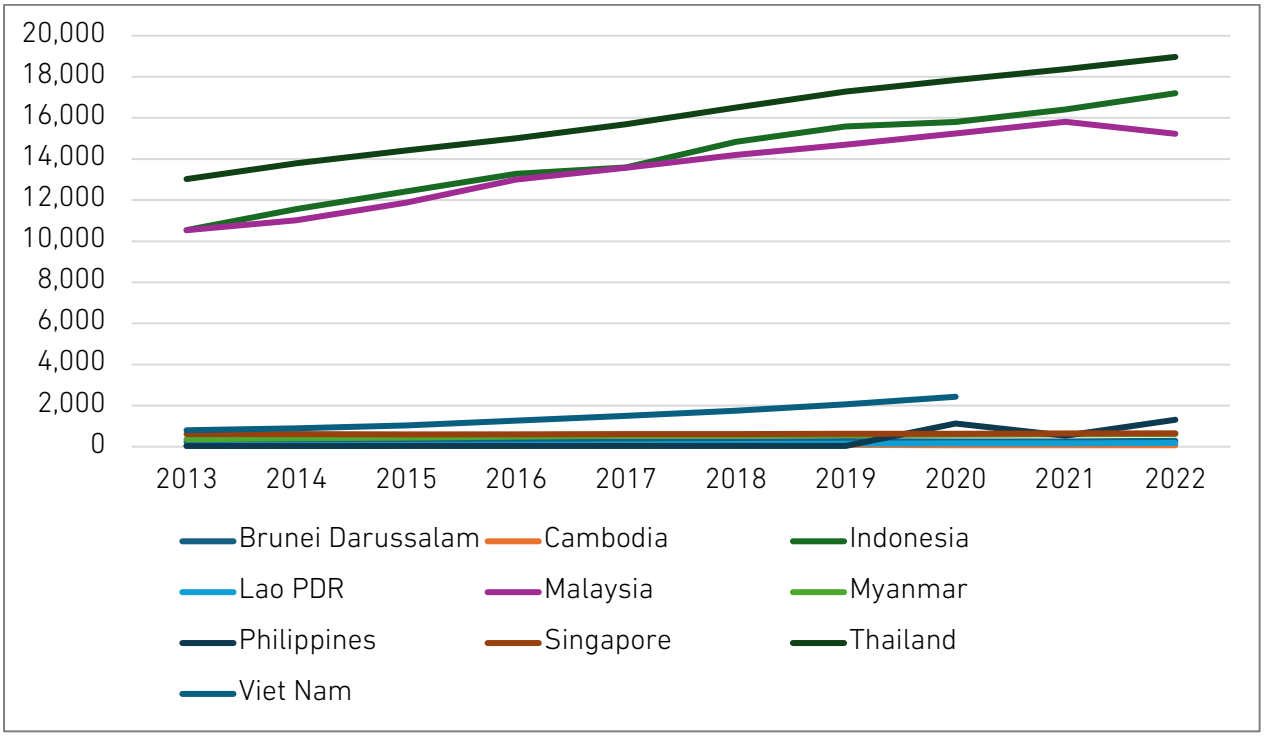
GDP trends can be interpreted as a proxy for household purchasing power and the capacity to acquire vehicles. Statistics covering 2013–2022 (Figure 2.6) show that the number of registered cars (four-wheelers) is dominated by three ASEAN countries: Thailand, with about 19 million cars in 2022; Indonesia, 17 million; and Malaysia, 15 million.

With respect to registered motorcycles (two-wheelers), Indonesia recorded exceptionally high figures, rising from about 85 million motorcycles in 2013 to about 125 million in 2022, equivalent to an average annual growth rate of about 5% (Figure 2.7). This level is significantly higher than that observed in other AMSs, such as Malaysia and Thailand, where motorcycle

ownership has remained relatively stagnant at about 20 million units in 2022. Other AMSs record substantially lower figures.

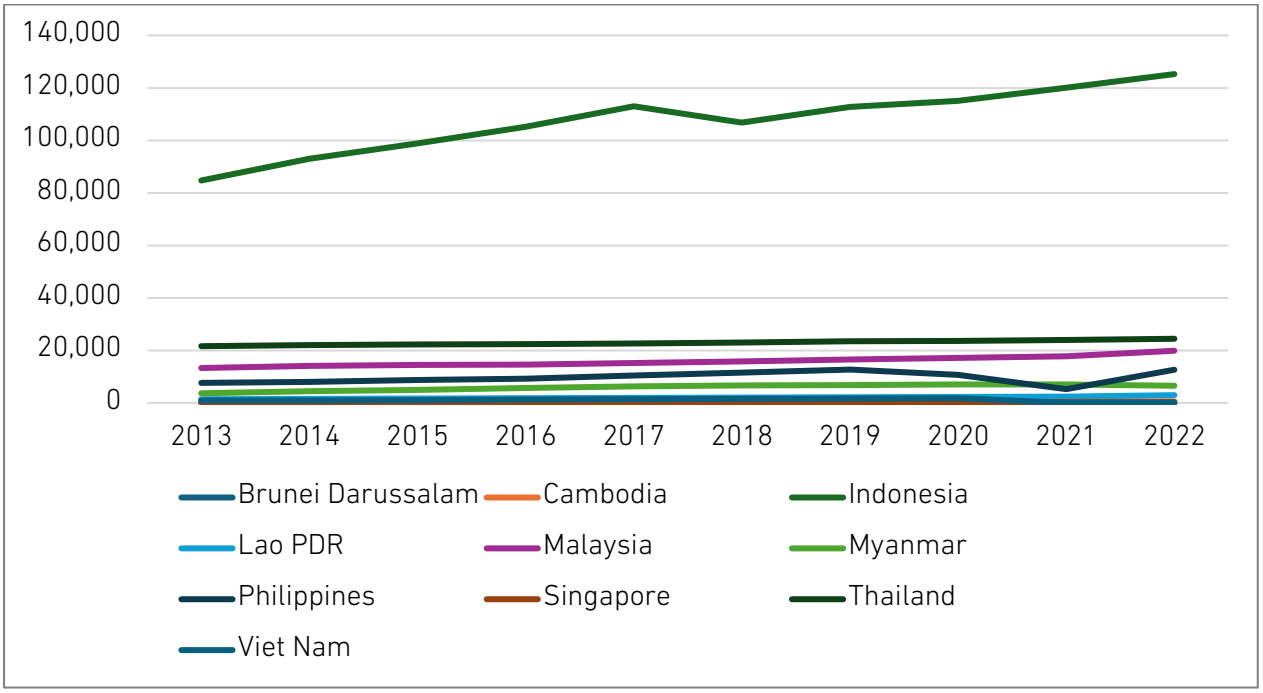
When these vehicle numbers are aggregated using a single unit of passenger car equivalent (PCE) (Figure 2.8), a broadly similar pattern emerges in growth trends and absolute magnitudes compared with the aggregated vehicle counts.

Figure 2.6. Number of Registered Cars in ASEAN Member States



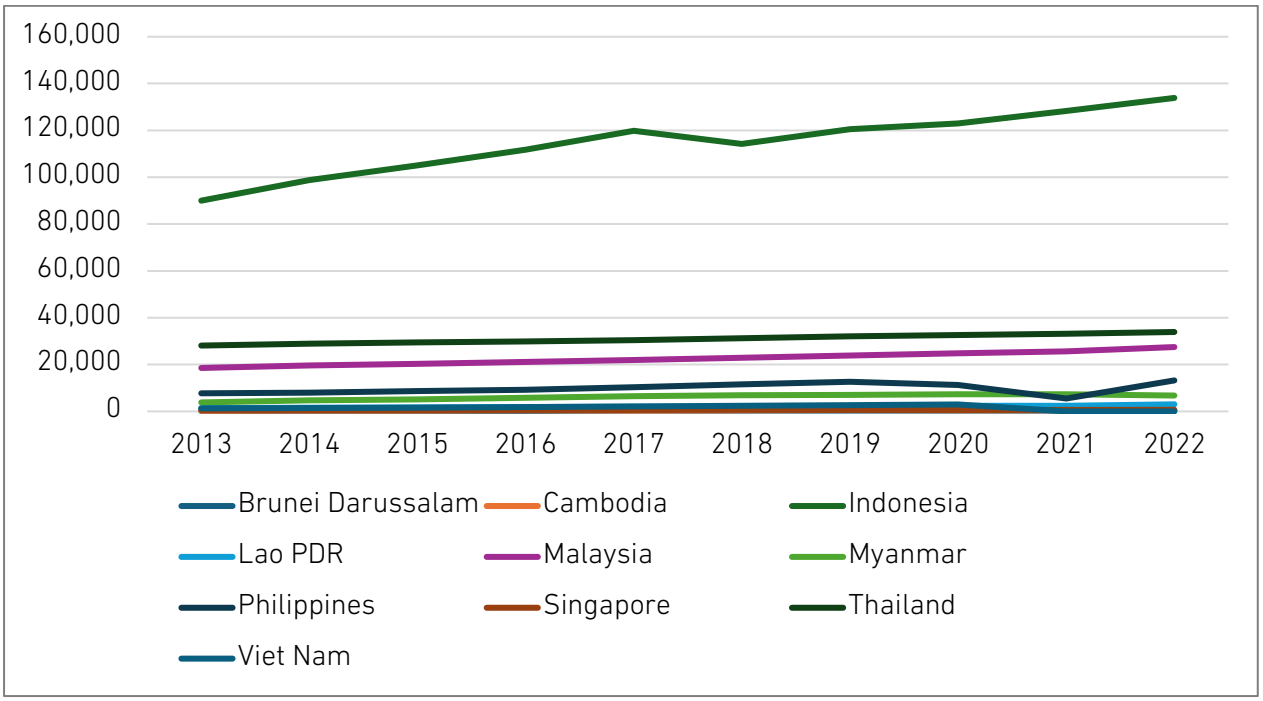
ASEAN = Association of Southeast Asian Nations, Lao PDR = Lao People's Democratic Republic.
Source: Authors, adapted from ASEAN (2024b).

Figure 2.7. Number of Motorcycles in ASEAN Member States



ASEAN = Association of Southeast Asian Nations, Lao PDR = Lao People's Democratic Republic.
Source: Authors, adapted from ASEAN (2024c).

Figure 2.8. Number of Registered Vehicles in Passenger Car Equivalents in ASEAN Member States (thousand PCEs)



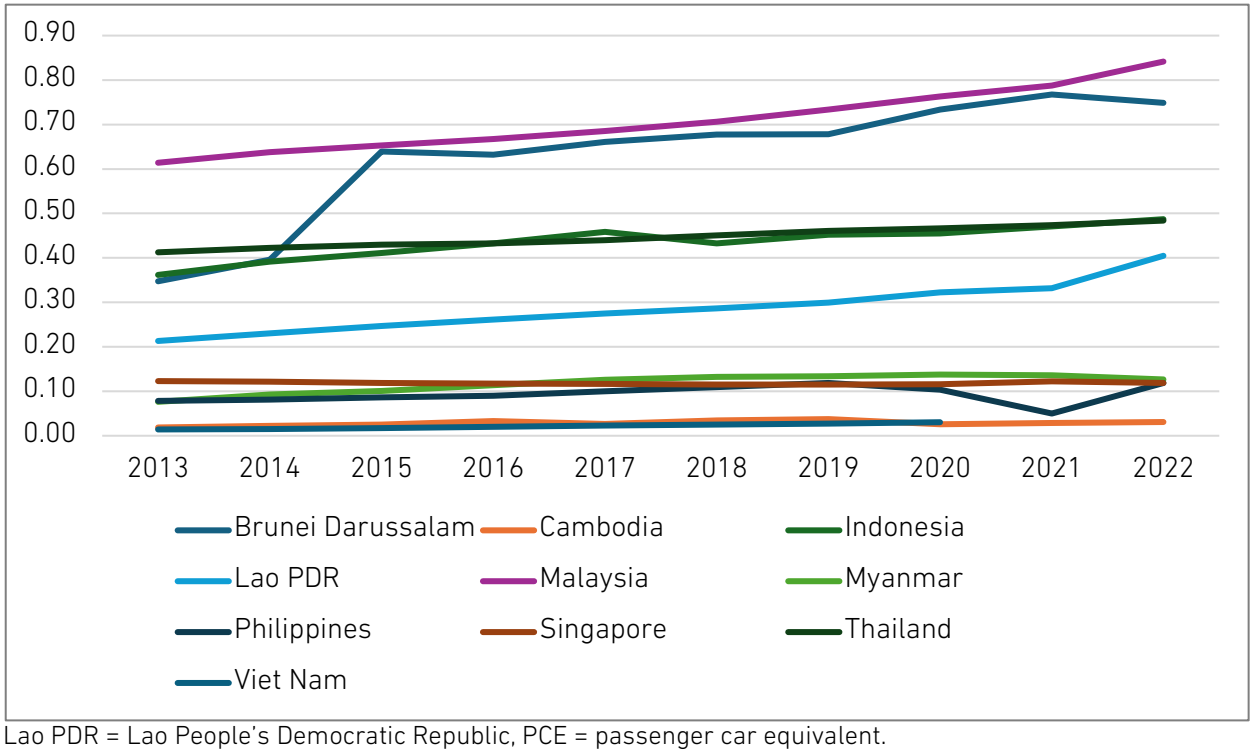
ASEAN = Association of Southeast Asian Nations, Lao PDR = Lao People's Democratic Republic.
Note: 1 passenger car = 1 PCE; 1 motorcycle = 0.5 PCE (based on the Indonesia Highway Capacity Manual, 2023).
Source: Authors, adapted from ASEAN (2024b); International Monetary Fund (2024).

2.2.3. Transport Demand–Supply Analyses

To derive more conclusive measures of transport demand and supply for the automotive sector in AMSs, two prominent indicators are evaluated. Demand is represented by the ratio of registered vehicles, measured in PCEs, to population, whilst supply is proxied by the ratio of total paved road length to national landmass, or road density. Figure 2.9 shows the total number of registered vehicles per population for each AMS as an indicator of vehicle ownership.

The figure shows that Malaysia and Brunei Darussalam record the highest ratios, ranging from 0.7 to 0.9, indicating that almost everyone owns a vehicle. Indonesia and Thailand have ratios close to 0.5, implying one vehicle for every two persons. Other countries, such as the Lao People's Democratic Republic (Lao PDR), record ratios below 0.4, followed by Cambodia, Myanmar, the Philippines, Viet Nam, and Singapore, with ratios below 0.1. A high ratio may indicate a relatively smaller population, whereas a low ratio may indicate limited vehicle ownership, particularly in the case of Singapore, which imposes strict quotas on vehicle ownership.

Figure 2.9. Ratio of Registered Vehicles (PCE) per Population

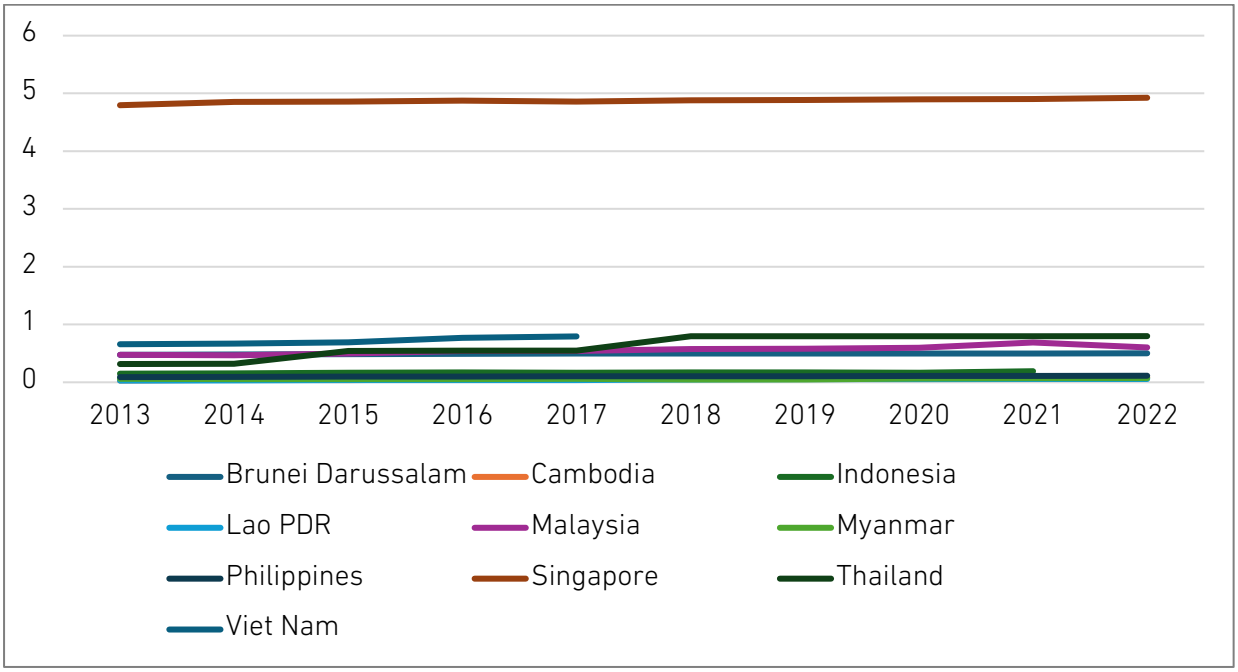


Lao PDR = Lao People's Democratic Republic, PCE = passenger car equivalent.
Note: 1 passenger car = 1 PCE; 1 motorcycle = 0.5 PCE (based on the Indonesia Highway Capacity Manual, 2023.
Source: Authors, adapted from Association of Southeast Asian Nations (2024b) and International Monetary Fund (2024).

On the supply side, Figure 2.10 shows road density, defined as paved road length relative to landmass, for each AMS. Singapore has the highest ratio, at about 5 km per square kilometre (km^2), reflecting its small geographical size (about 650 km^2) compared with other countries. In contrast, the other AMSs record ratios below 1 km/km^2. To some extent, these ratios can

be interpreted as indicators of the capacity of road infrastructure to accommodate road transport demand.

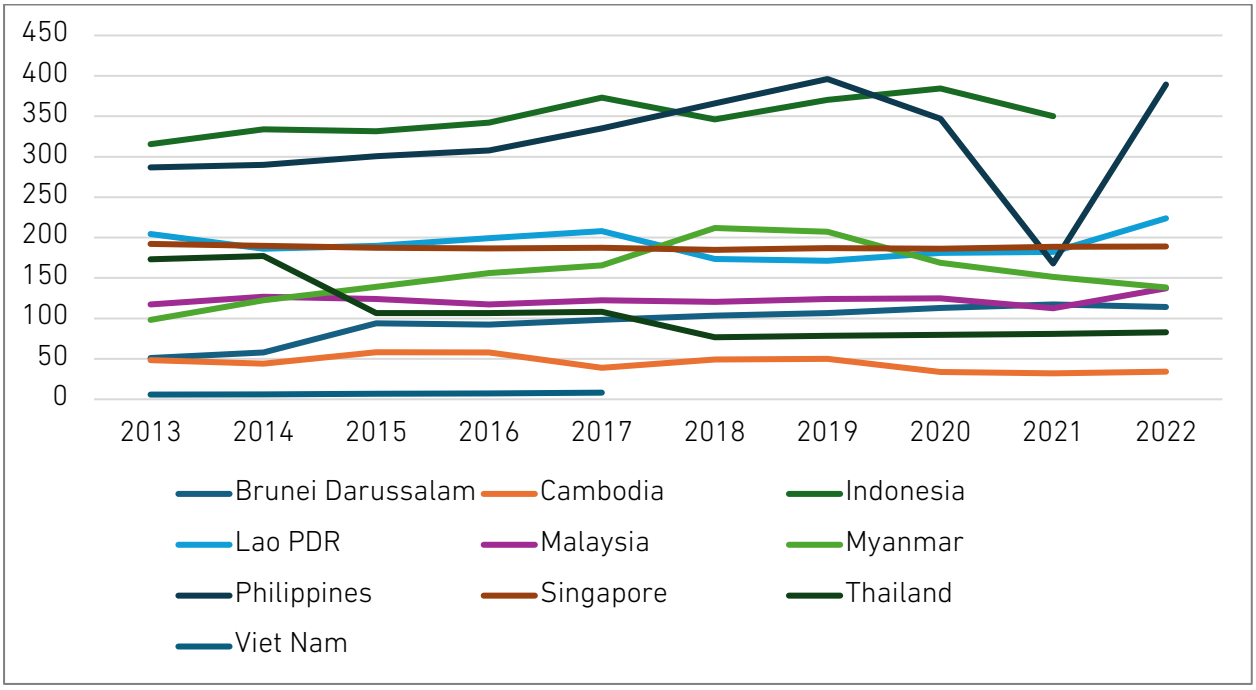
Figure 2.10. Ratio of Paved Road Length to Landmass (km/km²)



Lao PDR = Lao People's Democratic Republic.
Source: Authors, adapted from Association of Southeast Asian Nations (2024a).

When demand meets supply, or when flow equilibrium within the road network is achieved, a balance exists between the demand and supply functions (Figure 2.11). This figure presents the ratio of registered vehicles per km of paved road, where a higher ratio indicates a greater level of road congestion.

Figure 2.11. Ratio of Registered Vehicles (PCE) per Kilometre of Paved Road



Lao PDR = Leo People's Democratic Republic, PCE = passenger car equivalent.
Source: Authors, adapted from Association of Southeast Asian Nations (2024a, 2024b); International Monetary Fund (2024).

Indonesia and the Philippines record the highest ratios, at about 350–400 PCEs per km, indicating heavily loaded or congested roads (Figure 2.11). Countries such as Singapore, Malaysia, Brunei Darussalam, Thailand, Myanmar, and Lao PDR fall into a medium range, with ratios from 150 to 250 PCEs per km. The lowest ratios are observed in Cambodia and Viet Nam, at less than 50 PCEs per km. Despite Singapore's strict controls on vehicle ownership, the country still experiences traffic congestion. Similarly, although Viet Nam has a high number of two-wheelers, the congestion level appears more moderate once vehicle numbers are adjusted using PCE values.

2.2.4. ASEAN Transport Policy Instruments

The overall transport supply–demand analysis presented above is primarily based on traffic indicators and provides general insights into road traffic performance and vehicle ownership across ASEAN countries. Nevertheless, many other measures need to be considered when assessing and predicting the automotive market amongst AMSs, as these countries may adopt inherently different policy approaches.

ASEAN Road Transport Policy

ASEAN countries have established a form of road transport policy under the development of the Regional Strategy on Sustainable Land Transport of ASEAN. Although the vision, guidance, and recommended actions set out in the strategy are not binding on individual AMSs, the strategy aims to support the region's transition towards sustainable development, in which transport plays an essential role. It articulates ASEAN's vision for sustainable land

transport, including road transport, and sets out a range of recommendations and possible actions to implement regional cooperation. At the same time, it provides guiding principles for national action plans and strategies that each AMS may consider or develop in line with its own policy priorities. The expected implementation period, from 2018 to 2025, with a longer-term outlook to 2030, is in line with global sustainable development and climate change agendas.

In developing the ASEAN masterplan for next-generation automotive industries, three regional policy domains merit particular attention. Each domain is associated with a set of recommended regional actions, as outlined below:

- Urban transport, with recommended regional actions:
    - development of guidance for sustainable urban mobility plans and national urban mobility plans, including a menu of policy options;
    - rewarding of leadership, for example, through award schemes for cities that achieve key progress in sustainable urban mobility; and
    - development of planning and design guidelines for bicycle infrastructure, such as cycle tracks, lanes, and intersections, across different urban and non-urban contexts, which can be included in national road design manuals.
- Fuel economy, with a recommended regional action:
    - implementation, as appropriate, of the ASEAN Fuel Economy Roadmap for the Transport Sector 2018–2025: With Focus on Light-duty Vehicles, which supports development and adoption of nationally appropriate fuel economy policies.
- Clean fuels and low-carbon vehicles, with recommended actions:
    - establishment of a regional electric vehicle (EV) platform to discuss and develop standards for charging infrastructure, as well as environmentally sound methods for battery recycling and disposal; and
    - further study of vehicle emission and fuel quality standards, including their impacts on human health, the environment, and green growth.

Transport in ASEAN, as elsewhere in the world, faces a tremendous emissions challenge. A central difficulty is that a large share of transport activity is likely too dependent on fossil fuels, despite transformative efforts to electrify road transport, including both two- and four-wheelers. The route to decarbonisation has become clearer and is increasingly embedded in government transport policies through a push-and-pull dynamic between EVs and fossil fuel-based vehicles. This approach reflects a clear-eyed view of electrifying what can be electrified, whilst shifting modes that cannot be electrified in the near term towards sustainable advanced biofuels. In this context, ASEAN leaders are expected to formulate and promote forward-thinking national transport policies that are critical to both national and regional competitiveness within a decarbonising, sustainable transport system and an increasingly connected world.

Although ASEAN's road transport policy framework is not mandatory for all AMSs, it may implicitly or explicitly shape regional automotive markets. Accordingly, this policy framework, together with the transport supply–demand analysis presented above, can be further tailored to assess automotive modal choice, such as preferences for cars (four-wheelers) relative to other transport modes. However, to avoid misleading implications, additional transport measures need to be analysed and incorporated as influencing factors in modal choice and market development. These factors include policies on public transport development, road infrastructure expansion, green energy and decarbonisation, emerging vehicle technologies, and the potential substitution of physical mobility through information and communication technology and digitalisation.

The following sub-sections examine these interrelated issues in greater detail to capture the broader ecosystem shaping the future automotive industry and informing strategic and plausible automotive market trajectories in ASEAN and beyond.

2.3. Emerging Technologies in Automotive Operation and Services

ASEAN countries, like the rest of the world, are experiencing new features in automotive operation and services and are increasingly benefiting from them. Many of these benefits stem from the effective integration of information and communication technology into automotive operations and service applications. This technological integration has reshaped the characteristics of people's mobility. Mobility is no longer limited to private vehicles or public transport alone, but increasingly includes hired vehicles, which occupy an intermediate space between these two modes of transport. In this context, the emergence of mobility-as-a-service (MaaS) has become a major trend, using digital technologies to support and enhance everyday mobility.

2.3.1. Mobility-as-a-service

MaaS is a concept that seeks to generate a modal shift via the digital and physical integration of alternative on-demand transport services (Alyavina et al., 2024). It refers to the purchase of mobility services as a package tailored to consumers' needs, rather than the purchase of transport modes themselves. With public transport as its backbone, MaaS plays a role in substituting some public transport trips with car-centric services. Instead of owning a car, users access mobility services through digital platforms. Digitalisation acts first as an enabler of customer orientation and second as a facilitator of mobility services.

Within the auto-mobility sector, several value propositions underpin current business models. Vehicles can be used more efficiently and productively through digitalisation, for example, with car- and taxi-sharing, carpooling, car-hailing, hiring of private drivers, peer-to-peer car rental, and, increasingly, autonomous vehicles.

In ASEAN countries, MaaS can be broadly classified into three service categories: micromobility, car-sharing, and ride-hailing. Amongst these, ride-hailing represents the largest segment. A key innovation and emerging trend is the integration of ride-hailing services with public transport systems. As this integration deepens, it becomes possible to

plan an entire journey using a single application that combines multiple modes of transport, such as buses or trains, alongside car-based services.

Ride-hailing services

The ride-hailing business model connects passengers with drivers through mobile applications. Regional platforms such as Grab and Gojek have become household names across ASEAN and have expanded their offerings to include food delivery and payment services. Motorcycle-hailing has also emerged as a key trend, reflecting the widespread use of motorcycles across many ASEAN countries.

Car-sharing services

Car-sharing services involve the shared use of vehicles amongst multiple users for short periods, typically on an hourly or daily basis. Car-sharing provides members with short-term access to automobiles and aims to offer a mobility solution with lower responsibilities and costs than vehicle ownership, including reduced initial capital expenditure, fuel, maintenance, and insurance costs. Convenience and affordability are core features of car-sharing, making it particularly attractive to users who require vehicles only occasionally or who cannot afford a private vehicle ownership (Zhou et al., 2017).

Micromobility services

Micromobility focuses on short-distance trips, typically under 8 km, using lightweight vehicles such as electric scooters, bicycles, and electric bicycles. Local micromobility operators in Singapore, such as Beam and Neuron, emphasise affordable and sustainable urban transport solutions. Across ASEAN, micromobility companies have attracted significant investment and formed partnerships to widen service offerings. Regional initiatives have also emerged, including collaborations with shopping centres in Malaysia that provide electric scooters for customer use.

Market size and trend of MaaS in ASEAN countries

The MaaS market in ASEAN countries followed an upward trajectory until it experienced a significant downturn during the COVID-19 pandemic. Growth has since returned as restrictions were lifted, and the market is forecast to continue expanding rapidly over the next 5 years. Indonesia, Viet Nam, Thailand, and Singapore are at the forefront of MaaS development in the region, leading in sub-segments such as micromobility, ride-sharing, and ride-hailing.

MaaS in ASEAN is projected to grow until 2027 at an annual rate of 5.8% from 2017 onwards, driven mainly by rising urbanisation and increasing smartphone penetration. As of 2022, ride-hailing remained the largest segment by revenue, accounting for 96.5% of the total market. This share is projected to decline slightly to 95.8% by 2027, as car-sharing and micromobility expand. Both ride-hailing and car-sharing experienced sharp declines during the COVID-19 pandemic but are expected to rebound strongly, with double-digit growth rates forecast from 2020 to 2027 as travel restrictions eased and transport spending recovered. Micromobility was the only MaaS segment that continued to grow during the pandemic, as it

met demand for affordable, short-distance, and perceived safer transport options.

Regarding market size across ASEAN countries, Figure 2.12–Figure 2.15 show that Indonesia and Viet Nam generate the highest MaaS revenues in overall mobility. As rapidly urbanising developing economies, both countries seek to improve economic efficiency and inclusiveness through transport services. By contrast, Singapore records lower overall revenue, reflecting its strong reliance on public transport and a smaller population size.

Figure 2.12. Total Mobility Revenue in ASEAN, 2022 (in US$ billion)

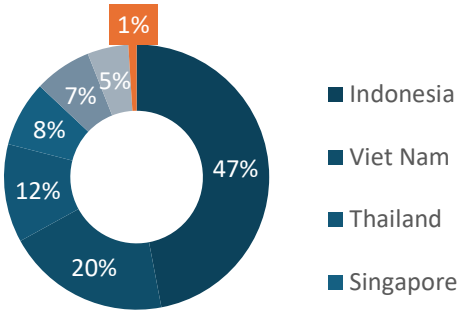


Figure 2.13. Ride-hailing Revenue in ASEAN, 2022 (in US$ billion)

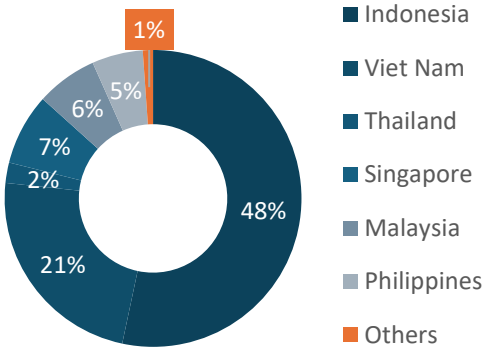


Figure 2.14. Car-sharing Revenue in ASEAN, 2022 (in US$ billion)

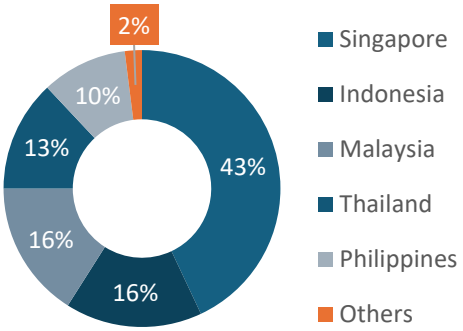
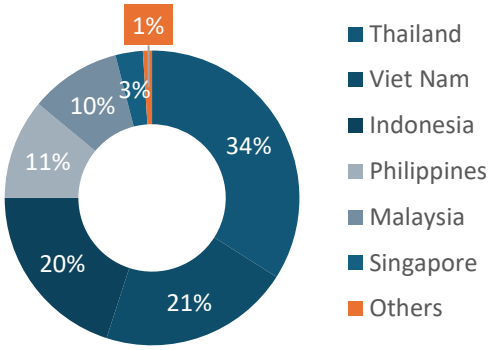
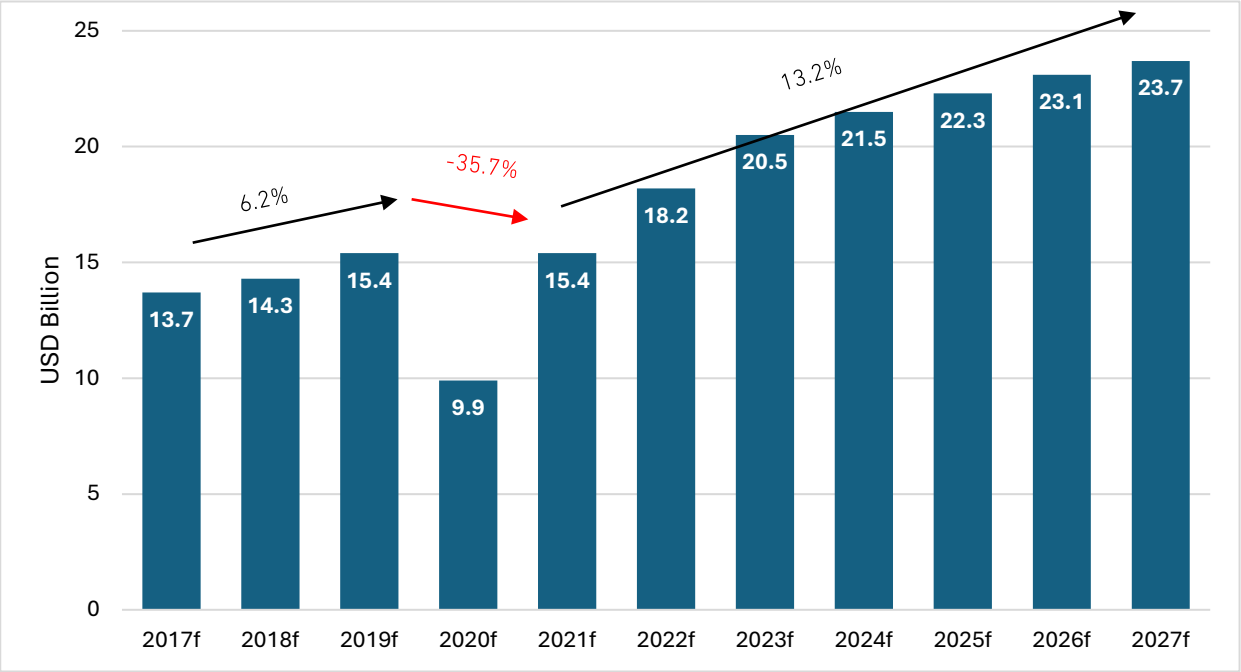


Figure 2.15. Micromobility Revenue in ASEAN, 2022 (in US$ billion)



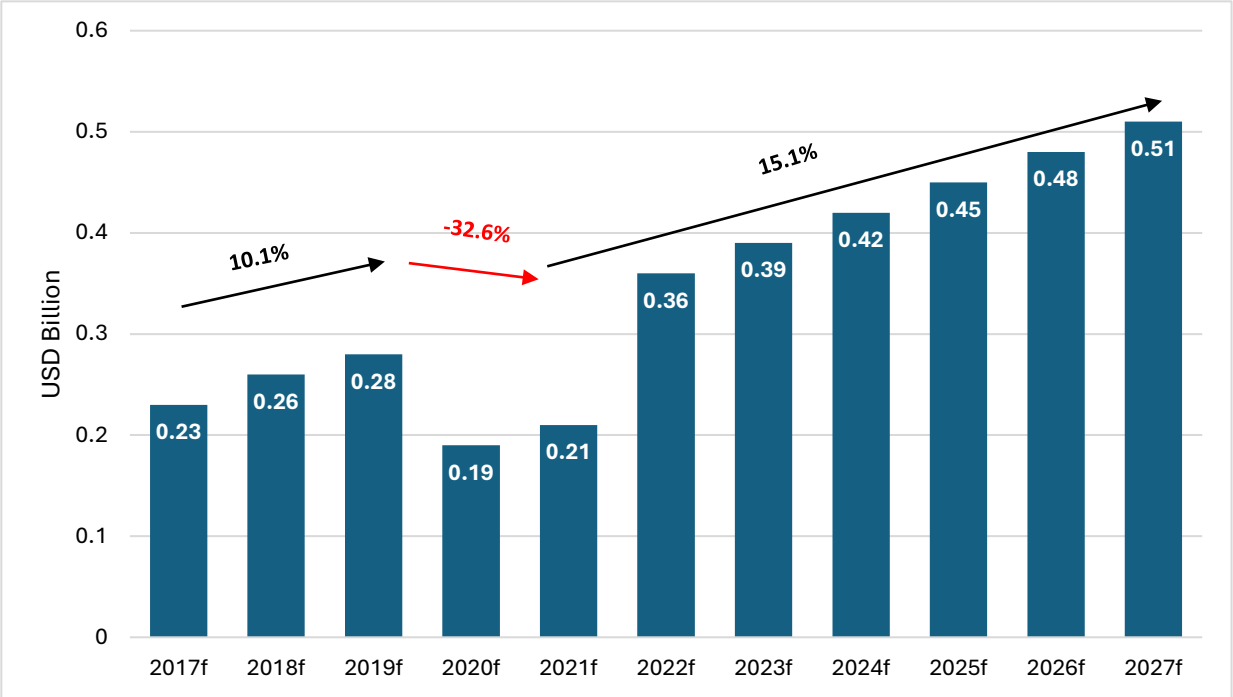
Source: Authors, adapted from YCP Solidiance (2023).

Figure 2.16. Ride-hailing Revenue in ASEAN Countries



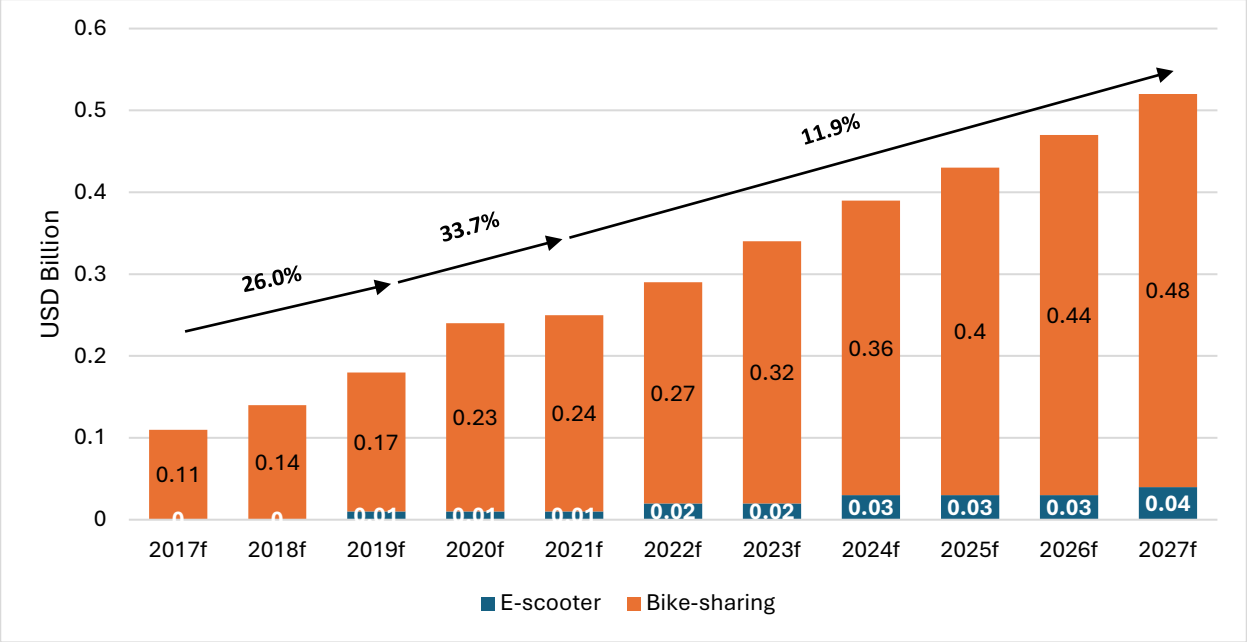
Source: Authors, adapted from YCP Solidiance (2023).

Figure 2.17. Car-sharing Revenue in ASEAN Countries



Source: Authors, adapted from YCP Solidiance (2023).

Figure 2.18. Micromobility Revenue in ASEAN Countries



Source: Authors, adapted from YCP Solidiance (2023).

In the ride-hailing segment, Indonesia and Viet Nam, as lower-income countries, exhibit higher penetration rates than higher-income economies. Ride-hailing allows users who cannot afford private car ownership to access vehicle-based mobility at lower cost. In contexts where public transport systems are perceived as inadequate or underinvested, ride-hailing has been widely adopted by residents and visitors as a primary mobility option.

For car-sharing, Singapore leads the region in revenue. This reflects the high costs and regulatory requirements associated with vehicle ownership, which have been introduced as part of the government's sustainable mobility strategy. Malaysia and Indonesia have also begun to adopt car-sharing services, driven by rising costs of living, unaffordable vehicle ownership, and high conventional car rental prices.

In the micromobility segment, Thailand, Viet Nam, and Indonesia account for most bike-sharing revenue, reflecting high motorcycle usage. In Thailand and Viet Nam, more than 85% of households own a motorcycle. Indonesia, with its severe urban traffic congestion, relies heavily on motorcycles rather than cars as the dominant mode of intra-city transport.

MaaS is expected to function most efficiently in contexts with well-developed public transport systems. Where public transport remains limited, private vehicles are likely to remain the preferred mode of travel (Zhou et al., 2017). In developed countries, where vehicles per capita are high, car-sharing aims to shift users away from private cars. In developing countries with lower car ownership, by contrast, car-sharing seeks to accommodate more users within fewer vehicles. This transition is often easier, as travellers tend to be more sensitive to the costs and disadvantages of non-chosen modes than to those of their preferred mode, even during major disruptions. These conditions suggest that the popularity of ride-sharing and low private car ownership in many Asian countries could facilitate wider MaaS adoption. In

several ASEAN countries, car-sharing therefore has the potential to significantly disrupt the personal mobility market (Zhou et al., 2017) .

Despite its potential, the attractiveness of MaaS does not automatically guarantee its sustainable uptake. Most users remain unwilling to give up car ownership, even where MaaS options are available. In some cases, MaaS may encourage substitution away from public transport towards shared cars rather than reducing car use overall. Pre-existing car ownership and habitual driving practices limit MaaS's capacity to deliver transport futures less dependent on private cars. Car ownership continues to be perceived as necessary, particularly in emergencies or during service disruptions, situations in which even well-functioning MaaS systems may offer limited reassurance. These perceptions constrain the ability of MaaS to reduce car ownership levels. More broadly, it is not only attitudes towards ownership, but general dependence on cars, that hinders sustainable MaaS uptake. Positive perceptions of car travel, even in shared forms, may lead MaaS users to replace public transport journeys with shared car trips.

The expansion of MaaS will have significant implications for the automotive industry. Product-oriented manufacturers may face challenges to established business models, whilst new opportunities will emerge for both existing and new market entrants. This process of creative destruction is likely to accelerate the shift of manufacturing and service-oriented companies towards service-based models, or servitisation (Goehlich et al., 2020). Several major automotive manufacturers, including BMW, Nissan, Peugeot, and Citroën, have already diversified into innovative mobility services such as car-sharing and flexible vehicle rental, deploying their vehicle fleets, including EVs, within MaaS platforms.

2.3.2. Autonomous Vehicles

Autonomous vehicles (AVs) represent an emerging mobility technology in ASEAN countries. They have strong potential for deployment in MaaS applications as well as in public transport services, such as buses. AVs are expected to influence future urban transport systems in multiple dimensions, including traffic flow stability, network congestion, land-use patterns, and road safety. AVs offer several advantages, such as high levels of compliance with traffic rules, extended service hours, reduced labour requirements, and minimisation of human error. These characteristics make AVs an efficient mode of urban transport, enabling lower operating costs and the provision of travel demand with smaller fleet sizes.

Numerous studies have examined the impacts of AVs across different aspects of transport systems. In connected and autonomous traffic environments, AVs can improve string stability and help prevent the formation and propagation of traffic shockwaves. AVs influence travel behaviour, as the technology has the potential to alter travel patterns in terms of mode shares, route choices, and activity destinations (Mo et al., 2021). Fagnant and Kockelman (2014) estimate that each shared AV could replace about 11 conventional vehicles, although it may generate up to 10% more vehicle–kilometre travelled (VKT) than comparable non-shared AV trips. Empirical studies in parts of Europe and the United States further suggest that AV technologies can reduce VKT, emissions, average travel times, and the number of

vehicles on the road.

As a critical component of urban transport systems, public transport cannot avoid the impacts of AV deployment. Some studies suggest that AVs may compete with, or even substitute for, public transport systems, whilst others highlight the potential for AV–public transport integration, arguing that the two modes could be complementary.

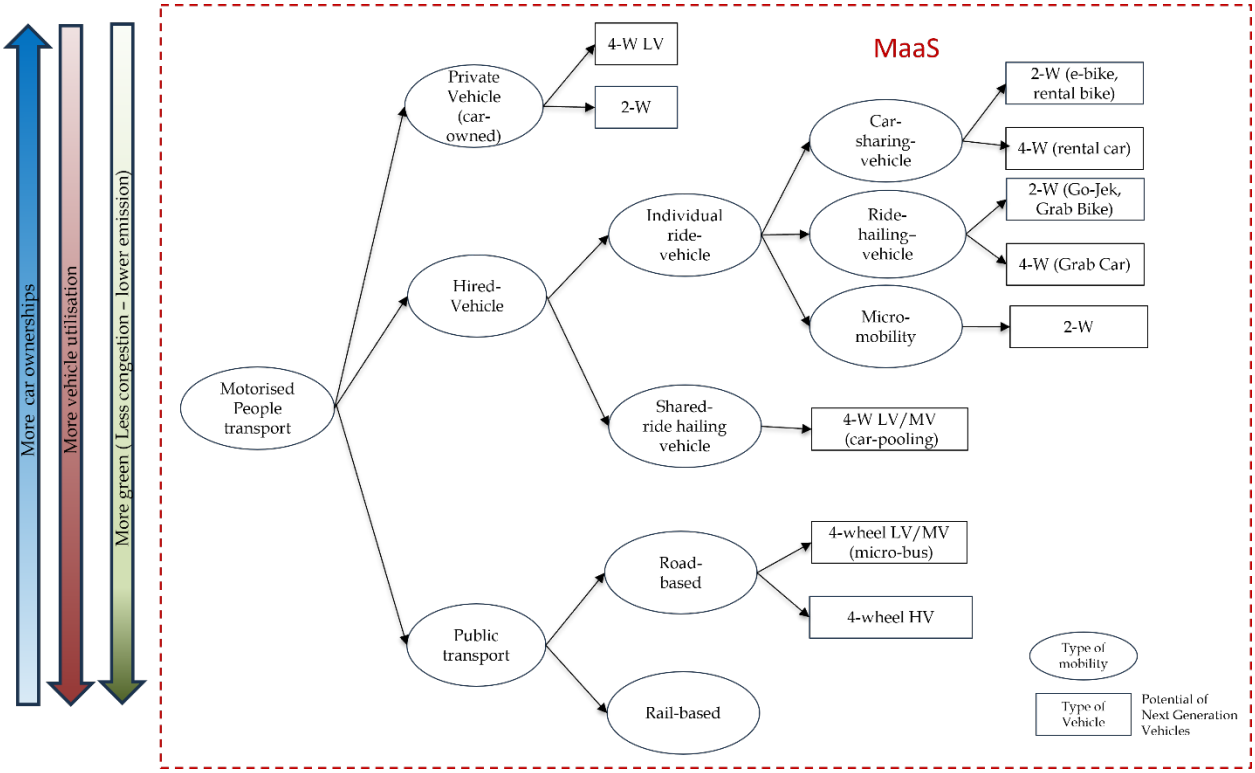
Despite the significant benefits associated with AVs and their more advanced development in several developed countries, adoption in ASEAN remains at an early stage. Initial efforts are underway in countries such as Singapore, Thailand, Malaysia, and Indonesia. Nevertheless, ASEAN countries continue to encounter multiple barriers, including limited infrastructure, economic constraints, and concerns related to security and safety. Indonesia, in particular, represents a highly promising market for AVs, given its rapidly expanding middle-class population and strong prospects for regional economic growth. The country's underdeveloped public transport infrastructure and heavy dependence on personal vehicles indicate a potential shift towards autonomous transport solutions (Widyanti et al., 2024).

Advances in autonomous driving technology have accelerated demand for, and adoption of, EVs. As autonomous systems become more sophisticated and widespread, demand will increase for vehicles capable of delivering adequate power whilst remaining environmentally sustainable. EVs are well-suited to meet these requirements, as they provide ample power supply whilst producing zero tailpipe emissions. Given expectations that AVs will be predominantly electric, Indonesia is well-positioned as a prospective automotive manufacturing base (Nurliyana et al., 2023). As a major supplier of vital EV components, such as nickel, cobalt, and copper ores, Indonesia plays a strategic role in the global transition towards electrified transport. Although EVs and AVs are distinct concepts, they share complementary characteristics, particularly with respect to environmental performance, energy efficiency, and advanced digital features (Widyanti et al., 2024).

Given the anticipated reliance of AVs on electricity, Indonesia could emerge as a key hub for automotive manufacturing. These conditions highlight considerable opportunities for stakeholders to leverage Indonesia's market potential in developing advanced strategies and technologies (Widyanti et al., 2024). Several pilot projects and initiatives are already underway in Indonesia to assess the feasibility and benefits of AV deployment, particularly in ride-hailing, logistics and delivery services, and public transport. However, regulatory frameworks, infrastructure restrictions, and public acceptance continue to constrain the mainstream adoption and deployment of AVs in the country (Sitinjak et al., 2024).

2.3.3. Mode Choice in People's Mobility and the Role of the Automotive Industry

Figure 2.19. Mode Choice in People's Mobility



2-W = two-wheeler, 4-W = four-wheeler, HV = heavy vehicle, LV = light vehicle, MV = motor vehicle.
Source: Authors (2024).

With the emergence of new automotive technologies and mobility services, the range of mode choices within road transport systems, particularly for motorised transport, has expanded significantly. These choices span private vehicles, public transport, and hired-vehicle services that occupy an intermediate position in the form of MaaS. Figure 2.19 shows the range of mode choices available in most cities worldwide.

Mobility based on private two- and four-wheelers is closely associated with high levels of vehicle ownership. At the same time, privately owned vehicles typically remain unused for about 95% of the day (Zhou et al., 2017), indicating low utilisation rates. MaaS is expected to increase vehicle utilisation by increasing VKT relative to private vehicle use. However, the use of hired vehicles or public transport does not necessarily imply the absence of private vehicle ownership. Many users of these services also own vehicles and rely on them occasionally.

The business objectives of the automotive industry have traditionally been aligned with vehicle ownership. In contrast, cities worldwide increasingly prioritise improvements in public and active transport systems rather than private car–oriented mobility, given that transport is a major contributor to global emissions. In this context, new-generation vehicles (NGVs) offer low-emission alternatives, and their uptake in some countries is supported through policy incentives aimed at facilitating ownership. Despite their lower emissions, increasing vehicle ownership continues to generate additional challenges, particularly

congestion. Many cities lack adequate public transport systems and sufficient road infrastructure capacity to accommodate increasing vehicle movements. As a result, severe traffic congestion persists in cities such as Jakarta, Bangkok, and Manila. In these urban environments, transport challenges intensify as private vehicle numbers continue to grow, even where vehicles themselves are relatively low-emission.

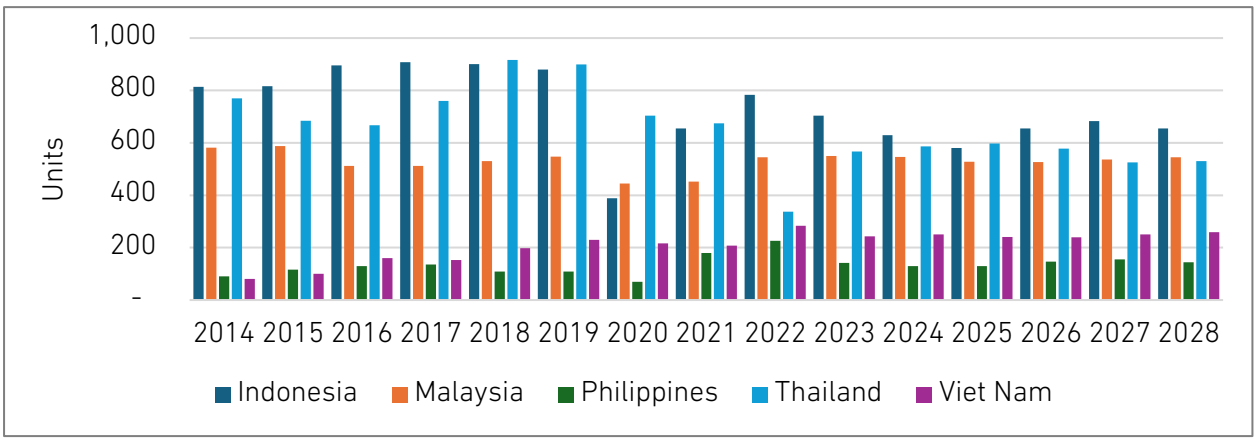
Against a backdrop of global economic growth, the automotive industry not only has opportunities to develop NGVs but also bears responsibility for contributing to a sustainable transport system. The industry plays a key role in balancing the goals of increasing vehicle ownership whilst simultaneously reducing congestion and emissions, and increasing vehicle utilisation. Achieving zero-emission targets requires optimising competing interests. Whilst demand for car ownership remains, including amongst public transport users, NGVs provide part of the solution. At the same time, automotive manufacturers can extend their business models into innovative mobility services, such as car-sharing and ride-hailing, by deploying low-emission vehicles within shared mobility fleets to increase utilisation rates.

Governments must design policy frameworks that stimulate the development of NGVs and diverse mobility services, recognising that transport mode shares are shaped by competition. Targeted and carefully calibrated incentives for private EVs are required to avoid undermining the promotion of public transport and shared mobility services. This, in turn, calls for careful market segmentation and the development of targeted strategies for different user groups.

2.4 Market Conditions of the Automotive Industry

Market stagnation has been notable in major ASEAN countries, such as Indonesia, Thailand, Malaysia, and the Philippines, as evidenced by sales figures over the past 10 years. This stagnation is primarily driven by a disparity between increases in per capita income and the rising prices of new vehicles, particularly those equipped with advanced technologies such as hybrid electric vehicles (HEVs) and battery electric vehicles (BEVs). Whilst consumers' purchasing power has grown, it has not kept pace with the cost escalation associated with these technologically superior vehicles.

Figure 2.20. Sales of Hybrid Electric Vehicles and Battery Electric Vehicles Since 2014



Source: Authors, adapted from Statista (2024a).

The prices of HEVs and BEVs are influenced by several factors, including advanced technology, higher production costs, and the need for specialised infrastructure. These elements contribute to higher retail prices, making such vehicles less accessible to a significant portion of the population, despite their potential benefits from fuel efficiency and reduced environmental impact.

To address this issue and stimulate the market for NGVs, several strategic measures need to be implemented. First, tax instruments are crucial. Governments can introduce tax incentives, such as reductions or exemptions for HEVs and BEVs. These incentives can significantly lower the overall cost for consumers, making these vehicles more affordable and attractive. Subsidies can be provided either to manufacturers, to reduce production costs, or directly to consumers, to offset purchase prices.

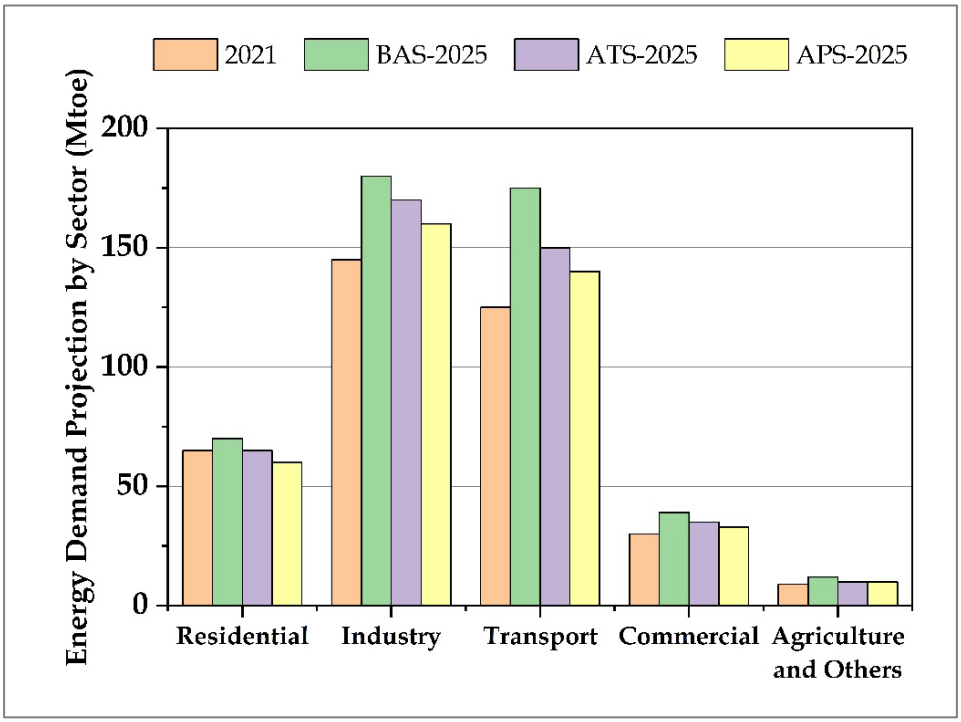
Carbon trading pathways present a viable method to decreasing the selling prices of NGVs. By incorporating carbon credits, manufacturers of HEVs and BEVs can benefit financially from producing low-emission vehicles. These benefits can then be passed on to consumers in the form of lower prices. The integration of carbon trading mechanisms not only supports reductions of greenhouse gas (GHG) emissions but also encourages the adoption of environmentally friendly vehicles.

Alongside these financial measures, it is essential to develop and enhance supporting infrastructure. This includes expanding networks of charging stations for BEVs and ensuring that renewable energy sources are integrated into power supplies, thereby making the entire ecosystem more sustainable. Building robust infrastructure will increase consumer confidence in transitioning to NGVs.

2.5. Trends in Vehicle Technology Development: Environmentally Friendly, Smart, and Safe

Global warming, the predominant driver of climate change, has precipitated severe environmental degradation and catastrophic natural disasters, posing a significant threat to human survival. In response, global efforts have increasingly focused on fostering environmental sustainability. A major contributor to global warming is the substantial rise in GHG emissions, notably carbon dioxide (CO_2), largely emanating from transport, particularly motor vehicles, as documented by the Intergovernmental Panel on Climate Change (2022). Figure 2.21 shows energy consumption in the ASEAN region (ASEAN Energy Report, 2024).

Figure 2.21. ASEAN Energy Consumption by Sector



BAS = baseline, ATS = ASEAN Member States target scenario, APS = ASEAN Plan of Action for Energy Cooperation target scenario.
Source: Authors, adapted from ASEAN Centre for Energy (2024).

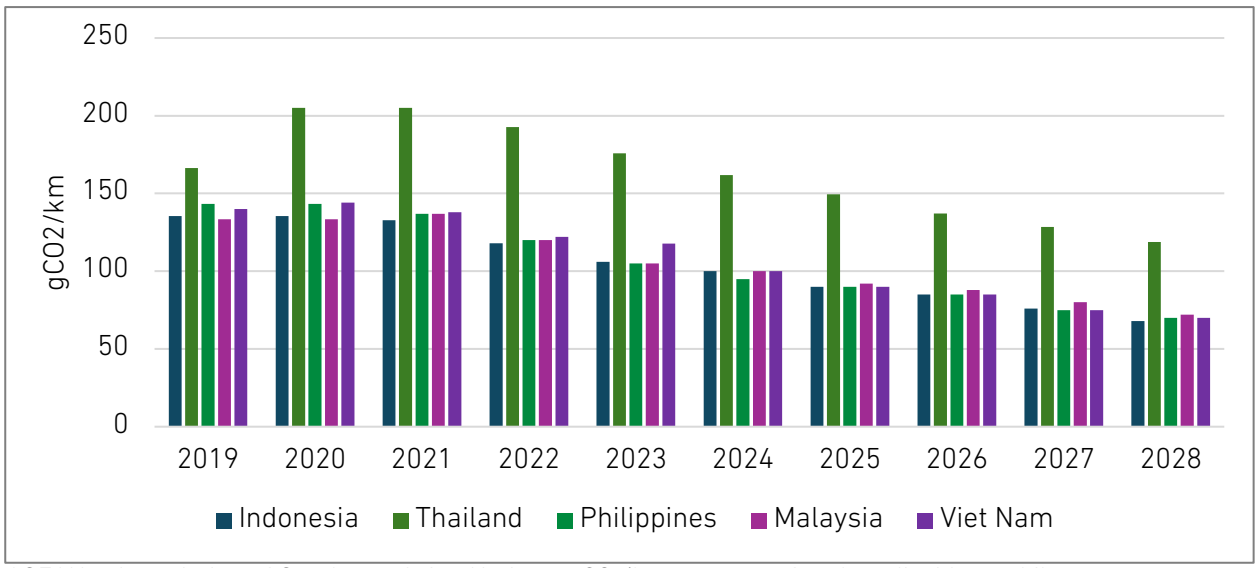
The International Energy Agency (IEA) identifies vehicle electrification as a key strategy for enhancing the environmental performance of transport (IEA, 2021). Across end-use sectors, energy consumption continues to rise as a result of combined population growth and economic expansion. Regional energy demand is projected to increase by 21% by 2024 compared with 2021 levels. Fossil fuels are expected to maintain their dominance in the energy mix, with oil accounting for the biggest portion at 46% of total energy consumption. Under the AMSs target scenario (ATS), the implementation of fuel-shifting policies would lead to modest increases in the shares of electricity (9%) and bioenergy (2%) in ASEAN's energy consumption by 2024. These changes are driven by the adoption of electric cooking, the wider uptake of EVs, and the enforcement of biofuel mandates in several AMSs.

The application of more advanced technologies across all end-use sectors is expected to greatly decrease the proportion of fossil fuels. Implementation of the ASEAN Plan of Action for Energy Cooperation (APAEC) target scenario (APS) is expected to result in a significant reduction in energy consumption. By 2024, energy savings are estimated to reach 11% relative to the baseline scenario. As of 2026, transport and industry sectors remain the most critical, serving as the main drivers of energy demand and key targets of efficiency improvements under the regional aspiration scenario in the APAEC 2026–2030 Framework (ASEAN Centre for Energy, 2025d).

To achieve the regional objectives set under the announced pledged scenario, enhanced energy-conservation measures need to be embedded within national policies across all sectors of final energy consumption. Transport remains heavily reliant on fossil fuels and is

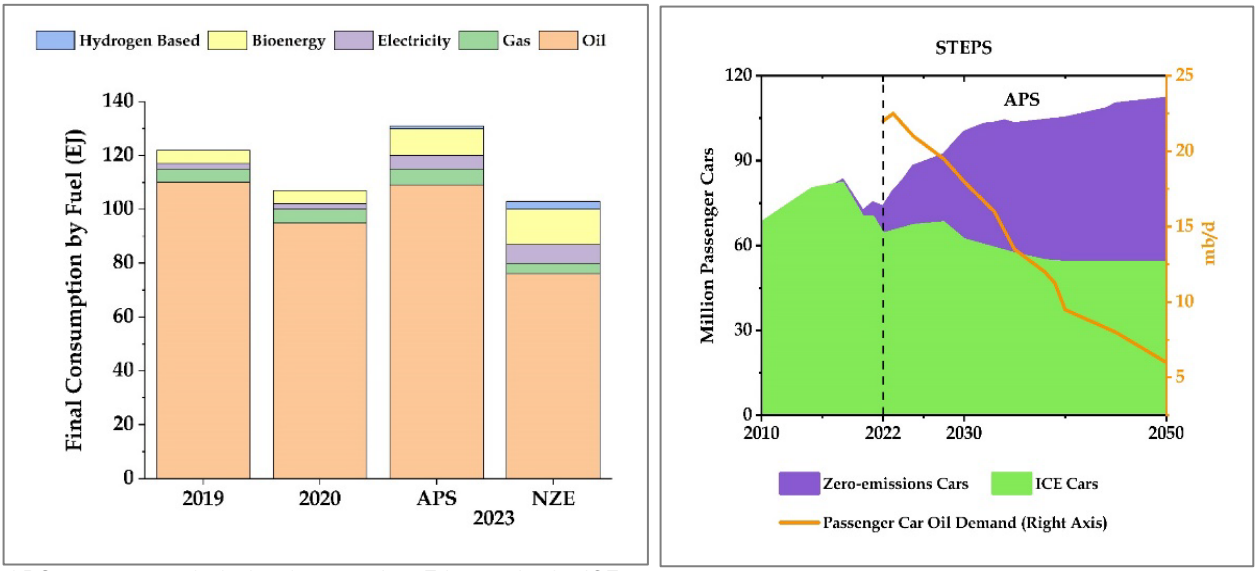
responsible for 37% of CO_2 emissions from end-use sectors, amounting to 7.1 gigatonnes (Gt) in 2020. In recent years, transport has recorded the fastest growth in CO_2 emissions, driven by increasing demand and limited adoption of alternative fuels. By 2030, transport emissions under the announced pledged scenario are projected to be about 2.5 Gt higher than those under the net-zero emission (NZE) scenario. Road transport accounts for about three-quarters of the difference in ambition between the two scenarios (Figure 2.21). Figure 2.22 shows the average carbon emissions in the ASEAN region.

Figure 2.22. Average Emissions per Kilometre in Major ASEAN Countries



ASEAN = Association of Southeast Asian Nations, gCO_2/km = grams of carbon dioxide per kilometre.
Source: Authors, adapted from Statista (2024a).

Figure 2.23. Projection of Energy Demand in Transport and Passenger Registration



APS =announced pledged scenario, , EJ = exajoule, ICE = internal combustion engine, mb/d = million barrels per day, NZE = net zero emissions, STEPS = stated policies scenario.
Source: Authors, adapted from International Energy Agency (2023).

Seventeen governments have released strategies focused on low-carbon hydrogen, whilst over 20 countries are actively developing such strategies. These strategies primarily emphasise hydrogen supply targets, with a growing focus on policies to stimulate demand for low-carbon hydrogen and hydrogen-based liquids. These include ammonia, methanol, and other synthetic liquid hydrocarbons with very low emission profiles (Figure 2.22).

By 2030, the share of oil in road transport energy demand is projected to decrease from 92% currently to 88% under the Stated Policies Scenario (STEPS), 84% under announced pledged scenario, and 78% under the NZE scenario (Figure 2.22). This decrease is driven by a significant shift towards electromobility and increased use of biofuels. Electricity use in transport is projected to increase by almost 12-fold by 2030 under STEPS and by more than 15-fold under announced pledged scenario.

The introduction of phase-out dates for internal combustion engine vehicles (ICEVs), together with incentives for electromobility, implies that EVs will account for about 20% of total distance travelled by road vehicles under announced pledged scenario. Despite their significantly higher efficiency compared with ICEVs, EVs are expected to represent only about 5% of total energy consumption in road transport.

Addressing the severity of global warming necessitates a global transition towards vehicles that produce no exhaust emissions. These vehicles can be broadly categorised into three main types: BEVs, powered by batteries; fuel cell electric vehicles (FCEVs), which use hydrogen to generate electricity; and hydrogen internal combustion engine vehicles (HICEVs), which are fuelled directly by hydrogen. The combustion process in hydrogen internal combustion engines (HICEs) closely resembles that of conventional ICEVs, with the key difference that HICEs do not emit CO_2 but instead produce water, as hydrogen contains no carbon chain (Wrobel et al., 2022; Dash et al., 2022; Maisel, 2023).

BEVs, FCEVs, and HICEs produce no emissions during operation. However, their production processes and the extraction of raw materials remain dependent on conventional energy sources. (Song et al., 2023; Yu et al., 2023; Tian et al., 2024). Assessments of vehicle environmental performance, therefore, need to account not only for operational performance but also for the full life cycle, including production and end-of-life disposal (Verma et al., 2022; Gan et al., 2022; Oliveri et al., 2023; Hirz et al., 2022). FCEVs and HICEs face additional challenges, as hydrogen production, whether through electrolysis or natural gas reforming, is energy-intensive and often reliant on non-renewable energy. Hydrogen production, storage, and distribution infrastructure remains at an early stage of development and requires substantial investment to become more sustainable (Singla, 2021; Qureshi, 2023; Lagioja, 2023; Hassan, 2023).

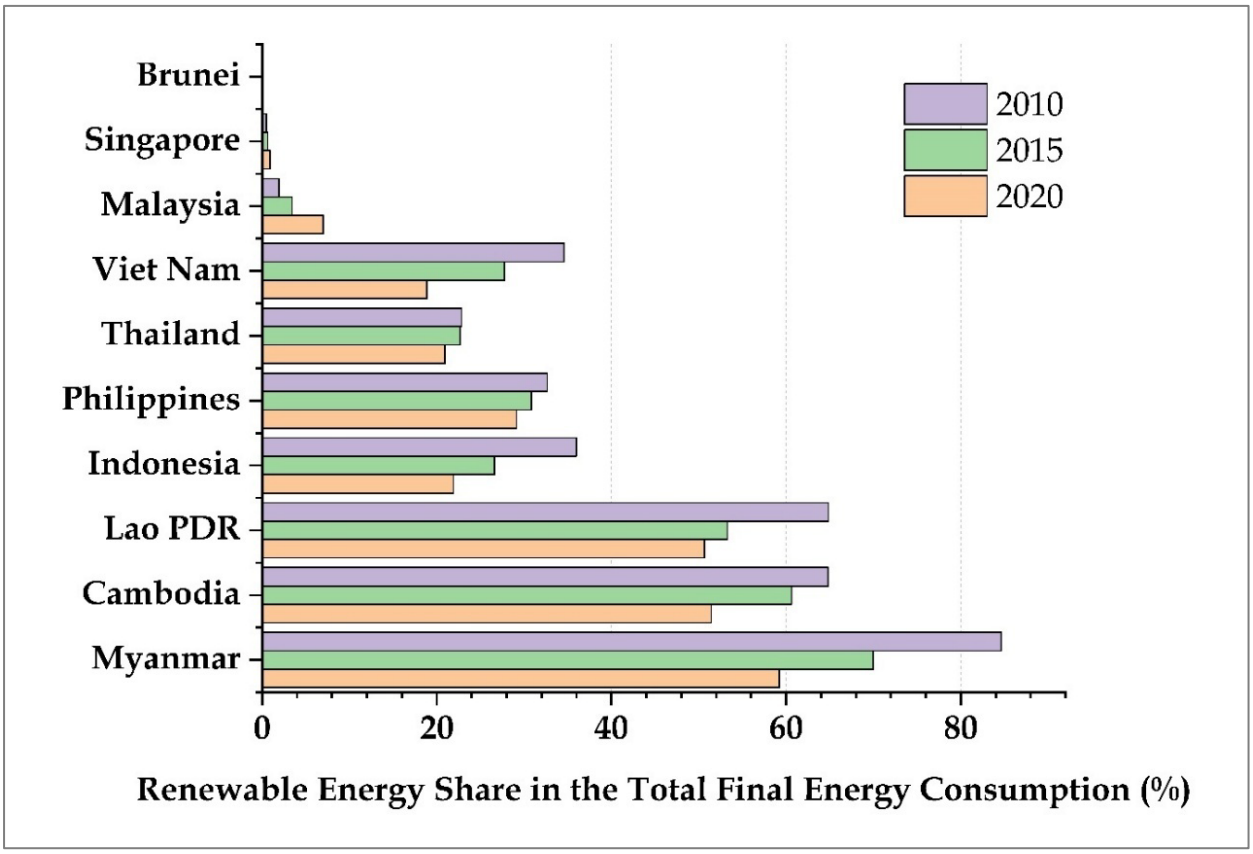
The power industry has a significant role in ensuring energy security, particularly by maintaining a stable electricity supply and facilitating the transition to clean energy and decarbonisation. Electricity generation capacity in ASEAN remains dominated by fossil fuels, with coal and natural gas accounting for 67% of installed capacity in 2022. By 2024, power capacity is projected to expand by about 18%–19% under the baseline scenario, the AMSs target scenario, and the APS. In terms of electricity generation, projections indicate that AMSs

will need to generate 1,524 TWh (terawatt-hours) in 2025, whilst the AMSs target scenario will operate at 16% less capacity than the baseline scenario. In 2025, hydropower will continue to dominate renewable energy within the APS, supplemented by contributions from geothermal, solar, and wind sources.

Several prevailing trends indicate that ASEAN is making steady progress towards meeting its regional target of securing 35% of its installed power capacity from renewable energy sources by 2025. Revised power data for Brunei Darussalam and Viet Nam in 2022 indicate a total installed capacity of 315 gigawatts, representing an increase compared with the 2023 ASEAN power update. Lao PDR has emerged as a major exporter of electricity to neighbouring countries, including Cambodia, Thailand, and Viet Nam. A notable milestone has been achieved through the export of 100 megawatts of renewable energy to Singapore through the Lao PDR–Thailand–Malaysia–Singapore Power Integration Project.

As ASEAN enters 2026, the region is implementing the first year of APAEC 2026–2030, transitioning from earlier baseline projections to a more ambitious regional aspiration scenario. Total energy consumption is projected to grow by 10.7% from 2023 to 2026 under the baseline scenario. Under the AMSs target scenario, electricity is expected to secure a 21.7% share of total final energy consumption by 2026, driven by ongoing electrification in transport and buildings. By the end of 2025, the region had made significant progress towards its goal of 35% renewable energy in installed power capacity, having already achieved a 33.5% share by late 2023. Whilst hydropower remains a key component, the current focus has shifted towards the rapid scaling up of variable renewable energy, specifically solar and wind, supported by enhanced regional grid connectivity through the ASEAN Power Grid

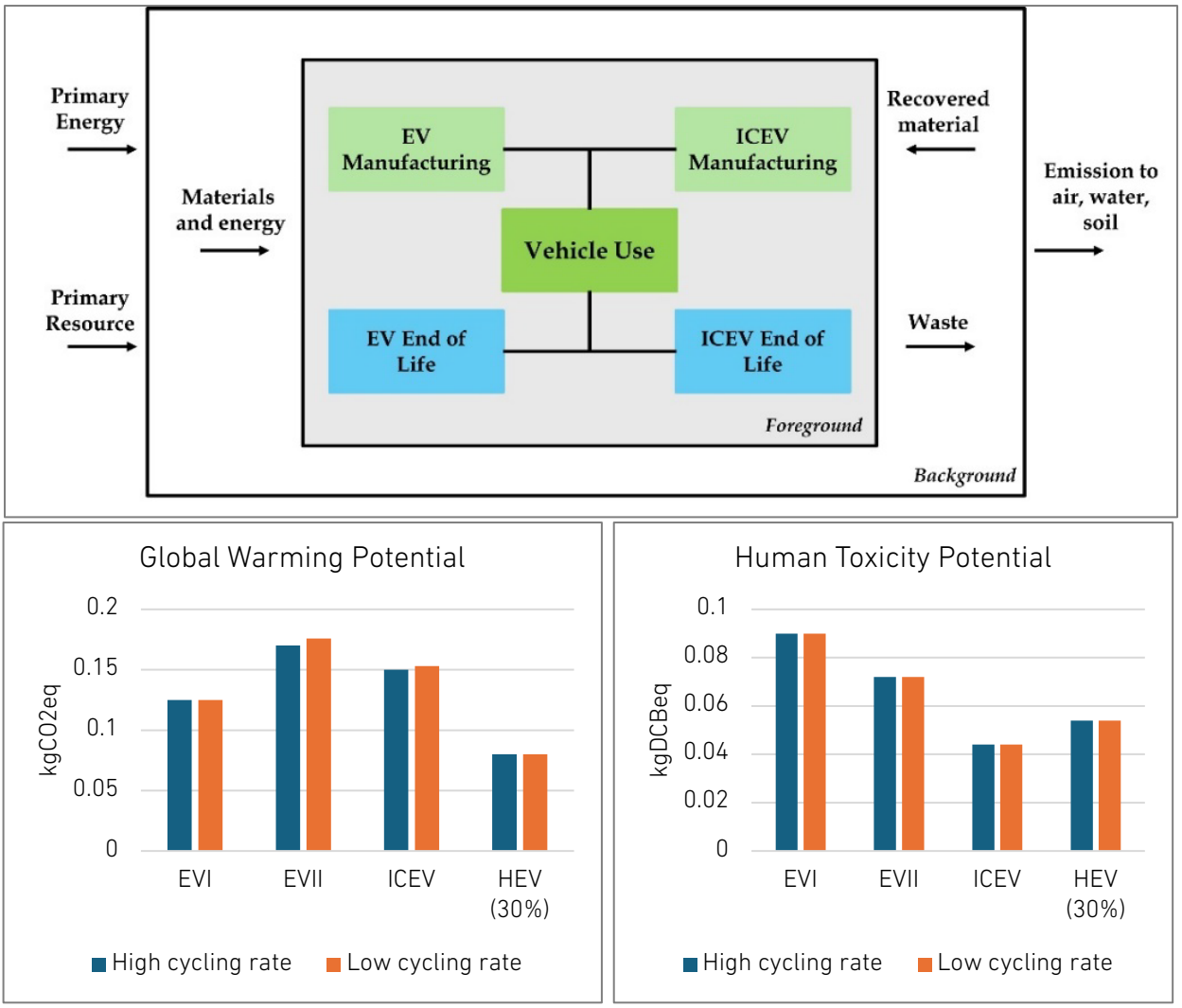
Figure 2.24. Renewable Energy Share in the Total Final Energy Consumption (%) by ASEAN Member States, 2010, 2015, 2020



ASEAN = Association of Southeast Asian Nations, Lao PDR = Lao People's Democratic Republic.
Source: Authors, adapted from ASEAN (2023a).

Net emission reductions from vehicle electrification hinge on a complex interplay of factors that vary across regions. Key determinants include vehicle energy efficiency and manufacturing processes, as well as the sources of energy used for vehicle production and electricity generation. Figure 2.25 shows the life-cycle assessment (LCA) framework, which evaluates environmental impacts across all stages of a product's life, from raw material extraction and manufacturing to use, maintenance, and end-of-life treatment.

Figure 2.25. Study on Global Warming Potential and Human Toxicity Potential of Internal Combustion Engine Vehicles and Battery Electric Vehicles



EV = electric vehicle, HEV = hybrid electric vehicle, ICEV = internal combustion engine vehicle, $kgCO_2eq$ = kilogram of carbon dioxide equivalent, KgDCBeq = kilogram of dichlorobenzene equivalent.
Source: Authors, adapted from Tagliaferri et al. (2016) and Gan (2022).

The main output of an LCA is an inventory of emissions and resource use (Figure 2.25), encompassing inputs and outputs such as raw material, energy, water, emissions to air and water, land use, and waste generation. These inventories are translated into environmental impact categories, including global warming potential, ozone depletion, acidification, resource depletion, and human health impacts. The environmental benefits of electrification vary significantly depending on whether energy inputs are derived from renewable or fossil sources, and this variability is shaped by regional energy structures, technological capacity, and regulatory frameworks (Hawkins et al., 2013; Tagliaferri et al., 2016; Farzaneh, 2023; Cimprich et al., 2023; Sun et al., 2023; Gan et al., 2022).

Vehicle energy efficiency has a considerable impact on overall environmental footprint (Table 2.1). Vehicles equipped with energy-saving technologies consume less energy than those without such features.

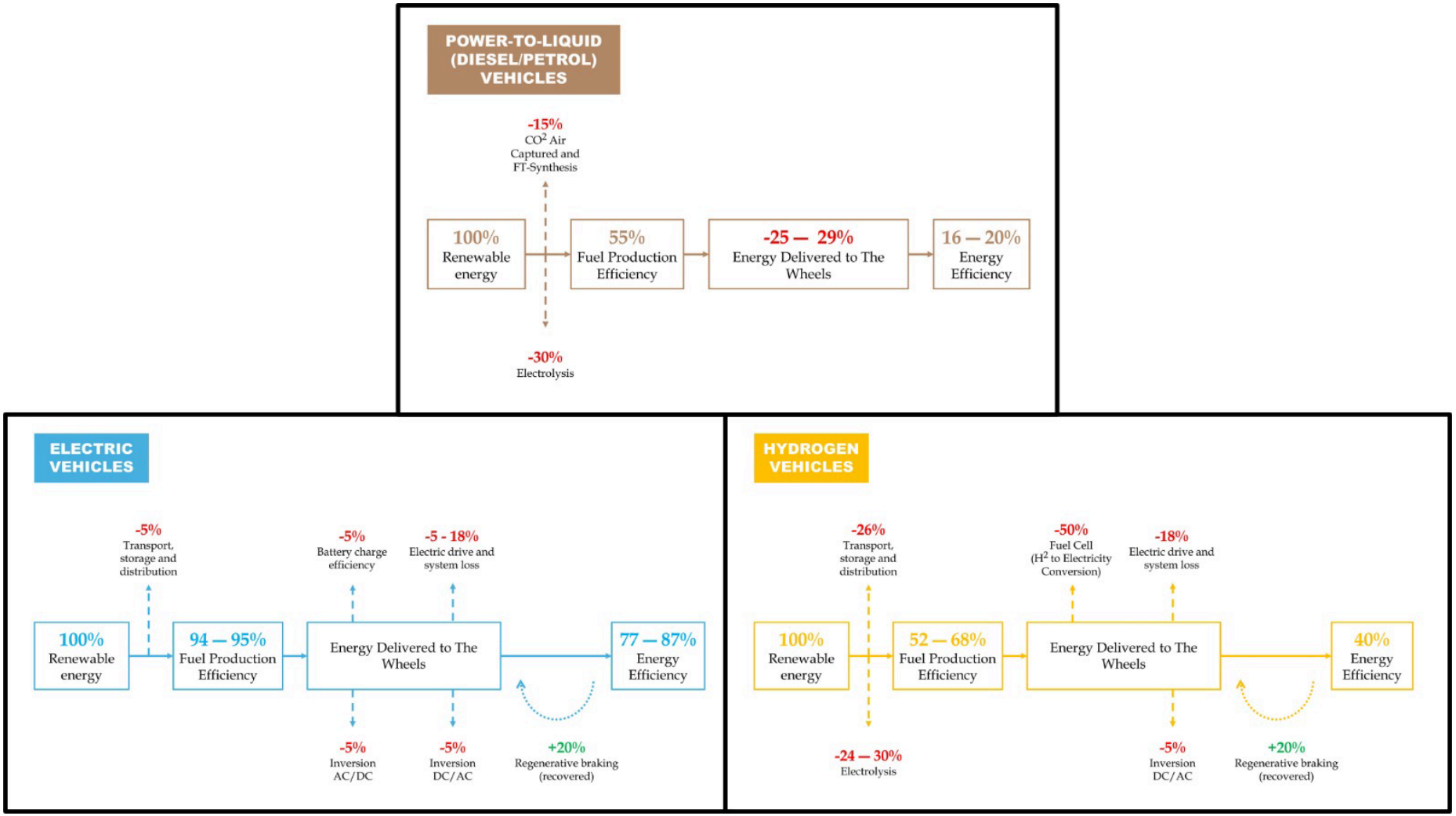
Table 2.1. Efficiency of Current Vehicles and Projections Over the Next 30 Years

		Direct Electrification		Hydrogen		Power-to-liquid (Diesel)		Power-to-liquid (Petrol)	
		2020	2050	2020	2050	2020	2050	2020	2050
	Renewable Energy	100%	100%	100%	100%	100%	100%	100%	100%
Well-to-tank	Electrolysis			76%	85%	76%	86%	76%	86%
	Carbon dioxide air capture and Fischer–Tropschsynthesis					56%	61%	56%	61%
	Transport, storage, and distribution	94%	94%	69%	76%				
	Fuel production efficiency	**94%**		**68%**		**55%**		**55%**	
Tank-to-wheel	Charging equipment	90%	90%						
	Battery charge efficiency	85%	85%						
	Hydrogen-to-electricity conversion			54%	54%				
	DC/AC inversion	82%	85%	95%	95%				
	Engine/motor efficiency	78%	82%	34%	43%	22%	24%	18%	20%
	Overall efficiency	**77%**	**81%**	**33%**	**42%**	**20%**	**22%**	**16%**	**18%**

AC = alternating current, DC = direct current.
Source: Transport and Environment (2017).

EVs, including BEVs and FCEVs, employ regenerative braking systems that convert kinetic energy into electrical energy during deceleration, thereby improving energy efficiency (Figure 2.26). This feature enhances the efficiency of electric motor–driven vehicles relative to those powered by combustion engines (Hamada et al., 2022; Lee et al., 2023; Kurc et al., 2024; Jiang et al., 2024, Mohseni et al., 2024).

Figure 2.26. Regenerative Braking and Vehicle Energy Efficiency

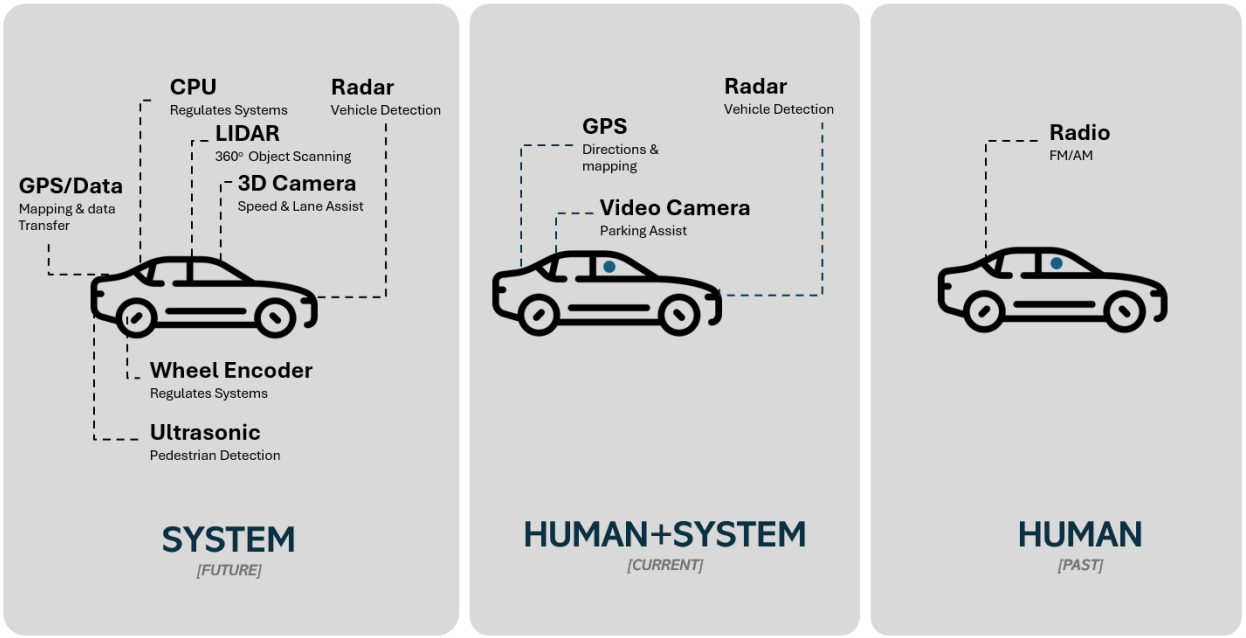


AC = alternating current, CO_2 = carbon dioxide, DC = direct current.
Source: Authors, adapted from Kurc et al. (2024).

As vehicle technology has evolved, driving safety has become a primary focus, reflecting the need to prevent accidents and mitigate their consequences. Accidents arise from multiple factors, including vehicle condition, driver behaviour, and road infrastructure. Nonetheless, vehicle designs that prioritise safety play a crucial role in reducing fatalities. Vehicle safety systems are commonly divided into active and passive systems. Active safety systems aim to prevent accidents, whilst passive systems reduce injury severity during collisions. Examples include advanced driver assistance systems (ADAS) as active safety systems, and reinforced vehicle structures and supplemental restraint systems as passive measures.

Within active safety systems, advances in ADAS increasingly rely on automated control technologies capable of managing steering, braking, and transmission functions to prevent accidents (Figure 2.27).

Figure 2.27. Assistive Technologies in Future Vehicles



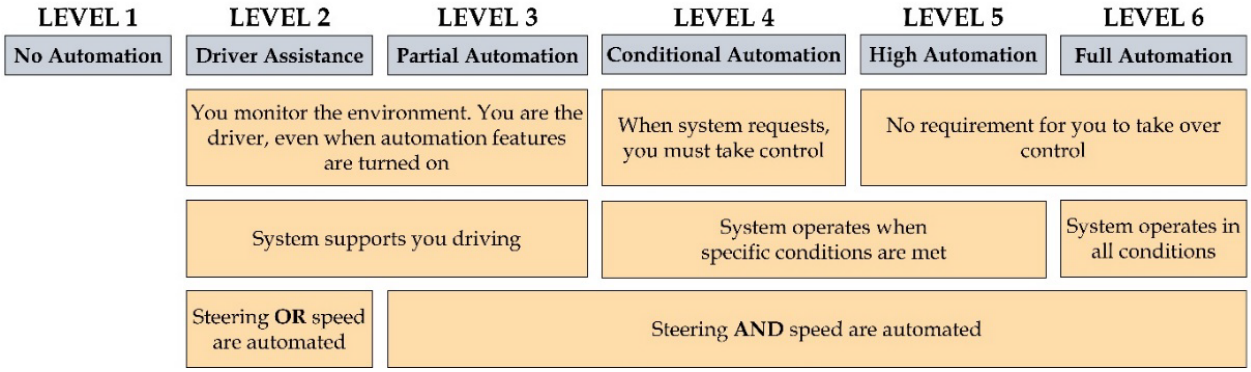
CPU = central processing unit, GPS = global positioning system, LIDAR = light detection and ranging.
Source: Authors based on Orient Software (2020).

Key features include automatic emergency braking, which reduces or halts vehicle motion when a potential collision is detected, and lane-keeping assistance, which helps guarantee vehicles stay within their lanes when unintended deviations occur. Driver behaviour remains a dominant factor in road accidents, with driver fatigue being a frequent cause. The development of autonomous vehicle systems aims to address driver fatigue and further improve accident prevention (Indu, 2020; Teng et al., 2023; Bouhsissin et al., 2023).

Autonomous vehicles are typically equipped with control systems capable of steering, regulating engine power, and applying brakes to manage diverse driving situations. The vehicle control centre generally consists of an electronic unit, such as a microcontroller, which sends electrical impulses to actuator systems controlling the steering wheel,

accelerator, gearbox, and braking system (Figure 2.28). In vehicles that rely on electric power for systems such as electric power steering, throttle-by-wire, electric brake boosters, and automatic transmissions, actuator systems are directly integrated with the electrical architecture, improving control precision and efficiency (Chen et al., 2023; Li et al., 2021; Cao et al., 2023).

Figure 2.28. Categorisation of Autonomous Vehicles According to SAE Standards



SAE = Society of Automotive Engineers.
Source: Authors, adapted from Society of Automotive Engineers (2021).

EVs, including BEVs and FCEVs, benefit from more efficient control architectures, as the control centre can directly regulate electric motor output through motor driver systems. From a vehicle engineering perspective, an optimal future vehicle should therefore exhibit the following characteristics:

1. environmental friendliness through the elimination of exhaust emissions;
2. extensive use of electric drive systems to simplify control architectures, reduce reliance on mechanical actuators, and lower vehicle weight and complexity;
3. energy conservation capabilities during operation; and
4. lightweight construction to minimise energy consumption whilst in motion.

2.6. Transformation in the Value Chain of Automotive Industries

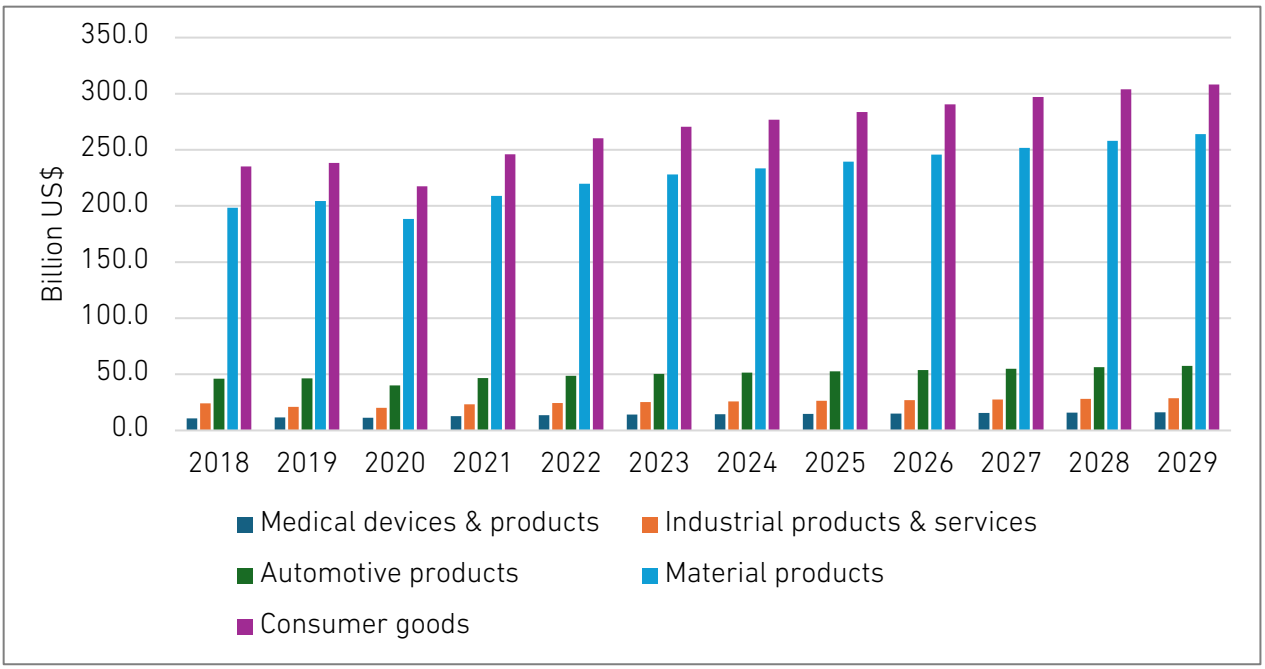
Manufacturing in ASEAN constitutes a cornerstone of the region's economic strength, contributing significantly to economic growth, employment, and technological advancement. Each sector within manufacturing – automotive products, material products, consumer goods, medical devices, and industrial products and services – adds unique value to the ASEAN economy.

Automotive products. This sector is pivotal in driving ASEAN's economy. Supported by a strategic geographic location and a robust supply chain, ASEAN has emerged as a major hub for automotive production. Countries such as Thailand and Indonesia are leading players, not only in manufacturing but also in the export of automotive products. The development of this sector spurs technological advancement and generates a significant number of jobs,

strengthening the middle class.

Material products. Essential to the construction and manufacture of high-technology products, this sector includes metals, chemicals, and composites. ASEAN's rich natural resources, such as tin, nickel, and copper, serve as critical inputs into global supply chains for electronics and construction materials. Growth of this sector supports infrastructure development and attracts foreign investment, enhancing ASEAN's competitive edge in global markets.

Figure 2.29. Added Value of the Manufacturing Industry in ASEAN



Source: Authors, adapted from Statista (2025a).

Consumer goods. Ranging from textiles to electronics, ASEAN's consumer goods sector benefits from a vast domestic market and increasing global demand. The expansion of the middle class has increased consumption, encouraging multinational companies to set up production facilities across ASEAN countries. This development not only diversifies economic activity but also supports small and medium-sized enterprises (SMEs) that supply larger manufacturers.

Medical devices. As global healthcare demand continues to grow, ASEAN is positioning itself as an important manufacturing base for medical devices. Countries such as Singapore and Malaysia lead this high-value industry, focusing on the production of sophisticated devices such as diagnostic imaging systems and orthopaedic implants. Expansion of the medical devices sector boosts ASEAN's technological profile and provides high-skilled employment crucial to long-term socio-economic development.

Industrial products and services. Encompassing a wide range of products from machinery to petrochemicals, this sector underpins ASEAN's industrialisation. It supports other manufacturing activities by providing essential equipment and services required for

manufacturing processes. Growth in industrial products and services is closely linked to overall industrial development, contributing to higher productivity and innovation across the regional economy.

2.6.1. Production Issues: Manufacturing, Raw Materials, Human Resources

An intermediate phase is being implemented to bridge the gap between the current and future generations of vehicles by generating a more environmentally friendly fuel for ICEVs (Jacobson et al., 2023; Nemmour et al., 2023). Although these engines still release CO_2, the production of environmentally friendly fuels, such as bioethanol and biodiesel, generates cleaner emissions than conventional oil and gas exploration and production. This transition has been further driven by rising demand for fuels to support the efficient transport of people and the long-distance logistics of goods, particularly in the marine and aviation sectors (Vasi and Sauder, 2024; Kiehbadroudinezhad et al., 2023).

The following are several alternatives:

Compressed natural gas vehicles. Compressed natural gas (CNG) vehicles resemble conventional ICEVs but are powered by CNG rather than diesel or petrol. Compared with conventional vehicle fuels, CNG burns more cleanly, resulting in reduced emissions of GNG and air pollutants. Modified variants of vehicles such as the Ford Transit and the Honda Civic provide examples of CNG-compatible models.

Ethanol and flexible-fuel vehicles. Flexible-fuel vehicles are engineered to operate on multiple fuel types. They typically run on blends of petrol and ethanol, such as E85, which consists of 15% petrol and 85% ethanol. These vehicles can switch between fuel mixtures, depending on cost and availability, enabling the use of renewable fuel sources and enhancing fuel flexibility (Reddy et al., 2024).

The environmental impacts of flexible-fuel vehicles and BEVs vary significantly depending on factors such as energy sources and operational phases. For instance, global warming potential ranges from 130 to 180 grams of carbon dioxide equivalent (gCO_2eq) per km for E5 flexible-fuel vehicles, whilst BEVs exhibit a broader range, from 42 to 176 gCO_2eq per km. This variability for BEVs largely reflects the proportion of renewable energy in the electricity consumed during vehicle operation. For flexible-fuel vehicles, the use phase accounts for about 68% of total global warming potential. By contrast, BEVs tend to exhibit higher environmental burdens in terms of freshwater and marine eutrophication potential, as well as metal depletion potential. Consequently, depending on the renewable share of the electricity grid, flexible-fuel vehicles may, in some contexts, represent a more environmentally favourable option (Arcentales et al., 2023).

Toyota and Guangzhou Automobile Group have developed a 2.0-liter combustion engine powered by liquefied ammonia, which offers a significant reduction in carbon emissions compared with traditional petrol engines. This engine produces 161 horsepower whilst emitting 90% less CO_2. Ammonia-based combustion offers a potential alternative to hydrogen fuel cells and conventional fossil fuels, showcasing higher energy content per unit mass and lower storage costs (Chai et al., 2021; Valera-Medina et al., 2021). Despite its potential,

ammonia engine technology faces technical challenges and uncertainties that must be resolved before large-scale commercial adoption becomes feasible (Manigandan et al., 2023, Jin et al., 2023).

2.6.2. Value Chain of the Next Automotives Industry

Vertical integration versus horizontal integration

Shifts in employee skill requirements differ markedly between vertical and horizontal integration models, as illustrated by the contrasting strategies of BEV manufacturers, such as Tesla, and ICEV manufacturers.

Under a vertically integrated BEV model, employees are required to possess a broad and integrated skill set that spans multiple stages of the production process. Workers must demonstrate a high degree of flexibility and adaptability, as their responsibilities may range from battery development and software engineering to final vehicle assembly. This model demands strong problem-solving capabilities, a profound comprehension of diverse production processes, and the ability to collaborate effectively across functions. Emphasis is placed on innovation and continuous improvement, with a strong focus on technological capability and technical proficiency to retain authority over the entire value chain.

In contrast, the horizontal integration model traditionally adopted by ICEV manufacturers places greater emphasis on specialisation. Workers typically concentrate on specific tasks within the production process, with clearly defined roles and responsibilities. This approach exploits economies of scale and specialised competencies in domains such as component production, assembly, and logistics. Employees are therefore expected to acquire specialised knowledge and skills within their assigned functions, enhancing efficiency and product quality across the manufacturing system. Toyota, for example, emphasises lean manufacturing concepts, which require workers to be proficient in waste reduction, quality control, and continuous process improvement within their specific area of work.

BEV manufacturers have also disrupted the traditional asymmetrical dependence on dominant buyers by leading key product segments and achieving high performance that favours profitable investment in sustainable technologies. Although OEMs continue to govern the overall value chain, suppliers specialising in sustainable mobility increasingly control high value-added activities and exert significant influence over strategic decisions related to key sustainable technologies (Lampon and Munoz-Duenaz, 2023).

Empirical evidence from the European automotive sector indicates that peripheral economies with lower unit labour cost (ULC) became increasingly important suppliers within European automotive value chains from 2000 to 2014. Econometric analysis shows that lower ULCs in supplier countries are associated with increased shares of value-added inputs in automotive production by major European producers. This finding indicates that cost-competitiveness is a key driver of structural change in the automotive sector, particularly favouring peripheral economies within the evolving international division of labour (Grodzicki and Skrzpek, 2020).

The transition to EVs is fundamentally reshaping global automotive value chains. The study

by Ramos and Ruiz-Galvez (2024) identifies three main impacts:

1) Increased competition amongst assembly plants
   The transition to EVs has intensified competition amongst assembly plants within the same corporate groups for the allocation of new vehicle models. This competition is driven by the adoption of modular EV platforms, which enable greater flexibility and standardisation in production.

2) Reconfiguration of supply chains
   Electrification is reconfiguring supply chains by threatening the position of traditional component suppliers whilst introducing new players, particularly battery manufacturers. These entrants are challenging established hierarchies within automotive GVCs.

3) Shifting in employment
   The transition to EVs is contributing to a reduction in employment across the value chain. EVs have simpler designs and require fewer components than ICEVs, leading to lower labour demand in production and assembly processes.

ASEAN economies face significant challenges in integrating into GVCs. These challenges have been empirically validated using Fuzzy Analytic Hierarchy Process modelling and prioritised as follows:

- Infrastructural and logistical constraints. Identified as the most critical challenge, inadequate infrastructure and high trade costs significantly hinder the participation of least developed countries (LDCs) in GVCs.
- Limited foreign direct investment (FDI) inflows. Restricted FDI constrains economic development and reduces competitiveness in LDCs.
- Inadequate development of SME clusters. Insufficient development of SME clusters hampers their ability to participate effectively in GVCs.

Other challenges include inadequate aid-for-trade, dismal LDC participation in regional trade agreements and free trade agreements, the absence of robust industrial policies, and constraints to value chain upgrading. Pushp and Ahmed (2023) provided valuable insights for policymakers seeking to allocate resources more effectively and enhance trade competitiveness and economic development in the region.

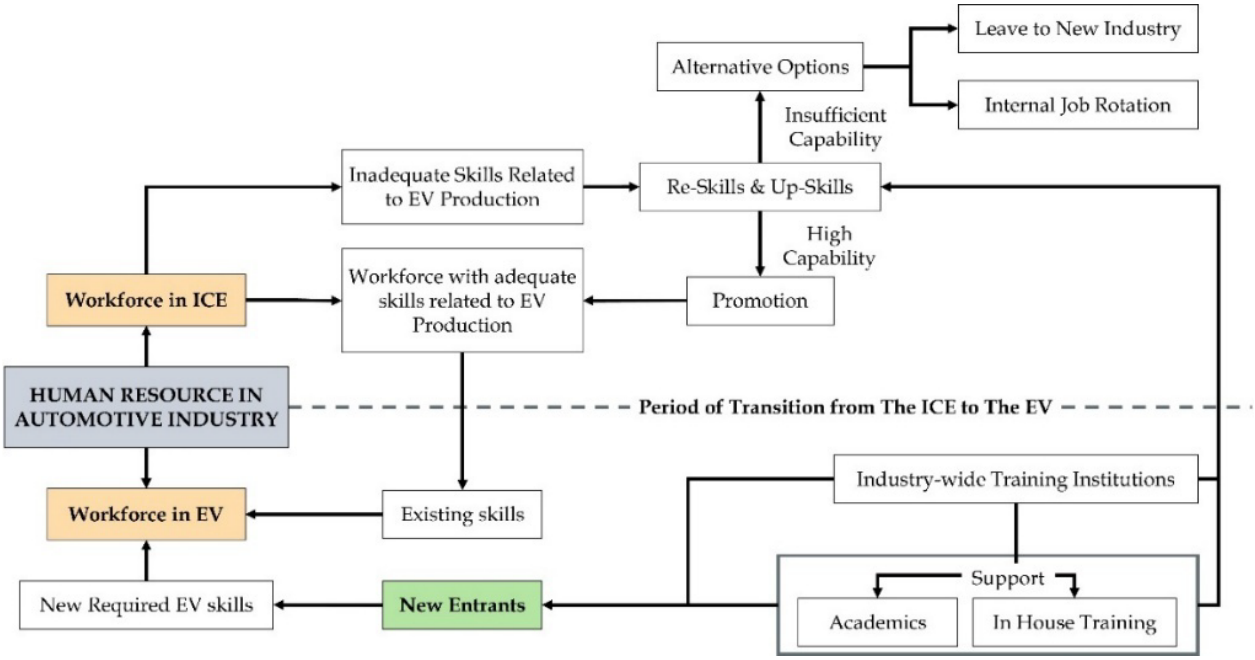
Table 2.1. Human Resource Shifts Resulting from Industry Transformation

Position and Skill Level	Major Skill Types	Indicative Change
Engineer – Highly skilled	• Hybrid engines, lightweight body design, suspension, motor braking, battery management systems. • Lean automation integration, artificial intelligence, mechatronics, programming, and coding	Increase from 10% to 20%
Technician – Skilled non-manual	• Programmable logic controllers, enterprise resource planning, material requirements planning, supply chain management • Sensors, relays, timers, and pneumatics	Increase from 20% to 50%
Technician – Skilled manual	• Advanced information technology or digital skills • Complex multi-skills • Soft skills	
Operator – Low-skilled	• Basic information technology or digital skills • Multi-tasking	Decrease from 70% to 30%

Source: Authors, based on Osatis et al. (2022).

These shifts in competency requirements reflect broader changes in underlying business strategies. Tesla's vertically integrated approach prioritises innovation, control, and quick incorporation of new technologies, necessitating a flexible and technologically proficient workforce. By contrast, Toyota's horizontally integrated model emphasises efficiency, specialisation, and quality, requiring deep expertise and operational excellence within defined functional areas.

Figure 2.30. Shifts in Human Resources for the Next-generation Vehicle Industry



EV = electric vehicle, ICE = internal combustion engine.
Source: Authors, adapted from Osatis et al. (2022).

2.6.3. Analysis and Observations of Manufacturing

Complexity of manufacturing steps

ICEVs often contain a large number of intricate components and systems that require frequent upkeep, including periodic oil changes, fuel filter replacements, and emission system inspections. This level of intricacy typically leads to higher long-term maintenance costs. Table 2.3 shows a breakdown of component production processes in the vehicle industry.

Table 2.2. Production Process Steps and Modelling Input Variables Collected from Confidential Industry Sources

Component	Combined Process Steps	References
Transmission	Deburring, drilling, cutting, lapping, rolling, straightening, tempering, turning, washing, laser welding, balancing, pre-assembly, final assembly, testing	Auto supplier E
Drive unit	Turning, marking, cutting, rolling, shot peening, lapping, washing, laser cleaning, testing, packing	Auto supplier F
Fuel injection	Machining, washing, deburring, oiling, plastic injection, pre-assembly, final assembly, inspection, pack out	Auto supplier G
Braking	Machining, component assembly, final assembly	Auto supplier G

Component	Combined Process Steps	References
Electric motor, drive	Turning, hobbing, skiving, washing, grinding, deburring, milling, machining, balancing, pre-assembly, assembly, testing, packing	Auto supplier E Auto supplier F Auto supplier G
Battery cell, pack	Materials preparation, coating, calendaring, slitting, drying, canister, stacking, welding, enclosing, filling, formation, module assembly, pack assembly	Battery manufacturer H

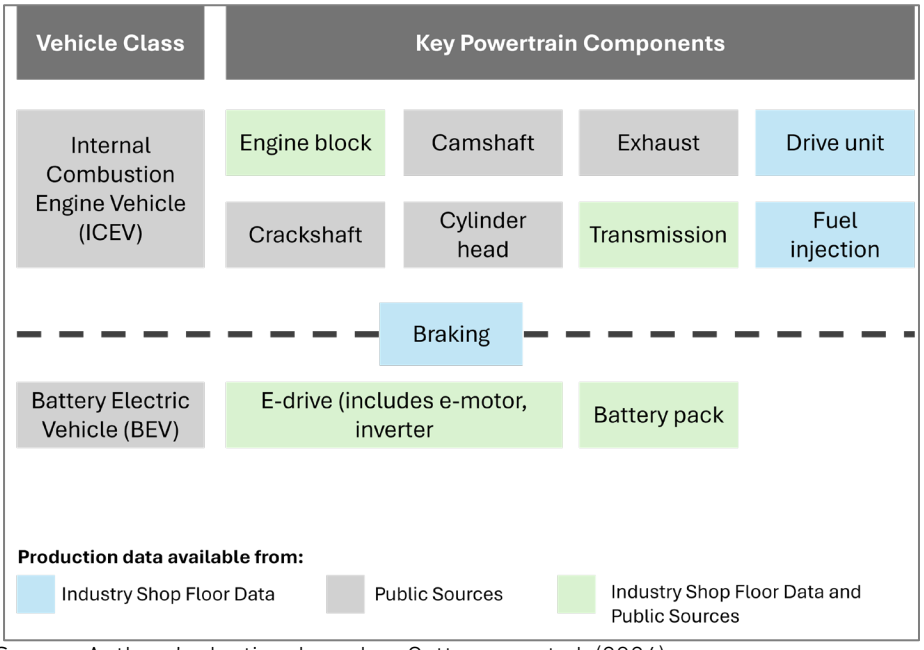
Source: Authors, based on Cotterman (2024).

Number of components

ICEVs typically comprise from 1,400 to 10,000 individual parts, depending on vehicle size and complexity. By contrast, BEVs are characterised by a considerably lower number of moving parts. The electric motor is estimated to contain about 20 moving parts, and the total number of components generally falls in the hundreds rather than the thousands. This reduction is largely attributable to the elimination of numerous mechanical elements, including the engine and the complex transmission system.

BEVs therefore exhibit a less complex mechanical structure with fewer components, mainly because they do not incorporate an internal combustion engine or associated systems such as exhaust, fuel, and conventional cooling systems. The simplicity can translate into reduced maintenance requirements and potentially fewer repairs compared with ICEVs. Nevertheless, BEVs introduce novel elements, such as sizable battery packs and sophisticated power electronics, which involve specific maintenance considerations and associated expenses.

Figure 2.31. Conventional Engine and Battery Electric Vehicle Powertrain Components and their Production Implications



Source: Authors' adaption, based on Cotterman et al. (2024).

Vehicle electrification may increase the number of manufacturing worker-hours required per vehicle due to the complexity of new production processes. The transition from ICEVs to EVs is therefore expected to reshape the labour market. However, EV powertrain manufacturing is anticipated to be sufficiently extensive to absorb a significant share of workers previously involved in ICEV powertrain production (Figure 2.31). Battery manufacturing is poised to become a major contributor to employment within the EV sector. Ensuring that these jobs support a liveable wage will depend largely on the implementation of targeted policy measures to support workers during this industrial transition (Cotterman et al., 2024).

Raw materials

ICEVs depend heavily on conventional automotive production materials, notably steel and iron, and require specific catalyst materials for emission control technologies. The principal raw materials used in ICEVs include the following:

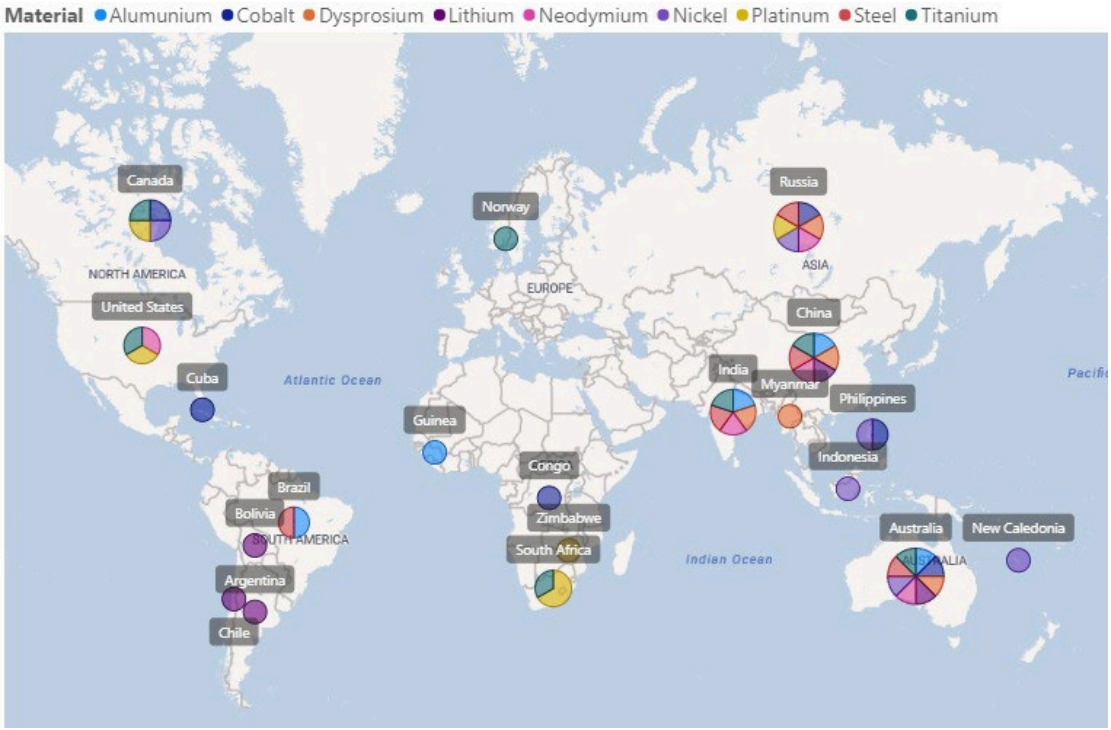
1. Steel and iron. Primarily used in the vehicle frame, structural elements, and numerous mechanical components.
2. Aluminium. Widely used in engines and transmissions to reduce weight and improve fuel efficiency.
3. Plastics and composites. Applied extensively in interior and exterior trim, dashboard components, and fluid tanks.
4. Rubber. Required for tyres, seals, and hoses.
5. Lead. Primarily used in lead–acid batteries for engine starting and auxiliary electrical power.
6. Copper. Commonly used in wiring and electrical components.
7. Glass. Used for windows and windscreens.
8. Lubricants and fluids. Including engine oil, transmission fluid, and coolant, which are crucial for ICE operation.
9. Platinum, palladium, and rhodium. These are essential materials in catalytic converters for reducing exhaust emissions.

BEVs prioritise materials that are essential for battery manufacturing and high-performance electric motors. Demand for lithium, cobalt, nickel, and rare earth elements is exceptionally high due to their critical role in enhancing battery capacity, efficiency, and power. Key materials used in BEV production include the following:

1. Lithium. A core component of lithium-ion batteries used in BEVs.
2. Cobalt. Used to enhance energy density and extend battery life.
3. Nickel. Increases the energy storage capacity of battery cathodes.
4. Manganese. Incorporated into cathode materials.
5. Graphite. Used as the anode material in lithium-ion batteries.
6. Copper. Widely used in electric motors and battery wiring.
7. Rare earth elements. Such as neodymium and dysprosium, essential for high-strength permanent magnets in electric motors.

8. **Aluminium.** Frequently used in vehicle bodies and frames to reduce overall weight.
9. **Steel.** Used in structural components, generally in smaller quantities than in ICEVs.
10. **Silicon.** Used extensively in semiconductors and automotive electronics.

Figure 2.32. Availability of Main Raw Materials in the Vehicle Industry



Source: Authors, adapted from Backhaus (2021).

2.6.4. Environmental and Supply Chain Factors to be Considered

The transition from ICEVs to BEVs has far-reaching implications for global supply chains and environmental outcomes. The extraction of battery materials, including lithium, cobalt, and nickel, is frequently criticised for its adverse environmental impacts and the challenging labour conditions associated with mining activities. In response, ongoing efforts seek to enhance the sustainability of these supply chains and to advance recycling technologies that enable the recovery of valuable materials from batteries at the end of their useful life (Niri et al., 2024).

2.6.5. Energy Provision for the Industry

Energy provision is a critical factor for the manufacturing industry, as every phase of production needs energy in different forms. Energy is consumed throughout material extraction, material processing, and manufacturing operations. Process heat is particularly important in material processing and is typically provided through a combination of chemical and electrical energy, whilst electricity is required across multiple stages of the product life cycle.

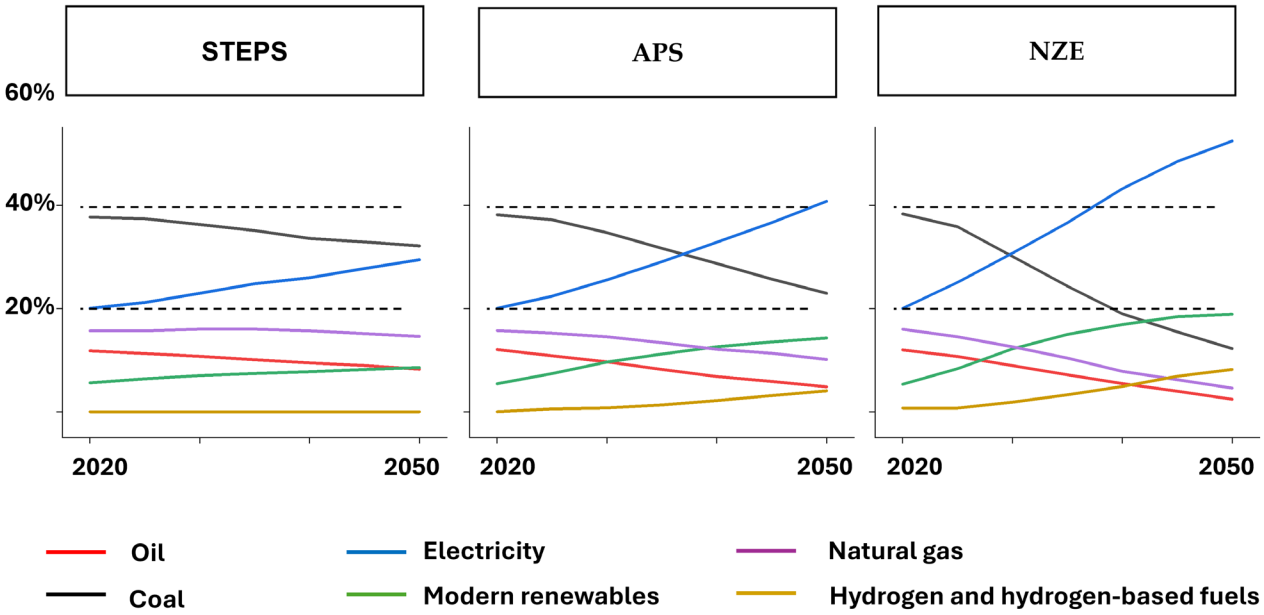
Table 2.3. Carbon Dioxide-equivalent Emission Impacts of Selected Electricity Generation Technologies

Electricity Generation Technology	Grams of CO_2-Equivalent per kWh
Brown coal	1100
Hard coal	950
Oil	700
Natural gas	450
Solar cells	50
Wood chips	40
Biogas	25
Wind power	25
Nuclear	25
Hydropower	20

CO_2 = carbon dioxide, kWh = kilowatt-hour.
Source: Hirz et al. (2022).

Total final energy consumption (TFC) currently amounts to 442 exajoules (EJ), distributed across industry (167 EJ), buildings (133 EJ), transport (116 EJ), and other end-uses (27 EJ). Under STEPS, TFC rises by an average of 1.1% per year until 2030 and then continues to grow at a slower pace through to 2050. In the APS, TFC rises until the mid-2020s before starting a gradual decline. Under the NZE scenario, TFC declines at an average annual rate of 0.9% from the present to 2050.

Figure 2.33. Shift Towards Renewable Energy Power Plants Over the Next 30 Years



APS = announced pledged scenario, NZE = net-zero emissions, STEPS = stated policies scenario.
Source: Authors, adapted from International Energy Agency (2023).

The push towards renewable energy extends beyond a response to the global energy crisis; it represents a structural transformation that addresses a range of socio-economic and environmental challenges. Renewable energy facilities, including solar, wind, hydropower, and geothermal facilities, are central to this transformation. Understanding their requirements is crucial to fully realise their potential and ensure their effective integration into the overall energy mix.

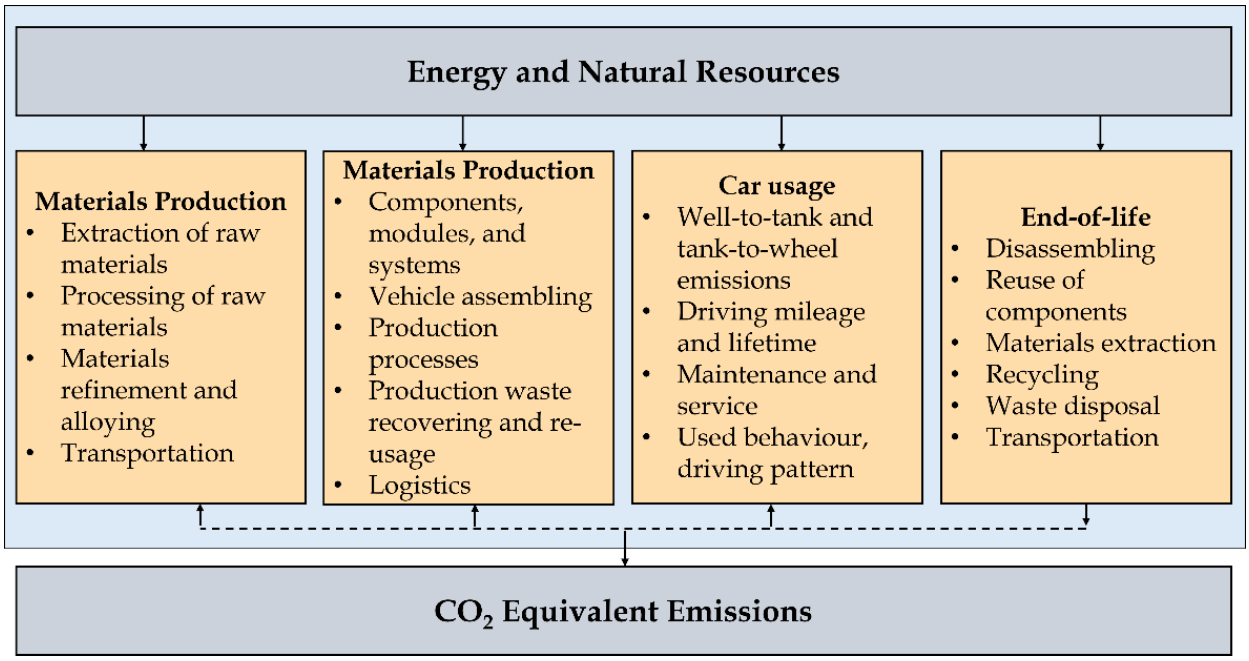
1. Infrastructure development. Renewable energy plants require robust infrastructure, encompassing not only physical components such as turbines and solar panels but also upgraded grid systems capable of handling variable power generation. Investment in energy storage technologies, including batteries, pumped hydro storage, and other solutions, is essential to balance supply and demand, stabilise the grid, and store surplus electricity during periods of low generation.
2. Technological innovation. Continuous technological advancement is necessary to improve efficiency and reduce the costs of renewable energy technologies. Advances in materials science can lead to more efficient photovoltaic cells and lighter, more durable wind turbines. Progress in energy storage technologies is equally important, as it improves the feasibility and reliability of renewable energy by allowing a more stable and predictable electricity supply, regardless of weather conditions.
3. Regulatory and policy support. Supportive regulatory frameworks are necessary to encourage the deployment and integration of renewable energy. These include incentives such as subsidies, tax relief, and feed-in tariffs, as well as regulations that streamline permitting and construction processes. Policies that mandate or promote renewable energy use in both public and private sectors can further stimulate demand and industry growth.
4. Financial investment. The development of renewable energy infrastructure requires substantial upfront capital. Access to finance through public funding, private investment, green bonds, and other financial instruments is critical to support initial costs and to drive down technology costs through economies of scale. Well-designed financial mechanisms that attract investors are therefore essential to sector expansion.
5. Skilled workforce. The growth of the renewable energy sector increases demand for a skilled workforce, including engineers and technicians involved in design and construction, as well as personnel responsible for operation and maintenance. Investment in education and training programmes is necessary to equip workers with the skills required for employment in renewable energy industries.
6. Environmental and social governance. Renewable energy projects must be developed in ways that respect local communities and ecosystems. This involves careful site selection to minimise environmental impacts, engagement with local stakeholders, and the protection of biodiversity and the rights of indigenous peoples.
7. International collaboration. Addressing climate change and advancing sustainable

development require coordinated international action. The exchange of technology, best practices, and financial resources across borders can accelerate renewable energy deployment, particularly in developing countries where energy demand is growing rapidly and renewable energy potential is high.

2.6.6. Assessment of a Cleaner Future Industry

The relationship between energy resources and LCA is pivotal to understanding the environmental impacts of products and systems from inception to disposal. LCA is a comprehensive method used to assess the environmental effects associated with all stages of a product's life, from cradle to grave (from raw material extraction through materials processing, manufacture, distribution, use, repair and maintenance, and disposal or recycling). This method is particularly significant in the analysis of energy resources, as it helps quantify the ecological consequences of different energy choices and technologies, thereby providing a holistic view of their sustainability.

Figure 2.34. CO_2-equivalent Emissions of the Automotive Industry



CO_2 = carbon dioxide.
Source: Authors, adapted from Hirz et al. (2022).

Extraction and production. The initial phase of an LCA of energy resources involves the extraction and production of raw materials. For fossil fuels, this includes oil drilling, coal mining, and natural gas extraction, all of which can have substantial environmental impacts, such as habitat destruction, water pollution, and GHG emissions. Renewable energy resources, such as solar and wind, also require raw materials, such as silicon and metals, whose extraction may similarly affect the environment.

Manufacturing and processing. Once extracted, raw materials are processed and transformed into energy products or systems. The manufacturing of solar panels, wind

turbines, and batteries for energy storage involves various chemical and physical processes. LCA helps in assessing the emissions, waste, and energy consumption during this stage, and in identifying opportunities to make manufacturing processes more environmentally friendly and efficient.

Distribution and use. The transport of energy resources and the operational phase of energy production systems also contribute to life cycle impacts. For example, the environmental impact of transporting coal to a power plant, together with emissions from the plant itself, forms a critical component of coal's life cycle impact. Similarly, the efficiency of solar panels and the intermittency of wind energy affect their overall environmental footprint during use. LCA evaluates these aspects to determine total environmental impacts and to facilitate comparisons across different energy sources.

End-of-life management. The final stage of LCA concerns the disposal or recycling of energy systems. For instance, the disposal of nuclear waste requires long-term management strategies due to its hazardous nature, whilst solar panels and wind turbines also pose significant end-of-life challenges. LCA assesses the effectiveness of recycling processes and the environmental impacts of disposal methods, which is crucial for developing sustainable end-of-life practices.

Policy and decision-making. By providing a detailed picture of environmental impacts across each life cycle stage of energy resources, LCA serves as an invaluable tool for policymakers and industry leaders. It informs sustainable energy policies, guides research and development in cleaner technologies, and supports business decisions aligned with environmental sustainability goals.

The current study indicates the environmental impacts of BEVs in comparison with ICEVs, based on an impact assessment.

1. Climate change impact. BEVs have a positive effect on reducing climate change impacts, primarily because they produce no exhaust gas emissions during operation. This environmental advantage increases further when the electricity used to power BEVs is generated from renewable energy sources.
2. Electricity production and grid mix. The climate change impact of BEVs depends strongly on the electricity generation mix. When electricity is generated from renewable sources, the positive effects of BEVs are enhanced; when it is generated from non-renewable sources, these benefits are reduced.
3. Manufacturing load. The production of BEVs is more environmentally intensive than that of ICEVs. This higher burden arises from the extensive use of metals, chemicals, and energy required for EV-specific components, particularly high-voltage batteries.
4. Other environmental impacts. BEVs also show higher levels of other environmental impacts, including acidification, human toxicity, particulate matter emissions, photochemical ozone creation, and resource depletion. These impacts mainly stem from the environmental loads associated with manufacturing and constructing the

electric powertrain.

Overall, whilst BEVs significantly reduce emissions during operation, their total environmental impact is mixed. They perform better in terms of climate change impacts, particularly when powered by renewable electricity, but their production processes and certain other environmental impacts remain greater than those of ICEVs (Taglieferi, 2021).

2.6.7. Pros and Cons of Available Trajectories in the Vehicle Industry

Trajectory of shifting from ICEVs to BEVs

The non-combustion feature of BEVs presents an attractive opportunity for adoption in modern vehicles. Ease of use is an additional advantage of this technology. Nevertheless, businesses must still address various challenges to mitigate the adverse environmental effects associated with battery manufacture and recycling. The transition from conventional combustion engine-based technology to BEVs may exert a significant influence on the existing industrial ecosystem.

Advantages

The battery, as the main powertrain component, accounts for approximately 50%–60% of the total vehicle price. Battery technology is considerably more mature than it was 10 years ago and is expected to reach its lowest cost point within the next 5 years. At that stage, the price of a BEV is projected to fall below that of an ICEV. Operating costs are also lower, as BEVs have fewer moving parts than ICEVs. This cost structure encourages BEV manufacturers to pursue vertical integration in their production processes. Tesla and BYD report that they manufacture up to 70% of their vehicle components in-house.

BEVs are also more easily adapted for autonomous and smart or connected driving, enabling communication between drivers and other vehicles. Passenger safety is a core goal of AV operation. However, current deployment remains largely at Society of Automotive Engineers Level 2 autonomy.

An alternative to BEVs is the FCEV, which uses hydrogen to propel the motor and relies on a battery management system like that of BEVs. This type of vehicle has been introduced by Toyota, Honda, and Hyundai, but global deployment remains limited. Nonetheless, the technology is considered promising, particularly in light of the expanding hydrogen energy network.

Disadvantages

ASEAN countries still lack sufficient charging infrastructure. This makes BEVs less attractive for long-distance travel (greater than 400 km), as charging is more time-consuming and less convenient than conventional refuelling.

Vertical integration also has adverse implications for the existing ICE supplier ecosystem. The potential loss of business for hundreds of suppliers requires careful national assessment. In addition, the workforce must be prepared for the BEV industry, which involves production

processes that differ substantially from those of ICEVs.

Batteries rely on mineral resources that are unevenly distributed across countries. Indonesia and the Philippines possess significant nickel reserves, but other critical minerals are required to complete battery components. In Indonesia, for example, mined nickel must still be processed abroad before it becomes a finished battery product. Batteries are not yet fully recyclable, raising environmental concerns.

Several LCAs comparing cradle-to-grave impacts of BEV components indicate that, in some contexts, carbon emissions associated with BEVs remain higher than those of ICEVs. The availability of low-carbon electricity generation is therefore critical to realising BEVs' contribution to NZE in the transport sector. Emissions of toxic and acidic substances have been identified in BEV production. Improved recycling management is required to minimise reliance on continuous new mining.

For FCEVs, production depends on expensive critical minerals, notably platinum, which is used as a catalyst. Industrial capacity is limited to a small number of countries, making FCEVs more expensive than ICEVs or BEVs. Widespread adoption also requires hydrogen distribution networks, which remain scarce. Hydrogen-fuelled vehicles require high-pressure hydrogen tanks, representing a major barrier to adoption.

Trajectory of shifting ICEVs to decarbonised ICEVs

To attain NZE, several countries have mandated the phased withdrawal of ICEVs over the next 20 to 30 years. As a result, projections indicate a gradual decline in the share of ICEVs from current levels. In response, the automotive industry has developed more efficient combustion-based engines capable of operating under multiple fuel modes, including flexible fuels such as biofuels, hydrogen, and ammonia. However, as discussed below, this transition has several implications.

Flexible-fuel vehicles

Advantages

Fuels with lower emissions than those in widespread use are being developed, notably biofuels and natural gas. Although biofuels still generate emissions, they are considered more environmentally favourable because they do not require energy-intensive oil exploration and are associated with lower overall carbon emissions. Natural gas produces cleaner emissions than petrol, which is commonly used today. The adoption of natural gas can also serve as a transitional pathway towards hydrogen fuels, thereby expanding opportunities to achieve NZE.

Disadvantages

ICEVs require additional converters when operating on natural gas. Although biofuels can be used in a manner similar to conventional fuels, their prices tend to be higher. Natural gas also requires dedicated refuelling infrastructure that differs from existing installations. As a

result, natural gas vehicles remain limited in uptake due to the insufficient availability of refuelling stations.

Hydrogen fuel vehicles

Advantages

Hydrogen is a fuel that can be synthetically produced. Current production routes include steam methane reforming, biomass gasification, and water electrolysis, all of which require additional energy inputs. Recent developments focus on using renewable energy to electrolyse water, thereby producing hydrogen as a form of energy storage. This approach has been widely adopted in countries such as Saudi Arabia, India, China, and several European countries. If hydrogen production becomes economically viable at scale, it could enable manufacturing and transport systems to progress towards NZE.

The structure of HICEVs is broadly similar to that of conventional ICEVs, resulting in minimal disruption to the existing ICE supplier ecosystem. Toyota has claimed to be developing a water-engine vehicle that integrates an electrolyser within the engine to supply hydrogen for combustion. Whilst ambitious, this concept requires further validation.

Ammonia-based fuels offer advantages over gaseous fuels in terms of refuelling and transport complexity. Consumers are already accustomed to using liquid fuels, which provide practical benefits. Moreover, ammonia fuels are derived from the hydrogen network that has been established over the past 2 decades.

Disadvantages

HICEVs require the installation of robust safety technologies, as hydrogen is a highly flammable gas. The expansion of hydrogen distribution networks will be essential if HICEVs are to be mass-produced. Several countries have begun preparing for this transition by incorporating natural gas connections into their energy supply frameworks. Nevertheless, substantial investment is still required to develop hydrogen production facilities and pipeline infrastructure capable of supporting large-scale deployment.

2.7. Perspectives on Japan’s Next-generation Automotive Industry

2.7.1. Japan's Transport Partnership with ASEAN

Japan has consistently emphasised its partnership with ASEAN. Established in 1998, the ASEAN Economic Ministers–Minister of Economy, Trade and Industry of Japan (AEM-METI) (ASEAN–Japan) Economic and Industrial Cooperation Committee (AMEICC) serves as a policy consultation body on issues such as enhanced industrial cooperation, improvement of ASEAN’s competitiveness, and development cooperation assistance to newer AMSs. The AMEICC secretariat oversees ASEAN–Japan cooperative projects and operates at both ministerial and sectoral levels through a range of working groups, including the Automotive Industry Working Group. This group facilitates information sharing on relevant regulations and the future direction of the automotive industry, whilst also providing development cooperation assistance to Cambodia, Lao PDR, and Myanmar (AMEICC, 2025). AMEICC

submits recommendations to the annual AEM–METI consultation.

In transport, the Japanese government has actively promoted collaboration through initiatives such as the ASEAN–Japan Transport Partnership (AJTP). The primary goal of the AJTP is to strengthen cooperative relations between AMSs and Japan, especially considering the increasing importance of regional economic integration, global and regional environmental challenges, and the urgent need to enhance transport security and safety through emerging technologies (AJTP, n.d.). The first ASEAN–Japan Transport Ministers' Meeting was held in Yangon, Myanmar, on 25 October 2003 (ASEAN, 2003).

Japan's keen focus on ASEAN can be attributed to two main factors. First, Japan's domestic transport market has been in sustained decline. Transport and construction have struggled to expand in a shrinking domestic market, raising concerns that Japan's advanced engineering and operational expertise in transport systems could erode due to limited business opportunities. ASEAN, therefore, represents a crucial external market for Japan's transport and construction industries, offering opportunities that are essential for their continued viability and growth. Second, demand for infrastructure and transport development in neighbouring regions has increased markedly. Rapid economic growth across ASEAN has generated an urgent need for enhanced infrastructure and transport systems, creating attractive opportunities for Japanese firms to expand their operations and apply their expertise in these emerging markets.

At the same time, global policy agendas have increasingly prioritised green transport, including NZE policies, and a trend is evident across many developing Asian economies (ADB, 2023). The Japanese government has shown a strong interest in supporting green transport policies in ASEAN through the deployment of Japanese technologies. This support includes initiatives such as mass rapid transit systems, including metro networks, and smart city technologies. An example is the SMART JAMP project, implemented under the Japan–ASEAN Mutual Partnership by the Japan Association for Smart Cities in ASEAN (MLIT and ASEAN, 2022). Japan has provided extensive official development assistance to AMSs (Kato, 2018).

Low- and zero-emission vehicles, particularly EVs, represent a key technological pathway towards net-zero targets in emerging economies. The Japanese government views engagement in this area as an opportunity to enhance Japan's global competitiveness whilst contributing to the resolution of transport-related challenges in emerging markets (METI, 2022).

Japan has long been a highly industrialised economy with a globally competitive automotive sector. As Japanese manufacturers advanced their technologies to meet evolving consumer demands, brands such as Toyota, Honda, and Nissan gained international recognition for quality and affordability (Shigeta and Hosseini, 2021). Sales of ICEVs produced by Japanese manufacturers remain strong in many ASEAN countries. Nevertheless, many Japanese manufacturers face challenges in transitioning from ICEVs to BEVs, despite the global shift towards decarbonisation. These challenges encompass supply-side constraints, infrastructure development gaps, demand-side factors, and institutional barriers (Trencher et al., 2020).

2.7.2. Strategy of the Automotive Industry in Japan

The Japanese government is addressing significant disruptions in the automotive industry arising from technological advancements in connected–autonomous–shared–electric (CASE) vehicles (METI, 2022), whilst simultaneously pursuing energy self-sufficiency and carbon neutrality by 2050 (Bogdanov et al., 2013). As part of its green growth strategy, the government is promoting the decarbonisation of the entire automobile life cycle. This approach includes stimulating the battery industry to support infrastructure for new types of energy. Japan is exploring multiple pathways by integrating various powertrains and energy sources, including HEVs, PHEVs, and carbon-neutral fuels (METI, 2022; JAMA, 2022). This orientation has been reflected in the Asia Zero Emission Community Ministerial Meeting Joint Statement, which highlighted potential cooperation on multi-pathway transitions through the promotion of ICEVs and HEVs combined with the use of sustainable fuels, alongside future investment in BEVs (METI, 2024).

Regarding automobile electrification, the government highlights the importance of establishing a strong battery industry and developing the infrastructure necessary for the widespread diffusion of BEVs. To achieve carbon neutrality by 2050, METI has established a green innovation fund, allocating JPY2 trillion under the FY2020 Tertiary Supplementary Budget. Managed by the New Energy and Industrial Technology Development Organization, this fund provides continuous support to companies and organisations committed to achieving ambitious targets for 2030 (METI, 2023). It supports initiatives ranging from research and development to demonstration and social implementation over the next decade, with a focus on next-generation batteries and motors, hydrogen supply chains, and synthetic fuels.

The Japanese government also acknowledges that discussions on BEVs must be situated within the broader context of CASE technologies. Japan is exploring a backcasting approach combined with mission-oriented policymaking to guide its automotive industrial strategy more effectively (METI, 2022).

2.7.3. Japanese Automotive Manufacturers' Strategy in ASEAN

As the automotive industry evolves, Japanese manufacturers are increasingly targeting emerging markets such as ASEAN, mainly for the sale of ICEVs and HEVs. This focus reflects the steady growth of the automotive market in ASEAN, where middle-class households are expected to upgrade from motorcycles to cars. This shift is driven by a rising middle class that is highly sensitive to vehicle prices (Nasrul and Hamid, 2021). Despite the technological readiness of BEVs, challenges in commercialisation persist, necessitating further price reductions or the development of more affordable models to achieve wider market penetration (Maghfiroh et al., 2021).

Global economic and political instability, marked by wars, conflicts, and volatility in national financial markets, has contributed to rising petroleum prices and broader inflationary pressures. In such a context, HEVs present an attractive option for middle-income households

by offering fuel efficiency that surpasses that of ICEVs whilst remaining more affordable than BEVs.

Japanese automotive manufacturers capitalise on their well-established after-sales service networks as a key competitive advantage in the ASEAN market (Nasrul and Hamid, 2021). These extensive networks, originally developed to support ICEVs, can also be adapted to serve BEV customers, thereby maximising value along the automotive value chain. Revenue generated from ICEV and HEV sales not only facilitates investment in BEVs but also supports the advancement of related technologies, including hydrogen fuel cell vehicles, autonomous vehicles, and new mobility systems.

By leveraging these established service networks, Japanese manufacturers enhance their market position and create a solid foundation for the gradual transition to BEVs and other advanced vehicle technologies. This strategy balances current market demand with the imperative for future innovation, positioning Japanese manufacturers effectively within the evolving automotive landscape.

2.8. Highlights for the Masterplan of the ASEAN–Japan Next-generation Vehicle Strategy

This section synthesises the issues discussed in the preceding sections and provides indicative directions for the formulation of the masterplan elaborated in the subsequent chapters, as follows:

1. Due to imbalances between transport supply and demand in most ASEAN countries, demand for next-generation vehicles is expected to emerge under conditions of constrained growth in road transport infrastructure and facilities.
2. Specific and inherent traffic performance characteristics have rendered transport policy ambiguous with respect to mode choice between private and public vehicles, a challenge that is exacerbated where motorcycles remain the dominant mode of transport. Indonesia and Viet Nam illustrate this problem acutely, and other ASEAN countries with similarly limited road infrastructure may evolve comparable conditions. Market penetration strategies for next-generation vehicles should therefore reflect a clear orientation towards green transport, particularly in response to the rapid growth in motorcycle use (e.g. whether to counteract or accommodate such growth).
3. Although ASEAN road transport strategies exist, they are not binding on member states, resulting in each country pursuing its own road transport policies and plans. It is therefore necessary for next-generation vehicle stakeholders to develop robust strategies that can effectively influence policymakers and governments to advance road transport systems towards a more sustainable transport ecosystem.
4. In the context of global economic growth, the automotive industry not only has the opportunity to develop next-generation vehicles but also the responsibility to

contribute to a sustainable transport system. The industry plays a key role in balancing increased vehicle ownership with the need to reduce congestion and emissions, whilst also improving vehicle utilisation. Automotive firms can expand into innovative mobility services, such as car-sharing and ride-hailing, and deploy low-emission vehicles within these services to increase utilisation rates.

5. Governments need to establish policies that appropriately stimulate the development of NGVs and a range of mobility services. This requires careful market segmentation, leading to targeted strategy development for different customer groups.
6. Market stagnation has been observed in Indonesia and Thailand, as reflected in vehicle sales over the past 10 years. This trend is driven by increases in per capita income that have not kept pace with rising prices of new vehicles incorporating advanced technologies, such as HEVs and BEVs. Tax instruments are therefore needed to stimulate demand for vehicles using these technologies. Additionally, carbon trading pathways may be used as a mechanism to lower the retail prices of NGVs.
7. ICEs, characterised by a more horizontal production structure and a larger number of components, may face disadvantages relative to non-combustion engines, which exhibit a more vertical structure with fewer components. Non-combustion engines may generate higher value in logistics and along the value chain, thereby creating additional opportunities for industrial hubs within the ASEAN region. These contrasting production characteristics should form a basic premise for the NGV market, particularly in relation to low-cost manufacturing and distribution.
8. ASEAN countries face significant challenges in integrating into GVCs:
    - Infrastructural and logistical constraints. Identified as the most critical challenge, these constraints significantly limit the participation of least developed countries in GVCs due to inadequate infrastructure and high trade costs.
    - Limited FDI inflows. As the second most critical challenge, limited FDI inflows restrict economic development and competitiveness.
9. The development of NGVs requires the emergence of a new, more environmentally friendly vehicle industry, supported by adjacent industries, including renewable-based power generation, transport and charging infrastructure, raw materials and mining, fuel supply, and digital and artificial intelligence industries.
10. Although BEVs substantially reduce pollutant emissions during operation, their overall environmental impact reflects a complex combination of positive and negative effects. EVs demonstrate superior performance in mitigating climate change impacts, particularly when powered by renewable energy sources. However, their production processes and certain associated environmental effects remain more resource-intensive than those of ICEVs.

Chapter 3

Summary and Overview of the Questionnaires

3.1. Introduction

The project team conducted a questionnaire survey to assess the current status of the Association of Southeast Asian Nations (ASEAN) powertrain transition towards decarbonisation. The primary objective was to comprehensively capture how original equipment manufacturers (OEMs) and suppliers across ASEAN perceive recent shifts in the business environment, including evolving market dynamics, technological advancements, and policy changes, and how these factors influence powertrain transition strategies.

The survey targeted Southeast Asian countries: Cambodia, Indonesia, Lao People's Democratic Republic (Lao PDR), Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Viet Nam. A total of 2,133 respondents participated, comprising 2,106 suppliers and 27 OEMs. The Marklines supplier list for Southeast Asia was used to minimise selection bias in company coverage and country representation.

Data collection combined computer-assisted telephone interviewing and face-to-face interviews, enabling the project team to gather responses from a broad range of companies across the ASEAN Member States (AMSs) region.

The questionnaire was structured into three main sections:

1. Company overview. Capturing company profiles, financial performance, current markets, and production activities.
2. Market forecast. Examining expectations regarding future production, markets, financial performance, and strategies to achieve these targets.
3. Strategic challenges. Identifying obstacles related to product diversification, supply chain efficiency, and supply chain decarbonisation.

Table 3.1 shows the number of survey respondents by role, categorised into suppliers and OEMs. Most respondents are based in Indonesia, Thailand, and Malaysia, reflecting the scale and maturity of their automotive markets. These countries host numerous vehicle manufacturers producing locally to meet strong domestic demand. In contrast, the number of respondents from Cambodia, Lao PDR, Myanmar, and the Philippines is relatively small, as automotive manufacturers in these countries tend to focus their expansion efforts on global markets and other Southeast Asian economies.

Table 3.1. Number of Survey Respondents

Country	Suppliers	OEMs	Total
Brunei Darussalam	0	0	0
Cambodia	5	0	5
Indonesia	331	4	335
Lao PDR	3	0	3
Malaysia	260	8	268
Myanmar	2	0	2
Philippines	74	1	75
Singapore	88	0	88
Thailand	1,187	10	1,197
Viet Nam	156	4	160
Grand Total	2,106	27	2,133

Lao PDR = Lao People's Democratic Republic, OEM = original equipment manufacturer.
Note: Brunei Darussalam is not represented in the survey findings, as no suppliers or OEMs from the country were included in the respondent list. For this report, suppliers are defined as entities that provide raw materials, components, or services to other companies. OEMs are entities that manufacture products or components ultimately sold to customers, either under their own brand or another company's brand. *(Q5: Please select the country in which your company is located. [SINGLE CHOICE: choose one option]).*
Source: Authors (2025).

3.2. Questionnaire Results

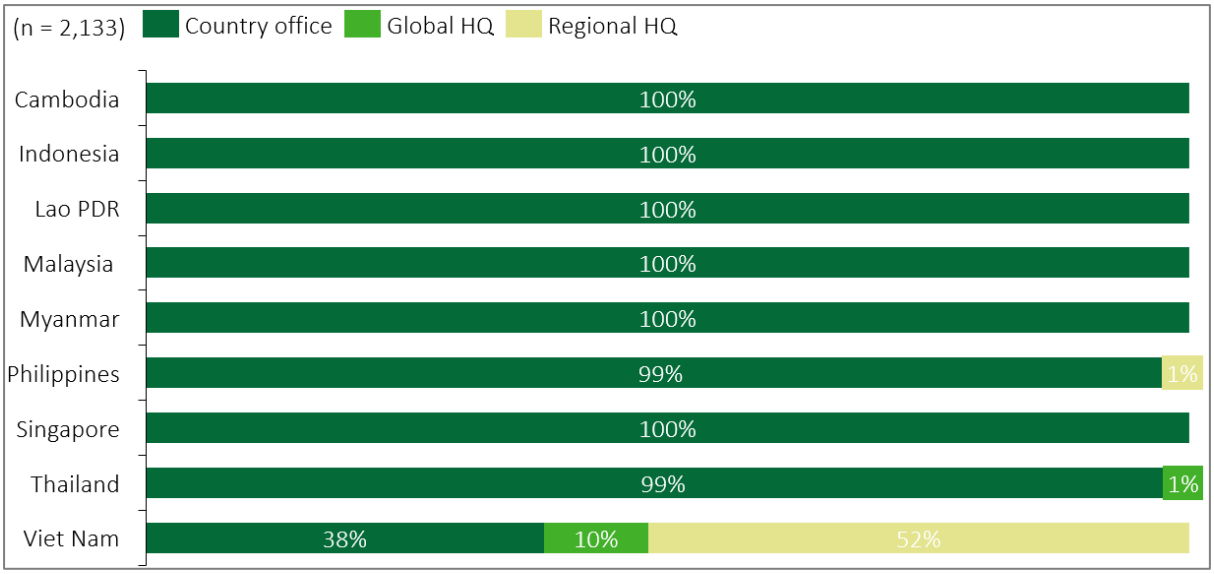
This section presents the survey results from respondents across nine ASEAN countries.

3.2.1. Respondents' Profile

This section presents an overview of respondents by location type, business relationships with OEMs, year of establishment, ownership structure, company size, and production type.

Figure 3.1 shows the distribution of company location types across ASEAN countries. It identifies three main categories: country offices, regional headquarters, and global headquarters. The results show that respondents from Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, the Philippines, Singapore, and Thailand are predominantly based in country offices. In contrast, most respondents from Viet Nam are located in regional headquarters.

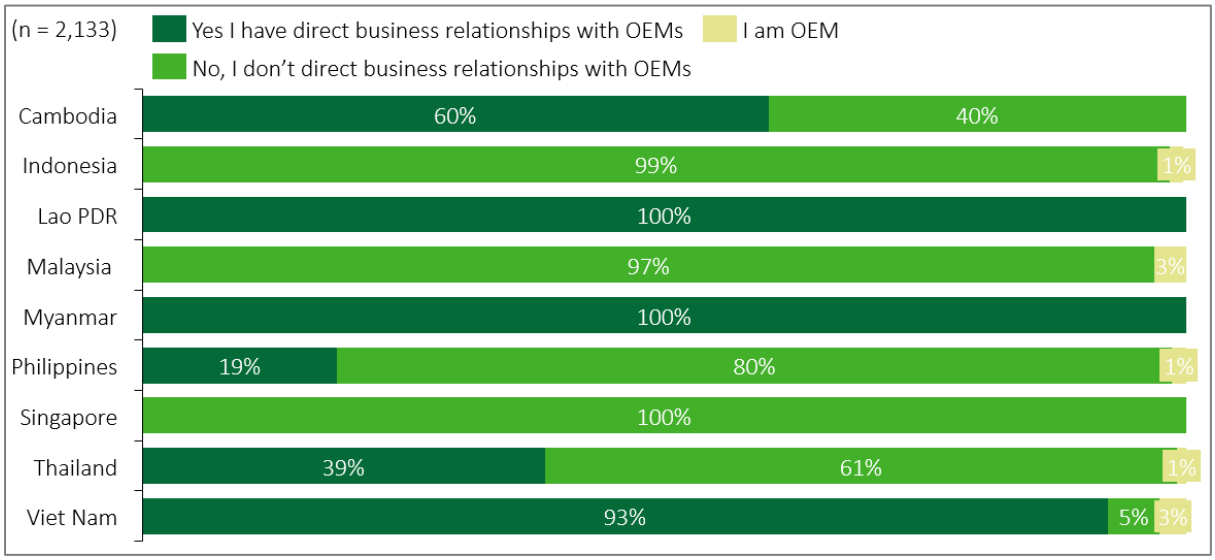
Figure 3.1. Breakdown of Respondents by Location Type Across ASEAN Countries



ASEAN = Association of Southeast Asian Nations, HQ = headquarters.
Note: Data points with a value of 0% are not displayed in the graph to enhance clarity and readability. Percentages for each bar are calculated by dividing the number of responses for each answer option by the total number of respondents within the corresponding country. A 'country office' refers to a national branch or local presence of a multinational company or international organisation. A 'global headquarters' refers to the primary office of an organisation – particularly a multinational corporation – responsible for overseeing, coordinating, and managing operations worldwide. A 'regional headquarters' refers to an office established by transnational corporations in strategically important locations, often global or regional cities, to manage operations within a specific geographic area or across neighbouring regions. *(Q2: Please choose the location you are assigned to [SINGLE CHOICE: choose one option]).*
Source: Authors (2025).

Figure 3.2 presents a country-level breakdown of suppliers with direct and indirect business relationships with OEMs. Overall, the results indicate a relatively balanced distribution between direct and indirect suppliers. Nearly all respondents from Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Singapore, and Viet Nam report direct business relationships with OEMs. In contrast, most respondents from the Philippines (80%) and Thailand (61%) do not have direct relationships with OEMs.

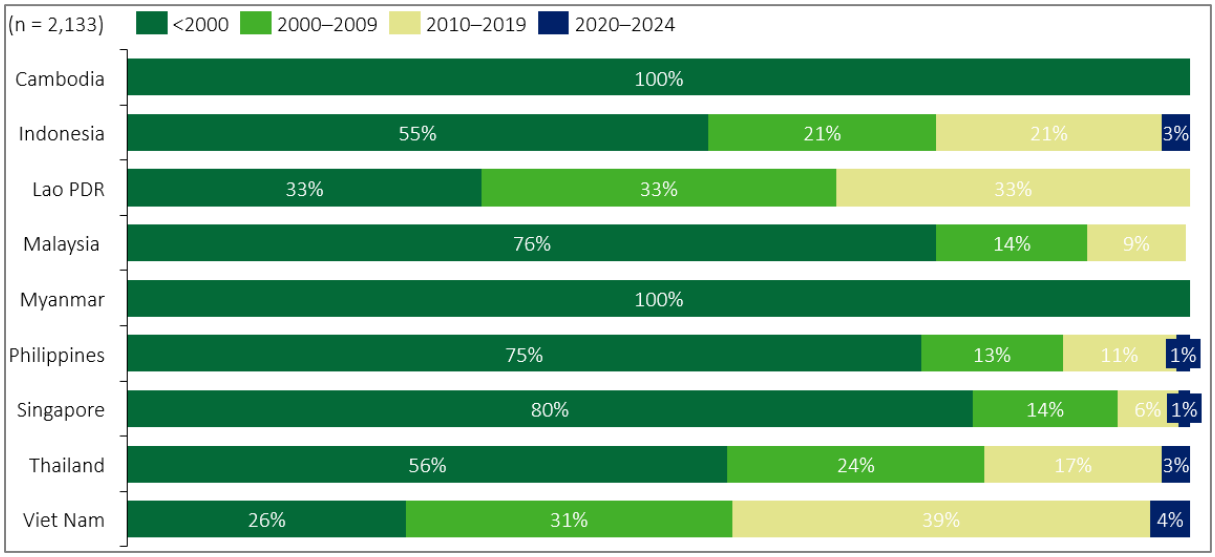
Figure 3.2. Direct Business Relationship with Original Equipment Manufacturers, by Country



Lao PDD = Lao People's Democratic Republic, OEMs = original equipment manufacturers.
Note: Data points with a value of 0% are not displayed in the graph to enhance clarity and readability. Some figures may exceed 100% due to rounding. Percentages for each bar are calculated by dividing the number of responses for each answer option by the total number of respondents within the corresponding country.
(Q3: Do you have direct business relationships with OEMs? [SINGLE CHOICE: choose one option]).
Source: Authors (2025).

Figure 3.3 shows the distribution of company establishment years across ASEAN countries. Most respondents represent well-established companies, with most founded around 1990 or operating for more than 30 years. Consistent with this finding, most respondents are based in country offices established before 2000. This suggests that the surveyed companies are well-positioned to provide informed perspectives on the automotive supply chains, thereby supporting the formulation of effective policy recommendations at the regional level. Based on the respondent distribution presented in Table 3.1, automotive markets in larger ASEAN economies – Indonesia, Malaysia, Singapore, Thailand, and Viet Nam – appear significantly more developed than those in Cambodia, Lao PDR, and Myanmar. Considering these disparities, establishing a country grouping framework that reflects industrial capacity and stages of economic development may be beneficial.

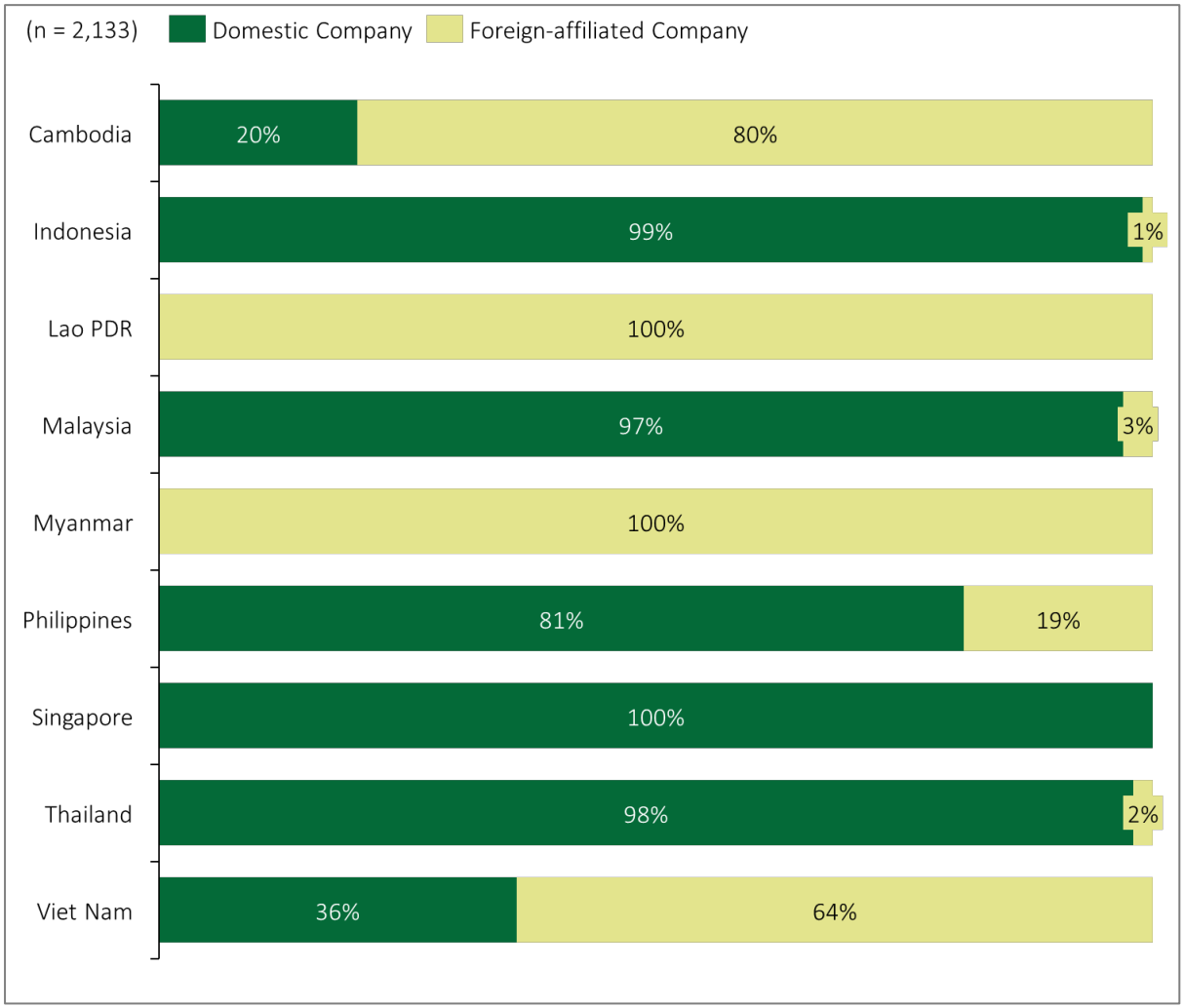
Figure 3.3. Breakdown of Company Establishment Timeline in ASEAN, by Country



Lao PDR = Lao People's Democratic Republic.
Note: Data points with a value of 0% are not displayed to enhance clarity and readability. Percentages for each bar are calculated by dividing the number of responses for each answer option by the total number of respondents within the corresponding country. The category '<2000' aggregates establishments founded from 1900 to 1999. *(Q4: Which year was your company established? Please answer your company's information, not parent company. [SINGLE CHOICE: choose one option]).*
Source: Authors (2025).

Figure 3.4 presents the distribution of company ownership types, classified as either domestic or foreign-affiliated. Respondents from Indonesia, Malaysia, the Philippines, Singapore, and Thailand are predominantly domestic companies. By contrast, respondents from Cambodia, Lao PDR, Myanmar, and Viet Nam are largely foreign-affiliated.

Figure 3.4. Breakdown of Company Ownership in ASEAN, by Country

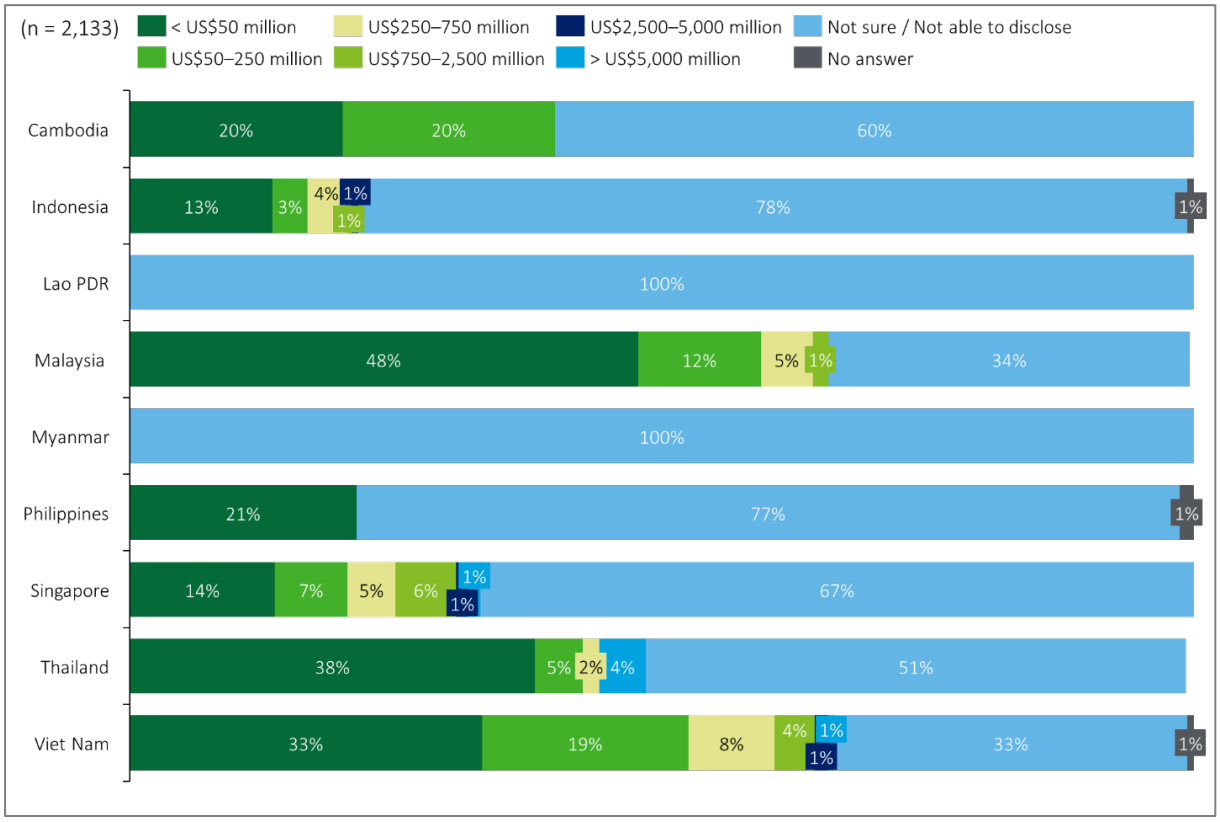


ASEAN = Association of Southeast Asian Nations, Lao PDR = Lao People's Democratic Republic.
Note: Data points with a value of 0% are not displayed to enhance clarity and readability. Percentages of each bar are calculated by dividing the number of responses for each answer option by the total number of respondents within the corresponding country. A foreign-affiliated company is defined as one in which a foreign investor holds 10% or more of the company's shares. *(Q 6: 1 What is your company's ownership type? [SINGLE CHOICE: choose one option]).*
Source: Authors (2025).

3.2.2. Respondents' Company Value

Figure 3.5 presents the distribution of respondents by total company sales. Across Southeast Asian countries, most respondents reported that they were unable to disclose sales information. The main reasons cited for non-disclosure include confidentiality concerns, lack of access to exact figures, and the absence of updated data at the time of the survey. In some cases, respondents indicated that financial information is typically disclosed only during annual meetings, or that they did not have access to finance-related details despite holding managerial positions. Amongst respondents who were able to provide sales information, the average reported company sales in Cambodia, Indonesia, Malaysia, the Philippines, Singapore, Thailand, and Viet Nam were below US$50 million (Figure 3.5).

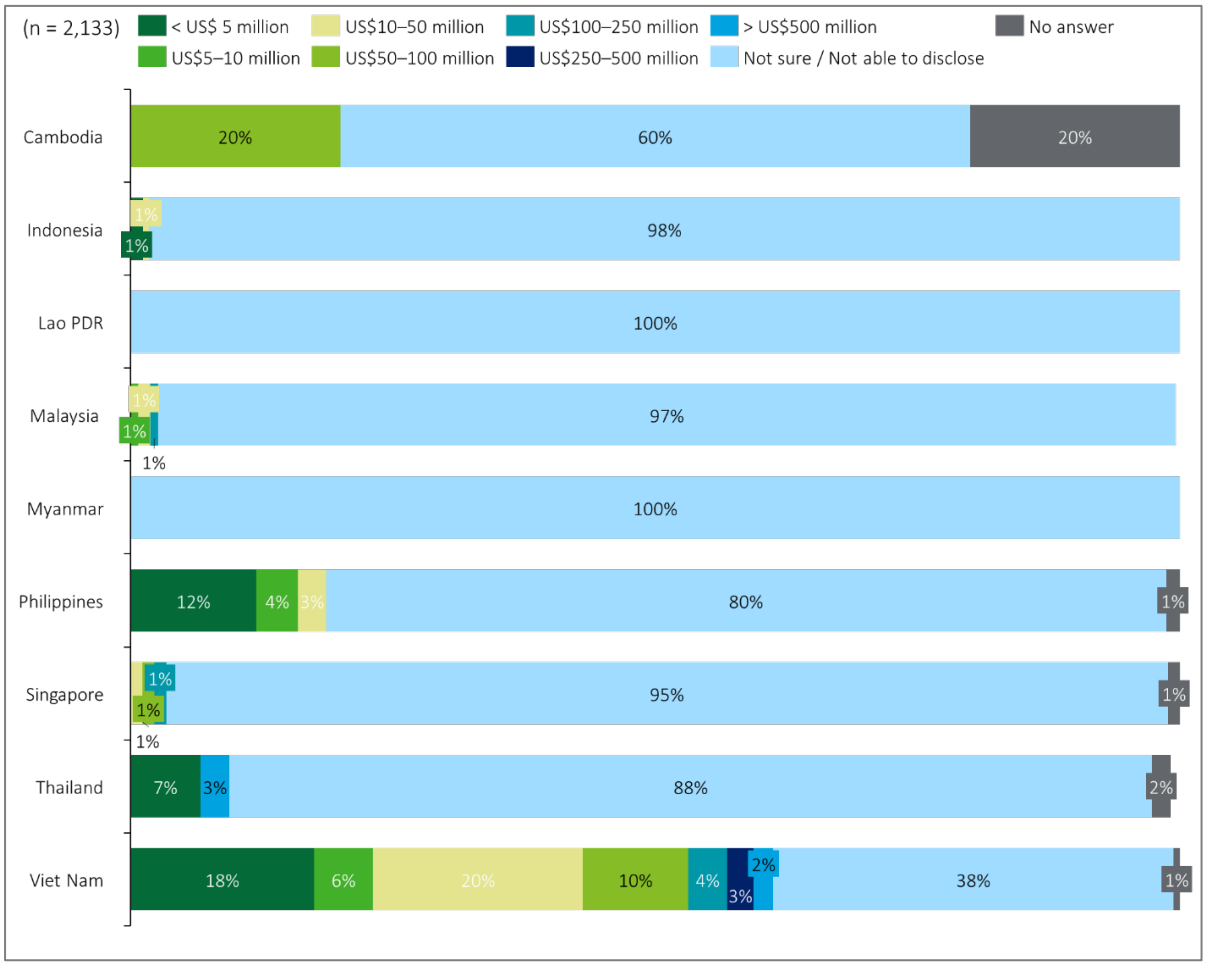
Figure 3.5. Breakdown of Total Company Sales in ASEAN, by Country



ASEAN = Association of Southeast Asian Nations, Lao PDR = Lao People's Democratic Republic.
Note: Data points with a value of 0% are not displayed to enhance clarity and readability. Some figures may exceed 100% due to rounding. Percentages for each bar are calculated by dividing the total number of responses for each answer option by the total number of respondents within the corresponding country. Over half of respondents chose not to disclose their company's sales figures, including 3 from Cambodia, 261 from Indonesia, 3 from Lao PDR, 91 from Malaysia, 2 from Myanmar, 58 from the Philippines, 59 from Singapore, 607 from Thailand, and 53 from Viet Nam. *(Q7-1: What is the total sales amount of your company in US$ for FY 2023? [SINGLE CHOICE: choose one option]).*
Source: Authors (2025).

Figure 3.6 shows the distribution of respondents by profit level. As with sales reporting, most respondents across Southeast Asia indicated that they were unable to disclose company profit information. This was attributed to confidentiality concerns, limited access to precise financial data, and the unavailability of updated information at the time of the survey. Some respondents further noted that profit figures are generally disclosed only during annual meetings, or that they lacked access to such data despite being part of management.

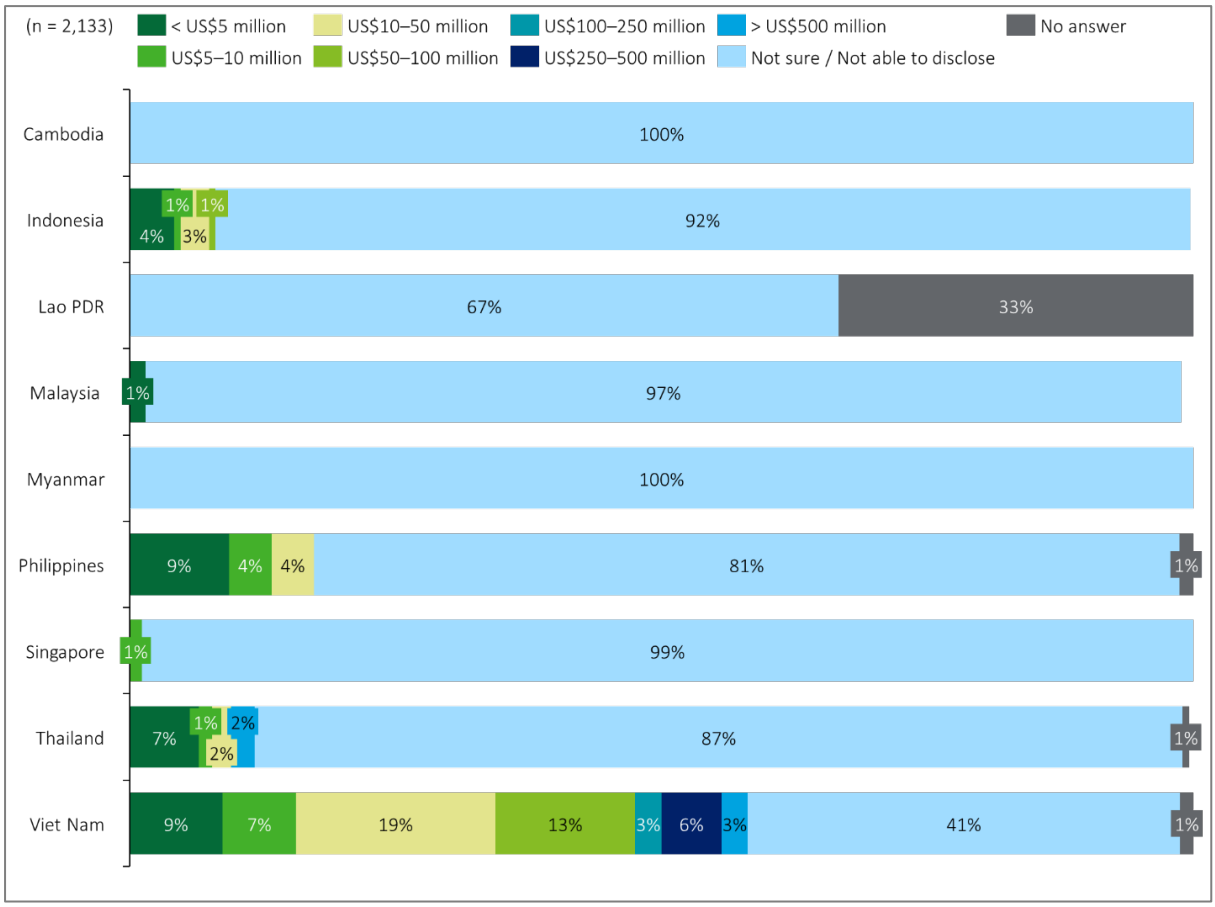
Figure 3.6. Breakdown of Total Company Profit in ASEAN, by Country (US$ million, 2023)



ASEAN = Association of Southeast Asian Nations, Lao PDR = Lao People's Democratic Republic.
Note: Data points with a value of 0% are not displayed to enhance clarity and readability. Percentages of each bar are calculated by dividing the total number of responses for each answer option by the total number of respondents within the corresponding country. More than 80% of respondents chose not to disclose their company's profit figures, including 3 from Cambodia, 329 from Indonesia, 3 from Lao PDR, 260 from Malaysia, 2 from Myanmar, 60 from the Philippines, 84 from Singapore, 1,052 from Thailand, and 61 from Viet Nam. *(Q7-2: What is the total profit of your company in US$ for FY 2023? [SINGLE CHOICE: choose one option]).*
Source: Authors (2025).

Figure 3.7 presents the distribution of respondents by total capital size. Over 80% of respondents from Cambodia, Indonesia, Malaysia, Myanmar, the Philippines, Singapore, and Thailand, along with 67% from Lao PDR and 41% from Viet Nam, reported that they were unable to disclose this information. The primary reasons mirror those cited for sales and profit data, including confidentiality concerns, lack of access to exact figures, and the unavailability of updated data at the time of the survey.

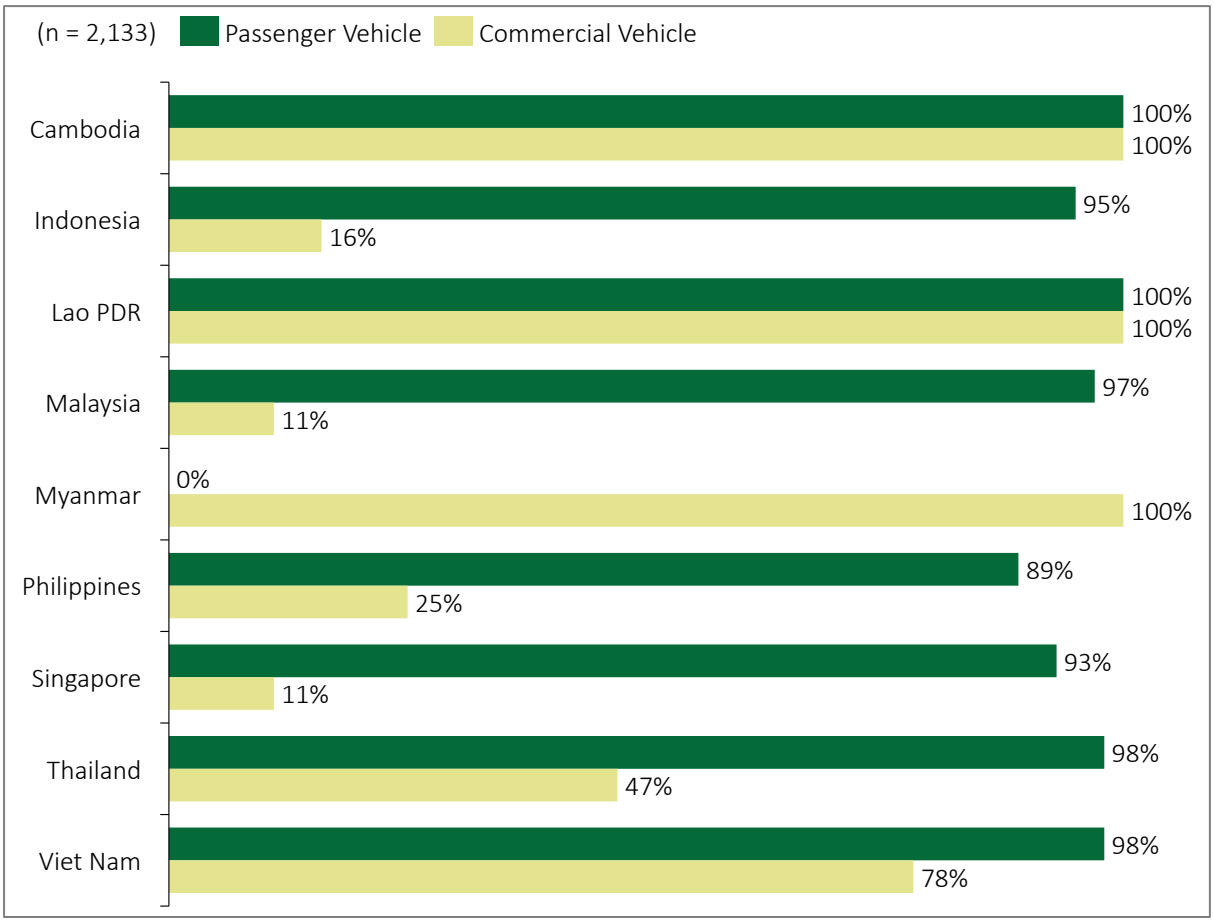
Figure 3.7. Breakdown of Total Company Capital Size in ASEAN, by Country (US$ million, 2023)



ASEAN = Association of Southeast Asian Nations, Lao PDR = Lao People's Democratic Republic.
Note: Data points with a value of 0% are not displayed to enhance clarity and readability. Percentages of each bar are calculated by dividing the total number of responses for each answer option by the total number of respondents within the corresponding country. *(Q7-3: What is the total capital size (total value) of your company in US$ for FY 2023? [SINGLE CHOICE: choose one option]).*
Source: Authors (2025).

Figure 3.8 presents the types of vehicles and vehicle parts produced by respondent companies. More than 80% of suppliers and OEMs from Indonesia, Malaysia, the Philippines, Singapore, Thailand, and Viet Nam are engaged in the production of passenger vehicles. In contrast, respondents from Myanmar primarily focus on commercial vehicle production, whilst those from Cambodia and Lao PDR are engaged in the production of both passenger and commercial vehicles.

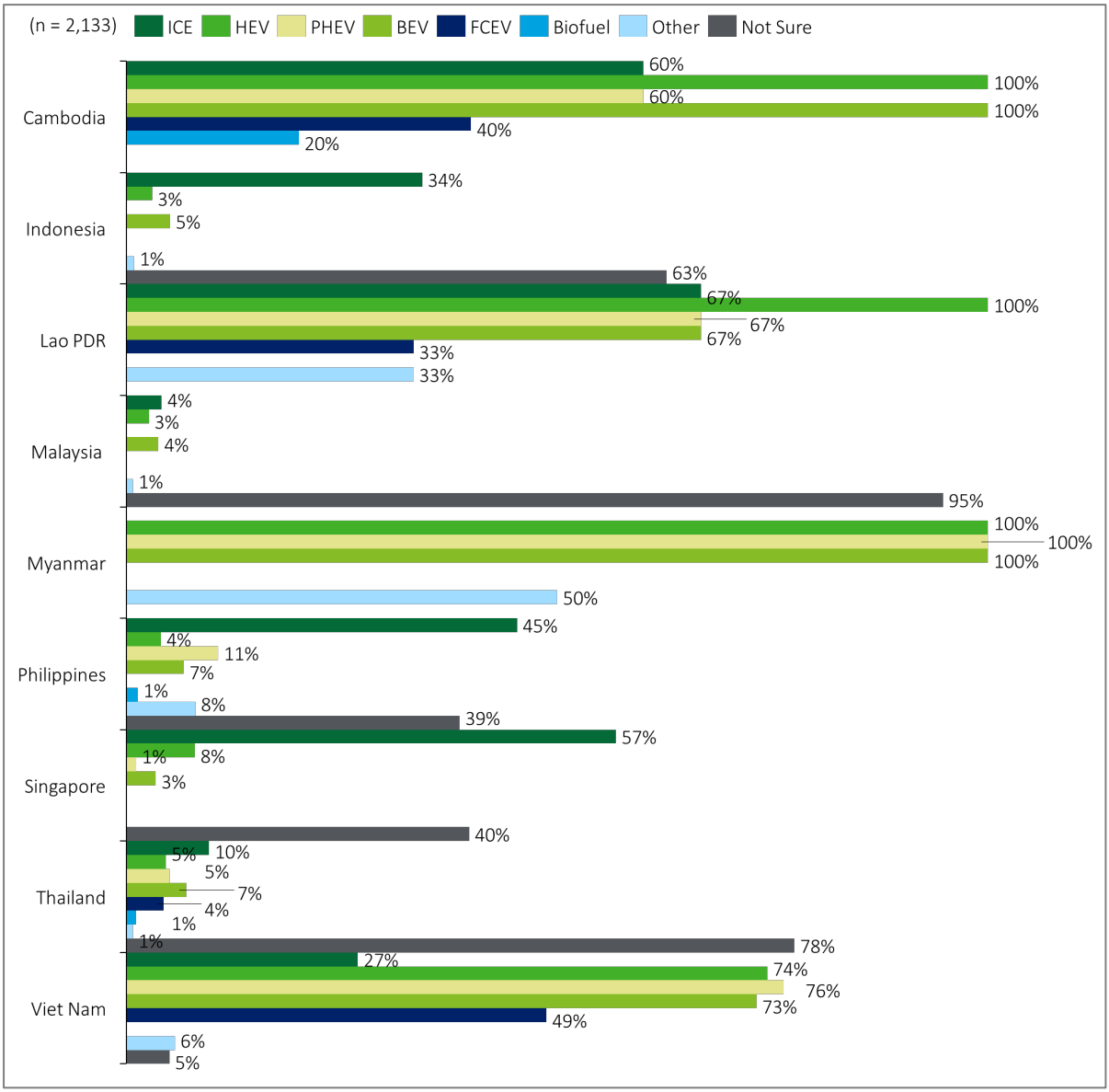
Figure 3.8. Breakdown of Vehicles and Vehicle Parts Produced by Companies, by Country



Lao PDR = Lao People's Democratic Republic.
Note: Percentages for each bar are calculated by dividing the total number of responses for each answer option by the total number of respondents within the corresponding country. *(Q9_1: What type of vehicles or vehicle parts does your company produce? [MULTIPLE CHOICE: choose all options that apply]).*
Source: Authors (2025).

Figure 3.9 presents the distribution of powertrain vehicle types produced by respondent companies. The results indicate distinct production profiles across countries. Cambodia, Myanmar, and Viet Nam concentrate production on hybrid electric vehicles (HEVs), battery electric vehicles (BEVs), and plug-in hybrid electric vehicles (PHEVs), which together account for more than 70% of responses. The Philippines and Singapore primarily focus on internal combustion engine vehicles (ICEVs), representing about 40%–50% of responses. Relatively few respondents identified biofuel powertrain vehicles as a production focus. A significant share of respondents from Indonesia, Thailand, and Malaysia reported uncertainty regarding the powertrain types in which their products are used, with over 50% indicating a lack of clarity. This uncertainty largely reflects limited information provided by OEMs, as suppliers are often involved only in production and distribution stages and may not be informed of OEMs' specific powertrain strategies.

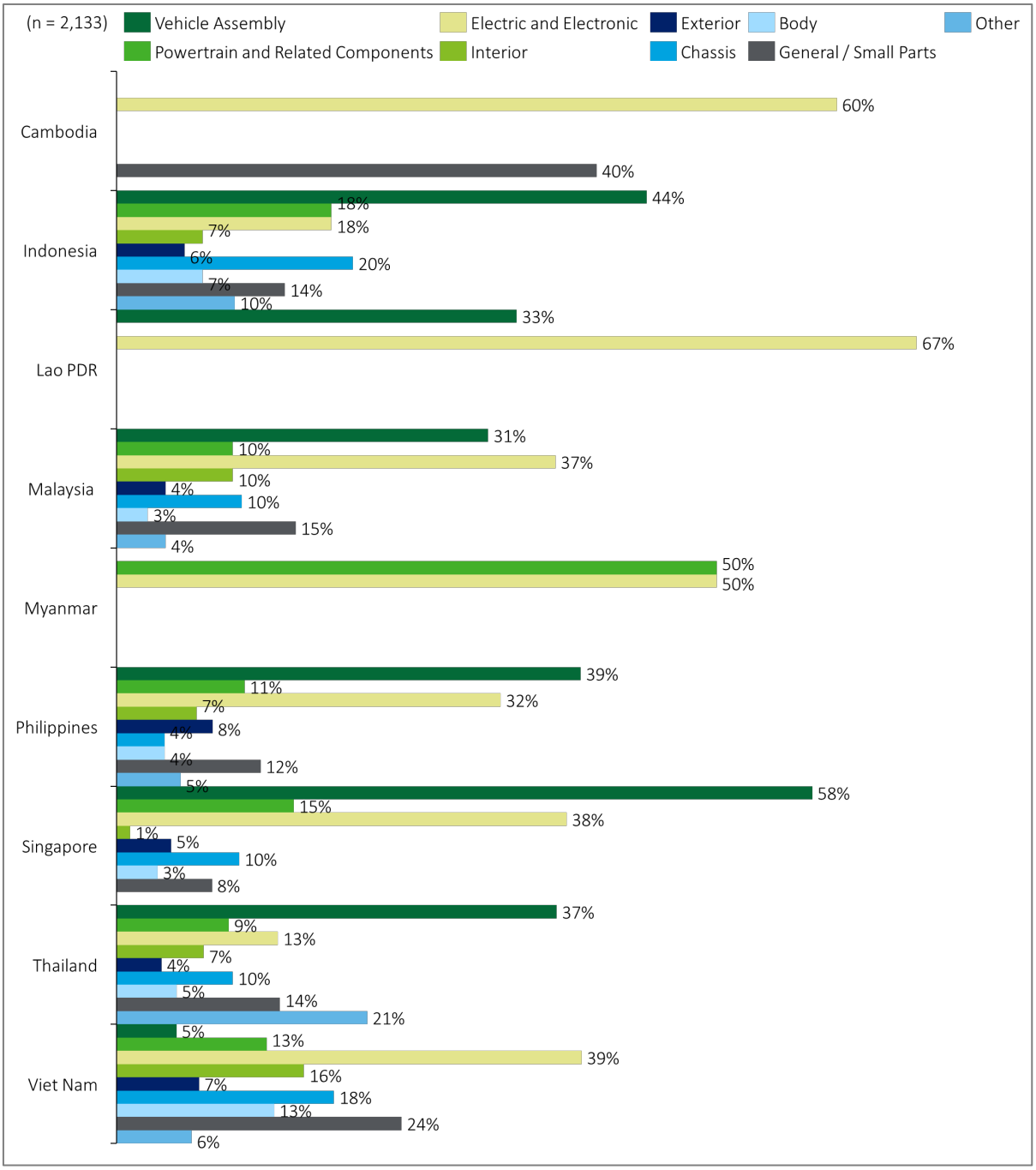
Figure 3.9. Breakdown of Powertrain Vehicle Types Produced by Companies, by Country



BEV = battery electric vehicle, FCEV = fuel cell electric vehicle, HEV = hybrid electric vehicle, ICE = internal combustion engine, Lao PDR = Lao People's Democratic Republic, PHEV = plug-in hybrid electric vehicle,
Note: Data points with a value of 0% are not displayed to enhance clarity and readability. More than 50% of responses indicated uncertainty regarding powertrain vehicle types. Percentages for each bar are calculated by dividing the total number of responses for each answer option by the total number of respondents within the corresponding country. *(Q10_1: Which type of powertrain vehicles does your company produce? Or in which powertrain vehicles are your company's products used? [MULTIPLE CHOICE: choose all options that apply].*
Source: Authors (2025).

Figure 3.10 presents the distribution of product types manufactured by respondent companies. Vehicle assembly is the most frequently reported activity amongst respondents from Indonesia (44%), the Philippines (39%), Singapore (58%), and Thailand (37%). By contrast, respondents from Cambodia (60%), Lao PDR (67%), and Viet Nam (39%) predominantly focus on the production of electrical and electronic components.

Figure 3.10. Breakdown of Product Types Produced by Companies, by Country



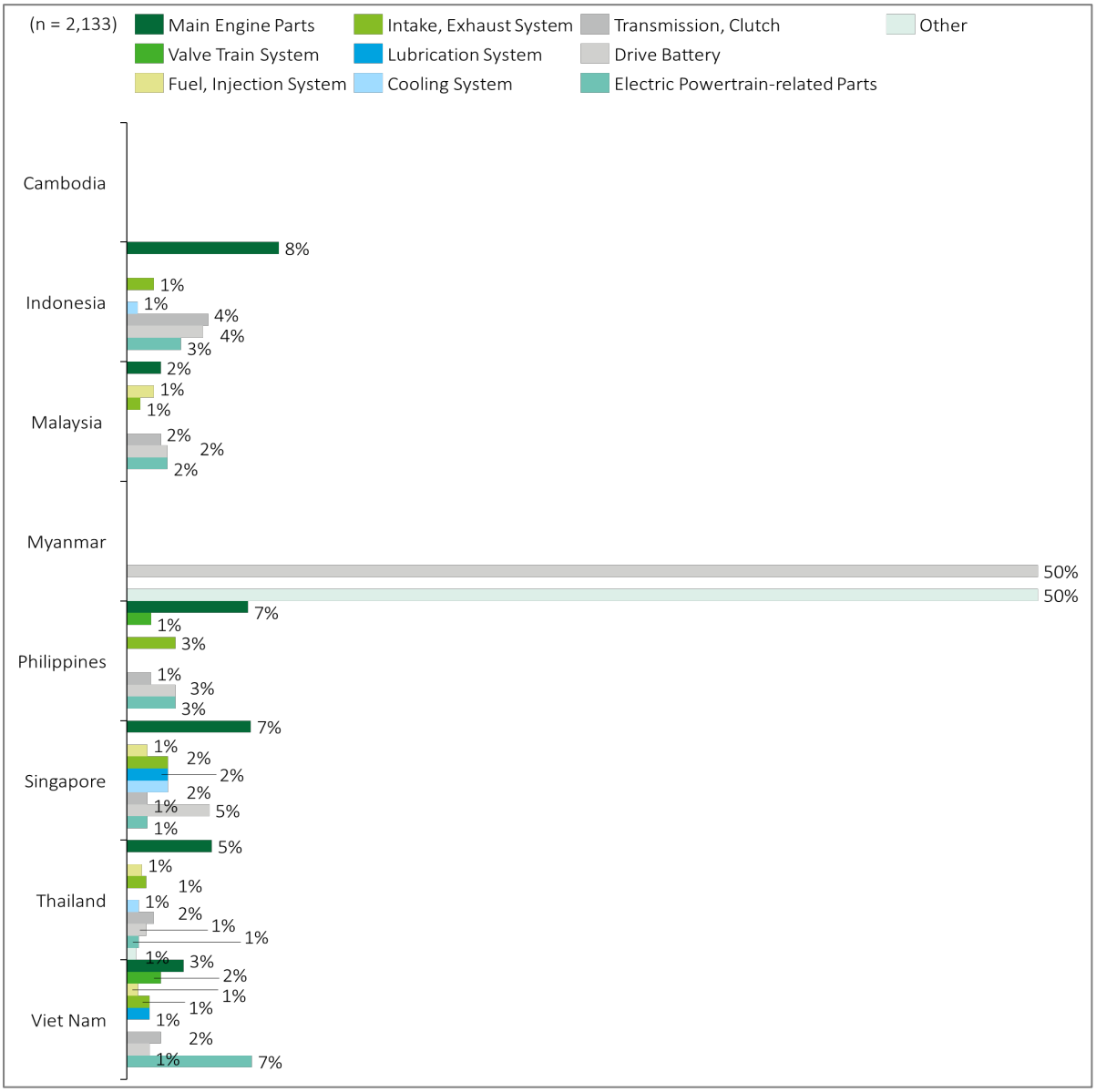
Lao PDR = Lao People's Democratic Republic.

Note: Data points with a value of 0% are not displayed to enhance clarity and readability. Electrical and electronic components include advanced driver-assistance systems and automated driving systems (ADAS/AD), in-vehicle infotainment systems (IVI), air conditioning systems, security systems, domain controllers, electronic control units (ECUs), sensors, motors and actuators, switches, connectors, harnesses, and other electronic components. Interior components include cockpit modules, trunks, pedals, seat-related products, airbags, and safety-related products. Exterior components include windows and glasses. Body components include chassis frames, bumpers, and fuel systems. General and small parts include ducts, fasteners, boots, grommets, diaphragms, bushings, control cables, bearings, acoustic materials, and insulators. Percentages for each bar are calculated by dividing the total number of responses for each answer option by the total number of respondents within the corresponding country *(Q11-1: Which products does your company currently produce? (Choose up to 3 items at maximum) [MULTIPLE CHOICE: choose all options that apply]).*

Source: Authors (2025).

Figure 3.11 provides a detailed breakdown of powertrain and related components produced by respondent companies. Respondents from Indonesia, the Philippines, Singapore, and Thailand identified main engine parts as the primary powertrain-related products, accounting for 7%–8% of responses. In contrast, respondents from Myanmar reported transmission, clutch, and drive battery components as their primary outputs.

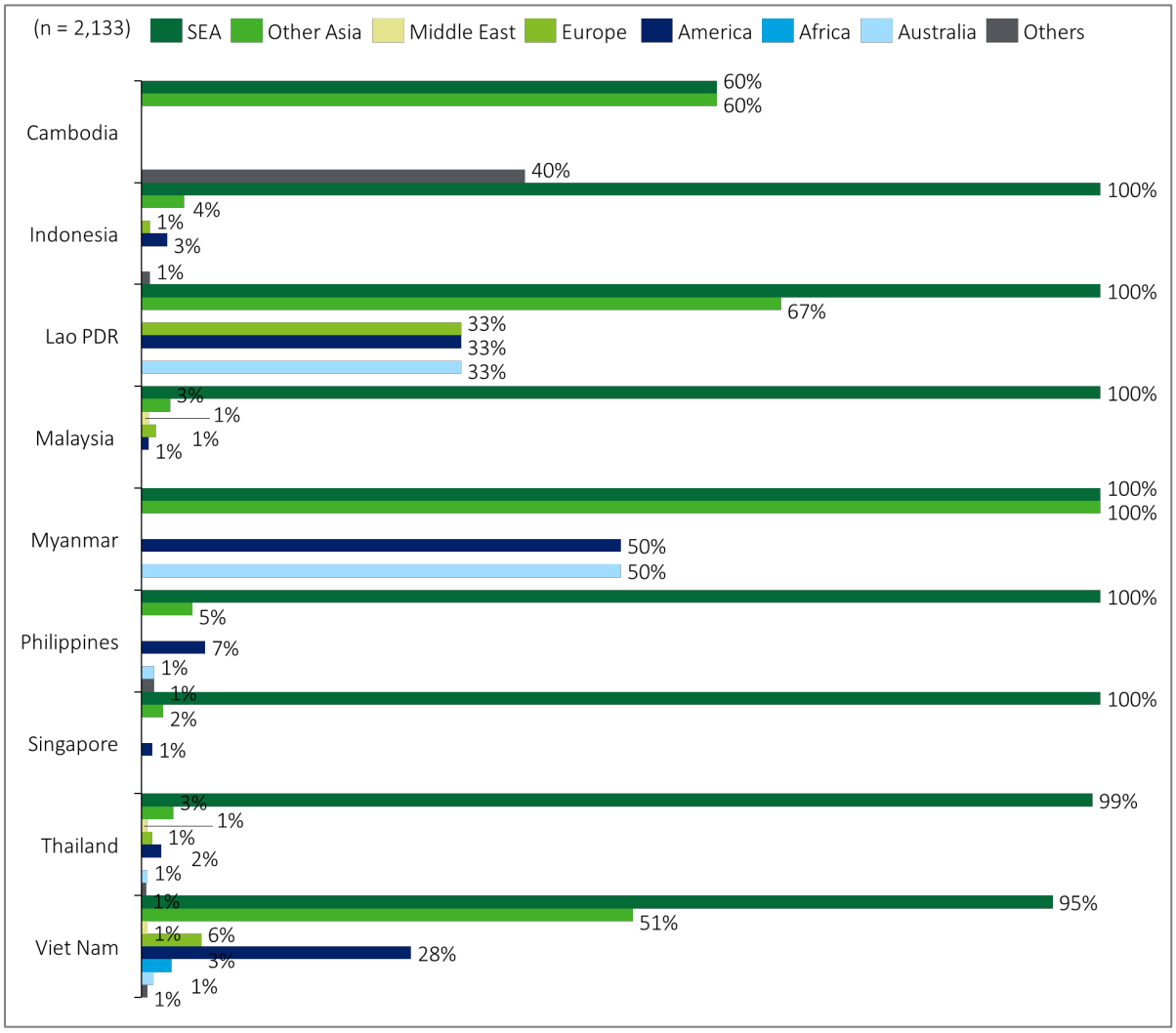
Figure 3.11. Powertrain-related Products Produced by Companies, by Country



Note: Data points with a value of 0% are not displayed to enhance clarity and readability. Percentages shown in each bar represent the proportion of responses for each answer option, calculated by dividing the number of selections for a specific component by the total number of respondents associated with that category. The term 'powertrain and related components' encompasses main engine parts, valve train systems, fuel systems, intake systems, ignition systems, lubrication systems, cooling systems, starters, transmissions, drive batteries, e-axles, electric powertrain-related components, and other associated items. It should be noted that no respondents indicated the production of ignition systems, starters, or e-axles. No responses were recorded from Cambodia and Lao PDR for this question. *(Q11-1: If you selected '2'. Powertrain and related components on the previous question (11-1), please specify which products your company produces. (Choose up to a maximum of 3) [MULTIPLE CHOICE: choose all options that apply]).*
Source: Authors (2025).

Figure 3.12 presents the markets in which companies offer their products. The findings indicate that most suppliers and OEMs primarily distribute their products within the Southeast Asian region, including their respective domestic markets. Additionally, the survey results reveal that over 50% of suppliers and OEMs, particularly from Cambodia, Lao PDR, and Viet Nam, export to other Asian markets, such as Japan and China. Respondents from Lao PDR, Myanmar, and Viet Nam also reported exports to America, with 33%, 50%, and 28% of total respondents, respectively.

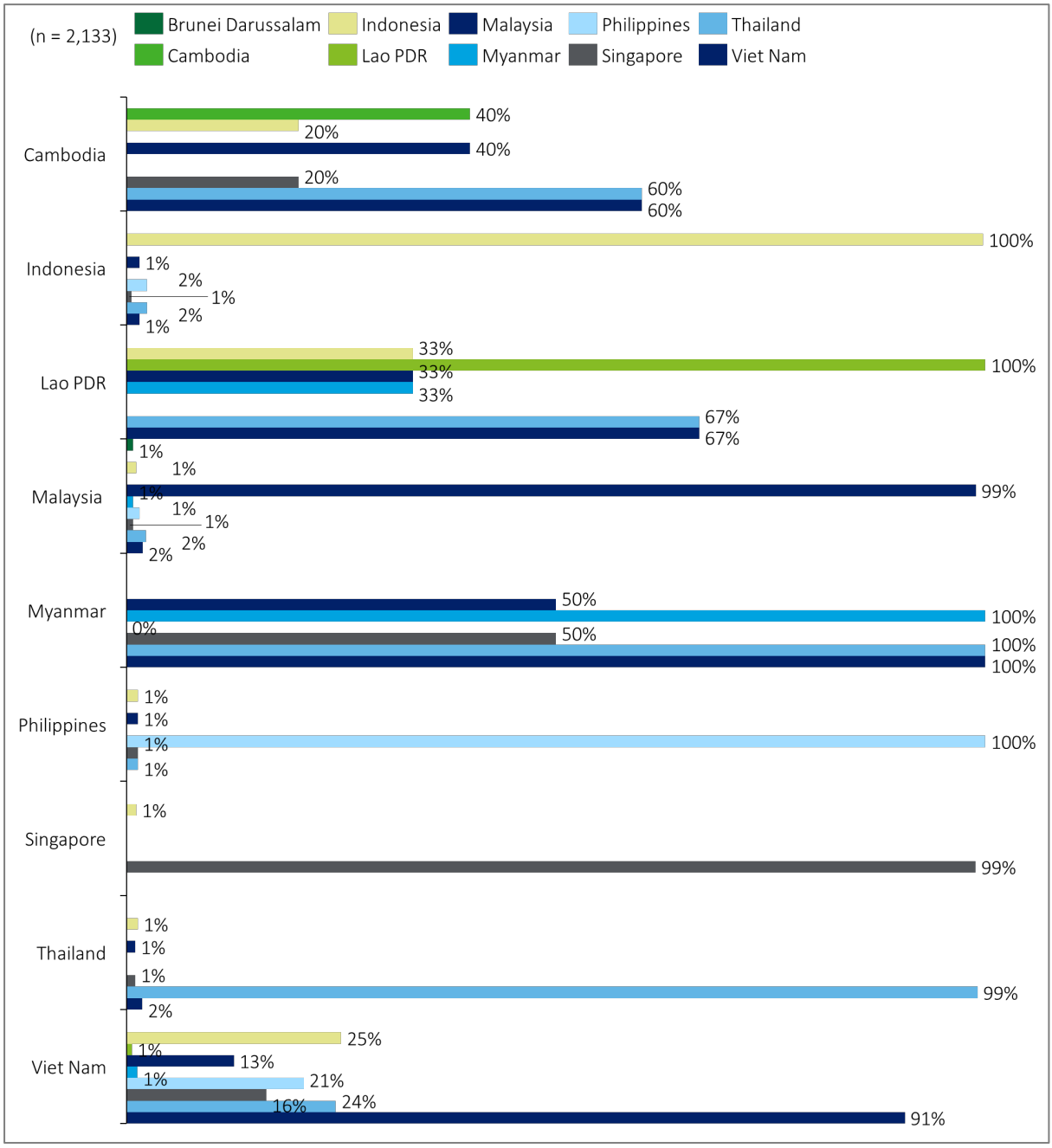
Figure 3.12. Breakdown of Current Supply Distribution, by Country



Lao PDR = Lao People's Democratic Republic, SEA = Southeast Asia.
Note: Data points with a value of 0% are not displayed to enhance clarity and readability. The data reflect the number of companies from each country operating in the regional market. The Southeast Asia region includes Brunei Darussalam, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Viet Nam. The 'Other Asia' category comprises China, Hong Kong, Japan, the Republic of Korea, India, and other Asian economies. The 'America' category includes the United States, Canada, Mexico, Central America, and South America. The 'Africa' category encompasses Central and Middle Africa, East Africa, Northern Africa, Southern Africa, and Western Africa. The percentage shown in each bar is calculated by dividing the total number of companies selecting each answer option by the total number of companies in the corresponding row answer option. *(Q12-1: For each product selected in Q11-1 and Q11-3, please indicate the market(s) in which you offer each product? [MULTIPLE CHOICE: choose all options that apply]).*
Source: Authors (2025).

Figure 3.13 shows that most respondents from Indonesia, Malaysia, the Philippines, Singapore, and Thailand distribute their products primarily within their respective domestic markets. By contrast, respondents from Cambodia, Lao PDR, Myanmar, and Viet Nam reported serving both domestic and foreign markets.

Figure 3.13. Breakdown of Current Supply Distribution within Southeast Asian Countries, by Country



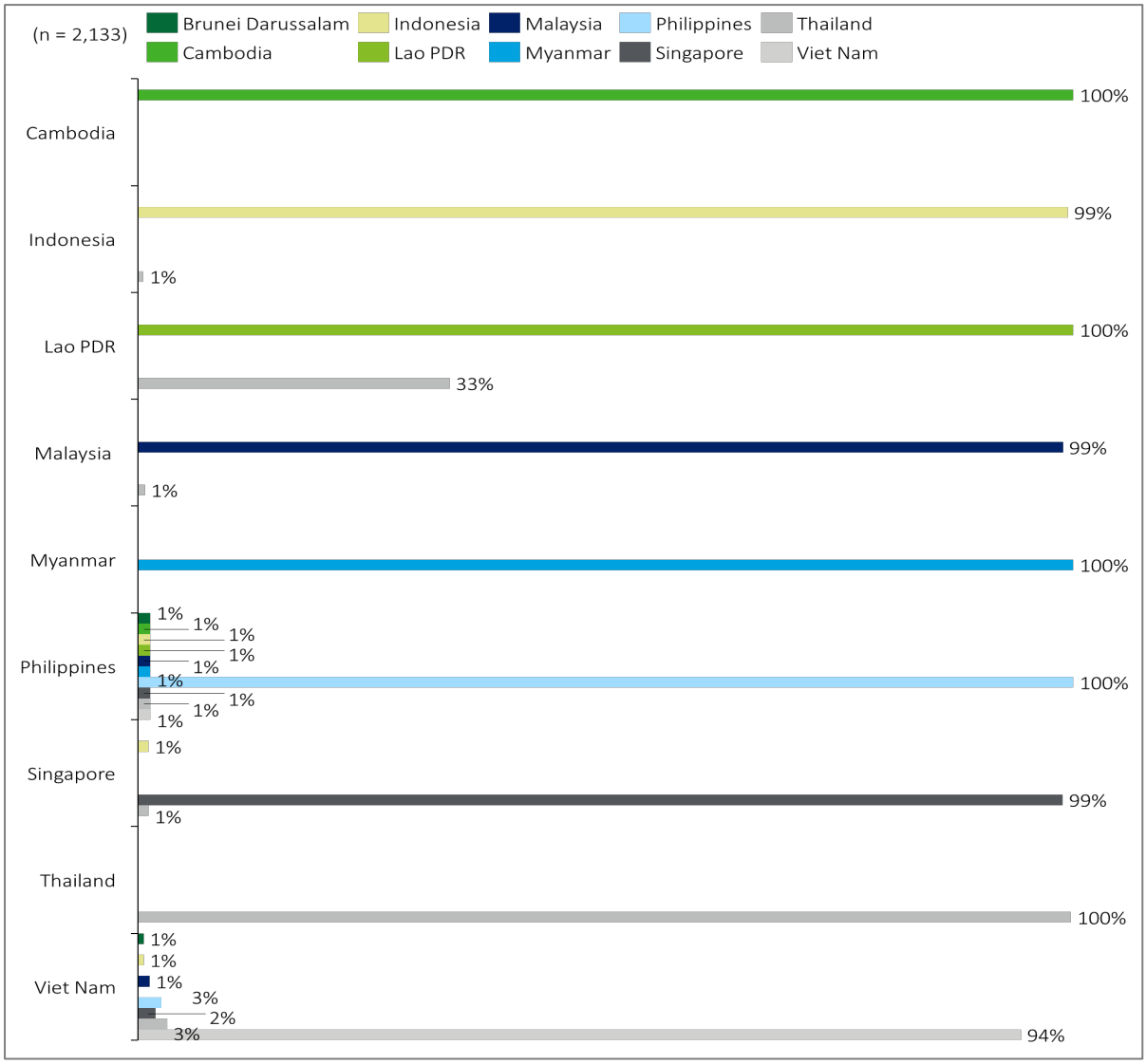
Lao PDR = Lao People's Democratic Republic.

Note: Data points with a value of 0% are not displayed to enhance clarity and readability. Percentages for each bar are calculated by dividing the total number of responses for each answer option by the total number of respondents within the corresponding country. *(Q12-1: For each product that was selected on Q11-1 and Q11-3, please indicate the market(s) in which you offer each product? [MULTIPLE CHOICE: choose all options that apply]).*

Source: Authors (2025).

Figure 3.14 shows the locations where companies manufacture their products. The results indicate that most companies across Southeast Asia are local manufacturers, as they primarily produce their products within their own countries.

Figure 3.14. Breakdown of Current Manufacturing Locations, by Country



Lao PDR = Lao People's Democratic Republic.

Note: Data points with a value of 0% are not displayed to enhance clarity and readability. Percentages for each bar are calculated by dividing the total number of responses for each answer option by the total number of respondents within the corresponding country. Manufacturing locations by country and province include Cambodia (Phnom Penh, Koh Kong, Kandal); Indonesia (Bali, Banten, Central Java, East Java, East Nusa Tenggara, Jakarta, North Sumatra, Riau Islands, West Java, West Nusa Tenggara); Lao PDR (Bokeo, Champasak, Savannakhet, Vientiane); Malaysia (Johor, Kedah, Malacca, Negeri Sembilan, Pahang, Penang, Perak, Sabah, Sarawak, Selangor, Terengganu); Myanmar (Bago, Chin, Yangon); Philippines (Abra, Aklan, Batangas, Bulacan, Cavite, Cebu, Laguna, Pampanga, Pangasinan, Rizal); Thailand (Ang Thong, Chachoengsao, Chonburi, Nonthaburi, Pathum Thani, Phra Nakhon Si Ayutthaya, Rayong, Samut Prakan, Samut Sakhon, Saraburi, Sing Buri); Viet Nam (Bac Giang, Bac Kan, Bac Ninh, Ben Tre, Binh Duong, Binh Phuoc, Binh Thuan, Cao Bang, Da Nang City, Dak Lak, Dien Bien, Dong Nai, Gia Lai, Ha Nam, Ha Noi City, Hai Duong, Hai Phong City, Hoa Binh, Hung Yen, Long An, Nghe An, Ninh Binh, Ninh Thuan, Phu Tho, Quang Tri, Son La, Tay Ninh, Thai Nguyen, Tien Giang, Tra Vinh, Vinh Phuc)

(Q13-1: For each product selected in Q11-1 and Q11-2, where does your company manufacture each of these products? [MULTIPLE CHOICE: choose all options that apply])

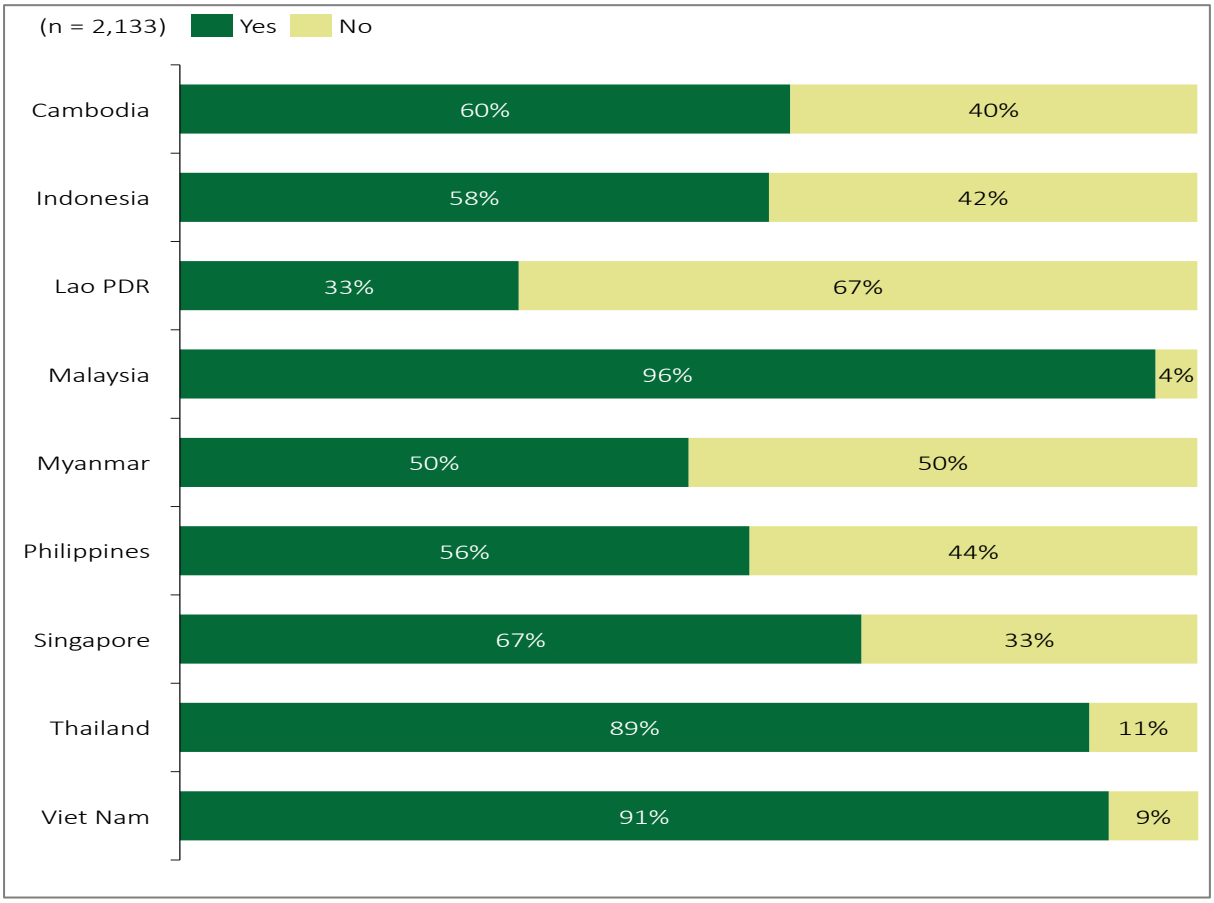
Source: Authors (2025).

3.2.3. Respondents' View on Battery Electric Vehicle and Plug-in Hybrid Electric Vehicle Penetration Rate Forecast

This section presents respondents' views on the forecast penetration rates of BEVs and PHEVs. Figure 3.15 shows that more than 80% of respondents believe that the penetration rate of BEVs and PHEVs will rise to 13% by 2035. Responses vary across ASEAN countries, reflecting differing national perspectives and contexts.

Most respondents from ASEAN countries anticipate an increase in the penetration rates of BEVs and PHEVs. In Myanmar, one of the two respondents expressed confidence in the forecast, whilst the other did not. Lao PDR represents an exception, where most respondents (67%) expressed uncertainty regarding the forecast. As shown in Figure 3.17, this uncertainty is primarily attributed to concerns over the high cost of EVs, driven largely by elevated battery prices and other manufacturing components.

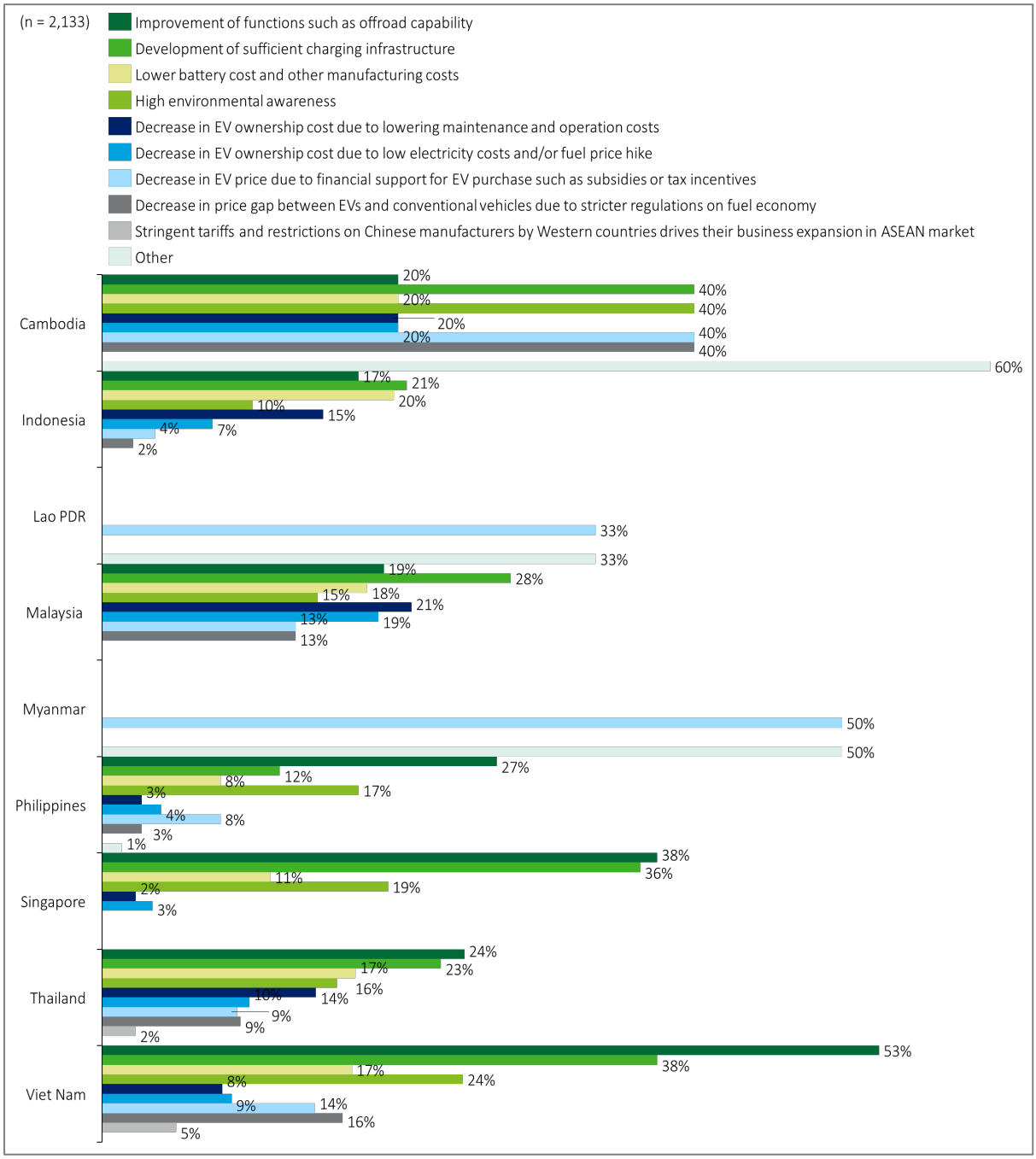
Figure 3.15. Breakdown of Respondents' Views on Battery Electric Vehicle and Plug-in Hybrid Electric Vehicle Penetration Rate Forecast, by Country



Lao PDR = Lao People's Democratic Republic.
Note: 'Yes' indicates that respondents believe the BEV and PHEV penetration rate, particularly for passenger vehicles, will increase to 13% by 2035 or even at a faster pace than forecast in ASEAN. Percentages for each bar are calculated by dividing the total number of responses for each answer option by the total number of respondents of the corresponding country. *(Q14: According to public data, the BEV and PHEV penetration rate in new car sales in ASEAN was 5% in 2023 and is forecast to reach 13% by 2035. Do you believe that the BEV and PHEV penetration rate will increase to the same level or even at a faster pace than this forecast, or will it remain below the projected figure? [SINGLE CHOICE: choose one option]).*
Source: Authors (2025).

Figure 3.16 presents the rationales provided by respondents who support the penetration rate projection. Most respondents from the Philippines, Singapore, Thailand, and Viet Nam believe that advancements in automotive functions will drive increased demand for BEV and PHEV products. By contrast, respondents from Indonesia and Malaysia identified the availability of sufficient charging infrastructure as the main driver.

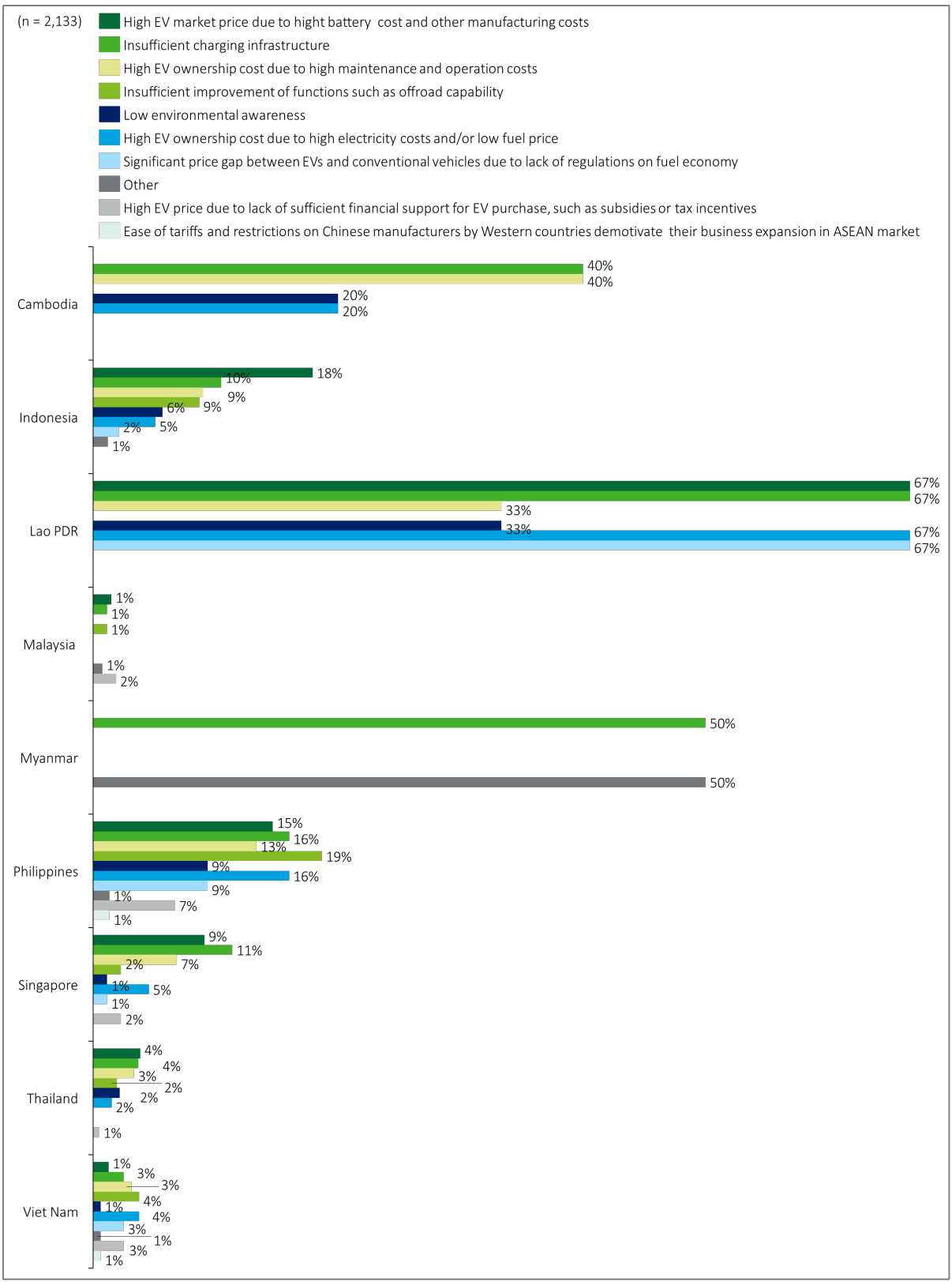
Figure 3.16. Breakdown of Rationales Behind the 'Yes' Prediction, by Country



Lao PDR = Lao People's Democratic Republic.
Note: Data points with a value of 0% are not displayed to enhance clarity and readability. Percentages for each bar are calculated by dividing the total number of responses for each answer option by the total number of respondents within the corresponding country. *(Q15-1: If you selected 'Yes', what is the rationale behind the above prediction? [MULTIPLE CHOICE: choose all options that apply]).*
Source: Authors (2025).

Figure 3.17 presents the rationales provided by respondents who believe that the penetration rate will not increase as forecast. The high market price of EVs, driven by elevated battery and manufacturing costs, is identified as the primary factor limiting market growth by respondents from Indonesia, Malaysia, and Thailand. Respondents from the Philippines, Singapore, and Viet Nam cited insufficient infrastructure as the major barrier. Respondents from Cambodia and Lao PDR reported that both factors are equally significant constraints.

Figure 3.17. Breakdown of Rationales Behind the 'No' Prediction, by Country



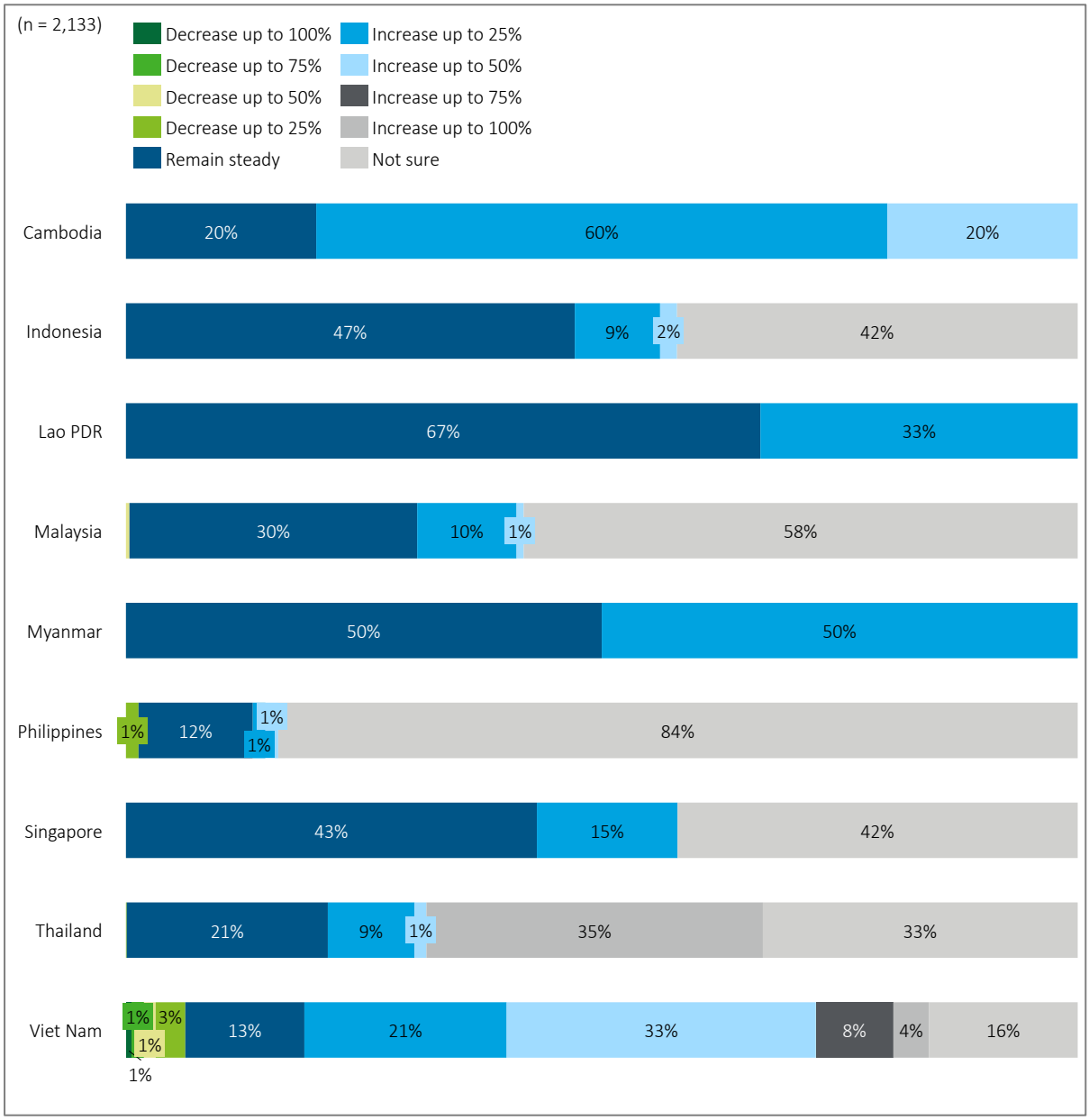
Lao PDR = Lao People's Democratic Republic.

Note: Data points with a value of 0% are not displayed to enhance clarity and readability. Percentages for each bar are calculated by dividing the total number of responses for each answer option by the total number of respondents within the corresponding country. *(Q15-2: If you have selected 'No', what is the rationale behind the above prediction? [MULTIPLE CHOICE: choose all options that apply]).*

Source: Authors (2025).

Figure 3.18 shows the breakdown of revenue projection by 2035.

Figure 3.18. Breakdown of Revenue Projection by 2035, by Country



Lao PDR = Lao People's Democratic Republic.

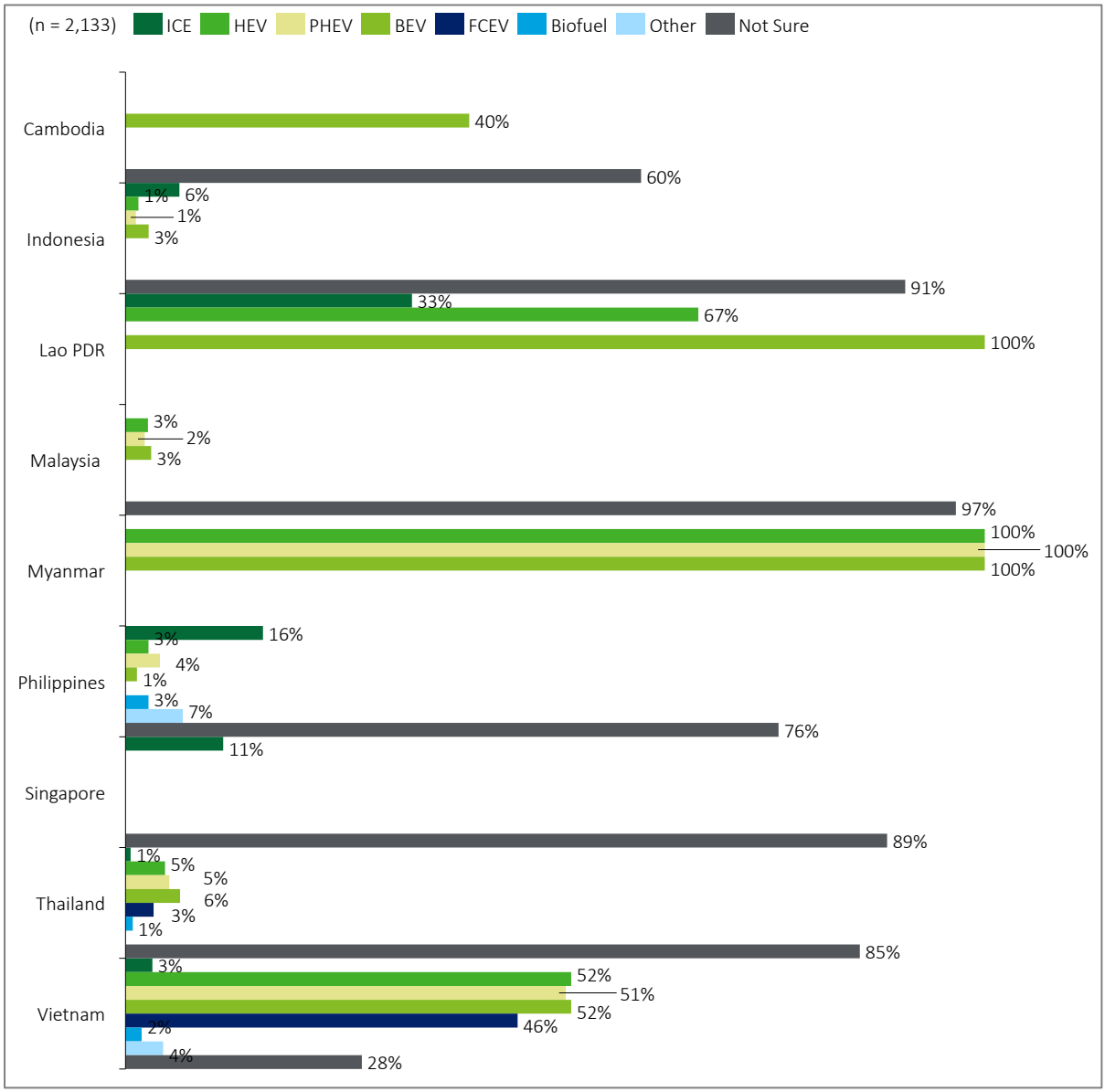
Note: More than 30% of respondents were uncertain about their company's revenue projections. The primary reasons for non-disclosure include privacy concerns, lack of access to exact figures, and the unavailability of updated data at the time of the survey. In some cases, respondents indicated that financial information is typically reported during annual meetings, or that they did not have access to finance-related details despite being part of management. Percentages for each bar are calculated by dividing the total number of responses for each answer option by the total number of respondents within the corresponding country. *(Q16: Based on the above prediction, please provide your revenue projections for the automotive business by 2035. [SINGLE CHOICE: choose one option]).*

Source: Authors (2025).

Figure 3.19 presents the breakdown of powertrain vehicle types that companies plan to prioritise in the future. More than 70% of respondents, particularly from Cambodia, Indonesia, Malaysia, the Philippines, Singapore, and Thailand, reported uncertainty

regarding their plans. This uncertainty appears to be linked to a lack of clear communication from OEMs. Suppliers operating at Tier 2 or Tier 3 levels are often not directly involved in final assembly or strategic decision-making, which limits their visibility into the long-term product roadmaps of OEMs.

Figure 3.19. Breakdown of Powertrain Vehicle Types Companies Plan to Focus on in Response to the Above Forecast, by Country



BEV = battery electric vehicle, FCEV = fuel cell electric vehicle, HEV = hybrid electric vehicle, ICE = internal combustion engine, Lao PDR = Lao People's Democratic Republic, PHEV = plug-in hybrid electric vehicle.
Note: Data points with a value of 0% are not displayed to enhance clarity and readability. Percentages for each bar are calculated by dividing the total number of responses for each answer option by the total number of respondents within the corresponding country. *(Q17_1: Considering the above prediction, which type of powertrain vehicles will your company focus on by 2035? [MULTIPLE CHOICE: choose all options that apply]).*
Source: Authors (2025).

Table 3.20 compares current and planned powertrain vehicle focus. Respondents from Lao PDR indicated plans to focus exclusively on BEV and HEV production, marking a slight shift from the current situation, which includes a wider variety of powertrain types. Respondents from Myanmar and Viet Nam indicated intentions to maintain their current production focus. In contrast, respondents from Indonesia, Malaysia, the Philippines, Singapore, and Thailand exhibited higher levels of uncertainty, with over 70% indicating that future powertrain strategies remain undecided (Figure 3.20).

Figure 3.20. Breakdown of Current versus Planned Powertrain Vehicle Focus

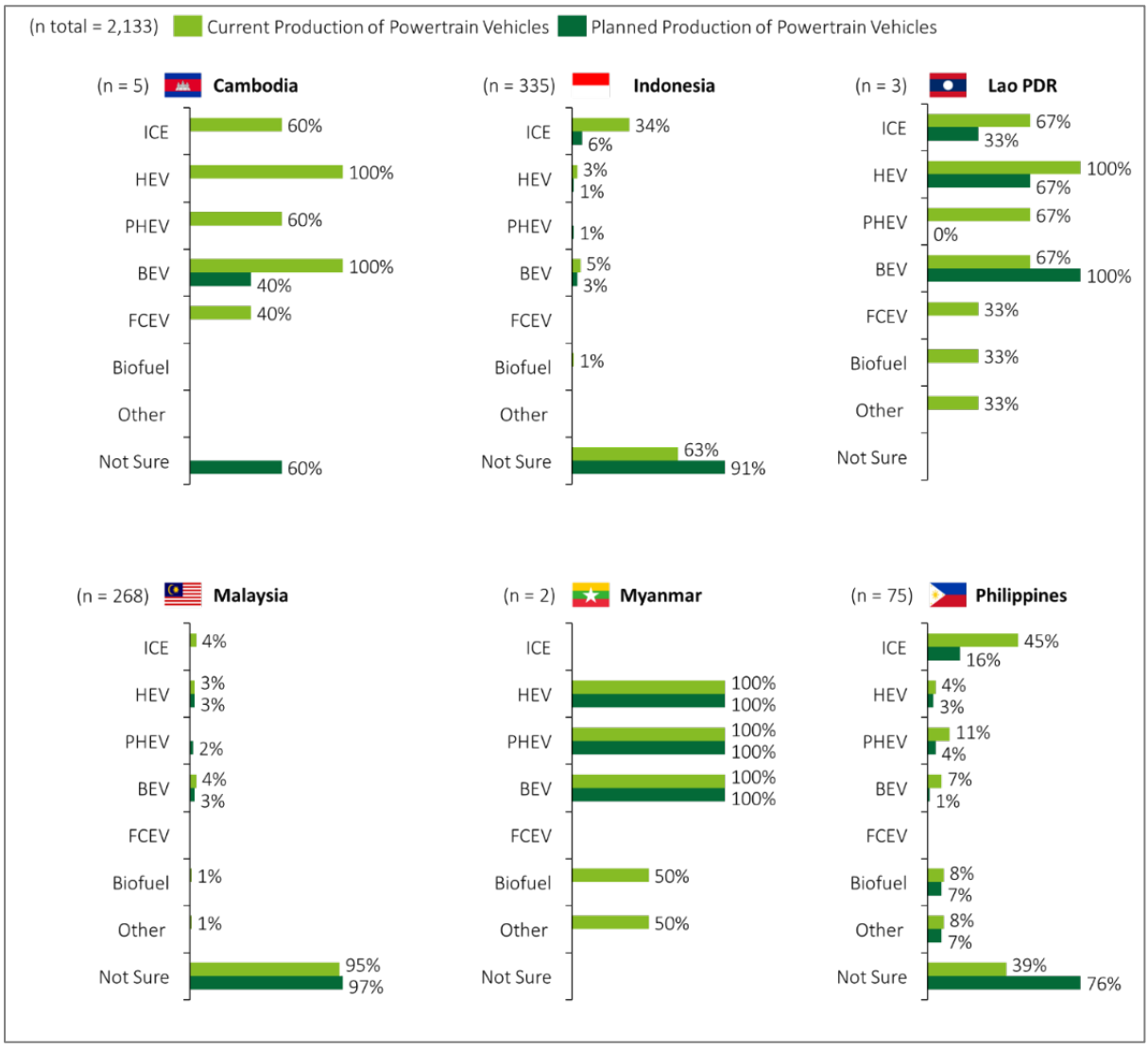
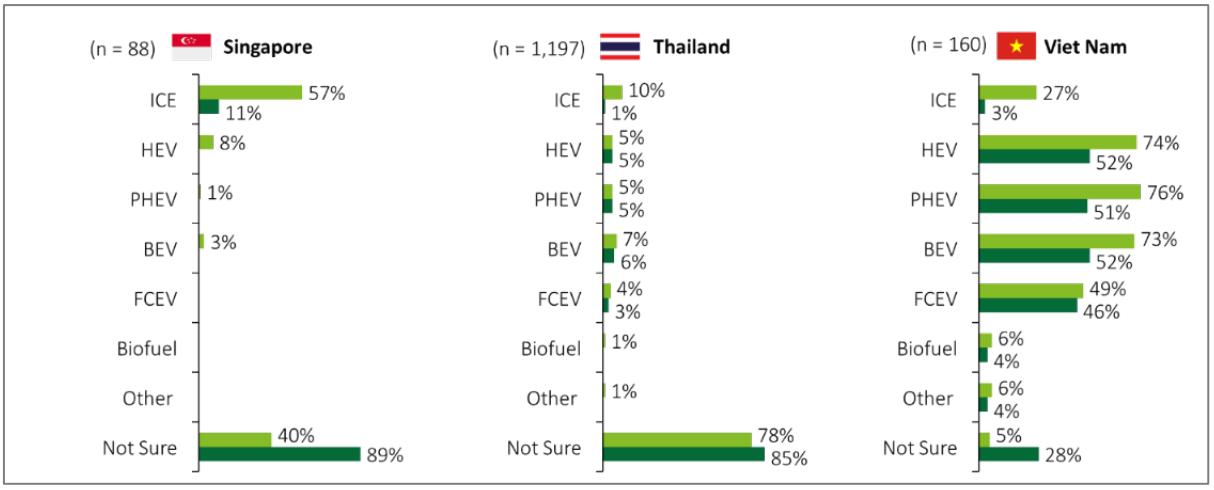


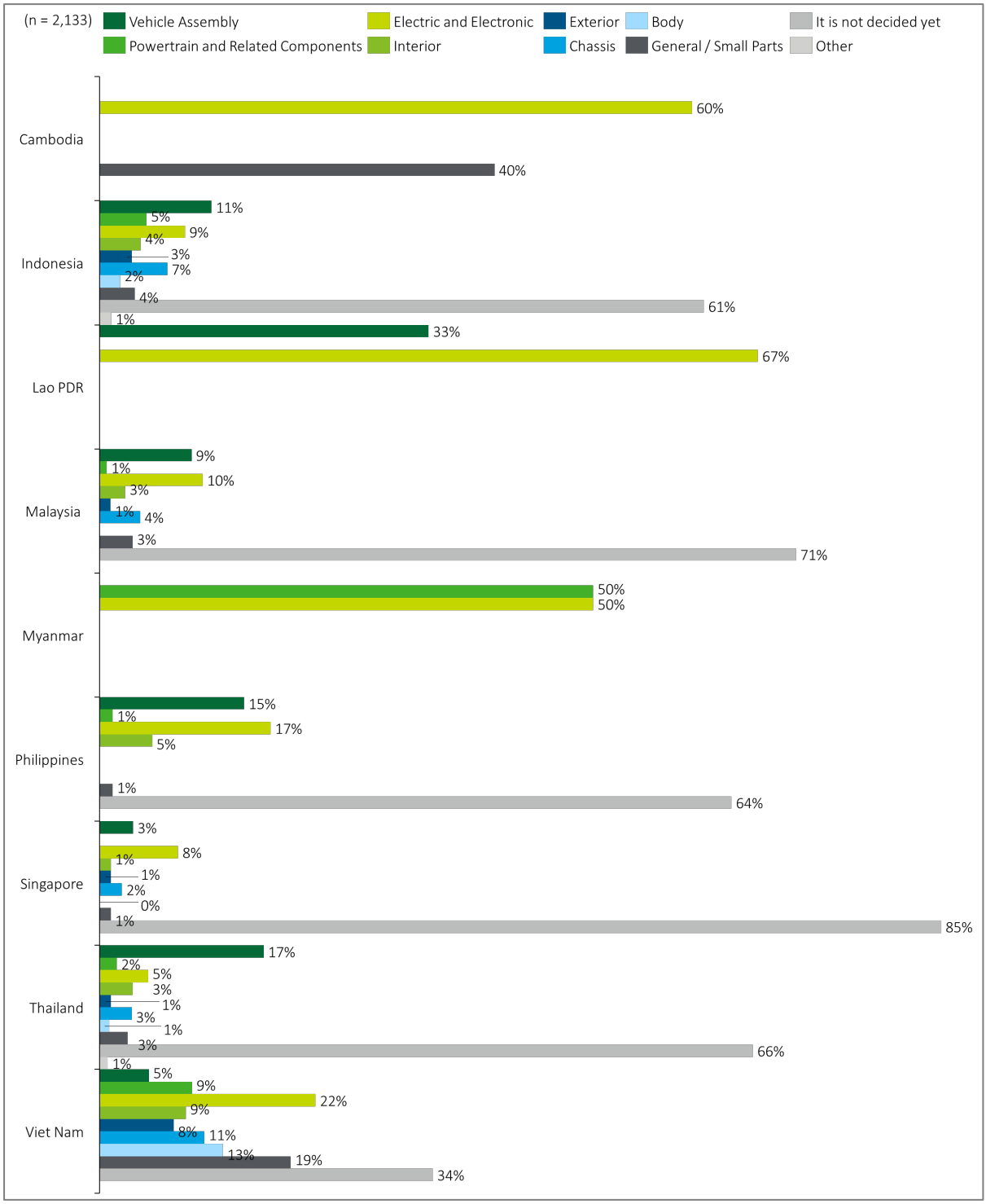
Figure 3.20. *Continued*



BEV = battery electric vehicle, FCEV = fuel cell electric vehicle, HEV = hybrid electric vehicle, ICE = internal combustion engine, Lao PDR = Lao People's Democratic Republic, PHEV = plug-in hybrid electric vehicle.
Note: Percentages of each row are calculated by dividing the total number of responses for each answer option in the columns by the total number of respondents in the corresponding row country. *(Q17_1: Considering the above prediction, which type of powertrain vehicles will your company focus on by 2035? [MULTIPLE CHOICE: choose all options that apply]).*
Source: Authors (2025).

Figure 3.21 shows the breakdown of product types that companies plan to develop by 2035. Consistent with previous findings, the majority of respondents, except those from Cambodia and Myanmar, have not yet determined which product types they will prioritise. Respondents from the latter countries indicated an intended focus on powertrain-related components as well as electric and electronic parts.

Figure 3.21. Breakdown of Product Types Planned for Production by 2035, by Country



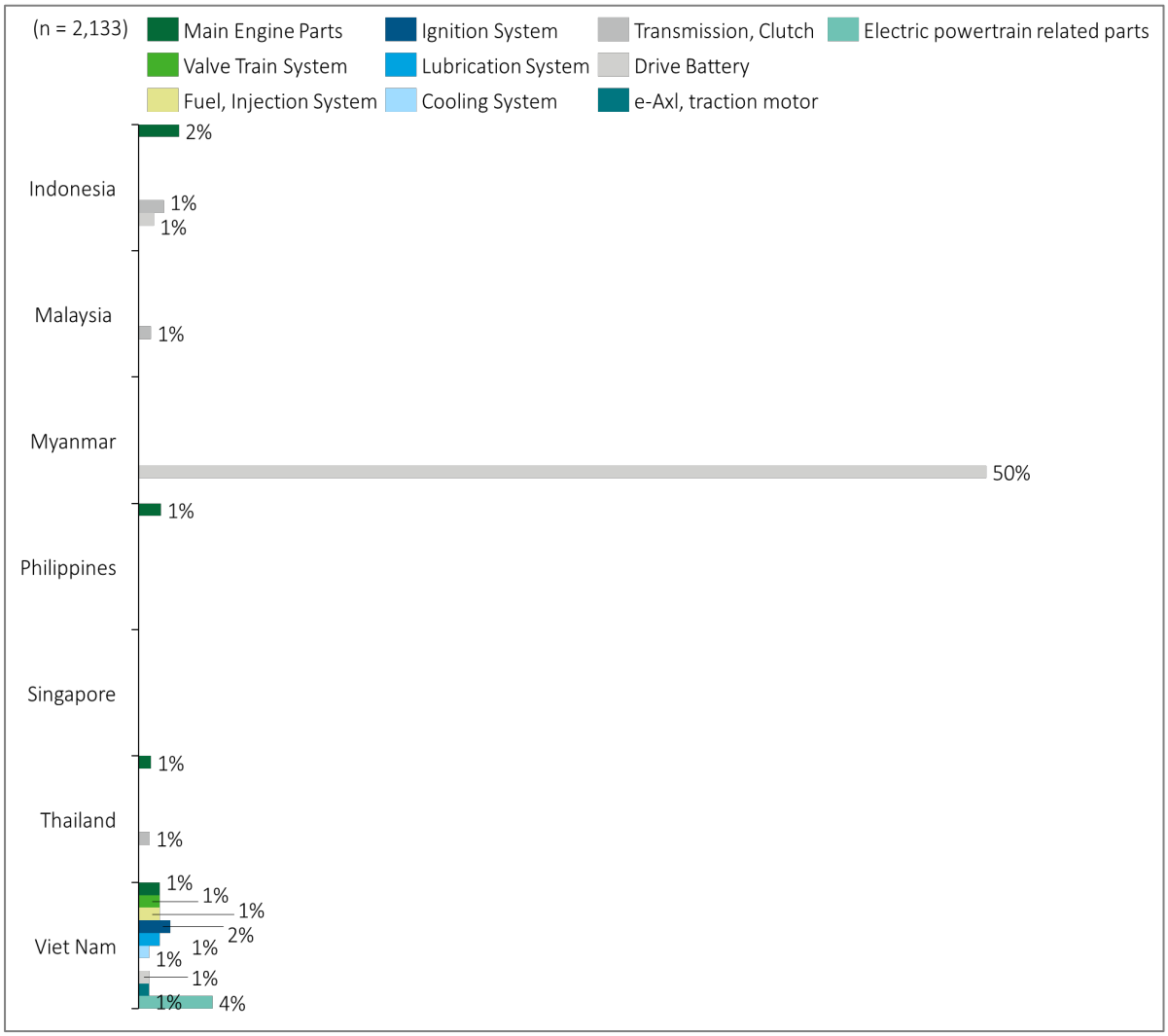
Lao PDR = Lao People's Democratic Republic.

Note: Data points with a value of 0% are not displayed to enhance clarity and readability. Percentages for each bar are calculated by dividing the total number of responses to each answer option by the total number of respondents within the corresponding country. *(Q18-1: Which products does your company plan to produce by 2035 (Choose up to a maximum of three)? [MULTIPLE CHOICE: choose all options that apply]).*

Source: Authors (2025).

Figure 3.22 presents the planned product types for powertrain and related companies by 2035. The results align with the current situation, indicating that companies intend to continue focusing primarily on main engine parts, followed by transmission and clutch components.

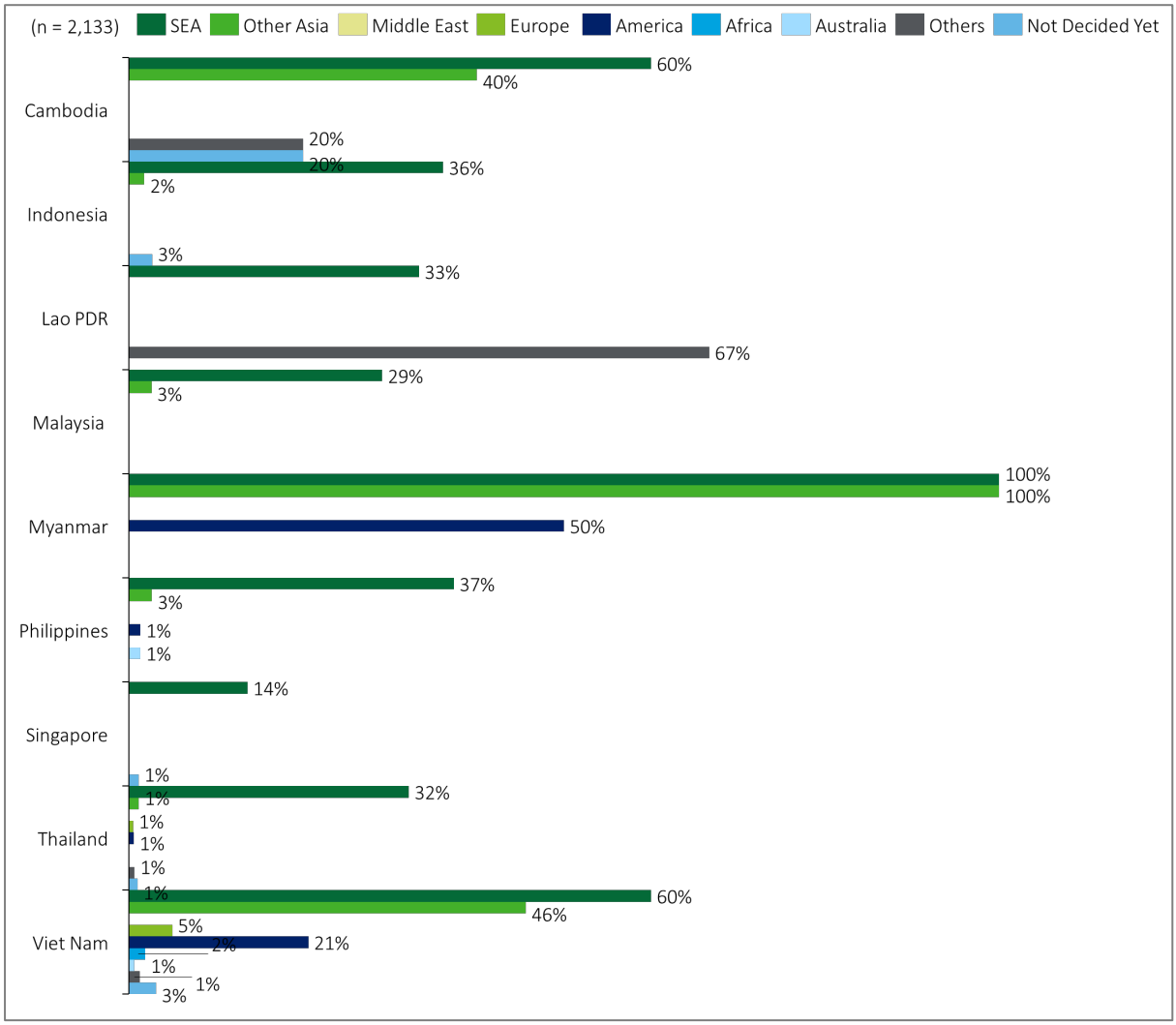
Figure 3.22. Breakdown of Product Types Planned for Powertrain and Related Companies, by Country



Lao PDR = Lao People's Democratic Republic.
Note: Data points with a value of 0% are not displayed to enhance clarity and readability. The term 'powertrain and related components' includes main engine parts, valve train systems, fuel systems, intake systems, ignition systems, lubrication systems, cooling systems, starters, transmissions, drive batteries, e-axles, electric powertrain-related components, and other associated items. No respondents indicated plans to produce intake systems or starters. No responses were recorded from Cambodia and Lao PDR. Percentages for each bar are calculated by dividing the total number of responses for each answer option by the total number of respondents within the corresponding country. *(Q18-2: If you selected 'Powertrain and related components', please specify which products your company plans to produce. (Choose up to a maximum of three)? [MULTIPLE CHOICE: choose all options that apply]).*
Source: Authors (2025).

Figure 3.23 shows the markets that companies plan to target for product distribution by 2035. Southeast Asia emerges as the primary target market, accounting for 34% of total companies across all countries, followed by other Asian markets at 5%.

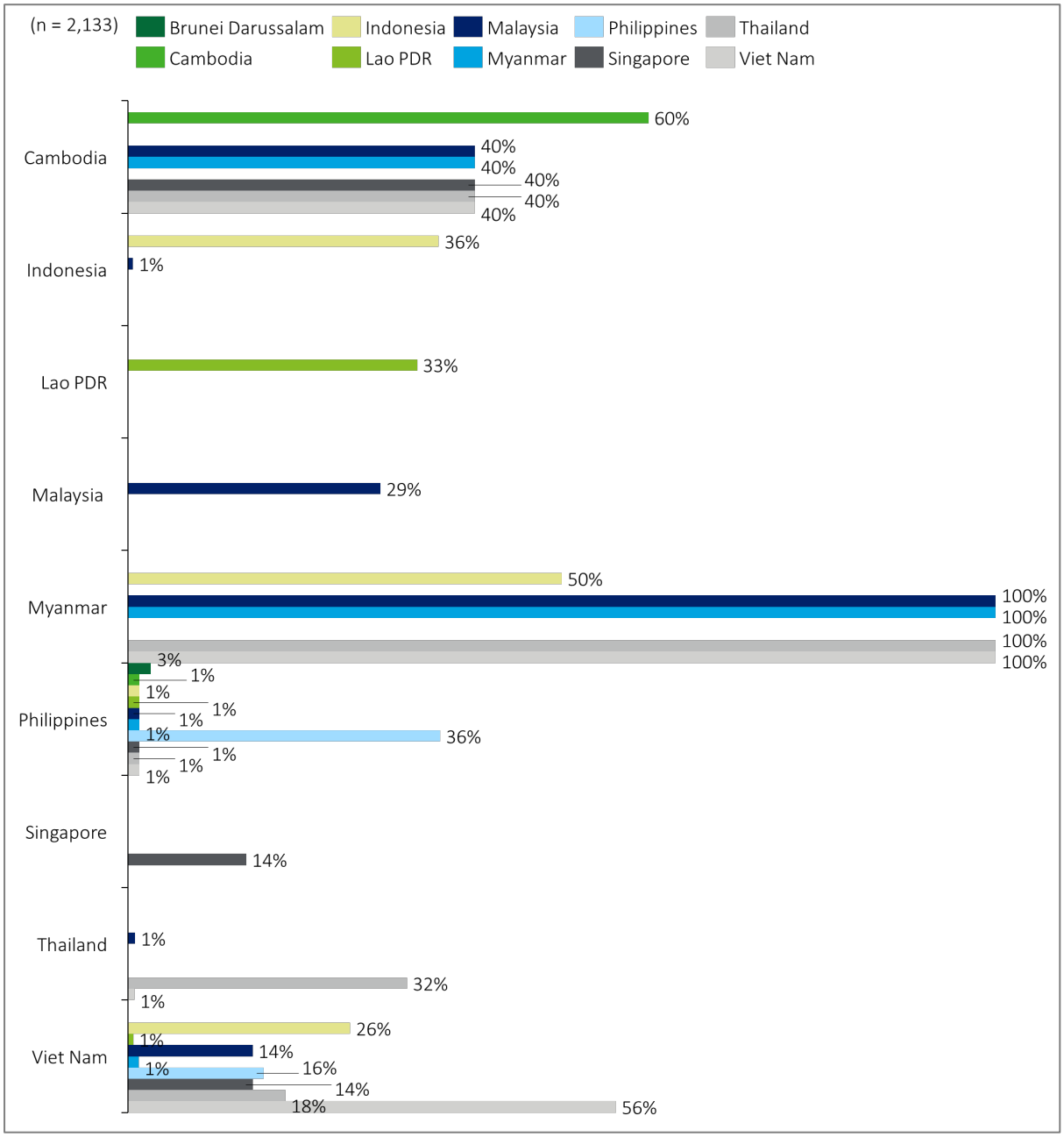
Figure 3.23. Markets Where Companies Intend to Distribute Supplies by 2035, by Country



Lao PDR = Lao People's Democratic Republic, SEA = Southeast Asia.
Note: Data points with a value of 0% are not displayed to enhance clarity and readability. The SEA region includes Brunei Darussalam, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Viet Nam. 'Other Asia' includes China, Hong Kong, Japan, the Republic of Korea, India, and other Asian economies. The 'America' includes the United States, Canada, Mexico, Central America, and South America, whilst 'Africa' includes Central and Middle Africa, East Africa, Northern Africa, Southern Africa, and Western Africa. Percentages for each bar are calculated by dividing the total number of responses to each answer option by the total number of respondents with the corresponding country. *(Q19-1: For each product selected on Q18-1 and Q18-2, please indicate the market(s) in which your company plans to offer each product. [MULTIPLE CHOICE: choose all options that apply]).*
Source: Authors (2025).

Figure 3.24 illustrates that within Southeast Asia, most respondents from Indonesia, Lao PDR, Malaysia, Singapore, and Thailand intend to prioritise domestic markets. By contrast, respondents from Cambodia, Myanmar, and Viet Nam plan to engage in cross-border supply, indicating an intention to export to other countries.

Figure 3.24. Breakdown of Future Supply Distribution within Southeast Asian Countries by 2035



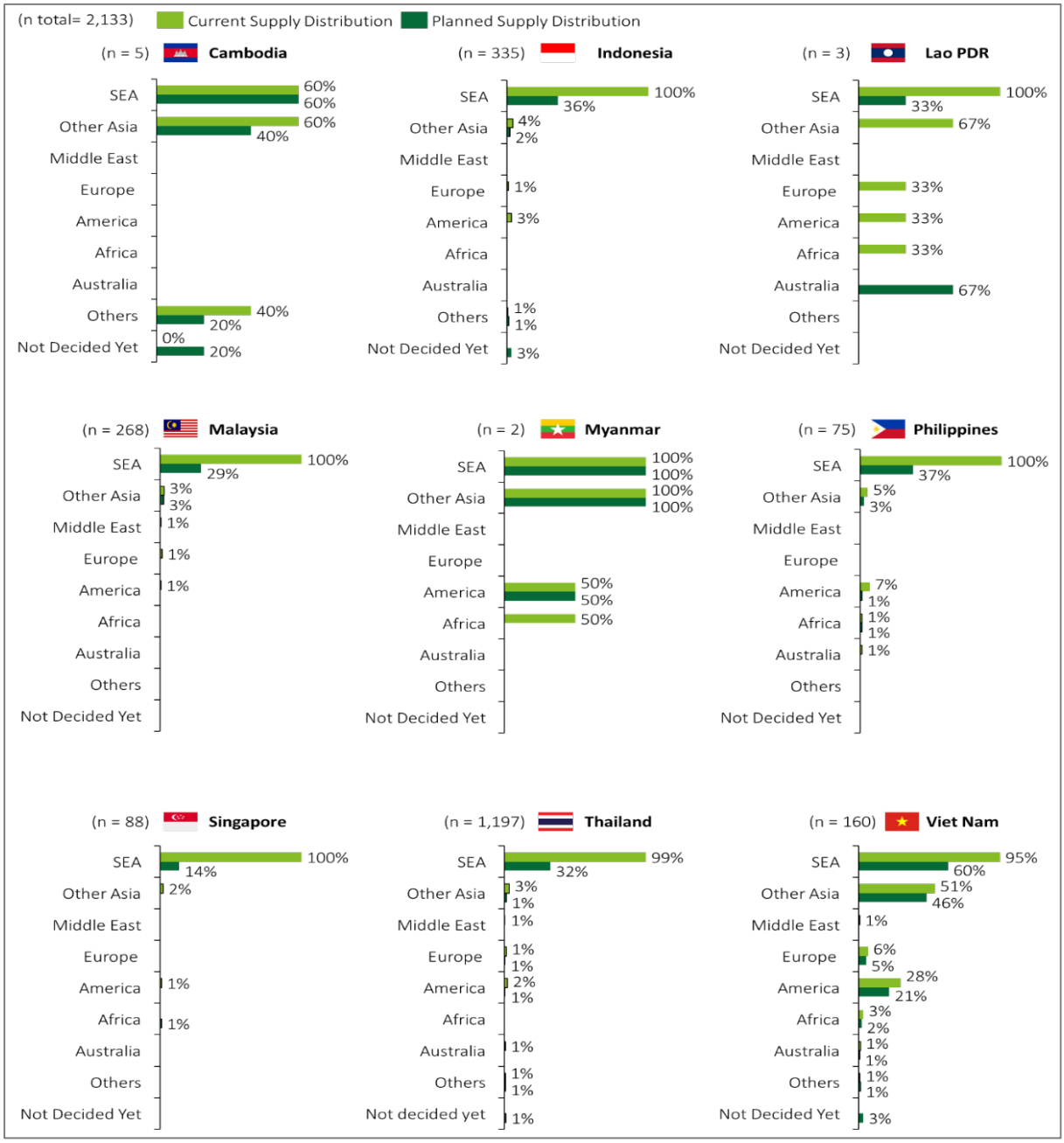
Lao PDR= Lao People's Democratic Republic.

Note: Data points with a value of 0% are not displayed to enhance clarity and readability. Percentages for each bar are calculated by dividing the total number of responses to each answer option by the total number of respondents within the corresponding country. *(Q19-1: For each product selected on Q18-1 and Q18-2, please provide the market your company plans to offer each product. [MULTIPLE CHOICE: choose all options that apply]).*

Source: Authors (2025).

Figure 3.25 compares current and planned supply distribution. Overall, no significant shift is observed, as Southeast Asia remains the main focus. Most countries continue to prioritise domestic supply, with the exception of Cambodia, Myanmar, and Viet Nam.

Figure 3.25. Current versus Planned Supply Distribution, by Country

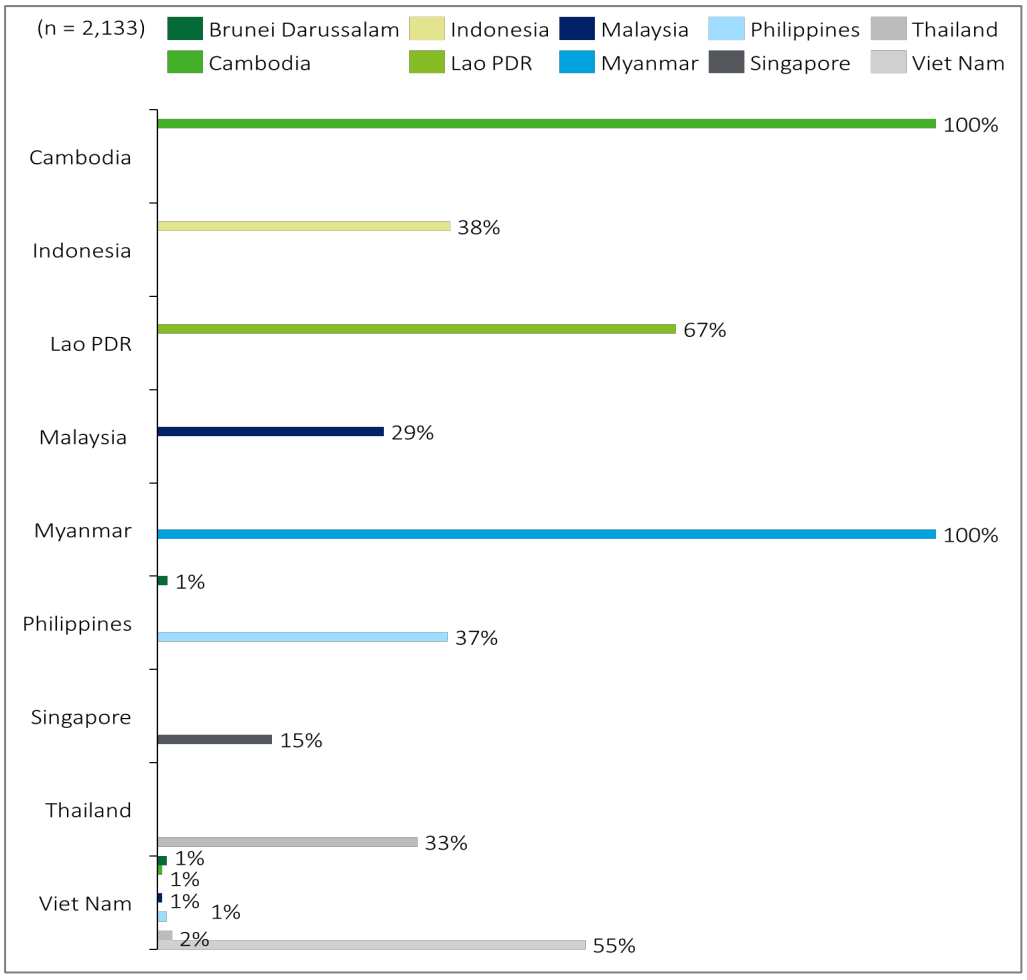


Lao PDR = Lao People's Democratic Republic, SEA = Southeast Asia.
Note: Percentages for each row are calculated by dividing the total number of respondents for each answer option in columns by the total number of respondents within the corresponding country. The data presented in the graph represent the regions in which companies currently offer, or plan to offer, their products. Regions outside the scope of each company's country are not included. *(Q19-1: For each product selected in Q18-1 and Q18-2, please indicate the market(s) in which your company plans to offer each product.[MULTIPLE CHOICE: choose all options that apply]).*
Source: Authors (2025).

Figure 3.26 shows the locations where companies plan to establish or expand their

manufacturing operations across Southeast Asia by 2035. Most respondents indicated an intention to maintain manufacturing operations within their own countries. This approach is supported by strong government incentives, such as Thailand's Eco-Car Scheme (United Nations Environment Programme, 2008) and Indonesia's low-cost green car policy (Centre for Digital Society, 2017), as well as robust domestic demand that must be effectively accommodated. Only a small number of respondents from the Philippines and Viet Nam reported plans to establish manufacturing facilities abroad. Overall, these plans reflect a continuation of the current situation, in which companies primarily operate manufacturing facilities domestically.

Figure 3.26. Breakdown of Planned Manufacturing Locations, by Country



Lao PDR = Lao People's Democratic Republic.
Note: Data points with a value of 0% are not displayed to enhance clarity and readability. The data reflect the number of companies from each country selecting each manufacturing location. A country may select multiple countries. Manufacturing location refers to both facilities that are currently operating and those planned for future operation. Percentages for each bar are calculated by dividing the total number of responses to each answer option by the total number of respondents within the corresponding country. *(Q20-1-C_1: For each product selected in Q18-1 and Q18-2, where does your company plan to manufacture these products? [MULTIPLE CHOICE: choose all options that apply]).*
Source: Authors (2025).

Figure 3.27 compares the current situation and the outlook for manufacturing locations by 2035. Overall, no significant shift is observed, with the notable exception of companies in Lao PDR, which plan to fully localise their manufacturing operations. This marks a change from the current situation, in which manufacturing activities are divided between Lao PDR and Thailand. This question received fewer responses, with only 36% of total respondents providing an answer.

Figure 3.27. Domestic versus Foreign Manufacturing: Current Situation and Outlook, by Country

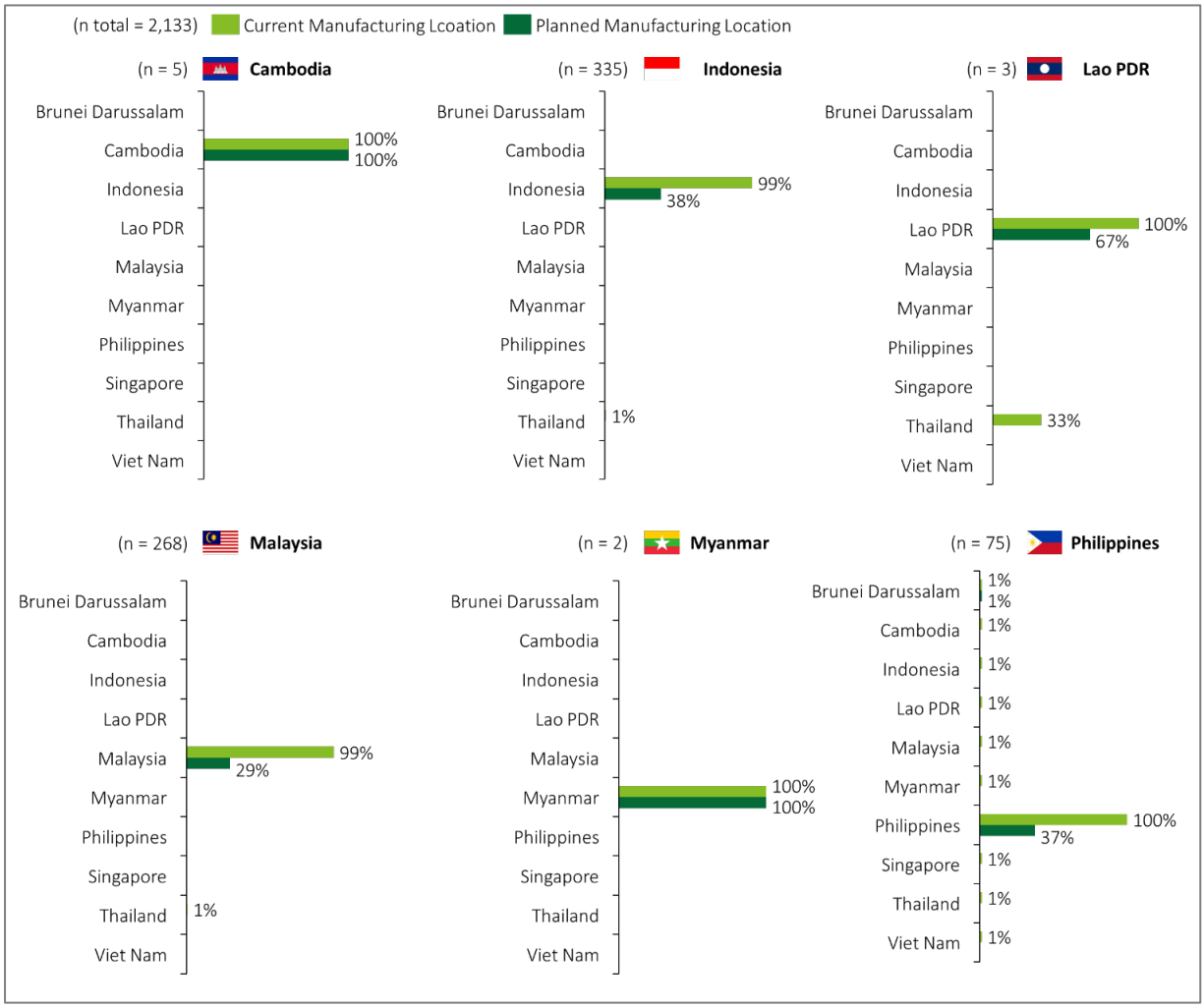
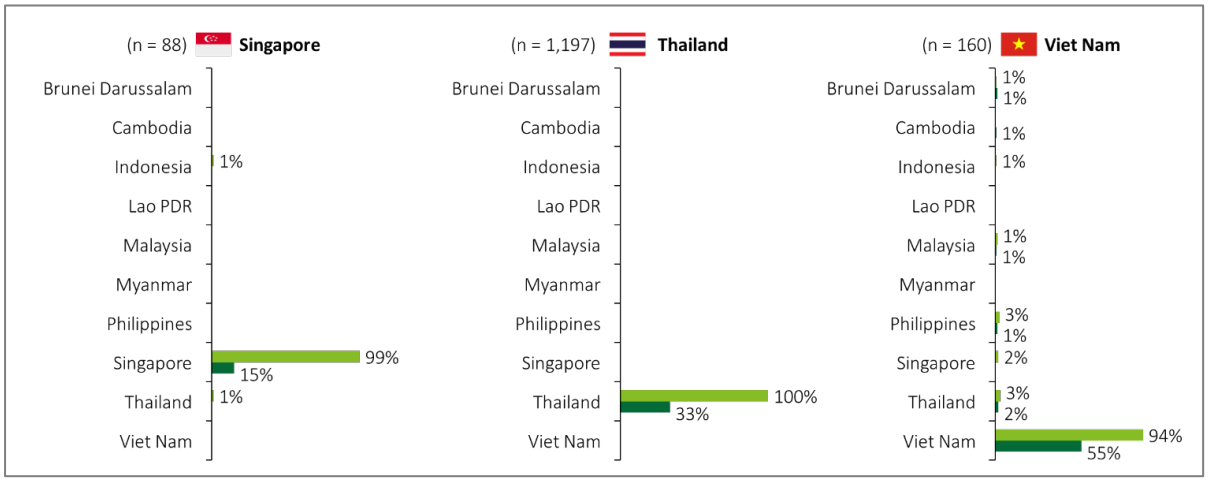


Figure 3.27. *Continued*

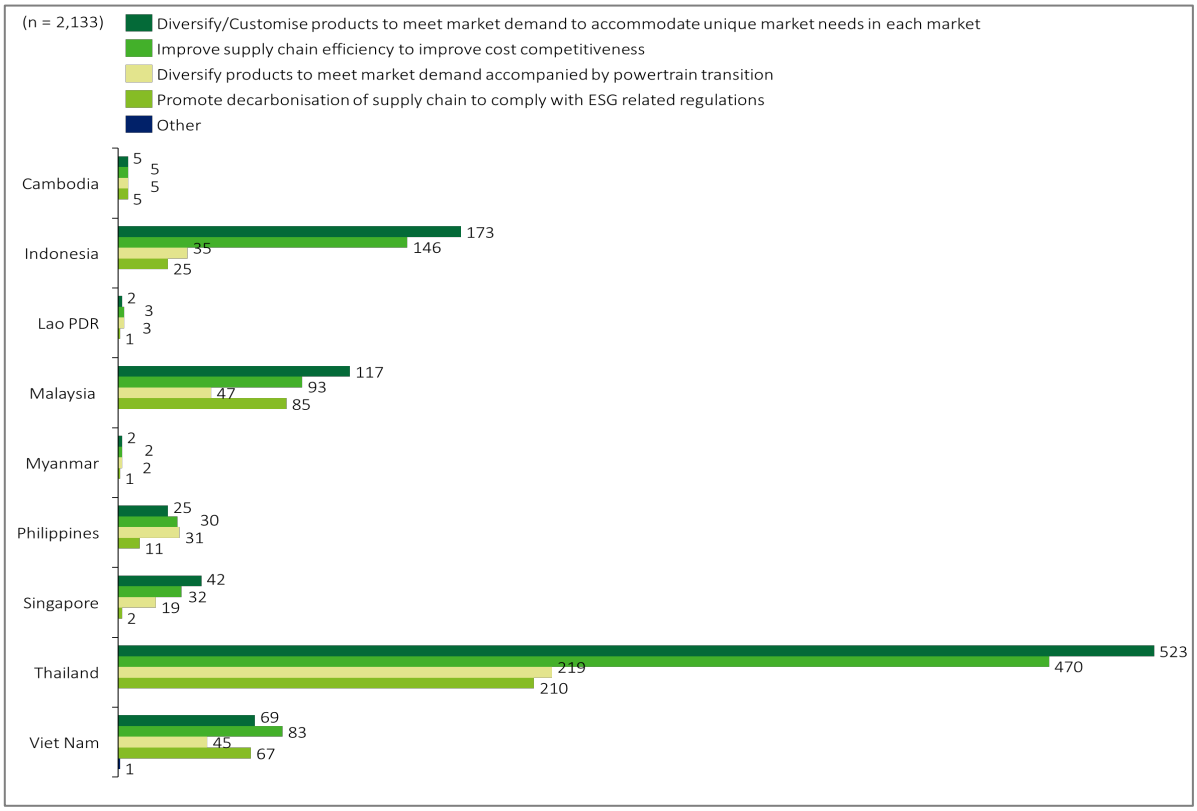


Note: Data points with a value of 0% are not displayed to enhance clarity and readability. Percentages for each row are calculated by dividing the total number of responses for each answer option in columns by the total number of respondents within the corresponding country. *(Q20-1-C_1: For each product selected in Q18-1 and Q18-2, where does your company plan to manufacture these products? [MULTIPLE CHOICE: choose all options that apply]).*
Source: Authors (2025).

3.2.4. Respondents' Companies' Strategic Planning

Figure 3.28 presents the breakdown of strategies that companies plan to implement by 2035. Product diversification to meet market demand is the most frequently selected strategy, with a total of 958 responses, driven primarily by companies in Indonesia and Thailand. This strategy is followed by efforts to improve supply chain efficiency, with 864 responses; decarbonisation of the supply chain to comply with environmental, social, and governance (ESG) requirements (407); and product diversification combined with powertrain transition (406). Strategic priorities vary across countries, reflecting different national targets and market conditions. Respondents from Indonesia, Malaysia, Singapore, and Thailand identified product diversification to accommodate unique market needs as their primary strategy. By contrast, respondents from Lao PDR and the Philippines emphasised both product diversification alongside powertrain transition and improvements in supply chain efficiency. Respondents from Viet Nam focused primarily on enhancing supply chain efficiency to boost cost competitiveness. Respondents from Myanmar highlighted product diversification alongside powertrain transition, supply chain efficiency, and product adaptation to meet unique market needs as their main strategic priorities.

Figure 3.28. Breakdown of Strategies Companies Plan to Implement by 2035, Based on Current Industry Trends, by Country



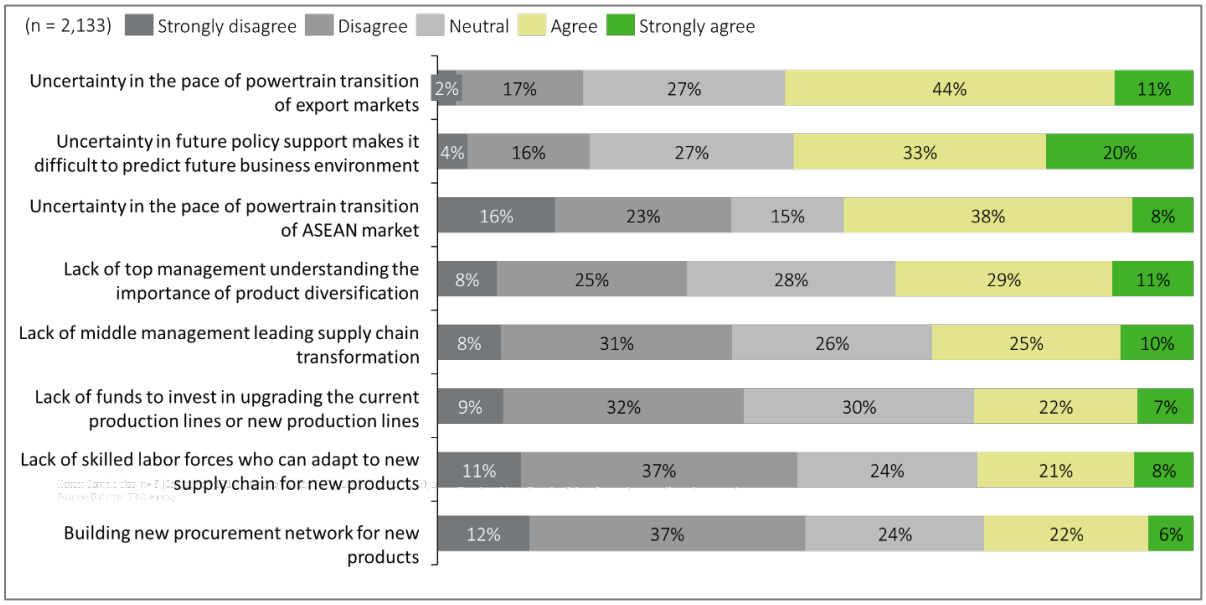
Lao PDR = Lao People's Democratic Republic.
Note: *(Q21_1: Considering current industry trends, what strategies does your company deem necessary to implement by 2035? [MULTIPLE CHOICE: choose all options that apply]).*
Source: Authors (2025).

3.2.4.1. Product diversiźcation amid powertrain transition

a. Challenges

Figure 3.29 presents the breakdown of challenges encountered in product diversification amid the ongoing powertrain transition. Most respondents (55% of total responses) identified uncertainty regarding the pace of the powertrain transition in export markets as the most significant challenge. This is followed by concerns over uncertainty in future policy support, which complicates the formulation of long-term business plans.

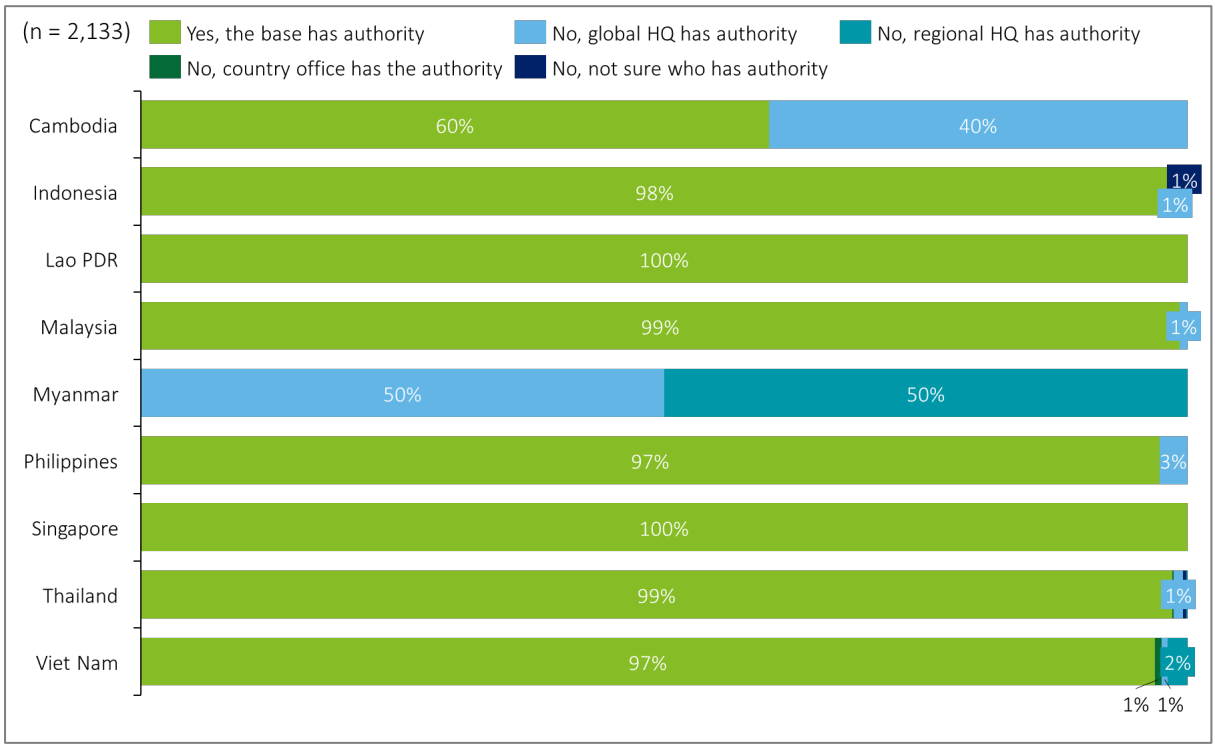
Figure 3.29. Breakdown of Challenges in Product Diversification Amid Powertrain Transition by 2035, by Country



Note: 54% of respondents identified 'uncertainty in future policy support' as the most significant challenge, as it hampers the ability to predict the future business environment; 52% cited 'uncertainty in the pace of powertrain transition in the ASEAN market' as a major challenge; 46% pointed to 'uncertainty in the pace of powertrain transition in export markets' as a key concern; 40% agreed that a 'lack of top management understanding the importance of product diversification' is a critical issue; 35% cite a 'lack of middle management capable of leading supply chain transformation' as a challenge; 29% highlighted both the 'lack of funds to invest in upgrading current or new production lines' and the 'lack of skilled labour able to adapt to new supply chains for new products'; 28% see 'building new procurement networks for new products' as a significant challenge. *(Q22-1_1: What will be the challenges for diversifying the products accompanied by powertrain transition by 2035? [SINGLE CHOICE: choose one option]).*
Source: Authors (2025).

Figure 3.30 shows that companies in all countries, except Myanmar, generally have the authority to make decisions and allocate investments to address challenges related to product diversification. In contrast, respondents from Myanmar reported having limited or no decision-making authority over actions and investments, as such decisions are predominantly made by global or regional headquarters.

Figure 3.30. Breakdown of Ultimate Decision-making Authority for Actions and Investments in Response to Product Diversification Challenges



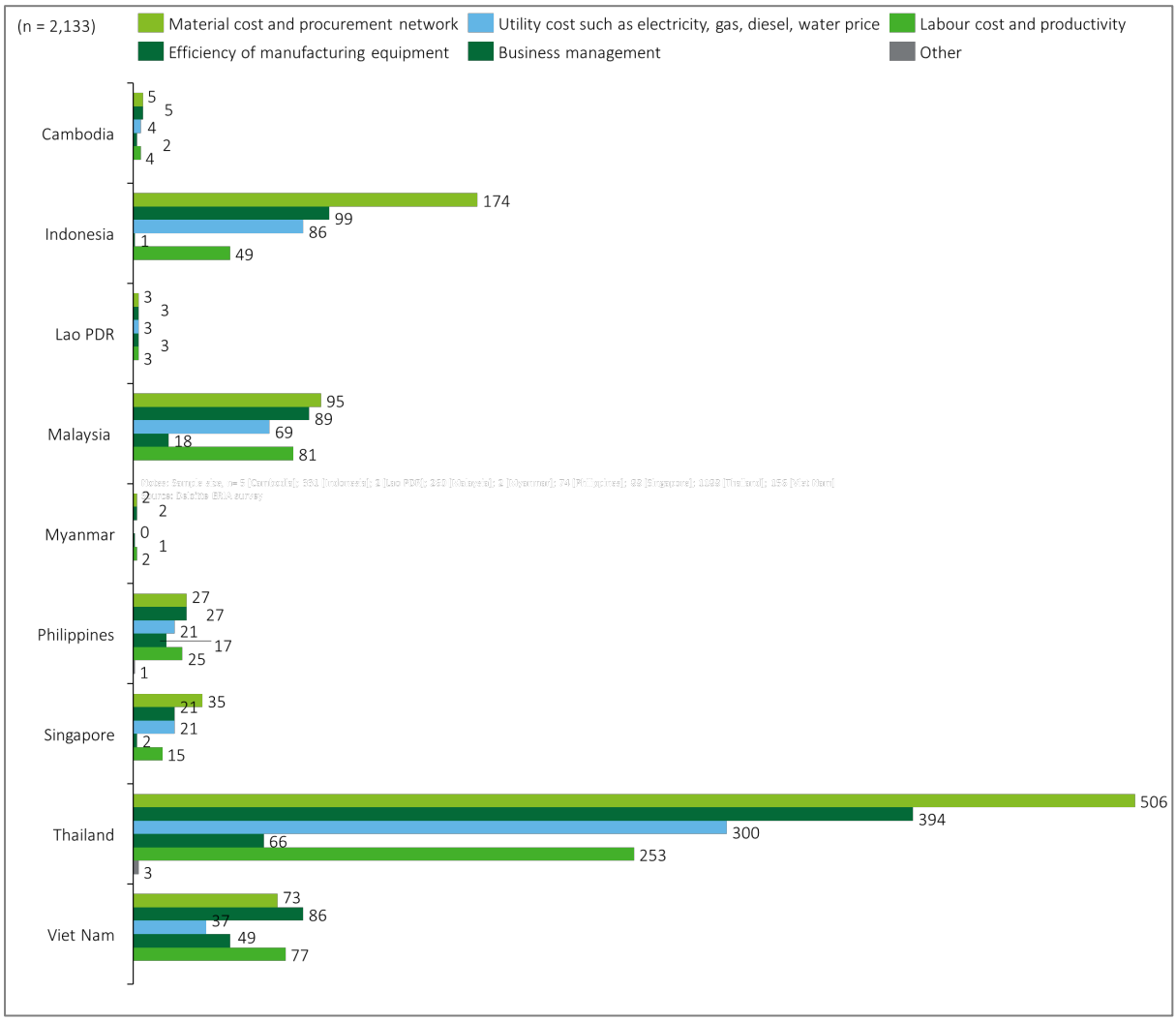
Lao PDR = Lao People's Democratic Republic.
Note: Base refers to the company location of the respondent. *(Q23-1: Does your base have the authority to decide on the course of action and investments for addressing these challenges? [SINGLE CHOICE: choose one option]); (Q23-2: If 'No', who is the ultimate decision-making office to address this challenge? [SINGLE CHOICE: choose one option].*
Source: Authors (2025).

3.2.4.2. Supply chain eij ciency

a. Critical supply chain factors

Figure 3.31 presents the critical factors identified by respondents for maintaining supply chain efficiency. Most respondents, particularly from Indonesia, Malaysia, Singapore, and Thailand, agreed that material costs and procurement channels are the most important factors, as they significantly influence the efficiency and effectiveness of supply processes. By contrast, respondents from Viet Nam primarily cited the efficiency of manufacturing equipment as the key driver, followed by material costs and procurement networks.

Figure 3.31. Breakdown of Critical Supply Chain Factors for Maintaining Supply Chain Efficiency by 2035, by Country



Note: (Q24_1: What will be the critical factors in your company's supply chain to maintain supply chain efficiency by 2035? [MULTIPLE CHOICE: choose all options that apply]).
Source: Authors (2025).

b. Challenges associated with each critical factor

Table 3.2 outlines the critical supply chain factors and the associated challenges faced by suppliers and OEMs. The main challenges, identified through expert interviews and supported by secondary sources, include shortages in personnel capability, high operational costs, and inadequate equipment maintenance of manufacturing equipment.

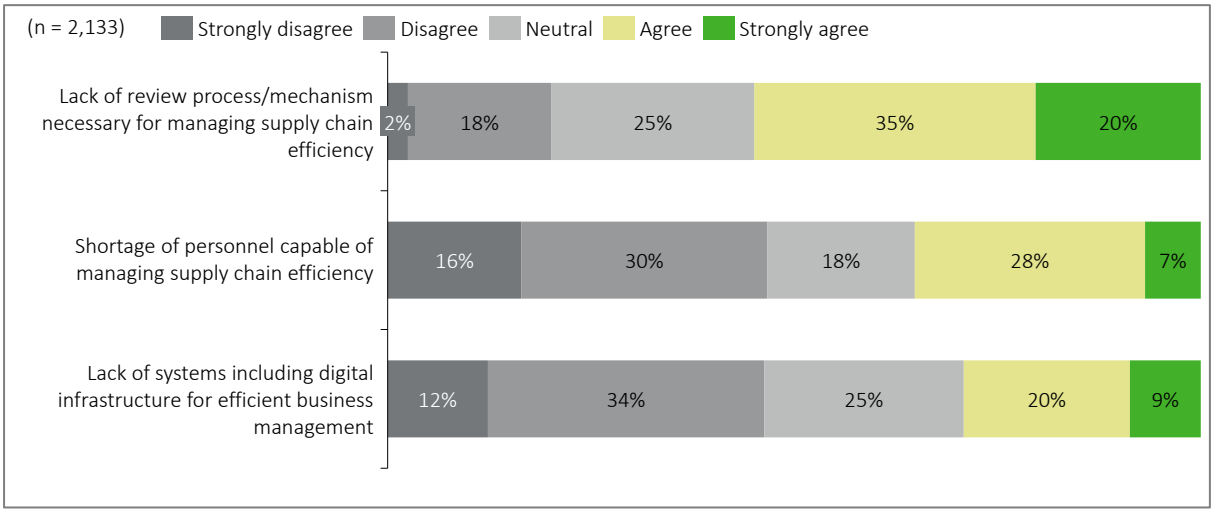
Table 3.2. Challenges Associated with Each Critical Supply Chain Factor

Critical Factors	List of Challenges
Business Management	Shortage of personnel capable of managing supply chain efficiency
	Lack of review processes or mechanisms necessary for managing supply chain efficiency
	Lack of systems, including digital infrastructure, for efficient business management
Labour Cost and Productivity	Rising labour costs
	Low labour productivity amongst blue-collar workers
	Low labour productivity amongst white-collar workers
	Lack of flexibility to adapt to new industry trends
Efficiency of Manufacturing Equipment	Deterioration in efficiency due to ageing equipment
	Low efficiency due to the limited utilisation of digital and new technologies
	Low product quality due to failure to adopt the latest equipment to meet evolving market needs
Material Cost and Procurement Network	Rising material costs associated with economic growth
	Rising material costs due to the arising geopolitical risks, such as the Ukraine crisis
	Rising material costs resulting from changes in sourcing locations and the replacement of suppliers
	Inability to procure materials and components required for the manufacturing process due to material shortages or the offshoring of suppliers
	Inability to procure materials and components that comply with ESG-related regulations and standards
Utility Cost	Inability to procure stable utilities due to inadequate infrastructure
	Inability to procure stable utilities due to geopolitical issues, such as the Ukraine crisis
	Inability to procure stable utilities due to the limited availability of renewable energy sources
	Inability to procure utilities at competitive prices due to dominant market structures
	Inability to procure utilities at competitive prices due to increases in fossil fuel prices
	Inability to procure utilities at competitive prices due to insufficient supplies of renewable energy sources and/or taxes on fossil fuels

Source: Authors (2025).

Figure 3.32 presents the breakdown of challenges related to business management. The most critical challenge identified is the lack of a review process, which is essential for effectively managing supply chain efficiency. This challenge was selected by all respondents (100%) from Cambodia, Lao PDR, and Myanmar, and by 50% of respondents from Indonesia, Malaysia, the Philippines, and Viet Nam.

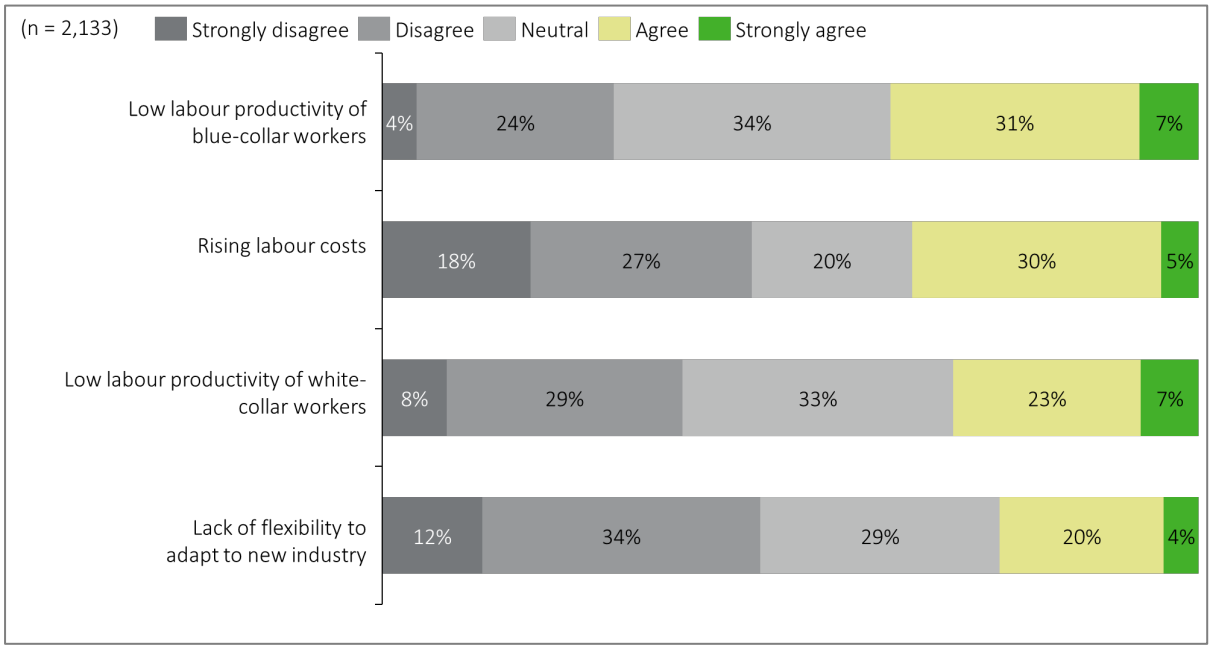
Figure 3.32. Breakdown of Respondents' Views on the Business Management Challenge



Note: Combining 'agree' and 'strongly agree' responses shows that 55% of respondents identified 'lack of review process' as the most significant challenge. A further 35% pointed to 'shortage of personnel capable of managing supply chain efficiency', whilst 29% identify 'lack of systems, including digital infrastructure' as a key concern. (Q25-1: Regarding Business Management, what will be the challenges by 2035? [MULTIPLE CHOICE: choose all options that apply]).
Source: Authors (2025).

Figure 3.33 presents respondents' perspectives on challenges related to labour costs and productivity. Low labour productivity amongst blue-collar workers was identified as the most critical challenge by respondents from all countries. This view was particularly pronounced in Cambodia, Lao PDR, and Myanmar, where 100% of respondents highlighted this issue.

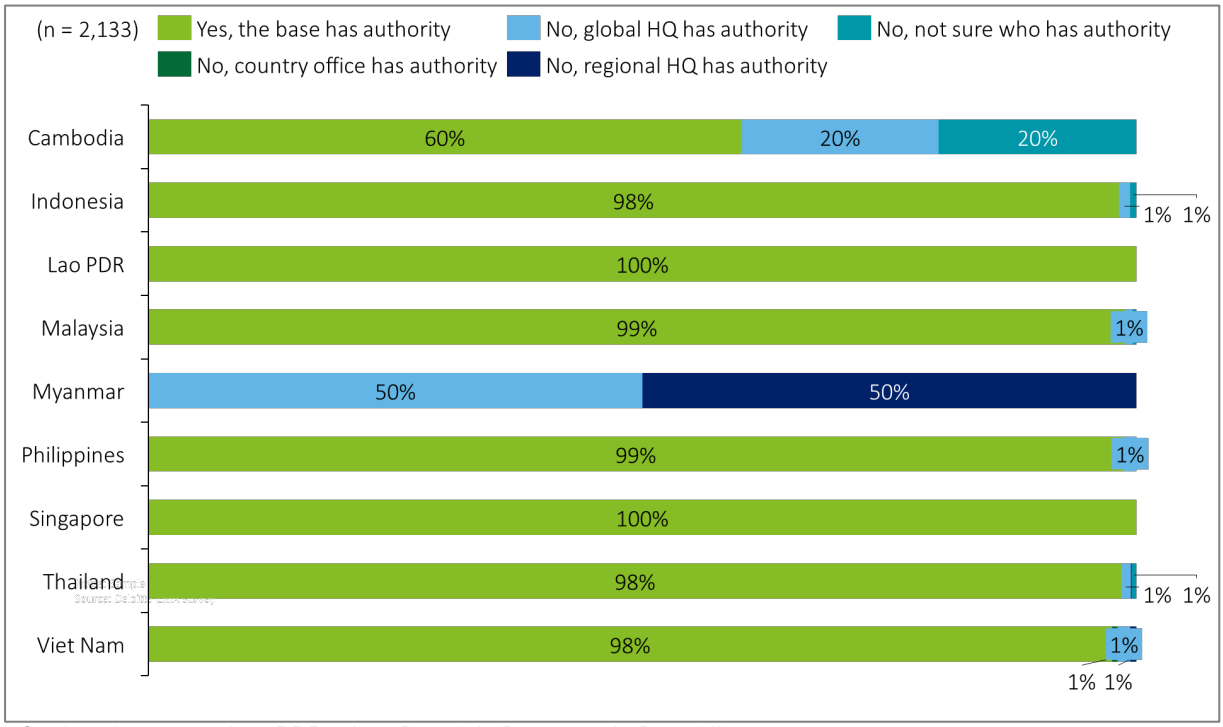
Figure 3.33. Breakdown of Respondents' Views on the Labour Cost and Productivity Challenge



Note: Combining 'agree' and 'strongly agree' responses shows that 38% of respondents identified 'low labour productivity of blue-collar factory workers' as the most significant challenge. A further 35% cited 'rising labour cost', whilst 30% identified 'lack of systems including digital infrastructure', as a key concern. ('Q26-1: Regarding labor cost and labor productivity, what will be the challenges by 2035?' [MULTIPLE CHOICE: choose all options that apply]).
Source: Authors (2025).

Figure 3.34 shows the distribution of ultimate decision-making authority over actions and investments to address labour cost and productivity challenges. Over 95% of respondents from Indonesia, Lao PDR, Malaysia, the Philippines, Singapore, Thailand, and Viet Nam indicated that this authority resides within their local operations. By contrast, all respondents from Myanmar (100%) reported that they lack such authority, whilst 40% of respondents from Cambodia also indicated an absence of local decision-making authority.

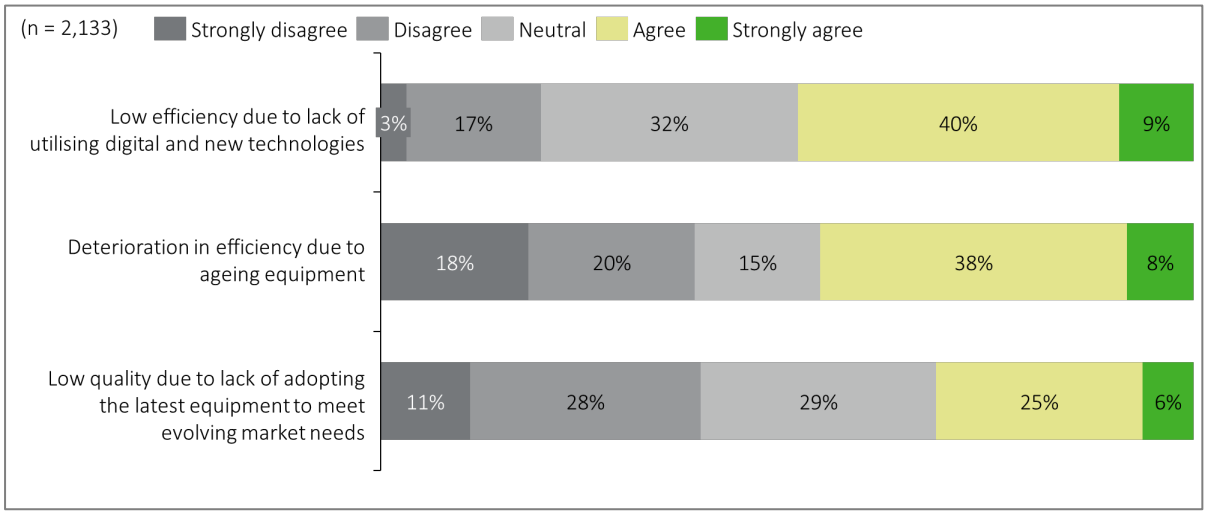
Figure 3.34. Breakdown of Ultimate Decision-making Authority for Actions and Investments in Response to Labour Cost and Productivity Challenges



HQ = headquarters, Lao PDR = Lao People's Democratic Republic.
Note: Base refers to the company location of the respondent. *(Q 27-1: Does your base have the authority to decide on the course of action and investments for addressing these challenges?); (Q28-2: If 'no', Who is the ultimate decision-making office to address this challenge? [SINGLE CHOICE: choose one option]).*
Source: Authors (2025).

Figure 3.35 presents the breakdown of challenges related to manufacturing equipment efficiency. The lack of utilisation of digital and advanced technologies was identified as the most significant challenge, cited by 49% of total respondents.

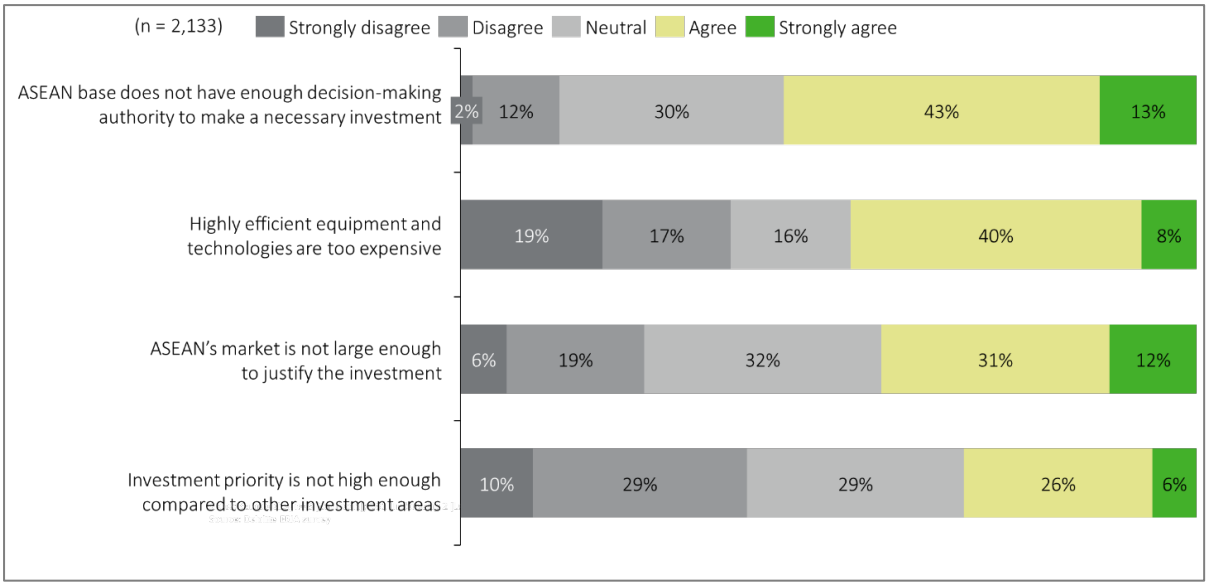
Figure 3.35. Breakdown of Respondents' Views on the Efficiency of Manufacturing Equipment Challenge



Note: Combining 'agree' and 'strongly agree' responses shows that 49% of respondents identified 'low efficiency due to lack of digital utilization' as the most significant challenge. A further 46% pointed to 'deterioration in efficiency due to ageing equipment' as a major challenge, whilst 31% identified 'low quality due to lack of adopting the latest equipment to meet evolving market needs' as a key concern. *(Q28 -1: Regarding manufacturing equipment, what will be the challenges by 2035? [SINGLE CHOICE: choose one option])*
Source: Authors (2025).

Figure 3.36 presents the breakdown of challenges related to manufacturing equipment upgrade. The lack of decision-making authority to undertake necessary investments was identified as the main challenge, cited by 56% of total respondents.

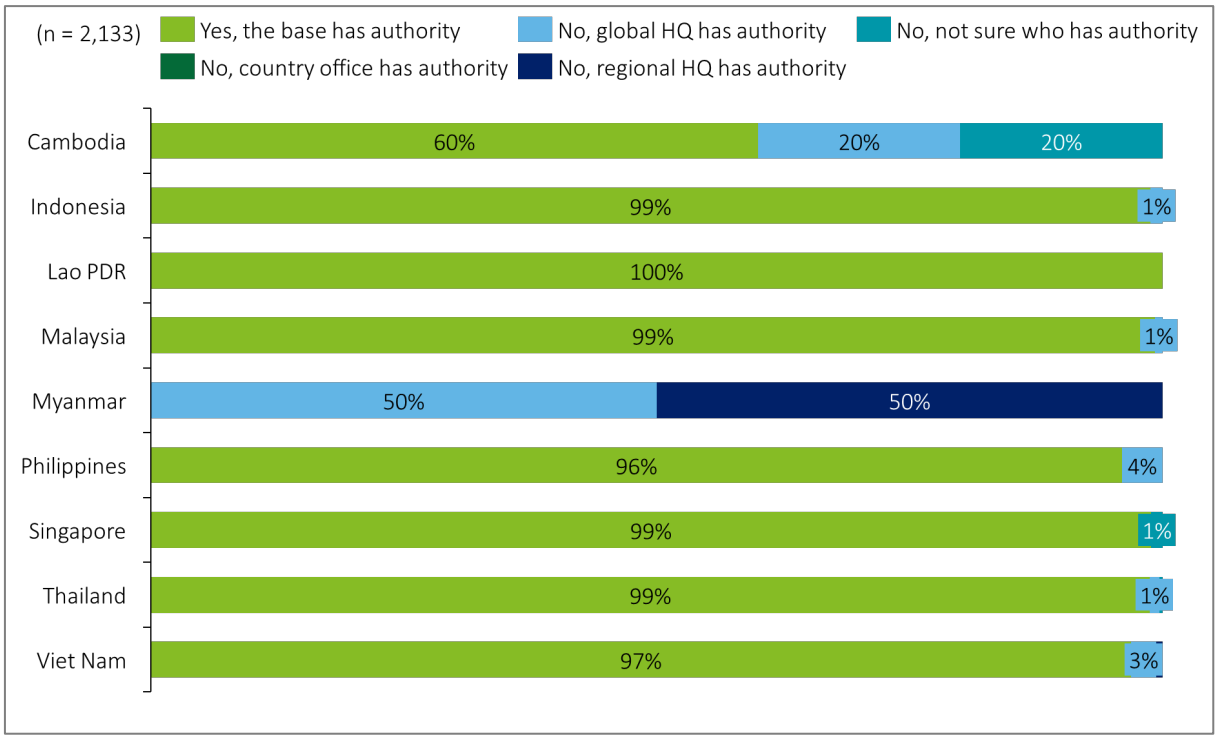
Figure 3.36. Breakdown of Respondents' Views on the Manufacturing Equipment Upgrade Challenge



Note: Combining 'agree' and 'strongly agree' responses shows that 56% of respondents identified 'ASEAN base does not have enough decision-making authority to make a necessary investment' as the most significant challenge. In addition, 48% pointed to 'highly efficient equipment and techs are too expensive' as a major challenge, whilst 43% identified 'ASEAN's market is not large enough to justify the investment' as a key concern. *(Q29 -1 What will be the challenges for upgrading the manufacturing equipment by 2035? [SINGLE CHOICE: choose one option]).*
Source: Authors (2025).

Figure 3.37 shows the distribution of ultimate decision-making authority over actions and investments to address manufacturing equipment upgrade challenges. More than 95% of respondents from Indonesia, Lao PDR, Malaysia, the Philippines, Singapore, Thailand, and Viet Nam reported that such authority resides within their local operations. Conversely, all respondents from Myanmar (100%) reported that they lack this authority, whilst 40% of respondents from Cambodia also indicated an absence of local decision-making authority.

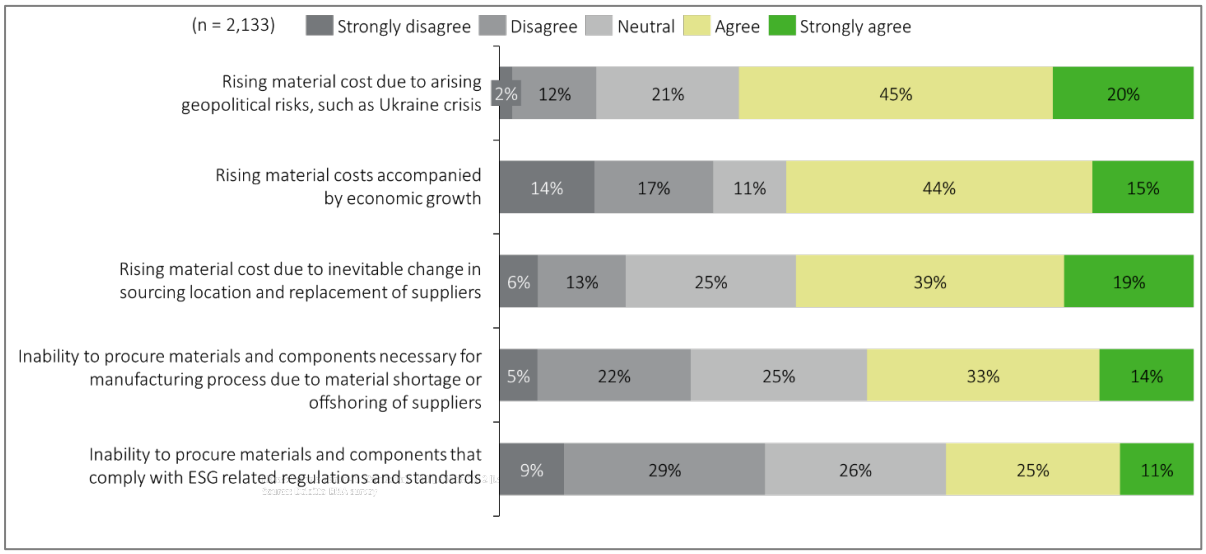
Figure 3.37. Breakdown of Ultimate Decision-making Authority for Actions and Investments in Response to Manufacturing Equipment Upgrade Challenges



HQ = headquarters, Lao PDR = Lao People's Democratic Republic.
Note: Base refers to the company location of the respondent. *(Q30-1: Does your base have the authority to decide on the course of actions and investments for addressing these challenges? [SINGLE CHOICE: choose one option]); (Q30-2: If 'no', Who is the ultimate decision-making office to address this challenge? [SINGLE CHOICE: choose one option]).*
Source: Authors (2025).

Figure 3.38 presents the breakdown of challenges related to material costs and procurement networks. Geopolitical risks, such as the Ukraine crisis, emerged as the most significant challenge, contributing to rising material costs. Respondents generally viewed this as a short-term challenge, which is expected to ease within a relatively limited timeframe.

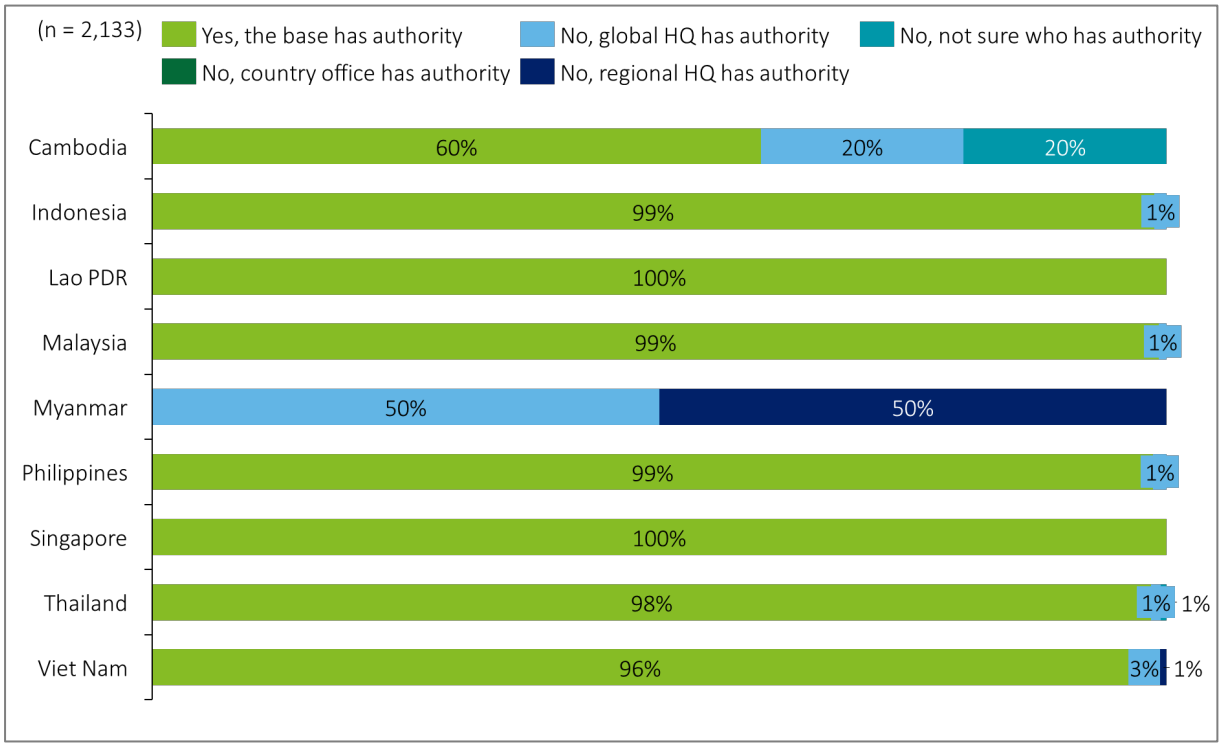
Figure 3.38. Breakdown of Respondents' Views on the Material Cost and Procurement Network Challenge



Note: Combining 'agree' and 'strongly agree' responses shows that 65% of respondents identified 'rising material cost due to arising geopolitical risks' as the most significant challenge. A further 59% pointed to 'rising material cost accompanied by economic growth' as a major challenge, whilst 58% identified 'rising material cost due to inevitable change in sourcing location and replacement of suppliers' as a key concern. In addition, 47% agreed that 'unable to procure materials and components necessary for manufacturing process due to material shortage or offshoring of suppliers' is a critical issue, whilst 36% cited 'unable to procure material and components that comply with [environmental, social, and governance] ESG-related regulations and standards' as a challenge. *(Q31-1: Regarding material cost and procurement network, what will be the challenges by 2035? [SINGLE CHOICE: choose one option]).*
Source: Authors (2025).

Figure 3.39 presents the ultimate decision-making authority for actions and investments in response to challenges related to material costs and procurement networks. More than 95% of respondents from Indonesia, Lao PDR, Malaysia, the Philippines, Singapore, Thailand, and Viet Nam reported that this decision-making authority resides within their local operations. By contrast, all respondents from Myanmar (100%) indicated that they do not hold such authority, whilst 40% of respondents from Cambodia also reported a lack of decision-making authority.

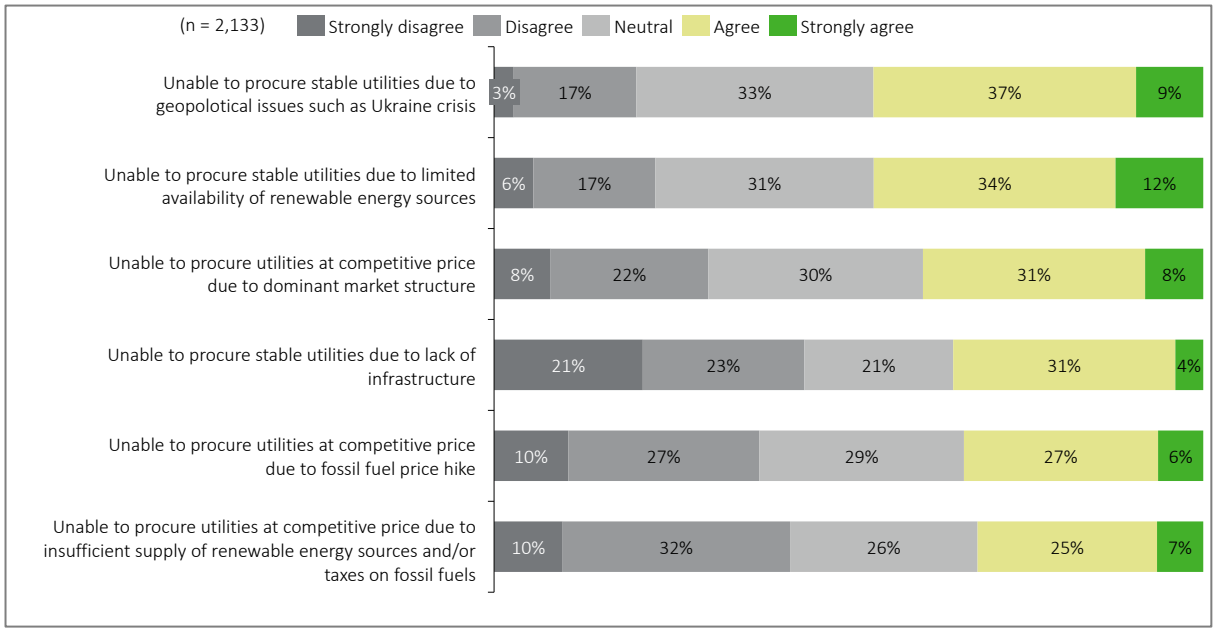
Figure 3.39. Breakdown of Ultimate Decision-making Authority for Actions and Investments in Response to Material Cost and Procurement Network Challenges



HQ = headquarters, Lao PDR = Lao People's Democratic Republic.
Note: Base refers to the company location of the respondent. *(Q32-1: Does your base have the authority to decide on the course of actions and investments for addressing these challenges? [SINGLE CHOICE: choose one option]); (Q32-2: Who is the ultimate decision-making office to address this challenge? [SINGLE CHOICE: choose one option]).*
Source: Authors (2025).

Figure 3.40 presents the breakdown of challenges related to utility costs. Geopolitical risks, such as the Ukraine crisis, have been identified as the most significant challenge, as they lead to difficulties in securing stable utility supplies. However, respondents generally regard this issue as a short-term challenge that is expected to be resolved within a relatively short timeframe.

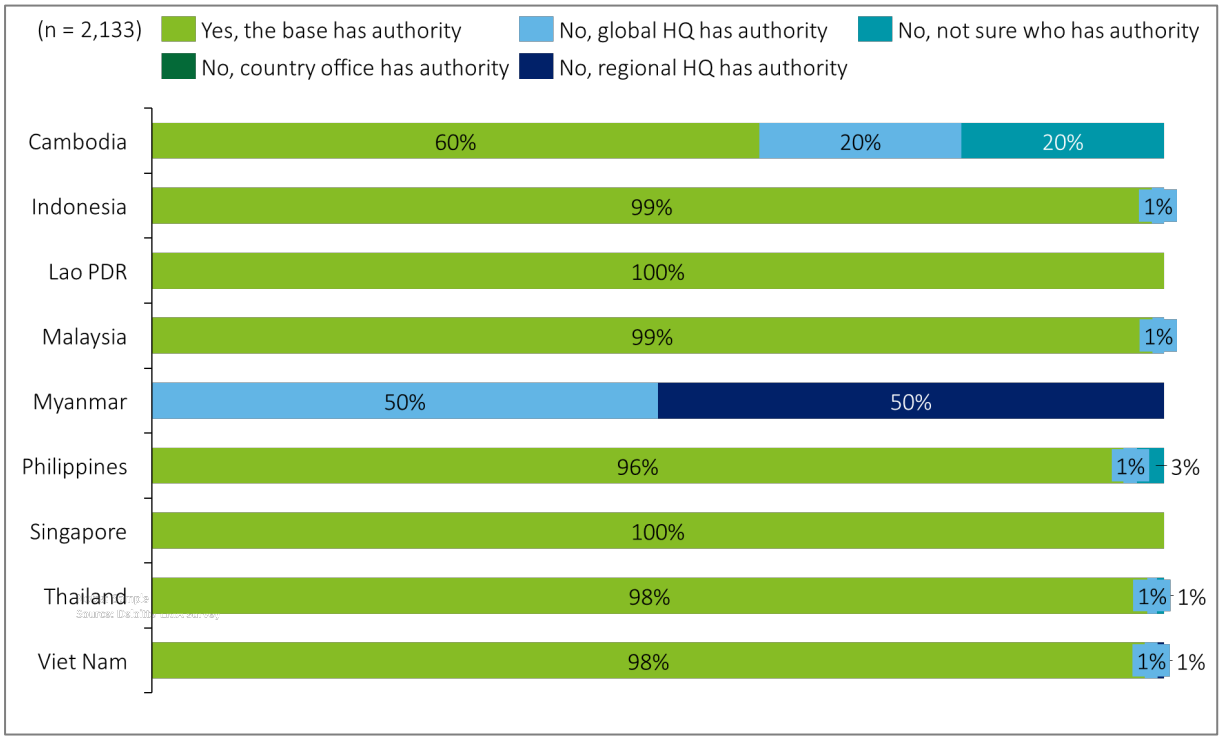
Figure 3.40. Breakdown of Respondents' Views on the Utility Cost Challenge



Note: Combining 'agree' and 'strongly agree' responses shows that 46% of respondents indicated that 'unable to procure stable utilities due to geopolitical issues such as the Ukraine crisis' is the most significant challenge. A further 46% pointed to 'unable to procure stable utilities due to limited availability of renewable energy sources' as a major challenge. In addition, 39% identified 'unable to procure utilities at competitive price due to dominant market structure' as a key concern, whilst 35% agreed that 'unable to procure stable utilities due to lack of infrastructure' is a critical issue. Moreover, 33% cites 'unable to procure utilities at competitive price due to fossil fuel price hike' as a challenge, and 32% agreed that 'unable to procure utilities at competitive price due to insufficient supply of renewable energy sources and/or taxes on fossil fuels' was a critical challenge**.** *(Q33-1: Regarding utility cost, what will be the challenges by 2035? [SINGLE CHOICE: choose one option]).*
Source: Authors (2025).

Figure 3.41 presents the ultimate decision-making authority for actions and investments undertaken in response to challenges related to utility cost. Most respondents from Indonesia, Lao PDR, Malaysia, the Philippines, Singapore, Thailand, and Viet Nam reported that this decision-making authority resides within their local operations. By contrast, all respondents from Myanmar (100%) indicated they do not hold such authority, whilst 40% of respondents from Cambodia also reported a lack of decision-making authority.

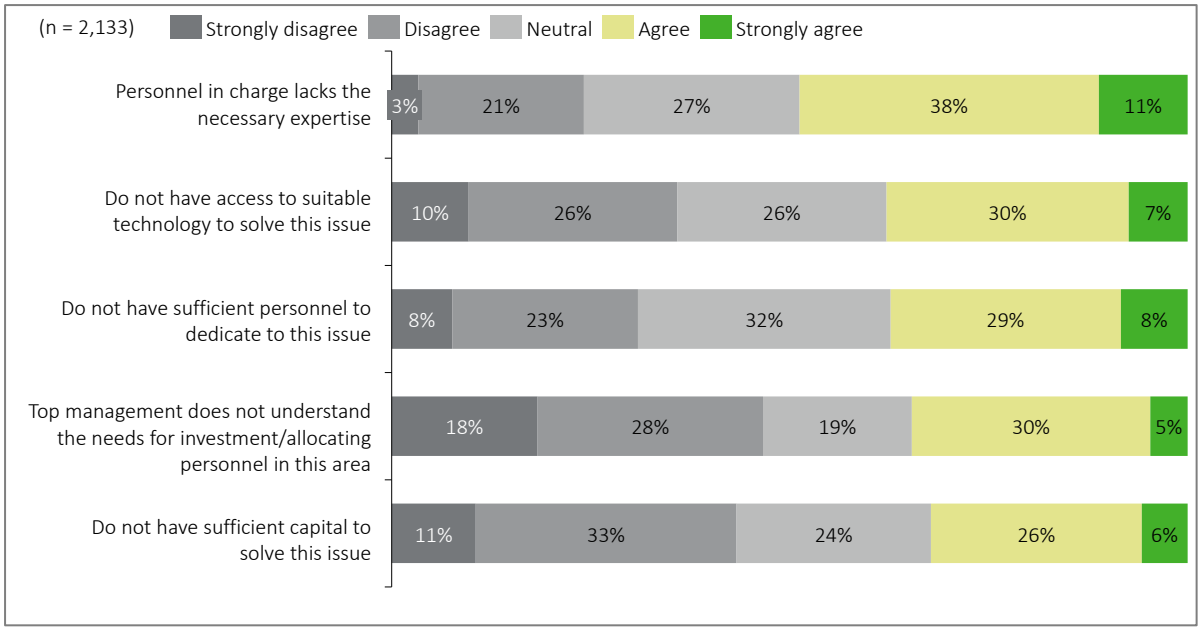
Figure 3.41. Distribution of Ultimate Decision-making Authority for Actions and Investments in Response to Utility Cost Challenges



HQ = headquarters, Lao PDR = Lao People's Democratic Republic.
Note: Base refers to the company location of the respondent. *(Q34-1: Does your base have the authority to decide on the course of actions and investments for addressing these challenges? [SINGLE CHOICE: choose one option]); (Q34-2: Who is the ultimate decision-making office to address this challenge?).*
Source: Authors (2025).

Figure 3.42 presents the distribution of additional challenges affecting the current supply chain. A notable challenge identified is the lack of specialised skills amongst personnel in charge, indicating an area that may require greater attention from respondents.

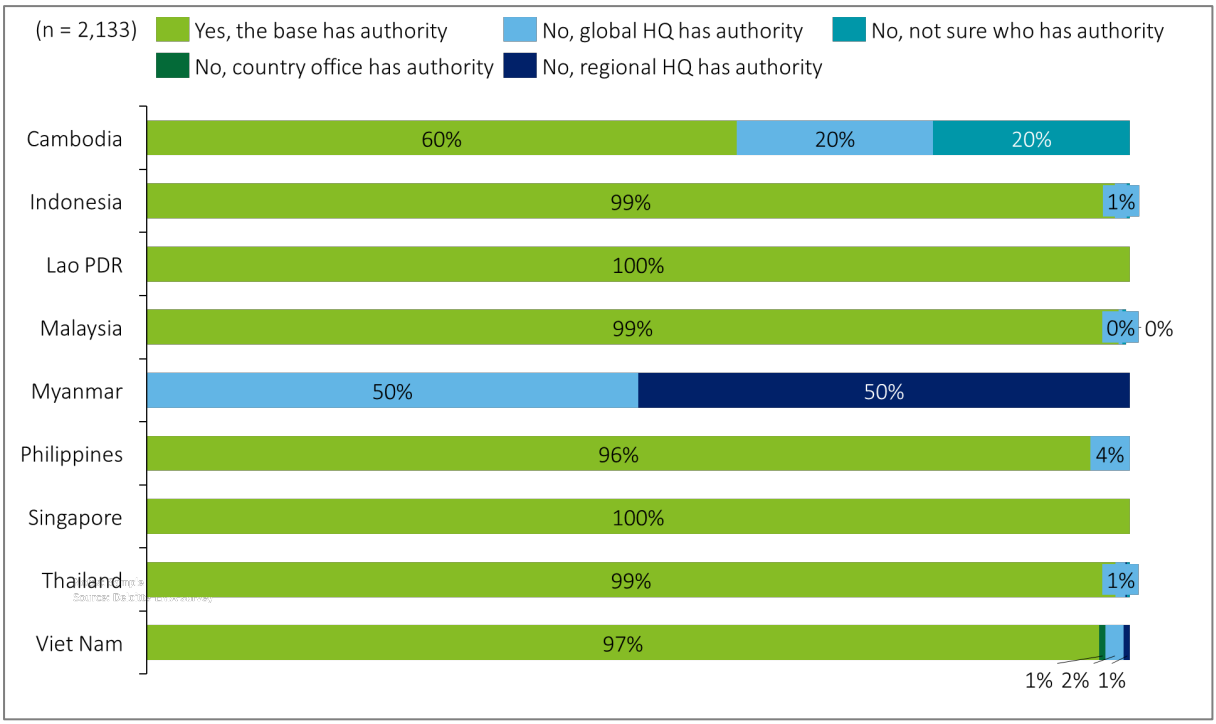
Figure 3.42. Distribution of Other Challenges Affecting the Current Supply Chain



Note: Combining 'agree' and 'strongly agree' responses shows that 49% of respondents indicated that 'personnel in charge lack the necessary expertise' is the most significant challenge. A further 37% pointed to 'do not have access to suitable technology to solve this issue' as a major challenge, whilst another 37% identifies 'do not have sufficient personnel to dedicate to this issue' as a key concern. In addition, 35% agreed that 'top management does not understand the needs for investment/allocating personnel in this area' is a critical issue, and 32% cited 'do not have sufficient capital to solve this issue' as a challenge. *(Q35-1_1: Other challenges - Regarding the problem that you have identified, what will be the challenges for the current supply chain to address these issues? [SINGLE CHOICE: choose one option]).*
Source: Authors (2025).

Figure 3.43 presents the ultimate decision-making authority for actions and investments undertaken in response to other challenges. More than 95% of respondents from Indonesia, Lao PDR, Malaysia, the Philippines, Singapore, Thailand, and Viet Nam reported that this decision-making authority resides within their local operations. In contrast, all respondents from Myanmar (100%) indicated that they do not hold such authority, whilst 40% of respondents from Cambodia also reported lacking decision-making authority.

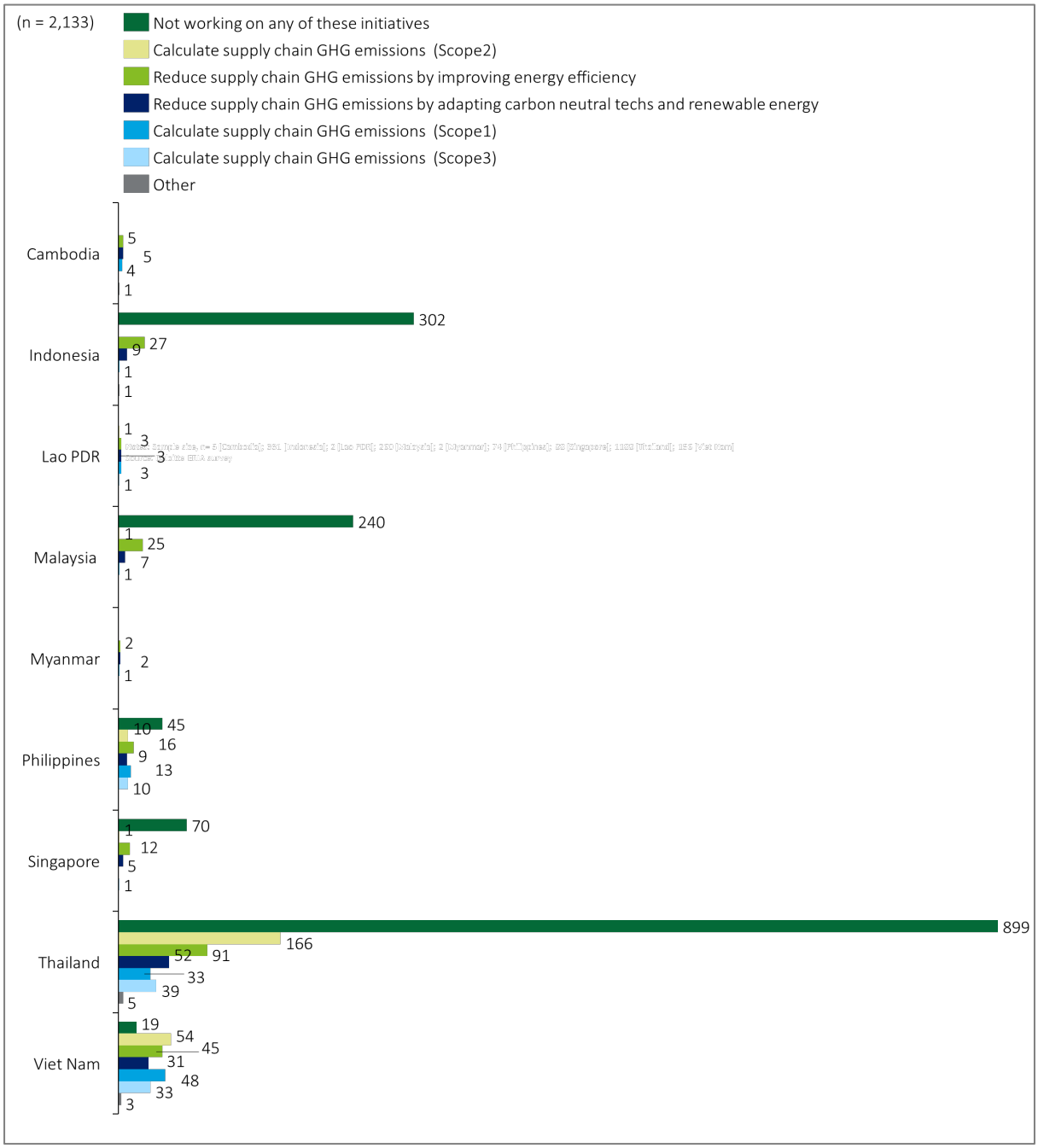
Figure 3.43. Distribution of Ultimate Decision-making Authority for Actions and Investments in Response to Other Challenges



HQ = headquarters, Lao PDR = Lao People's Democratic Republic.
Note: Base refers to the company location of the respondent. *(Q36-1: Does your base have the authority to decide on the course of actions and investments for addressing these challenges?); (Q36-2 Who is the ultimate decision-making office to address this challenge? [SINGLE CHOICE: choose one option]).*
Source: Authors (2025).

Figure 3.44 presents the distribution of current company initiatives. Amongst the options provided, most respondents, except those from Viet Nam, indicated that they are not currently implementing any of the initiatives. This finding reflects a general lack of consideration of supply chain GHG emissions at this stage. This situation may be attributed to limited internal capabilities or insufficient financial support.

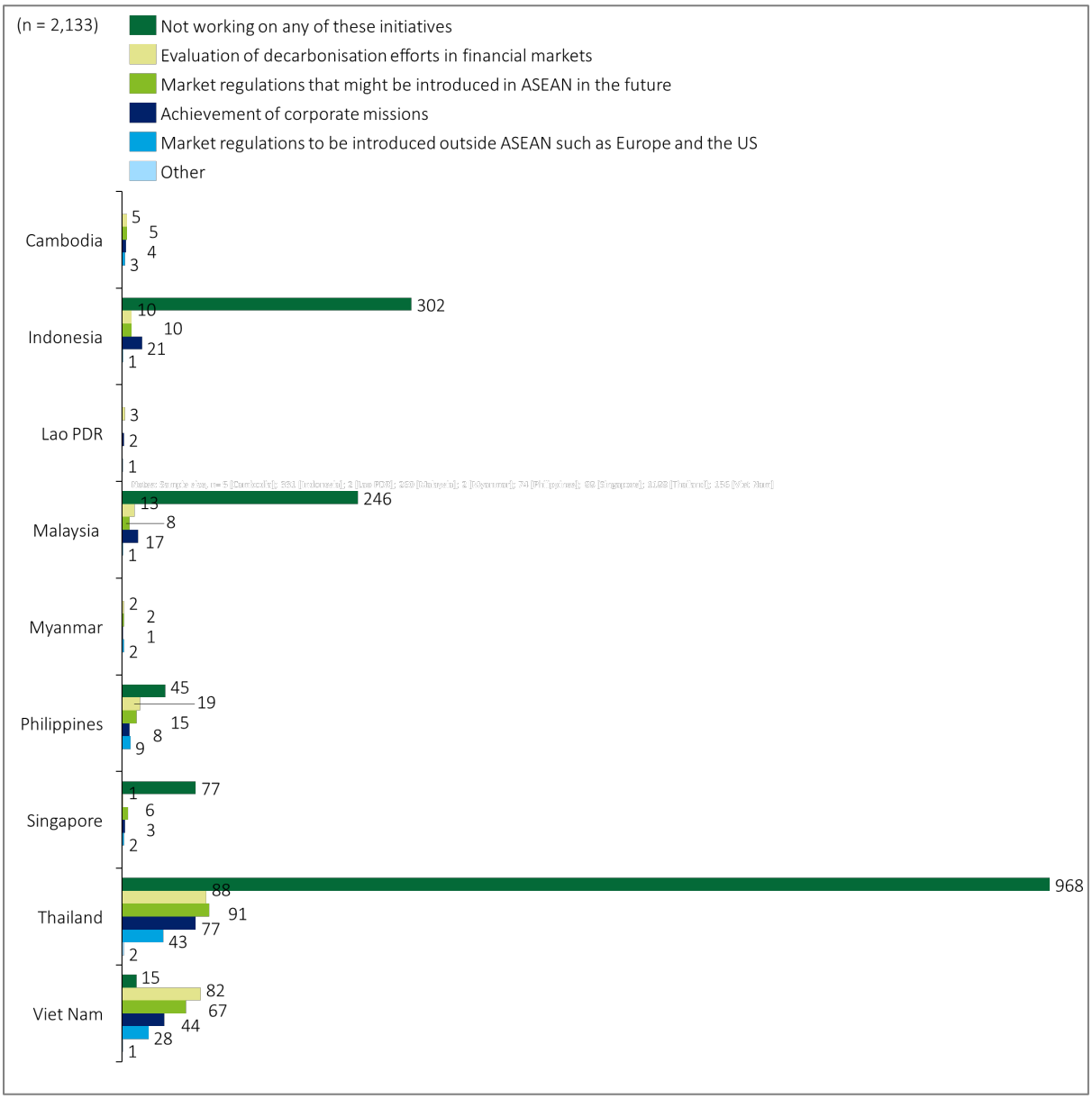
Figure 3.44. Distribution of Current Company Initiatives to Support Supply Chain Decarbonisation, by Country



GHG = greenhouse gas, Lao PDR = Lao People's Democratic Republic.
Note: Scope 1 refers to emissions from sources that an organisation owns or controls directly. In the automotive industry, this includes emissions from the operation of facilities and plants where vehicles and parts are manufactured, including the combustion of fuels for heat and power (AIAG, 2011a). Scope 2 refers to emissions that a company causes indirectly through the generation of purchased energy that it consumes. In the automotive industry, this primarily relates to electricity use, as manufacturing plants consume large amounts of electricity for machinery, assembly robots, lighting, heating, ventilation, and air conditioning systems (AIAG, 2011b). Scope 3 refers to emissions that are not produced by the company itself and do not result from assets owned or controlled by the company, but from activities across its value chain. In the automotive industry, this includes emissions generated from the production of materials and parts supplied to the manufacturer, such as steel, plastics, and electronic components (AIAG, 2011c). *(Q37_1: What initiatives is your company currently working on? [MULTIPLE CHOICE: choose all options that apply]).*
Source: Authors (2025).

Figure 3.45 shows the distribution of motivations behind supply chain decarbonisation initiatives. Given that most respondents have not yet implemented any initiatives, their current focus appears to be on fostering motivation and readiness to address GHG emissions. At this stage, companies may need to enhance internal capabilities or secure additional financial support.

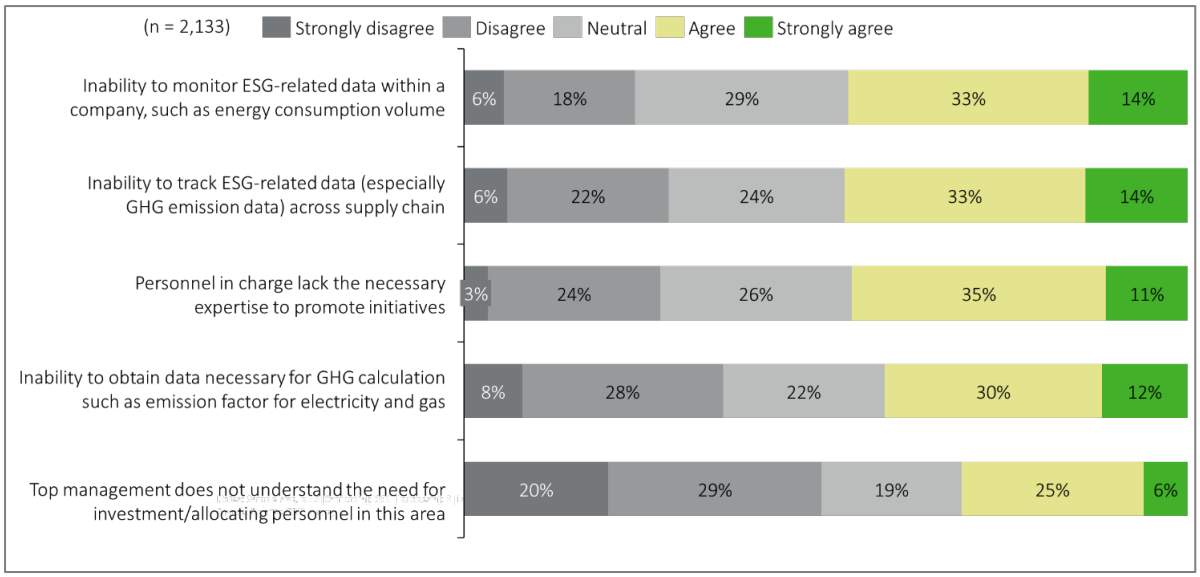
Figure 3.45. Distribution of Motivations Behind Supply Chain Decarbonisation Initiatives, by Country



Note: (Q38_1: What are the motivations for promoting these initiatives? [MULTIPLE CHOICE: choose all options that apply])
Source: Authors (2025).

Figure 3.46 presents the distribution of challenges encountered in implementing GHG emissions calculation and environmental, social, and governance (ESG) reporting initiatives. The most frequently cited challenges relate to the inability to monitor ESG-related data within the company and the inability to track ESG-related data across the supply chain.

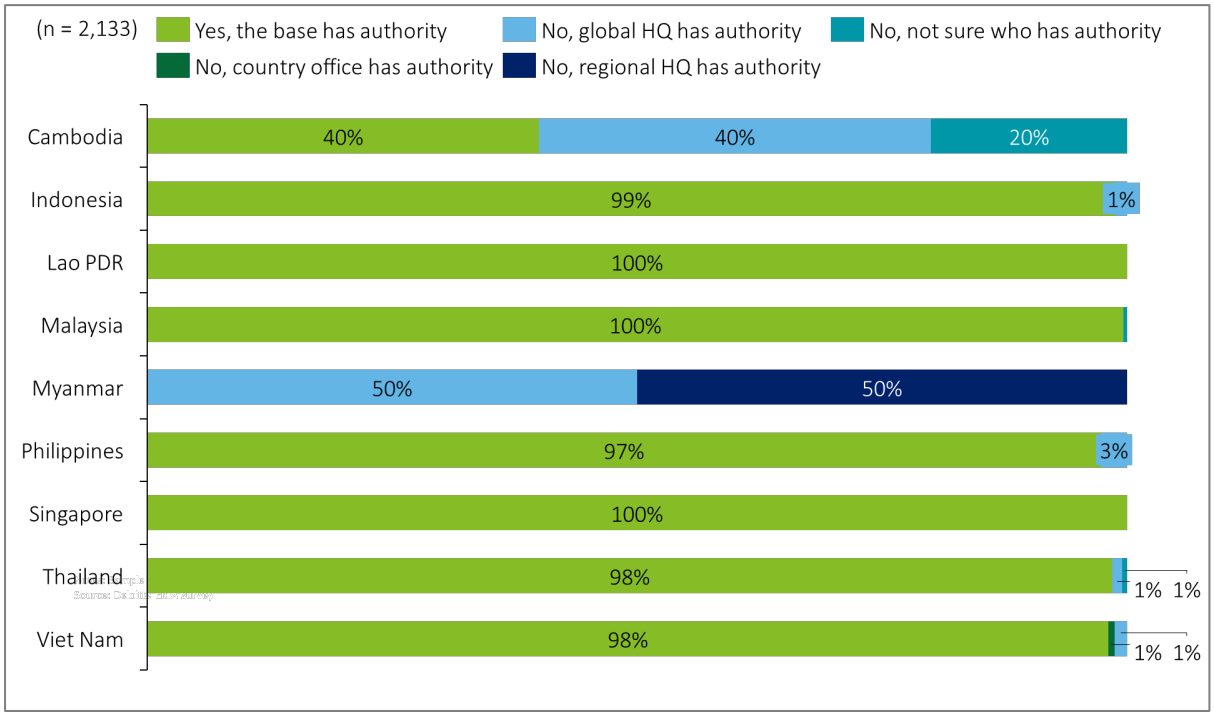
Figure 3.46. Distribution of Respondents' Views on Challenges Related to the Greenhouse Gas Emissions Calculation and Environmental, Social, and Governance Reporting Initiatives



ESG = environmental, social, and governance, GHG = greenhouse gas.
Note: Combining 'agree' and 'strongly agree' responses shows that 47% of respondents indicated that 'unable to monitor ESG-related data within a company, such as energy consumption volume' is the most significant challenge. An equal share of respondents (47%) pointed to 'unable to track ESG-related data across supply chain' as a major challenge. In addition, 46% identified 'personnel in charge lack the necessary expertise to promote initiatives' as a key concern, whilst 42% agreed that 'unable to obtain data necessary for GHG calculation, such as emission factor for electricity and gas' is a critical issue. Furthermore, 31% cited 'top management does not understand the need for investment/allocating personnel in this area' as a challenge. *(Q39-1: GHG emission calculation and ESG reporting - What are/will be the challenges to promote these initiatives? [SINGLE CHOICE: choose one option]).*
Source: Authors (2025).

Figure 3.47 presents the ultimate decision-making authority for actions and investments undertaken in response to challenges related to GHG emissions calculation and ESG reporting. More than 95% of respondents from Indonesia, Lao PDR, Malaysia, the Philippines, Singapore, Thailand, and Viet Nam reported that this decision-making authority resides within their local operations. By contrast, all respondents from Myanmar (100%) indicated that they do not hold such authority, whilst 60% of respondents from Cambodia also reported a lack of decision-making authority.

Figure 3.47. Overview of Decision-making Authority for Strategic Actions and Investments in Response to Greenhouse Gas Emissions Calculation and Environmental, Social, and Governance Reporting Challenges



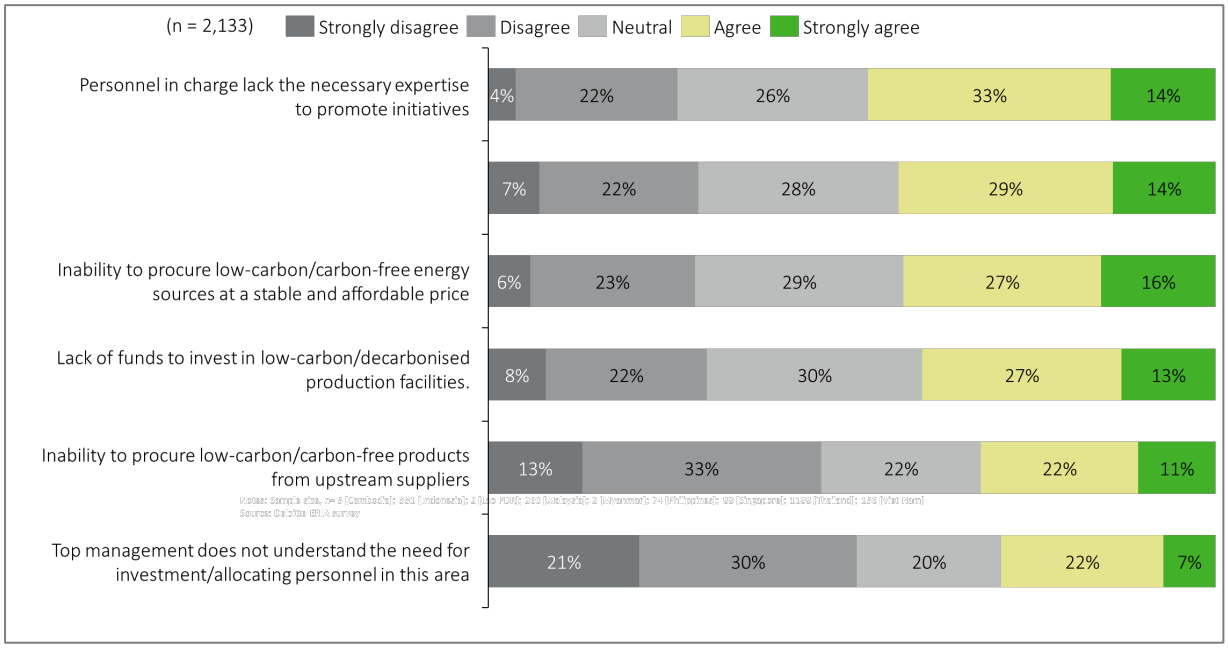
ESG = environmental, social, and governance; GHG = greenhouse gas; HQ = headquarters.
Note: Base refers to the company location of the respondent. *(Q40-1: Does your base have the authority to decide on the course of actions and investments for addressing these challenges? [SINGLE CHOICE: choose one option]); (Q41-2: Who is the ultimate decision-making office to address this challenge?).*
Source: Authors (2025).

3.2.4.3. Supply chain decarbonisation

Figure 3.48 presents the distribution of challenges related to supply chain decarbonisation. Most respondents identified a lack of expertise amongst personnel in charge as the primary challenge, followed by uncertainties in government policies and in the strategic direction of OEMs.

a. Challenges

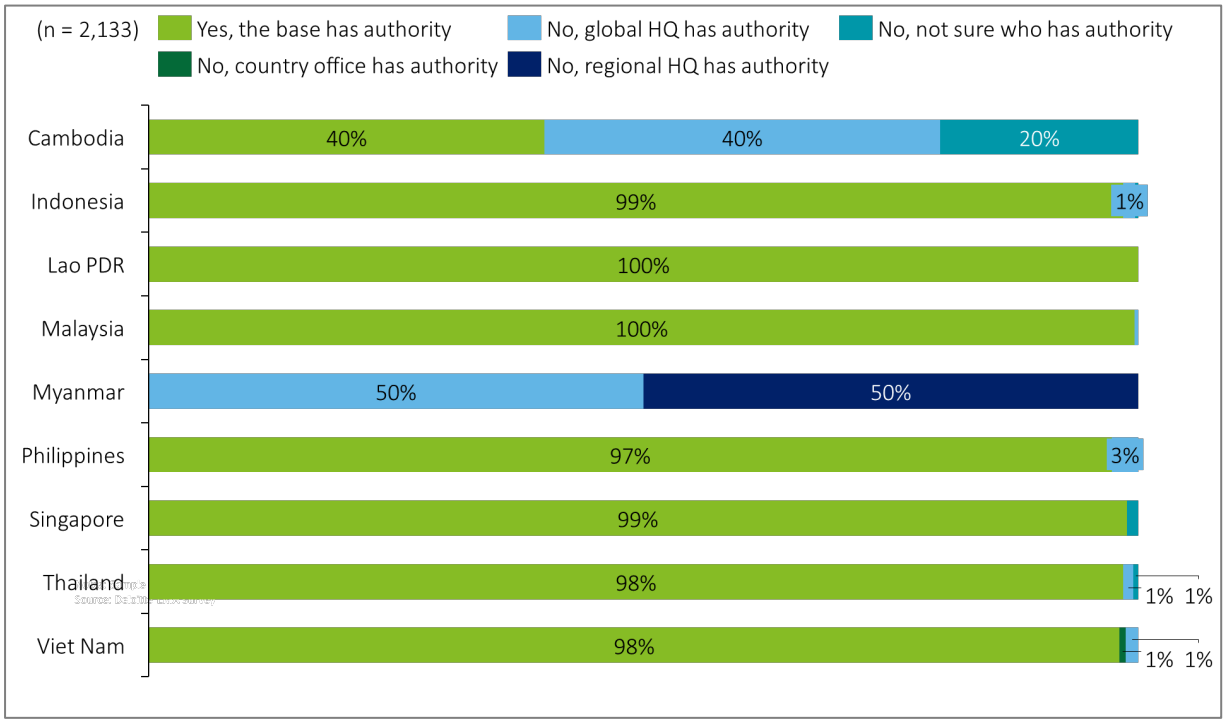
Figure 3.48. Distribution of Respondents' Perspectives on the Challenges of Supply Chain Decarbonisation



OEM = original equipment manufacturer.
Note: *(Q41-1 Regarding supply chain decarbonisation, what will be the challenges for the current supply chain to address these issues? [SINGLE CHOICE: choose one option]).*
Source: Authors (2025).

Figure 3.49 presents the ultimate decision-making authority for actions and investments undertaken in response to challenges related to supply chain decarbonisation. More than 95% of respondents from Indonesia, Lao PDR, Malaysia, the Philippines, Singapore, Thailand, and Viet Nam reported that this decision-making authority resides within their local operations. In contrast, all respondents from Myanmar (100%) indicated that they do not hold such authority, whilst 60% of respondents from Cambodia also reported a lack of decision-making authority.

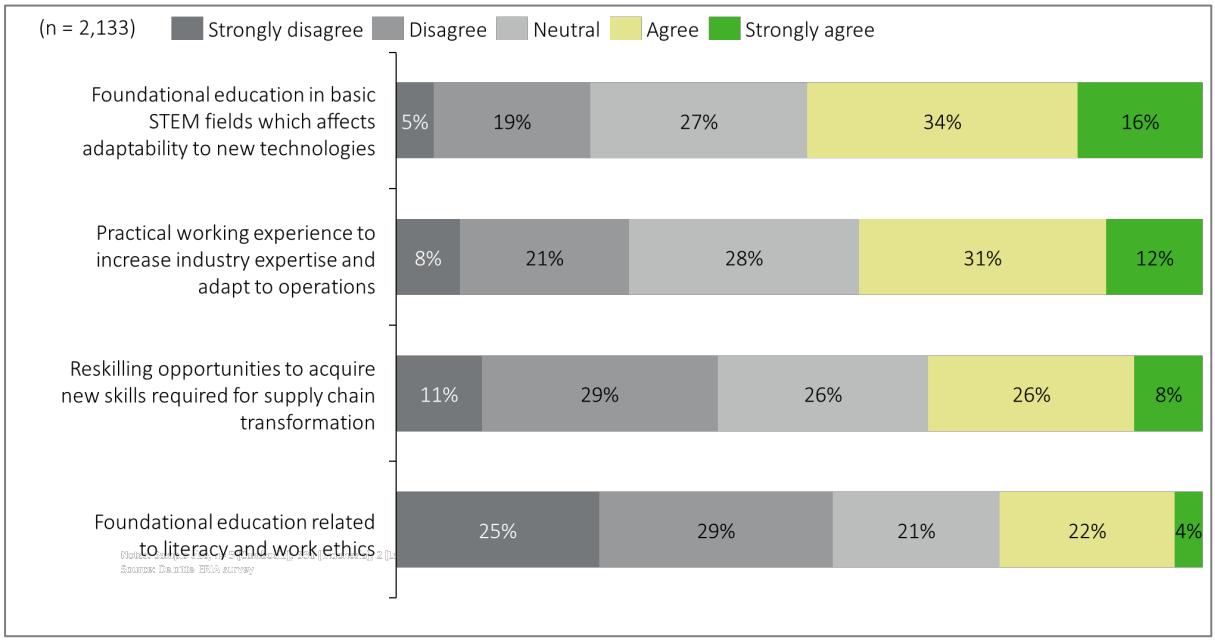
Figure 3.49. Overview of Decision-making Authority for Strategic Actions and Investments in Response to Supply Chain Decarbonisation Challenges



HQ = headquarters, Lao PDR = Lao People's Democratic Republic.
Note: Base refers to the company location of the respondent. *(Q42-1: Does your base have the authority to decide on the course of actions and investments for addressing these challenges? [SINGLE CHOICE: choose one option]); (Q42-2: Who is the ultimate decision-making office to address this challenge?)*
Source: Authors (2025).

Figure 3.50 illustrates the distribution of specific skill gaps identified amongst non-management workforces. The primary area requiring development is foundational education in core science, technology, engineering, and mathematics (STEM) disciplines, as deficiencies in this domain impede the workforce's capacity to adapt to emerging technologies.

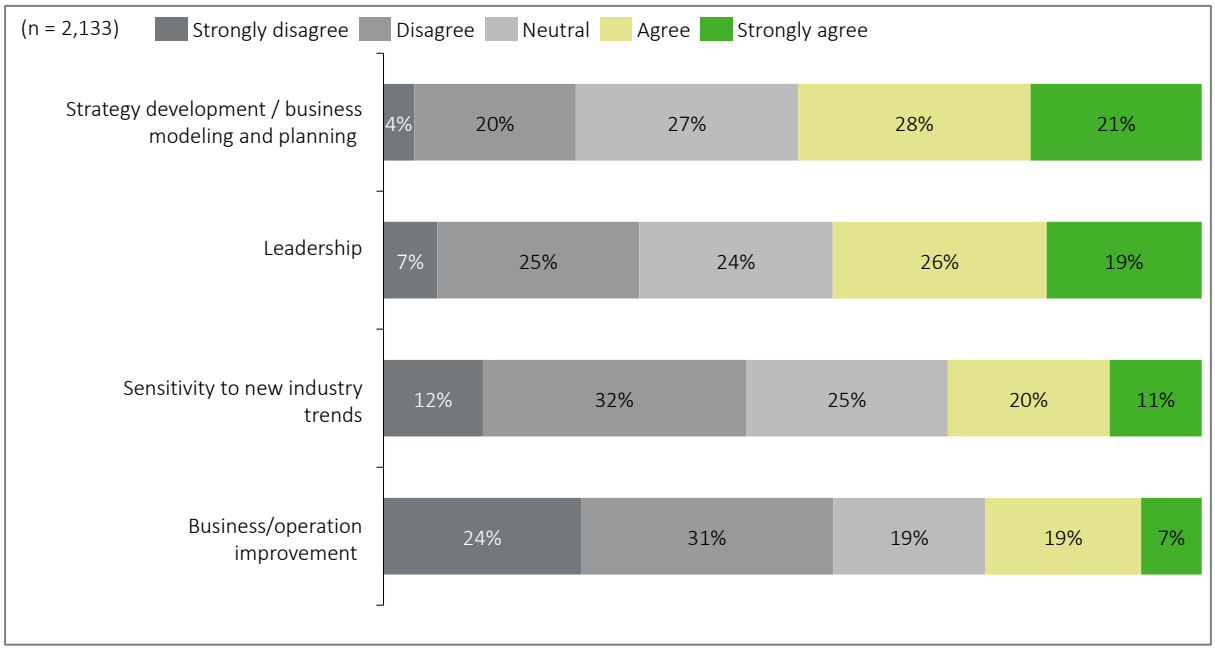
Figure 3.50. Distribution of Respondents' Perspectives on the Specific Skill Gaps Amongst Non-management Workforces



STEM = science, technology, engineering, and mathematics.
Note: *(Q43-1_1 To address these challenges provided in the previous questions, what specific qualities are missing from non-management workforces?).* These challenges include a lack of understanding amongst top management regarding the need to invest in or allocate personnel to this area, as well as insufficient expertise amongst those responsible for effectively promoting initiatives.
Source: Authors (2025).

Figure 3.51 illustrates the distribution of specific skill gaps identified amongst management workforces. Notably, the primary area requiring development pertains to strategy development, business modelling, and planning.

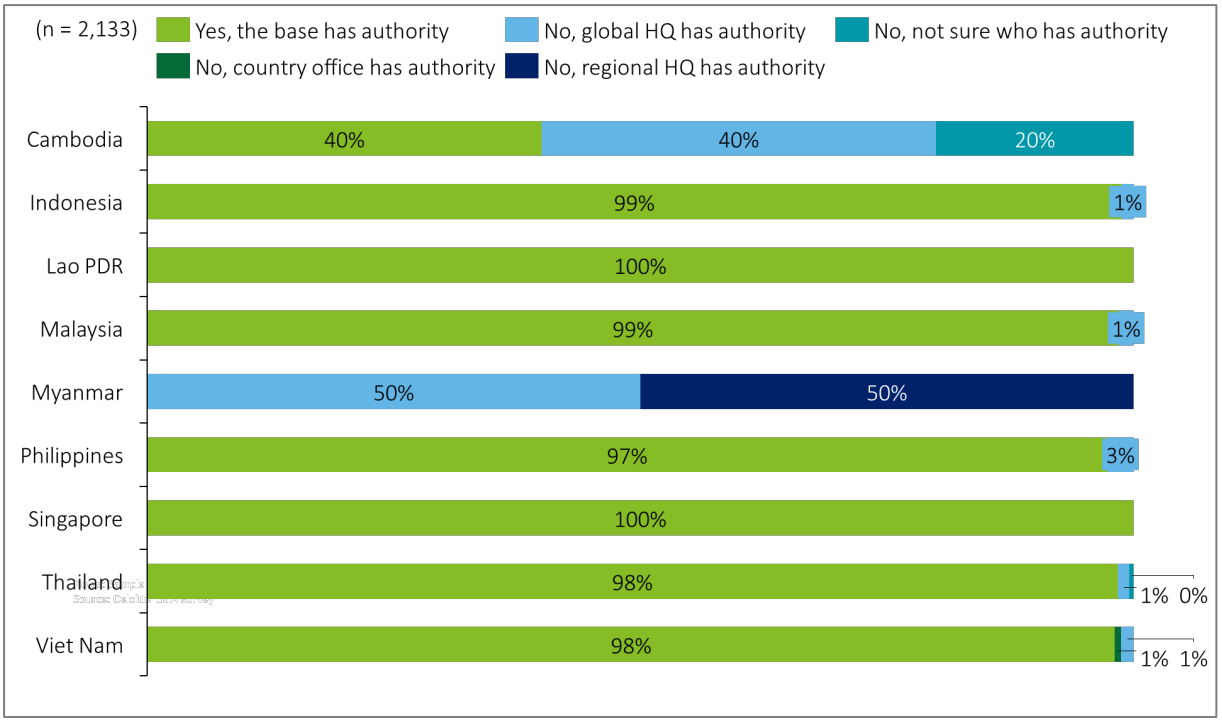
Figure 3.51. Distribution of Respondents' Perspectives on the Specific Competencies Lacking in Management Workforces to Address These Challenges



Note: (Q44-1_1: To address these challenges provided in the previous questions, what specific qualities are missing from management workforces?).
Source: Authors (2025).

Figure 3.52 presents the ultimate decision-making authority for actions and investments undertaken in response to workforce-related challenges. Most respondents indicated that they possess decision-making authority, with over 95% of responses coming from Indonesia, Lao PDR, Malaysia, the Philippines, Singapore, Thailand, and Viet Nam. In contrast, all respondents from Myanmar indicated that they do not hold such authority, whilst 60% of respondents from Cambodia also reported lacking decision-making authority.

Figure 3.52. Overview of Decision-making Authority for Management and Non-management Workforces



HQ = headquarters, Lao PDR = Lao People's Democratic Republic.
Note: Base refers to the company location of the respondent. (Q45-1: Does your base have the authority to decide on the course of actions and investments for addressing these challenges?); (Q45-2: Who is the ultimate decision-making office to address this challenge?)
Source: Authors (2025).

3.3. Conclusion

This report presents the results of a survey conducted in Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Viet Nam. The survey aimed to capture respondents' perspectives on the current state and strategic direction of the automotive sector across selected ASEAN countries.

In current powertrain vehicle production, Cambodia, Myanmar, and Viet Nam demonstrate a notable focus on HEVs, BEVs, and PHEVs (Figure 3.9). By contrast, the Philippines and Singapore remain primarily concentrated on ICEVs, which account for over 40% of total responses (Figure 3.9). The production of biofuel powertrain vehicles remains minimal, with fewer than 5% of respondents reporting such activity. Notably, over half of the respondents in Indonesia, Thailand, and Malaysia expressed uncertainty regarding the specific powertrain types their products serve. This uncertainty extends into future planning, with more than 80% of respondents from these countries reporting ambiguity about their strategic direction. This prevailing uncertainty highlights the critical need for clearer policy signals and stronger strategic alignment within these markets. To strengthen the future competitiveness of ASEAN suppliers, it may be valuable to consider grouping countries according to their respective production specialisations and stages of economic development, given the notable differences across the region.

Regarding market distribution, the data indicate that firms in Indonesia, Malaysia, the Philippines, Singapore, and Thailand are predominantly oriented towards their domestic markets, both currently and in their plans (Figure 3.25). This trend is largely driven by strong local demand. However, firms in these countries also face challenges such as complex taxation systems, customs procedures, and certification processes, which hinder their ability to compete globally (ASEAN Business Advisory Council, 2019). In contrast, companies in Cambodia, Lao PDR, Myanmar, and Viet Nam tend to serve both domestic and international markets, as local demand remains relatively limited compared to that of larger ASEAN economies. A notable shift towards a greater domestic focus is anticipated in Lao PDR. As Southeast Asian countries generally prioritise domestic markets, exports, particularly to the United States and the European Union, remain limited. To position the region as a potential export hub for ICEVs and HEVs, it is essential to enhance competitiveness across the region, including through improvements in supply chain efficiency and integration.

The outlook for BEV and PHEV penetration is cautiously optimistic, with over 80% of respondents forecasting an increase in market share to 13%, supported by advancements in vehicle functionality and the development of adequate supporting infrastructure (Figure 3.15). Nevertheless, responses vary across ASEAN countries. Most respondents from Cambodia, Indonesia, Malaysia, the Philippines, Singapore, Thailand, and Vietnam are optimistic that BEV and PHEV penetration rates will increase. Lao PDR stands out as an exception, where 66.7% of respondents indicated uncertainty about future electrified vehicle (xEV) adoption. This hesitation is primarily attributed to concerns over the high upfront costs of EVs, driven largely by high battery and manufacturing expenses.

In terms of strategies, each market adopts an approach tailored to its specific needs and objectives. Indonesia, Malaysia, Singapore, and Thailand prioritise product diversification to address unique market demands (Figure 3.28). Lao PDR and the Philippines balance product diversification with powertrain transition and supply chain improvements. Viet Nam focuses primarily on enhancing supply chain efficiency to strengthen cost competitiveness, whilst Myanmar pursues a combination of strategies, including product diversification alongside powertrain transition, supply chain efficiency, and adaptation to specific market needs.

However, the transition towards diversified and sustainable powertrain production presents formidable challenges. Most respondents identified uncertainty regarding powertrain transitions in export markets as a major barrier, highlighting the risks associated with evolving international standards and demand patterns. Supply chain efficiency is further hindered by material costs and procurement challenges, compounded by short-term disruptions such as low productivity, insufficient process reviews, limited adoption of digital technologies, and constrained decision-making authority for investment.

Finally, efforts to advance supply chain decarbonisation face significant hurdles, most notably a shortage of qualified personnel with the expertise necessary to effectively drive

decarbonisation initiatives. In summary, the survey results underscore the importance of strategic clarity, workforce development, and targeted investment in supply chain capabilities and sustainability initiatives to ensure that the region's automotive sector can navigate the transition towards next-generation powertrains whilst remaining competitive in an evolving global market. At the same time, the survey results are subject to the following limitations:

1. Respondents' answers may reflect biases that vary across countries and the business conditions faced by respondents.
2. The survey was conducted from November 2024 to February 2025, and responses reflect conditions during that period. These responses may change over time due to shifts in market conditions, government regulations, or other external factors.

Chapter 4

Current and Future State of the Global Automotive Market

In 2024, China, the European Union (EU), and the United States (US) dominated global automotive sales, accounting for 18%, 17%, and 29%, respectively, whilst Association of Southeast Asian Nations (ASEAN) and India represented 3% and 5%, respectively, of the global market (GlobalData, 2025). Although ASEAN and India account for relatively small shares of global sales, India's growth is expected to outpace the global average in the coming years. The growth is primarily driven by a rapidly expanding population, projected to reach 1.5 billion, which is expected to increase the car ownership rate to 41 vehicles per 1,000 people by 2029–2030 (Economist Intelligence Unit [EIU], 2025a). This trend is further supported by strong economic performance, with average gross domestic product growth estimated at 6.4% in 2025–2029 (EIU, 2025b).

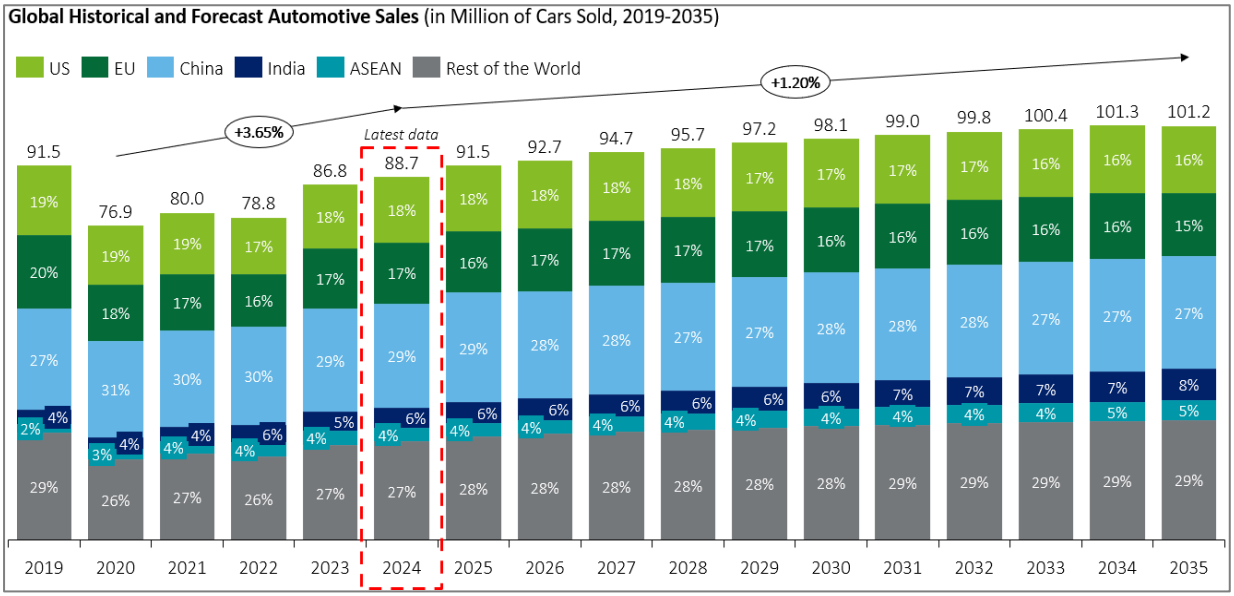
However, disparities in infrastructure readiness and purchasing power contribute to varying transition speeds between developed and emerging regions. Consequently, uncertainties remain regarding the pace and trajectory of this shift, and internal combustion engine vehicles (ICEVs) are expected to retain a share of the market in leading economies for the foreseeable future.

4.1. Global Automotive Market Trend

In 2024, global automotive sales reached 88.7 million units, reflecting strong post-coronavirus disease (COVID-19) pandemic growth, with a historical compound annual growth rate (CAGR) of 3.65%. Growth is expected to moderate, with a projected CAGR of 1.2%. China, the EU, and the US remain the dominant markets, whilst ASEAN accounts for about 4% of total sales (GlobalData, 2023).

The global market is projected to grow at a CAGR of 1.2% until 2036, with the group of leading markets remaining largely unchanged. India, which held a 6% market share in 2024, is expected to outpace overall market growth and increase its share to 8% by 2036. Although total sales volume in ASEAN is projected to increase, the region's share of the global market is expected to reach only about 5%.

Figure 4.1. Global Sales: Historical and Forecast (million units, 2019–2035)



ASEAN = Association of Southeast Asian Nations, EU = European Union, US = United States.
Source: GlobalData (2025).

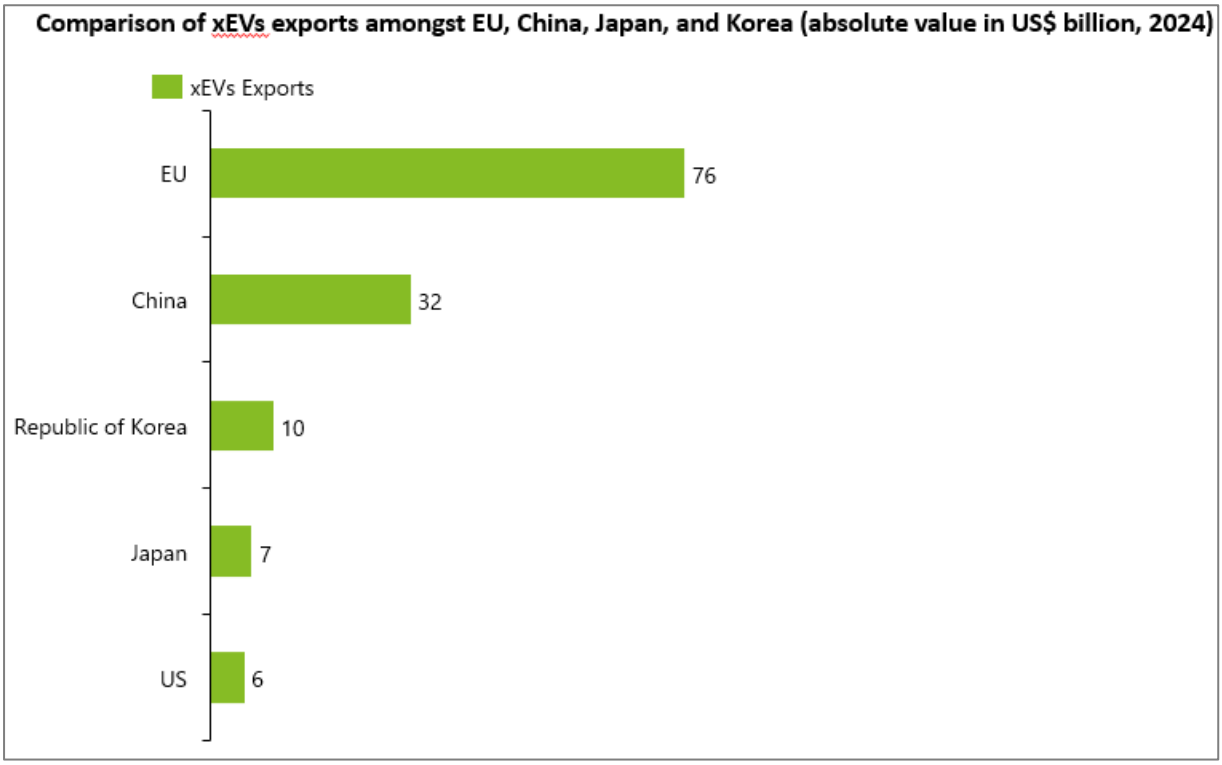
Global Electrified Vehicle Exports by Country

As shown in Figure 4.2, the EU emerged as the leading exporter of electrified vehicles (xEVs) in 2024, with export values reaching about US$76 billion, representing 53% of total global xEV exports. Germany played a particularly dominant role, driven by strong regional demand and strict emissions regulations that promote the adoption of zero-emission vehicles (Clean Energy Wire, 2024).

Nevertheless, Germany faces increasing competition from China, which ranked as the second-largest xEV exporter, with exports valued at US$32 billion, accounting for 23% of the global total. Germany and China were followed by the Republic of Korea (henceforth, Korea) (US$10 billion, 7%), Japan (US$7 billion, 5%), and the US (US$6 billion, 4%). China's electric vehicles (EVs) are often more competitively priced, especially in emerging markets (International Energy Agency [IEA], 2025a).

Japan and Korea accounted for most of the nearly 640,000 EVs exported from Asia and the Pacific – excluding China – primarily through their domestic automakers (IEA, 2025b). Although Japan's xEV export volumes remain lower than those of the EU and China, the country is actively advancing research into carbon-neutral fuels. These include e-fuels produced from captured carbon dioxide and hydrogen derived from renewable sources, as well as biofuels made from sustainable raw materials, all of which aim to support the transition towards zero-emission vehicles. Several companies, including Idemitsu, ENEOS, Toyota Motor, and Mitsubishi Heavy Industries, have agreed to jointly introduce these fuels domestically by 2030 (S&P Global, 2024).

Figure 4.2. Global Electrified Vehicle Exports, by Country



Note: xEVs refer to electrified vehicles, including battery electric vehicles, hybrid electric vehicles, and plug-in hybrid electric vehicles.
Source: Tendata (2025).

4.2. Global Powertrain Transition Towards Decarbonisation

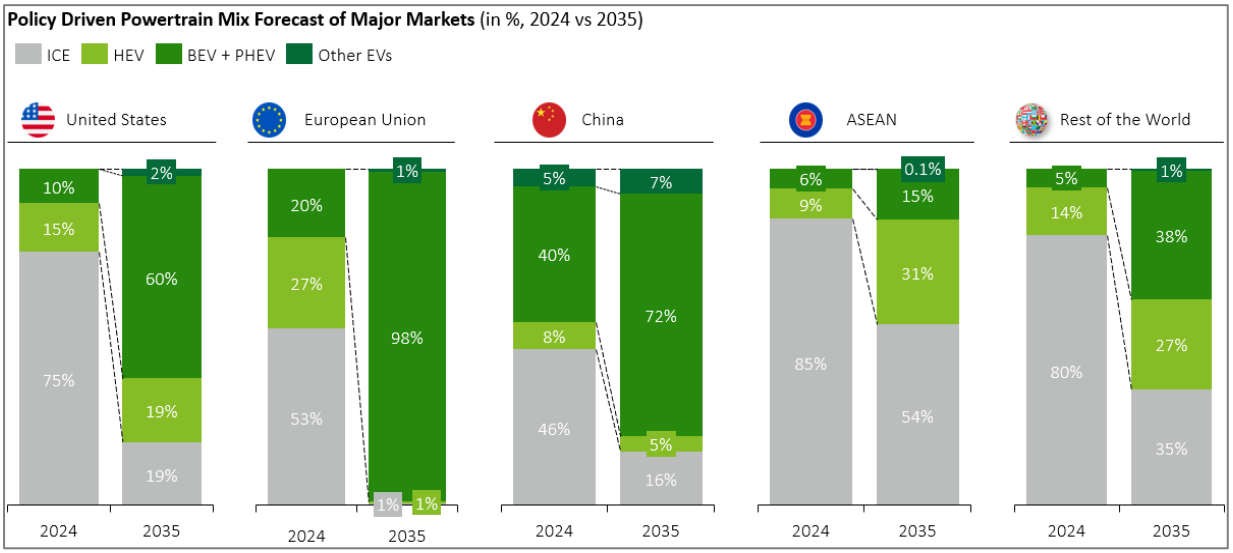
The global automotive market is undergoing a significant transition, particularly in powertrain technologies, with China, the EU, and the US leading the shift (IEA, 2024). Sales of battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) have increased steadily, rising from 0.2% of global vehicle sales in 2013 to 18% in 2023. These major automotive markets are expected to drive the transition from ICEVs and HEVs powertrains towards BEVs and PHEVs, thereby shaping the industry's trajectory.

The continued shift towards xEVs, which comprise BEVs, and PHEVs is largely driven by national decarbonisation targets (see Chapter 6 and Chapter 8 for details), with BEVs and PHEVs positioned as the most viable technological solutions. For example, the EU has made notable progress in decarbonisation through its Action Plan on Digitalising the Energy System. The plan includes investments in technologies such as smart Internet of Things devices and metres, fifth-generation (5G) and emerging sixth-generation (6G) connectivity, and digital twins of the energy system, all aimed at accelerating the clean energy transition (European Commission, 2022). These digital technologies create a supportive environment for the development and production of xEVs within the EU.

However, the pace of the powertrain transition varies significantly across regions. Whilst China, the EU, and the US are expected to maintain leadership in xEV adoption, emerging

markets, including ASEAN, are transitioning at a slower rate. The powertrain transition in the ASEAN region is discussed in greater detail in Chapter 5. In ASEAN, ICEV and HEV powertrains are expected to continue to dominate, with projections indicating that they will remain the largest segment even in 2035.

Figure 4.3. Policy-driven Powertrain Mix Forecast of Major Market (%)



BEV = battery electric vehicle, EV = electric vehicle, HEV = hybrid electric vehicle, PHEV = plug-in hybrid electric vehicle.
Note: 'Other EVs' include extended-range EVs, hydrogen fuel cell EVs, and hydrogen plug-in fuel cell EVs. Percentages may not add up to 100% due to rounding.
Source: GlobalData (2024a).

In 2024, xEV sales accounted for about 10% of total vehicle sales in the US, 20% in the EU, and 40% in China. By 2035, as shown in Figure 4.2, the EU is expected to lead in xEV penetration, with 98% of vehicle sales comprising BEVs and PHEVs, followed by China at 72% and the US at 60%. The EU's leadership is driven by government mandates to fully phase out ICEV sales by 2035 (International Council on Clean Transportation, 2021a). In China and the US, EV adoption rates are influenced by factors such as oil prices and government incentives, including subsidies and tax breaks (Energy Information Administration [EIA], 2023). In ASEAN, the proportion of BEVs and PHEVs is not expected to increase as drastically as in advanced countries. Instead, HEVs are projected to play a significant role in 2035, accounting for about 31% of the powertrain mix.

According to Bradsher (2025), China's domestic EV market has been characterised by intense competition amongst automakers, with about 50 manufacturers engaged in a fierce price war. Many EV producers have struggled to pay suppliers whilst continuing to borrow from state-run banks to expand production capacity. This dynamic has resulted in extensive overcapacity, which has driven EV prices even lower.

Bradsher (2025) further notes that, as a consequence of oversupply, the number of car dealers in China has increased sharply, whilst the value of dealer inventories has declined

due to falling EV sticker prices. Another outcome has been the export of about one-fifth of China's EV production, with Southeast Asian countries emerging as key destinations. This trend has been facilitated by EV incentives introduced by Southeast Asian governments to reduce carbon emissions.

With the inflow of surplus EVs from China into Southeast Asia, concerns have emerged that the rapid expansion of EV production facilities in countries such as Thailand may lead to overcapacity in the regional EV market. However, Suzuki (2025) reports that, in an effort to promote the healthy development of the new energy vehicle trade, China plans to introduce export controls on pure electric passenger cars from 1 January 2026. These measures reflect domestic concerns over excessive price competition amongst Chinese EV manufacturers, as well as global complaints regarding the influx of low-priced EVs.

The 'rest of the world' category includes all countries for which data are available, except ASEAN, China, the EU, and the US. In this group, xEVs accounted for 5% of vehicle sales in 2024, with projections indicating an increase to 38% by 2035. ICEVs and HEVs are expected to retain shares of 35% and 25%, respectively, indicating a future characterised by a diversified powertrain mix.

To maintain competitiveness in EV adoption, leading regions such as China are advancing vehicle-to-grid (V2G) integration and expanding charging infrastructure (IEA, 2025). Drawing lessons from global leaders, particularly the EU and China, it is increasingly important to develop enabling technologies within supply chains in the Southeast Asian region. Such efforts can support the establishment of a competitive ICE and HEV manufacturing hub, alongside a cost-efficient and integrated production network, thereby strengthening the region's overall market positioning.

4.3. Key Drivers of the Powertrain Transition

The key drivers influencing xEV adoption across regions and countries can be broadly categorised into three main factors: (1) infrastructure readiness, (2) product line-up, and (3) total cost of ownership (TCO).

4.3.1. Infrastructure Readiness

Infrastructure readiness can be measured using two main indicators: (1) power sources and system capacity and (2) xEV charging infrastructure. A comprehensive understanding of electricity demand patterns, grid stability, and frequency regulation is critical for integrating intermittent renewable energy sources into the power system, particularly as the expansion of EV charging infrastructure is expected to place additional pressure on electricity demand. To support this transition, several measures related to supply chain decarbonisation are required, including enhanced forecasting practices, improved system and operational flexibility, and increased grid reliability (Ember, 2024).

Countries such as Malaysia, the Philippines, and Singapore exhibit similar electricity

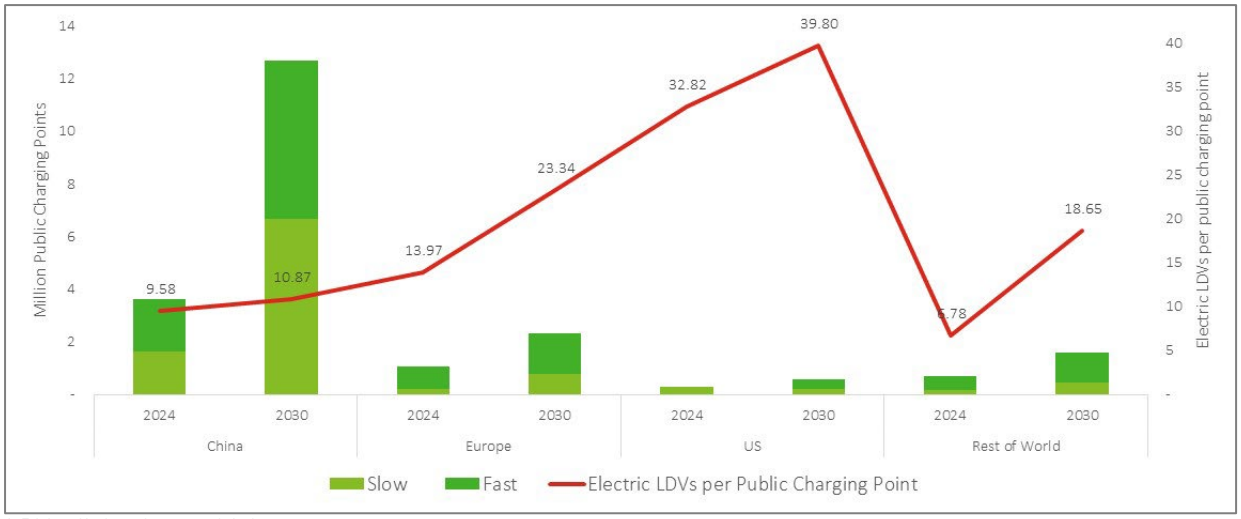
demand trends, with peak demand occurring during daylight hours. In 2023, Malaysia reached a peak demand of 20 gigawatts (GW) at 16:00, the Philippines recorded 20 GW at 14:00, and Singapore peaked at 7.6 GW at 16:00 (Ember, 2024). These daytime peaks present an opportunity to expand solar power generation as a viable solution for meeting electricity demand during peak periods.

Charging infrastructure is a critical factor distinguishing xEVs from ICEVs and HEVs. The rising adoption of xEV chargers is expected to increase demand for electrical power. As more users plug in their vehicles for charging, electricity grids must accommodate the additional load. If not properly managed, this increase could result in overloaded local transformers, higher peak loads, and potential power disruptions. To address these challenges, utilities will need to upgrade infrastructure such as transformers, substations, and distribution lines to ensure reliable service under higher demand conditions (Wattcrop, 2024).

Public charging infrastructure is generally categorised into two main types: slow chargers and fast chargers. Slow chargers, with power ratings below 20 kilowatts (kW), can take up to 24 hours to fully charge an EV battery and typically deliver about 50 kilometres (km) of driving range per hour (Chargelab, 203a). In contrast, fast chargers, with power ratings of up to 350 kW, can complete charging in under 1 hour and provide light-duty vehicles (LDVs) with up to 30 km of range per minute (Chargelab, 2023b). Public slow chargers in urban areas provide a practical solution for EV users without access to home charging, whilst fast chargers along highways are essential for facilitating long-distance travel.

Fast charging deployment is expected to expand rapidly. Ultra-fast charging capacity has more than doubled in Europe since 2022, whilst China has maintained its position as the global leader in fast-charging deployment, accounting for about 80% of global growth from 2023 to 2024 (IEA, 2025a). By 2030, China is projected to have about 12 million public LDV charging points (Figure 4.4), of which about 47% will be fast chargers. In comparison, Europe is expected to reach about 2 million public LDV charging points, with over 60% being fast chargers, whilst the US is projected to have nearly 1 million public LDV charging points, also with about 60% fast-charger penetration.

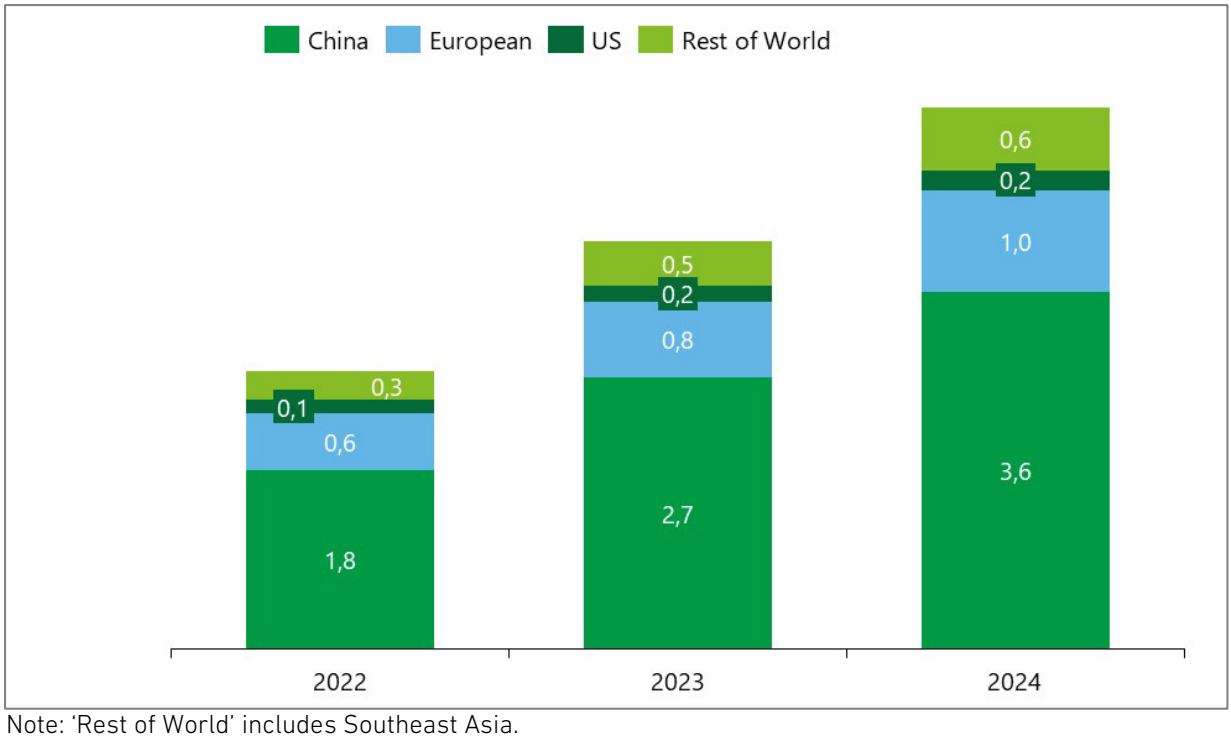
Figure 4.4. Number of Public Light-duty Vehicle Charging Points by Region, 2024–2030



LDV = light-duty vehicle.
Note: 'Slow' refers to charging points with a power rating of 22 kilowatts or below, whilst 'fast' refers to charging points with higher power ratings.
Source: Global EV Outlook (2025).

Unlike conventional refuelling stations, charging networks must be developed separately to enable widespread xEV adoption. Range anxiety remains a significant barrier, particularly in regions with underdeveloped charging infrastructure. Nevertheless, several countries have made notable progress in expanding public charging networks. In the EU, the number of public charging points increased by 36%, rising from 0.76 million units in 2023 to 1.03 million units in 2024 (IEA, 2025a). China recorded a 31% increase, with public charging points growing from 2.73 million units in 2023 to about 3.58 million units in 2024, whilst the US experienced a 20% increase, from 0.16 million units in 2023 to 0.20 million units in 2024 (IEA, 2025b). This expansion is expected to continue, supported by strong government policy. For example, the EU's Alternative Fuels Infrastructure Regulation mandates the installation of fast-charging stations with a minimum capacity of 150 kW for cars and vans every 60 km along the Trans-European Transport Network core road network by 2025 (IEA, 2025).

Figure 4.5. Global Stock of Public Charging Points by Region, 2022-2024



Note: 'Rest of World' includes Southeast Asia.
Source: Global EV Outlook (2025).

The rapid development of charging infrastructure has been facilitated by proactive government policies in leading markets. In the US, the National Electric Vehicle Infrastructure Formula Program provides funding to states for the deployment of EV charging stations (United States Department of Energy, 2025). The Infrastructure Investment and Jobs Act allocates US$7.5 billion to expand the national EV charging network (IEA, 2025). In the EU, the Alternative Fuels Infrastructure Regulation similarly mandates the deployment of fast-charging stations with a minimum capacity of 150 kW at intervals of no more than 60 km along major transport corridors by 2025 (IEA, 2025). Germany has committed US$300 million to support the expansion of charging infrastructure (Federal Ministry for Economic Affairs and Climate Action [Germany] [BMWK], 2025). Sustained government support is expected to further accelerate the pace of xEV adoption in these regions.

4.3.2. Product Line-up

The entry of Tesla and the rise of Chinese original equipment manufacturers (OEMs) have significantly expanded the range of EV models available, offering consumers a wider set of choices. As a result, EVs are increasingly compared with ICEVs based on overall vehicle performance, rather than powertrain type alone. However, automakers tend to prioritise model development in markets with strong demand, particularly in leading xEV-adopting countries.

In advanced xEV countries such as China and the US, major OEMs offer a much broader range of models than in developing countries and regions such as ASEAN and India. For example, BYD offers eight BEV and five PHEV models in China, covering a wide range of vehicle types, including multi-purpose vehicles, sport utility vehicles (SUVs), sedans, and compact cars. By contrast, BYD offers only four models in Thailand and Indonesia. Similarly, Tesla offers six models in the US, spanning luxury sedans, SUVs, and pick-up trucks, but only three models in Thailand and Indonesia. Whilst leading markets provide consumers with extensive choice, ASEAN countries continue to face limited model availability. Relative to ICEVs, xEVs are not yet fully represented in ASEAN markets, and limited product line-ups in developing regions are likely to slow the pace of the transition to xEVs.

Product portfolios, however, are shaped not only by research and development investment but also by regional market requirements. Automotive manufacturers often tailor their offerings to reflect local consumer preferences and regulatory environments. For example, EVs are often prioritised in European markets, where environmental regulations are more stringent, whereas more cost-effective models tend to be emphasised in developing regions (Gocious, 2024). A case in point is the Chinese automaker Chery, which introduced its Omoda 5 SUV to the European market. Originally designed for China's smoother road conditions and lower average speeds, the model required substantial modification to meet European expectations. In response, Chery developed a revised version of the Omoda 5 with upgraded steering, traction control, braking systems, vibration dampers, and tyres to accommodate Europe's more demanding driving conditions (Reuters, 2025a).

4.3.3. Total Cost of Ownership

BEVs, on average, have a higher upfront cost than ICE and HEV models (Figure 4.6). For example, the purchase cost of the Ford F-150 Lightning EV is higher than that of a comparable Ford F-150 ICE. Whilst some consumers prioritise EV adoption regardless of price, affordability remains a key factor for mass adoption. Disparities in purchasing power between leading and emerging markets affect overall market demand and access to higher-priced EVs.

Beyond the initial purchase cost, TCO plays a crucial role in consumer decision-making. A key advantage of xEVs lies in the structure of fuel subsidies and taxation. In developed markets with well-established electricity infrastructure, electricity costs per km are lower than petrol costs, making EVs more economical over their life cycle. Conversely, in emerging markets where electricity infrastructure remains underdeveloped, high electricity prices and lower fuel costs, especially in oil-producing countries, diminish the economic benefits of EV ownership and slow adoption rates.

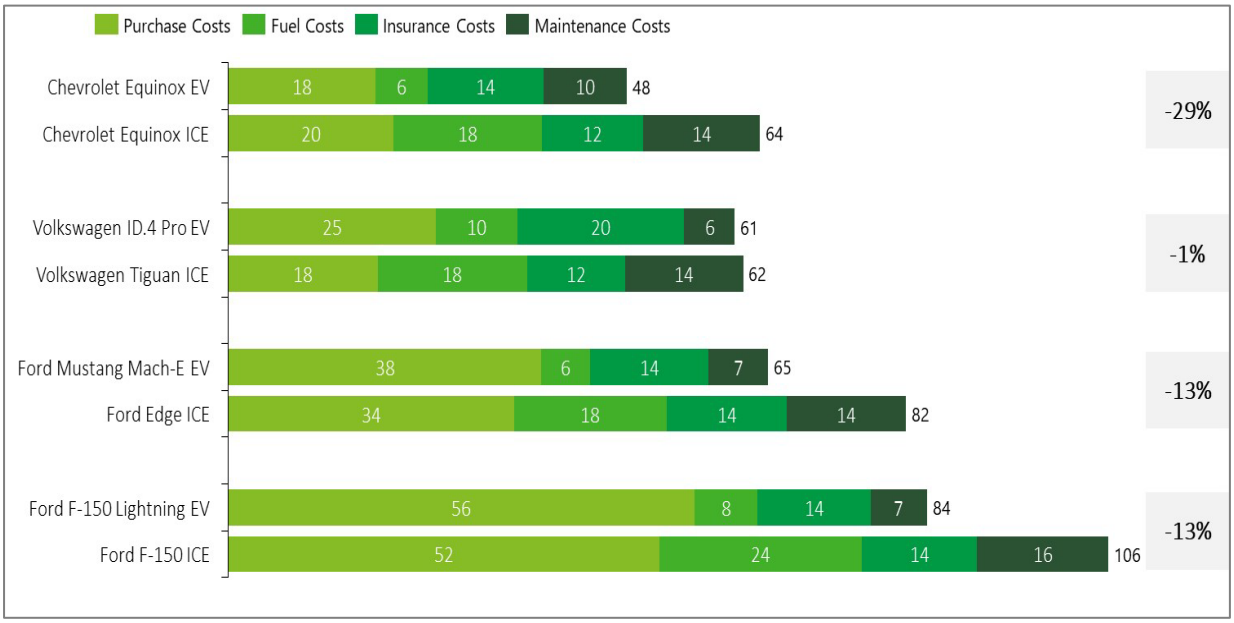
According to a report by the Environmental Defense Fund (2023), the TCO of an xEV in the US is, on average, 13% lower than that of an ICEV of the same brand and model (Figure 4.6). This calculation considers purchase costs, fuel expenses, insurance premiums, and maintenance costs over a 10-year ownership period. Maintenance costs for xEVs are

generally lower than those for ICEVs, primarily due to fewer moving components and reduced fluid requirements. For instance, the maintenance cost of the Chevrolet Equinox EV is about 40% lower than that of its ICE counterpart. Similarly, the Volkswagen EV shows an even greater reduction, with maintenance costs more than halved compared with those of the comparable Volkswagen ICE model (Figure 4.6).

By way of explanation, an electric motor typically contains only one moving part, whereas a combustion engine may include dozens. As a result, xEVs are more resistant to mechanical wear and tear and less prone to frequent repairs. Battery replacement, however, remains one of the most significant expenses, although it is not classified as a routine maintenance item.

Battery prices vary across regions. China records the lowest average battery costs, whilst other parts of Asia and the Pacific face comparatively higher prices. This disparity largely reflects China's dominant position in battery production, accounting for about 65% of global battery cell manufacturing and nearly 80% of cathode production (IEA, 2023). In Southeast Asia, countries without domestic battery manufacturing capacity may incur higher battery replacement costs due to reliance on imports.

Figure 4.6. Comparison of Electric Vehicle and Internal Combustion Engine Vehicle in the ASEAN Region – Total Costs After 10 years (US$ thousand, 2023)



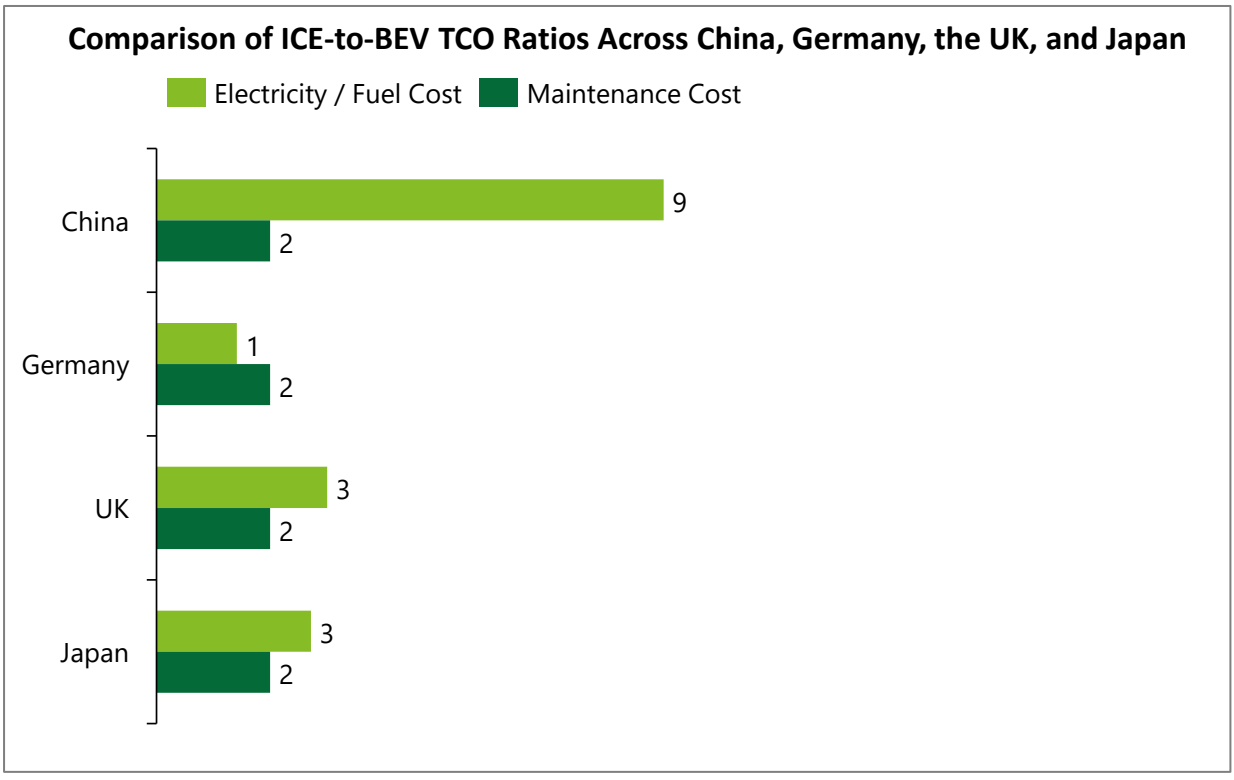
ASEAN = Association of Southeast Asian Nations, EV = electric vehicle, ICE = internal combustion engine.
Source: Total Cost of Ownership and Tipping Point of Electric Vehicles in ASEAN Countries (2023).

The TCO gap between developed and developing markets is further exacerbated by aggressive government support in developed countries, which directly lowers TCO. For example, Germany has provided subsidies of up to US$10,000 per xEV, with these incentives gradually reduced in line with the pace of EV adoption (IEA, 2025). In China, the government

provided subsidies totalling about US$690,000 for new energy vehicles (NEVs) until 2023, alongside a 10% tax reduction for NEVs extended until 2027 (IEA, 2023). Such government support measures have been effective in lowering TCO in developed markets.

Figure 4.7 presents global ICE-to-BEV TCO ratios across China, Germany, the United Kingdom (UK), and Japan. These ratios vary significantly by country, particularly in electricity costs, reflecting differences in policy measures and market conditions. China shows the largest gap between electricity and fuel costs, with ICE fuel expenses about nine times higher than BEV electricity costs. This outcome reflects China's historically low electricity prices, partly influenced by generous government subsidies, which reached up to US$29,000 per EV in 2018. However, these subsidies have since been phased out. Maintenance costs for EVs are estimated at about 50% of those for ICE vehicles (Avicenne Energy, 2021).

Figure 4.7. Comparison of Global ICE-to-BEV Total Cost of Ownership Ratios Across China, Germany, the UK, and Japan



BEV = battery electric vehicle, ICE = internal combustion engine, UK = United Kingdom.
Note: The ICE-to-BEV electricity–fuel cost ratio represents the total fuel cost of an ICEV divided by the total electricity cost of a BEV. Similarly, the ICE-to-BEV maintenance cost ratio is calculated by dividing the total maintenance cost of an ICEV by that of a BEV.
Source: Avicenne Energy (2021).

In parallel, findings from Deloitte's Global Automotive Consumer Study (Table 4.1) indicate that key drivers of EV adoption differ according to each country's stage of development. For instance, in 2025, Chinese consumers prioritise driving experience and environmental

considerations, whereas consumers in developing regions such as Southeast Asia and India cite lower fuel costs as the major driver of adoption (Table 4.1). Over time, lower fuel costs remain one of the main drivers of EV adoption globally, with the notable exception of China, where consumers place greater emphasis on driving experience and environmental benefits.

Table 4.1. Driving Forces for Electric Vehicle Adoption

Countries	2022	2023	2024	2025
US	- Lower fuel costs - Concern for the environment - Better driving experience	- Lower fuel costs - Better driving experience - Concern for the environment	- Lower fuel costs - Concern for the environment - Less maintenance	- Lower fuel costs - Concern for the environment - Driving experience
Germany	- Concern for the environment - Lower fuel costs - Government incentives	- Lower fuel costs - Concern for the environment - Government incentives	- Lower fuel costs - Concern for the environment - Government incentives	- Concern for the environment - Lower fuel costs - Government incentives
China	- Concern for the environment - Better driving experience - Concern about personal health	- Driving experience - Lower fuel costs - Back-up battery	- Driving experience - Lower fuel costs - Government incentives	- Driving experience - Concern for the environment - Lower fuel costs
India	- Concern for the environment - Lower fuel costs - Better driving experience	- Lower fuel costs - Better driving experience - Less maintenance	- Concern for the environment - Lower fuel costs - Less maintenance	- Lower fuel costs - Concern for the environment - Better driving experience
Southeast Asia	- Lower fuel costs - Concern for the environment - Better driving experience	- Lower fuel costs - Better driving experience - Less maintenance	- Lower fuel costs - Concern for the environment - Better driving experience	- Lower fuel costs - Concern for the environment - Better driving experience

Note: Factors are listed in order of importance from top to bottom.
Q42: Which of the following factors have had the greatest impact on your decision to acquire an EV? Please select all that apply.
Source: Deloitte Global Automotive Consumer Study (2022, 2023, 2024, 2025).

Despite these economic advantages, EV adoption in many regions remains limited due to persistent barriers, such as insufficient charging infrastructure, range anxiety, and concerns related to convenience and reliability. According to Deloitte consumer surveys, these factors continue to play a significant role in deterring consumers from transitioning to EVs.

Beyond adoption drivers, the nature of challenges and barriers also varies across countries. In regions with well-developed infrastructure, such as China and the US, public EV charging availability is no longer a major concern. In contrast, in emerging markets such as India and Southeast Asia, limited public charging infrastructure and long charging times remain significant obstacles (Table 4.2).

Table 4.2. Challenges for Electric Vehicle Adoption

Countries	2022	2023	2024	2025
US	- Driving range - Lack of public EV charging infrastructure - Cost/price premium	- Cost/price premium - Driving range - Time required to charge	- Time required to charge - Driving range - Cost/price premium	- Driving range - Time required to charge - Cost/price Premium
Germany	- Driving range - Lack of public EV charging infrastructure - Cost/price premium	- Driving range - Lack of public EV charging infrastructure - Time required to charge	- Driving range - Cost/Price premium - Lack of charge at home	- Driving range - Cost/Price premium - Lack of public EV charging infrastructure
China	- Driving range - Safety concerns with battery technologies - Lack of public EV charging infrastructure	- Safety concerns with battery technologies - Time required to charge - Driving charge	- Time required to charge - Cost to eventually replace the battery - Cold-weather performance	- Time required to charge - Driving range - Cold-weather performance
India	- Lack of public EV charging infrastructure - Safety concerns with battery technologies - Cost/price premium	- Time required to charge - Lack of public EV charging infrastructure - Safety concerns with battery technologies	- Time required to charge - Lack of public EV charging infrastructure - Driving range	- Time required to charge - Lack of public EV charging infrastructure - Safety concerns with battery technologies

Countries	2022	2023	2024	2025
Southeast Asia	- Lack of public EV charging infrastructure - Driving range - Cost/price premium	- Lack of public EV charging infrastructure - Time required to charge - Driving range	- Time required to charge - Lack of public EV charging infrastructure - Driving range	- Driving range - Time required to charge - Lack of public EV charging infrastructure

Note: Factors are listed in order of importance from top to bottom.
Q52: What are your biggest concerns regarding all battery-powered EVs? Please select all that apply.
Source: Deloitte Global Automotive Consumer Study (2022, 2023, 2024, 2025).

Governments, therefore, play a crucial role in lowering consumer barriers through fiscal incentives and investments in technological development. One example is the Advanced Research Projects Agency–Energy in the US, which supports pre-commercial energy research in areas such as batteries, grid reliability, nuclear fission and fusion, and critical materials (Association of American Universities, 2025). Differences in infrastructure readiness, cost structures, and the effectiveness of policy support contribute to variations in the pace of the EV transition across regions.

4.4. Development of Servitisation Models

Amid the ongoing powertrain transition towards decarbonisation, the automotive industry is increasingly embracing new business models, such as vehicle subscriptions and rental services. These models are emerging as innovative solutions to address evolving consumer preferences and mobility demands. Research indicates that about two-thirds of OEMs in developed countries have already integrated service-based offerings into their business models (Vendrell-Herrero et al., 2017).

The adoption of servitisation serves several strategic objectives. It enhances economic performance by diversifying and extending revenue streams, strengthens competitive advantage and customer loyalty, and contributes to environmental goals by prolonging product life cycles and reducing the consumption of natural resources. Although this business model presents inherent challenges, such as capital-intensive vehicle procurement and significant marketing expenditures, it has evolved from a niche concept into a viable and rapidly expanding segment of the automotive market.

A practical example is Germany's Finn, whose car subscription service experienced remarkable growth, with revenue increasing from EUR3.2 million in 2022 to EUR44.3 million in 2024 (Sifted, 2025). This expansion was driven primarily by rising business-to-business demand, growing consumer interest in EVs, and improved vehicle availability.

Given that this business model remains relatively uncommon in the ASEAN region, it presents a valuable opportunity for future development. By optimising vehicle utilisation and offering flexible access options, servitisation can serve as a strategic lever to support

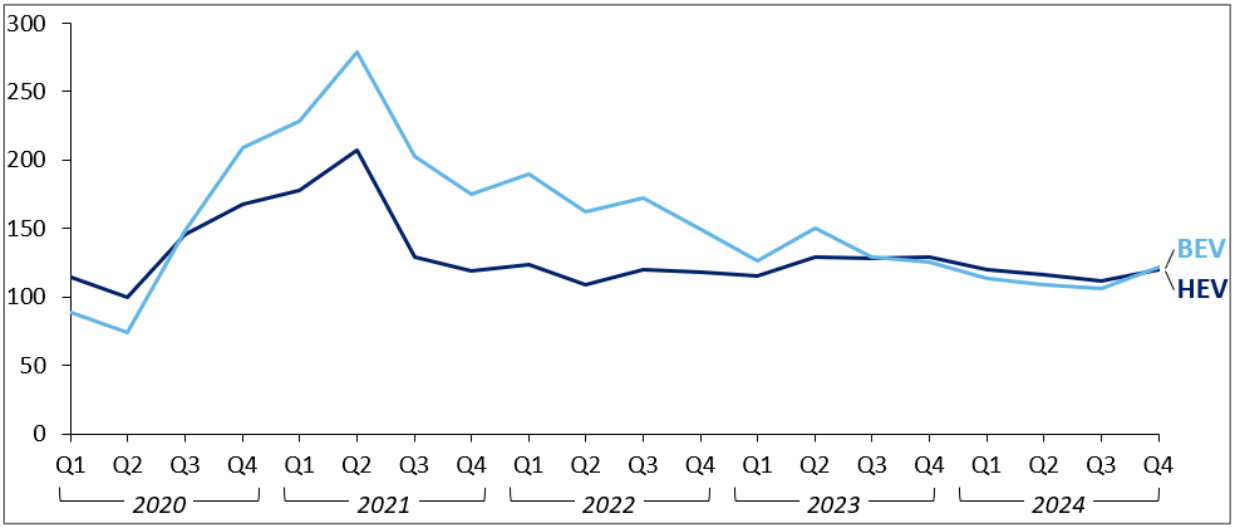
broader adoption of xEVs across the region.

4.5. Uncertainty in Future Projections

Short-term sales volatility and policy changes contribute to a broad spectrum of powertrain mix projections, introducing significant uncertainty into the forecasts currently available in the market. Forecasts of powertrain mix are likely to fluctuate not only in response to changes in sales trends and policy frameworks, but also due to other variables, such as local market needs (e.g. pick-up trucks in Thailand), infrastructure development costs, particularly in rural areas; the impact of falling used car prices linked to challenges in evaluating battery performance; and ongoing concerns regarding battery safety assessment (Chapter 5).

As a result, projections vary widely, reflecting differences in underlying assumptions across sources as well as the historically volatile pattern of global BEV sales. This volatility adds another layer of complexity to forecasting future powertrain adoption. Figure 4.8 illustrates year-on-year changes in BEV and HEV sales. Compared with HEVs, which follow a relatively stable growth trajectory, BEV sales have experienced sharper and more frequent fluctuations. Although BEVs previously underwent a rapid expansion, their growth has since stabilised at levels closer to those of HEVs. What initially appeared to be an inevitable overtaking of HEVs has instead evolved into BEVs becoming one option amongst multiple powertrain technologies. This trend highlights the difficulty of assuming convergence towards a single dominant technology, as demand may rise strongly for a period before normalising.

Figure 4.8. Year-on-Year Changes in Global Battery Electric Vehicle versus Hybrid Electric Vehicle Sales (% change from previous year)

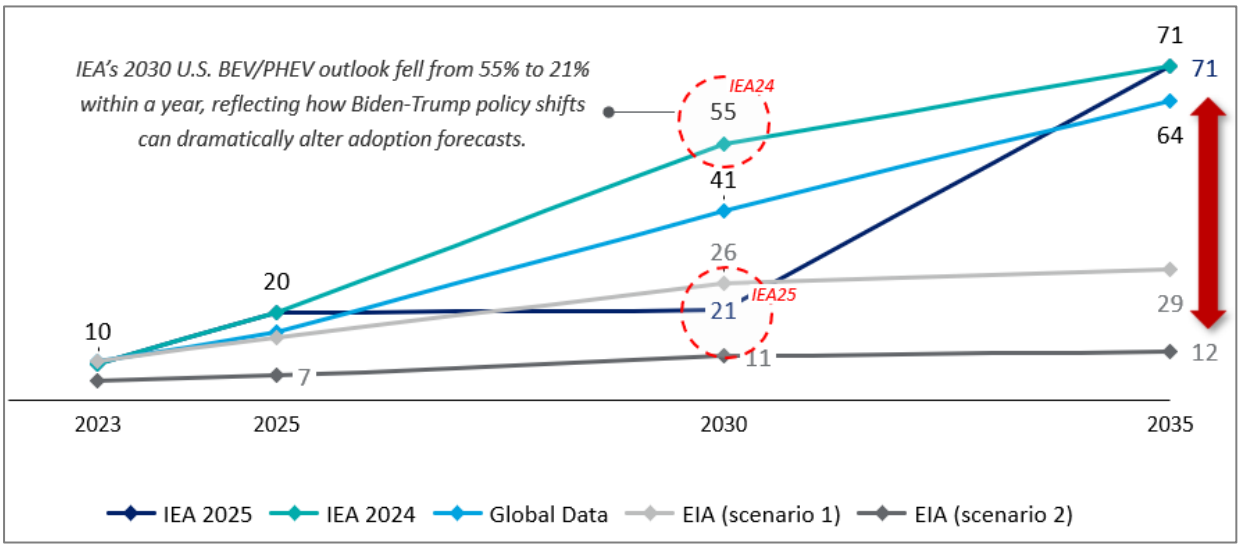


BEV = battery electric vehicle, HEV = hybrid electric vehicle, Q = quarter.
Source: GlobalData (2025).

Figure 4.9 further presents a comparison of multiple projections for future BEV and PHEV market penetration in new car sales in the US. By 2035, projected BEV and PHEV sales shares range from 12% to 71%, indicating a margin of 59 percentage points between the most optimistic and least optimistic forecasts. These differences reflect the influence of various underlying assumptions. For instance, in EIA forecasts, the divergence between scenario 1 and scenario 2 is driven primarily by differing oil price assumptions. Scenario 1 assumes a high oil price, whereas scenario 2 assumes a low oil price. The resulting 17% point gap between the two scenarios implies that oil prices, through their influence on the TCO of ICEVs, remain one of the most influential factors shaping powertrain adoption (EIA, 2023).

Similarly, the IEA revised its forecast for BEV and PHEV sales share in the US for 2030 downwards from 50% in its 2024 outlook to 21% in its 2025 update. This revision was driven primarily by changes in US policy, including the removal of subsidies and other supportive measures for xEVs under the Trump administration. This example illustrates how external policy shifts can substantially affect the pace of the powertrain transition. More recently, uncertainty surrounding xEV adoption has intensified due to the withdrawal of xEV targets and zero-emission vehicle regulations in the US, ongoing reviews of the Inflation Reduction Act, and the introduction of new tariffs. In Europe, revisions to carbon dioxide regulations add further uncertainty. Even global reference institutions such as the IEA continue to revise their projections, reflecting the rapidly evolving policy environment.

Figure 4.9. United States Market Battery Electric Vehicle and Plug-in Hybrid Electric Vehicle Penetration Forecast (%)



BEV = battery electric vehicle, EIA = US Energy Information Administration, IEA = International Energy Agency, PHEV = plug-in hybrid electric vehicle.
Sources: GlobalData (2025); International Energy Agency (2024, 2025, 2023).

Based on multiple projections and government targets, global penetration of BEVs and PHEVs is expected to increase over time. However, ICEVs and HEVs are likely to remain dominant globally in the foreseeable future. The evolution of the global powertrain mix, therefore, remains highly uncertain, as projections are sensitive to socio-economic factors such as oil prices, infrastructure development, and the availability of vehicle models and supporting ecosystems.

Globally, developed and developing countries are undergoing significant powertrain diversification, although the pace of transition varies widely. Key determinants include government policies, subsidies, infrastructure readiness, consumer purchasing power, and expectations regarding the future of oil prices. In developed countries, where policy support is relatively strong, charging infrastructure is more advanced, and purchasing power is higher, the shift towards BEVs and PHEVs is likely to proceed more rapidly. Conversely, in developing economies, the transition may be slower due to lower purchasing power, limited charging infrastructure, and continued reliance on conventional ICEVs. Oil price trajectories will also play a crucial role: higher prices may accelerate the shift towards xEVs, whereas lower prices could slow the adoption of lower-emission alternatives. This divergence underscores the complex and multifaceted nature of the global automotive transition.

In supporting the long-term trajectory of the automotive market, technological advancements will play a critical role by expanding available pathways for vehicle development and energy use. Innovations such as e-fuels offer the potential to enhance decarbonisation outcomes for ICEVs. However, the development of e-fuel production in Southeast Asia remains uncertain despite its potential to reduce greenhouse gas (GHG) emissions by up to 70% (Concawe, 2024). Key obstacles include the absence of robust regulatory frameworks and dedicated financial incentives from governments in the region. Instead, policy efforts continue to focus more heavily on biofuel development, which is estimated to deliver GHG emission reductions of about 80%–90% relative to fossil fuels (IFP Energies nouvelles, 2024). The region lacks the necessary infrastructure and technological readiness, particularly in carbon capture, utilisation, and storage, as well as the integration of reliable renewable power grids, both of which are critical for large-scale production of blue and green hydrogen for e-fuel synthesis.

At the same time, solid-state batteries, which offer higher energy transfer efficiency and improved durability, are under development by several manufacturers. In Southeast Asia, adoption remains at an early stage. For instance, Toyota plans to commercialise solid-state batteries in 2027–2028, targeting a driving range of up to 1,200 km and charging times of 10 minutes or less (Carbon Credits, 2024). These developments aim to significantly enhance energy density and safety relative to conventional lithium-ion batteries. BYD has announced the launch of its flash-charging battery technology, capable of delivering up to 400 km of driving range with just 5 minutes of charging (BYD, 2025a). To support this technology, the company plans to deploy more than 4,000 megawatt-scale flash-charging stations across China. Nevertheless, the development and deployment of such advanced technologies will require substantial capital investment.

The transition from ICE and HEV powertrains towards xEV is irreversible in the context of global decarbonisation efforts. However, the pace of transition will continue to vary across regions due to differences in infrastructure readiness, product availability, TCO, and consumer purchasing power. Future powertrain forecasts remain subject to uncertainty arising from policy shifts and technological development. An exclusive focus on a single powertrain or technology risks constraining the long-term development of the automotive industry, highlighting the need to prepare for multiple technological pathways.

To respond to prevailing uncertainty, policymakers should design sustainable and well-targeted policies that support the adoption of diverse vehicle technologies whilst accounting for fiscal limitations. Such policies should tackle technological innovation, decarbonisation across both vehicles and supply chains, and the development of new business models, including servitisation. For automotive manufacturers, strengthening investment decision-making capabilities and advancing technological expertise will be essential. These measures will support the modernisation of manufacturing processes and enable the production of a wider range of advanced, low-emission vehicle technologies.

Chapter 5
Current and Future State of the ASEAN Automotive Market

5.1 Chapter Overview

This chapter provides an in-depth analysis of trends and prospects in the Association of Southeast Asian Nations (ASEAN) automotive market. It focuses on the powertrain transition, which is expected to proceed more slowly than in leading global automotive markets. As a result, the region is projected to remain a market dominated by internal combustion engine (ICE) and hybrid electric vehicle (HEV) technologies until 2035.

By examining these trends, this chapter highlights the key challenges faced by ASEAN during the global powertrain transition and assesses their implications for the region's position within the automotive industry. The analysis here yields insights into measures required for ASEAN to sustain and strengthen its automotive sector.

5.2 Current State of ASEAN Automotive Market Trends

5.2.1. Overview of Historical and Current Automotive Sales

The automotive industry has long played a central role in ASEAN's industrialisation. The region has emerged as a dominant automotive market (International Labour Organization, 2016), driven by sustained economic growth and the expansion of middle-class households (ASEAN, 2025). Whilst ASEAN is expected to remain a key market, characterised by rising motorisation rates and vehicle ownership, it is also well-positioned to function as a global manufacturing hub serving both domestic and export demand (European Union [EU]–ASEAN Business Council, 2017).

ASEAN automotive sales first reached 3.4 million units in 2012, led primarily by Indonesia and Thailand (Figure 5.1). During the period before the coronavirus disease (COVID-19) pandemic, automotive sales grew at a compound annual growth rate (CAGR) of only 0.2%. In 2019–2021, sales declined sharply, contracting at a compounded rate of 9.5% due to the pandemic. By 2024, total sales stood at 3.2 million units, representing a decline of 0.2 million units compared with 2023.

Although Indonesia and Thailand have historically accounted for the largest shares of regional sales, Malaysia emerged as the leading contributor in 2024, accounting for 26% of total sales. It was followed by Indonesia at 25%, Thailand at 18%, and both the Philippines and Viet Nam at 15%. As shown in Figure 5.1, the ASEAN automotive market recovered after the pandemic, recording a CAGR of 4.4% in 2021–2024.

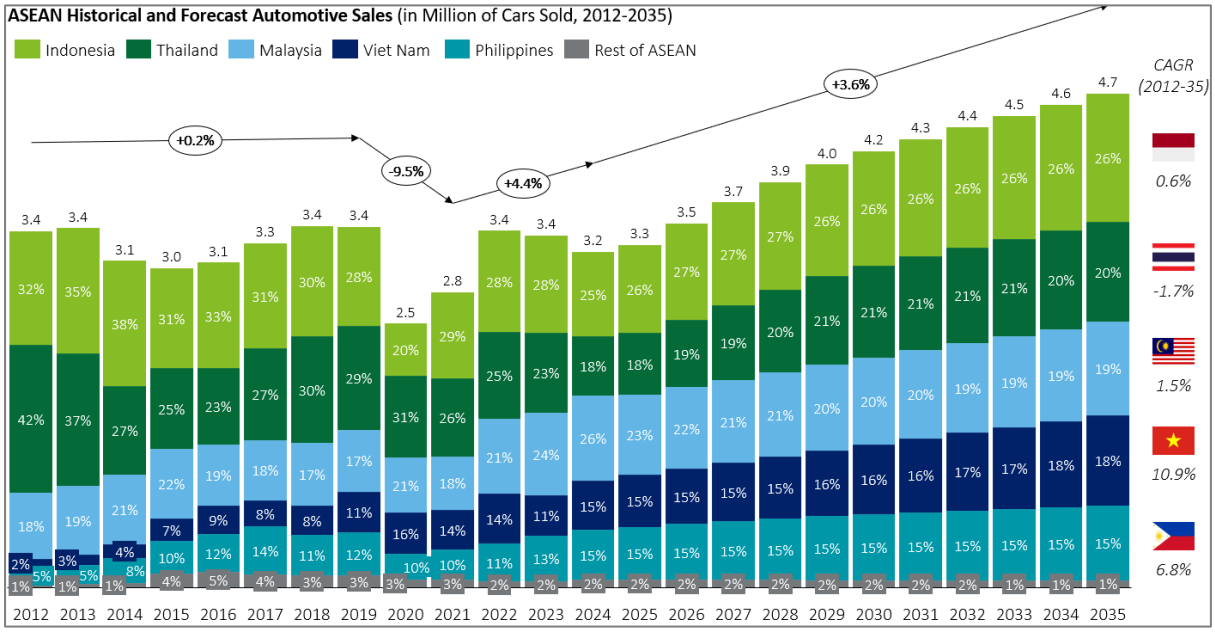
Looking ahead, market growth is projected to moderate, with a forecast CAGR of 3.6% in 2024–2035, lower than the post-pandemic growth observed during 2021–2024. Indonesia (26%) and Thailand (20%) are expected to maintain their lead in market share, followed by

Malaysia (19%), Viet Nam (18%), and the Philippines (15%). Viet Nam is projected to record the fastest growth amongst ASEAN Member States (AMSs), with its market share increasing by an estimated 4% in 2024–2035.

One key trend highlighted in Figure 5.1 is the significant decline in Thailand's share of regional automotive sales, which fell by about 5%, from 23% to 18%, in 2024. In that year, Thailand recorded its lowest level of automotive sales in 15 years (Nikkei Asia, 2025). Several factors have contributed to this decline, including weakened consumer purchasing power, sluggish economic growth, and stricter automotive loan criteria imposed by banks and vehicle financing companies in response to high household debt levels (Thailand Business News, 2024). Collectively, these factors have exerted significant downward pressure on vehicle sales.

According to the Bank of Thailand, household debt accounts for about 90% of the national gross domestic product (GDP). This high debt-to-GDP ratio has reduced banks' willingness to extend credit. Non-performing automotive loans increased by 22.8% in the third quarter of 2024 compared with the previous year, prompting lenders to adopt a more cautious stance. As a result, loan approval rates fell to about 3% of total automotive loan applications (Vietnam Investment Review, 2024). Under these conditions, year-on-year declines in automotive sales have become increasingly evident. For instance, Hyundai reported a reduction in loan approval rates for its vehicles from 90% to 70%, as banks and financing institutions expressed growing concerns over non-performing loans (Bangkok Post, 2024).

Figure 5.1. Historical and Forecast Automotive Sales in ASEAN
(millions vehicles sold, 2019–2035)



ASEAN = Association of Southeast Asian Nations, CAGR = compound annual growth rate.
Note: Automotive sales data include passenger cars and light commercial vehicles for Indonesia, Thailand, Malaysia, Viet Nam, the Philippines, Singapore, Lao People's Democratic Republic, and Myanmar.
Source: MarkLines and GlobalData (2025).

5.2.2. Factors Contributing to Stagnant Automotive Sales

Despite ASEAN's growing foothold in the global automotive market, the persistence of stagnant sales at about 3 million units over the past decade (Figure 5.1) signals a trend that warrants closer examination. To explain the stagnation, this study focuses on two factors: the affordability gap, which is shaped by low household purchasing power and the plateauing growth of the middle-income group, the key consumer segment for new vehicle purchases; and the slow growth of vehicle stocks.

In the following sub-section, the analysis focuses on Indonesia and Thailand, where stagnation has been particularly evident compared with other AMSs. As shown in Figure 5.1, Indonesia and Thailand record the lowest CAGR over 2012–2035, at only 0.6% and –1.7%. By contrast, other ASEAN markets exhibit significantly stronger growth, with Viet Nam and the Philippines recording CAGRs of up to 10.9% and 6.8%, respectively.

In 2024, Indonesia and Thailand together accounted for 43% of total ASEAN automotive sales and are projected to retain this dominant share through to 2035. As a result, trends observed in these markets are likely to reflect the broader forces shaping the overall trajectory of the ASEAN automotive sector.

5.2.2.1. Afiordability gap in the ASEAN auto market

To better understand the stagnation of automotive sales, this section assesses the extent to which individuals in the region can afford vehicle purchases. Two primary factors influencing vehicle affordability are household income levels and consumers' disposable income.

The analysis compares the price of the best-selling model with the annual median household income and average disposable income. Median household income is used because it represents the income level at which 50% of households earn more and 50% earn less (Muth, 2018). Unlike mean income, the median is not distorted by extremely high- or low-income values in skewed income distributions (Chiripanhura, 2011). Median household income provides a more accurate representation of the typical household's earning capacity, especially in emerging economies such as Indonesia and Thailand, where income inequality is relatively pronounced (MacDonald, 2014).

Disposable income serves as a useful indicator of vehicle affordability, as it reflects the amount of income remaining after taxes and essential expenditures.

5.2.2.1.1. Household income

When examining purchasing power, prices of ICE vehicles (ICEVs) remain higher than annual household incomes in ASEAN countries. By contrast, annual incomes in developed economies are generally higher than average car prices. A comparison of median household income with the price of the best-selling vehicle in each country reveals that car prices are more affordable in developed economies. As shown in Figure 5.2, in all four

developed countries examined, annual income surpasses the price of the best-selling vehicle. For instance, in the United States (US), households earn about 3.5 times the cost of the vehicle. In Canada, Germany, and Japan, citizens earn about 2.3, 1.7, and 2.7 times the vehicle price, respectively. From another perspective, the cost of a car in the US is about 71.5% lower than the annual income; the corresponding figures are 57.1% in Canada, 41% in Germany, and about 63.6% in Japan. These findings suggest that consumers in developed markets enjoy easier financial access to vehicle purchases and greater affordability than in markets where car prices often significantly exceed annual incomes.

By contrast, new car prices are substantially higher in Indonesia and Thailand than household income. In both countries, annual income levels are generally insufficient to afford an average-priced vehicle. In Thailand, the price of the Toyota HiLux, the country's most popular model, is about 26% higher than the annual household income. In Indonesia, the price of the Toyota Avanza is about 64% higher than the annual income of an Indonesian household. These figures imply that vehicles in these ASEAN countries are considerably less affordable than in developed markets, where incomes exceed vehicle costs. This situation highlights a clear disparity in purchasing power between ASEAN citizens and consumers in more developed economies, where buying a vehicle absorbs a smaller portion of earnings.

The use of median household income further indicates that a significant proportion of the population still finds car purchases financially inaccessible. As median income reflects the midpoint of income distribution, such a gap suggests that sales stagnation is likely to persist unless there are significant reductions in car prices or effective policies to increase household incomes across AMSs.

From another perspective, income growth has not been sufficient to offset increases in car prices. In Indonesia, median household income grew at a CAGR of 4% from US$6,212 in 2015 to US$8,835 in 2024 (Euromonitor, 2024a), whilst car prices increased at a CAGR of 3.1% over the past 10 years (Toyota Indonesia, 2025). As a result, despite sustained income growth, car prices have continued to keep pace, yielding a net increase in purchasing power of less than 1%. Consequently, the response in automotive purchasing has remained limited.

In Thailand, median household income grew at a CAGR of 3.5% in 2015–2024 (Euromonitor, 2024a), whilst average car prices declined at a CAGR of –2.2% over the same period (Toyota Thailand, 2025). Although this suggests a net annual improvement in purchasing power of about 1.3%, the impact on automotive demand has remained minimal. This moderate gain is likely offset by rising costs in other essential expenditure categories, such as housing, education, and healthcare, which continue to account for a significant share of household budgets.

The pool of individuals able to afford a car purchase remains constrained in ASEAN. As shown in Figure 5.3, a much larger proportion of households in developed economies can afford to buy a car than those in ASEAN countries. In the US, 89.5% of households earn

more than the average price of the best-selling car model. The corresponding figures are 92.0% in Canada, 77.5% in Germany, and 88.9% in Japan.

When evaluating car affordability, two commonly used benchmarks provide useful reference points, although their applicability varies across households. For cash purchases, a widely accepted guideline suggests that the total vehicle cost, including taxes and fees, should not exceed 35% of the buyer's annual income. For financed purchases, consumers often refer to the '20/4/10' rule of thumb, which recommends a 20% down payment, a loan term of no more than 4 years, and total monthly transport expenses, including loan repayments, fuel, maintenance, and insurance, kept within 10% of monthly income.

Within ASEAN, however, meeting the 10% affordability threshold remains highly challenging. For example, the average price of electrified vehicles (xEVs) in the ASEAN market is about US$36,779. With a 20% down payment, the financed amount would be US$29,423. Assuming an interest rate of 4% over a 4-year loan term, the estimated monthly repayment would be around US$663.[1] Including additional expenses such as maintenance and electricity, total monthly transport expenditure rises to about US$683. Given that the average monthly household income in ASEAN is about US$819, transport costs would account for roughly 83% of monthly income, far exceeding recommended benchmarks. This highlights the persistent difficulty of achieving car affordability, even when financing options are used.

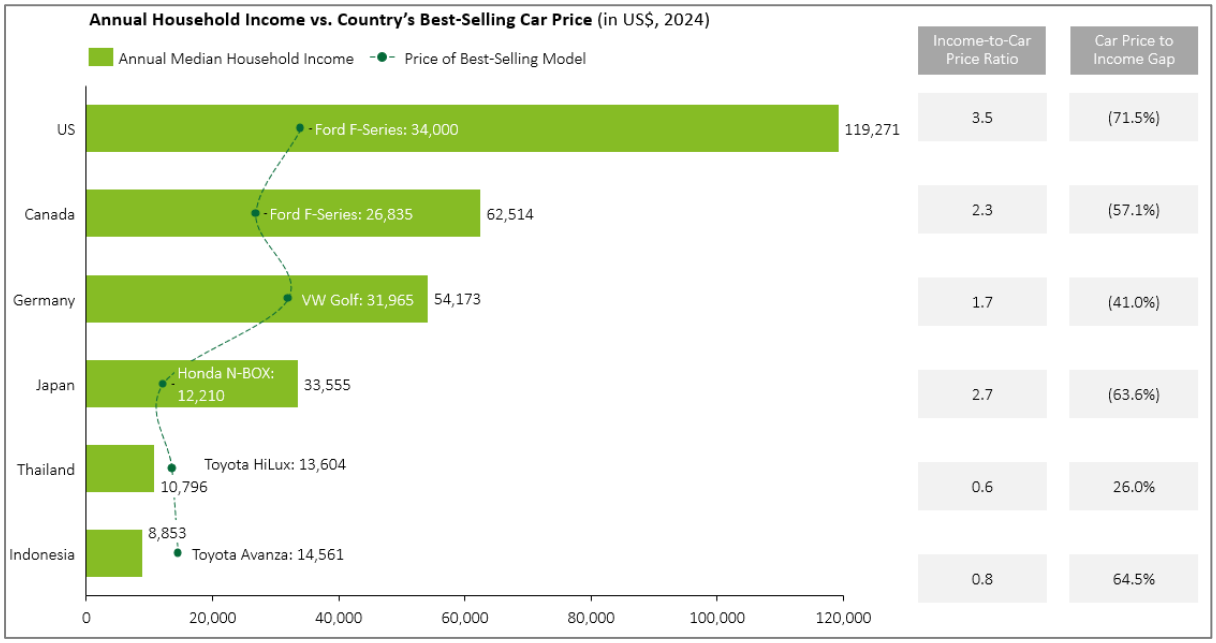
In summary, without substantial improvements in purchasing power or the introduction of innovative financing solutions, affordability will remain a key constraint on the adoption of both ICEVs and xEVs in ASEAN.

5.2.2.1.2. Disposable income

Car prices remain substantially higher than the average household income, rendering automobile purchases largely unaffordable and hindering the pace of motorisation and, consequently, vehicle sales across the region. In Thailand, only about 41.7% of households have an annual disposable income above US$15,000. With the average price of a Toyota HiLux at US$13,640 in 2024, vehicle ownership remains financially out of reach for more than half of all households. In Indonesia, only about 21.3% of households nationwide have an annual disposable income of US$15,000. Given that the average price of the Toyota Avanza in 2024 was US$14,561, only a small proportion of the population can realistically afford such a purchase.

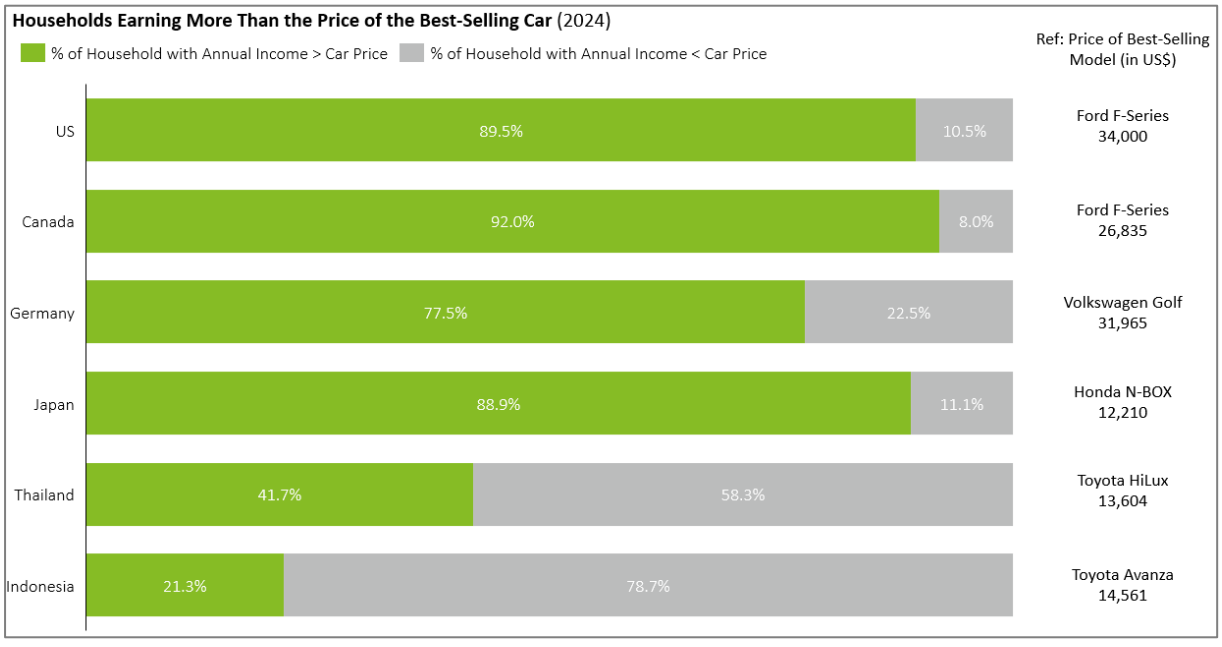
[1] Based on the loan calculator (Annex 3).

Figure 5.2. Cross-country Comparison of Annual Household Income versus Car Price



Notes: (1) Values in brackets denote that, in these countries, income exceeds car price. (2) In the United States, car prices are 71.5% lower than income, whereas in Thailand, car prices are 26% higher than income.
Sources: Euromonitor (2024a), Toyota Astra Indonesia (2025), Toyota Motor Thailand (2025), Volkswagen Global (2025), Ford America (2025).

Figure 5.3. Cross-country Comparison of Annual Household Income and Car Prices



Sources: Euromonitor (2024b), The Economist Intelligence Unit (2024).

According to Table 5.1, a comparison of three key indicators – household income, vehicle sales, and vehicle stock – indicates that automotive markets in developing countries remain

relatively stagnant, primarily due to limited purchasing power. In Thailand and Indonesia, more than 50% of households have annual incomes below the average vehicle price, which significantly limits their capacity to purchase cars. By contrast, in developed markets such as the US, Germany, and Japan, over 75% households have incomes exceeding the average vehicle price. As a result, although vehicle sales have also declined in these developed countries, the contraction is less pronounced than in developing markets.

Table 5.1. Comparison of Households with Annual Income Above Car Price, Vehicle Sales, and Vehicle Stock, 2024

Country	% of Households with Annual Income > Car Price	Vehicle Sales Growth	Vehicle Stock Growth
United States	90%	–4%	–33%
Germany	78%	–1%	0%
Japan	89%	–7%	0%
Thailand	42%	–35%	–1%
Indonesia	21%	–16%	1%

Sources: GlobalData (2025), The Economist Intelligence Unit (2025), Euromonitor (2024b), The Economist Intelligence Unit (2024).

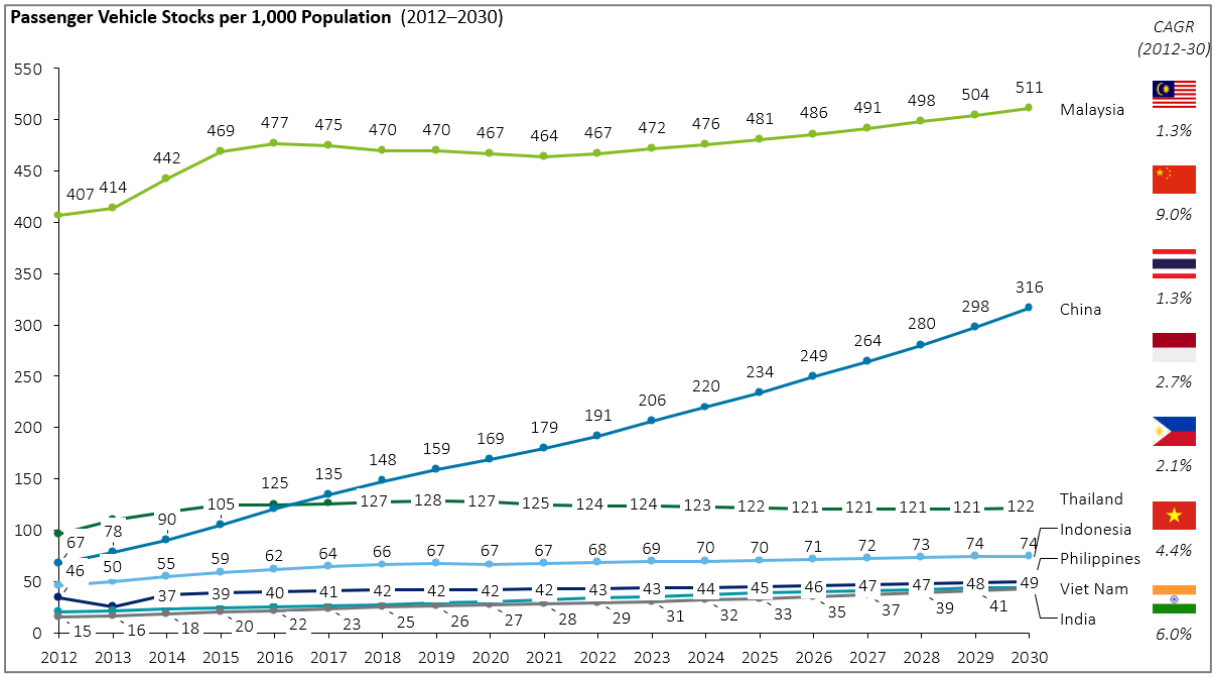
5.2.2.2. Growth of vehicle stock

ASEAN case

Beyond purchasing power, the current level of vehicle ownership inevitably influences automotive sales within a country. The growth of vehicle stock in ASEAN countries has been slower than in emerging markets such as China and India (Bloomberg, 2024). As shown in Figure 5.4, Malaysia records the highest level of motorisation in ASEAN, even surpassing other emerging economies, with projections indicating over 500 passenger vehicles per 1,000 people. Thailand ranks second, followed by Indonesia, the Philippines, and Viet Nam. Despite some ASEAN countries exhibiting relatively high vehicle stock levels, their expected growth rates remain lower than those of China and India. Over 18 years, China is expected to expand at a CAGR of 9.0% and India at 6.0%. By contrast, amongst AMSs, the highest growth is projected for Viet Nam at 4.4%, followed by Indonesia at 2.7%, the Philippines at 2.1%, and Thailand and Malaysia at 1.3% each. This slower pace highlights the underlying stagnation in vehicle sales across the region, driven in part by subdued growth in passenger vehicle stocks.

Whilst national growth rates offer a regional overview, they often disguise underlying disparities between and within countries. Indonesia and Thailand are selected as case studies, as stagnation amongst ASEAN countries is most pronounced in these two markets. As the two largest automotive markets in ASEAN, trends observed in these countries are likely to reflect broader structural challenges faced by the region. The following discussion therefore examines the specific dynamics shaping vehicle stock growth in these two countries.

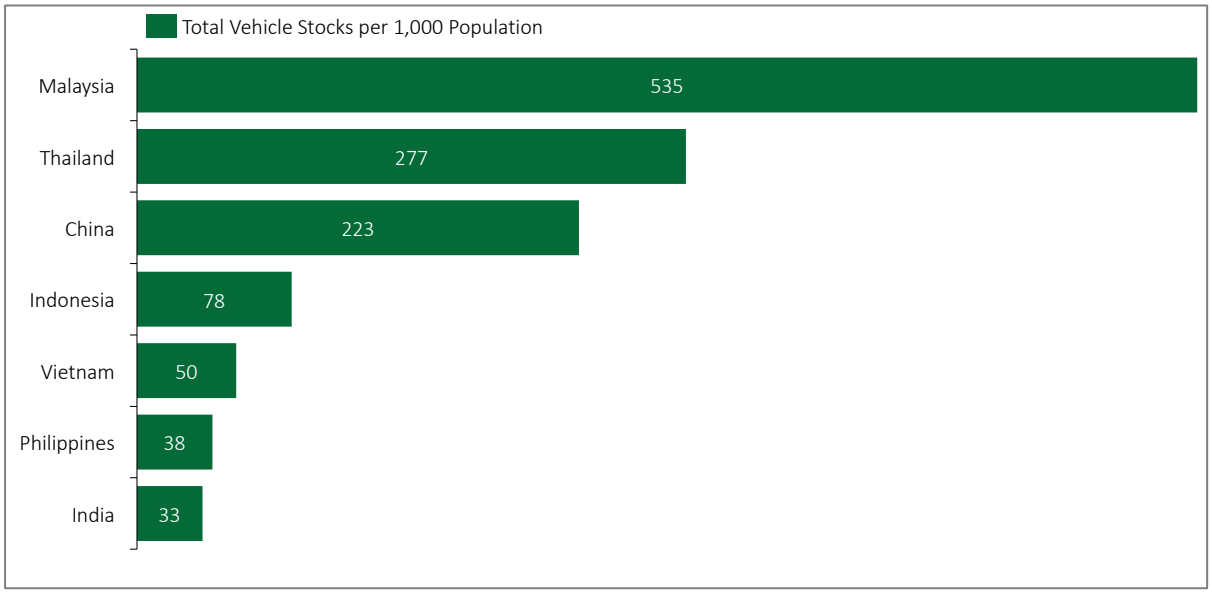
Figure 5.4. Historical and Forecast Growth of Vehicle Stocks in Emerging Economies



Note: Passenger vehicles include only four-wheel vehicles and exclude pick-up trucks.
Source: The Economist Intelligence Unit (2025).

Given that a large share of consumers in Thailand use pick-up trucks for both personal and commercial purposes, Figure 5.5 presents total vehicle stock, including pick-ups. The pattern remains consistent with Figure 5.4, with Malaysia recording the highest level of motorisation in ASEAN at 535 vehicles per 1,000 population in 2020, followed by Thailand, China, Indonesia, Viet Nam, the Philippines, and India.

Figure 5.5. Total Vehicles in Use



Note: Total vehicles include pick-up trucks.
Source: International Organization of Motor Vehicle Manufacturers (2020).

Indonesia and Thailand: Disproportionate vehicle distribution and economic growth constraints

Two interlinked dynamics help explain the stagnation in vehicle stock growth. The first is evidence of market maturity in major urban centres, particularly Jakarta and Bangkok. The second is the sluggish expansion of the middle class, traditionally the backbone of vehicle demand. Together, these factors explain why vehicle stock growth has failed to meet expectations despite the size and potential of the Indonesian and Thai markets.

In Indonesia, vehicle penetration varies markedly across provinces relative to the national average. These differences reflect variations in economic conditions, demographics, infrastructure availability, and policy frameworks. Provinces with higher GDP per capita, well-developed infrastructure, supportive government policies, and deep networks of dealerships tend to exhibit higher vehicle ownership. National passenger vehicle ownership stands at 69 vehicles per 1,000 population (Figure 5.4). Provincial ownership rates diverge widely. As shown in Figure 5.6, Jakarta records the highest penetration, at 361 vehicles per 1,000 population, whilst the three lowest-ranking provinces have fewer than 10 vehicles per 1,000 population, indicating very low levels of motorisation.[2]

Amongst the three provinces with the highest vehicle-to-population ratios, growth has remained moderate, with CAGRs of 4.1%, 5.2%, and 4.7% in Jakarta, East Kalimantan, and South Sulawesi, respectively. Moderate to low growth in provinces with already high vehicle stock suggests that further expansion is increasingly driven by vehicle replacement rather than first-time purchases.

Focusing on Jakarta as the country's leading urban and economic hub, vehicle stock of 361 vehicles per 1,000 population in 2023 suggests that the province is approaching market maturity relative to its income level. However, compared with countries with similar per capita incomes of about US$20,000, Jakarta's motorisation rate remains relatively low. For example, Hungary records 424 vehicles per 1,000 population (Eurostat, 2024), whilst Bulgaria records about 449 (Statista, 2025a). This comparison indicates that, in principle, scope remains for further vehicle stock growth given Jakarta's economic position.

Nevertheless, post-COVID-19 pandemic trends point to emerging constraints. National passenger car sales grew at a CAGR of 10.7% in 2021–2023 (MarkLines, 2025), whilst vehicle stock per 1,000 population grew by only 3.7% over the same period (Figure 5.6). This divergence suggests that vehicle stock in key provinces is not expanding at the expected rate, signalling a slowdown in new demand. As these provinces have historically driven automotive sales, this trend points to increasing market saturation and weaker future growth opportunities.

Compounding this trend is the contraction of Indonesia's middle-class, which is predominantly concentrated in large urban centres such as Jakarta. Rising living costs combined with stagnant wages have eroded purchasing power, pushing a growing share of

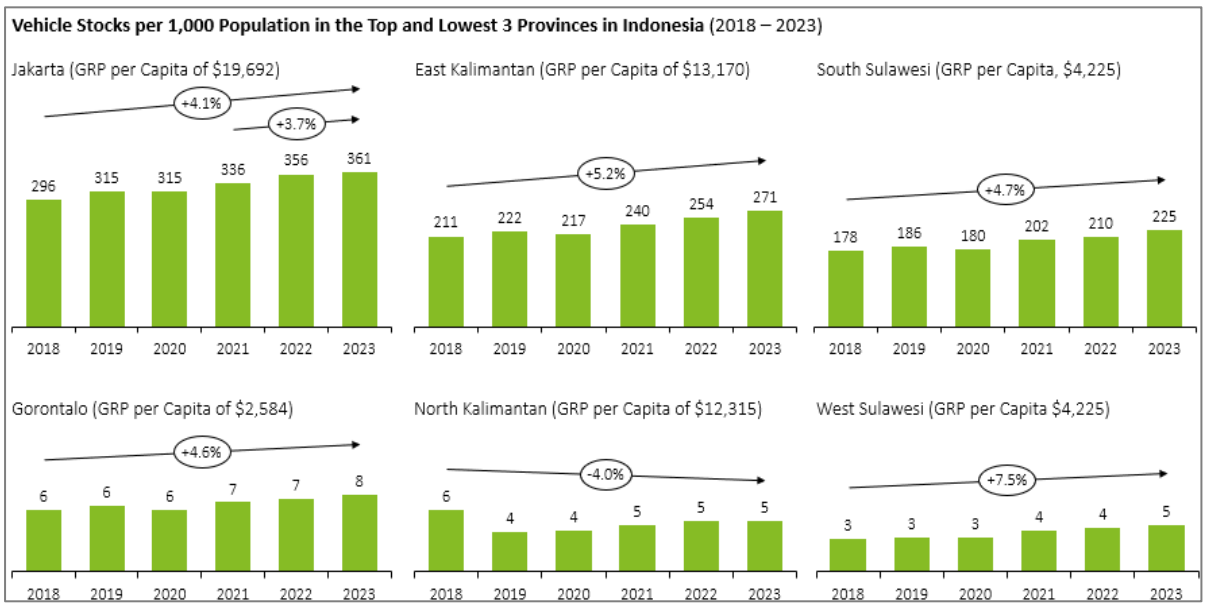
[2] Vehicle stock per 1,000 population for all 34 provinces in Indonesia is presented in Annex 1.

the population into lower income brackets. Data from the National Research and Innovation Agency show that the middle-class population declined by 19% from 57.3 million in 2019 to 48.3 million in 2023 (CNBC, 2024). This sharp decrease has weakened domestic consumption, including car purchases, and has contributed to stagnation in Indonesia's automotive market.

Although some lower-ranked provinces, such as Gorontalo and West Sulawesi, recorded comparable or even higher CAGRs of 4.6% and 7.5%, respectively, their absolute contribution to national vehicle sales remains limited due to their low starting base. At the same time, provinces such as North Kalimantan experienced negative growth, with a CAGR of –4.0%, indicating that low motorisation does not automatically translate into future expansion. Overall, automotive sales in Indonesia remain stagnant because growth in low-penetration regions has been insufficient and inconsistent to offset the slowdown in major urban markets.

Taken together, vehicle stock distribution in Indonesia is highly uneven, with a strong concentration in urban centres such as Jakarta. Whilst these areas still account for the highest vehicle ownership, growth has continued to slow as the middle-class shrinks. Lower-tier cities, which were expected to offset urban stagnation, have instead shown moderate or even negative growth. Although this analysis focuses on Indonesia, the findings are likely indicative of broader trends across the ASEAN market, especially in countries where urban dominance and middle-class stagnation impose similar structural constraints on vehicle stock growth.

Figure 5.6. Vehicle Stocks per 1,000 Population in the Top and Bottom Three Provinces in Indonesia



GRP = gross regional product.
Source: Central Bureau of Statistics of Indonesia (2024).

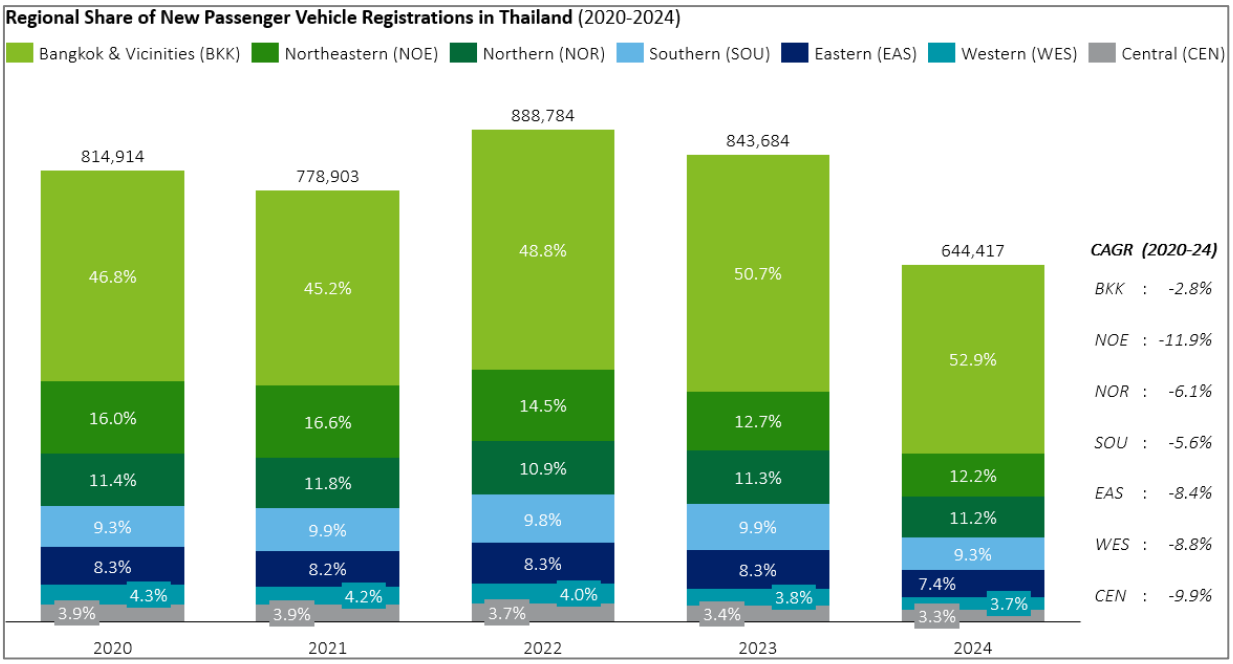
Thailand exhibits a broadly similar pattern. Bangkok and its surrounding areas form the country's economic core and account for a disproportionate share of national vehicle stock, mirroring Jakarta's role in Indonesia. Vehicle ownership in Bangkok stands at 686 vehicles per 1,000 population (Greigarn et al., 2024), compared with a national average of only 122. This level is comparable with developed markets such as Japan, which records 487 vehicles per 1,000 population. Japan's automotive market is widely regarded as mature, with sales expected to remain below 5 million units annually until 2035 (GlobalData, 2025a). High motorisation levels are commonly associated with market saturation. Singh et al. (2020) suggest that saturation in Asian countries occurs at ownership levels of 400–450 vehicles per 1,000 population. On this basis, Bangkok can be considered a saturated market, where demand is largely driven by vehicle replacement rather than first-time purchases. As the country's principal automotive market, saturation in Bangkok has inevitably dampened Thailand's overall vehicle market momentum and contributed to a broader slowdown in vehicle sales.

Whilst regions outside Bangkok, particularly rural areas, theoretically offer potential for first-time buyers, recent trends indicate otherwise. Despite a national average of only 122 vehicles per 1,000 population, data on new passenger vehicle registrations from the Department of Land Transport (2025) show declining registrations outside Bangkok. As shown in Figure 5-7, Bangkok consistently accounts for the largest share of new registrations, and this share has continued to increase, whilst other regions have experienced declines. Although registration numbers have fallen across all regions, the contraction has been more severe outside Bangkok, ranging from –5.6% in the southern region to –11.9% in the northeastern region, compared with –2.8% in Bangkok. These declines have been exacerbated by tighter financing conditions, particularly affecting pick-up trucks, which are widely used in rural areas for personal and commercial purposes (Reuter, 2024). This pattern points to a structural stagnation in the vehicle market, where growth remains concentrated in the capital and expected contributions from other regions have yet to materialise.

Regional economic performance further constrains demand. As shown in Figure 5-8, gross regional product (GRP) per capita in Bangkok grew at a CAGR of only 0.6% in recent years, indicating stagnating purchasing power in the country's economic centre. The southern and eastern regions recorded negative GRP per capita growth of –1.41% and –0.3%, respectively. Although the northern and northeastern regions continue to grow, their expansion has remained moderate, with GRP per capita growth generally below a CAGR of 4%. Such growth rates are insufficient to offset stagnation in Bangkok and drive a strong national recovery in vehicle demand.

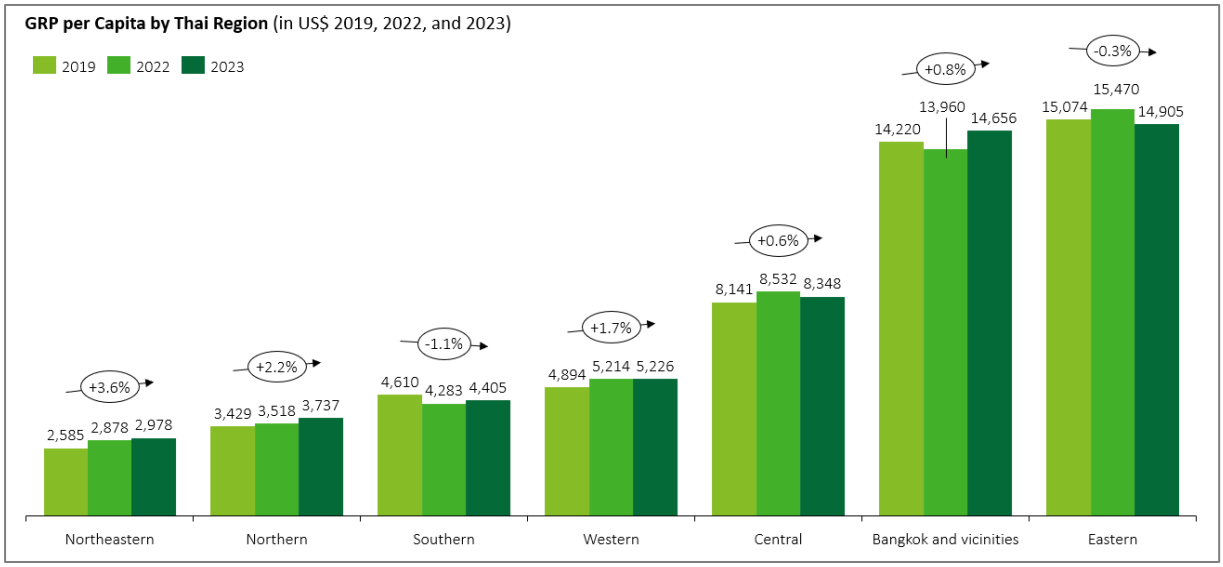
Overall, the experiences of Indonesia and Thailand point to a common pattern: when economic growth slows in dominant urban centres and smaller regions fail to expand rapidly enough, automotive markets reach a natural plateau. This urban concentration of demand places both markets – and potentially other ASEAN countries with similar structural characteristics – at risk of prolonged stagnation.

Figure 5.7. New Passenger Vehicle Registrations in Thailand



Source: Department of Land Transport of Thailand (2025).

Figure 5.8. Gross Regional Product in Thailand



GRP = gross regional product.
Source: Office of the National Economic and Social Development Council (2022).

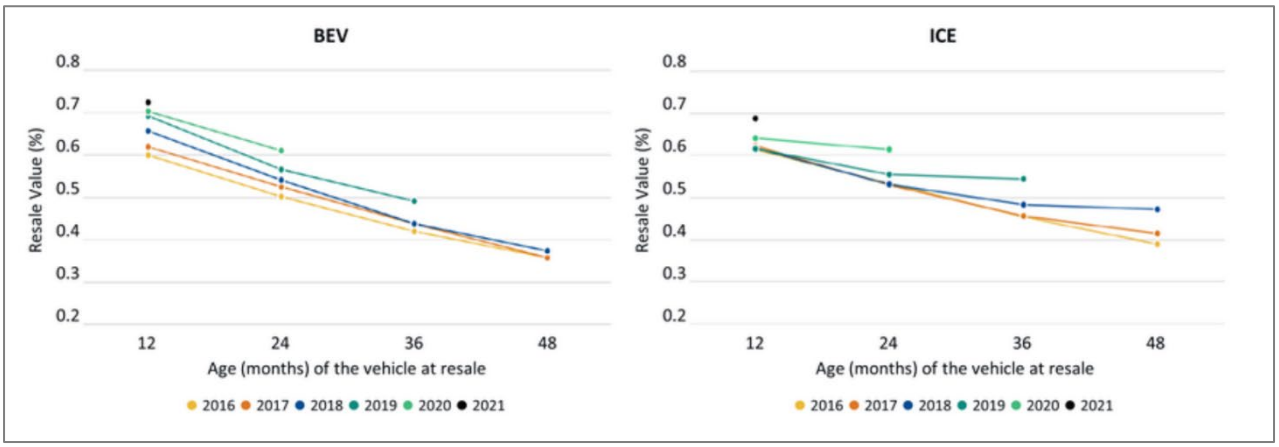
Despite sluggish growth in new vehicle sales, the used car market has emerged as a potential alternative. In Southeast Asia, market size is projected to grow from US$69.66 billion in 2025 to US$96.12 billion by 2030, corresponding to a CAGR of 6.6% (Mordor Intelligence, 2024a). This growth is driven mainly by consumer preference for more affordable options amid rising new vehicle prices, alongside the increasing use of online platforms for vehicle transactions.

Indonesia and Thailand are amongst the Southeast Asia markets expected to experience

strong growth in used car sales, with projected CAGRs of 6% (Mordor Intelligence, 2024b) and 7% (Mordor Intelligence, 2024c), respectively, over 2025–2030. In addition to affordability and the convenience of remote purchasing, a wider range of financing options has further supported demand for used vehicles.

Nevertheless, the used car market in Southeast Asia remains highly competitive and fragmented, with numerous participants, particularly unorganised dealers, who often offer significantly lower prices than organised players. By contrast, the used xEV market, particularly in Thailand, remains relatively small and is concentrated largely in the premium segment. Used EVs tend to depreciate more rapidly than used ICEVs. The estimated resale value of used BEVs that are 48 months old and produced in 2016 is about 0.35%, compared with 0.40% for used ICEVs of the same age (Figure 5.9). This faster depreciation reflects the transitional stage of the market, as well as intense price competition in the new vehicle segment driven by rapid advancements in battery technology and frequent model updates (Krungsri Research, 2024a).

Figure 5.9. The Relationship between Resale Value and the Age of Electric Vehicles and Internal Combustion Engine Vehicles, by Production Year

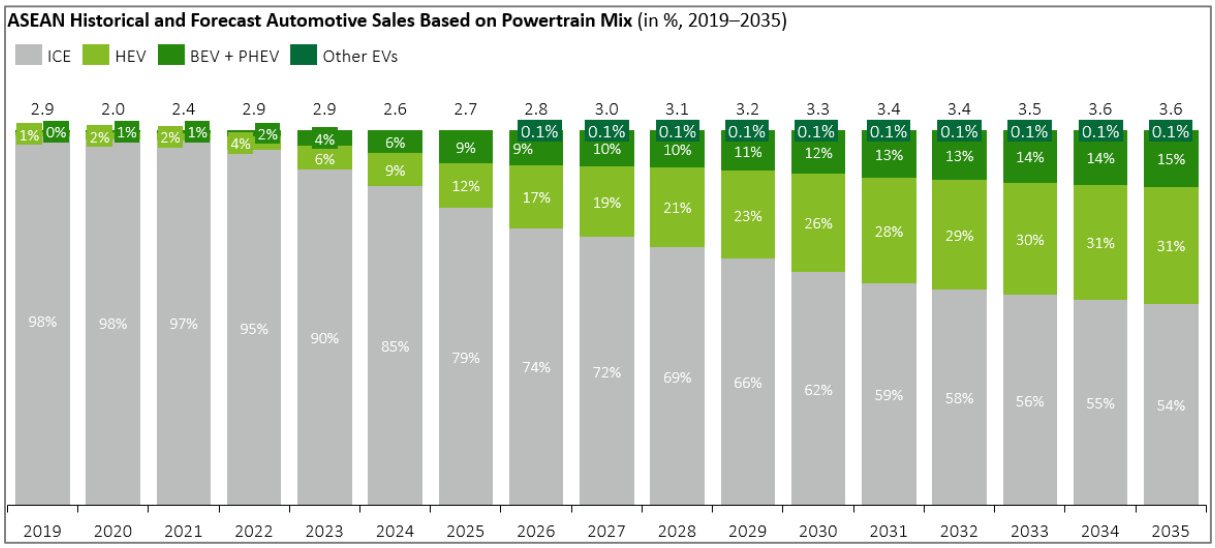


BEV = battery electric vehicle, ICE = internal combustion engine.
Source: Krungsri Research (2025).

5.3 ASEAN Powertrain Transition Towards Decarbonisation

The ASEAN automotive market has long been dominated by ICEVs. However, a gradual transition towards HEVs and xEVs has become increasingly apparent, as the share of new ICEV sales continues to decline (Figure 5-10). In 2024, ICEVs accounted for 82% of new car sales, followed by HEVs at 11%, and BEVs and PHEVs combined at 7% share. The dominance of ICE and HEV powertrains is expected to persist with a combined share of 83% in 2035. Amongst all powertrains, HEVs are expected to experience the most significant growth, increasing by up to 23 percentage points, from 11% in 2024 to 34% in 2035. By contrast, xEV penetration is expected to remain relatively modest, rising by only 9 percentage points, from 7% to 16%.

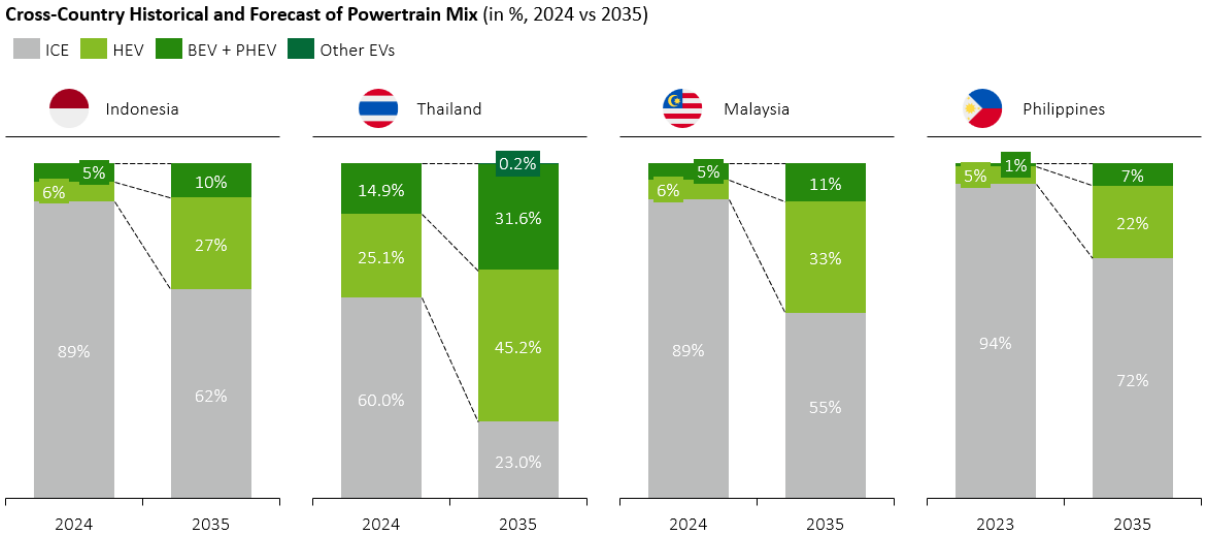
Figure 5.10. ASEAN Historical and Forecast Powertrain Mix
(shares of total new car sales, 2019–2035)



BEV = battery electric vehicle, EV = electric vehicle, HEV = hybrid electric vehicle, ICE = internal combustion engine, PHEV = plug-in hybrid electric vehicle.
Note: Automotive sales data for powertrain mix cover passenger cars and light vehicles up to a gross vehicle weight of 6 tonnes, registered for both commercial and personal use. Data are available only for Indonesia, Thailand, Malaysia, and the Philippines.
Source: GlobalData, Automotive Sales by Powertrain (2024).

Based on current market positioning, Thailand is expected to outpace its ASEAN peers in the powertrain transition. As shown in Figure 5.11, Thailand's xEV market is forecast to account for 31.6% of total vehicle sales by 2035. HEVs are expected to form the largest share at 47%, whilst ICEVs are projected to decline to just 22%. Other AMSs are anticipated to experience a slower transition, with BEV and PHEV shares not exceeding 10% in each country. Malaysia and Indonesia are expected to display broadly similar powertrain distributions, with xEV shares of 10%–11%, HEV shares of 27%–33%, and ICEV shares of 55%–60%. The Philippines is likely to lag further, maintaining a high ICEV share of about 72% in 2035.

Figure 5.11. Cross-country Historical and Forecast Powertrain Mix (share of total new car sales, 2024 and 2035)



BEV = battery electric vehicle, EV = electric vehicle, HEV = hybrid electric vehicle, ICE = internal combustion engine, PHEV = plug-in hybrid electric vehicle.
Note: Automotive sales data for the powertrain mix cover passenger cars and light vehicles up to a gross vehicle weight of 6 tonnes, registered for both commercial and personal use. Data are available only for Indonesia, Thailand, Malaysia, and the Philippines.
Source: GlobalData, Automotive Sales (2024).

5.4 Challenges for the Powertrain Transition

Electrification has become a central pillar of AMSs' decarbonisation strategies. Governments across the region have set ambitious targets to accelerate xEV uptake, with several member countries already establishing national strategies to support vehicle electrification and the development of enabling ecosystems (ASEAN, 2024).

Indonesia, for example, has set a long-term target to phase out ICEV sales by 2040, with the aim that all new vehicles sales will be fully electric by that year. In the nearer term, the country targets xEVs to account for 20% of total vehicle production by 2025 (RE Global, 2024). The Coordinating Minister for Maritime and Investment Affairs announced a target of 600,000 BEV units in production by 2030 (ASEAN Energy Database, 2025). Despite these ambitions, combined sales of xEVs and HEVs accounted for only 11% of total vehicle sales in 2024 (Figure 5.11). BEV production reached just 15,318 units in 2023, representing only 2.6% of the 2030 target (CRIF Asia, 2024). This significant gap suggests that current production capacity remains constrained and that planned targets are unlikely to be met in the near term. As a result, opportunities for BEV exports are expected to remain limited, as domestically produced vehicles are likely to be prioritised to meet domestic targets before addressing export demand, a common development policy approach in emerging economies (Runde et al., 2019).

Thailand, by contrast, has largely adopted a supply-driven approach. The Ministry of Transportation has set a target for BEVs to account for 30% of annual domestic vehicle

production by 2030 (S&P Global, 2024). To support this target, Thailand launched the EV 3.0 policy in 2022, offering subsidies of up to THB150,000 (about US$4,130) per vehicle and exemptions from import tariffs on Chinese-built BEVs sold in 2022–2025. These incentives were conditional on Chinese manufacturers commencing BEV production in Thailand by 2024 at a 1:1 ratio (one locally produced vehicle for every imported unit) and increasing this to 1:1.5 by 2025.

From 1 January 2024, Thailand introduced the EV 3.5 programme, which further reduces import duties and excise taxes through to 31 December 2027. Importers of completely built-up BEVs are required to offset imports through domestic production at a ratio of 1:2 by 2026 or 1:3 by 2027 to qualify for subsidies and tax incentives.

These incentives attracted more than 20 Chinese automakers to Thailand (Akama, 2025). According to data from the Excise Department cited by Phoonphongphiphat (2024), from the launch of the scheme in 2022 to mid-2024, 185,029 BEVs were imported, whilst new BEV registration reached only 86,043 units. This indicates that by July 2024, at least 90,000 vehicles remained in oversupply.

At the same time, total car sales from January to November 2024 were 27% lower than during the same period in 2023 (Akama, 2025). BEV sales specifically declined by 5% to 61,443 units, following an almost eightfold increase in 2023 to about 76,000 units. Tomiyama et al. (2024) observed that ample EV supply amid weak purchasing power triggered an intensified price war, prompting many prospective buyers to delay purchases in anticipation of further price reductions.

More recently, market conditions have shown signs of improvement. By July 2025, Thailand recorded its fourth consecutive month of growth in vehicle sales following 2 years of sharp decline (Just Auto, 2025). Amongst the contributing measures was the Bank of Thailand's reduction of the benchmark interest rate by 25 basis points on four occasions over the past year, lowering the rate from 2.5% to 1.5%. During the first 7 months of 2025, BEV sales rose by 58% to 63,760 units, accounting for 19% of total vehicle sales. Industry sources expect BEV sales to exceed 100,000 units for the year, supported by new model launches and aggressive pricing strategies.

To further ease oversupply and reduce price competition, Thailand's government announced that, from 31 July 2025, each BEV exported by participating manufacturers would count as 1.5 units towards their EV offset obligations. This policy is intended to provide greater flexibility for manufacturers and to strengthen Thailand's position as a regional EV production and export hub (Setboonsarng et al., 2025).

In Malaysia, the Low Carbon Mobility Blueprint and the National Energy Transition Roadmap set a target for xEVs to account for 15% of new vehicle sales by 2030 and 80% by 2050 (MGTC, 2024), with a longer-term vision of 1.5 million xEVs on the road by 2040 (Bernama, 2023). Similarly, the Philippines has set an ambitious target of achieving full vehicle electrification by 2040 (Department of Energy, 2024).

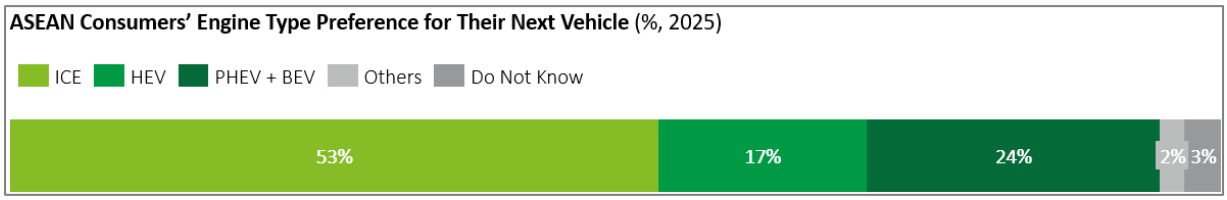
Thailand primarily sets its targets from a supply-side perspective. The Ministry of

Transportation aims for BEVs to account for 30% of the country's annual domestic vehicle production by 2030 (S&P Global, 2024).

Whilst these targets are ambitious, the pace of electrification remains heavily dependent on consumers' behaviour. According to Deloitte's Global Automotive Consumer Survey, four key behavioural trends shape ASEAN consumers' sentiment towards xEVs. Whilst some of these trends align with those observed in global markets, others are specific to the region.

First, ICEVs remain the preferred option for most ASEAN consumers. As shown in Figure 5-12, 53% of respondents indicated that they would consider an ICEV for their next purchase, up from 52% in the previous year. Although the increase is negligible, it further highlights the challenges facing the powertrain transition, as ICEVs continue to dominate consumer preference. By comparison, only 17% of respondents expressed a preference for HEVs, whilst 24% considered xEVs. This strong inclination towards ICEVs is consistent with patterns observed in other major markets, where ICEVs remain the most preferred option across the US, India, Germany, the United Kingdom, Japan, the Republic of Korea (henceforth Korea), and China.

Figure 5.12. ASEAN's Engine Type Preference for Next Vehicle



BEV = battery electric vehicle, HEV = hybrid electric vehicle, ICE = internal combustion engine, PHEV = plug-in hybrid electric vehicle.
Note: Percentages may not sum up to 100 due to rounding.
Question: What type of engine would you prefer in your next vehicle?
Source: Deloitte Global Automotive Consumer Survey (2025).

Second, the three factors that most affect ASEAN consumers' decision to purchase an xEV are lower fuel costs, environmental concerns, and driving experience. These factors closely mirror those identified in global markets. They are unlikely to explain differences in adoption trends between ASEAN and other regions, suggesting instead that xEV growth will depend more heavily on policy support and infrastructure readiness.

Third, 62% of respondents indicated that they prefer or plan to charge their vehicles at home, compared with 28% who prefer public charging stations and 10% who would charge at work. Nevertheless, even amongst ASEAN consumers who intend to purchase an xEV and charge at home, 58% reported that they do not have access to charging infrastructure.

Fourth, ASEAN consumers are generally most concerned about BEV charging time, range, vehicle cost, and the limited availability of public charging infrastructure, despite most expecting to charge at home. Most EVs require recharging after about 200–300 kilometres, which is substantially shorter than the range of comparable ICEVs (CNA, 2022). Charging

may take an hour or more, whereas refuelling an ICEV typically requires no more than 5 minutes. As a result, range anxiety is more pronounced amongst BEV users, largely due to slower charging times and less extensive refuelling infrastructure.

According to the National Motorists Association, about 32% of ICEV drivers delay refuelling until the low-fuel warning indicator is activated. By contrast, anxiety amongst BEV drivers tends to increase once battery charge drops below 50% of capacity. BEV users often prefer to maintain a buffer beyond their intended travel distance, with studies indicating an average additional range of 6.43 kilometres for short trips and up to 16.20 kilometres for longer journeys (Rainieri et al., 2023). Distance-based range estimation may be less reliable in cities with severe traffic congestion, such as Jakarta and Bangkok, where prolonged delays and higher energy demand from air conditioning use can significantly affect energy consumption.

Overall, the survey highlights several persistent factors constraining the powertrain transition in ASEAN. Unlike in developed economies where xEV adoption has accelerated, these challenges remain pronounced in the ASEAN context. Despite increasingly ambitious xEV-focused policies, unresolved issues related to consumer preferences, infrastructure access, and perceived risks continue to slow the region's pace of transition towards vehicle electrification.

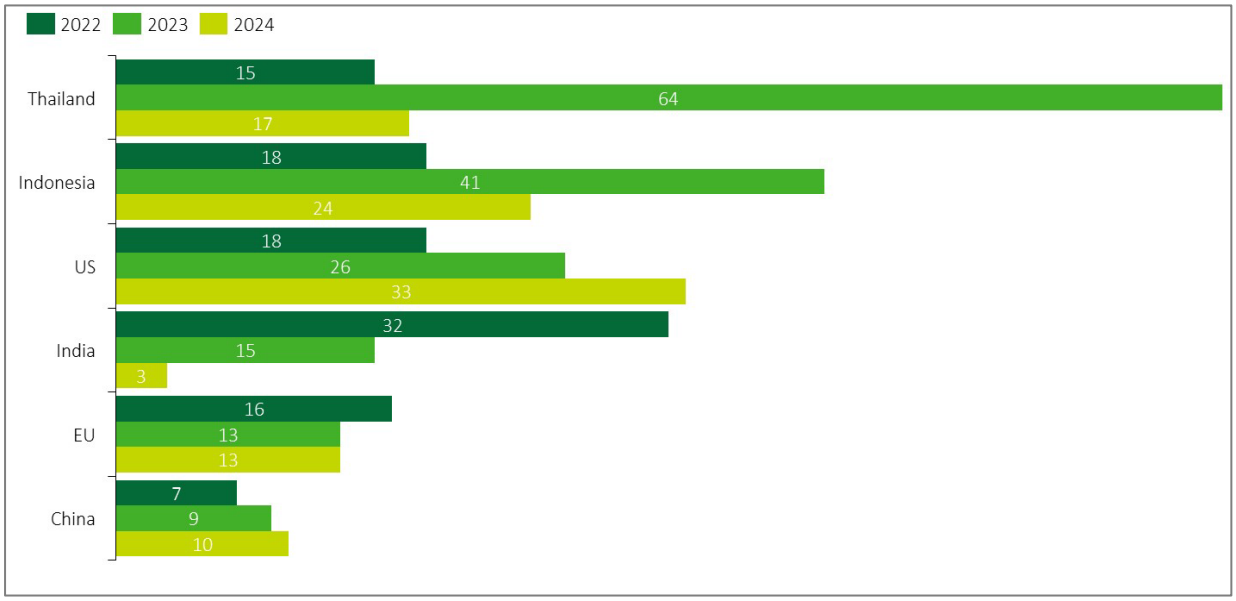
5.4.1. Infrastructure

5.4.1.1 Charging infrastructure

The limited availability of BEV charging infrastructure is widely regarded as a major constraint on xEV development. ASEAN countries continue to lag global market benchmarks. In general, the ratio of xEVs to public charging points in ASEAN is higher than the global average (Figure 5.13). In 2024, the average charger-to-vehicle ratio in Indonesia and Thailand stood at 1:17 and 1:24, respectively. By comparison, the European Union (EU) reported a lower ratio of 1:14, whilst India and China recorded ratios of 1:4 and 1:10, respectively. As a benchmark, the EU, under the Alternative Fuel Infrastructure Directive, recommends a target of no more than 10 xEVs per public charger to enhance convenience and support broader adoption (European Environment Agency, 2024).

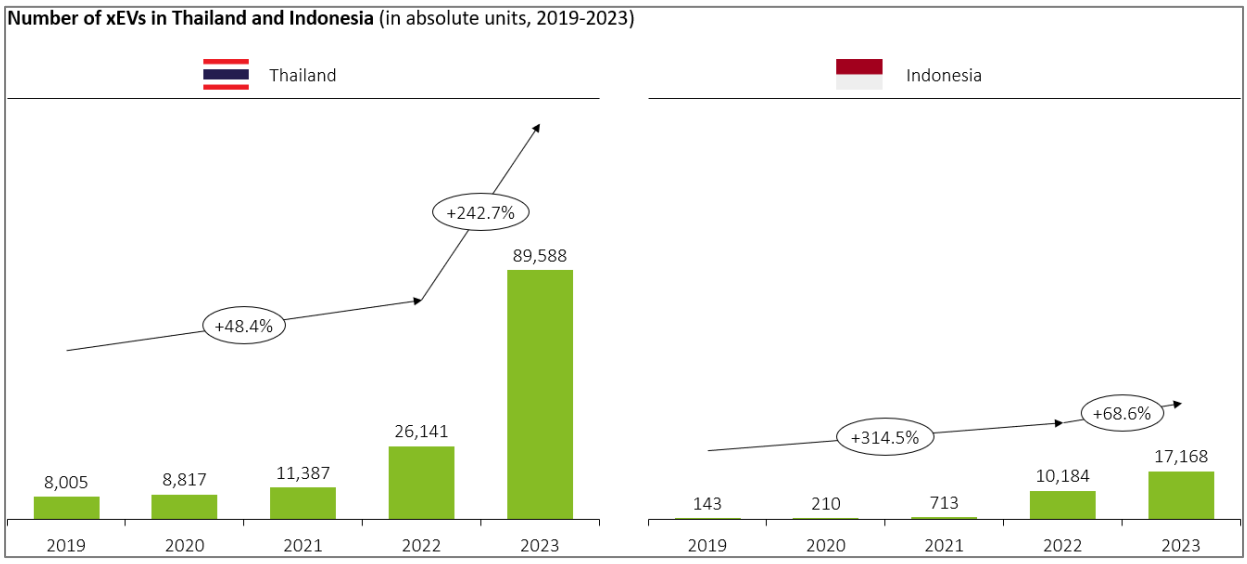
Despite these relatively high ratios, Thailand and Indonesia have made notable improvements in expanding their charging infrastructure. In Thailand, the ratio improved significantly from 1:64 in the previous year to 1:18 in 2024, whilst Indonesia saw an improvement from 1:41 in 2023 to 1:24 in 2024. These advancements are largely attributable to government initiatives to expand charging infrastructure deployment in response to rising xEV adoption.

Figure 5.13. Cross-country Comparison of Charging Ratios in ASEAN and Global Markets



ASEAN = Association of Southeast Asian Nations, EU = European Union, US = United States.
Note: In Thailand, 18 electrified vehicles share one public charger. In ASEAN, data are available only for Thailand and Indonesia.
Source: International Energy Agency (2025).

Figure 5.14. Growth of Electrified Vehicles in Thailand and Indonesia

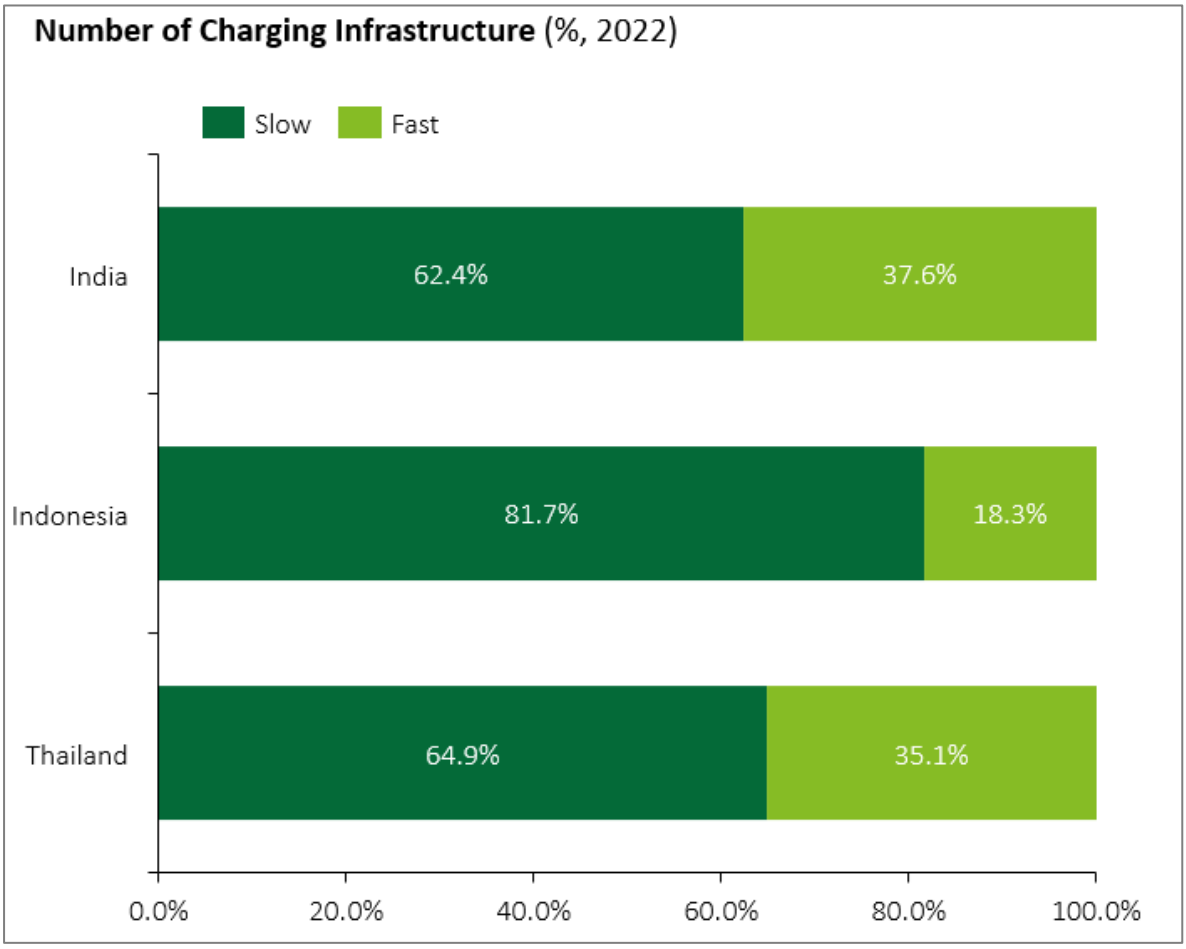


xEV = electrified vehicle.
Source: GlobalData, Automotive Sales by Powertrain (2024).

Slow chargers account for the largest share of charging infrastructure in Indonesia and Thailand, representing over 50% of total installations across Asian countries (Figure 5.15). By contrast, the proportion of fast chargers remains relatively low, especially in Indonesia, where xEV adoption is still limited. Nevertheless, across Asia and the Pacific, the EV fast-

charging market is expected to grow at a CAGR of 13.3% in 2023–2033. This expansion is driven by government efforts to lower carbon emissions and the growing adoption of BEVs, with China, Japan, Korea, and India amongst the countries investing substantially in fast-charging infrastructure.

Figure 5.15. Proportional Distribution of Fast- and Slow-charging Infrastructure Across ASEAN Countries (%, 2022)



ASEAN = Association of Southeast Asian Nations.
Source: Authors, based on Maybank Investment Banking Group, *ASEAN Mobility* (2023) data.

To narrow infrastructure gaps, AMS governments have introduced national policies to promote xEV adoption and advance electrification targets. In Thailand, the Board of Investment has implemented a 5-year corporate income tax exemption, with up to 3 additional years of tax incentives, for businesses investing in charging stations that meet specified criteria. A green loan of US$48 million was provided by the Asian Development Bank in partnership with Energy Absolute to support the development of a nationwide xEV charging network (ASEAN Centre for Energy, 2022).

In Indonesia, the Ministry of Energy and Mineral Resources (MEMR) issued Ministerial Decree No. 182.K/ TL.04/MEM.S/2023, which regulates electricity tariffs for fast and ultra-fast charging. These tariffs provide profit guarantees designed to encourage private

investment in charging infrastructure (International Council on Clean Transportation, 2024). The government has simplified permitting procedures through MEMR Regulation No 5/2021. Alongside the expansion of public charging facilities, Indonesia is actively promoting home charging. The State Electricity Company of Indonesia (Perusahaan Listrik Negara [PLN]) offers incentives such as discounted costs for electricity system upgrades and reduced overnight electricity tariffs for xEV charging (PLN, 2024). PLN has lowered fees for adding household electricity capacity for xEV owners by 75%–90%.

In Malaysia, the limited availability of public xEV charging has long been attributed to insufficient incentives for private sector investment. In 2024, despite the absence of specific provisions in the 2025 budget, the government introduced several incentives through the Ministry of Investment, Trade, and Industry to encourage the deployment of charging stations (Malaysia Investment Development Authority, 2024). Charging site operators are eligible for a 100% investment tax allowance for 5 years, enabling deductions of up to 100% of statutory income annually. Companies manufacturing xEV charging equipment receive full income tax exemptions on statutory income from 2023 to 2032.

The growing adoption of xEVs is expected to place increasing pressure on electricity demand, particularly during peak hours. Without appropriate management, this surge could strain grid capacity and increase the risk of outages. Overnight charging presents a more efficient solution, as it reduces peak-load pressure and mitigates capacity constraints. Despite existing policy measures, however, the limited number and uneven distribution of charging stations continue to impede xEV adoption across the region. Mazda (2025) found that many xEV users experience range anxiety, discouraging longer journeys. Charging facilities remain insufficient in both scale and geographic coverage, and concerns persist regarding charging capacity. On average, a full charge at existing charging stations typically requires 40–60 minutes. In Indonesia, the uneven distribution of charging infrastructure means that xEV use remains largely practical only on Java (The Jakarta Post, 2023).

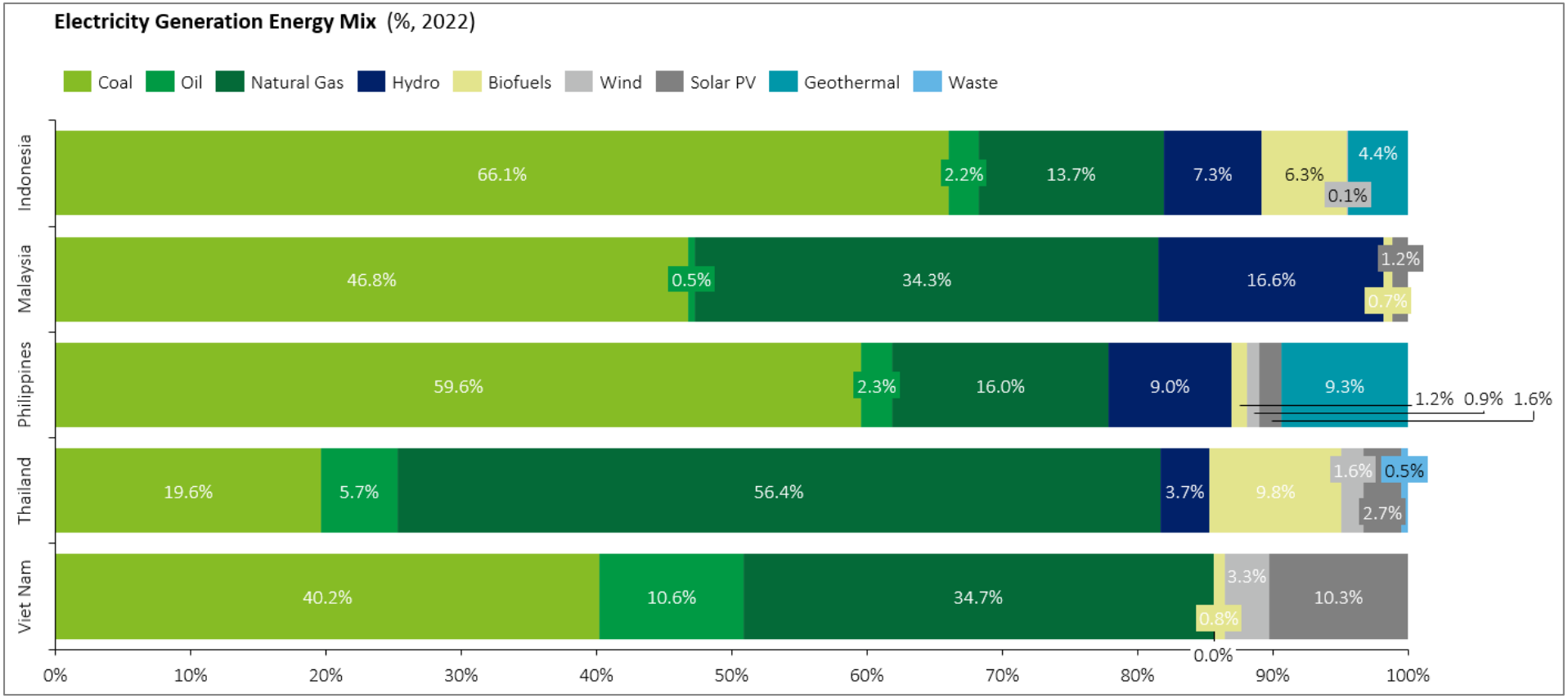
Beyond charging infrastructure, broader transport infrastructure conditions affect xEV adoption. Road quality across Southeast Asia varies considerably. Whilst urban and more developed areas generally benefit from well-maintained roads, many regions continue to face underdeveloped infrastructure, characterised by uneven surfaces and rough terrain. Concerns have emerged regarding potential damage to battery packs mounted beneath vehicles when operating on such roads (Siemens, 2024), presenting an additional barrier to large-scale xEV deployment.

Taken together, these findings suggest that AMSs seeking to accelerate xEV adoption must prioritise the development of comprehensive national xEV ecosystems. This requires not only favourable policy frameworks but also rapid and coordinated investment in infrastructure extending beyond charging networks alone. Strengthening these foundations will be critical to stimulating domestic demand and supporting a sustained transition towards electric mobility.

5.4.1.2 Electricity generation mix

Coal remains the dominant source in the electricity generation mix across many ASEAN countries. Most economies in the region continue to rely heavily on coal as a primary fossil fuel, despite its combustion being a major contributor to greenhouse gas emissions. This reliance positions coal amongst the least environmentally sustainable energy sources in the global energy system. As of 2022, about 66% of Indonesia's electricity generation was derived from coal, highlighting the country's continued reliance on high-emission fossil fuels. In parallel, natural gas continues to play a significant role in the regional energy mix, contributing over 30% of electricity generation in countries such as Malaysia, Thailand, and Viet Nam (Figure 5.16).

Figure 5.16. Electricity Generation Energy Mix (%, 2022)



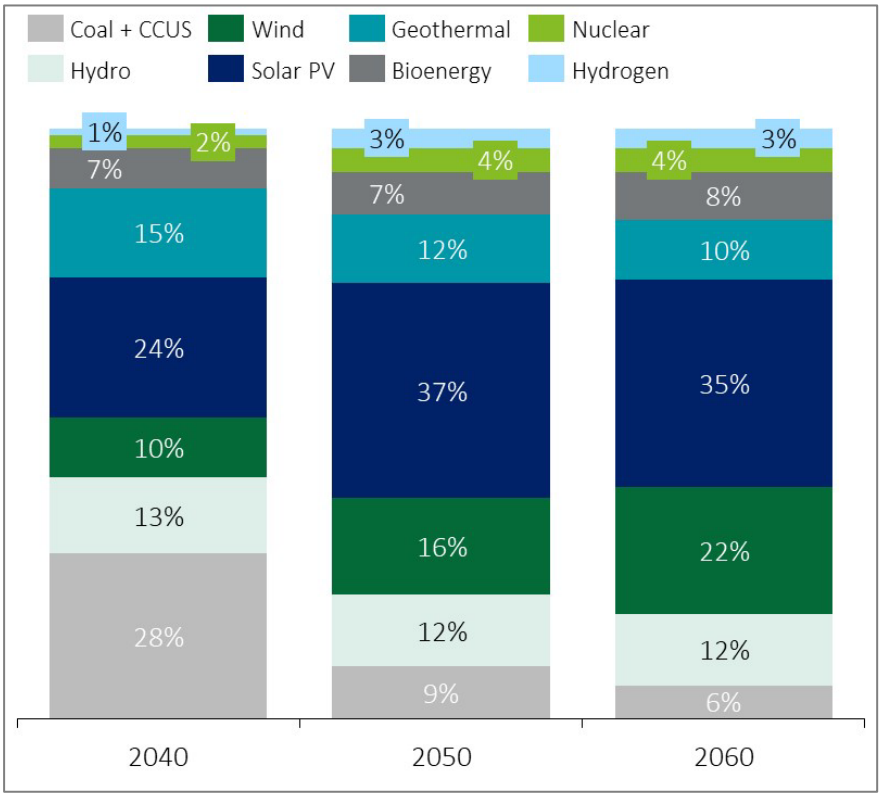
PV = photovoltaic.
Source: International Energy Agency (2023).

As part of broader decarbonisation efforts linked to the automotive transition, several Southeast Asian governments have introduced energy policies and set targets to shift electricity generation towards cleaner sources. Malaysia and Thailand have committed to phasing out coal-fired power generation by 2044 and 2050, respectively. Similarly, Indonesia, under its National Electricity General Plan (Rencana Umum Ketenagalistrikan Nasional), has outlined plans to phase out coal by 2056 (International Energy Agency, 2024). As shown in Figure 5-17, coal's share in Indonesia's electricity generation is projected to decline, from 28% in 2040 to just 6% by 2060.

Brunei Darussalam has set a target for renewable energy to account for at least 30% of electricity generation by 2035. Indonesia plans to add about 30 gigawatts (GW) of renewable energy capacity by 2033, whilst Malaysia targets the deployment of about 59 GW of solar photovoltaic capacity by 2050. As shown in Figure 5.17, Indonesia's electricity generation mix is expected to shift significantly towards renewable sources, with renewables projected to reach a 72% share by 2040. Over the same period, coal's contribution is forecast to decline steadily through 2040, 2050, and 2060.

Regional initiatives such as the ASEAN Power Grid will be critical in reducing dependence on fossil fuels by enabling cross-border electricity trade and renewable energy integration.

Figure 5.17. Electricity Generation Energy Mix Forecast in Indonesia (%)



CCUS = carbon capture, utilisation, and storage; PV = photovoltaic.
Source: International Energy Agency (2024).

5.4.2. Product Line-up

Compared with leading global xEV markets, the ASEAN xEV market offers a limited selection of models, which reduces the likelihood of consumers switching to xEVs when suitable options are unavailable. ASEAN countries remain behind their developed counterparts in model availability. Malaysia leads the region, with up to 61 BEV models available in the market (WAP Car Malaysia, 2025), whilst Thailand offers 54 BEV models produced by 25 manufacturers (Krungsi, 2024). By contrast, the Philippines offers only 15 models, with Nissan, Porsche, BYD, Jaguar, and WM Motor as the leading brands (Profile of the Electric Vehicle Industry in the Philippines, 2023). The US market, by contrast, offers up to 100 models, with the availability of mainstream options steadily increasing due to new product entries and price improvements for existing models (Argonne National Laboratory, 2025). Europe recorded about 371 BEV models in 2023, representing a 47% increase compared with 2022 (Statista, 2024). This expansion indicates a continuously growing market that enhances consumer sovereignty by providing a wider range of choices.

Another constraint on consumer choice and market penetration arises from the limited availability of models that cater to the specific demands of ASEAN customers. xEV development remains centred on consumer trends associated with transitions in leading global markets. Original equipment manufacturers (OEMs) have not yet fully incorporated ASEAN-specific preferences, such as off-road capability, larger payload capacity, increased seating capacity, and durability. As discussed in Section 4.3, major OEMs continue to offer a wider variety of models in developed xEV markets, such as China and the US, than in developing regions, including ASEAN and India.

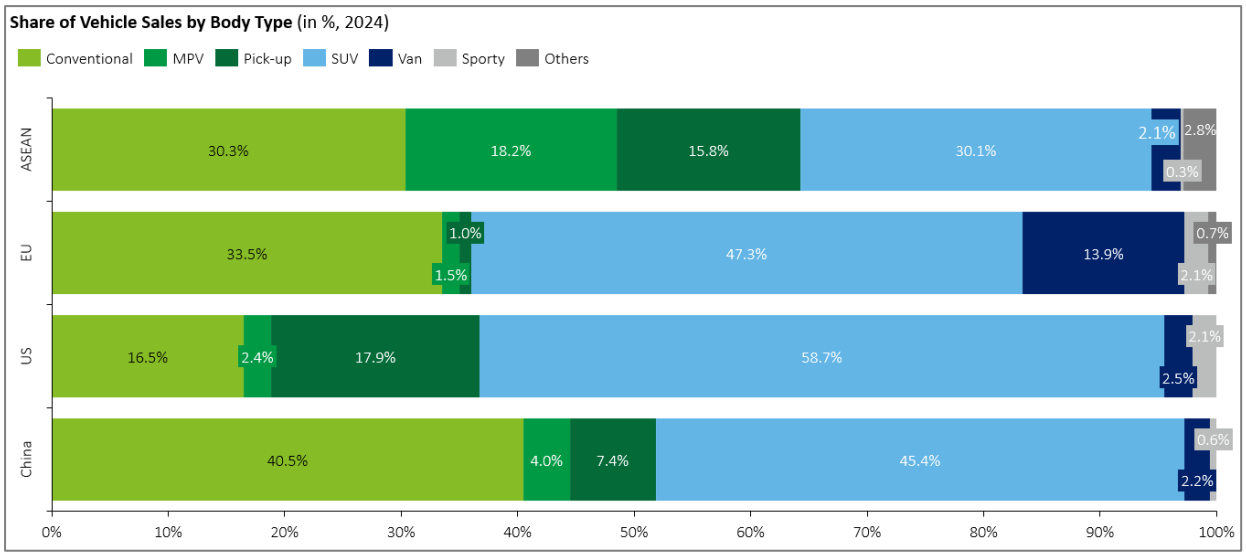
Meeting region-specific demand may not be a priority for OEMs, as vehicle platforms are increasingly unified globally. Homogenisation has become more prevalent in the automotive industry, as developing new models is both extremely expensive and complex (Hill, 2024). Hill notes that vehicles based on the same platform often share common front and rear axles, suspension systems, engine types, and steering systems. Many OEMs have adopted modular systems that allow a single platform to be deployed across multiple segments (Magna, 2022). This global platform strategy is pursued primarily for cost efficiency, not only in manufacturing but also in design, engineering, and regulatory compliance (Car and Driver, 2014). Consequently, ASEAN-specific requirements related to vehicle size, resilience to road conditions, and price sensitivity may not be sufficiently reflected in current and future xEV offerings.

As shown in Figure 5.18, ASEAN demonstrates a higher demand for pick-up vehicles compared with the EU and China, accounting for 15.8% of vehicle sales in 2024. The US shows a comparable level of demand at 17.9%, whilst China and the EU record significantly lower shares of 7.4% and 1.0%, respectively. Demand for multi-purpose vehicles (MPVs) is also highest in ASEAN, comprising at least 18.2% of total vehicle sales, whereas the share does not exceed 5% in the EU, the US, or China. Given that pick-up trucks and MPVs are not the primary types in major xEV manufacturing regions, it can be inferred that the current BEV offerings do not adequately meet the needs of many ASEAN consumers. As these

demand segments remain insufficiently served, constraints on xEV adoption persist.

A clear illustration of this issue can be observed in the Indonesian automotive market. A key factor contributing to Indonesia's slow xEV transition is the mismatch between consumer preferences and xEV designs. Indonesian consumers generally favour seven-seat MPVs, such as the Toyota Avanza and Suzuki Ertiga, due to their versatility for activities, including school transport, shopping, recreation, and commuting (CNN, 2022). In contrast, most available xEVs are sedans, hatchbacks, and SUVs designed to accommodate no more than five passengers. Within Hyundai's xEV lineup, for example, only two of eight models offer a seven-seat configuration, with one model (the Ioniq 9) yet to be released (Hyundai Motor Corporation, 2025). A similar pattern is observed in BYD, where only one of seven xEV models provides seven seats (BYD, 2025b). This limited availability of larger-capacity vehicles, which are generally preferred by ASEAN consumers, creates a structural mismatch between consumer demand and xEV supply, thereby hindering broader adoption across the region.

Figure 5.18. Share of Vehicle Sales by Body Type in ASEAN, the European Union, the United States, and China



ASEAN = Association of Southeast Asian Nations, EU = European Union, MPV = multi-purpose vehicle, SUV = sport utility vehicle, US = United States.
Source: GlobalData for Automotive Sales (2025).

To tackle the shortage of consumer options, ASEAN governments have introduced policies to encourage manufacturing and research and development. From 2025 onwards, Indonesia's Ministry of Industry will exempt import taxes and a 15% local luxury tax for companies committed to establishing xEV production facilities in the country. These incentives have been extended to China's BYD and GAC Aion, as well as France's Citroën, to stimulate xEV production and sales across ASEAN (SCMP, 2024). Whilst the impact of these measures remains uncertain, as these incentives were in place only until the end of 2025

and discontinued in 2026 (Aftermarket ID, 2026; Scuto Indonesia, 2026), the government has attempted to promote BEV adoption by exempting EVs from Jakarta's odd–even traffic regulation.[3] This policy allows BEVs to operate freely irrespective of licence plate numbers. However, it has not significantly increased adoption, as consumers often respond by owning two vehicles with alternating plate numbers instead (Kompas, 2019).

In Thailand, incentives and tax relief schemes have been extended to encourage carmakers to set up EV research and development centres (Reuters, 2023). To promote BEV production, manufacturers and importers may receive import duty reductions of up to 40% for completely built-up units priced at up to THB2 million. These measures underscore Thailand's aggressive approach to incentivising xEV availability. On the production side, as outlined in Section 5.4, Thailand's government set a target for 30% of all vehicles manufactured domestically to be electric by 2030. This objective is expected to stimulate nationwide production and expand xEV model availability for consumers.

In Malaysia, imported completely built-up units are fully exempt from import duties until the end of 2025, whilst excise duty and sales tax exemptions apply to domestically produced xEVs (primarily BEVs) until the end of 2027. According to the Malaysian Green Technology and Climate Change Corporation (2024), companies involved in the manufacture of HEVs, xEVs, and related critical components may also benefit from corporate tax exemptions and a 70% statutory income exemption for 3 years.

In the Philippines, enterprises engaged in xEV-related activities are eligible for an income tax holiday of 4–7 years under the Corporate Recovery and Tax Incentives for Enterprises (CREATE) Act.[4]

These policies aim to increase production by creating favourable business environments for manufacturers. The goal extends beyond localising assembly to expanding product line-ups that address diverse consumer segments. Nevertheless, despite ongoing efforts to diversify offerings, tangible impacts remain limited. Unless policy and industrial strategies adopt a more consumer-driven approach that aligns xEV models with ASEAN consumers' needs and preferences, the transition to powertrain technologies is likely to continue facing significant hurdles.

5.4.3. Total Cost of Ownership

When comparing the total cost of ownership (TCO) of xEVs with ICEVs, xEVs across Southeast Asia remain considerably more costly, even after accounting for government subsidies that reduce vehicle purchase prices. Across all geographies and comparable models, xEV prices remain higher than those of ICEVs. ASEAN-6 countries have implemented rebates and subsidies for xEV purchases, primarily through tariff reductions

[3] To manage traffic congestion, vehicles with licence plates ending in odd numbers are permitted to use certain roads only on odd-numbered dates. A corresponding regulation applies to vehicles with even-numbered licence plates on even-numbered dates (Jakarta Globe, 2025).
[4] This regulation applies to BEVs, PHEVs, and FCEVs.

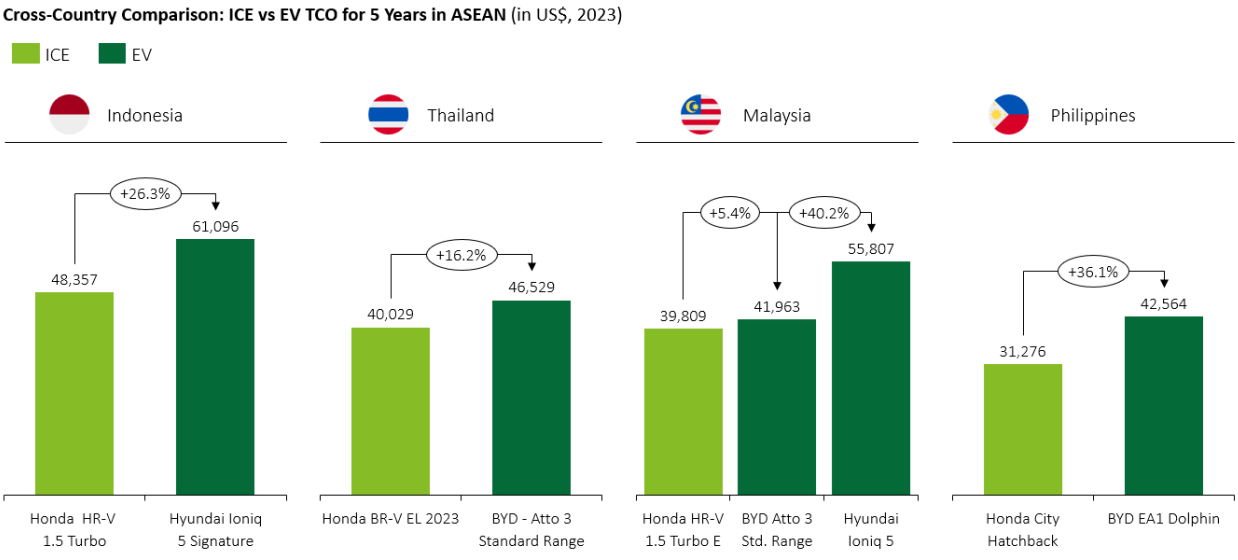
and lower vehicle registration fees. Despite these incentives, however, the price premium for xEVs in ASEAN ranges from 13% to 51% (Maybank, 2023).

In Indonesia, for instance, xEVs have an average price of IDR618 million, about 47% higher than the average ICEV price of IDR420 million (The Jakarta Post, 2023). This high upfront cost represents a major barrier for many potential ICEV owners considering a transition to xEVs. These estimates exclude resale values, which may further influence TCO outcomes in practice.

In contrast to the global overview in Section 4.3, which shows that xEV ownership costs are generally lower than those of ICEVs, TCOs for xEVs in ASEAN remain significantly higher. The TCO estimates shown in Figure 5.19 incorporate a comprehensive set of cost components, including purchase price, registration fees, financing, maintenance, insurance, and fuel costs over 5 years. Across ASEAN countries, TCOs for xEVs consistently exceed those of ICEVs.

Malaysia records the lowest TCO gap between xEVs and ICEVs. Ownership of a mainstream BEV model, such as those offered by BYD, is about 5.4% more expensive than an ICEV, whilst a premium xEV model, such as Hyundai's Ioniq, costs around 40.2% more. In Thailand, the TCO of a BEV is 16.2% higher than that of an ICEV, compared with 26.3% in Indonesia and 36.1% in the Philippines. These figures indicate that, even with government subsidies, xEV ownership does not yet deliver financial savings, and overall ownership costs remain significantly higher.

Figure 5.19. Cross-Country Comparison of Total Cost of Ownership Over 5 Years in ASEAN Countries



ASEAN = Association of Southeast Asian Nations, ICE = internal combustion engine, xEV = electrified vehicle.
Note: Total cost of ownership includes the purchase price, taxes, insurance, and total running costs (e.g. maintenance and fuel).
Source: Authors, based on Maybank Investment Banking Group (2023) data.

Although xEV adoption is often associated with significant fuel cost savings relative to petrol-powered vehicles, the impact of these savings on total ownership costs remains limited. Figure 5.20 shows that, for average ICE and xEV models, xEV purchase prices are significantly higher across ASEAN countries. Indonesia records the largest price differential, at US$15,840, followed by the Philippines at US$9,095, Thailand at US$6,580, and Malaysia at US$4,347.

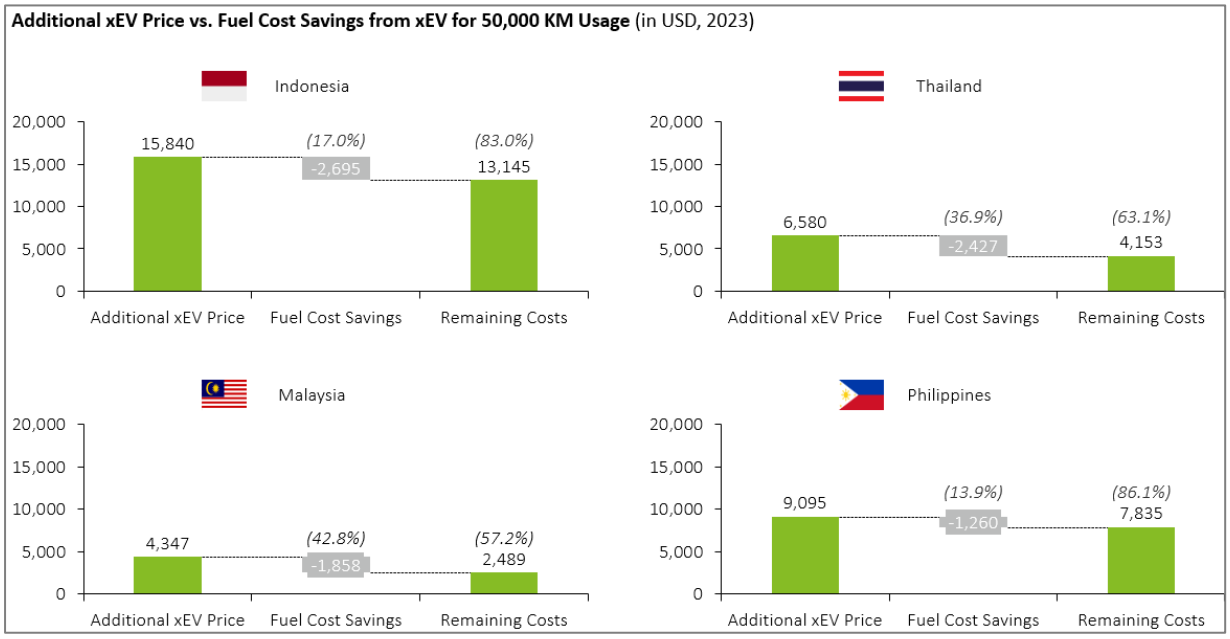
The price gap in Thailand may narrow in the near term, as several Chinese manufacturers have slashed BEV prices by more than 20% to stimulate demand. As an example, the Neta brand offers three models in Thailand, with its lowest-priced model, the Neta V-II Lite, retailing at THB549,000 (about US$16,924) before discounts, compared with BYD's entry-level Dolphin model priced at THB569,900 (about US$17,893).

As anticipated, xEV usage results in lower fuel expenditure compared with ICEVs. Figure 5-20 shows that xEVs reduce fuel expenses by about US$2,695 in Indonesia, US$2,427 in Thailand, US$1,858 in Malaysia, and US$1,260 in the Philippines.[5] However, these fuel savings offset no more than 50% of the initial price premium after 50,000 kilometres of vehicle usage. In Malaysia, fuel savings compensate for only 42.8% of the additional xEV price, whilst Thailand shows a similar ratio of 36.9%. In Indonesia and Viet Nam, fuel savings account for an even smaller share of the price premium, at 17.0% and 13.9%, respectively.

Whilst fuel cost reductions are expected to encourage adoption, their limited magnitude does not sufficiently counterbalance the higher upfront purchase price. Across ASEAN, residual ownership costs associated with xEV price premiums remain substantial. In the Philippines, the remaining cost amounts to US$7,835, representing about 86.1% of the initial xEV price premium. In Indonesia, residual costs reach US$13,145, or 83% of the price premium. Although comparatively lower, Thailand and Malaysia still exhibit residual costs of US$4,153 (63.1%) and US$2,489 (57.2%), respectively. These findings suggest that the difference between electricity and fuel costs alone is insufficient to compensate for higher xEV purchase prices.

[5] Detailed step-by-step calculation of TCO comparison between ICEV and xEV for Indonesia, Thailand, Malaysia, and the Philippines is presented in Annex 2.

Figure 5.20. Comparisons of xEV Price Premium and Fuel Cost Savings After 50,000 Kilometres of Usage (in US dollars, 2023)

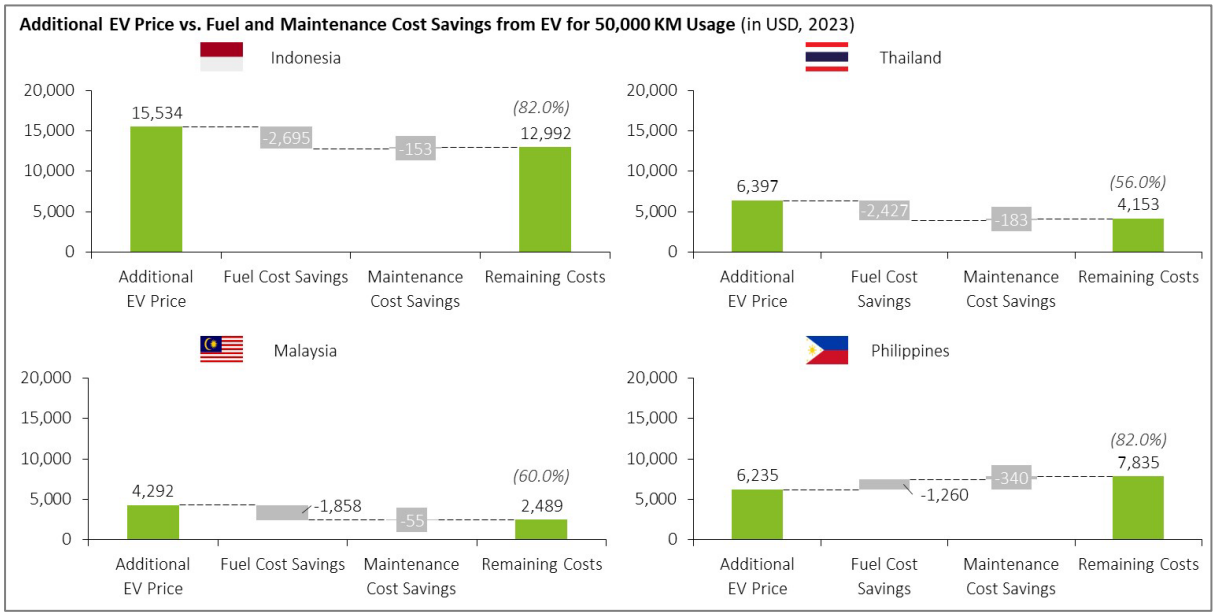


xEV = electrified vehicle.
Source: Authors, based on Maybank Investment Banking Group (2023) data.

Similarly, although xEVs benefit from lower maintenance costs due to fewer mechanical components, these savings, particularly within the first year of ownership, are not substantial enough to offset higher purchase prices. Maintenance cost savings amount to about US$153 in Indonesia, US$183 in Thailand, US$55 in Malaysia, and US$340 in the Philippines (Figure 5.21). Even when fuel and maintenance savings are combined, the remaining price gap remains considerable, with Indonesia showing the largest gap at US$12,992,[6] followed by the Philippines at US$7,835, Thailand at US$4,153, and Malaysia at US$2,489.

[6] Detailed step-by-step calculation of TCO comparison between ICEV and xEV for Indonesia, Thailand, Malaysia, and the Philippines is presented in Annex 2.

Figure 5.21. Comparison of xEV Price Premium Against Fuel and Maintenance Cost Savings (in US dollars, 2023)



EV = electric vehicle.
Note: Fuel cost savings are based on 50,000 kilometres of usage, whilst maintenance costs reflect the first year after purchase.
Source: Authors, based on Maybank Investment Banking Group (2023) data.

Reducing the gap between savings from fuel and maintenance and the higher purchase price of xEVs, therefore, requires a more targeted and comprehensive policy mix. Governments across the region have clearly signalled their support for xEV adoption through a range of pro-xEV policies aimed at lowering TCO burdens.

In Indonesia, BEV purchases are exempt from luxury tax, and a special 0% import duty applies to four-wheeled xEVs imported in incomplete form. Subsidies of IDR80 million (about US$5,000) are provided for new BEV purchases, whilst IDR40 million (about US$2,500) is offered for conventional hybrid vehicles (Maybank, 2023).

The Malaysian government exempted zero-emission vehicles from road tax from 2022 to 31 December 2025. From 2026 onwards, xEV owners will benefit from a lower tax rate based on vehicle power output. To further reduce operating costs, individuals may claim up to MYR2,500 (about US$ 619) in annual income tax relief until 2027 for the installation, rental, or purchase of xEV charging equipment and related subscription fees (Malaysian Investment Development Authority, 2024).

From 2024 to 2027, Thailand's government is offering subsidies ranging from THB50,000 (about US$1,397) to THB100,000 (about US$2,794) for each new BEV purchase (ASEAN Briefing, 2023). The Philippine government provides a 100% excise tax exemption for BEVs and a 50% exemption for HEVs, alongside discounted registration fees of 30% for BEVs and 15% for HEVs.

Despite strong policy support across AMSs, financial subsidies alone may not be sufficient

to narrow the TCO gap and accelerate mass-market uptake. In practice, xEVs remain more expensive to own, constraining the region's ability to fully embrace electrification. Without parallel improvements in charging infrastructure, product availability, and consumer readiness, the transition towards electrification is likely to remain gradual and limited to specific market segments.

Table 5.2 summarises the status of xEV deployment, adoption targets, charging infrastructure, and policy frameworks across Southeast Asia, offering insights into national readiness for EV adoption. Indonesia leads in terms of sales targets, aiming for over 1 million xEV units by 2030, followed by Thailand with a target of 875,000 units. These ambitious targets position both countries as potential regional leaders in xEV adoption, supported by strong policy frameworks and ongoing infrastructure development.

Regarding charging infrastructure, Thailand, Indonesia, Singapore, and Malaysia have made greater progress than their regional peers. Thailand records about one public charging point for every 17 electric light-duty vehicles (LDCs) (Table 5.2), indicating comparatively better accessibility. Indonesia follows with one charger per 24 electric LDCs. As of 2019, Singapore and Malaysia had established 569 and 309 charging points, figures that have likely increased in recent years.

Thailand and Viet Nam have announced plans to phase out ICEVs by 2035, whilst Indonesia has adopted a longer transition horizon, targeting a complete phase-out by 2050.

Table 5.2. Overview of EV Fleet Development, Sales Targets, Charging Infrastructure, and ICEV-related Government Policies in Southeast Asia

Country	EV Definition	EV Fleet	EV Sales Target by 2030 (unit, million)	Charging Infrastructure	Government Policy Relating to ICEV Restrictions
Brunei Darussalam	HEV, PHEV, BEV	HEV: 293 (2018) BEV: 15	21,852	n/a	n/a
Indonesia	HEV, PHEV, BEV	4.2 million by 2050 (proposal under the National Energy Plan)	1,091,011	24 electric LDVs per public charging point (2024)	Ban on ICEVs by 2050
Malaysia	BEV (Full EV) HEV, PHEV (Partial EV)	BEV < 120 (2016)	827,630	309 charging points (2020)	n/a
Philippines	HEV, PHEV, BEV, NEV	BEV: 64 NEV: 89 (2018)	632,631	95 public charging	n/a

Country	EV Definition	EV Fleet	EV Sales Target by 2030 (unit, million)	Charging Infrastructure	Government Policy Relating to ICEV Restrictions
				stations	
Singapore	HEV, PHEV, BEV	HEV: 44,894 PHEV: 473 BEV: 1,336 (2019)	31,327	143 (569 charging points) (2019)	n/a
Thailand	HEV, PHEV, BEV	HEV: 153,184 BEV: 2,854 (2019)	875,205	17 electric LDVs per public charging point (2024)	Ban on ICEVs by 2035
Viet Nam	HEV, PHEV, BEV, NEV	1,086 (2016)	664,788	1 fast-charging station	Ban on ICEVs by 2035

BEV = battery electric vehicle, EV = electric vehicle, HEV = hybrid electric vehicle, ICE = internal combustion engine, LDV = light-duty vehicle, n/a = not applicable, NEV = new energy vehicle, PHEV = plug-in hybrid electric vehicle.
Note: Cambodia, Lao People's Democratic Republic, and Myanmar are excluded, as they did not have dedicated EV policies as of 2021.
Sources: Economic Research Institute for ASEAN and East Asia (2021), International Energy Agency (2025), GlobalData (2025), Krungsri (2024), ASEAN Secretariat (2024).

5.5 Need for a Unique Pathway

ASEAN's transition towards xEV is expected to progress more slowly than the global shift. This lag can be attributed to several structural factors, including limited purchasing power, underdeveloped infrastructure, a mismatch between product offerings and local demand, and unfavourable TCO dynamics for prospective consumers. Although policies have been introduced to bolster xEV growth, the level of preparedness and development in these areas has not yet reached a point where xEVs can become the dominant vehicle type.

Compared with developed economies, car prices in ASEAN remain high relative to annual household income, reaching up to 54% and 64% in Thailand and Indonesia, respectively. As key provinces that have historically driven automotive sales show signs of saturation, overall automotive sales growth has weakened. Infrastructure constraints further pose a considerable barrier to xEV adoption across much of the region. ASEAN consumers continue to express concerns about charging times, range anxiety, and the limited availability of public charging infrastructure. Despite mandates and incentives to accelerate infrastructure development, ASEAN countries still fall short of the global standard of one public charging point per 10 EVs.

Current xEV offerings do not precisely address the specific preferences of ASEAN consumers, who show stronger demand for vehicles with larger payloads, such as seven-seat MPVs and pick-up trucks. This gap is partly driven by the increasing global unification of vehicle platforms, which reduces manufacturers' incentives to customise models for regional markets. EVs produced for leading xEV markets are mainly sedans, hatchbacks, and SUVs, which typically accommodate no more than five passengers. Pick-up trucks and MPVs, which are favoured in ASEAN, are not core vehicle types in developed xEV markets, resulting in limited production availability for the region. The number of xEV models available in ASEAN remains modest compared with developed markets, which offer over 100 models. In comparison, Malaysia offers 61 models, Thailand 54, and the Philippines only 15.

The commonly held assumption that xEVs offer lower TCO through fuel cost savings does not hold in the ASEAN context. Potential savings from reduced fuel expenditure account for less than 10% of the additional upfront cost of xEVs relative to ICEVs. Whilst governments actively promote xEV adoption through supportive policies, uptake remains slow as consumers become increasingly sensitive to overall ownership costs. The price gap between electricity and petrol is insufficient to offset the higher initial purchase price of xEVs.

Given the pace of transition and the challenges identified, focusing solely on accelerating powertrain transition by replicating strategies from leading global markets risks further stagnation in ASEAN's automotive sector. Instead, ASEAN requires a deliberate and phased approach that continues to accommodate existing ICEV demand whilst progressively advancing towards an xEV-majority market. Central to this strategy is a balanced approach: sustain the region's sizeable ICEV market, whilst gradually strengthening HEV development as a transitional pathway. At the same time, ASEAN should prepare strategically for broader xEV adoption through a multi-pathway approach tailored to the region's distinct characteristics and comparative advantages. This approach should also promote the use of biofuels, ensuring that decarbonisation efforts do not rely solely on full electrification.

Beyond HEVs, a diversified vehicle portfolio in ASEAN would include biofuel-compatible vehicles, for which the region has the potential to emerge as a production hub. Countries such as Indonesia and Malaysia already possess experience in biofuel production, although scaling up remains constrained by cost pressures and land use considerations. More efficient biofuel production could improve trade balances by reducing reliance on fossil fuel imports, enhancing energy self-sufficiency, and boosting domestic industries. Establishing ASEAN as a biofuel centre could also attract R&D activities and skilled labour, strengthening the region's competitive position in sustainability-related industries. A dual focus on HEVs and biofuels would reinforce ASEAN's automotive sector, promote economic growth, and support environmental objectives.

In parallel with advances in supply chains and vehicle technologies, new mobility models offer additional opportunities to support automotive market growth in Southeast Asia. One such model is vehicle subscription, which allows consumers to access vehicles through

recurring payments rather than traditional ownership or long-term leasing. In Asia and the Pacific, the vehicle subscription market was valued at US$1.53 billion in 2024 and is projected to grow to US$5.38 billion by 2032, corresponding to a CAGR of 17%. This growth is expected to be driven by rising demand and improving living standards across the region.

A notable example is Toyota's KINTO service. Launched in 2019, KINTO offers an all-inclusive subscription package covering insurance, maintenance, and registration. By November 2021, subscriptions had grown from about 1,200 vehicles at launch to over 28,000 vehicles (Reuters, 2021). In 2022, Toyota introduced its first mass-produced BEV, the bZ4X, for use within its subscription service. One motivation behind this model is to improve affordability, as high upfront costs continue to deter consumers from purchasing EVs outright.

Overall, ASEAN is well-positioned to supply low-emission ICEVs, HEVs, and vehicles compatible with biofuels and e-fuels, thereby meeting the needs of ICEV-centric markets pursuing decarbonisation. Rather than aiming for an exclusive shift towards xEVs, the region should further promote HEVs and biofuels as complementary pathways alongside gradual xEV adoption. Simultaneously, ASEAN should invest strategically in the development and production of BEVs and other xEVs from a long-term perspective. This balanced approach would allow the region to leverage its current strengths whilst positioning itself to respond to future growth in xEV demand.

Chapter 6

Current State and Future Pathway of the Global and ASEAN Automotive Industries

This chapter provides an overview of the state and trajectory of the global and Association of Southeast Asian Nations (ASEAN) automotive industries. It begins by examining global production and powertrain trends, emphasising the continued dominance of China, the United States (US), and the European Union (EU), alongside the emergence of India, and the growing importance of decarbonisation and digitalisation through software-defined vehicles (SDVs) and autonomous technologies. It then analyses ASEAN's competitive positioning, highlighting its existing strengths and its notable challenges. The chapter explores how these global shifts are reshaping not only vehicles but also the supply chains that support them. Decarbonisation requirements are compelling manufacturers and suppliers to reconfigure production processes, whilst digital innovations are redefining vehicle design, functionality, and system integration. At the same time, servitisation is emerging as a new revenue stream, further transforming industry dynamics.

To remain competitive, ASEAN must adapt and upgrade its capabilities to keep pace with changes in the global supply chain. This chapter examines the automotive industry through three lenses: the transformation of the vehicle, the evolution of the supply chain, and the rise of servitisation as a business model.

Together with the analysis presented in Chapter 5, this chapter aims to build the foundation for proposing a varied pathway strategy that enables ASEAN to sustain and grow its role in the global automotive value chain. In this context, ASEAN's capacity to adapt and to position itself strategically within these global shifts will be crucial in determining whether it can sustain and strengthen its role in the evolving automotive value chain over the coming decades.

6.1. Current State and Future Outlook of the Global Automotive Industry

This section provides an overview of the global automotive production and powertrain landscape as of 2024. It highlights key trends, including the industry's resilience to global disruptions, the continued dominance of China, Europe, and the US in production volumes, and the emergence of India and ASEAN as rising manufacturing hubs. It outlines major supply-chain shifts, the impact of trade policies, and the ongoing transition towards electrified vehicles (xEVs), setting the foundation for more detailed regional and technology-specific analyses in the following sections.

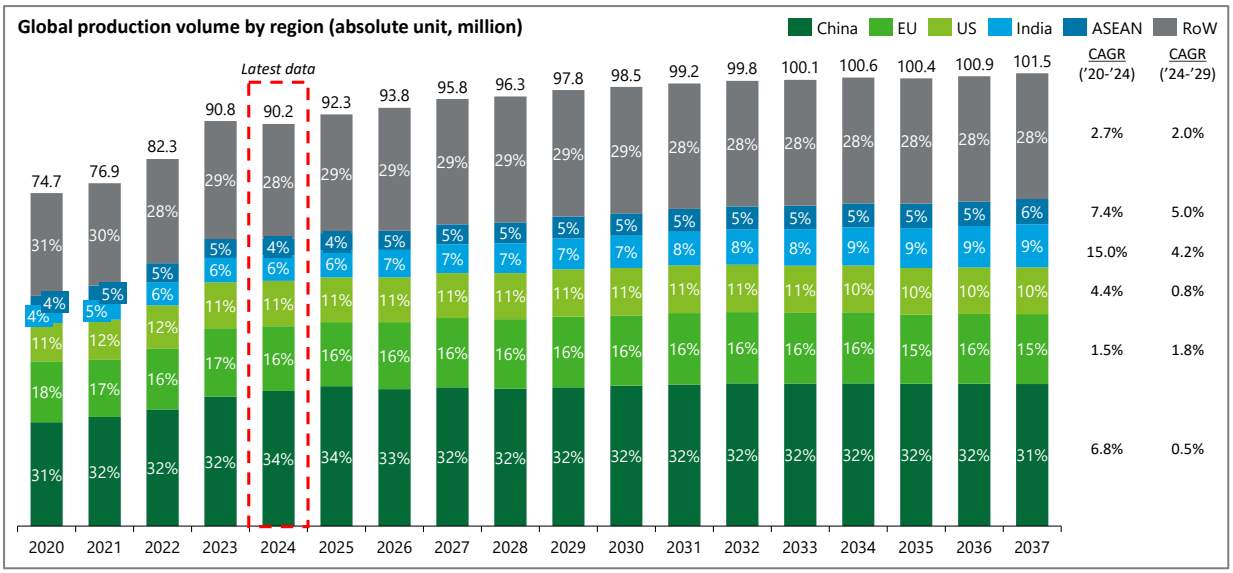
6.1.1. Vehicle

6.1.1.1 Global vehicle production landscape

The global automotive industry remains a vital pillar of the world economy, with production reaching 90.2 million units in 2024, a testament to its resilience amid ongoing economic and geopolitical disruptions (GlobalData, 2025b). Whilst pandemic-era supply-chain blockages have largely eased, new shocks, including conflicts in Ukraine and the Middle East, as well as a resurgence in global protectionism, have raised costs for key inputs such as aluminium, nickel, and cross-border shipping (Economist Intelligence Unit [EIU], 2025g). Semiconductor supply constraints continue to pinch production, as rising demand from battery electric vehicles (BEVs) and advanced driver assistance systems (ADAS) places increasing pressure on capacity. Electric vehicles (EVs) require significantly more chips than internal combustion engine (ICE) vehicles: a mainstream ICE-passenger vehicle typically contains just over 1,000 chips, whereas modern BEV platforms integrate about 2,700–3,000 devices to support power electronics, battery management, and ADAS functions (Dziczek, 2022; Applied Energy Systems, 2023).

Applied Energy Systems (2023) projects that the semiconductor bill of materials per vehicle will climb from roughly US$500 in 2020 to US$1,400 by 2028. This surge has already prompted some original equipment manufacturers (OEMs) to delay vehicle launches or scale back planned features. Yole Group (2024) forecasts that this increase in per-vehicle content will double the global automotive semiconductor market to nearly US$100 billion by 2029. Sweeping US tariffs introduced in early 2025 have disrupted planning cycles and intensified cost pressures, particularly for manufacturers dependent on highly integrated supply chains (EIU, 2025a). Despite these challenges, the automotive production landscape continues to be dominated by China, Europe, and the US, which together accounted for over 61% of global output in 2024 (GlobalData, 2025b).

Figure 6.1. Global Passenger Vehicle Production Volume by Region (absolute unit, million)



ASEAN = Association of Southeast Asian Nations, CAGR = compound annual growth rate, EU = European Union, RoW = rest of world, US = United States.
Source: GlobalData (2025).

1. China. Producing 30.3 million units in 2024, China solidified its position as the world's leading automotive manufacturer, accounting for 33.6% of global production (GlobalData, 2025b). This performance is underpinned by a vast domestic market, vertically integrated supply chains, and strong policy alignment. Although historically centred on ICE manufacturing, China began a decisive shift in January 2019, when the government halted approvals for new factories producing fossil fuel–powered vehicles and tied capacity expansion permits to new BEV investment (EIU, 2025b). This transition has been supported by more than a decade of subsidies, research and development incentives, and state-led planning. Domestic champions such as BYD have surged, whilst the liberalisation of joint-venture rules – allowing full foreign ownership of passenger vehicle ventures since 2022 – has not stopped the exit of some foreign brands, including Mitsubishi and Jeep (CNBC, 2021; EIU, 2025b). China's competitiveness may nevertheless be tested by newly imposed 25% US automotive tariffs and a broader surge in trade barriers, which could disrupt export growth and force strategic recalibration (EIU, 2025a). Despite these risks, China remains the most strategically positioned hub for next-generation vehicle production, anchored by scale, policy certainty, and upstream control. As tariffs on Chinese xEVs take effect in the US, the EU, Canada, and emerging markets such as Türkiye and Brazil, ASEAN has become increasingly important both as an overseas production base and as an end market for Chinese companies (Kelly and Wester, 2025). Whilst ASEAN governments generally view Chinese xEV investment as a driver of industrial modernisation and economic growth, the rapid influx of Chinese EVs and their vertically integrated

supply chains is placing growing pressures on existing local supply chains and manufacturers.

2. Europe. With production of 14.5 million vehicles in 2024, equivalent to 16.1% of global output, the EU remains a cornerstone of the global automotive industry, anchored by Germany, which accounts for about 30% of regional production (GlobalData, 2025b). Europe's strength lies in its diversified industrial base, high-quality passenger vehicle manufacturing, and close alignment with stringent environmental regulations that have accelerated BEV adoption. However, structural challenges are mounting. Operating margins have come under pressure across most European OEMs due to high fixed costs, restructuring expenses, weak topline growth, cost pressures, softening BEV demand, and intensifying global trade protectionism. In Germany, output remains 25% below pre-pandemic levels, prompting automakers such as Volkswagen to slash capacity and employment. Although European OEMs such as BMW and Mercedes-Benz continue to benefit from resilient luxury demand, especially in export markets, profits have declined amid rising input costs, softening sales in China, and growing discounting pressures, resulting in double-digit declines in net profit for both brands (EIU, 2025c; EIU, 2025d). Newly imposed EU tariffs of up to 45.3% on Chinese BEV imports aim to shield domestic producers but risk further straining price competitiveness (Reuters, 2024a). The US decision to impose 25% tariffs on imported vehicles from April 2025 threatens market access, particularly for German manufacturers with significant exposure to the US market (EIU, 2025l). As legacy automakers recalibrate their strategies – cancelling BEV plant plans, implementing cost-cutting programmes, and deepening partnerships in software and batteries – Europe's role is shifting from global pacesetter to a region navigating industrial reinvention amid sustained macroeconomic and geopolitical strain.

3. United States. The US produced 10.2 million vehicles in 2024, representing 11.3% of global output (GlobalData, 2025b). Whilst the country remains a key production base, its automotive supply chain is deeply intertwined with partners across North America and Asia. Data from the US Department of Commerce show that Canada and Mexico together account for about half of all vehicle parts imported into the US, amounting to nearly US$100 billion annually, trade flows that now face renewed tariff risks under the Trump administration. In April 2025, a broad tariff package took effect, including a baseline 10% tariff on all goods and a 25% duty on imported vehicles, along with reciprocal measures targeting key partners such as China, Mexico, and Canada. Although exemptions under the United States–Mexico–Canada Agreement remain in effect, compliance has become increasingly complex, creating uncertainty and additional costs for manufacturers. Whilst temporary reprieves have been negotiated, planning disruptions are already evident, with OEMs such as General Motors signalling contingency strategies and warning of margin compression. These measures risk undermining the cost

competitiveness of vehicles assembled in the US, especially given their high reliance on cross-border components. At the same time, federal support for xEV subsidies and charging infrastructure is under review, leading several automakers to revise sales forecasts and delay production ramp-ups. Amid rising geopolitical and trade frictions, the US production base remains significant, supported by resilient demand for larger vehicles such as sport utility vehicles (SUVs) and pick-up trucks, but is increasingly exposed to policy-induced volatility and shifting industrial incentives (EIU, 2025l; EIU, 2025f).

4. India. With production of 5.6 million units in 2024, India ranked as the world's fourth-largest automotive manufacturer, contributing 6.3% of global output (GlobalData, 2025b). Growth has been fuelled by strong domestic demand, policy momentum under the government's 'Make in India' initiative, which increased import duties to encourage local manufacturing, and targeted incentives through the production-linked incentive scheme (EIU, 2025g). The scheme, designed to boost investment in advanced automotive technologies, has approved 115 companies committing INR748.5 billion (about US$9 billion) through to 2028. In the 2025–2026 budget, allocations to the automotive and components sector surged nearly tenfold to INR28.2 billion (about US$32.9 million), alongside customs duty exemptions for key BEV battery inputs and critical minerals such as copper. These measures support the government's ambition to grow automotive output to US$300 billion by 2026, with domestic demand as the primary growth driver and exports expected to rise steadily. The industry remains a vital pillar of India's economy, contributing about 6% of gross domestic product and attracting US$36.3 billion in cumulative foreign direct investment since 2000 (EIU, 2025g). However, India's federal governance structure means that the implementation of industrial policies may vary across states, potentially influencing the consistency of initiatives such as xEV adoption and vehicle recycling. With strong fundamentals and increasing interest from global OEMs seeking to diversify beyond China, India is well-positioned to emerge as a hub for compact vehicles and affordable xEVs, although execution risks remain.

Global production dynamics are shifting. Although China, the EU, and the US continue to dominate in absolute volume (Figure 6.1), India and ASEAN are gaining strategic relevance as OEMs diversify their manufacturing footprints. This shift reflects the growing adoption of China+1 strategies in response to rising trade barriers and localisation requirements. From 2020 to 2024, India and ASEAN posted some of the fastest production growth rates amongst major regions, at compound annual growth rates of 15.0% and 7.4%, respectively, and are projected to sustain strong momentum through to 2029 (Figure 6.1) (GlobalData, 2025b). Whilst their global shares remain relatively modest – 6.3% for India and 4.2% for ASEAN in 2024 (Figure 6.1) – their accelerated growth is drawing targeted investments, as discussed earlier in relation to India and in Section 6.3.1 for ASEAN.

ASEAN's strategic relevance has grown not only because of industrial policies in Western economies but also because of ASEAN's position at the intersection of two powerful global forces: China's surging automotive exports and efforts by Western economies to de-risk supply chains. This position makes Southeast Asia an increasingly attractive production base and partner for multinational OEMs seeking both resilience and market access (Asia Society, 2024). Momentum has intensified following the imposition by the US of a 25% tariff on all imported vehicles and automotive parts in April 2025, a policy intended to encourage reshoring but likely to raise costs and disrupt OEM planning cycles (EIU, 2025l). Industrial initiatives such as the CHIPS Act in the US and the EU also seek to localise semiconductor and battery production[1] – both critical to xEVs – whilst local-content requirements tied to subsidies are pressuring OEMs to adjust sourcing and assembly strategies (EIU, 2025g). As a result, industrial policy is increasingly regarded as not only an economic instrument but also a geopolitical tool. Looking ahead, regions such as India and ASEAN are likely to play a growing role in shaping a more diversified and resilient global automotive ecosystem.

6.1.1.2. Decarbonisation: Production trends by powertrain

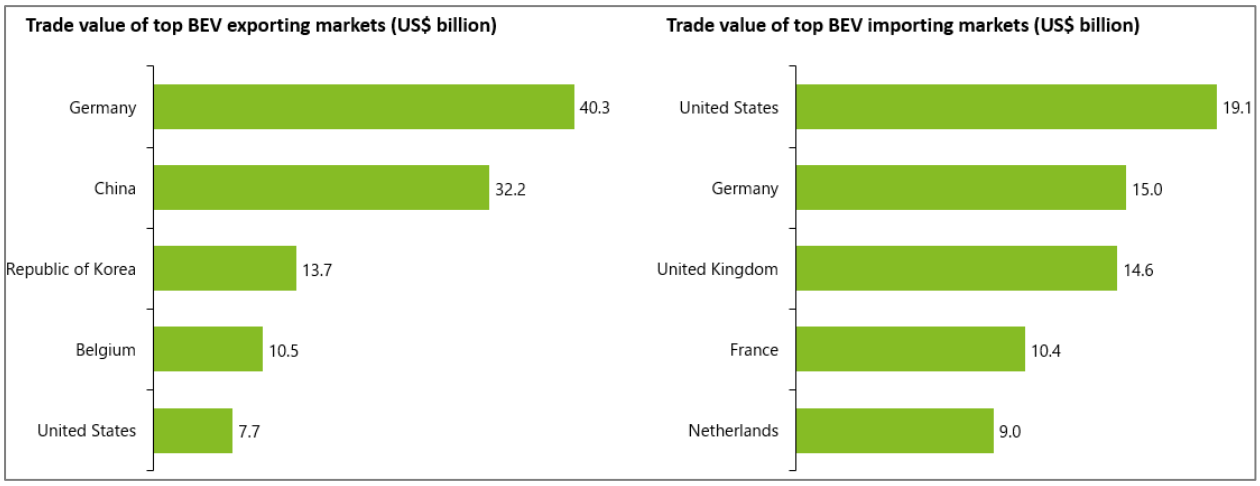
The global powertrain transition is accelerating. Although ICEVs continue to dominate overall output, the rise of xEVs, particularly BEVs and plug-in hybrid electric vehicles (PHEVs), is increasingly evident in production and trade data.

In 2023, BEVs became the sixteenth most traded product globally, with trade reaching US$150 billion, representing a 60% year-on-year increase. Germany led BEV exports with shipment values of US$40.3 billion, followed by China with US$32.2 billion and the Republic of Korea (henceforth, Korea) with US$13.7 billion, reflecting both production strength and strategic positioning within the value chain. The US, despite being a major producer, emerged as the world's largest BEV importer, absorbing US$19.1 billion, underscoring the gap between domestic output and rapidly growing demand (Observatory of Economic Complexity [OEC], 2024a).

These divergent trade patterns reveal the uneven pace of powertrain adoption across markets. China's year-on-year BEV export growth of US$13.8 billion indicates that a significant share of its vehicle production is now focused on BEVs, driven by strong domestic policy support and rising global competitiveness. Europe's strong performance in both exports and imports reflects deepening BEV trade integration, supported by emission regulations and OEM fleet targets. By contrast, the position of the US as a net importer points to rising consumer demand for electrification, even as domestic production capacity scales up under the Inflation Reduction Act (OEC, 2024a).

[1] The US CHIPS and Science Act (2022) allocates US$52.7 billion to boost domestic semiconductor manufacturing, research, and workforce development. Similarly, the EU Chips Act (2023) mobilises EUR43 billion to reinforce Europe's semiconductor ecosystem and reduce dependence on external suppliers (IndustryWeek, 2023; Innovation News Network, 2023).

Figure 6.2. Trade Value of Top Battery Electric Vehicle Exporting and Importing in 2023 (US$ billion)



BEV = battery electric vehicle.
Source: Observatory of Economic Complexity (2024a).

Despite this momentum, the transition remains far from uniform. Developed markets are fast-tracking xEV adoption in response to regulatory mandates and sustainability goals. In contrast, many emerging markets continue to prioritise ICEV and hybrid electric vehicle (HEV) production, constrained by infrastructure gaps and affordability concerns. This multi-speed transition is prompting automakers to adopt differentiated production strategies that align with regional market realities.

ASEAN Supply-chain Resilience and 'Friend-shoring' Snapshot

ASEAN now sits at the crossroads of three geo-economic shocks that are reshaping automotive supply chains.

First, US–China trade fragmentation has intensified since Washington imposed a 25% duty on imported finished vehicles in April 2025. Any model with substantial China content routed through ASEAN risks falling within the scope of these tariffs. Japanese OEMs can mitigate this exposure by undertaking final assembly of China-light kits in Thailand or Malaysia and completing production in United States–Mexico–Canada Agreement plants, thereby creating a more tariff-resilient corridor for US sales (Reuters, 2025f).

Second, the EU Carbon Border Adjustment Mechanism will move from its transitional phase to full implementation in 2026, putting a price on embedded carbon dioxide in steel and aluminium. Without cleaner inputs and verifiable emission data, ASEAN-produced ICEV and HEV exports could face carbon surcharges approaching EUR1,000 per vehicle. The use of hydro-powered aluminium in Sarawak, scrap-based electric arc furnace steel in Viet Nam, and the integration of Catena-X product carbon passports to trace embedded emissions can provide Japanese firms with a credible low-carbon value proposition that mitigates carbon border adjustment mechanism-related costs (European Commission, 2025).

Third, resource nationalism is increasingly affecting battery metals. Indonesia's ban on raw nickel ore exports requires battery cell manufacturers either to undertake refining within the country or to diversify their feedstock sources. Establishing high-pressure acid leach and mixed hydroxide precipitate processing facilities in Indonesia can secure access to Class-I nickel, whilst recycled nickel streams routed through Singapore can provide a hedge against price volatility (BRICS Today, 2024).

By blending tariff-efficient assembly routes, lower-carbon material inputs, and dual sourcing strategies for critical metals, Japanese OEMs can position ASEAN as a politically neutral, compliance-ready 'friend-shoring' hub. This approach enables firms to serve Western markets without absorbing excessive China-centric risk, whilst maintaining selective integration within the Chinese value chain.

Trade and technology tensions, particularly between the US and China, have intensified the fragmentation of critical supply chains for semiconductors, critical minerals, and xEV batteries. The 2025 US tariffs on all imported vehicles and automotive parts, introduced under renewed protectionist policies, are expected to reshape global production networks. Beyond direct cost increases, these measures introduce retaliatory risks and compliance uncertainty for OEMs. Combined with new restrictions on entities deemed foreign entities of concern and export controls on critical technologies and minerals,[2] these measures have accelerated so-called friend-shoring efforts.[3] As a result, Southeast Asia, India, and Eastern Europe are gaining prominence as relatively neutral and cost-efficient production hubs across both ICEV and xEV supply chains.

[2] In the US, the Inflation Reduction Act disqualifies EVs from subsidies if they contain components sourced from entities designated as foreign entities of concern, including many Chinese manufacturers. Similar restrictions are emerging within EU industrial policy frameworks (EIU, 2025b).

[3] Friend-shoring refers to the strategy of relocating supply chains and production activities to countries considered geopolitical allies or trusted partners, with the objective of reducing dependence on potentially adversarial nations.

Nevertheless, even diversified production networks remain vulnerable. In early 2024, attacks in the Red Sea disrupted key shipping routes, forcing manufacturers such as Tesla and Volvo to halt production at European plants, highlighting the continued fragility of global just-in-time logistics systems (Automotive News Europe, 2024).

Whilst China, the EU, and the US are expected to retain production leadership in vehicle production, India is emerging as a competitive base for compact and affordable models. For ASEAN, the strategic challenge lies in defining its production role amid this global reconfiguration. This role may encompass both cost-effective export-oriented production of ICEVs and HEVs and gradual integration into BEV and PHEV value chains. As global OEMs diversify their manufacturing footprints to enhance resilience and comply with evolving policy requirements, ASEAN's positioning will depend on the speed at which it can modernise its supply chains, reduce cost-to-serve, and align with increasingly complex compliance demands in a fragmented global trade landscape. Recent tariff measures present opportunities for ASEAN to absorb redirected production demand from tariff-affected exporters, particularly in cost-competitive ICEV and HEV assembly and the localisation of selected xEV components.

6.1.1.3. Digitalisation: Emergence of software-deźned vehicles

This section explores the transformative trends in vehicle technology that are reshaping the global automotive landscape. It focuses on the rise of SDVs, which marks a shift from traditional hardware-centric design towards vehicles increasingly driven by software capabilities. This transition enables new features, including ADAS, connected services, and autonomous driving, fundamentally changing how vehicles operate and deliver value. These developments reflect a broader industry move towards integrating vehicles into digital ecosystems, where software plays a central role in enhancing user experience, safety, and sustainability.

6.1.1.3.1. Software-deźned vehicles as a new paradigm of vehicle development

The automotive industry is undergoing a profound transformation. Vehicles are evolving from predominantly combustion-powered, mechanical machines into SDVs, fundamentally reshaping how they are designed, operated, and experienced (Deloitte, 2023a). Demand for a wide range of software-driven experiences is rising across consumer segments, from personalised in-cabin features and connected applications to advanced driver-assistance and entertainment functions. As vehicles become more software-centric, over-the-air (OTA) updates will increasingly allow continuous improvement and feature deployment, both onboard and offboard.

Market adoption of SDVs is accelerating. Companies surveyed expect mainstream adoption within an average of 5.7 years, consistent with forecasts projecting that SDVs will account for 90% or more of the automotive market by 2029, up from 2.4% in 2021 (Deloitte, 2023a). Moreover, 89% of respondents report that software strategy already plays a major role in their overall corporate strategy.

Automotive OEMs are investing heavily in digital technologies to transform the in-vehicle experience beyond traditional driving functions (Deloitte, 2023b). Future electrical and electronic (E/E) architectures will convert vehicles into Internet-of-Things (IoT)–enabled platforms that support diagnostics, new driving functions, and updates to be centrally managed by OEMs. E/E architectures are evolving from distributed systems, where each electronic control unit (ECU) performs specific tasks, towards integrated domains that group ECUs by functional area, such as powertrain, chassis, or ADAS. This evolution allows faster development, centralised control, and improved adaptability to new software-driven features.

The strategic benefits of SDV technologies further highlight their importance for automakers. By enabling real-time updates and greater responsiveness to market conditions, SDVs allow manufacturers to customise vehicle features through software without modifying physical components. According to Jama Software (2023), this capability supports the rapid deployment of new functionalities and enhancements to user experience directly via the cloud-based systems.

SDVs generate rich, real-time data on vehicle usage, driver behaviour, and performance outcomes (Renault Group, 2024). Automakers can leverage this data to optimise product development and production planning, ensuring that future models align more closely with consumer needs. This data-driven approach improves demand forecasting, reduces inventory waste, and supports more agile manufacturing processes. Consequently, SDVs enable hyper-personalisation at scale, strengthening competitiveness and brand relevance. As highlighted by Deloitte (2023b), such capabilities also create opportunities for predictive maintenance, performance-based upgrades, and subscription-based services that can generate recurrent revenue streams.

SDVs enhance flexibility for regional customisation. By adopting SDV architectures, OEMs can centralise strategic decision-making whilst maintaining responsiveness to local market conditions, thereby improving cost efficiency and shortening response times. According to Deloitte (2024c), about 69% of global OEMs have implemented SDV strategies that balance centralised governance with market-specific customisation.

6.1.1.3.2. Autonomous driving gaining traction

Autonomous vehicles, widely regarded as the future of personal and public transport, are slowly gaining their market presence. The global autonomous vehicle market is projected to reach about US$114.5 billion by 2029, although most vehicles sold in 2023 still featured only Level 2 automation, highlighting the gradual pace of technological advancement (Statista, 2025a; Statista, 2026).

Several major players have started offering a comprehensive range of autonomous vehicles and related services, whilst investing heavily in research and development to advance the technology. Xiao (2024) noted that Tesla, as a market leader, has pioneered driverless technology through the development of self-driving vehicles featuring

automatic steering, cruise control, navigation on autopilot, and automatic lane changing. These innovations have attracted significant market attention and continue to influence broader industry development. Tesla's autopilot system is widely regarded as one of the most mature solutions available. Tesla has now entered a phase of autopilot development, significantly expanding its features to include augmented summon, self-parking, and enhanced safety functions. According to Zhang and Ding (2024), autonomous driving technologies have had a multi-faceted impact on Tesla's revenue, profitability, and market valuation, with income generated from these technologies accounting for a growing share of overall corporate performance year on year.

The Chinese technology company Xiaomi introduced a full-scenario, end-to-end assisted driving system in its debut xEV, the SU7 sedan, launched in March 2024 (Alves, 2025). Xiaomi has developed three key technologies: adaptive BEV technology, a road-mapping foundational model, and super-resolution occupancy network technology (Electric Motor News, 2024). Adaptive BEV technology applies different perception algorithms according to driving scenarios, ensuring wide visibility in urban conditions, extended perception at higher speeds, and greater precision during parking. The road-mapping foundational model redefines road perception by enabling real-time recognition and smoother navigation through complex intersections without relying on high-definition maps, instead drawing on accumulated learning from driver behaviour.

For obstacle recognition, Xiaomi's super-resolution occupancy network technology enables virtually unlimited recognition categories by modelling visible objects as continuous curved surfaces rather than discrete blocks. The company has developed what it describes as the world's first production-ready 'end-to-end sensing and decision-making artificial intelligence model' for automated parking, further cementing its position as an innovation leader.

Breakthroughs by pioneers such as Tesla and Xiaomi show that autonomous driving is no longer a distant vision. The technology continues to mature, adoption is accelerating, and innovations once regarded as futuristic are now actively shaping the global mobility landscape.

6.1.2. Supply Chain

6.1.2.1. Upstream

This section highlights the growing importance of securing critical materials within the automotive upstream supply chain. As xEV adoption accelerates, access to rare metals has become essential for battery production and overall vehicle performance. At the same time, the emergence of SDVs has increased demand for advanced semiconductors, which are vital for powering new digital features and autonomous capabilities. Effective management of these key inputs is therefore crucial to meeting production targets and satisfying the technological requirements of an evolving industry.

6.1.2.1.1. Critical rare metals security in the age of electriźcation

Upstream supply chains are becoming strategically critical as the automotive sector advances electrification. The rapid electrification of transport is generating an unprecedented surge in demand for critical minerals. According to Chapter 4's GlobalData powertrain forecast, global BEV and PHEV sales are projected to rise from 13.4 million units in 2023 to nearly 58.9 million by 2035, representing a 4.4-fold expansion over the period (GlobalData, 2024b). The International Energy Agency (IEA) (2024a) global xEV outlook further projects that this transition will raise battery demand to 7–12 times 2023 levels by 2035.

This surge has intensified the need to secure rare metals, including lithium, copper, cobalt, nickel, graphite, and rare earth elements (REEs), which are increasingly described as the 'new oil' due to their indispensable role in modern automotive technologies.

Graphite illustrates the structural concentration risk. Although no immediate volume shortage is anticipated, supply is highly concentrated, with over 90% of battery-grade graphite production in 2030 projected to originate from China (IEA, 2024b). Between now and 2030, about 70%–75% of projected supply growth for refined lithium, nickel, cobalt, and REEs is expected to come from the current top three producing countries. Nearly 95% of growth in battery-grade spherical and synthetic graphite capacity is projected to occur in China (IEA, 2024b). Such concentration levels create vulnerabilities for the energy transition, as extreme weather events, trade disputes, or geopolitical tensions could severely disrupt supply chains.

Mining market values are projected to expand across regions, including Latin America, Indonesia, and Africa, each reaching about US$80 billion–US$120 billion by 2040. However, the refining stage remains heavily concentrated in China (IEA, 2024b). By 2030, China is expected to account for more than half of the global refining market, valued at close to US$300 billion, compared with about US$180 billion for all other regions combined. This imbalance highlights that, although other regions are building up their mining capabilities, the critical refining stage, where significant value is added, continues to be dominated by China.

As global demand for these minerals continues to surge, securing reliable and diversified sources of critical metals has become a strategic imperative for the automotive industry. This is particularly important to ensure the stable growth of the xEV market.

6.1.2.1.2. Rising software-deźned vehicles heighten competition for semiconductor supply

The global shift towards SDVs is intensifying the strategic importance of semiconductor procurement for automakers. As vehicles become smarter, safer, and increasingly enabled by artificial intelligence (AI), their reliance on chips and software grows rapidly. The automotive semiconductor market is projected to exceed US$80 billion by the end of the decade (Schutter, 2025), driven primarily by rising chip content per vehicle. Global

OEM-based demand for automotive semiconductors increased by 24% year-on-year across all applications, including sensors (Anwar, 2023). This strong demand, combined with constrained supply, has pushed semiconductor prices higher, benefiting chip manufacturers whilst creating procurement pressures for automakers. As vehicle architectures evolve towards zonal designs and high-performance computing platforms for battery electric SDVs, demand for advanced system-on-chip solutions is rising, gradually displacing traditional microcontrollers.

The increasing semiconductor content per vehicle underscores the growing importance of procurement strategies. Estimates suggest that the value of semiconductor devices per vehicle stood at about US$590 in 2023 and is expected to rise to roughly US$1,000 per vehicle by 2029 (Boulay, 2024). This upward trajectory highlights how essential a secure and reliable semiconductor supply has become for sustaining vehicle production and meeting SDV performance requirements.

Competition for semiconductors extends beyond the automotive sector. The electronics, telecommunications, and data centre industries also vie for chip allocations, creating a risk that automakers may be deprioritised in the absence of formal allocation mechanisms. Semiconductors are crucial not only for advanced xEV platforms but also for conventional ICEV and HEV models. Consequently, insufficient supply can disrupt production schedules and erode competitiveness.

Global automakers are responding proactively. For example, Hyundai Motor has initiated a major effort to boost domestic semiconductor production and reduce reliance on imports, with a target of fulfilling over 90% of its vehicle chip requirements locally (Fan and Wu, 2024). The OEM has committed to lowering dependence on foreign components in anticipation of future supply chain disruptions. To achieve this objective, Hyundai has engaged multiple Korean integrated circuit suppliers in collaborative efforts to co-develop automotive semiconductors. This decision reflects Hyundai's recognition of the increasing strategic importance of semiconductor supply within the automotive sector and reinforces its intention to maintain a leadership position in the mobility market through secure access to stable semiconductor sources.

This strategic approach illustrates the broader acknowledgement amongst global players that semiconductor procurement has become a core enabler of vehicle electrification, software-defined functionality, and long-term mobility competitiveness.

In summary, as SDVs become more prevalent, semiconductor content per vehicle is increasing substantially, elevating procurement to a central strategic priority. Securing a stable chip supply is now critical for automakers worldwide to sustain production, deliver advanced vehicle functionalities, and remain competitive in an increasingly software-driven mobility market.

6.1.2.2. Midstream

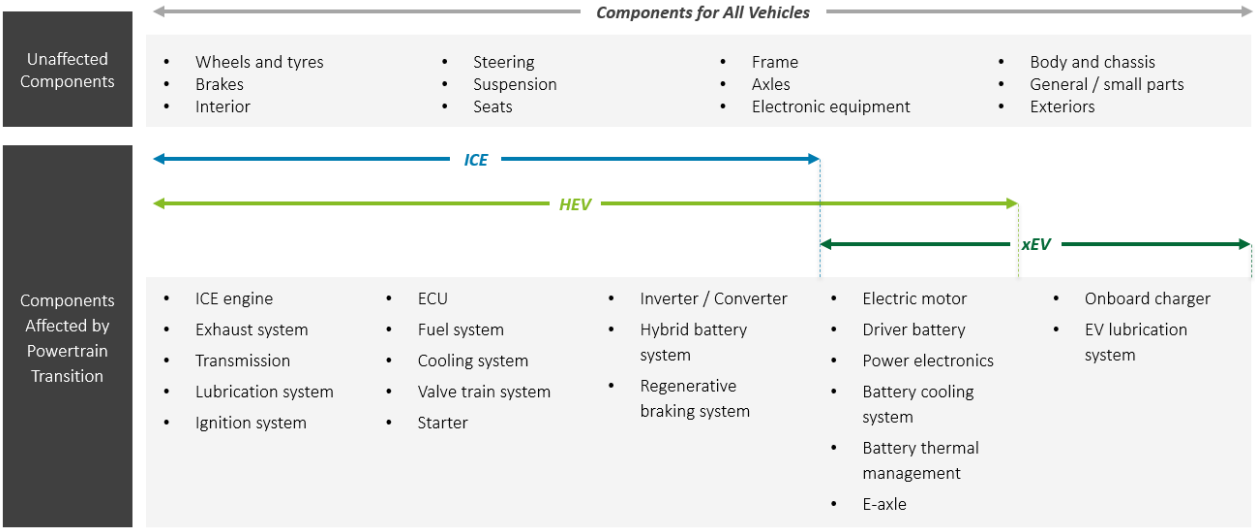
This section outlines key changes in the midstream automotive supply chain arising from the shift towards xEVs. Component requirements are evolving, often leading to a reduction in the number of parts required per vehicle. Emerging brands are increasingly adopting vertically integrated production models to strengthen control, improve efficiency, and capture greater value. The decoupling of hardware and software is advancing, placing greater emphasis on in-house software development and system integration. Manufacturing innovations, such as giga casting, AI, and advanced automation, are transforming production processes to enhance scalability, flexibility, and cost efficiency.

6.1.2.2.1. Change in component requirements for xEVx

As the automotive industry accelerates electrification, the fundamental architecture of vehicle design is being reshaped. Component requirements are shifting dramatically from traditional ICE systems to xEV powertrains. BEVs are engineered with significantly simpler drivetrains than their ICE counterparts. On average, a BEV drivetrain contains about 20 to 25 moving parts (Alpha Motor, 2025). By contrast, ICEVs are considerably more complex, with between 200 and over 2,000 moving parts across the engine and drivetrain.

As depicted in Figure 6.3, the shift to xEVs not only reduces overall component counts but also renders many ICE- and HEV-specific parts redundant. BEVs need no exhaust systems, alternators, fuel injectors, or starter motors. These long-established components will gradually disappear from future production lines. In comparison, HEVs maintain greater overlap with ICEVs, retaining a substantial proportion of conventional components. This divergence underscores the need for suppliers to adapt their portfolios and capabilities to remain competitive in the evolving powertrain landscape.

Figure 6.3. Transition of Components by Powertrains



Source: Deloitte Supplier Risk Monitor (2023).

Manufacturing xEVs in facilities originally configured for ICEV production requires significant reconfiguration of assembly processes and plant layouts. This transition poses challenges not only for suppliers of traditional components but also for OEMs that depend on established supply networks. Recent analyses indicate that major suppliers are reallocating capital and engineering resources towards electrification. For example, Dana Inc. has shifted its focus from conventional axle and driveshaft production towards components tailored to EVs (Brereton, 2024). Although demand for xEV-specific components and advanced electric systems is projected to expand, legacy systems such as suspension and steering will remain relevant in the medium term, albeit with declining relative importance and increasing requirements for redesign and integration.

Brereton (2024) further observes that large-volume parts suppliers are increasingly concentrating their investment on e-mobility technologies, whilst scaling back production of traditional components such as steering drag links and steering gears. This shift is already reshaping the supplier landscape. Smaller manufacturers and aftermarket suppliers are being compelled to identify alternative sourcing strategies to support existing vehicle fleets and low-volume production. As electrification advances, demand grows for suppliers capable of offering design flexibility and customised engineering solutions to fill emerging gaps. Firms unable to pivot risk marginalisation within the value chain, as the industry's momentum towards electrification reduces the viability of legacy supply models.

6.1.2.2.2. Vertically integrated production models

The coronavirus disease (COVID-19) pandemic, component shortages, and rising geopolitical tensions in regions central to global manufacturing have prompted automakers to reconsider their sourcing, production, and distribution strategies (Batra et al., 2023). One increasingly explored approach is vertical integration, which involves taking greater direct ownership of upstream or downstream operations previously outsourced, either by building internal expertise or through acquisitions. In some cases, this strategy requires companies to build in-house capabilities in products and processes that were not historically part of their core competencies. Through vertical integration, automakers aim to strengthen control over supply chains, reduce reliance on third-party suppliers, and enhance resilience against disruptions.

Tesla

Tesla exemplifies the vertical integration model. The company reportedly controls about 80% of its supply chain, encompassing battery and electric motor manufacturing, vehicle assembly, power electronics, software development, supercharger networks, and sales and distribution (Bongdap, 2024). Tesla has invested heavily in gigafactories to scale battery and vehicle production, enabling it to fulfil large pre-sale orders efficiently. Its facilities can produce up to 5,000 Model 3 vehicles per week, thereby reducing exposure to supply-chain bottlenecks, including disruptions in raw material sourcing.

Tesla produces a greater volume of batteries, measured in kilowatt-hours across its gigafactories than all other carmakers combined, reaching about 15 gigawatt-hours (GWh) (0.15 terawatt-hours) per year. This vertical integration not only ensures quality control but also allows rapid innovation. By managing multiple stages of the value chain internally, Tesla can shorten the development cycle, bypass traditional supply constraints, and respond quickly to technological or market shifts (Emmer, 2024). This organisational agility allows the company to implement improvements swiftly, often outpacing legacy automakers with more fragmented supply structures.

Tesla secures critical raw materials through long-term agreements. In 2020, the company signed a 5-year agreement with Piedmont Lithium for the supply of spodumene concentrate sourced entirely within the US, reducing dependence on overseas suppliers and stabilising costs (Bongdap, 2024). Such contracts enhance supply security and pricing certainty for critical inputs, including lithium. Tesla's in-house software development further strengthens its competitive position (Morrison, 2022). Unlike many traditional automakers, Tesla has never outsourced core software development. It continues to refine proprietary self-driving systems using real-world data collected from over 1 million beta testers.

In vehicle design, bringing processes in-house allows Tesla to specify features and functionalities beyond those typically offered by tier-2 suppliers (Jeffs, 2023). Off-the-shelf components are designed for broad applicability and may not align with specific OEM requirements. By internalising design and development, Tesla can produce customised chips and components tailored to its vehicles, thereby enhancing performance differentiation.

BYD

BYD's success has been underpinned by vertical integration (Lee, 2024). Instead of relying extensively on external suppliers, BYD produces most of its core components internally, enabling cost-effective xEV production whilst maintaining quality and performance control. Its vertical integration spans eight key components: vehicle control unit, battery management system, motor control unit, power distribution unit, direct current–direct current controller, on-board charger, drive motor, and transmission. These systems are integrated into the world's first mass-produced 8-in-1 electric powertrain system, which optimises space utilisation and energy efficiency (BYD, 2025).

A defining feature of BYD's model is the in-house production of batteries, power electronics, electric motors, and semiconductors. The introduction of the blade battery in 2020, using a cell-to-pack configuration, further exemplifies this approach by improving safety and energy density (Dixit, 2025). By controlling core systems internally, BYD can offer a broad range of affordable xEVs whilst maintaining scale and market expansion.

According to EV Boosters (2025), BYD's growth is supported not only by demand but also by its vertically integrated structure. By overseeing nearly the entire value chain, from raw material extraction and battery production to software development and vehicle

assembly, the company achieves high efficiency, cost control, and responsiveness to market dynamics. To secure upstream supply, BYD acquired mineral rights in Brazil's lithium-rich Jequitinhonha Valley, helping stabilise pricing and supply whilst reducing exposure to volatility.

In 2023, BYD strengthened its upstream integration and sustainability credentials by establishing a joint venture with Huayou Cobalt in China to expand refining capacity. Owning refining operations ensures consistent quality, reduces reliance on external processors, and allows faster response to demand fluctuations. BYD Semiconductor, founded in 2004 to produce integrated circuits for power electronics, has become a cornerstone of this strategy. Internal chip production mitigates supply shortages and allows seamless integration between hardware and proprietary software.

Producing most major systems internally allows BYD to maintain stringent quality control. From semiconductor testing to battery safety validation and overall vehicle performance assessment, each model undergoes rigorous internal evaluation. This approach facilitates rapid iteration, efficient cross-model upgrades, and cost reduction whilst enhancing reliability. It also shortens lead times, aligns production with forecasts, and supports predictable supply to dealers.

At the final stage of its value chain, BYD emphasises battery recycling and reuse. Through partnerships with domestic recycling firms and expansion of its own facilities, the company recovers valuable metals from end-of-life battery packs. This circular approach reduces reliance on newly mined raw materials, lowers production costs, and enhances environmental, social, and governance (ESG) performance, an increasingly important consideration for investors and consumers.

The experiences of Tesla and BYD reflect a broader structural shift within the automotive industry towards vertical integration as a key strategy for xEV production. Automakers are increasingly internalising upstream and downstream functions to enhance supply-chain resilience, reduce cost exposure, and accelerate innovation. By controlling critical stages of the value chain, companies can mitigate risks associated with supplier dependency, commodity price volatility, and geopolitical disruption, whilst ensuring high-quality customised products. As demand for xEVs continues to rise, vertical integration is emerging not merely as an operational preference but as a strategic necessity for leading automakers.

6.1.2.2.3. Software development

As vehicles evolve into increasingly digital platforms, the decoupling of hardware and software is reshaping the automotive industry and positioning software development as a central driver of innovation and value creation. In the xEV and SDV era, software is emerging as a primary source of differentiation. According to Deloitte (2023), the growing complexity of vehicle functions has already elevated the importance of embedded software, and this trend is expected to intensify as more advanced features are

introduced.

Future E/E architectures are expected to transform vehicles into fully networked IoT devices on wheels, enabling diagnostics, driving functions, and feature updates to be centrally managed by OEMs. OTA updates are likely to become an industry standard, supporting continuous performance improvements, security enhancements, and the deployment of personalised, on-demand services. As software becomes the backbone of value creation, cybersecurity assumes heightened importance. OEMs and suppliers must therefore integrate robust protection measures into system design and life cycle management.

Although OEMs can leverage flexible and scalable software platforms to customise product launches across different geographies, they must also manage the integration of multiple platforms and applications sourced from different providers, whilst ensuring reliability, security, and interoperability (Deloitte, 2023b). At the same time, suppliers are well-positioned to benefit from growing demand for high-performance hardware components, including sensors, processors, and network systems. The growing complexity of integration underscores the need for more sophisticated programme management approaches, as vehicle development increasingly mirrors the life-cycle management of digital products.

According to Deloitte Insights (2020), the competitive landscape in automotive software development is evolving rapidly. OEMs, traditional tier-1 suppliers, software-focused entrants, engineering service providers, and semiconductor manufacturers are all competing to capture value in this expanding domain. Industry participants are pursuing varied strategic pathways. Some OEMs are building in-house software capabilities, such as BMW's Car-IT and Volkswagen's Car.Software.org. Others have formed joint ventures with specialist software firms, for example, Audi and Elektrobit's e.solutions. Many continue to rely on outsourced engineering service providers whilst retaining intellectual property ownership. Concurrently, large tier-1 suppliers are increasingly assuming the role of system integrators, developing joint platforms and integration solutions that bridge OEM requirements and software innovation.

The industry is moving towards greater standardisation of hardware–software interfaces and modularity within the software stack, supported by initiatives such as the AUTomotive Open System Architecture (AUTOSAR) (Deloitte Insights, 2020).[4] Standardisation is expected to reduce verification costs, promote software re-use, and clarify responsibilities across the value chain. In this evolving environment, software development is no longer a supporting function; rather, it is becoming the organising principle for collaboration, competition, and value capture within the automotive sector.

[4] The AUTOSAR initiative is a global partnership of leading automotive and software companies that seeks to develop and establish a standardised software framework and open E/E system architecture to support intelligent mobility.

6.1.2.2.4. Manufacturing innovations

Manufacturing innovations are playing a pivotal role in reshaping the global automotive value chain. Gigacasting is driving a structural revolution by simplifying vehicle assembly and reducing weight. The application of digital twins and AI enhances process precision and supports predictive maintenance, whilst advances in automation, robotics, and intelligent factory systems boost productivity and flexibility. Collectively, these developments are redefining traditional production models and strengthening supply-chain resilience in response to electrification and the rise of software-defined vehicles.

A. Gigacast manufacturing: A structural revolution in vehicle manufacturing

Gigacasting represents a paradigm shift in vehicle manufacturing. It deploys high-pressure aluminium die-casting to produce large, complex structural components as single pieces. This approach replaces traditional methods that require welding dozens of individual parts, enabling automakers to streamline assembly lines, reduce material waste, and improve structural integrity. As global markets accelerate towards battery-based xEV adoption, gigacasting has gained strategic importance. Its efficiency gains and cost-reduction potential are particularly relevant for manufacturers aiming to scale production whilst meeting decarbonisation targets. For ASEAN, where automotive exports remain concentrated in ICE and hybrid models, understanding this shift is vital to maintaining competitiveness in a rapidly evolving global supply chain.

Tesla: The Gigacasting Pioneer

Tesla's introduction of gigacasting in 2020, starting with the Model Y rear underbody, marked a significant inflexion point in automotive manufacturing. By deploying 6,000–9,000-tonne die-casting presses, Tesla replaced multiple welded components with large single-piece castings, pioneering a production model that has since shaped industry benchmarks. Key outcomes include the following:

- Elimination of about 1,600 welds in the rear structure.
- Production capacity of up to 150,000 units per year per gigapress, with 120–150-second cycle times at about 90% yield.
- Consolidation of more than 70 parts into a single module for Model Y compared with the Model 3.

Tesla's Shanghai facility operates three to four gigapress units for this process. Although the company explored a one-piece full underbody casting, it reverted to a more practical three-piece configuration due to repairability and scalability constraints. This experience illustrates both the transformative potential and current operational limitations of gigacasting at an industrial scale (Reuters, 2024b; S&P Global Mobility, 2023; CNBC, 2024).

Toyota: Scaling Gigacasting for Mass Production

Toyota's 2023 demonstration of gigacasting at its Miyoshi plant reflects a phased and pragmatic approach focused on efficiency improvements in stages. Key features include the following:

- Consolidation of 86 components and 33 assembly steps into a single aluminium casting for the rear third of the vehicle.
- Reduction of casting time from several hours to about 3 minutes per part.
- Target of 20% higher productivity compared with conventional xEV manufacturing by 2026.

This new casting method will initially be applied to the front and rear sections of a 2026 BEV. Since developing its prototype in 2022, Toyota has refined its approach to balance innovation with modularity, allowing adaptation across diverse vehicle platforms (IEN, 2023; Carscoops, 2023).

Case Study: Feasibility Outlook for Gigacasting in ASEAN (Thailand)

Despite comparatively low shop-floor wages – about US$400 per month in Thailand (Trading Economics, 2024) – gigacasting remains capital intensive. A 9,000-tonne IDRA gigapress costs roughly EUR10 million–EUR11 million before tooling and auxiliary equipment (ANP Management Consulting, 2024). Amortising this investment over 7 years typically requires annual production volumes of 90,000–120,000 units. However, the equipment can eliminate 200–250 weld-station roles per shift. Even at prevailing wage levels, payback periods may remain below 4 years for high-volume B-segment BEV platforms. Consequently, Thailand's and Viet Nam's labour cost advantages do not negate the economic case for gigacasting, provided programmes are export-oriented and operate at scale.

Thailand hosts more than 10 tier-1 aluminium die-casters supplying structural components to Toyota, Honda, and BYD, whilst Viet Nam is expanding capacity within its northern supplier parks (Casting YZ, 2024). Most facilities cast standard aluminium–silicon–magnesium alloys but require upgrades in alloy degassing and heat-treatment capability to support 100-kilogram one-piece structural castings. Japanese *keiretsu*[5] suppliers such as UACJ and Ahresty are exploring joint investments to narrow these capability gaps. Feedstock availability presents fewer constraints: aluminium billet can be sourced regionally, and hydro-powered primary aluminium from Sarawak provides a lower-carbon input, supporting compliance with mechanisms such as the European Union Carbon Border Adjustment Mechanism.

Repair infrastructure presents a more significant constraint. Early collision cases

[5] *Keiretsu* refers to a Japanese business network of independent companies that maintain close relationships, often including cross-shareholdings.

involving Tesla's gigacast Model Y showed that rear-end repairs could exceed US$30,000, accompanied by higher insurance premiums, because entire castings required replacement (Foundry Planet, 2024). Although repair techniques have improved – sectional machining and cold-metal stitching now allow partial repairs – these methods require specialised equipment and thermal management expertise that remain limited in many ASEAN body shops (InsideEVs, 2024). Widespread adoption would therefore require investment in certified cast-repair centres and targeted workforce training.

In conclusion, gigacasting can be economically viable in Thailand and, at sufficient scale, in Viet Nam, provided that Japanese OEMs pair gigapress investment with (i) high-volume export programmes, (ii) supplier upgrades to support high-integrity alloy casting, and (iii) development of a certified body-repair network. Without these enabling conditions, conventional modular cast-and-weld approaches are likely to remain the lower-risk manufacturing pathway for ASEAN production in the near to medium term.

6.1.2.2.5. Reconźguring manufacturing through digital twins and artiźcial intelligence

Amid rising labour costs and intensifying competition, the automotive industry is increasingly adopting digitalisation to boost efficiency, lower costs, and enhance operational flexibility. This transformation harnesses technologies such as digital twins and AI to reconfigure design, production, and maintenance processes. Moving beyond physical prototyping and manual oversight, digitalisation enables real-time data capture and virtual simulation, supporting faster and more data-driven decision-making.

At the core of this transformation are digital twins – virtual replicas of physical assets, including vehicles and production lines – that are continuously updated through sensor inputs. These models allow manufacturers to simulate performance, test design changes, and monitor operations in a virtual environment. AI augments digital twins by analysing complex datasets to predict maintenance needs, optimise production flows, and improve product quality. Together, these tools shorten development cycles, strengthen quality control, reduce waste, and contain costs. Equally important, the same digital backbone underpins the rise of SDVs, in which functionalities are delivered and upgraded via software rather than fixed hardware.

Digitalisation has therefore evolved from a technological enhancement into a strategic imperative. As regulatory requirements tighten and product development cycles shorten, leading markets such as China, Germany, and Japan are embedding these capabilities to maintain global competitiveness.

SAIC Motor: Scalable Production Ecosystem

SAIC Motor has emerged as a leading adopter of digital twin technology to optimise manufacturing operations. By deploying virtual replicas of assembly lines connected to real-time sensor data, SAIC applies AI to predict equipment failures and streamline production scheduling. Reported outcomes include the following:

- 3.8% reduction in energy consumption per vehicle.
- 6% decrease in logistics costs per vehicle.
- 2% reduction in potential inventory capital.

SAIC's experience demonstrates how digitalisation can enhance scalability in high-volume production environments, a model particularly relevant for cost-sensitive markets (China Daily, 2024).

Nissan: Predictive Efficiency

Nissan's UK facility applies Twinn Witness Horizon software to create predictive digital twins of its production lines. These models simulate alternative scenarios to identify bottlenecks and optimise resource allocation, with AI likely enhancing predictive accuracy. Reported results include the following:

- An increase in throughput from 5 to 10 jobs per hour, with a target of 15, achieved by resolving sealing bottlenecks.
- Cost savings of GBP22,000 by reducing pallet stock from 100 to 70 units on the cylinder-head line.
- Avoidance of GBP25,000 in capital expenditure by validating capacity for paint-guard film application.

This case illustrates how digitalisation can refine operational efficiency in an established ICE and hybrid production environment (Royal HaskoningDHV, 2023).

Nissan's Intelligent Factory integrates digital twin principles, real-time IoT monitoring, and robotic execution to support next-generation vehicle production. Key features include cockpit fitting with ±0.05 mm precision, 11 robots performing automated paint inspections, and digital coordination of 27 module combinations during underfloor mounting. These systems enable flexible, high-quality, and future-ready manufacturing (Nissan Global, n.d.).

Digital twins and AI are reshaping efficiency, quality, and sustainability across the automotive value chain. Virtual simulations reduce reliance on physical prototypes and accelerate design timelines. AI enhances quality through real-time defect detection, whilst predictive maintenance reduces downtime and stabilises production output. Digital testing supports more sustainable design by minimising material waste and energy consumption. Together, these technologies lower costs, boost throughput, and strengthen environmental compliance, delivering key advantages in a highly competitive global market. The same real-time data infrastructure that powers factory digital twins also underpins post-sale services, from predictive maintenance applications to OTA feature deployment, creating a continuous digital value chain from manufacturing to in-use monetisation.

6.1.2.2.6 Automation: From fixed robotics to flexible, intelligent factories

Automation has long been a cornerstone of automotive manufacturing. However, its evolution towards intelligent and flexible systems represents a new frontier, moving beyond traditional fixed industrial robots used in welding and stamping. Today's frontier comprises flexible, intelligent automation, including collaborative robots (cobots), autonomous mobile robots, and, increasingly, humanoid robots integrated into lights-out or 'dark' factories.

This transition enables greater responsiveness to product variation, supports electrification, and offsets rising labour costs. Leading automakers in China, Europe, and Korea are redefining production not only for cost or scale, but also for agility, sustainability, and end-to-end quality. For ASEAN, these developments present both challenges and opportunities to adopt automation selectively in ways that enhance regional competitiveness and enable the transition towards xEV production.

BYD: High-automation xEV Factories

BYD, China's largest xEV manufacturer, has emerged as a global benchmark for automation-driven efficiency. Its Shenshan and Xi'an facilities illustrate a new paradigm in high-throughput, vertically integrated production.

Key automation features include the following:

- About 87% automation in body welding, completing one body-in-white every 58 seconds at Shenshan (RichelleShop, 2023).
- Stamping lines producing 13 components per minute, with battery workshops deploying autonomous mobile robots such as ForwardX's Max 1500-L and Apex 2000 autonomous forklifts (Global Times, 2024; PR Newswire, 2024).
- Pilot deployment of UBTECH's humanoid robot Walker S1 for component placement and visual inspection, supporting continuous 24-hour operations with minimal human intervention (UBTECH, 2024).

For BYD, automation functions not only as a cost lever but also as a mechanism for achieving scale, consistency, and rapid cycle times in a competitive xEV market. This production model is now being replicated globally. The company's facility in Rayong, Thailand, inaugurated in July 2024, is ramping up production and is expected to incorporate similar automation technologies as output increases, highlighting ASEAN's expanding role in xEV manufacturing (The Nation Thailand, 2024).

Mercedes-Benz: Factory 56 Precision Benchmark

Mercedes-Benz's Factory 56 in Sindelfingen represents a new standard in digitalised and flexible production. Built around the MO360 digital ecosystem, the facility employs digital twins, AI-driven analytics, and real-time connectivity to monitor and optimise production processes. Traditional fixed conveyor systems have been replaced by more than 400 autonomous guided vehicles, allowing dynamic reconfiguration of workflows. Cobots perform ergonomically challenging tasks, such as windscreen installation and cockpit assembly, improving precision whilst supporting workers (Mercedes-Benz Group, 2020). In 2025, Mercedes-Benz began piloting Apptronik's Apollo humanoid robot for material delivery and basic assembly operations, further advancing automation within the plant (Reuters, 2025b). Reported results include the following:

- Factory 56 operates 25% more efficiently than the previous S-Class assembly line (Carscoops, 2020).
- New models can be integrated within days without major reconfiguration, enhancing responsiveness to market demand (Mercedes-Benz Group, 2023).
- The production line supports mixed manufacturing of ICEV, HEV, and BEV models, reducing downtime and improving volume flexibility (Mercedes-Benz Group, 2020).

Mercedes-Benz combines advanced automation with skilled human input, using digital tools to augment rather than replace labour. This hybrid model provides a pathway for regions pursuing premium production strategies, where quality and customisation are strategic differentiators.

The global shift from fixed-function robotics to intelligent, flexible manufacturing systems is redefining vehicle production. China's OEMs have embraced 'dark' factory models characterised by high robot-to-worker ratios, whilst established OEMs in Europe are integrating cobots and digital systems to balance precision, flexibility, and worker ergonomics.

Automation, digital twins, and generative AI will reshape workforce composition, although evidence suggests a reconfiguration of skills rather than a net elimination of jobs. The World Economic Forum (2023) projects that, by 2027, technological change will create 69 million new roles whilst phasing out 83 million routine positions, representing a net global employment decline of about 2%. Job displacement is expected primarily in repetitive assembly and clerical tasks, whilst demand surges for data engineers, mechatronics technicians, and operational technology cybersecurity specialists (World Economic Forum, 2023). Even highly automated regions remain major employers: Europe installed 23,000 additional automotive robots in 2024, yet continues to support about 2.4 million direct manufacturing jobs, showing that large-scale automation can coexist with large workforces when accompanied by effective upskilling strategies (International Federation of Robotics [IFR], 2023b; European Automobile Manufacturers' Association [ACEA], 2024).

In ASEAN, similar trends are evident. A 2024 International Labour Organization (ILO) (2024) survey of automotive plants in Thailand found over 70% of firms intend to retrain rather than reduce their workforce as digitalisation progresses, signalling that job quality is likely to evolve more significantly than job quantity. The policy implication is clear: digital twin and automation initiatives should be accompanied by targeted reskilling programmes, training vouchers, and supplier-supported training hubs to transition at-risk line operators into higher-skilled maintenance and data-oriented roles, thereby minimising social disruption whilst unlocking productivity gains.

For ASEAN, the immediate priority is not full automation but strategic benchmarking and selective adoption in high-impact processes such as welding, painting, battery module assembly, and final inspection, where quality, safety, and precision are paramount. A hybrid approach – automating key value-adding operations whilst preserving labour flexibility – offers a pragmatic pathway. The region can leverage open data standards, such as Europe's Catena-X and Japan's Ouranos initiatives, to digitally connect suppliers and enable traceable, low-carbon component flows. This will become especially relevant as labour costs rise and competition for investment intensifies.

The central implication is that automation is no longer optional for maintaining competitiveness within global automotive supply chains. For ASEAN to sustain its role in next-generation vehicle manufacturing, integrating automation readiness into its long-term industrial strategy is essential.

6.1.2.3. Downstream

6.1.2.3.1. Resource circulation initiatives

From a decarbonisation perspective, the shift towards circularity, through battery recycling, remanufacturing, and the use of secondary materials, is gaining traction as a hedge against supply chain shocks, price volatility, and geopolitical risk. The reuse of materials such as aluminium and low-carbon steel is being explored not only to reduce costs, but also to support compliance with extended producer responsibility regulations and to mitigate Scope 3 emissions[6]. The EU's Carbon Border Adjustment Mechanism (CBAM) is expected to further accelerate the uptake of secondary raw materials. Studies suggest that green steel produced under a strong circular model can deliver carbon dioxide emission reductions of up to 60% compared with conventional production routes (KPMG, 2023).

[6] Scope 3 emissions refer to indirect greenhouse gas emissions that occur across a company's broader value chain, beyond its direct operations. These arise from activities not owned or controlled by the company, such as supplier production, employee commuting, and the use of its products by customers.

BYD: Circular Integration at Scale

As the world's largest xEV manufacturer, BYD has expanded its scope beyond vehicle electrification to encompass broader supply-chain sustainability initiatives:

Battery recycling. BYD operates a closed-loop system, working with domestic and overseas partners to recover lithium, nickel, and cobalt from end-of-life batteries. Recovered materials are reintegrated into new battery production, with reported recovery rates of 80%–95% (Xray, 2025).

Green factories. BYD's battery subsidiary, FinDreams, has committed to achieving carbon neutrality across its entire value chain by 2045. Planned measures include the establishment of a comprehensive carbon emission management system, increased use of renewable electricity across facilities, and the development of zero-carbon demonstration parks and factories (CnEVPost, 2024).

BYD's vertically integrated structure allows tighter control over supply-chain emissions. However, the company continues to face challenges in areas such as the adoption of green steel and improvement of the transparency of supplier Scope 3 emissions, indicating room for further progress.

More broadly, resource circulation is becoming increasingly embedded within global supply-chain strategies, with circularity viewed as a core lever for enhancing both resilience and responsiveness. Empirical evidence indicates that circular economy practices are positively associated with improvements in sustainable supply-chain management and financial outcomes (Du et al., 2025). At its core, the circular economy focuses on maximising resource efficiency by extending product life cycles and minimising waste. Practices such as remanufacturing components, recycling parts, and reducing emissions during production are being adopted to lengthen the usable life of vehicles and components (Research and Markets, 2025).

For automotive manufacturers, circularity reduces dependence on primary raw materials and lessens exposure to volatile global supply chains. Recycled inputs, including aluminium, steel, and plastics, are often more cost-effective than newly extracted materials. In parallel, designing vehicles for easier disassembly and repair can extend product lifetimes whilst lowering overall production costs. Rather than discarding used components, manufacturers can refurbish or upgrade them to prolong their use. Components such as engines, transmissions, and batteries can be reconditioned and resold at a lower price, reducing demand for new inputs whilst minimising waste (Shoplogix Manufacturing, 2025). This approach creates additional revenue streams alongside cost savings.

In xEV manufacturing, circular strategies are particularly relevant due to the reliance on scarce and strategically important minerals used in battery production. Increasing recovery rates of these materials from end-of-life batteries can reduce long-term supply risks and improve the economic viability of battery manufacturing (Silvestri et al., 2021).

Research has identified the standardisation of battery designs, supported by stronger collaboration amongst manufacturers, recyclers, and end-of-life service providers, as a key enabler for scaling the recovery of rare earth and critical metals (Olsson et al., 2018).

Given the inherent scarcity of several materials essential to vehicle production, retaining and reusing these resources within regional systems is increasingly important. When implemented at scale, circular approaches can help sustain the material inputs needed for large-scale vehicle manufacturing. Although many circular practices take place at the downstream stage, their benefits extend across the entire value chain, supporting long-term sourcing continuity, reducing input costs, and enhancing overall supply-chain stability.

6.1.2.4. Cross-cutting theme

Across the global automotive value chain, decarbonisation and digitalisation have emerged as central cross-cutting themes shaping industry transformation. Carbon emission calculation and tracking are increasingly driven by carbon-neutrality commitments, creating new expectations for transparency, traceability, and accountability. At the same time, deeper integration and collaboration of data across the entire supply chain are advancing, enabling greater efficiency, resilience, and alignment with sustainability goals.

6.1.2.4.1. Decarbonisation: Calculating and tracking emissions

As the global automotive industry transitions towards sustainability, decarbonisation is emerging not only as an environmental imperative but also as a strategic lever for long-term competitiveness. Leading OEMs are no longer limiting their efforts to tailpipe emissions (Scope 1) and factory operations (Scope 2). Increasingly, they are addressing emissions across their entire value chain, including upstream materials, logistics, and supplier processes (Scope 3), in response to intensifying regulatory scrutiny, investor expectations, and consumer demand for credible sustainability action.

This shift is reinforced by regulatory mechanisms such as CBAM, which incentivises automakers to measure and reduce emissions embedded in carbon-intensive inputs such as steel and aluminium. Similar initiatives, including Japan's GX League, are further linking supply-chain sourcing and production costs to embedded carbon intensity (KPMG, 2023).

This full-spectrum approach is underpinned by growing pressure from regulators, capital markets, and consumers. Investors increasingly factor carbon exposure into valuation models, whilst OEMs with transparent, science-based Scope 1–3 targets benefit from preferential access to green capital and reputational advantages. Meanwhile, consumer-facing brands face growing risks where upstream sustainability claims cannot be substantiated.

Globally, automotive manufacturers are converging on a four-step approach to emissions tracking and reduction:

1. Define boundaries and establish baselines. Companies adopt the Greenhouse Gas (GHG) Protocol Corporate Accounting and Reporting Standard to quantify Scope 1 (direct operational emissions) and Scope 2 (purchased energy), whilst mapping the most material Scope 3 categories for ASEAN production. These typically include Category 1 (purchased materials such as steel, aluminium, and batteries); Category 4 (upstream transport and logistics); and Category 11 (use-phase fuel or electricity). This approach aligns with the Science Based Targets initiative's 2024 Land-Transport Guidance, which requires near-term 1.5°C-aligned targets covering at least 67% of Scope 3 emissions for automotive firms (Science Based Targets initiative, 2024; GHG Protocol, 2024).
2. Build a digital data backbone. Tier-1 suppliers are integrated into product carbon footprint (PCF) systems compatible with Catena-X standards. The PCF Rulebook, currently piloted by BMW and Mercedes-Benz, reduces double-counting and allows component-level emission traceability across borders (Catena-X, 2024). Japan's GX League voluntary emission trading scheme, whose Phase 2 trading window opens in 2026, already recognises Catena-X data schemas, providing Japanese OEMs with an efficient compliance pathway (Responsible Alpha, 2024).
3. Engage suppliers through a tiered approach.

   Tier A. Suppliers of critical materials (aluminium, steel, and battery materials) commit to science-based targets and share cradle-to-gate PCFs by 2027.

   Tier B. High-emission logistics partners adopt renewable fuels and route optimisation measures.
   Tier C. Long-tail suppliers participate in pooled training and audit programmes modelled on Toyota's Green Supplier scheme, which has delivered an average 3% year-on-year reduction in Scope 3 emissions across Toyota's ASEAN supply chain (Toyota Global, 2024a).
4. Assure and disclose. Emission data are consolidated into an ASEAN-specific addendum within OEM sustainability reports and externally verified under International Organization for Standardization (ISO) 14064-3. A dual-ledger system, distinguishing operational compliance data from investment-grade disclosures, mirrors revisions under consideration by the GHG Protocol and satisfies investor demand for decision-useful Scope 3 metrics (Deloitte, 2024a).

An illustrative example is Mercedes-Benz, whose Ambition 2039 road map targets carbon neutrality across its entire value chain. Key initiatives include securing supply agreements for green steel (near-zero-emission steel produced using hydrogen and electric arc furnaces) and transitioning all global manufacturing plants to renewable energy. These efforts not only support compliance with evolving European trade regulations but also reduce supply-chain risks and enhance brand value.

Mercedes-Benz: Full-spectrum Decarbonisation as a Competitive Strategy

Mercedes-Benz has adopted an aggressive decarbonisation strategy through its Ambition 2039 road map, which aims to achieve carbon neutrality across the entire value chain by 2039. Two flagship initiatives illustrate this approach:

- Green steel. Mercedes-Benz has secured long-term supply agreements with Svenskt Stål AB (SSAB) and H2 Green Steel to integrate over 200,000 tonnes per year of near-zero-emission steel into its European production lines by 2030. This steel is produced using hydrogen-based processes and electric arc furnaces with high scrap content, significantly reducing embedded emissions.
- Renewable manufacturing. All Mercedes-Benz–owned plants worldwide have operated on carbon-neutral energy since 2022. The company targets an 80% absolute reduction in production-related carbon dioxide emissions by 2030, relative to a 2018 baseline, with European facilities already operating on 100% renewable electricity.

Together, these initiatives position Mercedes-Benz to comply with carbon-related trade measures, lower exposure to supply-chain disruption, and reinforce its premium ESG brand positioning.

6.1.2.4.2. Digitalisation: Data collaboration

Across global industries, cross-border data collaboration is increasingly recognised as a strategic enabler of supply-chain resilience, efficiency, and decarbonisation. The deployment of integrated, cross-border digital platforms is gaining traction across major economies, driven by the need for greater supply-chain visibility, operational efficiency, and resilience. Two notable initiatives illustrate this trend: Japan's Ouranos and the EU's Catena-X Automotive Network. Japan's Ouranos is a state-led project that aims to establish a cross-enterprise, cross-industry, and cross-border data linkage system to promote large-scale data sharing and application, in line with Japan's Society 5.0 vision for a smarter and more connected society. Catena-X is a collaborative, open data ecosystem specifically designed for the European automotive industry, based on Gaia-X and International Data Spaces principles (T-Systems Europe, 2025). Catena-X is developing a decentralised data and service ecosystem spanning the entire automotive value chain, enabling participants, from large OEMs to small and medium-sized suppliers and recycling businesses, to benefit from data-based management whilst remaining protected by European data sovereignty and privacy laws (Institute for AI Safety and Security, 2025).

Similar momentum is emerging in other regions. China's Tianjin Port blockchain pilot project, widely considered the world's first port to integrate blockchain into cross-border trade systems, embeds distributed ledger technology that updates in real time as the status of goods in transit changes (China Daily, 2019). This system ensures that cargo

information remains transparent and accessible to all parties, from shippers to carriers, throughout the delivery process. At Hainan Port, cargo management personnel can monitor container and shipment status via mobile devices and quickly intercept problematic consignments when required (Liu and Wu, 2020). These pilot projects demonstrate how shared digital platforms can support secure, real-time coordination across international supply chains, improving both traceability and responsiveness.

Connected digital platforms allow firms to make faster and more accurate decisions by enabling real-time data exchange. This capability supports logistic optimisation, streamlines customs clearance and reduces unnecessary inventory buildup. In contrast, manual and siloed systems are more prone to delays, duplication of effort, and poor responsiveness. Empirical evidence indicates that digitally enabled supply chains can deliver strong business outcomes, including reductions in procurement costs of up to 20%, overall supply-chain cost savings of up to 50%, and revenue increases of up to 10%, even in sectors where supply chains are not traditionally viewed as revenue-generating functions (Wadlow, 2020).

The push towards digital collaboration therefore extends beyond efficiency gains and has become a strategic necessity. Disruptions arising from geopolitical conflicts, pandemics, and climate-related risks have elevated supply-chain visibility to a critical priority. Global supply-chain breakdowns are estimated to cost businesses nearly US$1.6 trillion annually, reflecting losses from raw material shortages, production stoppages, and shipping delays (Pazago, 2025). Digital connectivity addresses these vulnerabilities by allowing real-time tracking of inventory and logistics flows, enabling firms to detect emerging risks early, respond faster, and maintain operational continuity. Platforms that integrate sensors, tracking technologies, and secure data-sharing protocols also help build trust, improve coordination, and enhance competitiveness in increasingly complex trade networks.

Taken together, these international examples show that the adoption of interoperable, real-time, cross-border data platforms is a clear global trend reshaping industrial organisation, including within the automotive sector. Whether through open data ecosystems such as Catena-X or blockchain-powered trade systems such as those deployed at Tianjin Port, data collaboration is emerging as a foundational enabler of more resilient, transparent, and competitive supply chains. For ASEAN, aligning with this trajectory will be critical to sustaining integration within global value chains and meeting both commercial and policy objectives in the decade ahead.

6.1.3. Servitisation and Software-defined Mobility: The Next Value Pool

The next competitive frontier in the automotive industry is no longer a faster stamping press, but the ability to bind each vehicle to a sustained stream of post-sale, software-enabled revenue. Globally, leading OEMs are re-architecting vehicles as ‘rolling operating systems’, transforming one-off transactions into multi-year service relationships. These

increasingly bundle connectivity, on-demand performance upgrades, insurance, and even ride-sharing into application-centric user experiences. As a result, a growing share of industry profit pools is migrating towards recurring, software-enabled services, ranging from OTA feature unlocks and predictive maintenance packages to subscription-based insurance, infotainment, and vehicle-on-demand plans. The global OTA-enabled services market is projected to reach US$49 billion by 2030, up from just US$5 billion in 2022 (BMW Group, 2023). For ASEAN, where production remains largely focused on hardware-centric ICEV and HEV models, understanding how the servitised vehicle is designed, produced, and monetised is critical to staying relevant in a software-first future.

Why it matters for production

Centralised E/E architectures, high-speed networking, and secure telematics modules must be integrated into the production line. The same data backbone supports lifelong revenue streams, including subscriptions, pay-per-use features, usage-based insurance, and fleet management.

Two leading OEM playbooks illustrate how manufacturing upgrades and service strategies now move in lockstep.

Tesla: Turning a hardware sale into a software annuity

Tesla's vehicle platform is built around a highly centralised controller architecture and a proprietary OTA pipeline, allowing the company to treat software as a source of incremental gross margin. In 2024, Tesla's Services & Other segment, which includes connectivity services, paid supercharging, insurance, and full self-driving (FSD) subscriptions, grew by 27% to US$10.5 billion, offsetting softer margins in vehicle sales (Tesla, 2025). In April 2024, Tesla reduced its FSD subscription price to US$99 per month, broadening its addressable customer base whilst keeping the option value of future fully autonomous capability (Reuters, 2024f). The tight coupling between factory electronics integration, such as single printed circuit boards and fewer electronic control units, and lifetime OTA revenue illustrates how manufacturing and monetisation strategies now move in lockstep.

Toyota: Arene OS and the rise of mobility-as-a-platform

Japan's leading OEM is positioning its next-generation RAV4, (launched in December 2025) as the first production vehicle to deploy Arene, an in-house operating system developed by Woven by Toyota (Thai, 2026; Gazoo Racing, 2026). Arene enables OTA deployment of assisted-driving, infotainment, and safety features, transforming each vehicle into a rolling application platform. Toyota describes Arene as the first step towards fully SDVs, with future iterations expected to layer in subscription-based insurance, energy-management, and ride-sharing functions (Reuters, 2025c). In parallel, Toyota's KINTO brand has scaled flexible leasing and on-demand mobility services across more than 40 countries, underscoring the company's strategic pivot from a pure manufacturer to a provider of lifetime-mobility solutions.

Servitisation is no longer a peripheral enhancement but a core competitive strategy that is reshaping where – and how –value is created in the automotive industry. ASEAN's automotive development strategies must therefore integrate digital service readiness into plant upgrades, supplier incentive frameworks, and human-capital development. Without such integration, the region risks being confined to low-margin manufacturing roles, rather than emerging as a high-value node in the global software-defined mobility ecosystem.

6.2. Current State and Future Outlook of the ASEAN Automotive Industry

This section provides an overview of ASEAN's automotive production landscape as of 2024, highlighting output volumes, key manufacturing hubs, and the region's evolving role within the global automotive supply chain. It sets the context for assessing the region's strengths, emerging challenges, and strategic relevance amid ongoing global industry shifts.

6.2.1. Vehicle

6.2.1.1 ASEAN production landscape: Production and export status of vehicles

In 2024, ASEAN produced about 3.82 million vehicles, representing 4.2% of global automotive output of 90.1 million units (GlobalData, 2025b). This level of production reflects ASEAN's position as a modest yet strategically significant manufacturing hub for cost-competitive vehicles, particularly ICEV and HEV models, serving both domestic and export markets. Passenger vehicle production is concentrated in Thailand, Indonesia, Malaysia, Viet Nam, and the Philippines.

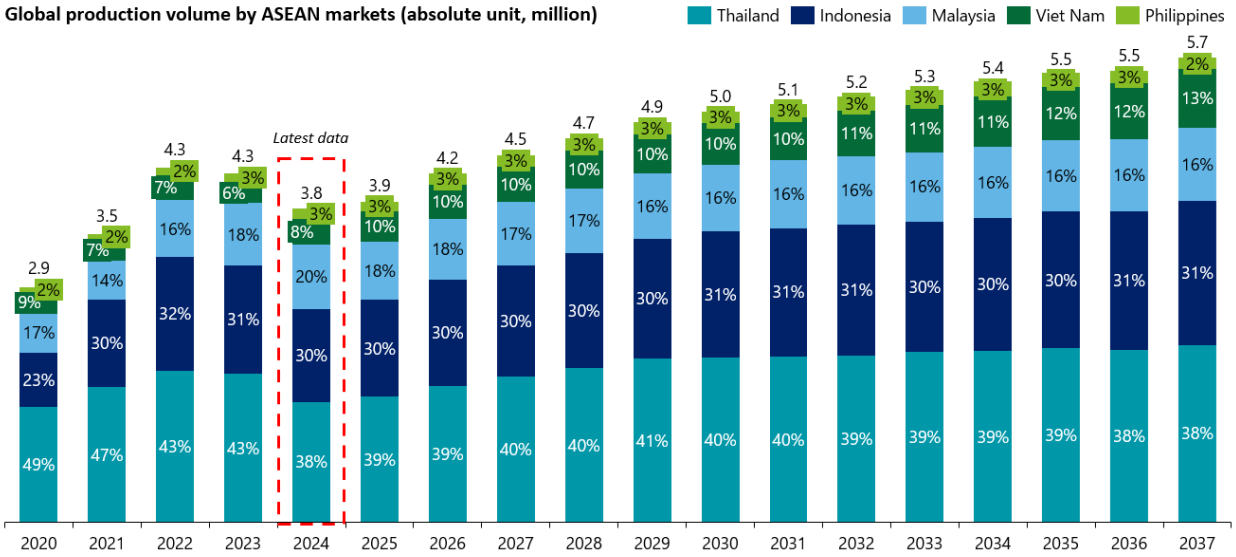
- Thailand. With an estimated 1.47 million vehicles produced in 2024, Thailand contributed 38% of total ASEAN automotive output, reaffirming its status as the region's largest and most mature manufacturing hub (GlobalData, 2025b). This position is underpinned by a well-established industrial ecosystem comprising over 1,800 local suppliers, integrated logistics infrastructure, and a stable policy environment that has consistently attracted foreign direct investment (ASEAN Briefing, 2024). Japanese OEMs, including Toyota, Honda, Isuzu, and Mitsubishi, have long anchored their regional operations in Thailand, using the country as a base for both domestic sales and exports.
- However, the sector has come under increasing pressure amid weakening global demand and sluggish domestic consumption. Vehicle production declined by 2% in 2023 and a further 20% in 2024, leaving output about 27% below its 2019 level (EIU, 2025k). At the same time, Chinese xEV manufacturers such as BYD and Great Wall have ramped up local investment, boosting output from about 1,800 units in January 2024 to 4,500 units in January 2025, positioning Thailand as a strategic xEV manufacturing hub for Chinese firms (EIU, 2025h). This expansion coincides with mounting external risks. New US trade tariffs announced in April 2025,

imposing a 37% rate on Thailand's exports, pose a significant threat to automotive exports, particularly given the US's importance as a destination for high-value vehicle components and tyres (EIU, 2025i). These headwinds may challenge Thailand's attractiveness as a China+1 export platform. Nevertheless, its extensive supplier networks, skilled workforce, and entrenched OEM presence continue to provide a degree of resilience.

- Indonesia. Indonesia produced about 1.13 million vehicles in 2024, representing about 30% of ASEAN output and ranking as the region's second-largest automotive producer (GlobalData, 2025b). Passenger vehicles accounted for roughly 85% of output, supported by a large domestic market and steady export demand. Production declined during 2023–2024 amid softer domestic sales and weaker global demand, especially from key export destinations. Output is expected to stabilise in 2025–2026 and grow over the medium term, supported by a low base effect and continued investment from Japanese, Korean, and Chinese automakers. Indonesia's relatively low ratio of trade to gross domestic product may partially cushion it from the full impact of recent US tariffs. However, reciprocal measures under the Trump administration's revised trade regime could still pose challenges for its export-oriented automotive sector (EIU, 2025j).
- Malaysia. Malaysia produced about 0.78 million vehicles in 2024, accounting for 20% of ASEAN output, with passenger vehicles comprising over 90% of total production (GlobalData, 2025b). Production is driven largely by the country's two national brands, Proton and Perodua. As one of only five Asian economies with proprietary brands, Malaysia has cultivated a robust domestic ecosystem, supported by about 20 vehicle assembly plants, over 600 parts manufacturers, and strong aftermarket networks. Strategic partnerships and investments, most notably Proton's revival under Geely and Perodua's ongoing capacity expansion, have revitalised output, which recovered by 28% during 2022–2023 and surpassed pre-COVID-19 pandemic levels. Foreign OEMs, including Hyundai and several Chinese manufacturers such as BYD, Chery, and Great Wall, are also deepening their presence, leveraging Malaysia's supplier base to serve domestic and export markets (EIU, 2024b).
- Viet Nam. Viet Nam produced about 0.31 million vehicles in 2024, equivalent to 8% of ASEAN output (GlobalData, 2025b). Passenger vehicle production has continued to expand gradually, despite a temporary contraction in 2023 driven by weaker domestic demand. The industry is led by VinFast, Viet Nam's first indigenous volume automaker and an aspiring global BEV exporter, alongside joint ventures with global OEMs such as Toyota, Honda, Ford, and Mercedes-Benz. Most production remains in the form of completely knocked-down (CKD) assembly, primarily serving the domestic market. Recent policy measures, including reduced import tariffs on components and streamlined vehicle-type approval procedures, have supported local manufacturing activity (EIU, 2024c).

- **Philippines**. The Philippines produced about 0.13 million vehicles in 2024, accounting for 3% of ASEAN output, with manufacturing largely centred on assembly for domestic consumption (GlobalData, 2025b). Japanese OEMs, notably Toyota and Mitsubishi, dominate production and benefit from the government's Comprehensive Automotive Resurgence Strategy programme. The scheme provides fiscal incentives of up to PHP9 billion (about US$153 million) for models meeting production volume and local content requirements. Toyota's Vios and Mitsubishi's Mirage are the principal beneficiaries, assembled at facilities in Santa Rosa, Laguna (EIU, 2024d).

Figure 6.4. Global Automotive Production Volume by ASEAN Markets (million units)



ASEAN = Association of Southeast Asian Nations.
Source: GlobalData (2025).

ASEAN's position as a competitive automotive export hub is reinforced by its performance in the passenger vehicle trade. In 2023, the region exported US$19 billion worth of passenger vehicles, up from US$17.7 billion in 2022, demonstrating resilience amid global uncertainty and deeper into global supply chains (International Trade Centre [ITC], 2024).

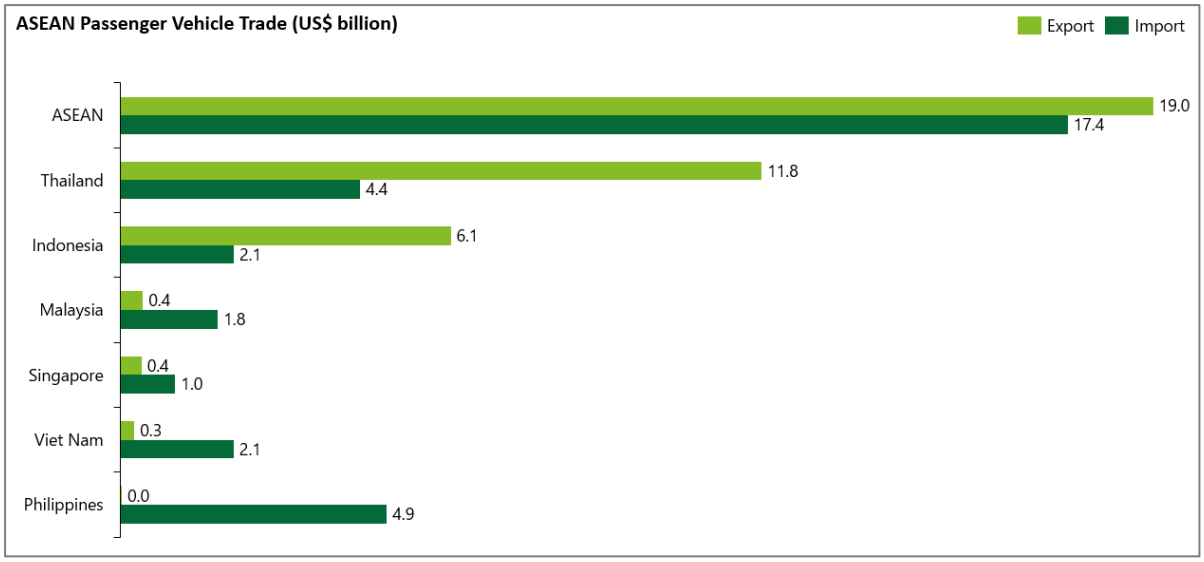
Thailand remains the dominant exporter, accounting for US$11.8 billion, or 62%, of ASEAN passenger vehicle exports. Export volumes grew by 6% year on year, supported by sustained demand for multipurpose vehicles and pick-up trucks in non-ASEAN markets such as the Middle East, Australia, and Latin America (ITC, 2024). This performance reflects Thailand's advanced supplier network, supportive policy environment, and long-standing relationships with Japanese OEMs.

Indonesia ranks second, exporting US$6.1 billion in passenger vehicles in 2023, a 9.4% increase from 2022. Unlike Thailand's emphasis on light commercial vehicles, Indonesia has specialised in passenger vehicle assembly, with exports directed largely towards

ASEAN markets, the Philippines in particular, and selected destinations in Latin America, including Mexico (ITC, 2024).

Other ASEAN members, including Malaysia, Viet Nam, Singapore, and the Philippines, play comparatively limited roles, collectively accounting for just over 7% of total exports. Malaysia's exports fell by nearly 17% year on year, whilst Singapore and Viet Nam recorded modest increases. Cambodia's exports rose sharply from US$3.3 million to US$8.9 million, albeit from a low base, indicating emerging CKD assembly or re-export activity (ITC, 2024).

Figure 6.5. ASEAN Passenger Vehicle Trade (US$ billion)



ASEAN = Association of Southeast Asian Nations.
Source: International Trade Centre (2024).

In contrast, ASEAN imported US$17.4 billion worth of vehicles in 2023, narrowing the region's trade surplus to US$1.6 billion, down from US$4.4 billion in 2022. This shift reflects rising import demand in markets such as the Philippines and Thailand, driven in part by a rising influx of xEVs from China and high-end vehicles from Japan and Korea. The Philippines alone imported nearly US$4.9 billion worth of passenger vehicles, a 37% year-on-year increase, making it the region's largest net vehicle importer (ITC, 2024).

Overall, ASEAN's automotive trade remains highly concentrated. Thailand and Indonesia together account for over 94% of total passenger vehicle exports, whilst five ASEAN economies – the Philippines, Thailand, Indonesia, Malaysia, and Viet Nam – each imported more than US$1 billion worth of vehicles in 2023 (ITC, 2024). These patterns underscore ASEAN's dual role as both a production-export platform and an increasingly important consumption market. However, the region's net export position is becoming more exposed to external headwinds, including intensifying trade protectionism and growing competition from Chinese xEV producers. Sustaining competitiveness will require continued cost discipline alongside a strategic pivot towards localised electrification and

deeper intra-ASEAN trade integration.

6.2.1.2. Decarbonisation: ASEAN powertrain transition

Despite growing global momentum towards EVs, ASEAN's automotive production in 2024 remains firmly rooted in ICEV and HEV technologies. ICEVs continue to dominate the region's output, reflecting entrenched consumer preferences, affordability constraints, infrastructure limitations, and the realities of export market demand.

Powertrain composition varies across ASEAN markets. Thailand's production remains weighted towards ICEV and HEV models, supported by an advanced supplier base and strong export orientation. At the same time, Thailand is emerging as ASEAN's leading xEV production hub, buoyed by government incentives introduced through the EV 3.0 policy and new investments from Chinese and Japanese OEMs, including BYD, Great Wall, and Toyota. Although full-year xEV volumes remain modest, the growth trajectory is clearly upward (EIU, 2024a).

By contrast, Indonesia, Malaysia, and Viet Nam continue to produce overwhelmingly ICEVs and HEVs, with electrification still at an early stage. Indonesia has yet to start volume BEV production, despite a government target of 600,000 BEVs by 2030, and output in 2024 remains almost entirely ICE passenger vehicles (EIU, 2025j). In Malaysia, national manufacturers Proton and Perodua launched their first EV models only in late 2025 (Channel News Asia, 2026a; New Strait Times, 2025), marking the early stages of domestic EV development, leaving 2024 production dominated by conventional powertrains (EIU, 2024b). In Viet Nam, EVs accounted for just 1.3% of new vehicle registrations in 2023, and domestic production continues to rely mainly on CKD assembly of ICEV models, with VinFast's BEV volumes still modest (EIU, 2024c). The Philippines similarly remains firmly ICEV oriented, with limited xEV momentum due to market size constraints, infrastructure gaps, and the absence of dedicated policy incentives.

Taken together, ASEAN's 2024 powertrain mix reflects a region undergoing a gradual and uneven transition. Whilst foundational steps towards electrification are evident, most notably in Thailand, and, to a lesser extent, in Indonesia and Malaysia, the prevailing production strategy remains centred on conventional technologies. This orientation is reinforced by export markets in the Middle East, South America, and Oceania, where consumer preferences and infrastructure conditions continue to favour ICEVs and HEVs.

As ASEAN faces growing external pressures, including tightening emission regulations, shifting trade patterns, and intensifying competition from xEV producers, its current production profile reflects a pragmatic dual-track strategy. By continuing to leverage its established ICEV and HEV ecosystem whilst cautiously scaling investment in BEV capabilities, the region aims to preserve industrial relevance in the near term whilst positioning itself for the powertrains transition ahead.

6.2.1.3. Digitalisation

Connected vehicles and ADAS are beginning to gain traction across ASEAN automotive markets. However, autonomous driving technologies remain at an early stage of development, reflecting evolving consumer demand, as well as the technological, infrastructural, and regulatory challenges that ASEAN continues to face compared to more mature markets.

6.2.1.3.1. Connected vehicles

Connected vehicle technologies are gradually entering ASEAN markets, offering early improvements in safety, driver convenience, and data-driven vehicle operations. According to the Deloitte Global Automotive Consumer Study (2024), consumers in emerging markets such as Southeast Asia are more willing to pay for connected vehicle services, viewing them as value-enhancing features. Compared with consumers in mature markets such as the US, Japan, and Germany, where connectivity is often considered a standard or nice-to-have feature, ASEAN consumers place relatively higher importance on advanced features, connectivity, and personalisation. In these mature markets, vehicle purchase decisions remain more strongly driven by price considerations.

Embedding SDV capabilities is therefore particularly important in ASEAN, where consumers actively seek connected services and are prepared to pay for them. These services, including real-time navigation, remote diagnostics, in-car personalisation, and OTA feature updates, are fundamentally powered by SDV architectures, which support continuous software upgrades and seamless connectivity. By integrating these capabilities, OEMs can better meet local expectations for advanced functionality and customisation, which are increasingly viewed as key differentiators in this price-sensitive yet technologically receptive region.

The growing uptake of connected vehicles is already evident in several ASEAN Member States. In Indonesia, mobile network operator Telkomsel has expanded its automotive footprint through agreements covering IoT and in-car wi-fi connectivity, as well as the development of a digital ecosystem for xEVs (Thanner, 2024). Telkomsel's enterprise unit is partnering with Toyota-Astra Motor to integrate IoT and in-car wi-fi services into Toyota's T Intouch telematics application for new-generation Fortuner SUVs. The platform allows users to track vehicle location, remotely switch off the engine, monitor key components, and apply time-fencing functions that restrict vehicle usage during predefined periods.

In Malaysia, ACO Tech, a domestic smart mobility company, supports over 300,000 connected vehicles nationwide (ACO Tech, 2025). Local manufacturer Proton has partnered with ACO Tech to launch models equipped with connected vehicle functionalities, offering integrated in-vehicle entertainment and information services. These models have achieved broad market adoption, demonstrating early consumer acceptance and highlighting the significant growth potential for connected vehicle technologies across ASEAN (Aco Tech, 2024).

6.2.1.3.2. Advanced driver-assistance systems

ADAS are gradually emerging across ASEAN, with a growing number of automakers equipping selected models with features such as lane-keeping assist, adaptive cruise control, and automated emergency braking. However, adoption remains uneven and largely confined to specific vehicle segments and markets, indicating an early stage of deployment rather than broad-based standardisation.

In Thailand, consumer interest in ADAS-equipped vehicles is growing. According to Cheng (2024), 74% of surveyed respondents expressed a willingness to purchase an ADAS-equipped vehicle, whilst 85% believe that automated driving technologies can improve road safety and reduce speeding-related accidents. Responding to this demand, Mitsubishi Motors launched the Xforce HEV model with Mitsubishi Motors Safety Sensing. The system integrates six preventive safety functions, including adaptive cruise control, forward collision mitigation, blind-spot warning with lane change assist, rear cross-traffic alert, automatic high beam, and lead car departure notification, delivering a relatively high level of active safety performance for the segment (Mitsubishi Motors, 2025).

Other automakers are also expanding ADAS availability in the region. KIA equips the EV5 with Forward Collision-Avoidance Assist, which monitors the vehicle's surroundings; alerts drivers to potential collisions with vehicles, pedestrians, or cyclists; and provides automated braking and steering support when needed (KIA, 2025). Chinese automaker NETA offers the NETA V-II with eight ADAS functions, including integrated cruise assist and an emergency lane-keeping system, providing a broader set of assistance features than many comparable models available in ASEAN markets (NETA Auto, 2024).

In Malaysia, ADAS adoption is progressing along a similar trajectory. Toyota has introduced T-Mate, a safety suite that combines Toyota Safety Sense with active driving and parking assistance functions, enhancing both driver convenience and road safety (Lye, 2021). The Chery Omoda 5 represents another example, offering a comprehensive set of ADAS features tailored to Malaysian consumers (Lien, 2024).

In Viet Nam, VinFast is expanding the deployment of ADAS. Several models, including the V7, V8, and V9, are equipped with Level 2 ADAS and smart services, incorporating functions such as highway driving assistance, automatic lane changing, and smart parking assistance. These systems are supported by continuous OTA updates, enabling incremental improvements in safety performance and system functionality over time (VinGroup, 2023; Vietnam News, 2024).

6.2.1.3.3. Autonomous driving

Fully autonomous driving remains largely underdeveloped across ASEAN. Fully autonomous vehicles are not yet commonly seen on public roads, although technological progress is ongoing and autonomous driving is expected to play a more prominent role in the region's transport landscape as capabilities mature and regulatory frameworks evolve (ASEAN, 2023).

The growth of the autonomous vehicle (AV) sector faces multiple challenges, including limitations in civil and digital infrastructure, road safety conditions, and cybersecurity readiness (Evans et al., 2025). Successful integration of AVs requires regulatory readiness to support innovation, testing, deployment, and eventual commercial adoption. Whilst countries such as China, Japan, and Korea have enacted AV-specific legislation, ASEAN presents a more uneven picture. Singapore and Hong Kong have begun introducing AV-friendly regulatory frameworks, whereas Indonesia and Thailand continue to rely on existing traffic and vehicle laws, with dedicated AV legislation still absent.

Public acceptance represents an additional barrier. In Indonesia, for example, Youwei (2025) found that most survey respondents expressed scepticism towards autonomous driving due to safety concerns and the complexity of traffic conditions in cities such as Jakarta. Governments face broader socio-economic considerations, including the potential displacement of driving-related jobs, particularly in logistics-heavy economies such as Indonesia and the Philippines.

In Viet Nam, autonomous driving is further constrained by infrastructural and behavioural hurdles. Major urban centres such as Hanoi and Ho Chi Minh City experience high traffic density, frequent congestion, and uneven road quality, all of which complicate AV deployment. Autonomous systems rely on clearly marked lanes, standardised traffic signage, and stable digital connectivity, conditions that are not yet consistently available across many urban and peri-urban areas. Highly adaptive and informal driving behaviours present challenges for AI-based systems to operate safely and predictably. Overall, whilst ASEAN economies are beginning to explore AV technologies, a combination of regulatory gaps, infrastructure limitations, and behavioural factors means that fully autonomous driving remains largely aspirational in the near term.

6.2.1.4. Strengths of the ASEAN automotive industry

This section outlines the structural advantages that have shaped ASEAN's role in the global automotive value chain. These strengths, built over several decades, form the foundation from which the region can navigate future shifts in technology, trade, and market demand, even as the global automotive industry undergoes rapid transformation.

The ASEAN automotive industry has developed into a resilient and competitive segment of the global market, leveraging long-standing capabilities to carve out distinct advantages in the production and export of ICEVs. Whilst global automotive trends are increasingly shaped by electrification and new manufacturing paradigms, ASEAN's existing strengths continue to offer stability and strategic relevance. These advantages can be grouped into three core areas: a robust and extensive ICEV supply chain, the development of vehicle models tailored to regional consumer preferences and infrastructure conditions, and a proven track record of exporting ICEVs to over 120 countries with similar market characteristics (ITC, 2024).

A robust and extensive ICEV supply chain

ASEAN's automotive industry benefits from a deeply entrenched ICEV supply chain, with its centre of gravity in Thailand, often referred to as the 'Detroit of Asia'. In 2024, Thailand produced about 1.47 million light vehicles, accounting for 38% of ASEAN's total output (GlobalData, 2025b). This production base is supported by a multi-tier supplier network comprising about 720 tier-1 suppliers and more than 1,100 tier-2 and tier-3 suppliers as of 2023. This ecosystem integrates about 23 automotive assemblers with a vast array of component manufacturers, enabling cost-competitive, large-scale production (Department of International Trade Promotion [Thailand], 2023).

The economic significance of this supply chain is substantial. By the late 2010s, ICE powertrain suppliers alone generated an estimated US$240 billion in regional revenue, employing millions of workers and making a significant contribution to national economies across ASEAN. The resilience of this industrial base has been proven through its ability to weather global disruptions, including the 2008 financial crisis, during which ASEAN maintained production and export momentum whilst other regions experienced sharper contractions (McKinsey, 2022b).

The depth and breadth of ASEAN's ICEV supply chain continue to provide a competitive edge in markets where ICEVs and HEVs remain dominant. At the same time, this established infrastructure is beginning to support a gradual transition towards electrification. A notable example is Isuzu, which plans to commence production of electric D-MAX pick-up trucks in Thailand for export starting in 2025, supported by a broader JPY1 trillion research and development investment programme through to 2030 (Reuters, 2024c). Whilst such initiatives signal a gradual pivot towards xEVs, the ICEV supply chain remains the backbone of ASEAN's automotive industrial base, providing the flexibility to meet current market demand whilst progressively adapting to future powertrain transitions.

Unique vehicle models tailored to regional needs

ASEAN's automotive industry has built a formidable competitive advantage by developing and refining vehicle models tailored to the region's diverse consumer preferences, infrastructure constraints, and climatic conditions. This emphasis on regional adaptation has become a central pillar of the industry's resilience and long-term competitiveness. The evolution of Toyota's product strategy provides a clear illustration, beginning with the Innovative International Multi-Purpose Vehicle (IMV) project. Launched in 2002, the IMV platform created a family of vehicles, including the Hilux pick-up truck, Fortuner SUV, and Innova MPV, built on a common platform and produced across key ASEAN countries such as Thailand and Indonesia. Guided by the principle of *genchi-genbutsu,* or first-hand understanding of local conditions, the IMV programme helped establish ASEAN as a global manufacturing and export hub for multipurpose vehicles and components (Toyota Global, 2002a; Toyota Global, 2012a; Malaya, 2023a). By 2012, cumulative global sales of IMV-series vehicles had reached 5 million units, with Thailand alone accounting for over

2.7 million domestic sales and about 4 million exports, underscoring the platform's enduring relevance (Malaya, 2023a).

Many of ASEAN's most successful vehicle models, including the Toyota Kijang (later Innova) and Mitsubishi Motors Xpander, directly reflect the region's challenging road conditions and the prevalence of large, multi-generational households. The Kijang originated in Indonesia in the 1970s as a basic, affordable pick-up truck designed for uneven and heavily congested roads. Over time, it evolved into a robust MPV, retaining high seating capacity, generous ground clearance, and durable suspension, attributes that continue to resonate in markets with challenging infrastructure (Reuters, 2014a). Contemporary successors such as the Innova and Mitsubishi Xpander Cross continue this formula through reinforced chassis designs, elevated ride height, and rugged components that enhance reliability and versatility (Mitsubishi Motors, 2017a).

Rapid urbanisation across Southeast Asia has further shaped demand for vehicles that balance compact dimensions with interior spaciousness. Models such as the Honda Mobilio and Toyota Avanza were developed with direct local input to address these requirements. The Mobilio, for example, was designed 'exclusively for Asian markets' with an overall length of under 4.4 metres to navigate narrow urban streets, whilst still offering three rows of seating suitable for extended families (Honda Global, 2013a). The Avanza, co-developed by Toyota and Daihatsu in Indonesia, features a tall, narrow body and tight turning radius, making it well-suited to congested urban environments (Toyota Global, 2023a).

Affordability and efficiency remain core design priorities in ASEAN markets. Regional policy initiatives, such as Thailand's Eco Car programme and Indonesia's Low Cost Green Car scheme, incentivise the production of fuel-efficient, low-emission vehicles. These policies have given rise to models such as the Toyota Agya/Daihatsu Ayla and Honda Brio Satya, which combine small-displacement engines with lightweight designs to meet strict taxation and fuel-efficiency criteria, thereby lowering barriers to vehicle ownership (BCG, 2023a; Honda Global, 2013a).

Southeast Asia's tropical climate strongly influences vehicle engineering. Manufacturers routinely 'tropicalise' models by incorporating more powerful air-conditioning systems, enhanced cooling capacity, and improved water sealing to withstand heat, humidity, and frequent flooding (EveryCarReview, 2025a). MPVs such as the Wuling Confero include dual rear air-conditioning blowers and mould-resistant interior materials to ensure comfort and durability in hot and humid conditions (Wuling Indonesia, 2025a). Rust-resistant coatings and climate-specific testing have become standard practice to maintain performance and resale value across the region (EveryCarReview, 2025a).

The success of ASEAN-specific vehicle models is underpinned by deep localisation, extending beyond product design to manufacturing and supply-chain integration. Major OEMs, particularly Japanese manufacturers, have established regional research and development centres and production hubs in Thailand, Indonesia, and Malaysia, enabling rapid feedback from local markets and the timely introduction of region-specific variants

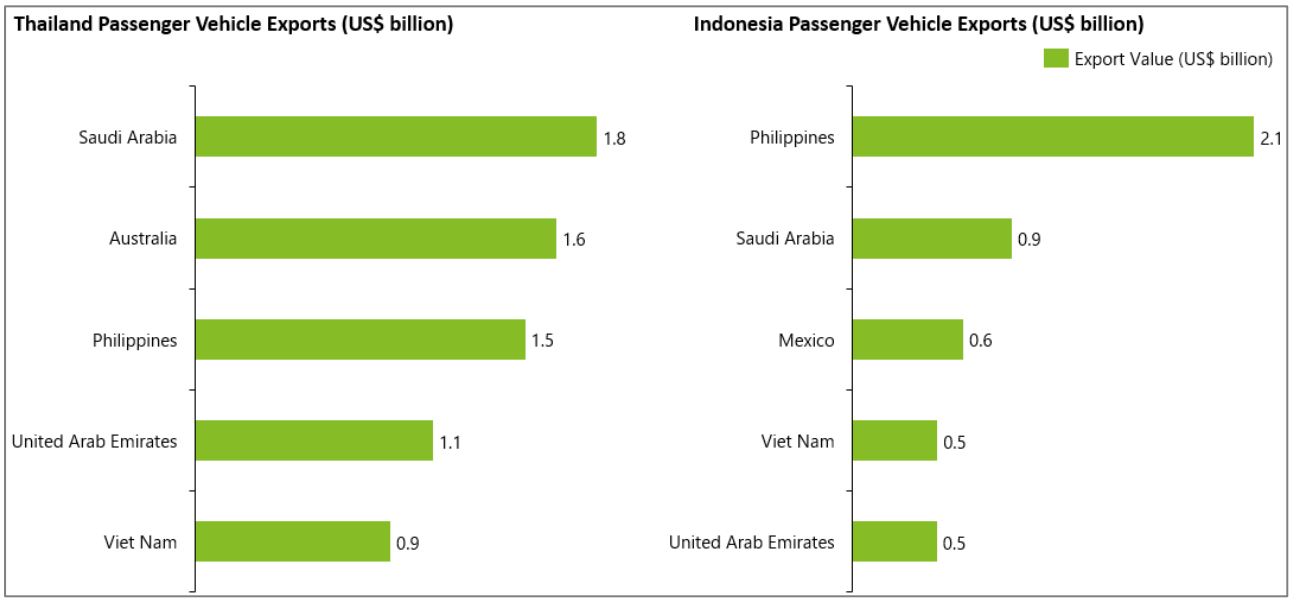
(Toyota Global, 2012a; Mitsubishi Motors, 2017a). More recent entrants, including Chinese manufacturers such as Wuling, have similarly localised both product features and branding strategies to better align with ASEAN consumer preferences (Wuling Indonesia, 2025a).

By prioritising ruggedness, versatility, efficiency, and climate adaptation, whilst leveraging local knowledge, policy incentives, and supplier ecosystems, ASEAN's automotive industry has developed a portfolio of vehicle models that are both regionally relevant and globally competitive. This sustained commitment to localisation remains a defining strength as the industry adapts to evolving consumer expectations and technological change.

A strong history of ICEV exports

ASEAN has solidified its position as a major global exporter of ICEVs, leveraging manufacturing expertise and cost advantages to serve over 120 destination markets. In 2023, the region exported passenger vehicles valued at US$19.0 billion (or US$12.0 billion excluding intra-ASEAN trade). Thailand led with exports worth US$11.8 billion, accounting for 62% of the total, followed by Indonesia at US$6.1 billion (ITC, 2024). ASEAN's principal export destinations underscore a strong product–market fit with emerging economies across the Middle East, Oceania, and Latin America, where demand remains robust for durable and affordable ICEVs tailored to local operating conditions.

Figure 6.6. Thailand and Indonesia Passenger Vehicle Exports in 2023 (US$ billion)



Source: Observatory of Economic Complexity (2025a, 2025b).

Thailand's passenger vehicle exports in 2023 were concentrated in Saudi Arabia (US$1.79 billion), Australia (US$1.61 billion), the Philippines (US$1.47 billion), the United Arab Emirates (US$1.06 billion), and Viet Nam (US$0.87 million) (OEC, 2025a). Indonesia's export profile showed a similar concentration in developing markets, with leading

destinations including the Philippines (US$2.14 billion), Saudi Arabia (US$0.85 billion), Mexico (US$0.59 billion), Viet Nam (US$0.452 billion), and the United Arab Emirates (US$0.45 billion) (OEC, 2025b).

This broad export reach is underpinned by strong demand alignment. In the Middle East, consumers favour workhorse pick-up trucks and seven-seat SUVs capable of operating in high temperatures, uneven terrain, and heavy-load conditions. Thailand's leading exports, such as models based on Toyota's IMV platform, including the Hilux and Fortuner, closely match these requirements. Indonesian exports, including models such as the Toyota Avanza and Rush, similarly provide affordable, family-oriented mobility with comparable durability standards (MarkLines, 2019; Board of Investment [Thailand] [BOI], 2023). These characteristics mirror ASEAN's domestic needs, allowing OEMs to scale production efficiently with limited additional localisation.

In Latin America, ASEAN-manufactured vehicles are gaining traction in cost-sensitive markets. Thailand exported about 6.7% of its passenger vehicles to Central and South America in 2023, whilst Indonesia recorded strong growth in shipments to Mexico (BOI, 2023; OEC, 2025a). Models such as the Mitsubishi Triton and Honda BR-V compete effectively against higher-priced alternatives from developed markets. ASEAN exporters also benefit from regulatory compatibility, including acceptance of right-hand-drive vehicles and relatively moderate emission standards, as well as tariff reductions under trade agreements such as the Thailand–Chile Free Trade Agreement, which eliminated vehicle import duties in 2015 (US Department of Agriculture [USDA], Foreign Agricultural Service, 2015).

Oceania represents another key anchor market, particularly following Australia's exit from domestic automotive manufacturing in 2017. In 2023, Thailand remained Australia's largest vehicle supplier, driven by strong demand for 1-tonne pick-up trucks such as the Hilux, Ranger, and Triton, which continue to dominate sales rankings (Just Auto, 2023). This position is reinforced by the Thailand–Australia Free Trade Agreement, under which vehicle tariffs were fully removed by 2010. Vehicles designed for ASEAN's terrain and climate align well with operating conditions across Oceania, supporting sustained export demand.

Across these markets, ASEAN's export resilience is rooted in structural similarities in demand. Manufacturers have optimised production for pick-up trucks, body-on-frame SUVs, and MPVs that perform reliably in infrastructure-challenged environments, responding to domestic and overseas needs. Thailand's mature supplier ecosystem, combined with preferential trade access, further strengthens competitiveness by enabling ASEAN-made vehicles to remain price competitive whilst meeting functional and durability standards (BOI, 2023). In summary, ASEAN's extensive ICEV supply chain, region-specific vehicle development, and broad export footprint underpin its strengths and provide a platform to face future challenges, ensuring that the region remains a vital contributor to the global automotive landscape amid ongoing transformation.

6.2.2. Supply Chain

6.2.2.1. Upstream

6.2.2.1.1. Supplying rare metals to the global market

ASEAN plays a significant role in the global supply of rare metals, particularly nickel, which is essential to produce electrified vehicles. This upstream position presents both opportunities and challenges as global demand for critical materials rises alongside the transition towards electric mobility.

The development of the minerals sector is central to ASEAN's socio-economic progress. Mining, minerals, and metals form the material base of any modern economy: virtually all manufactured, processed, or constructed products that are not plant or animal based ultimately depend on mineral inputs sourced from within or outside the region. ASEAN is amongst the world's largest suppliers of mineral raw materials, with several member countries ranking as leading global producers of major minerals and metals. In 2018, trade in minerals amounted to about US$250 billion, representing close to 9% of ASEAN's total trade, of which 21% was intra-ASEAN trade (ASEAN, 2025).

According to an Economic Research Institute for ASEAN and East Asia (ERIA) study, ASEAN countries, including Indonesia, the Philippines, Viet Nam, and Malaysia, are crucial to global supplies of strategic minerals (Phoumin, 2024). These economies possess substantial reserves, production capacity, and, in some cases, downstream processing capabilities that support global industrial activity. Indonesia, the world's largest nickel producer, holds about 25% of global nickel reserves. In 2020, it produced about 760,000 metric tonnes of nickel and has since prioritised downstream development, including refining and xEV battery production. The Philippines, the world's second-largest nickel producer, supplied about 280,000 metric tonnes in 2021, alongside significant volumes of copper, gold, and other minerals essential to electronics and renewable energy technologies. Viet Nam holds sizeable reserves of tungsten and REEs, although large-scale production and refining remain at an early stage. Malaysia plays a key role in rare earth processing, whilst Thailand, although a smaller player in critical minerals, possesses notable tin reserves and an expanding electronics manufacturing base.

Collectively, ASEAN countries account for nearly 47% of global nickel output and 35% of global tin production, alongside significant shares of other critical minerals, including bismuth, tungsten, REEs, and bauxite (ASEAN–Intergovernmental Forum on Mining, Minerals, Metals and Sustainable Development Minerals Cooperation, 2023). The region is estimated to hold about 20% of the world's REE reserves and 6.9% of global cobalt reserves (Jakarta Post, 2025), reinforcing its strategic importance within global supply chains.

ASEAN's position as a leading supplier of critical minerals places it at the centre of the global electrification transition. At the same time, the region faces the challenge of securing sufficient mineral inputs for its own rapidly expanding automotive and battery industries. Balancing export demand with domestic industrial needs will be crucial to

sustaining ASEAN's role in the global supply chain and strengthening resilience in the face of geopolitical, environmental, and market pressures.

6.2.2.2. Midstream

The midstream automotive sector in ASEAN has made limited progress in vehicle transformation. Preparations for this shift also lag regional peers, as reflected in recent survey findings. Whilst neighbouring economies are advancing through scale, automation, and production innovation, ASEAN continues to face structural constraints stemming from limited production scale and slower adoption of new technologies.

6.2.2.2.1. Vehicle transformation not progressing

Findings from this ERIA Automotive Masterplan survey indicate that industry players across the region do not yet view vehicle transformation as a core component of midstream digitalisation, suggesting that this shift has not meaningfully taken hold. As shown in Figure 3.17, uncertainty about vehicle transformation is driven primarily by concerns over the high cost of xEVs, largely attributable to elevated battery prices and broader component costs. Further results (Figure 3.21) show that, consistent with earlier findings on planned powertrain production, most respondents, except those in Myanmar and Cambodia, have yet to determine priority product types for future manufacturing. Only about 32% of respondents consider manufacturing as a priority investment area (Figure 3.36), whilst roughly 35% cite a lack of management understanding regarding the need for investment when addressing broader supply chain challenges. Taken together, these findings suggest that innovation-led vehicle transformation within ASEAN's midstream supply chain remains at a nascent stage and has yet to gain meaningful traction.

The slow transition towards xEV supply chains is evident in ASEAN's production structure, which remains overwhelmingly focused on ICEVs and HEVs, with BEV manufacturing limited largely to Thailand. Although Thailand has emerged as the region's BEV frontrunner – supported by EV 3.0 incentives and over US$6 billion in committed investment from global automakers such as Toyota, BYD, and Great Wall Motors – full-scale BEV output remains at an early stage and below policy targets (EIU, 2024a). Several OEMs have requested deadline extensions to meet domestic production requirements. Compounding these challenges, Thailand's total vehicle output fell by 19% year on year in 2024 amid weakening demand, further straining its export-led manufacturing model (GlobalData, 2025b).

Indonesia, despite its rich nickel reserves and strong BEV investment potential, is at an early phase of electrification. Whilst the government has set a target of producing 600,000 BEVs by 2030, output remains limited. Local content requirements have been extended to support ecosystem development, and major investments have been announced by OEMs such as BYD, Hyundai, and Mitsubishi. Nevertheless, a meaningful scale-up has yet to materialise, with no clear timeline for large-scale production (EIU, 2025j). Malaysia and Viet Nam, despite growing investor interest, also remain largely ICEV-focused in 2024,

with major BEV production, such as Proton's e.MAS and VinFast's export-oriented models, expected to ramp up only after 2025 (EIU, 2024b; EIU, 2024c).

Financial barriers further complicate the transition. The ASEAN-wide survey shows that 47.7% of respondents consider advanced manufacturing technologies prohibitively expensive, with concern levels highest in Thailand and Indonesia at about 50%. Of respondents, 24% cite limited organisational flexibility to adapt to new trends by 2035, with this challenge particularly pronounced in Viet Nam (69.9%) and Thailand (47.1%). These barriers continue to hinder the adoption of critical xEV-related technologies, such as automated assembly lines, and slow ASEAN's integration into emerging global xEV value chains.

Unless ASEAN accelerates midstream supply chain readiness, through greater localisation of battery and component manufacturing, policy harmonisation, and targeted infrastructure investment, the region risks being sidelined as global xEV supply chains realign. Despite strong fundamentals in ICEV and HEV manufacturing, the window to pivot into future mobility value chains is narrowing.

6.2.2.2.2. Transformation preparation lagging

ASEAN's competitiveness is increasingly hindered by ageing manufacturing infrastructure and slow technology adoption. The ASEAN-wide survey reveals that 47.5% of respondents expect deteriorating efficiency due to ageing equipment to become a major challenge by 2035, with concern highest in Thailand at 55.4%. This reflects the region's continued reliance on legacy ICEV production systems, which lag the modernised manufacturing bases of China and Europe. Of respondents, 36.6% cite low efficiency resulting from underutilisation of digital technologies, with Indonesia and Viet Nam reporting the highest levels of concern, at over 40% each.

These structural weaknesses are compounded by emerging capability gaps. The survey highlights a looming shortage of skilled personnel in supply chain management, noted by 34.6% of respondents and peaking sharply in Viet Nam at 78.8%. More than half (54.5%) identify inadequate supply chain review processes as a constraint, with Malaysia and Viet Nam reporting concern levels of about 80%. Nearly 30% of respondents flag gaps in digital infrastructure as a future hurdle, particularly in Viet Nam, the Philippines, and Malaysia. Together, these findings underscore the urgency of workforce upskilling, process modernisation, and sustained digital investment if ASEAN is to keep pace with global manufacturing standards.

6.2.2.2.3. Neighbouring countries outpacing ASEAN

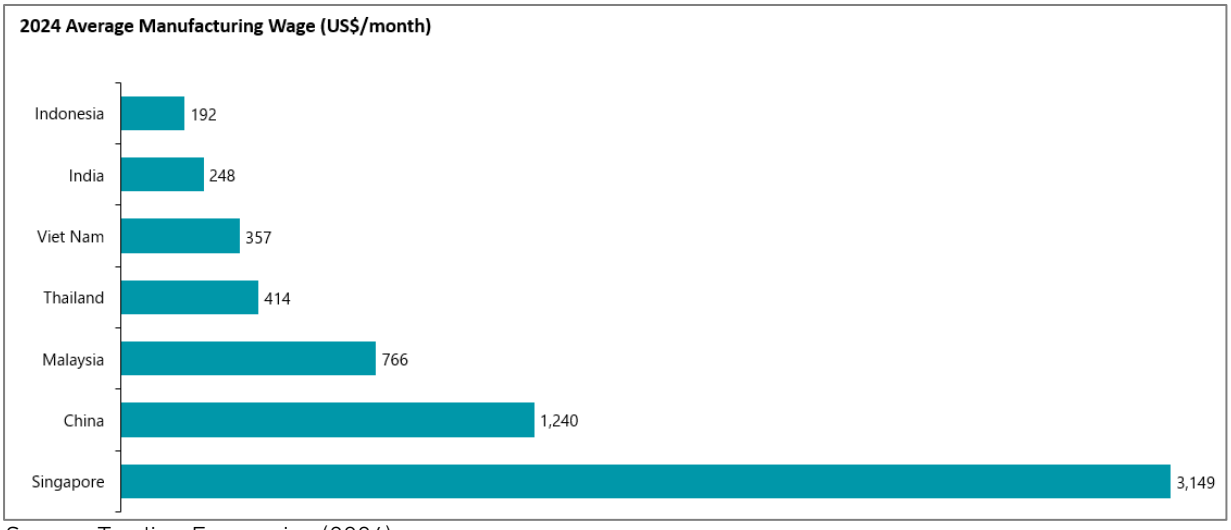
ASEAN faces intensifying competitive pressures as neighbouring economies accelerate the development of their automotive industries, eroding the region's traditional advantages and reshaping global investment flows. Two dynamics are particularly influential: declining cost competitiveness and the diversion of investment towards India

and other emerging manufacturing hubs.

Eroding cost competitiveness

ASEAN's long-standing edge in low-cost labour is eroding. In 2024, average monthly manufacturing wages range from US$192 in Indonesia (Trading Economics, 2024a) to US$766 in Malaysia (Trading Economics, 2024b), compared with US$248 in India (Trading Economics, 2024c). Whilst ASEAN remains more cost-competitive than China (US$1,240) (Trading Economics, 2024d) and high-income outliers such as Singapore (US$3,149) (Trading Economics, 2024e), the narrowing gap with India is increasingly salient as global OEMs seek alternative, cost-efficient production bases. The ASEAN-wide survey reinforces this trend, with 34.7% of respondents citing rising labour costs as a future challenge, particularly in Thailand (41.7%). In parallel, 37.9% highlight low labour productivity as a concern, peaking in Malaysia (66.9%) and Thailand (37.7%). These pressures point to a growing need for automation and digitalisation to sustain competitiveness.

Figure 6.7. Average Manufacturing Wage (US$/month)



Source: Trading Economics (2024).

Despite rising costs, ASEAN has yet to close the productivity gap. Asia accounted for 73% of global industrial robot installations in 2022, yet China, Japan, and Korea dominated deployment, leaving ASEAN behind in factory automation intensity (IFR, 2023a). Without more decisive investment in Industry 4.0 technologies, the region risks losing further ground in the evolving xEV supply chain.

Investment diversion to India and competing hubs

India is rapidly consolidating its position as a preferred destination for global automotive investment. Since 2020, India's automotive sector has attracted more than US$36 billion in foreign direct investment, including major capacity expansions by Hyundai (US$4 billion), Toyota (US$2.3 billion), and Mercedes-Benz (US$360 million) (Press Information

Bureau India, 2025). This momentum is complemented by supportive domestic policies, including production-linked incentive schemes for advanced batteries and xEV components, rapid electrification of the two-wheeler segment, and logistics reforms.

Whilst ASEAN economies such as Thailand and Indonesia continue to attract significant investment, illustrated by BYD's US$490 million plant in Thailand (Reuters, 2024d) and Hyundai's BEV facility in Indonesia (Reuters, 2024e), the scale and pace of investment flowing into India are accelerating faster. This divergence increasingly challenges ASEAN's position as a default manufacturing hub.

6.2.2.3. Downstream

In the downstream segment, resource circulation initiatives remain at an early stage across ASEAN. Efforts to introduce recycling, reuse, and sustainable materials management are only beginning to take shape, reflecting a growing, yet still nascent, awareness of circular economy principles within the automotive sector.

6.2.2.3.1. Limited resource circulation initiatives

Resource circulation in ASEAN's automotive industry is still in its infancy. Current material traceability efforts are concentrated in sectors such as food and beverage, textiles, and steel, rather than in automotive manufacturing. Regionally, ASEAN has established traceability frameworks for palm oil (Neo, 2022), aquaculture, and food and feed (ASEAN Secretariat, 2022). These frameworks aim to set baseline requirements, harmonise regulations, and support intra-ASEAN trade. However, similar formal tracking or traceability systems tailored to the automotive sector are largely absent, leaving a significant gap in material monitoring and life cycle management.

Policies to promote material circulation and end-of-life vehicle management also remain limited and uneven across member states. Not all ASEAN countries have implemented formal vehicle scrappage schemes. Singapore stands out as the regional leader, with a structured vehicle retirement system in place, whilst most other member countries remain at the pilot or early regulatory stage. Malaysia, for instance, has yet to implement a formal vehicle scrappage policy, despite policy recommendations aimed at reducing road congestion (Malaysian Reserve, 2025). In Indonesia, proposals have so far been confined to selected cities, such as Jakarta, where public opposition has reached about 49.2% (Jakarta Post, 2024). This wide variation in policy maturity highlights the difficulty of implementing resource circulation initiatives at scale across the region.

Overall, these patterns indicate that, although ASEAN has made progress in traceability and end-of-life management in other sectors, automotive resource circulation remains underdeveloped. Divergent national approaches and the absence of coordinated regional frameworks mean that large-scale, cross-border material circulation initiatives are not yet feasible.

6.2.2.4 Cross-cutting theme: Upstream to downstream

Across the automotive supply chain, from upstream to downstream, ASEAN is still at an early stage in adopting decarbonisation and digitalisation practices. Carbon emission calculation and tracking are not yet widely embedded, and methodologies are still developing. Similarly, data integration and collaboration across the supply chain are progressing gradually, reflecting ongoing efforts by governments and industry to align with evolving global standards.

6.2.2.4.1. Emission tracking and calculation are rarely conducted

Carbon emission tracking and calculation remain limited across ASEAN, with many companies lacking rigorous systems or standardised methodologies. Regulatory diversity across the region is a primary constraint: businesses face inconsistent carbon pricing mechanisms and differing verification standards, which create uncertainty and make cross-border carbon accounting and trading difficult (EU ASEAN Business Council, 2025). Differences in national energy mixes, from coal-heavy grids in Indonesia and Viet Nam to comparatively cleaner systems in the Lao People's Democratic Republic and the Philippines, further complicate efforts to harmonise carbon tracking across the region.

Reporting practices illustrate this gap. In 2023, fewer than 10% of the nearly 8,000 Carbon Disclosure Project (CDP) disclosures from Asia and the Pacific came from ASEAN companies, and those submissions often relied on grid-average emission factors or estimations rather than primary metered data (CDP, 2023). Carbon accounting aligned with the ISO remains uncommon; Viet Nam is the only ASEAN Member State with a formal guideline (TCVN 14067) for product carbon footprints (Vietnam Briefing, 2023). Overall, fewer than one in five ASEAN firms use primary data for emission calculations, far below the thresholds expected by OEMs and emerging regulatory frameworks, such as the EU's Catena-X digital product passport rules.

Most automotive players in ASEAN lack sufficient in-house capability to lead or manage decarbonisation efforts. Core functions, including carbon accounting; life-cycle assessment (LCA); and monitoring, reporting, and verification, are typically outsourced, whilst internal teams often require intensive technical support. This skills gap constrains systematic emission tracking and undermines confidence in reported data. According to the World Economic Forum (2024), only 49% of ASEAN suppliers have in-house LCA expertise, with 'lack of expertise' ranked as the single most significant barrier to decarbonisation.

6.2.2.4.2. ASEAN lagging behind global decarbonisation trends

As of the mid-2020s, ASEAN faces a widening gap in decarbonisation, efficiency, and technology relative to leading automotive markets. Export-oriented assemblers continue to rely heavily on Euro-4 ICE or mild-hybrid platforms. In Thailand, 1 tonne pick-up architecture alone accounts for about 61% of total vehicle output, whilst Malaysia's nationwide Euro-5 petrol mandate will not take effect until September 2026 (Thailand

Automotive Institute, 2024; Malay Mail, 2024; Paul Tan's Automotive News, 2025b). Efforts to decarbonise transport fuels are slowed by cost pressures and regulatory uncertainty. Indonesia's planned transition from B35 to B40 biodiesel missed its 1 January 2025 launch due to unresolved subsidy and quality issues, whilst Thailand's proposal to make E20 the default petrol grade still hinges on securing a reliable feedstock supply (Reuters, 2025d; USDA Foreign Agricultural Service, 2024).

Electrification, meanwhile, is emerging as a 'showroom without a supply chain'. Incentive schemes, such as duty waivers in Malaysia and Thailand until the end of 2025, and Thailand's EV 3.5 policy allowing two imported EVs for every unit assembled locally until 2026, have fuelled a surge in imported models from manufacturers such as Tesla and BYD (Reuters, 2024g). However, large-scale localisation remains elusive. Battery investment plans remain fragile, as illustrated by LG Energy Solution's withdrawal in April 2025 from an about US$8 billion Indonesian 'grand package', leaving only a proposed 10 GWh joint venture under consideration (Reuters, 2025e).

Taken together, these patterns – legacy ICEV and HEV engineering, volatile low-carbon fuel economics, and import-led xEV growth with minimal local integration – are slowing ASEAN's transition to a low-carbon vehicle sector. The region risks becoming trapped in a carbon-intensive middle ground: too emission-heavy to remain competitive in tightening export markets yet insufficiently integrated to capture the economic benefits of the electric transition.

Fuel quality standards further compound this challenge. Whilst a handful of markets have reached Euro 5 compliance, most ASEAN countries still rely on lower-grade fuels. This forces manufacturers and fleet operators to depend on premium imports, raising operating costs, complicating supply-chain management, and increasing exposure to volatile refining margins. In turn, these constraints dampen demand for newer vehicle technologies that require ultra-low-sulphur fuels, constraining both decarbonisation progress and global competitiveness.

As global markets accelerate towards cleaner fuels, deeper electrification, and integrated supply chains, ASEAN's slower pace on fuel standards, technology localisation, and emission reduction leaves the region increasingly exposed to falling behind international decarbonisation benchmarks.

6.2.2.4.3. Data integration not progressing

Unlike regions such as Europe and Japan, which have developed interoperable data-sharing platforms such as Catena-X and Ouranos, ASEAN has yet to establish a connected system that links automotive supply chain actors across borders. Automotive manufacturing in the region is increasingly cross-border, with production stages and components distributed across multiple countries. Despite this high level of interdependence, information exchange amongst supply chain actors remains fragmented.

Most manufacturers and suppliers still rely on siloed systems, bilateral data exchanges, and manual document transfers, limiting real-time visibility and coordination. Although some countries and firms have introduced domestic digital platforms to track manufacturing, logistics, or compliance-related information, these systems remain nationally bound and cannot be integrated regionally. In practice, visibility is relatively well developed within individual firms, but not across the broader supply-chain ecosystem, reflecting the absence of a shared or interoperable framework for real-time, cross-border data exchange.

ASEAN has taken some foundational steps to improve trade connectivity, notably through the ASEAN Single Window. However, cross-border operational and digital linkages specific to the automotive sector have yet to advance in a meaningful way. Operational practices continue to prioritise domestic markets over regional integration (Polachai, 2023), indicating that data integration across ASEAN's automotive supply chain remains limited and underdeveloped.

6.2.3. Servitisation

Servitisation in ASEAN's automotive sector is gradually emerging, led primarily by ride-sharing and mobility platforms. However, the broader shift from vehicle ownership to usage-based mobility remains at an early stage, with consumers offered far fewer alternatives than in more mature markets.

6.2.3.1. Ride-sharing development

Ride-hailing applications have been amongst the most disruptive forces in urban transport over the past decade (Chalermpong et al., 2023). The ride-hailing market in ASEAN has grown rapidly, driven by accelerating urbanisation, widespread digital connectivity, and rising demand for flexible and on-demand transport options. Southeast Asia is the birthplace of Grab and Gojek, 2 of only 11 global ride-hailing unicorns,[7] alongside dozens of local ride-hailing application operators now active across major cities in the region.

Consumers in ASEAN have shown a strong preference for ride-hailing services due to their convenience, affordability, and perceived reliability relative to traditional taxi services (Statista, 2025b). High smartphone penetration and improving internet connectivity have further reinforced this trend by lowering access barriers and improving service consistency. Studies indicate that users increasingly favour application-based transport for its safety, reliability, and transparent pricing (Wardhana and Pradana, 2023).

Although international operators initially dominated the market, locally embedded platforms have gained momentum by tailoring services to domestic preferences and regulatory environments. Competition has intensified innovation and adoption. In Indonesia during the mid-2010s, for example, Uber and local platforms such as GrabCar

[7] Privately held startups valued at over US$1 billion.

and GoCar engaged in aggressive promotional campaigns to attract users, a process that ultimately entrenched GrabCar and GoCar as market leaders (Wardhana and Pradana, 2023).

Ride-hailing application providers have also diversified their business models. Beyond car-hailing, many platforms now offer motorbike taxis, parcel delivery, and flexible subscription services, allowing them to capture additional demand and revenue streams. These shared mobility models also deliver environmental benefits. By increasing vehicle utilisation, ride-hailing, car-sharing, and subscription services allow a single vehicle to serve more passenger-kilometres, thereby reducing embodied carbon dioxide emissions per kilometre. Grab, for example, operates the region's largest xEV ride-hailing fleet and reported a 4.7% reduction in emissions in 2024 (Grab, 2024). In Singapore, GetGo operates over 3,000 shared vehicles across 1,600 locations (GetGo, 2025). Flexible subscription schemes further extend servitisation to private users: Toyota's KINTO programme in Thailand allows customers to switch vehicles or exit contracts with only a month's notice, encouraging faster uptake of newer and lower-carbon powertrains (Toyota Motor Thailand, 2024a; Toyota Motor Thailand, 2024b).

6.2.3.2. Limited customer options to shift from ownership to usage model

Despite the rapid expansion of ride-hailing and shared mobility services across ASEAN, personal vehicle ownership remains the dominant mode of transport, supported by rising incomes, urban sprawl, and entrenched cultural preferences. Ride-hailing operators such as Grab and Gojek have secured strong market positions within their home countries, yet cross-border integration of services across ASEAN remains limited. As a result, mobility-as-a-service (MaaS) solutions lack the scale and interoperability required to serve as a realistic substitute for personal car ownership. In practice, a commuter in cities such as Jakarta or Manila may use ride-hailing services occasionally, but these fragmented offerings cannot fully replace the convenience and flexibility of owning a vehicle.

Cultural norms and trust in privately owned vehicles further constrain the adoption of usage-based mobility. For many households, vehicle ownership continues to function as both a status symbol and a hedge against perceived shortcomings in public transport reliability and coverage. In the absence of strong policy interventions or disruptive industry-led initiatives, this mindset is likely to evolve only gradually, reinforcing private vehicle ownership as the default aspiration.

Tentative forays into servitisation, such as leasing or subscription schemes offered by a few small manufacturers, remain niche pilots rather than core business models. Consequently, servitisation models, including car-sharing and subscription services, attract only a limited user base, often concentrated in dense urban centres and amongst younger, digitally engaged consumers.

Most ASEAN automotive players continue to prioritise traditional, sales-driven business models. Revenue generation remains centred on one-off vehicle sales and basic after-

sales services, with relatively limited investment in integrated mobility solutions. Attempts by some European companies to introduce MaaS platforms in the region have met with modest uptake, reflecting adoption levels that remain well below those observed in more mature markets (Momentum Asia, 2020).

Structural constraints further impede MaaS development. Key barriers include limited public transport infrastructure; the absence of comprehensive legal frameworks covering licensing, safety, and insurance; and insufficient technological capabilities to support real-time, integrated information systems (Jaouadi, 2024). Together, these factors restrict the availability of reliable, end-to-end mobility options and reinforce the continued dominance of private vehicle ownership.

Whilst the long-term potential for MaaS in ASEAN is substantial, fragmented services, infrastructure gaps, regulatory uncertainty, persistent cultural preferences, and the pilot-scale nature of servitisation initiatives mean that customer options to shift from ownership to usage-based mobility remain limited.

6.3. Conclusion

The global automotive industry stands at a pivotal moment, reshaped by technological disruption, shifting trade paradigms, and an intensifying focus on sustainability. The industry landscape will be defined by decarbonised value chains, resilient supply networks, and the rise of servitisation as a new revenue stream, favouring players that can align cost efficiency with environmental responsibility.

For ASEAN, this transition presents both strategic risk and an opportunity. The analysis shows that ASEAN must take decisive action to update its supply chain, not only to participate but to continue playing an important role in the global automotive industry. Anchoring competitiveness in production scale and sales volume will remain essential, whilst selective automation in high-impact areas such as precision welding and component assembly can elevate efficiency without displacing the region's labour advantage. Beyond scale, sustainability is no longer optional. Next-generation ICEV and HEV models must transcend conventional designs by integrating decarbonisation-ready features, such as biofuel compatibility (e.g. E20) or synthetic e-fuels.

Vehicle digitalisation is redefining mobility itself. SDVs enable continuous upgrades, data-driven services, and new business models that extend far beyond manufacturing. This digital shift complements decarbonisation and servitisation, reinforcing the need for ASEAN to adapt quickly to remain relevant.

Taken together, these trends highlight both the urgency and the pathway for ASEAN's transformation. Building on the insights from Chapter 6, Chapter 8 sets out the envisioned state of ASEAN's automotive industry and identifies the policy measures needed to bridge the gap between the current trajectory and a more competitive, sustainable, and future-ready automotive ecosystem.

Chapter 7

Cradle-to-Cradle Aspects of Automotive Industry in ASEAN

7.1. Introduction

As the Association of Southeast Asian Nations (ASEAN) accelerates its shift towards sustainable and inclusive mobility, the automotive industry stands at the centre of a complex yet promising transition. Unlike previous development phases that prioritised industrial capacity expansion and export growth, the current wave of transformation is driven by decarbonisation, digitalisation, and circularity. These transitions require a holistic rethinking of how vehicles are designed, produced, used, and retired.

This chapter applies a cradle-to-cradle lens to analyse the environmental, economic, and social impacts of automotive transitions across ASEAN Member States (AMSs). It considers the full life cycle of vehicles and their components, including material circularity. Drawing on a multi-dimensional and integrated perspective, the chapter synthesises findings from multiple studies of the Economic Research Institute for ASEAN and East Asia (ERIA) to assess how new technologies, shifting global value chains, and evolving consumer and policy priorities are redefining the automotive sector in Southeast Asia.

The shift from conventional internal combustion engine vehicles (ICEVs) to electrified vehicles (xEVs), including hybrid electric vehicles (HEVs), plug-in hybrid vehicles (PHEVs), and battery electric vehicles (BEVs), has triggered far-reaching changes across the vehicle life cycle. These changes span upstream activities such as the extraction and processing of critical minerals, midstream developments including digital manufacturing and software-based vehicle control systems, and downstream strategies centred on circular strategies such as battery reuse and materials recycling.

To capture the full implications of these transformations, the chapter begins with an overview of the life-cycle assessment (LCA) and well-to-wheel analysis methodologies applied to different vehicle types. These tools measure greenhouse gas (GHG) emissions across vehicle production, use, and fuel or electricity supply chains, enabling comprehensive comparisons of the environmental performance of xEVs and ICEVs under varying electricity mixes and material sourcing pathways.

The chapter introduces total cost of ownership (TCO) frameworks to assess economic competitiveness from the user's perspective. These analyses are particularly relevant for policymaking and investment decisions in ASEAN markets, where affordability remains a key barrier to wider xEV adoption.

Subsequent sections examine upstream and downstream supply chains for critical minerals and battery technologies; address governance and infrastructure requirements for sustainable mining; and highlight the urgency of advancing circular value chains

through targeted policy, innovation, and investment. The role of biofuels and synthetic e-fuels, particularly in hard-to-electrify transport sectors, is explored.

The chapter then analyses the growing importance of digitalisation in the transport industry, covering not only vehicle manufacturing but also the broader mobility ecosystem. This is followed by a discussion of digital talent requirements in the automotive industry, informed by preliminary observations from several AMSs and a review of the region's emerging semiconductor ecosystem for automotive applications.

The chapter concludes with an assessment of strategies to renew the road transport vehicle fleet and an examination of automotive industry waste management and recycling systems to be further developed across the region.

7.2. Life-cycle Assessment, Externalities, and Total Cost of Ownership of Vehicles

As ASEAN transitions towards sustainable and decarbonised mobility, assessing the full environmental and economic impacts of vehicles becomes increasingly critical. Conventional assessments often focus narrowly on tailpipe emissions or upfront purchase costs. However, to support informed policymaking and investment decisions, it is essential to adopt a cradle-to-cradle perspective that considers a vehicle's entire life cycle, from raw material extraction and manufacturing to use-phase operation and end-of-life treatment.

This section brings together three interrelated assessment dimensions: LCA, externalities, and TCO. LCA captures the comprehensive GHG footprint of various powertrains: ICEVs, HEVs, PHEVs, and BEVs, by accounting for emissions across both the vehicle cycle (including materials and manufacturing) and the fuel or energy cycle (generation and consumption). These metrics provide a more accurate representation of the environmental benefits and trade-offs associated with vehicle electrification across AMSs, where electricity grid carbon intensity and automotive supply chains vary significantly (Doi et al., 2024).

In parallel, the assessment of externalities, including air pollution, noise, and upstream impacts related to mining and waste management, is essential for understanding the broader societal costs and benefits of different mobility choices (Doi et al., 2023). TCO analysis complements this environmental perspective by evaluating economic performance from the user's perspective, identifying the conditions under which xEVs become cost-competitive with ICEVs under different policy settings, fuel prices, and battery cost trajectories (Doi et al., 2022).

Taken together, these analytical tools provide an integrated foundation for shaping ASEAN's policy direction in support of sustainable automotive transformation, whilst balancing industrial competitiveness, environmental objectives, and consumer affordability.

7.2.1. Life-cycle Assessment of Vehicles

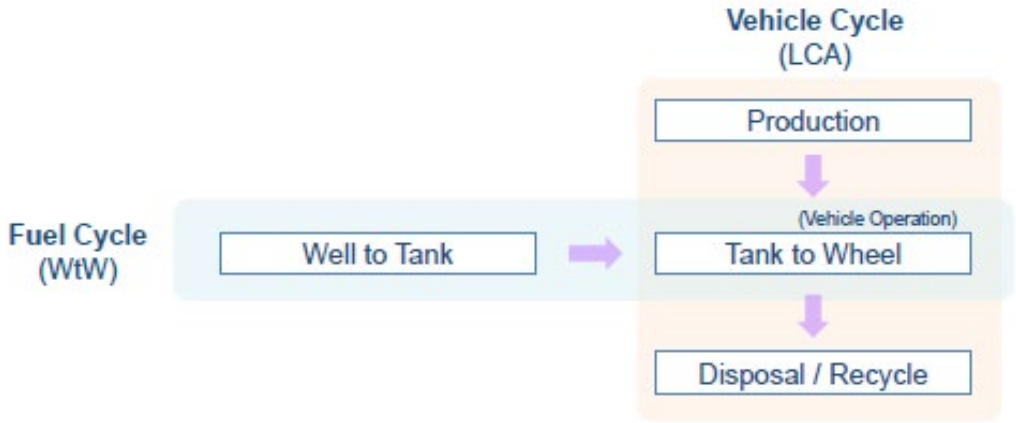
LCA is a methodological approach used to evaluate the environmental impacts of a product across its entire lifespan, from material extraction and production to use and end-of-life treatment. In the context of automotive transitions in ASEAN, LCA is a critical tool for assessing the net environmental benefits and trade-offs associated with adopting xEVs, including HEVs, PHEVs, and BEVs, relative to ICEVs.

7.2.1.1. Life-cycle assessment structure: Vehicle cycle and fuel cycle

LCA is structured around two components. The vehicle cycle captures emissions associated with raw material extraction, component manufacturing, vehicle assembly, and recycling or disposal at the end of life. The fuel cycle, or the well-to-wheel cycle, includes emissions from energy generation, fuel or electricity processing, distribution, and vehicle operation.

In ASEAN, a substantial share of emission reductions associated with xEV adoption arises in the fuel cycle, particularly in the tank-to-wheel phase, as electric drivetrains are inherently more energy-efficient than combustion engines. However, these gains can be partially offset by higher upstream emissions in the vehicle cycle, especially during battery production. Consequently, both the vehicle and fuel cycles must be assessed jointly to inform effective and context-specific policy design.

Figure 7.1. Fuel Cycle and Vehicle Cycle Framework

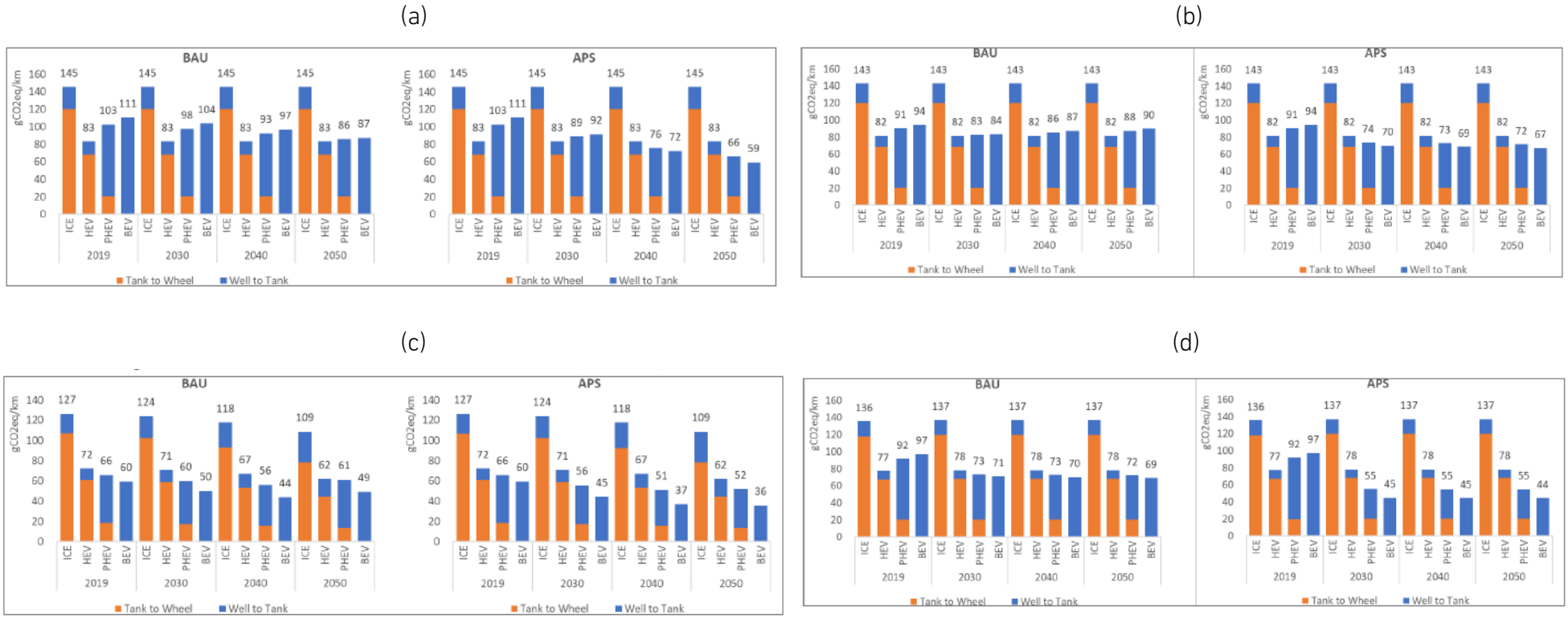


WtW = well to wheel, LCA = life-cycle assessment.
Source: Doi et al. (2024).

7.2.1.2. Life-cycle assessment across vehicle types

According to Doi et al. (2024), BEVs deliver the greatest GHG reductions over their life cycle. Still, the magnitude of these benefits depends heavily on the carbon intensity of the electricity mix in each AMS. In Indonesia, where coal continues to dominate power generation, the life-cycle GHG benefits of BEVs are relatively muted. By contrast, countries such as Viet Nam and Malaysia, which have comparatively cleaner electricity mixes, achieve more substantial life-cycle GHG reductions from BEVs.

Figure 7.2. Greenhouse Gas Intensities Based on a Well-to-Wheel Basis for (a) Indonesia, (b) Malaysia, (c) Thailand, and (d) Viet Nam

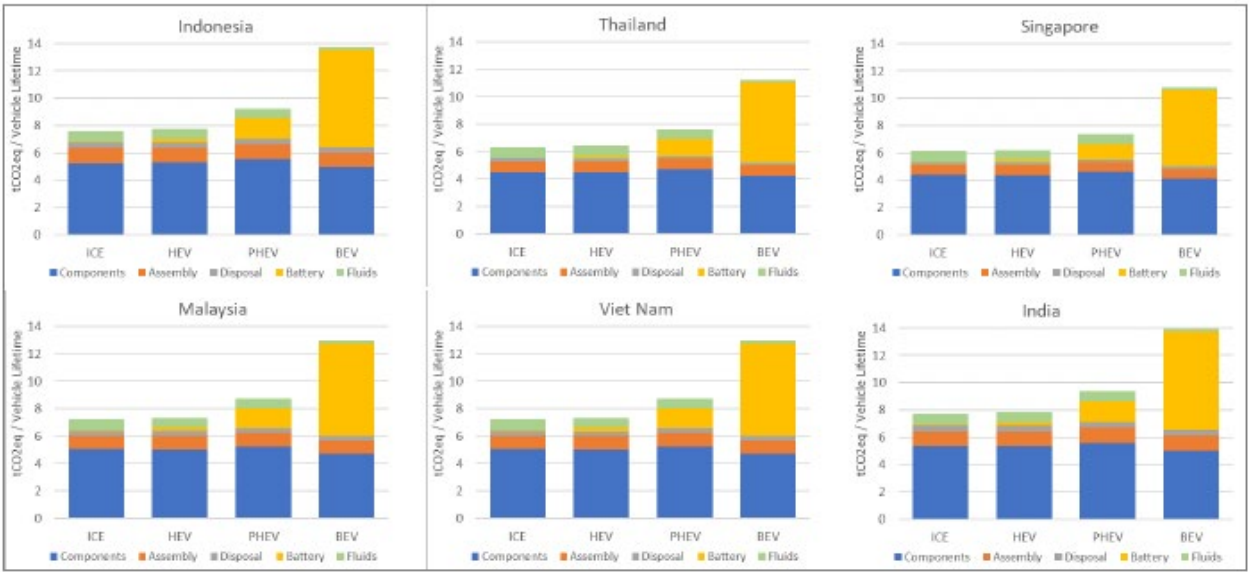


APS = advanced policy scenario, BAU = business as usual, BEV = battery electric vehicle, HEV = hybrid electric vehicle, ICE = internal combustion engine, PHEV = plug-in hybrid electric vehicle.
Source: Doi et al. (2024).

Figure 7.2 shows the GHG emission intensities for four AMSs, disaggregated into well-to-tank and tank-to-wheel phases under two scenarios: a business-as-usual (BAU) scenario, which assumes no significant change in the power generation mix, and an advanced policy scenario, which reflects more ambitious energy-efficiency improvements and a higher penetration of non-fossil fuels. Countries with higher coal shares exhibit substantially higher well-to-tank GHG emissions, which reduce the effectiveness of plug-in electric vehicles – BEVs and PHEVs – in reducing overall emissions.

Figure 7.3 extends the analysis by presenting vehicle-cycle emissions by powertrain type and country, covering a broader emissions boundary than Figure 7.2. Vehicle-cycle GHG emissions are estimated at 4–5 tonnes of carbon dioxide (tCO_2) for ICEVs and up to 6–8 tCO_2 for BEVs, primarily due to emissions associated with lithium-ion battery manufacturing (Doi et al., 2024). Nonetheless, over a typical vehicle lifetime of about 150,000 kilometres, BEVs emit 30%–50% less GHG than ICEVs on a well-to-wheel basis in countries with moderate to low grid carbon intensity.

Figure 7.3. Vehicle-cycle Emissions by Powertrain Type and Country



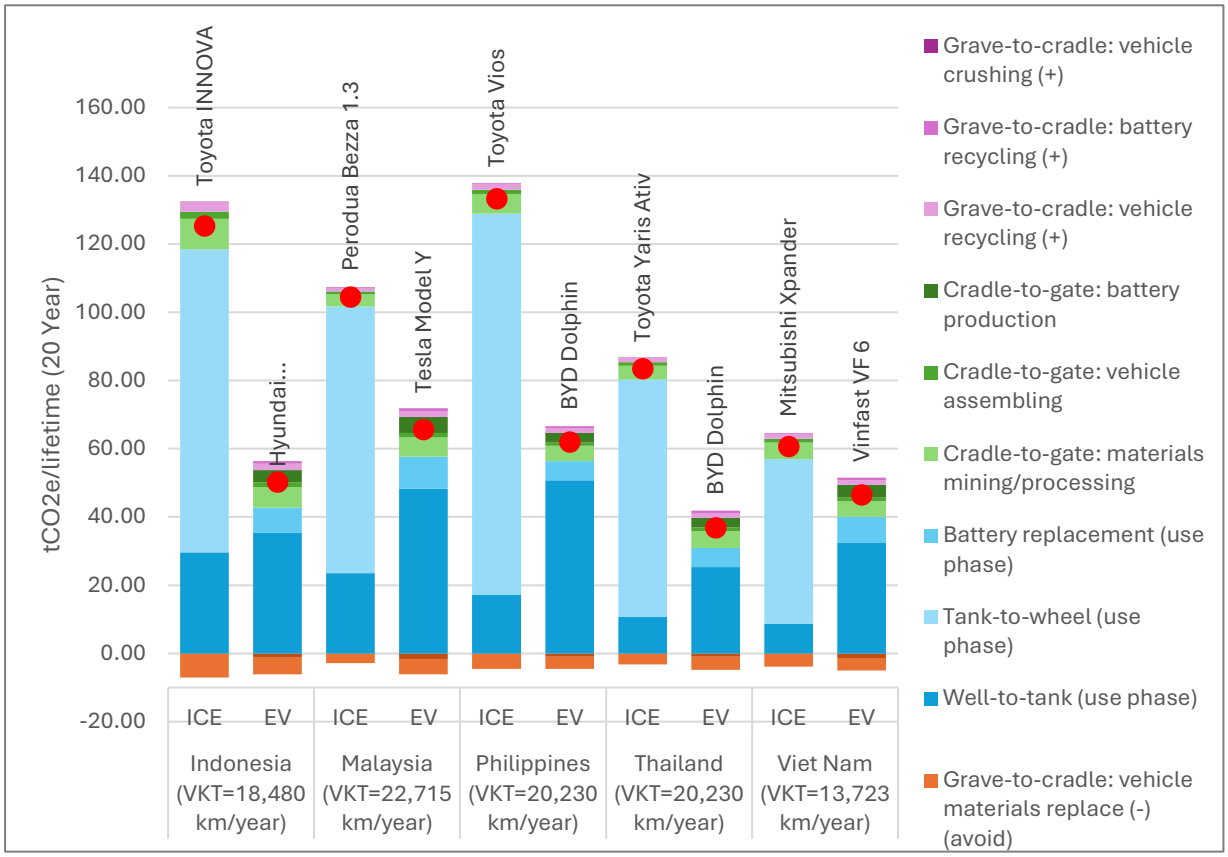
BEV = battery electric vehicle, HEV = hybrid electric vehicle, ICE = internal combustion engine, PHEV = plug-in hybrid electric vehicle, tCO_2eq = tonne of carbon dioxide equivalent.
Source: Doi et al. (2024).

An ERIA study by Saisirat et al. (forthcoming) reports broadly consistent findings. The study shows that total emissions in ASEAN are driven primarily by the vehicle-use phase, reflecting vehicle-kilometres travelled and fuel consumption. As shown in Figure 7.4, tank-to-wheel emission from ICEVs account for 71%–84% of total GHG emissions. Cradle-to-gate emissions (Figure 7.5) contribute 4.3%–30.9% of total GHG emissions (right vertical axis), with xEVs often exhibiting higher emissions than ICEVs in this phase due to battery production. In the grave-to-cradle stage (Figure 7.6), GHG savings from avoiding new material production, both for vehicles and, in the case of BEVs, batteries, consistently

offset emissions arising from energy use during scrappage and recycling.

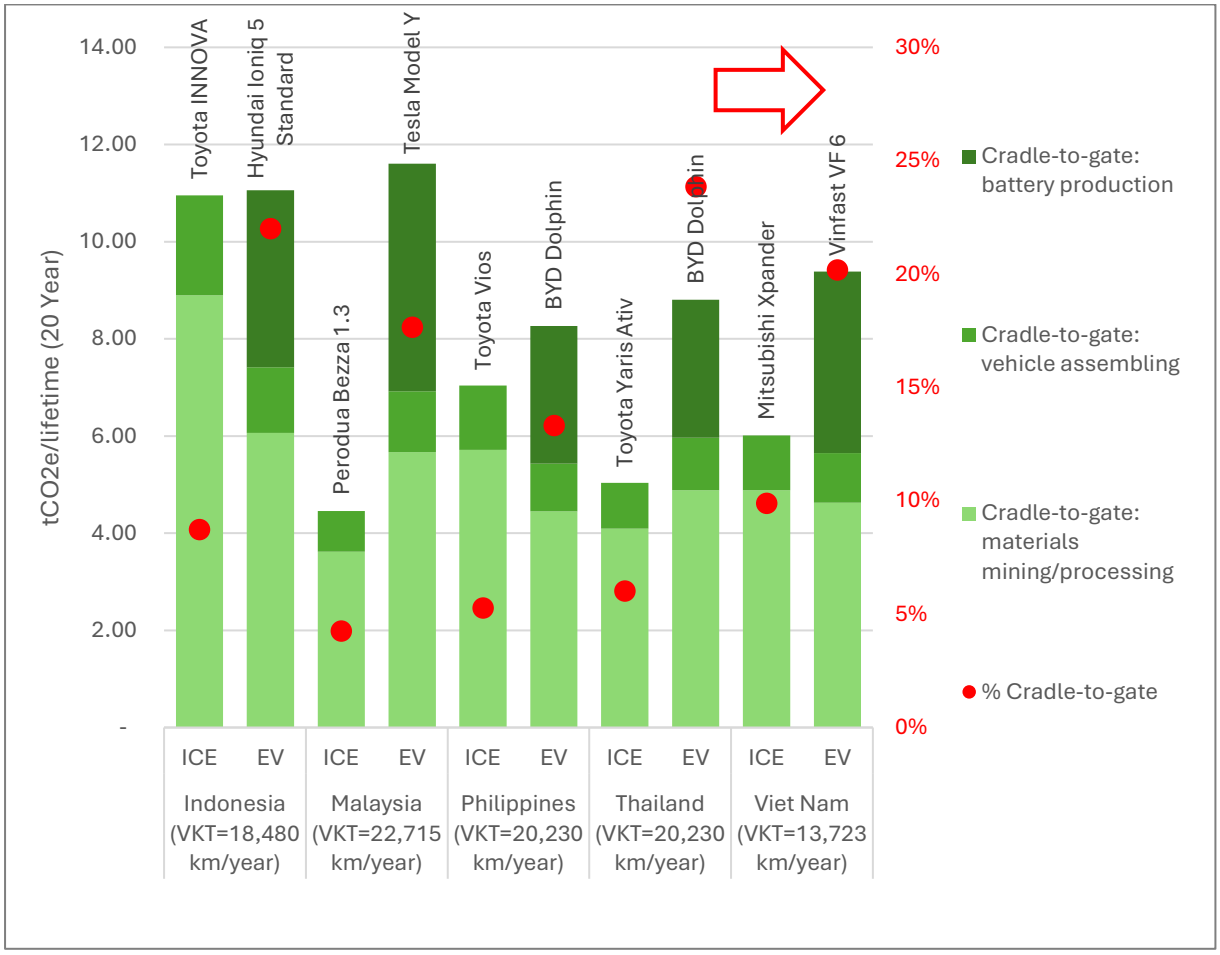
Cross-country comparisons in Saisirat et al. (forthcoming) highlight several additional drivers. First, differences in popular vehicle models and associated fuel consumption matter: Indonesia's large multi-purpose vehicle (MPV) (Toyota Innova) and the Philippines' B-segment car (Toyota Vios) exhibit higher fuel consumption than more economical models such as Malaysia's Perodua Bezza 1.3 and Thailand's Toyota Yaris Ativ. Second, vehicle-kilometres travelled differ markedly across countries. Viet Nam's light MPV (Mitsubishi Xpander) shows fuel economy comparable to the Philippines' Toyota Vios, yet average vehicle-kilometres travelled in Viet Nam are about 40% lower. Finally, Thailand's economic car (Toyota Yaris Ativ) records lower global-warming impacts than Malaysia's equivalent (Perodua Bezza 1.3), largely because Thailand's wheel-to-tank emission factor is lower than Malaysia's.

Figure 7.4. Lifetime Analysis of Global-warming Impacts Comparing Internal Combustion Engine Vehicles and Electric Vehicles (Four-wheelers): Complete



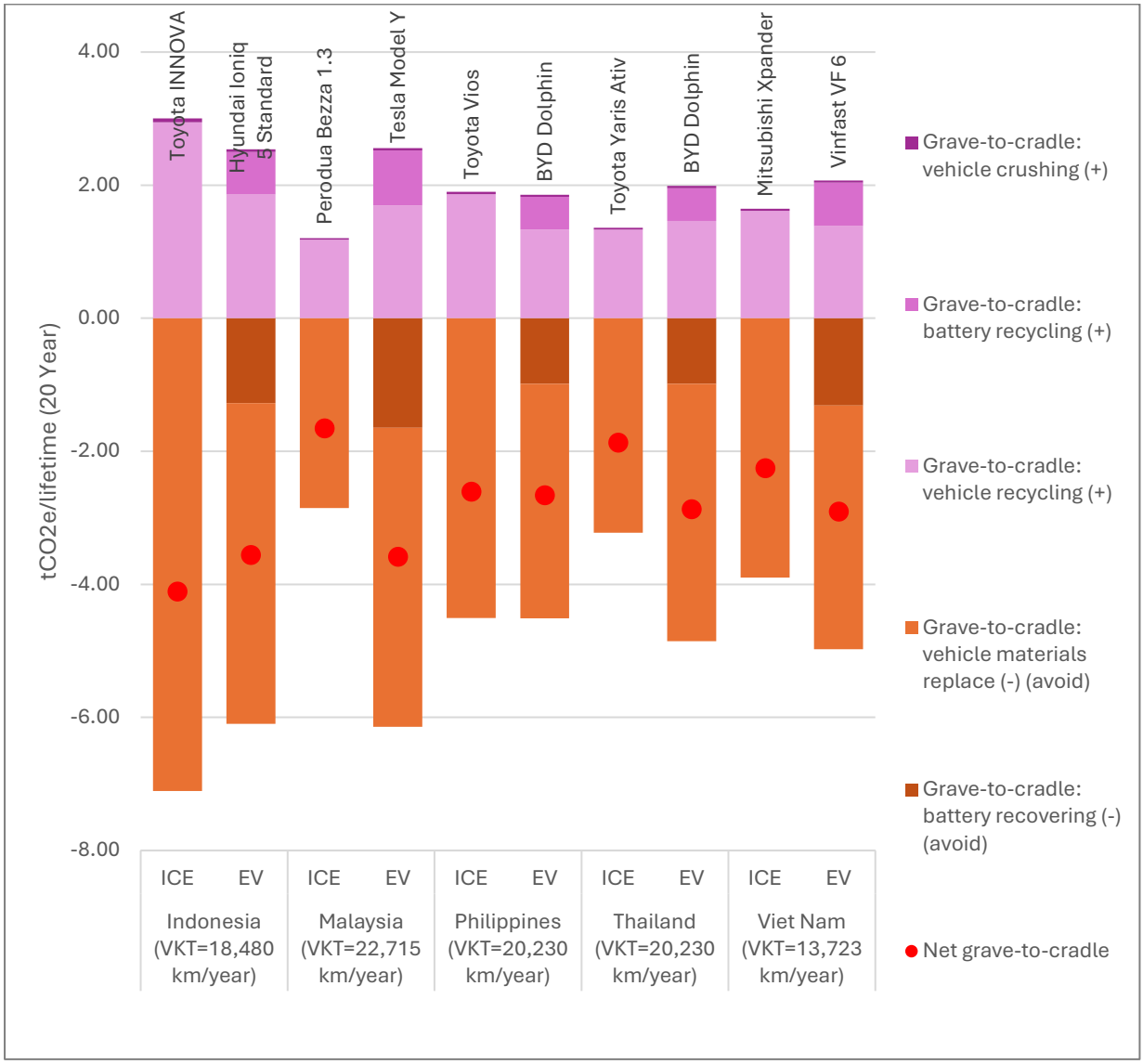
EV = electric vehicle, ICE = internal combustion engine, tCO_2eq = tonnes of carbon dioxide equivalent, VKT = vehicle-kilometres travelled.
Source: Saisirat et al. (forthcoming).

Figure 7.5. Lifetime Analysis of Global-warming Impacts Comparing Internal Combustion Engine Vehicles and Electric Vehicle (Four-wheelers): Cradle-to-Gate



EV = electric vehicle, ICE = internal combustion engine, tCO_2eq = tonnes of carbon dioxide equivalent, VKT = vehicle-kilometres travelled.
Source: Saisirat et al. (forthcoming).

Figure 7.6. Lifetime Analysis of Global-warming Impact Comparing Internal Combustion Engine Vehicles and Electric Vehicles (Four-wheelers): Grave-to-Cradle



EV = electric vehicle, ICE = internal combustion engine, tCO_2eq = tonnes of carbon dioxide equivalent, VKT = vehicle-kilometres travelled.
Source: Saisirat et al. (forthcoming).

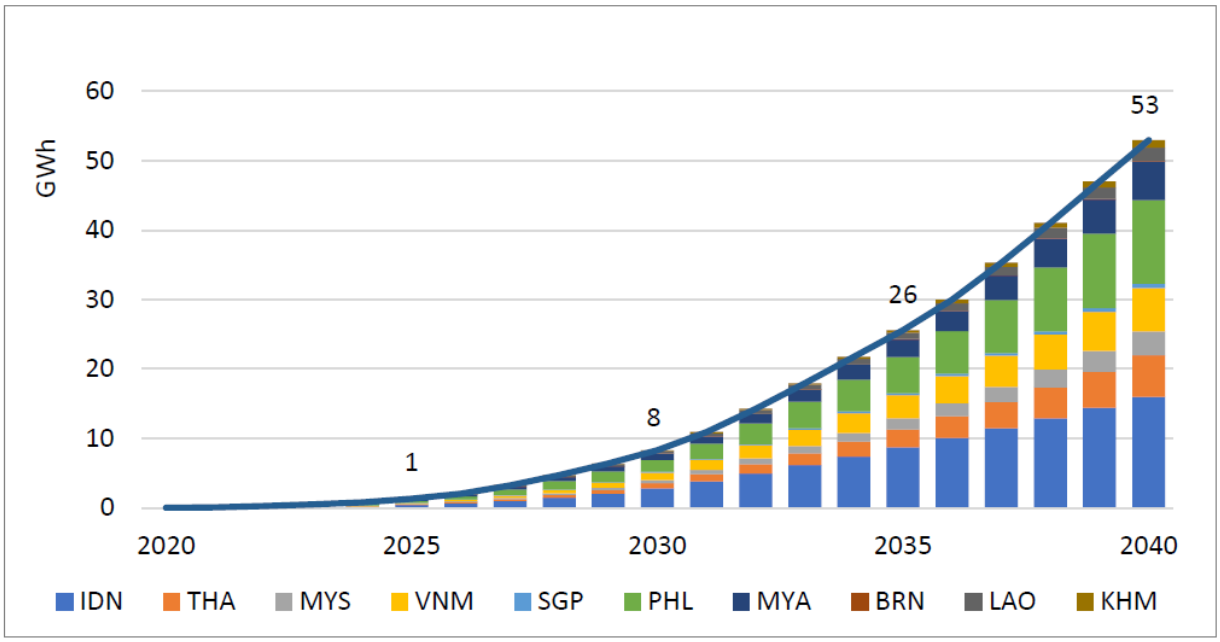
7.2.1.3. Life-cycle sensitivity to grid decarbonisation and battery supply chains

The emissions advantage of BEVs increases as ASEAN decarbonises its power sector. For instance, under a scenario in which the share of renewable energy increases to 50%, BEVs could emit less than 60 gCO_2 per kilometre, compared with over 150 gCO_2 per kilometre for ICEVs (Doi et al., 2024).

Beyond electricity generation, the regionalisation of battery production, reuse, and recycling will play a key role in reducing vehicle-cycle emissions. Most batteries used in ASEAN are imported, adding transport-related emissions and limiting oversight of supply-chain sustainability. By investing in local recycling infrastructure and second-life

battery applications, ASEAN can reduce material demand, lower emissions, and mitigate strategic supply risks (Doi et al., 2023). As shown in Table 7.7, Doi et al. (2023) project a steep increase in cumulative end-of-life battery volumes across ASEAN towards 2040.

Figure 7.7. Cumulative Used Battery Generation Forecast



BRN = Brunei Darussalam, GWh = gigawatt-hour, IDN = Indonesia, KHM = Cambodia, LAO = Lao People's Democratic Republic, MYA = Myanmar, MYS = Malaysia, PHL = Philippines, SGP = Singapore, THA = Thailand, VNM = Viet Nam.
Source: Doi et al. (2023).

7.2.1.4. Conclusion

The LCA results highlight the substantial, but conditional, environmental benefits of xEV adoption in ASEAN. Whilst BEVs and PHEVs can deliver significant reductions in GHG emissions over their life cycle, these benefits are maximised in countries with cleaner electricity systems and well-developed circular supply chains. Integrating LCA into policy design helps ensure that vehicle electrification not only decarbonises transport but does so holistically by minimising emissions across the entire value chain and maximising co-benefits for energy security, local industrial development, and environmental quality.

7.2.2. Total Cost of Ownership

As ASEAN accelerates its transition towards next-generation vehicles, affordability remains a crucial determinant of adoption, especially in developing markets. Whilst environmental benefits underpin national climate strategies, end-users, both individuals and fleet operators, respond primarily to cost signals. TCO analysis, therefore, provides a comprehensive view of the long-term economic implications of vehicle choice, capturing not only upfront purchase prices but also cumulative operating and life-cycle costs over a vehicle's useful life.

7.2.3.1. Cost structures: ICEVs versus xEVs

TCO comparisons across powertrain types, including ICEVs, HEVs, PHEVs, and BEVs, reveal that, whilst xEVs typically involve higher initial purchase prices, they partially offset this disadvantage through lower operating costs (Table 7.1), notably reduced fuel costs and lower maintenance needs (Doi et al., 2022). Depending on policy design and market maturity, owners may also benefit from fiscal incentives, registration exemptions, and stronger residual value retention. The convergence of these factors determines the point at which xEVs achieve cost parity with, or outperform, ICEVs.

Table 7.1. Breakdown of the Cost of Driving by Powertrain Technology

		2015	2020	2025	2030	2035	2040
ICEV							
Initial vehicle purchase	$/10 years	22,000	22,066	22,165	22,248	22,319	22,381
Vehicle purchase (annualised)	$/year	2,420	2,427	2,438	2,447	2,455	2,462
Petrol	$/year	493.8	477.7	462.4	444.6	427.1	409.9
Maintenance	$/year	121.0	121.4	121.9	122.4	122.8	123.1
Total annual cost	**$/year**	**3,035**	**3,026**	**3,022**	**3,014**	**3,005**	**2,995**
HEV							
Initial vehicle purchase	$/10 years	27,500	25,992	25,175	24,835	24,651	24,537
Vehicle purchase (annualised)	$/year	2,915	2,755	2,669	2,633	2,613	2,601
Petrol	$/year	334	304	297	291	284	277
Maintenance	$/year	73	69	67	66	65	65
Total annual cost	**$/year**	**3,322**	**3,128**	**3,033**	**2,989**	**2,962**	**2,943**
PHEV							
Initial vehicle purchase	$/10 years	38,500	31,000	27,410	26,083	25,388	24,959
Vehicle purchase (annualised)	$/year	4,043	3,255	2,878	2,739	2,666	2,621
Petrol + electricity	$/year	229	208	206	204	201	199
Maintenance	$/year	101	81	72	68	67	66
Personal charger	$/year	72.8	58.6	51.8	49.3	48.0	47.2
Total annual cost	**$/year**	**4,445**	**3,603**	**3,208**	**3,060**	**2,982**	**2,932**
EV							
Initial vehicle purchase	$/10 years	35,200	29,502	25,639	23,974	23,054	22,472
Vehicle purchase (annualised)	$/year	3,696	3,098	2,692	2,517	2,421	2,360
Electricity	$/year	144.4	131.9	130.2	130.2	129.5	128.8
Maintenance	$/year	92	77	67	63	61	59
Personal charger	$/year	66.5	55.8	48.5	45.3	43.6	42.5
Total annual cost	**$/year**	**3,999**	**3,363**	**2,938**	**2,756**	**2,654**	**2,590**

EV = electric vehicle, HEV = hybrid electric vehicle, ICEV = internal combustion engine vehicle, PHEV = plug-in hybrid electric vehicle.

Note: All monetary values are expressed in United States dollars.

Source: Doi et al. (2022).

One of the most substantial advantages of xEVs lies in their superior energy efficiency. In countries such as Thailand and Viet Nam, where electricity prices are relatively stable and dependence on imported oil is high, these savings are particularly pronounced. xEVs have fewer moving parts, which translates into lower routine maintenance costs.

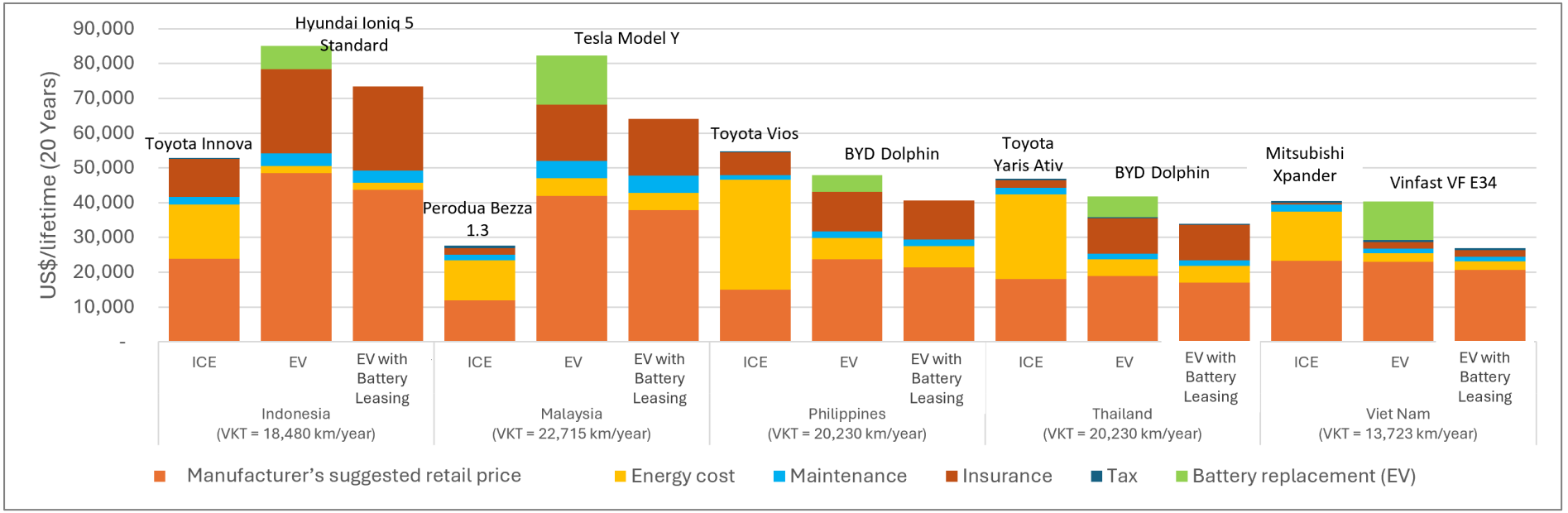
Evidence from an ERIA study by Chollachoop et al. (forthcoming) highlights several important patterns. First, the TCO of ICEVs in Indonesia and Malaysia remains lower than that of EVs. Second, Malaysia and Indonesia exhibit the highest EV TCO amongst the five countries analysed, compared with the Philippines, Thailand, and Viet Nam. More than 40% of EV TCO in these markets is attributable to the manufacturer's suggested retail price (MSRP).

Despite government subsidies supporting the EV market in Thailand, costs associated with battery replacement and insurance remain higher than for ICEVs. Battery leasing, most widely applied in Thailand, the Philippines, and Viet Nam, has emerged as an important strategy for reducing EV TCO, as it can substantially lower ownership costs. Across markets, the primary drivers of EV TCO remain the MSRP and insurance premiums.

Although energy costs for ICEVs are higher than electricity costs in Indonesia, Malaysia, and Viet Nam, ICEVs still record lower overall TCO than EVs in these countries. This pattern does not hold in the Philippines and Thailand, where fuel prices are relatively high. Newly prominent cost components for EVs, particularly insurance and battery replacement, explain much of this divergence. To strengthen the competitiveness of EVs, continued improvements in battery technology and energy density, alongside cost reductions, are essential. Such advances would help lower insurance, maintenance, and battery replacement costs associated with EV ownership.

Figure 7.8 shows a comparative TCO analysis of ICEVs, EVs, and EVs with battery leasing across five key countries, based on top-selling passenger vehicle models. The figure highlights the contribution of individual cost components, including MSRP, energy, maintenance, insurance, taxes, and battery replacement, to overall lifetime TCO. TCO outcomes vary across countries according to factors such as vehicle-kilometres travelled, vehicle prices, and related ownership costs. TCO is expressed in US dollars per vehicle lifetime, assuming a 20-year service life for passenger vehicles. The results indicate that battery leasing can be an effective mechanism for reducing EV TCO.

Figure 7.8. Comparative Total Cost of Ownership of Internal Combustion Engine Vehicles, Electric Vehicles, and Electric Vehicles with Battery Leasing



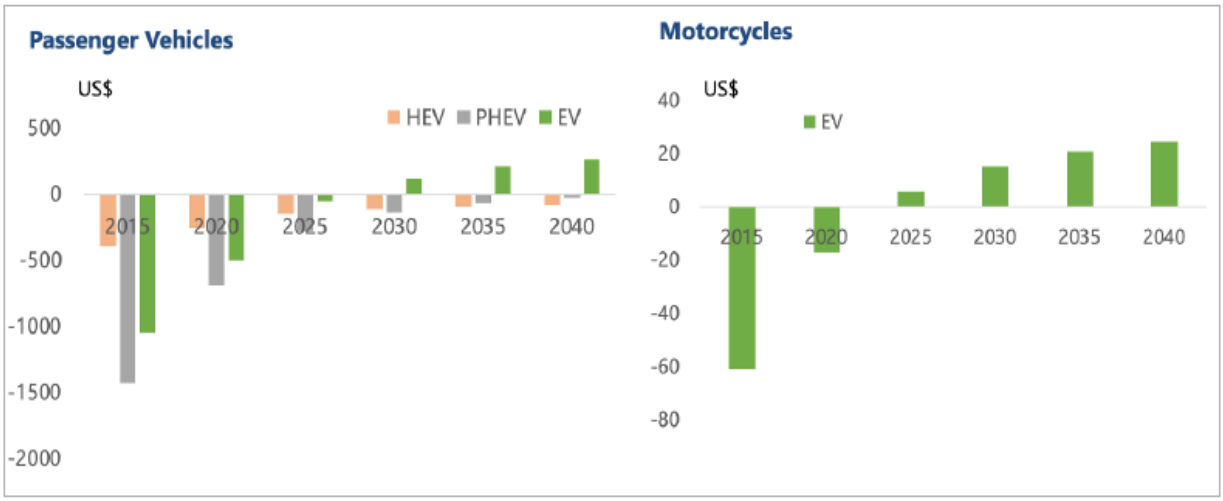
EV = electric vehicle, ICE = internal combustion engine, VKT = vehicle-kilometres travelled.
Note: The analysis is based on top-selling conventional ICE and EV models. Vehicle-kilometres travelled refers to the total distance travelled over the vehicle's lifetime. Battery leasing for passenger cars is estimated using a capital cost ratio of 90% and an operating cost ratio of 100%.
Source: Chollachoop et al. (forthcoming).

7.2.3.2. Total cost of ownership and the tipping point in ASEAN

The tipping point, at which the TCO of xEVs surpasses that of ICEVs and HEVs, varies by country and vehicle category. According to Doi et al. (2022), as shown in Figure 7.9, Thailand and Malaysia, where relatively high petrol prices, moderate electricity tariffs, and government purchase subsidies coexist, are forecast to achieve TCO parity for passenger xEVs in 2027–2029. Viet Nam may reach this threshold slightly earlier, supported by favourable electricity-to-fuel price ratios. Conversely, in Indonesia, parity is unlikely to occur before 2030, largely due to subsidised fossil-fuel pricing and higher vehicle import costs, unless local production scales up and policy support expands.

Figure 7.9. Country-specific Total Cost of Ownership Tipping Points: (a) Brunei Darussalam, (b) Indonesia, (c) Malaysia, (d) Thailand, (e) Viet Nam

(a)



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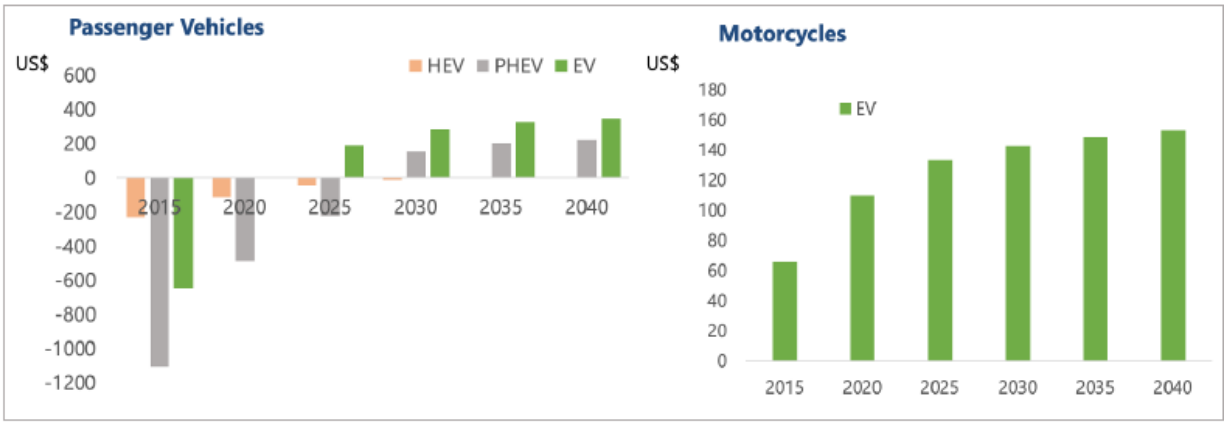

Figure 7.9. *Continued*

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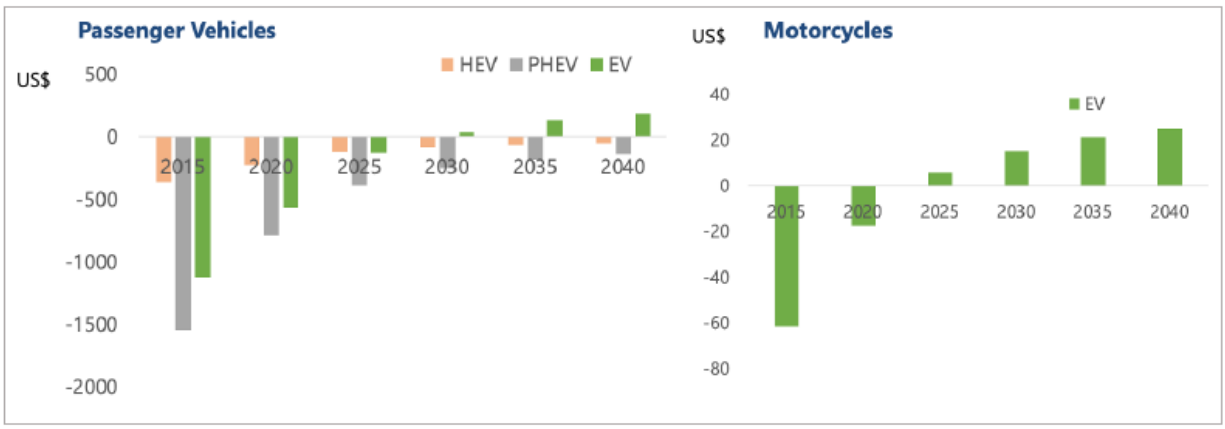

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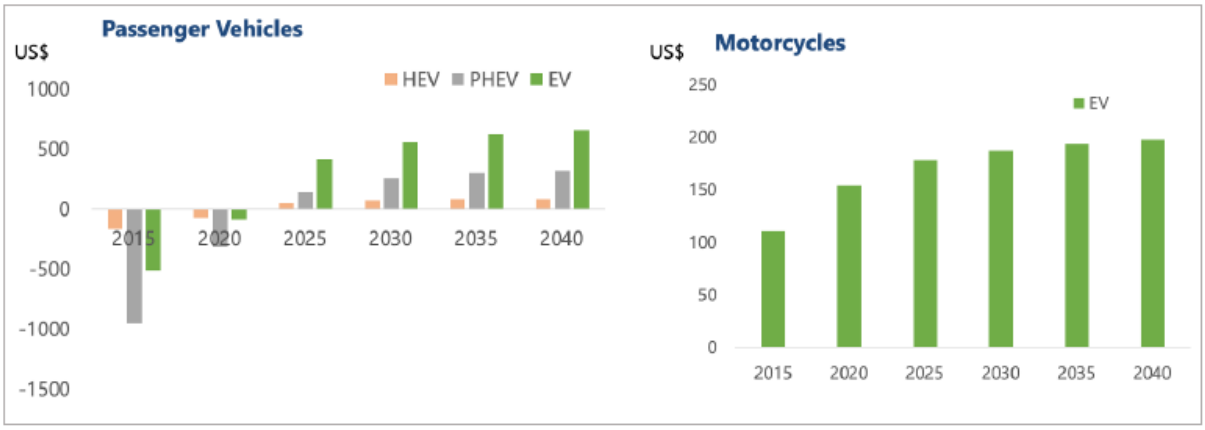

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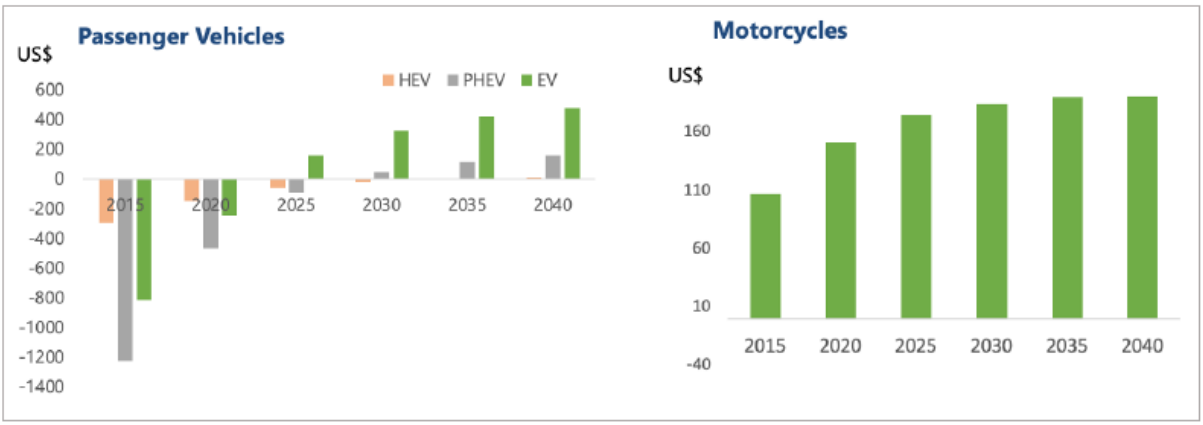
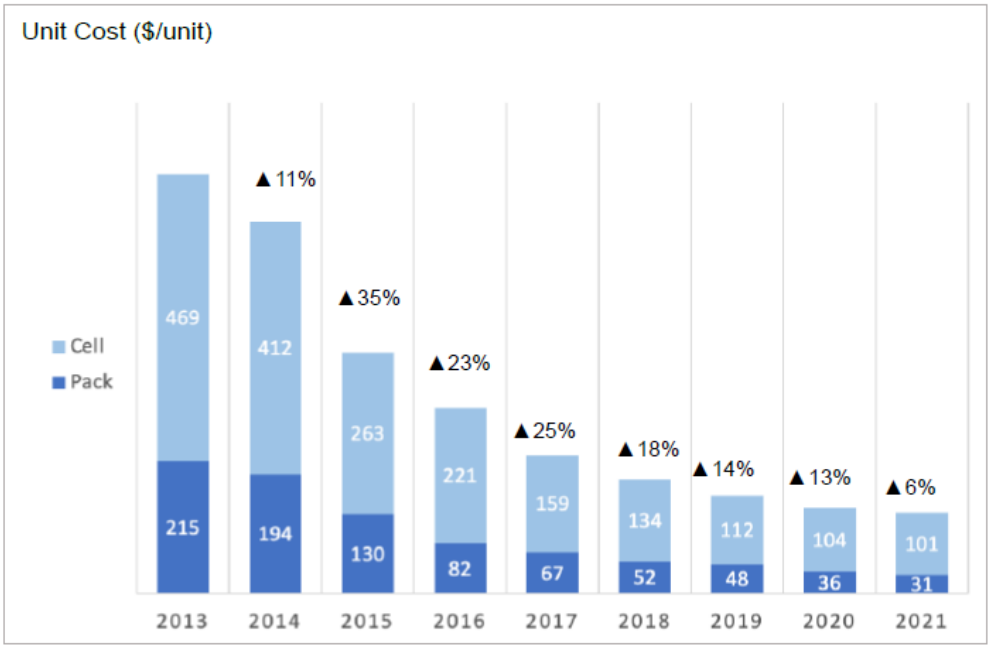


EV = electric vehicle, HEV = hybrid electric vehicle, PHEV = plug-in hybrid electric vehicle
Source: Doi et al. (2022).

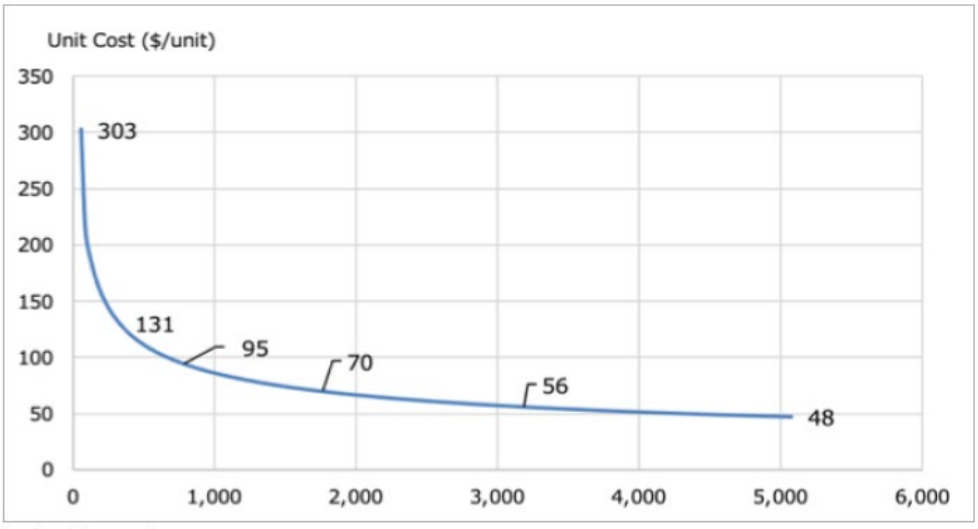
7.2.3.3. Role of battery costs and incentives

Battery costs remain a critical determinant of the TCO performance of EVs. As shown in Figure 7.10, lithium-ion battery module prices have declined from over US$1,000 per kilowatt-hour in 2010 to under US$209 per kilowatt-hour in 2017. With continued learning-curve effects, prices are expected to drop below US$72 per kilowatt-hour by 2030, significantly improving the affordability of xEVs for mass-market consumers in ASEAN (Doi et al., 2022).

Figure 7.10. Global and Projected Battery Price Trends



kWh = kilowatt hour.
Note: The figures include the cell plus pack price.
Source: Bloomberg New Energy Finance (2017).



kWh = kilowatt hour.
Source: Institute of Energy Economics, Japan (2018).
kWh = kilowatt-hour.
Source: Doi et al. (2022).

Government policy can further accelerate improvements in TCO. Thailand's 2022 EV incentive scheme provides subsidies of up to THB150,000 per vehicle, alongside excise-tax reductions and charging-infrastructure support. Indonesia's Presidential Regulation No. 79/2023 exempts value-added tax for domestically produced EVs and provides tax holidays for EV-related investments. Malaysia has waived import and excise duties for BEVs and promotes EV adoption through public-fleet procurement. When coupled with transparent electricity pricing and continued infrastructure development, these measures enhance the cost competitiveness of EVs across different use cases.

7.2.3.4. Conclusion

TCO analysis confirms that xEVs are approaching, and, in some cases, have already achieved economic competitiveness with ICEVs in ASEAN markets. These cost advantages are expected to strengthen further as battery prices fall, energy systems decarbonise, and policy frameworks mature. With effective alignment between market readiness, infrastructure provision, and targeted incentives, ASEAN can position electrified mobility not only as an environmental solution but also as a financially viable choice for households and businesses.

7.3. Supply Chain of Critical Minerals, Sustainable Mining, and Battery Manufacturing

A cradle-to-cradle analytical framework requires a systematic assessment of the critical mineral supply chain, alongside the sustainability of mining activities and EV battery manufacturing. In parallel, the global push towards carbon neutrality has positioned critical minerals at the heart of clean energy transitions. Lithium, nickel, cobalt, graphite, manganese, and rare earth elements (REEs) are indispensable inputs for EV batteries, permanent magnets for electric motors, and a wide range of components across EV and renewable energy value chains. As the decarbonisation of transport and power systems accelerates, demand for these minerals is projected to rise sharply, reshaping industrial strategies, trade patterns, and geopolitical alignments.

The emergence of electric mobility creates both opportunity and urgency for ASEAN. With its rich mineral endowment and growing industrial base, the region stands at a strategic crossroads. Countries such as Indonesia, the Philippines, and Myanmar hold significant shares of global reserves of nickel, cobalt, and REEs, whilst others, such as Viet Nam, Malaysia, and Thailand, are investing in downstream processing, battery production, and EV assembly. ASEAN, therefore, has the potential to become a vital node in global EV and battery supply chains, provided it can overcome persistent fragmentation, environmental risks, and external dependency.

However, ASEAN's mineral wealth remains under-leveraged. Supply chains are still marked by fragmentation, limited downstream integration, and high dependency on external actors, particularly China, for mineral processing and higher value-added stages.

A large share of mineral output continues to be exported in raw or semi-processed form, reinforcing dependency on external processing hubs. Divergent national strategies and weak regional coordination risk diluting ASEAN's collective bargaining power and undermining its long-term competitiveness (Bhaskara, 2025).

This section explores the full spectrum of the critical mineral supply chain in ASEAN, from extraction and processing to battery production. It addresses the environmental, social, and geopolitical risks associated with mineral development, whilst assessing the urgency of stronger regional cooperation, sustainable mining practices, and circular-economy solutions to ensure that ASEAN's emerging EV ecosystem is both resilient and equitable.

7.3.1. Global Demand and Strategic Dependencies

According to the International Energy Agency (IEA), the market size for critical minerals, largely driven by clean energy technologies such as EVs and solar photovoltaic (PV), is projected to exceed US$770 billion by 2040, marking a fivefold increase from 2020 levels (Bhaskara, 2025). Whilst nickel, lithium, cobalt, and graphite are all essential inputs for EV battery production, demand for lithium alone is projected to grow by about 40 times by 2040, with similarly steep growth projected for cobalt and graphite.

This rapid growth in demand is revealing major structural vulnerabilities in the global supply chain. Production remains highly concentrated in a few countries, whilst China continues to dominate the processing and refining stages. China processes more than 50% of global lithium and cobalt output, nearly 90% of REEs, and over 60% of the graphite used in EV anodes.

Such concentration creates substantial supply-side risks. Recent geopolitical disruptions, including Russia's invasion of Ukraine, escalating trade frictions between China and the US, and the growing fragmentation of global markets, have highlighted the fragility of mineral supply chains. Compounding these risks, mining investment is failing to keep pace with projected demand. The IEA estimates that, without major policy and financing shifts, only around 70% of projected copper demand and 50% of lithium demand will be met by 2035 (Bhaskara, 2025).

ASEAN is not immune to these dynamics. Although the region holds an estimated 46% of global nickel reserves, 22.7% of bauxite, 20% of REEs, and 6.9% of cobalt, most of this output is exported in unprocessed or minimally processed form. In 2022, more than 95% of nickel exports from Indonesia and the Philippines were sent to China. Similarly, Myanmar exports nearly all of its tin, rare earth, and manganese ores to China (Bhaskara, 2025).

This external dependency exposes ASEAN to price volatility, market-access risks, and forgone value-added opportunities, whilst also weakening the region's strategic leverage within the global battery and EV value chain. In response, several countries have introduced national policies to restrict raw mineral exports and stimulate domestic downstream processing. However, outcomes have been mixed and, in some cases,

politically contentious. The following sections, therefore, explore how the region can better leverage its resource endowment through sustainable practices, deeper regional integration, and targeted industrial innovation.

7.3.2. ASEAN's Resource Endowment and Global Value Chain Integration

Despite holding substantial reserves of critical minerals central to the clean energy transition, ASEAN countries remain predominantly exporters of raw materials, with limited control over downstream processing and recycling infrastructure.

The region's export structure remains heavily skewed towards raw or semi-processed materials. In 2022, over 95% of nickel exports, covering both ore and refined forms, from Indonesia and the Philippines were shipped to China. Myanmar also exported nearly all of its manganese, REEs, and tin ores to Chinese refiners (Bhaskara, 2025). This pattern of value leakage not only limits domestic economic multipliers but also reinforces the region's dependence on a single midstream hub, increasing exposure to geopolitical risk and price volatility.

Several ASEAN countries have attempted to address this imbalance through domestic downstreaming strategies. Indonesia's 2020 ban on unprocessed nickel exports sought to stimulate investment in refining, precursor materials, and battery-grade nickel production. Whilst the policy has attracted substantial foreign direct investment, particularly from firms from China and the Republic of Korea (henceforth, Korea), it has also raised concerns about environmental degradation and community displacement.

The Philippines initially proposed a similar export restriction in 2023 but reversed the policy following industry opposition. Instead, it has pivoted towards promoting a 'China-free' nickel supply chain to attract investment from Western and Japanese partners. Viet Nam and Malaysia have focused on downstream integration through EV assembly, battery-pack production, and electronics manufacturing. Viet Nam's VinFast, for example, is scaling up battery and EV exports, whilst Malaysia and Thailand together account for nearly 10% of global solar PV module production, supported by refining capacities for metallurgical-grade silicon.

7.3.3. Sustainable Mining for Circular Value Chains in ASEAN

Unprecedented volumes of critical raw materials will be needed to meet future demand as EVs account for a growing share of the global vehicle fleet. Lithium-ion batteries used in EVs rely heavily on critical metals, notably nickel in nickel–manganese–cobalt battery chemistries. To improve lithium-ion battery performance, the mass ratio of nickel, manganese, and cobalt has shifted from 1:1:1 to 8:1:1 and 9:0.5:0.5, increasing nickel content in battery cells by up to 80%. Under IEA's (2024) net-zero scenario, global nickel demand is projected to rise nearly fourfold, reaching about 7,000 kilotonnes of nickel equivalent by 2040, driven by clean energy technologies. Drysdale et al. (2025) observe that the shift to EVs is producing more specialised and comparatively streamlined supply

chains, with distinct implications for material inputs, particularly REEs and other critical minerals.

Nickel is found in two principal deposit types: laterites and sulphides. Although about 70% of global nickel reserves are found in laterite deposits, about 60% of historical nickel production has come from sulphide ores (Hazarbedia et al., 2023; Crundwell et al., 2011). In the early 2010s, laterites were primarily used to produce ferronickel for the steel industry, with only limited conversion into high-grade nickel products. By contrast, most high-grade nickel was produced from sulphide ores using pyrometallurgical processes. By 2019, however, about 70% of global nickel supply came from laterite resources and 30% from sulphides, reflecting a structural shift in production in which Indonesia played a central role as a global nickel supplier (Tijsseling et al., 2023).

According to data from the Indonesian Nickel Miners Association (Asosiasi Penambang Nikel Indonesia [APNI], 2024) and the Ministry of Energy and Mineral Resources (2020), Indonesia's total nickel reserves are estimated at 5.2 billion tonnes, comprising about 30% limonite and 70% saprolites ores. In the Philippines, total nickel reserves are estimated at 0.5 billion tonnes, although official statistics do not distinguish between limonite and saprolite deposits (Philippine Statistics Authority, 2020).

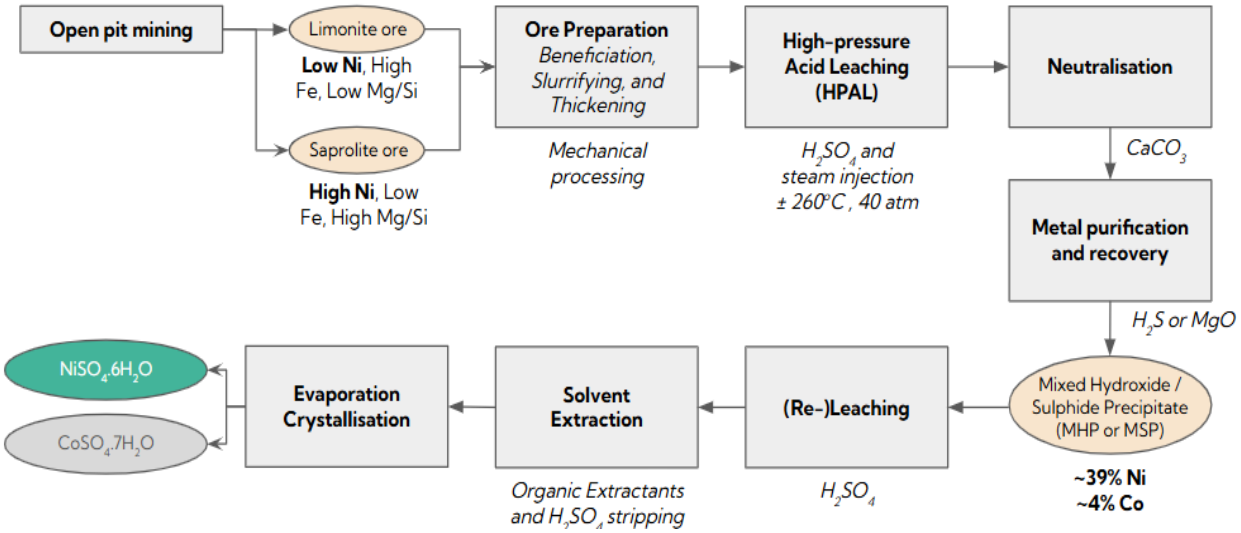
The mineralogical characteristics of nickel ores determine their economically viable processing routes. Limonite ores are usually processed using a hydrometallurgical process, most notably high-pressure acid leaching (HPAL), whereas saprolite ores are generally treated through pyrometallurgical routes such as rotary kiln–electric furnace processing. Hydrometallurgy is primarily used to produce higher-purity end products, including nickel sulphate hexahydrate, from laterite ores with relatively low magnesium and silica content. By contrast, pyrometallurgy is mainly applied to obtain nickel–iron alloys from saprolite ores (Crundwell et al., 2011). Iron and aluminium, the dominant impurities in limonite, can be economically removed through chemical treatment, making HPAL particularly suitable for converting limonite into battery-grade nickel sulphate (Crundwell et al., 2011; Zhang et al., 2025).

Nickel sulphate hexahydrate is a key precursor material for lithium-ion batteries used in EVs. It is produced by processing limonite ores through HPAL, which generates intermediate products in the form of mixed hydroxide precipitate or mixed sulphide precipitate. These intermediates are subsequently refined to separate nickel and cobalt and processed into sulphate hexahydrate. Although HPAL primarily processes limonite, small quantities of saprolite may be blended to reduce lime consumption during the neutralisation stage (Gultom and Sianipar, 2020).

Figure 7.12 shows a simplified HPAL process flow, centred on sulphuric acid leaching of iron-rich, low-magnesium limonite ores at high temperature and pressure. During leaching, nickel and cobalt dissolve into solution, whilst iron precipitates as hematite along with aluminium oxides. Subsequent neutralisation removes residual iron and aluminium (Crundwell et al., 2011; McDonald and Whittington, 2008). Nickel and cobalt are then

precipitated as mixed hydroxide precipitate or mixed sulphide precipitate by adjusting the solution pH to about 7–8 using hydrogen sulphide gas, sodium hydroxide, and/or magnesium oxide, yielding intermediates containing roughly 40% nickel and 5% cobalt. These intermediates are re-leached with sulphuric acid and subjected to solvent extraction to separate nickel and cobalt from remaining impurities, before crystallisation produces battery-grade sulphate hexahydrate (Dry et al., 2019; Zhang et al., 2025; Gultom and Sianipar, 2020; Crundwell et al., 2021).

Figure 7.11. Simplified Process Flow Diagram of High-pressure Acid Leaching and Refining for Nickel Sulfate Hexahydrate



$CaCO_3$ = calcium carbonate, $CoSO_47H_20$ = cobalt (II) sulfate heptahydrate, Fe = iron, H_2SO_4 = sulfuric acid, Mg = magnesium, Ni = nickel, $NiSO_46H_2O$ = nickel sulfate hexahydrate, Si = silicon.
Source: Tijsseling et al. (2023), Dry et al. (2019).

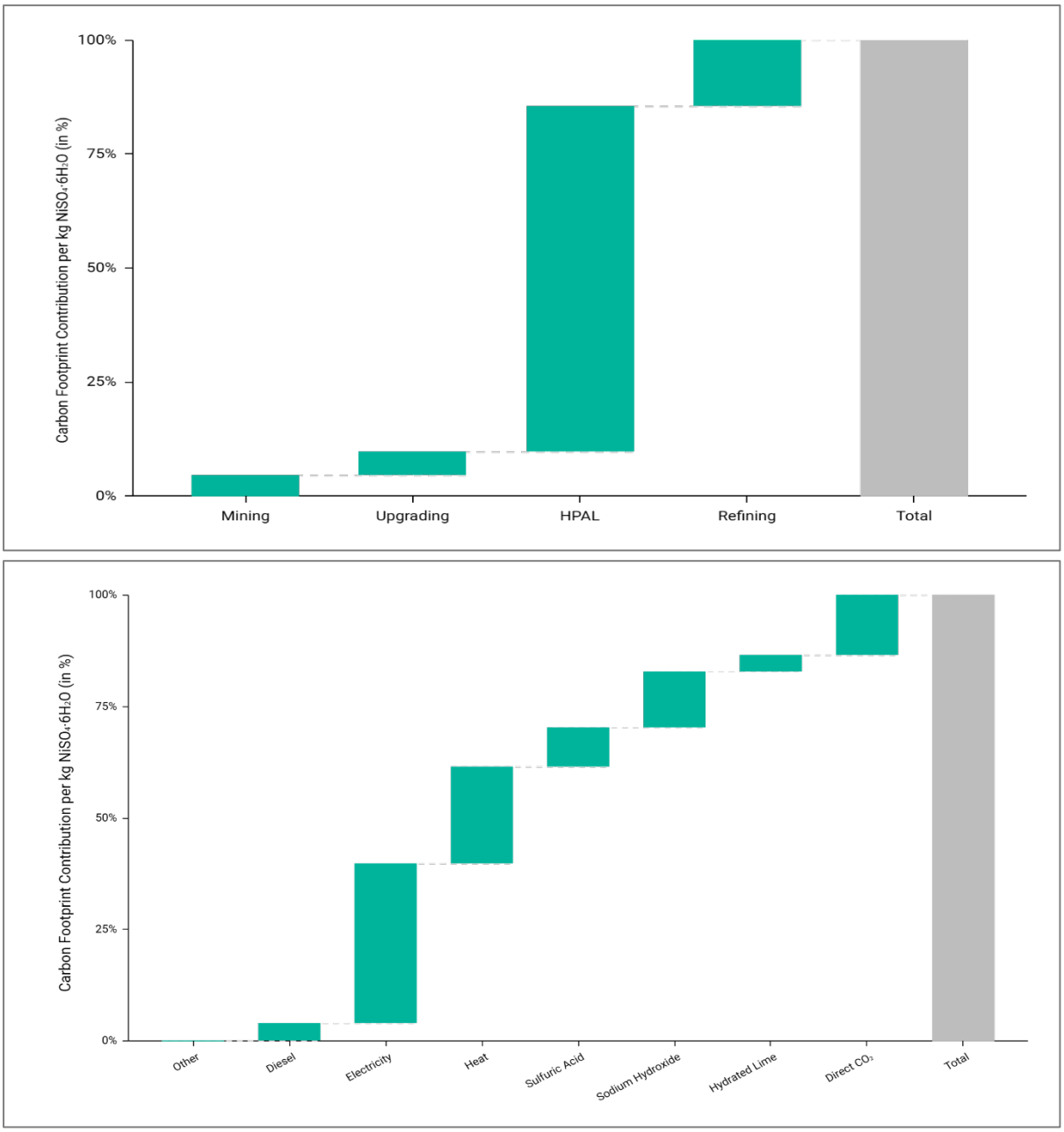
As of mid-2024, five HPAL facilities in Indonesia reported a combined annual processing capacity of about 48 million tonnes of nickel ore (Kementerian ESDM, 2020; APNI, 2024). Three more facilities under construction could add about 33 million tonnes annually, whilst up to 19 additional HPAL plants are planned, potentially contributing a further 68 million tonnes of annual capacity once operational. At the time of writing, no comparable data are available for HPAL capacity in the Philippines.

LCA studies carried out by Minviro using the XYCLE platform for ERIA (2025c) estimate that producing 1 kilogram of nickel sulphate hexahydrate emits about 8 kilograms of carbon dioxide equivalent, excluding transport from mine to processing facilities.

Figure 7.12 presents the contribution of each processing stage and material or energy input to the overall climate change impact. Mining covers open-pit limonite extraction, including diesel use for heavy equipment. Upgrading refers to ore beneficiation, where fine fractions containing nickel and cobalt are concentrated and chromite-bearing coarse material is removed. The HPAL stage encompasses high-temperature, high-pressure

sulphuric acid leaching to produce pregnant leach solution, followed by neutralisation and precipitation of mixed hydroxide precipitate. Refining involves re-leaching mixed hydroxide precipitate, solvent extraction, and crystallisation of nickel sulphate hexahydrate using thermal energy.

Figure 7.12. Climate Change Impact Contribution (%) of 1 Kilogram of Nickel Sulphate Hexahydrate Produced via High-pressure Acid Leaching and Refining, by Processing Stage (top) and Material and Energy Inputs (bottom)



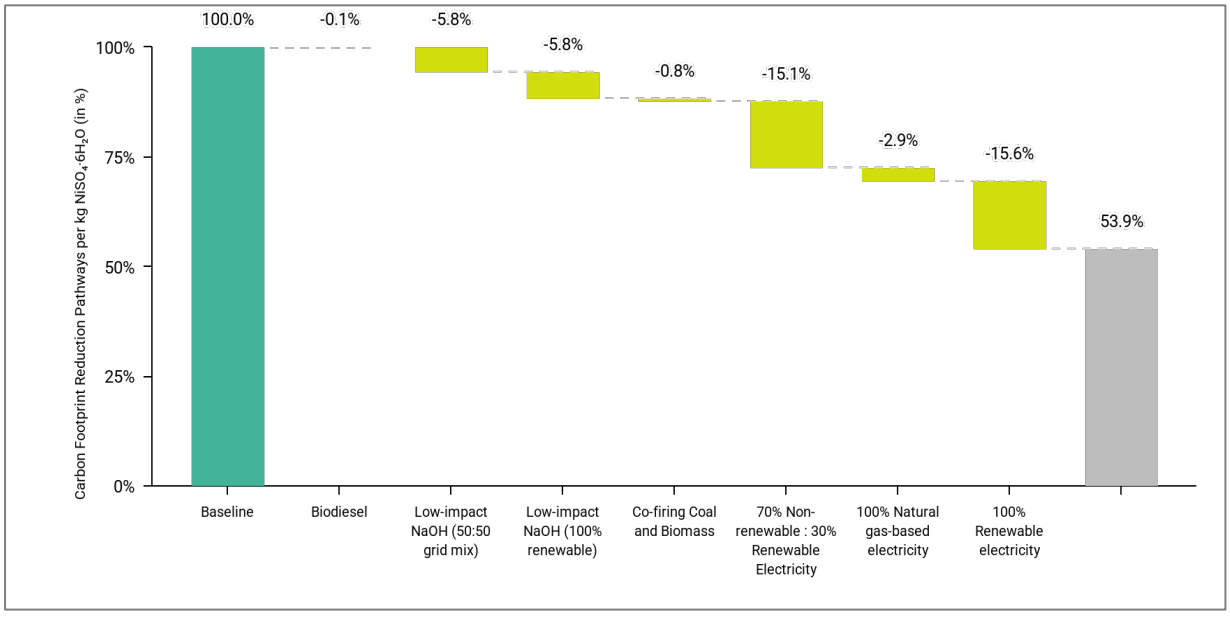
CO_2 = carbon dioxide, $NiSO_46H_2O$ = nickel sulphate hexahydrate.
Source: Economic Research Institute for ASEAN and East Asia (2025c).

The results indicate that mining, upgrading, and refining together account for about 25% of total climate change impacts, whilst leaching and neutralisation during HPAL contribute most of the impacts. These impacts are driven primarily by direct carbon dioxide emissions from neutralisation reactions and by high energy consumption, as HPAL operates at about 250°C and about 45 bar. Energy inputs – heat and electricity – account for more than half of total emissions, whilst direct carbon dioxide emissions contribute about 10%–15%. Amongst chemical inputs, sodium hydroxide contributes about 10% of total emissions, followed by sulphuric acid and hydrated lime.

These LCA results underpin the identification of potential decarbonisation pathways for producing nickel sulphate hexahydrate as a lithium-ion battery precursor. The proposed strategies focus on reducing emissions associated with energy and material inputs, particularly within Scope 3 supply chains. Figure 7.14 summarises potential climate change reduction pathways for producing 1 kilogram of nickel sulphate hexahydrate.

The analysis suggests that up to 54% of climate change impacts could be reduced if all assessed decarbonisation strategies were implemented, including fuel optimisation (for example, the use of B30 diesel), energy profile management through a fully renewable electricity supply, and low-carbon sodium hydroxide sourcing. The most substantial reductions arise from switching to 100% renewable electricity, whilst replacing conventional diesel with biodiesel or co-firing coal with biomass yields only marginal gains. Using lower-carbon sodium hydroxide could reduce total climate impact by up to 10%, depending on the electricity mix used in its production.

Figure 7.13. Climate Change Reduction Pathways for Nickel Sulphate Hexahydrate Production via High-pressure Acid Leaching and Refining



NaOH = sodium hydroxide, $NiSO_46H_2O$ = nickel sulphate hexahydrate.
Source: Economic Research Institute for ASEAN and East Asia (2025c).

7.3.4. Circularity, Recycling, and End-of-life Strategies

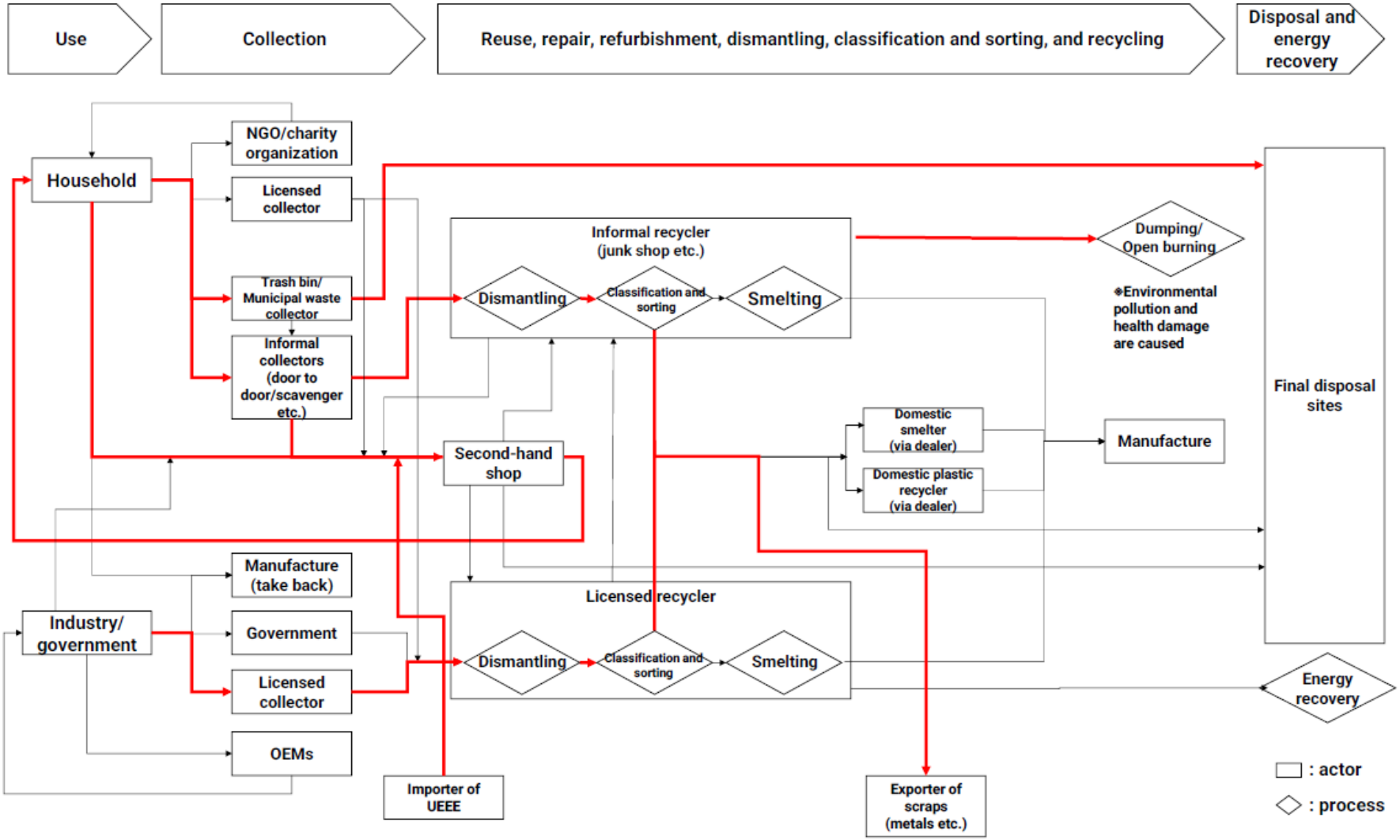
Whilst ASEAN's growing involvement in the extraction and processing of critical minerals is crucial for EV and battery value chains, it must be matched by sustained investment in circular economy strategies to minimise resource depletion, reduce emissions, and strengthen supply security. Circularity, through reuse, repair, remanufacturing, and recycling, not only mitigates environmental harm but also offers a long-term solution to reduce ASEAN's dependence on primary raw material extraction and exposure to global price volatility.

7.3.4.1. The circular economy case for battery and e-waste management

End-of-life batteries from EVs and consumer electronics contain high concentrations of valuable and recoverable materials such as lithium, cobalt, nickel, and REEs. According to ERIA's *Circular Value Chains of Electrical and Electronic Equipment in ASEAN*, urban mining from waste electrical and electronic equipment represents a critical secondary source of materials that would otherwise be imported at high cost or extracted through ecologically intensive mining processes (Oikawa and Iwasaki, 2023)

By 2035, ASEAN is expected to generate millions of used EV batteries, with Indonesia, Thailand, and Viet Nam accounting for the largest volumes. Yet, as of 2023, formal battery recycling infrastructure remains limited, and most AMSs lack binding regulatory frameworks for battery take-back or recycling. According to Oikawa and Iwasaki (2023), in several AMSs, battery and e-waste flows continue to be managed through informal scrap economies, posing major health and environmental hazards due to unsafe dismantling and disposal practices. This report indicates that end-of-life electrical and electronic equipment, including EV batteries, contains recoverable amounts of lithium, cobalt, copper, and REEs. Yet, many AMSs still lack the technical capacity and policy frameworks required to support recycling or remanufacturing at scale.

Figure 7.14. Circular Value Chain of Electrical and Electronic Equipment in ASEAN



ASEAN = Association of Southeast Asian Nations, NGO = non-governmental organisation, OEMs = original equipment manufacturers, UEEE = used electrical and electronic equipment.
Source: Oikawa and Iwasaki (2023).

The same study identifies five major structural gaps in circular value chains:

1. a lack of formal collection systems and take-back schemes for end-of-life batteries and electrical and electronic equipment;
2. limited technological access for identifying and processing high-value components;
3. an absence of product standards for quality assurance in remanufacturing;
4. insufficient public investment in recycling infrastructure; and
5. the dominance of informal actors in the metal scrap trade, which leads to health and environmental risks (Oikawa and Iwasaki, 2023).

These weaknesses compound the region's overreliance on primary mining and limit its ability to build secure and sustainable supply chains. Whilst mineral extraction delivers clear economic benefits, overdependence on it, especially in environmentally sensitive areas, risks undermining ASEAN's commitment to long-term decarbonisation and industrial resilience.

7.3.4.2. Policy and infrastructure gaps

Most AMSs do not yet have legislation specifically targeting lithium-ion battery recovery. Only a few countries, such as Malaysia, Thailand, and Viet Nam, have broader e-waste regulations that could indirectly apply. The absence of extended producer responsibility schemes for EV batteries remains a major governance gap, particularly given that such frameworks are already standard practice in the European Union, Japan, and Korea.

In Indonesia, draft regulations on the second-life use of EV batteries are under review, although implementation is pending. In Viet Nam, VinFast is piloting second-life battery storage applications, whilst Thailand is developing guidelines for safe battery dismantling and reverse logistics, supported by the Japan International Cooperation Agency and other international partners (Bhaskara, 2025; Oikawa and Iwasaki, 2023)

Malaysia shows the strongest potential capacity to recycle electronics, yet recycling rates remain low due to limited consumer awareness, poor collection systems, and the continued fragmentation of informal recycling activities.

7.4. Sustainable Biofuels and E-fuels: Supply Chains, Technology, and Potential Applications

As ASEAN advances towards carbon neutrality whilst enhancing energy security, sustainable biofuels and e-fuels have re-emerged as crucial components of a diversified clean mobility strategy. Although electrification through xEVs dominates current decarbonisation discourse, its deployment remains uneven due to infrastructural, technological, and affordability constraints across parts of the region and depends on the speed of vehicle fleet renewal. By contrast, biofuels, especially those derived from domestically abundant feedstocks, offer a pragmatic, near-term pathway to mitigate transport-sector emissions whilst strengthening rural economies and reducing fossil fuel dependency (Morimoto et al., 2021).

AMSs, particularly Indonesia, Malaysia, and Thailand, have accumulated considerable experience in deploying biodiesel and ethanol. Nevertheless, significant untapped potential remains in scaling next-generation biofuels, drop-in renewable fuels, and synthetic e-fuels. These fuels are especially relevant for hard-to-electrify segments such as aviation, maritime transport, and long-haul road freight, where direct electrification remains technically or economically challenging (Purwanto and Lutfiana, 2024).

The following sub-sections briefly outline the current policy landscape and regional strategies on biofuels and e-fuels, feedstock availability and its supply chain, technology pathways, industrial readiness, and environmental and socio-economic impacts.

7.4.1. Current Policy Landscape and Regional Strategies

Governments across the region have adopted varying biofuel mandates and blending targets. Indonesia, for instance, has incrementally advanced its mandatory biodiesel blending policy, reaching a mandatory 40% biodiesel blend from 1 January 2025. Thailand and Malaysia have similarly established structured road maps to scale up biodiesel use (B20/B30) and ethanol blends (E10/E20), supported by dedicated policy frameworks such as Thailand's Alternative Energy Development Plan and Malaysia's National Agricommodity Policy 2021–2030 (Morimoto et al., 2022) .

The promotion of diversified vehicle technologies, including ICEVs compatible with biofuels and flex-fuel vehicles, alongside biofuel development, aligns with the ASEAN Plan of Action for Energy Cooperation. In particular, these efforts support Programme Area No. 5 on Renewable Energy and Programme Area No. 6 on Regional Energy Policy and Planning (Morimoto et al., 2021).

7.4.2. Feedstock Availability and Supply Chains

ASEAN countries are well endowed with biomass resources suitable for both first- and second-generation biofuel production. Palm oil, sugarcane, cassava, molasses, coconut oil, and used cooking oil underpin existing biodiesel and ethanol programmes. Indonesia and Malaysia, for example, are global leaders in palm oil-based biodiesel production, whilst Thailand has diversified its feedstock base to include cassava-derived ethanol (Morimoto et al., 2022; Purwanto and Lutfiana, 2024).

Despite these advantages, persistent challenges remain, particularly in managing land-use trade-offs, ensuring feedstock sustainability, and safeguarding food security. Expanding advanced biofuels derived from lignocellulosic biomass, agricultural waste, algae, and municipal solid waste is therefore critical to mitigating these risks, preserving biodiversity, and reducing indirect land-use change emissions (Anbumozhi, 2020).

Logistical and infrastructural constraints continue to hinder biofuel supply chains, spanning feedstock collection and pre-treatment through to refining and final distribution. Scaling biofuel deployment across ASEAN's geographically fragmented landscape will require targeted investment in decentralised biorefineries, improved rural transport connectivity, and

supporting infrastructure such as storage and handling facilities.

7.4.3. Technology Pathways and Industrial Readiness

The technological maturity of biofuels in ASEAN varies significantly by fuel type. First-generation biodiesel and ethanol produced from edible crops are already commercially established. By contrast, second-generation biofuels, including lignocellulosic ethanol, renewable diesel such as hydrotreated vegetable oil, and algae-derived fuels, remain at the pilot, demonstration, or early deployment stage.

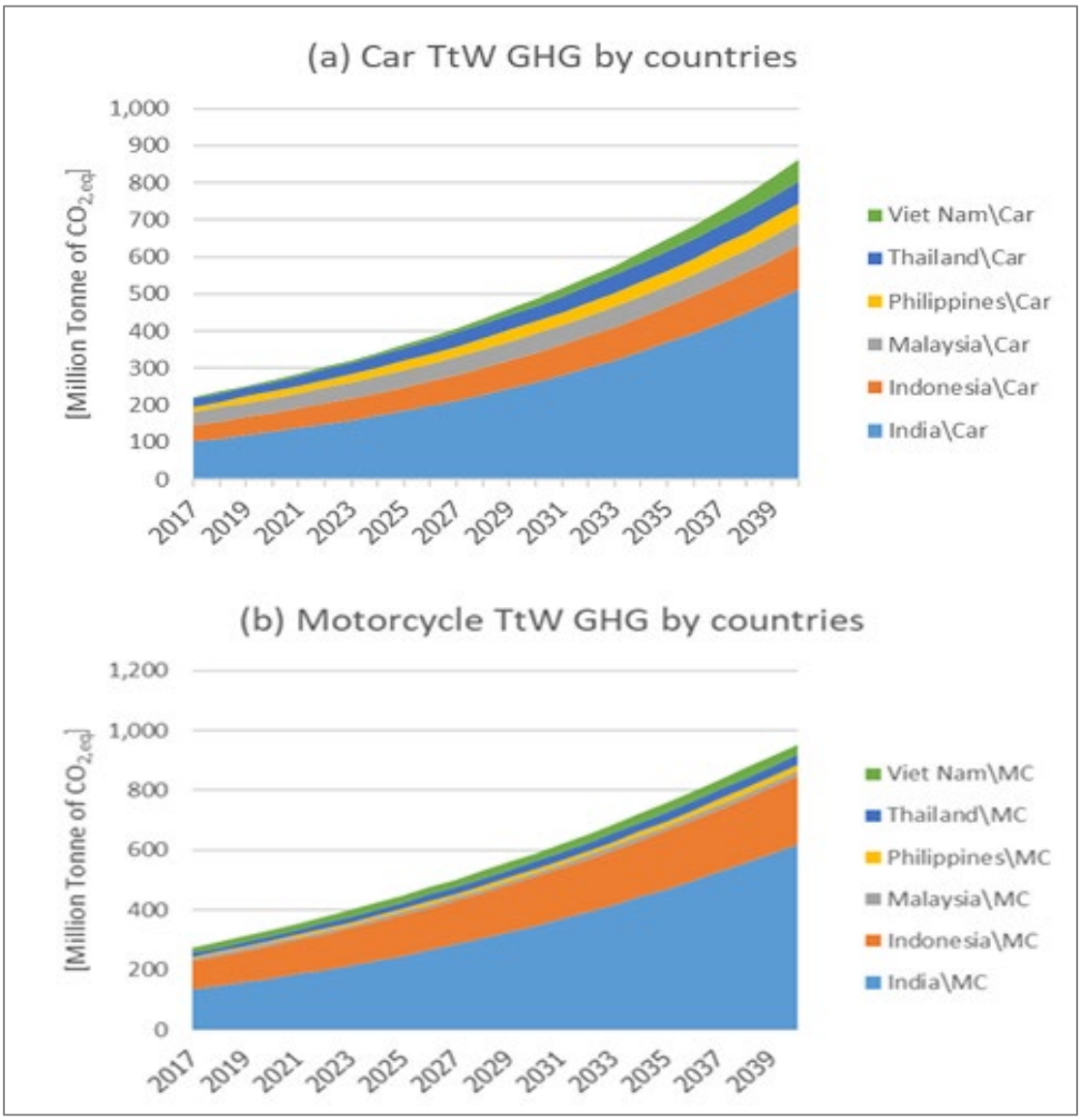
Indonesia's Pertamina has begun investing in green diesel (D100) production using hydrotreated vegetable oil technology, whilst Thailand has piloted second-generation ethanol plants that utilise bagasse and cassava pulp. However, high production costs, limited economies of scale, and constraints on technology transfer continue to impede wider adoption. Lowering these barriers will require policy-led de-risking mechanisms, enhanced international cooperation, and sustained research and development (R&D) incentives (Morimoto et al., 2022; Purwanto and Lutfiana, 2024).

E-fuels (synthetic fuels produced from green hydrogen and captured carbon dioxide) remain at a nascent stage in ASEAN. Although they offer a promising long-term alternative, particularly for aviation and heavy-duty transport, their scalability depends on the availability of abundant renewable electricity and the establishment of supportive regulatory and market frameworks.

7.4.4. Environmental and Socio-economic Impacts

LCAs of biofuels in AMSs demonstrate substantial reductions in well-to-wheel carbon dioxide emissions compared with conventional fossil fuels. For example, palm biodiesel in Malaysia, when combined with biogas recovery, records a GHG intensity of 21.20 grams of carbon dioxide equivalent per megajoule (gCO_2eq/MJ), significantly lower than the 83.8 gCO_2eq/MJ associated with conventional diesel (Morimoto et al., 2022). Similarly, ethanol produced from sugarcane or cassava in Thailand achieves net emission reductions when supported by sustainable agricultural practices.

Figure 7.15. Projection of Tank-to-wheel Greenhouse Gas Emissions, by Country (Business-as-usual Scenario)

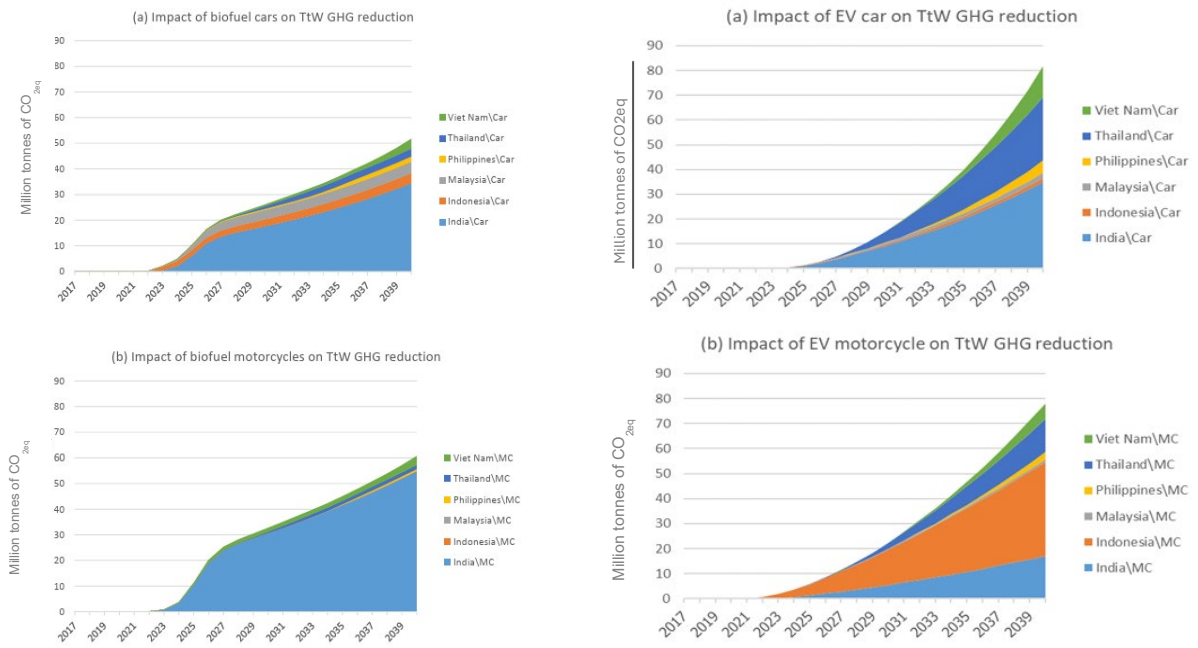


CO_2 = carbon dioxide, MC = motorcycle, TtW GHG = tank-to-wheel greenhouse gas.
Source: Morimoto et al. (2022).

Despite these benefits, potential risks, including deforestation, excessive water use, and social displacement, must be addressed through robust sustainability certification schemes and transparent land governance. Frameworks such as the International Sustainability and Carbon Certification, or locally adapted standards aligned with the Global Bioenergy Partnership indicators, can support alignment between regional production practices and global sustainability norms (Morimoto et al., 2021).

From a socio-economic perspective, the biofuel industry contributes to rural employment, farmer income, and energy access. In countries such as the Philippines and Viet Nam, biofuel programmes have supported rural economic diversification, reinforcing a mutually beneficial nexus between decarbonisation and inclusive development.

Figure 7.16. Tank-to-wheel Impact of Business-as-usual Scenario, Electric Vehicles, and Biofuels



BAU = business as usual, CO_2 = carbon dioxide, EV = electric vehicle, MC = motorcycle, TtW GHG = tank-to-wheel greenhouse gas.
Source: Morimoto et al. (2022).

7.5. Digitalisation in Automotive Manufacturing, New Technologies, and Business Models

The global automotive industry is undergoing an unprecedented transformation, driven by the convergence of digitalisation, automation, electrification, and mobility services. These shifts are reshaping traditional manufacturing paradigms and redefining competitive boundaries, drawing new entrants, such as technology firms, platform providers, and digital startups, into what has historically been a hardware-centred automotive value chain.

For ASEAN, this transformation presents both challenges and opportunities. Digital technologies such as Industry 4.0, cloud computing, artificial intelligence (AI), machine learning, Internet of Things (IoT), and digital twins are enabling more agile, efficient, and environmentally sustainable automotive manufacturing processes. However, the rise of mobility as a service (MaaS), autonomous driving technologies, and software-defined vehicles is fundamentally disrupting existing industrial structures and policy frameworks across the region.

To remain competitive, ASEAN must accelerate the integration of digital tools across the entire vehicle life cycle, from design and production to after-sales services, logistics, and mobility solutions, whilst fostering ecosystems that allow digital-native players to thrive alongside incumbent OEMs and suppliers.

This section briefly discusses the progress and opportunities of digital transformation in automotive manufacturing, software-defined vehicles and connected platforms, autonomous

driving, AI-driven mobility, and servitisation.

7.5.1. Digital Transformation in Automotive Manufacturing

Digitalisation in manufacturing, or Industry 4.0, enables a transition from traditional, linear assembly lines to smart, interconnected, and adaptive production systems. These systems deploy technologies such as IoT sensors, AI-driven analytics, robotics, and cloud-based platforms to support real-time monitoring, predictive maintenance, and flexible production scheduling.

Several AMSs, particularly Thailand and Malaysia, have begun piloting Industry 4.0 solutions in their automotive sectors. Thailand's Eastern Economic Corridor of Innovation is positioning itself as a smart manufacturing hub, supported by investments in robotics, digital supply chains, and integrated data platforms. Similarly, Indonesia's Making Indonesia 4.0 identifies the automotive industry as a priority for digital transformation.

Despite these advances, adoption remains uneven across the region. Many tier-2 and tier-3 suppliers continue to rely on manual processes and face constraints related to digital infrastructure, financing, and skills availability. Bridging this divide will require coordinated policy support, public–private partnerships, and targeted investment in digitalisation programmes for small and medium-sized enterprises (SMEs).

Digital twins – virtual representations of physical manufacturing systems – are increasingly applied to model and optimise production workflows, material flows, and energy consumption. Japanese firms operating in ASEAN have begun deploying digital twin technologies at greenfield facilities to simulate equipment layouts, test process modifications, and shorten commissioning timelines.

As manufacturing complexity grows with the rise of multi-platform EVs, digital twins will be vital in reducing cost, risk, and downtime during production transitions.

7.5.2. Software-defined Vehicles and Connected Platforms

Vehicles have been rapidly evolving into software-defined platforms, in which a growing share of value is embedded in software, connectivity systems, and digital services rather than purely mechanical components. This shift is driving demand for cross-domain integration between hardware and software, necessitating new forms of collaboration amongst automakers, tier-1 suppliers, and IT firms.

In ASEAN, Japanese automakers have begun introducing over-the-air update capabilities, advanced telematics, and connected navigation systems in higher-end vehicle models. Thailand and Viet Nam are emerging as regional testing grounds for in-vehicle infotainment systems, digital cockpit platforms, and connected fleet management solutions.

7.5.3. Autonomous Driving and Artificial Intelligence–driven Mobility

Autonomous driving and AI are poised to transform mobility across ASEAN, although their uptake remains at a nascent stage. Globally, autonomous vehicle (AV) development is progressing from advanced driver-assistance systems towards conditional (level 3) and high (level 4) autonomy. Whilst fully autonomous vehicles are not yet commercially deployed, low-speed autonomous applications and AI-assisted transport optimisation are gaining traction across the region.

Singapore leads AV development in ASEAN, with live trials of robo-taxis and autonomous buses operating in designated zones such as one-north. These pilots are supported by advanced digital infrastructure, including fifth-generation mobile network technology (5G) connectivity, smart intersections, and high-definition mapping. Operators such as nuTonomy and ST Engineering are operating within a supportive regulatory framework and a mature urban innovation ecosystem.

Thailand is piloting autonomous shuttle buses in university campuses and industrial parks, supported by Japanese partners and local research centres. In Malaysia, Cyberjaya has emerged as a testing ground for AV technologies, including vehicle-to-everything communications and cloud-based fleet coordination systems.

In the private sector, AI is transforming fleet logistics. Companies such as J&T Express are deploying AI-powered routing, predictive maintenance, and load balancing systems to optimise operations. These applications improve fuel efficiency, reduce delivery times, and lower emissions, addressing critical performance and sustainability priorities in ASEAN's logistics-heavy transport systems.

7.5.4. Servitisation

The major transformation of vehicle production systems makes it increasingly difficult to define a single trajectory for automotive industry development and market expansion. The automotive industry has evolved from a luxury item in the early 20th century to a mass necessity by the late 1990s (Buzzavo et al., 2023) and is now shifting towards a model that prioritises functionality and access over ownership. This transition reflects an increasing emphasis on services rather than products, influencing firms' market offerings, business models, and strategic orientations (Leminen et al., 2022). This phenomenon is commonly referred to as servitisation.

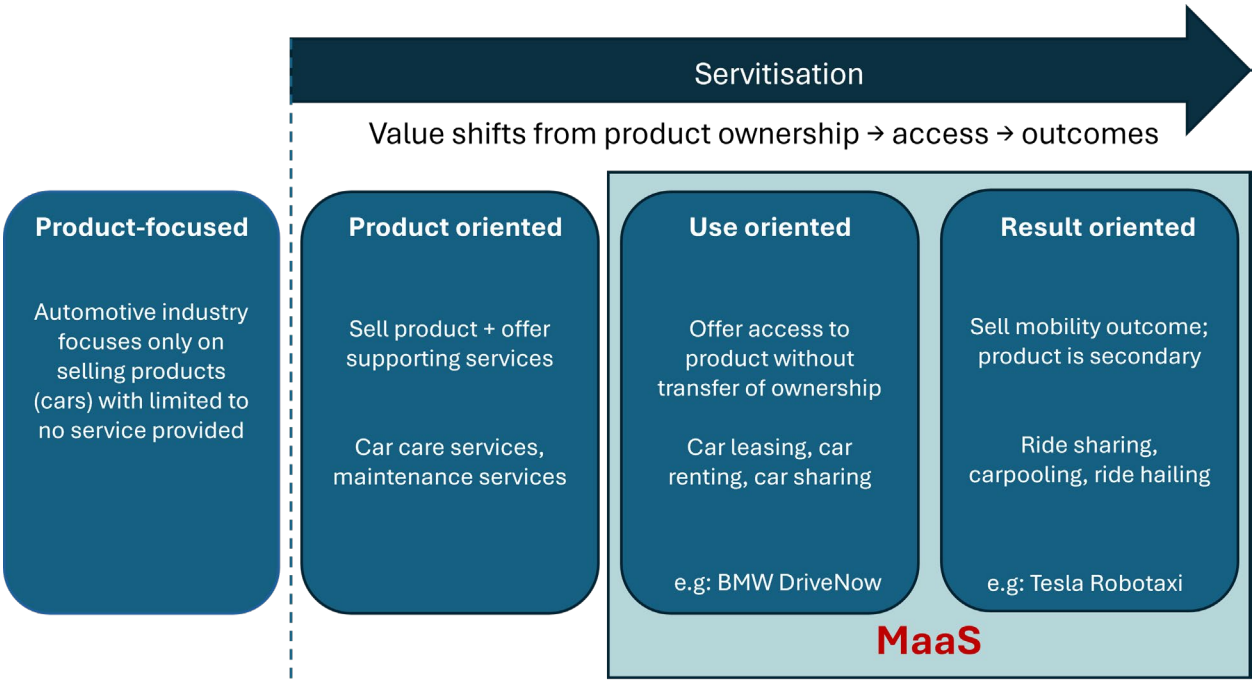
Servitisation is the transformation of firms' capabilities from selling standalone products to delivering integrated products and services that generate value in use (Baines et al., 2009). First introduced by Vandermerwe and Rada (1988), the concept emerged as manufacturing firms increasingly embedded service within their products to enhance customer value, strengthen competitiveness, and differentiate themselves from competitors. In the automotive context, servitisation translates into a shift by vehicle manufacturers or OEMs from selling vehicles as discrete products to offering bundled solutions that combine vehicles with services to deliver mobility, or MaaS (Genzlinger et al., 2020). Sertivitisation

trends in the automotive sector have become more evident over recent decades, driven by technological innovation, digitalisation, sustainability pressures, and changing consumer behaviour.

As customer preferences continue to evolve, the car's role as a status symbol is diminishing, particularly amongst younger generations of mobility users. These consumers increasingly prefer access to mobility over vehicle ownership, seeking to avoid operation and maintenance expenses such as insurance and parking (Genzlinger et al., 2020). This shift challenges the traditional automotive ecosystem dominated by OEMs (Buzzavo et al., 2023) as new value propositions increasingly centre on platform-based ecosystems and customer experience. Whilst evidence of this transition remains limited in ASEAN markets, developments in more advanced economies, particularly in Europe, indicate significant potential for future adoption in the region.

Genzlinger et al. (2020) argued that servitisation in traditionally product-focused manufacturing industries typically follows a staged process – product oriented, use oriented, and result oriented – based on Tukker's (2004) product-service system framework. Figure 7.16 depicts the servitisation journey of a traditional automotive manufacturer.

Figure 7.17. Servitisation Journey of a Car Manufacturer



MaaS = mobility as a service.
Source: Authors, adapted from Tukker (2004) and Genzlinger et al. (2020).

Figure 7.17 shows that servitisation diffuses services incrementally into business operations, with the value proposition evolving at each stage. In the initial product-oriented phase, manufacturers offer supporting services that enhance the customer experience whilst generating additional revenue streams. For example, in the case of BMW, product-

oriented services have accounted for up to 50% of revenue for manufacturers and dealers (Genzlinger et al., 2020). In the use-oriented stage, exemplified by leasing and car renting, the emphasis on ownership diminishes, allowing customers to access vehicles without transferring ownership. In the result-oriented stage, firms focus on delivering mobility outcomes rather than vehicles themselves.

Another distinguishing feature across these stages is the liability shift. As ownership progressively transfers from users to service providers, associated liabilities shift, increasing risk exposure for providers (Tukker, 2004). For OEMs, higher levels of digitalisation can mitigate these risks by enabling enhanced monitoring and control of assets, thereby facilitating the diffusion of servitised business models.

Servitisation offers manufacturing firms several strategic advantages. It enables the development of stronger, longer-term relationships with customers beyond the point of sale. By leveraging digital technologies and customer data, companies can deliver personalised, data-driven services that enhance customer experience and loyalty. Servitisation also opens access to new customer segments, particularly younger and urban populations that prioritise flexible mobility over ownership. It supports brand diversification through sub-brands, such as BMW's DriveNow, allowing firms to experiment with innovative service models without diluting their core image.

MaaS is therefore fundamentally reshaping ASEAN's transport paradigm, shifting from vehicle ownership towards on-demand, user-centric mobility. Through application-based platforms, MaaS integrates public and private modes, such as buses, trains, ride-hailing, micromobility, and car-sharing, into seamless, end-to-end travel services. ASEAN's growing urban density, digitally literate population, and persistent congestion challenges make the region an ideal environment for MaaS experimentation.

Leading platform providers, such as Grab, Gojek, and Be Group, have expanded well beyond ride-hailing into multi-service ecosystems that encompass food delivery, digital payments, financial services, and, increasingly, EV fleet operations. In doing so, they are reshaping mobility preferences and exerting growing influence over vehicle demand patterns and urban transport planning.

Several cities across the region are piloting public–private MaaS ecosystems. Singapore has embedded MaaS into its Smart Mobility 2030 strategy, combining journey planning, payments, and travel behaviour data through a unified digital interface. In Bangkok, the CityGo initiative links buses, metro lines, and private ride-hailing services via a real-time journey planning application. In Viet Nam, VinBus has collaborated with Be Group to integrate electric shuttle services into the urban MaaS landscape, providing low-emission alternatives for city travel.

MaaS platforms are also accelerating EV adoption. Grab and Gojek, in partnership with OEMs such as VinFast and Gesits, are piloting electric two-wheeler fleets, especially for delivery services and gig-economy mobility. By aggregating demand across commercial platforms, these operators help to create anchor markets for EV infrastructure, including battery

swapping networks and telematics-enabled fleet-monitoring systems.

Despite this progress, significant barriers remain. Data silos between platform operators and public authorities impede system-wide optimisation, whilst the absence of common application programming interface standards and open-data protocols limits multimodal interoperability. Regulatory frameworks have also struggled to keep pace with technological innovation, leaving MaaS platforms subject to unclear treatment under transport, data, and competition law.

MaaS in ASEAN is not just a convenience layer; it is a catalyst for EV penetration, digital infrastructure development, and more inclusive access to smart mobility. To realise this potential, ASEAN governments should recognise MaaS operators as core stakeholders in the next-generation automotive ecosystem and develop policies that incentivise zero-emission fleets, promote platform interoperability, and ensure secure, equitable access to mobility data.

Finally, despite its potential, servitisation in general still presents significant challenges. Profitability remains a key concern, as mobility services often involve high operating costs and thin margins. Internally, firms may encounter organisational resistance, as employees and leadership accustomed to product-centric models may be reluctant to embrace service-oriented strategies due to cultural inertia or concerns regarding the cannibalisation of existing businesses. Operational complexities also arise in managing shared-use services, including user behaviour, logistics coordination, and service quality. The collection and use of customer data raise concerns related to privacy and compliance with evolving regulatory frameworks. Whilst automotive manufacturing features high barriers to entry, mobility services are more accessible, exposing established OEMS to competition from nimble, digital-native firms whose platform-based models challenge incumbents' capacity to adapt quickly.

7.6. Digital Talents in the Automotive Industry

The rise of emerging digital technologies, such as digital twins, AI, and IoT (Section 7.5) is reshaping supply chains across many industries, including the automotive sector (Pourrahmani et al., 2022; Damtew, 2024). Whilst digitalisation in the automotive industry delivers clear benefits, such as higher efficiency, lower costs, and expanded opportunities for innovation and collaboration, it also transforms the broader ecosystem. These changes affect business models, customer behaviour, and, critically, the skills required of the workforce.

The automotive industry is already one of the largest adopters of advanced automation. Bartos et al. (2021) highlight that robotics applications are widespread in automotive manufacturing, particularly in automated assembly, paint spraying, and quality inspection (Robotics Business Review, 2021; Bartos et al., 2021). Looking ahead to 2030, roles such as robotics engineers, data analysts, and data scientists are expected to grow rapidly. Skills related to AI, big data, technological literacy, leadership, and social influence are projected to become increasingly essential in the next 5 years (World Economic Forum, 2025).

Maintaining ASEAN's competitiveness in the automotive sector, therefore, requires digital transformation to be matched by sustained investment in human capital development.

Preliminary observations across several AMSs reveal the following country-specific patterns:

In Cambodia, demand for digital talent in the automotive sector is emerging but remains uneven, with only a limited number of firms actively recruiting for roles in robotics, AI, or software engineering. Higher education institutions and technical training providers have strong foundations in core engineering and manufacturing disciplines, but curricula require updating to incorporate emerging digital skills. Greater flexibility in learning models and improved access to modern laboratory facilities are also needed. Industry–academia collaboration exists but remains limited in scale. National frameworks, including the Cambodia Industrial Development Policy and the Automotive and Electronics Sectors Development Roadmap, provide a strong policy foundation by emphasising public–private partnerships, upskilling programmes, and innovation ecosystems. However, stakeholders call for more targeted support, especially for private institutions, and better coordination to translate policy objectives into practical outcomes. Strengthening multi-stakeholder collaboration, modernising curricula with Industry 4.0 tools, and enhancing policy delivery mechanisms are therefore critical priorities.

In Indonesia, the adoption of advanced technologies in the automotive sector remains modest, particularly amongst SMEs. Uneven digital infrastructure, gaps in information and communication technology (ICT) access, and financial constraints continue to limit technology uptake. Although government programmes aim to accelerate upskilling in manufacturing-related technologies, fewer than 1% of workers possess advanced technical capabilities, indicating the scarcity of a highly skilled workforce. Skills mismatches persist, especially within the technical and vocational education and training system, as reflected in relatively high unemployment rates amongst its graduates. Enhancing automotive competitiveness, closing skills gaps, and fostering technology adoption will require progress across four major pillars: (1) policy and institutional reform; (2) curriculum transformation; (3) expansion of talent development infrastructure, such as centres of excellence; and (4) sustained investment in EV ecosystems and long-term workforce development.

In Malaysia, strategic frameworks such as the National Automotive Policy 2020 and the New Industrial Master Plan outline the long-term vision for the sector. Despite a sufficient supply of graduates, significant gaps remain between academic training and industry requirements. The automotive sector continues to focus largely on manufacturing and assembly, with limited R&D activity, resulting in continued dependence on external technologies and foreign expertise for smart mobility solutions. Additional constraints include relatively low wage competitiveness, inadequate facilities and infrastructure, slow technology adoption amongst SMEs, and gaps between policy formulation and implementation. Strengthening industry–academia collaboration, modernising curricula, encouraging more competitive remuneration, expanding R&D, and improving alignment between policy design and execution are essential to building a stronger digital talent ecosystem.

In the Philippines, direct automotive manufacturing activities declined from 2017 to 2021,

with the number of establishments falling by 31.53% and employment by 8.86%, alongside a 15.15% contraction in total income. By contrast, maintenance and repair services demonstrated resilience, with a 12.13% growth in establishments and a 26.07% increase in total income, highlighting the growing importance of the aftermarket sector. These services are delivered by both formal providers, employing Technical Education and Skills Development Authority–certified or manufacturer-trained technicians, and informal operators that rely heavily on practical experience. These trends suggest that closer collaboration amongst training institutions, industry players, automotive associations, and government bodies is essential to enhance digital skills. Policy harmonisation, expanded training in underserved areas, improved digital literacy and stronger ICT and soft skills development should be prioritised.

Thailand has been ASEAN's largest vehicle producer for more than 2 decades. As the industry undergoes green transformation and digital transformation, shifting towards EVs and software-defined mobility, it increasingly demands cross-disciplinary talent combining mechanical engineering, electronics, IT, and sustainability expertise. National initiatives such as the 30@30 policy and the EV 3.5 policy provide a regulatory foundation to accelerate low-carbon vehicle production and encourage local manufacturing through tax incentives and financial support. Key challenges include slow adaptation of academic curricula to industry demands, limited long-term funding for R&D activities, and insufficient laboratory facilities at universities. Resolving these issues will require curriculum reform, expanded public–private training programmes, development of inter-disciplinary education pathways, R&D tax incentives for private firms, improved university laboratory infrastructure, and systematic monitoring of outcomes.

In Viet Nam, digital transformation presents significant opportunities and challenges. Digitalisation can enable firms to leapfrog legacy technologies and enhance global competitiveness. However, without a robust pipeline of digital talent, skills gaps could widen and limit the sector's ability to scale or move into higher-value activities. A strengths, weaknesses, opportunities, and threats (SWOT) analysis highlights Viet Nam's institutional foundations and emerging partnerships as key strengths, whilst misalignment between training provision and industry demand remains a major weakness. Policy support for digital transformation and EV adoption presents clear opportunities, but skills gaps and SME resource constraints pose ongoing threats. Strengthening industry–education partnerships, modernising training infrastructure, and implementing retention policies for highly skilled workers are therefore critical. By aligning workforce development with future industry demands, Viet Nam can strengthen its competitiveness and position itself as a regional hub for digital automotive innovation.

7.7. Need for, and Ecosystem of, Semiconductors in the Automotive Sector

The surge in global demand for semiconductors, propelled by advances in AI, 5G, and clean energy transitions, has reinforced their strategic importance across industries. One of the most semiconductor-intensive sectors is electric mobility. As Southeast Asia positions itself

as a major hub for EV manufacturing and battery production, the intersection between semiconductor development and the EV value chain becomes strategically crucial. With growing semiconductor capabilities and vast critical mineral reserves, ASEAN stands to play a pivotal role in an integrated EV–semiconductor value chain.

Furthermore, chips govern battery management systems, power electronics, advanced driver-assistance and autonomous driving features, and infotainment and connectivity platforms. High-performance microcontrollers and power semiconductors are essential for inverters, on-board chargers, and electric drive systems. As a result, EV performance, efficiency, and safety are closely linked to the sophistication of their semiconductor components.

According to ERIA (2025), the global semiconductor industry is projected to reach US$1 trillion by 2030, whilst ASEAN's market is expected to grow from US$31.32 billion in 2023 to US$52.9 billion by 2032. The region's established strength in assembly, testing, and packaging (ATP), especially in Malaysia, Viet Nam, and the Philippines, positions ASEAN to support EV-specific semiconductor requirements, particularly in power electronics, sensors, and automotive-grade chips.

From the demand side, the rapid expansion of EV manufacturing in ASEAN, led by Thailand, Indonesia, and Viet Nam, necessitates more localised semiconductor capabilities. Thailand, dubbed the Detroit of Asia, is diversifying into EV assembly through government incentives and partnerships with Chinese and Japanese automakers. However, it remains heavily dependent on imported semiconductors and lacks upstream fabrication capacity.

Viet Nam's success in attracting investments from firms such as Intel, Samsung, and Amkor shows the potential for closer alignment between electronics and EV production ecosystems. From 2012 to 2023, Viet Nam's semiconductor exports grew from about US$1 billion to over US$20 billion. In parallel, the country is scaling up EV production through companies such as VinFast, whilst strengthening capabilities in battery manufacturing and chip-related activities.

Malaysia's Penang cluster, home to firms such as Infineon and ASE, is evolving into a full-stack ecosystem encompassing ATP, integrated circuit design, and R&D. These capabilities are critical for EV component suppliers. The country's strategic pivot towards higher-value design and advanced packaging is supported by institutions such as the Penang Skills Development Centre, which plays a key role in preparing the workforce for emerging EV-related semiconductor demands.

Thus, a defining strength of ASEAN lies in the complementarity of national capabilities, which should be built towards vertical integration and regional cooperation. Indonesia can supply nickel and cobalt; Malaysia can support chip testing, packaging, and design; and Viet Nam can serve as a manufacturing base for electronics and EVs. Through initiatives such as the ASEAN Framework for Integrated Semiconductor Supply Chain and national EV road maps, coordination across these segments is gradually improving.

To move from a comparative advantage in cost-competitive manufacturing to a competitive

advantage in innovation, ASEAN must prioritise three strategic shifts:

1. Build design and fabrication capabilities. Singapore has taken the lead by hosting advanced fabrication plants and electronic design automation hubs. Expanding this model to Malaysia and Viet Nam, through targeted incentives, skills development, and knowledge transfer, would broaden the region's capacity to design and fabricate automotive-grade semiconductors.
2. Invest in critical mineral refining and recycling. Despite abundant mineral resources, refining remains a bottleneck. Investment in sustainable refining, battery recycling, and advanced processing technologies, especially for rare earth elements, cobalt, and high-purity silicon, is vital to secure upstream continuity for the EV–semiconductor nexus.
3. Develop integrated innovation zones. Special economic zones in Cambodia, Viet Nam, and the Lao People's Democratic Republic offer scope for cross-border EV and semiconductor ecosystems. Joint ventures could create clusters where raw material inputs, chip assembly, and EV component manufacturing are co-located, boosting resilience and reducing lead times.

The development of ASEAN's semiconductor industry is therefore not only a technological imperative but also a strategic enabler of the EV revolution. As electric mobility accelerates, demand will rise for reliable, automotive-grade chips tailored to power electronics, energy management, and autonomous systems. By capitalising on its mineral wealth, skilled labour base, and growing manufacturing base, Southeast Asia can position itself as the battery and the brain of the global EV industry.

With targeted investment, stronger regional coordination, and coherent industrial policy, deeper integration of the semiconductor and EV value chains in ASEAN could become a transformative engine for sustainable development, technological sovereignty, and long-term economic resilience in the region.

7.8. Roles of Strategies in Vehicle Fleet Renewal

ASEAN's enhanced commitment to reducing carbon emissions places the transport sector at the centre of regional decarbonisation efforts. Road transport accounts for about 30% of regional GHG emissions, driven by rapid growth in vehicle ownership and continued dependence on fossil fuels. With motorcycles (in several AMSs) and passenger cars dominating the vehicle fleet, and demand projected to rise sharply, energy consumption and emissions will continue to grow in the absence of decisive policy intervention.

A key structural challenge is the persistence of ageing and inefficient vehicles, reflecting the limited adoption of structured fleet renewal policies across the region. ERIA (forthcoming) provides insights that underscore the need for a transition towards cleaner vehicle technologies in road transport, backed by incentives and stronger regulatory frameworks in Indonesia, findings that are broadly applicable across ASEAN.

The study identifies a steady increase in xEV sales in Indonesia over time, alongside a declining share of ICEV sales. This trend, supported by government incentives and growing consumer awareness, is expected to reduce fossil fuel consumption and lower transport emissions over the long term. Whilst conventional ICEV sales decline, the study assumes continued demand for highly efficient and low-cost ICEVs, such as Indonesia's low-cost green car segment. The modelling exercise evaluates several scenarios, including a one-off scrappage programme in 2030, gradual scrappage over 2030–2035, and increased annual vehicle registration taxes.

The combined scenario of gradual scrappage and higher annual taxation delivers the greatest reduction in fuel consumption and carbon dioxide emissions relative to other policy options. This finding indicates that continuous scrappage programmes are more effective than one-off interventions, with their impact further enhanced by higher annual taxes that incentivise vehicle replacement. As older, less efficient vehicles are replaced with newer and more efficient models, particularly xEVs, the resulting reductions in energy consumption and emissions become increasingly significant, underscoring the importance of fleet renewal within road transport decarbonisation strategies.

To support fleet renewal, governments can deploy a mix of policy instruments, including standards, subsidies, regulations, taxation, scrappage schemes, and public procurement:

- Standards can be introduced through emissions, fuel efficiency, or energy consumption benchmarks for EVs to limit environmental impacts.
- Subsidies reduce financial barriers to EV adoption and can target both consumers and manufacturers.
- Regulations support effective use of vehicles through measures such as roadworthiness testing, charging infrastructure deployment, and low-emission zones.
- Taxes can incentivise EV adoption through measures such as value-added tax reductions, income tax amnesty, or corporate tax incentives.
- Scrappage programmes provide direct financial incentives for replacing older, inefficient vehicles with cleaner alternatives.
- Public fleet mandates enable governments to lead by example by requiring EV adoption within public vehicle fleets.

Cost–benefit analysis is applied to evaluate alternative policy options based on the net social benefits they generate. Results indicate that scrappage programmes deliver the greatest benefits when combined with well-designed tax reforms. This integrated approach yields significantly greater net benefits than implementing either measure in isolation. Tax incentives should prioritise reductions in upfront costs for low- and zero-emission vehicles to accelerate adoption, complemented by regulatory measures such as age limits for high-emission vehicles or stricter emissions standards to ensure effective fleet modernisation. Given that the rising TCO for HEVs is largely driven by import dependence, governments should introduce policies that incentivise local assembly and production. These may include tax incentives, investment support for domestic manufacturers, or partnerships with global

automotive companies to localise supply chains.

Continued investment in battery R&D, alongside support for local battery manufacturing, will help sustain declining cost trends for PHEVs and BEVs, ensuring their increasing competitiveness compared with conventional vehicles over time.

Clear mechanisms for monitoring and evaluation should be established to assess programme effectiveness. Periodic reviews are necessary to adjust incentives, address unintended consequences, and ensure continued alignment with market and technological developments.

Finally, fleet renewal strategies can be further strengthened by incorporating the recycling potential of materials embedded in end-of-life vehicles. Adopting a circular economy perspective, the study maps the material composition and recycling value of two- and four-wheeled vehicles. The analysis identifies key recyclable materials, such as steel, aluminium, copper and brass, and battery components, and evaluates their economic value across ICEVs, BEVs, HEVs, PHEVs, and fuel cell EVs. Electric and hybrid vehicles contain higher concentrations of high-value materials, including nickel, REEs, and lithium-based compounds, enhancing their recycling potential despite relatively modest mass fractions.

7.5 Vehicle Industry Waste

Finally, the expansion of the automotive industry in ASEAN has heightened concern over the management of end-of-life vehicles (ELVs). By around 2035, most ASEAN countries will face a sharp increase in the volume of vehicles requiring dismantling and disposal. As several studies have pointed out (e.g. Kojima et al., 2018; Iwasaki et al. 2025), automotive recycling in the region is still dominated by the informal sector. In the absence of comprehensive ELV management systems, informal dismantling activities have generated significant environmental and public health risks. Formalising informal dismantlers, through the enforcement of regulations and targeted capacity-building programmes, is therefore critical to improving ELV management. This need is becoming more urgent as the vehicle fleet transitions from ICEVs to xEVs.

In response, some AMSs have started introducing extended producer responsibility frameworks that assign to vehicle manufacturers the responsibility for ELV dismantling and recycling. However, gaps remain between policy design and on-the-ground implementation, and many ELV-related challenges persist. Other countries are still at the phase of considering extended producer responsibility legislation or are exploring alternative policy approaches.

Recent ERIA research (Iwasaki et al., 2025) outlines the policy context and options required to establish effective and environmentally sound vehicle dismantling and recycling systems across the region.

Serious environmental and safety concerns

Informal ELV dismantling operations pose severe risks to environmental quality and occupational safety. Hazardous substances such as waste oil, brake fluid, and battery acid are frequently released directly into soil and water systems due to the absence of proper

treatment facilities. This results in air, water, and soil pollution, harming ecosystems and threatening the health of surrounding communities. Workers in informal dismantling operations often perform hazardous tasks without adequate protective gear or safety measures, leading to a high incidence of industrial accidents and chronic exposure to toxic materials. Although informal dismantlers remain dominant, a few companies have started operating formal dismantling facilities using advanced equipment and safer technologies.

Regulatory gaps and delayed technology adoption

In many ASEAN countries, comprehensive legal frameworks governing ELV collection, dismantling, and recycling are largely underdeveloped. This regulatory gap allows informal activities to persist and discourages investment in environmentally sound and technologically advanced recycling systems. Without clear regulations or targeted incentives, adoption of cleaner and more efficient dismantling technologies has progressed slowly. Establishing a robust legal framework that manages the entire ELV cycle is therefore essential.

Incentive mechanisms for compliant dismantlers are also critical. Malaysia's authorised automotive treatment facilities system provides an illustrative example. Certified dismantlers benefit from preferential access to ELVs, such as crashed vehicles supplied through insurance companies, thereby reducing acquisition costs and improving commercial viability.

New challenges: Electric vehicle proliferation and the circular economy transition

The rapid growth of EVs and HEVs presents new and urgent challenges for ELV recycling. EV batteries contain high concentrations of critical minerals, including lithium, cobalt, and nickel, making their recovery strategically important for resource security and environmental protection. However, most ASEAN countries lack the technology and infrastructure required to recycle these batteries safely and efficiently.

ERIA (2025b) points out the need to establish circular value chains for used batteries. Informal dismantlers generally lack the technical capacity to manage EV dismantling, given the fundamental differences between EV and ICEV platforms. Nevertheless, this transition presents an opportunity to accelerate the formalisation of dismantling activities, as EV dismantling requires higher technical standards and regulatory oversight.

Recommendations: Building sustainable end-of-life vehicle recycling systems

This study concludes that ASEAN countries should adopt a multi-faceted approach to establish sustainable ELV recycling systems:

- All AMSs should establish ELV dismantling and recycling legislation or systems tailored to national economic conditions and institutional capacity.
- Vehicle owners should be encouraged to replace older vehicles with poor emission performance through stricter inspection regimes and enforcement. Introducing maximum age limits for passenger vehicles could be considered.

- Existing licensing scheme for dismantlers and recyclers (e.g. in Malaysia, the Philippines, and Viet Nam) should be strengthened. These schemes should incorporate traceability systems for ELV and recyclable materials; battery collection and reuse mechanisms; and proper disposal of automotive shredder residue, chlorofluorocarbons, waste oil, and other hazardous wastes. Preferential treatment for licensed recyclers should be considered.
- Quality standards and testing protocols should be established for the reuse, repurposing, and refurbishment of second-hand parts. For used EV batteries, a battery passport system should be introduced to ensure traceability and safety.
- Capacity building for ELV management should be strengthened by the central and local governments.
- Non-AMSs should support AMS efforts to establish legislation or systems on appropriate ELV dismantling and recycling.
- Non-ASEAN partners should support AMSs in developing ELV legislation and management systems.
- International partners should facilitate technology transfer and private sector collaboration to support advanced ELV dismantling and recycling, fostering regional ELV circularity ecosystems.
- Collaboration between ASEAN and non-ASEAN partners should be pursued to establish standards for recycled materials, assess recycling costs and capacities, and conduct research on battery testing, reuse, and safety.

7.6. Conclusion

This chapter examines the ASEAN region as it transitions towards a sustainable automotive sector through a cradle-to-cradle framework. The region's shift from ICEVs to xEVs, focusing on the life-cycle assessment of emissions and the TCO for consumers, has been evaluated.

The strategic importance of the region's critical mineral reserves and the necessity of developing local battery manufacturing and semiconductor ecosystems are amongst the highlighted elements. An urgent need exists to embrace circular economy strategies, including formalised vehicle recycling and the management of end-of-life batteries. The roles of biofuels, digitalisation, and human capital development remain vital to ensuring long-term industrial resilience.

Ultimately, the chapter highlights the importance of a comprehensive strategic policy road map to balance decarbonisation with economic competitiveness across Southeast Asia, and to accelerate the transformation of the regional automotive industry. This strategic road map should provide an architecture for a competitive, resilient, and circular automotive future. Measures such as the harmonisation of standards for EV battery passports, investment in the critical mineral downstream industry, and the leveraging of ASEAN's dominance in

semiconductor assembly, testing, and packaging (ATP) should help the region transition from a basic manufacturing hub into a global leader in next-generation mobility.

First, a strategic vision: from industrial capacity to sustainable circularity. This transition necessitates a fundamental reconfiguration of the ASEAN automotive sector, pivoting from a legacy of export-driven capacity expansion to a sophisticated cradle-to-cradle industrial paradigm. Beyond mere environmental adjustment, the shift demands a strategic mandate for Southeast Asian competitiveness to play a more significant role in decarbonising the global economy. The traditional focus on assembly volume is being superseded by a focus on value retention, material circularity, and software integration.

The proposed transformation is anchored by a three-pillared driver: the decarbonisation of the regional fleet, the digitalisation of the manufacturing core, and the circularity of the material supply chain. These forces require a holistic rethinking of the entire vehicle life cycle, which demands that policymakers look beyond simplistic tailpipe metrics and employ rigorous analytical methodologies that reflect the granular realities of industrial manufacturing.

Second, the cradle-to-cradle analytical framework. ASEAN's strategic pivot must be grounded LCA and TCO models rather than tailpipe-only metrics. Reliance on tank-to-wheel data alone obscures the upstream environmental costs of battery production and the downstream advantages of recycling. For policymakers, adopting an LCA approach provides the empirical basis required to balance the higher carbon intensity of current electricity grids in some AMSs with the long-term operational efficiency of electric drivetrains.

Third, economic parity and the TCO tipping point. Affordability remains the primary barrier to adoption in Southeast Asia. The rapid growth of servitisation business models, including MaaS, whose main objectives include tackling these affordability issues, is unavoidable. For MaaS players, including both individual owners and large-scale fleet operators such as Grab and Gojek, environmental alignment must follow economic logic. TCO should serve as the primary market signal, shifting the focus from a high initial purchase price, such as the manufacturer's suggested retail price, to the maintenance dividend yielded by fewer moving parts and superior energy efficiency.

Fourth, upstream resilience: regional strategies in critical minerals and sustainable mining that include circular value chains. ASEAN stands at a strategic crossroads, possessing 46% of global nickel reserves; 20% of REEs; and significant cobalt, tin, and manganese. In this regard, the regional goal should shift from acting as a primary exporter to becoming a global value-added hub. Currently, the majority of certain critical minerals from the ASEAN region are exported to a single country outside the bloc, creating a monopsony in the trade of those commodities. Reclaiming this value chain is a prerequisite for regional industrial resilience.

By 2035, ASEAN will face a massive surge in ELVs. Policymakers must view these vehicles not as waste, but as a source of secondary mines. Crucially, GHG savings achieved by avoiding primary material production through recycling consistently offset the emissions from the

energy used during the scrappage process, a vital grave-to-cradle selling point for regional authorities.

Fifth, diversified decarbonisation: biofuels and e-fuels. Biofuels are not merely a stopgap; they represent a pragmatic, long-term solution for hard-to-electrify segments, including long-haul heavy-duty freight, maritime transport, and aviation. They also serve as a tool for rural economic diversification across the AMSs. E-fuels are also beginning to demonstrate usage and production potential within ASEAN.

The development of e-fuels should accelerate once renewable electricity, with which the region is potentially well endowed, becomes widely deployed. This must be supported by conducive regulatory and market frameworks, with initial commercial demand likely emerging from non-road transport sectors such as aviation and maritime shipping.

Sixth, digital ecosystems: manufacturing, talent, and semiconductors. The automotive industry is evolving from a hardware product into a software-defined vehicle platform. ASEAN's strength in the ATP of semiconductors, led by Malaysia, the Philippines, and Viet Nam, represents its most significant strategic advantage in this shift. The well-planned development of talent within digital ecosystems, manufacturing, and semiconductor industry is a crucial factor in establishing a competitive regional automotive industry.

Finally, strategic implementation: policy instruments for fleet renewal. To achieve their climate goals, AMSs must accelerate the decommissioning of ageing, inefficient vehicle fleets, as they hinder the impact of new vehicle technology penetration on decarbonisation and energy savings. The continued use of an old and inefficient vehicle fleet is detrimental not only to air quality and energy conservation but also to new vehicle sales. Because the road transport sector currently accounts for 30% of regional emissions, the speed of fleet renewal will ultimately dictate success.

Chapter 8

Transition Strategies and Policy Recommendations

This chapter aims to visualise the to-be state of the Association of Southeast Asian Nations (ASEAN) automotive industry and assess the gap between this desired future and the current trajectory. Through a systematic analysis of this gap, the chapter provides policy recommendations designed to close it, thereby supporting ASEAN's transition towards a more competitive, sustainable, and future-ready automotive ecosystem.

8.1. The To-Be State of the Next-Generation ASEAN Automotive Industry: A Varied Pathway

This section outlines ASEAN's future strategic positioning within the global automotive value chain, anchored in its existing industrial strengths whilst adapting to rising pressures related to costs, carbon constraints, and competitiveness. It introduces a differentiated pathway approach that balances short-term resilience with long-term structural transformation, driven by digitalisation and decarbonisation. This framework forms the foundation for the policy recommendations presented in the subsequent sections.

8.1.1. Strategic Rationale for a Varied Pathway

ASEAN faces a multi-pathway challenge (Chapter 6). The region must continue to leverage its dominance in internal combustion engine vehicles (ICEVs) and hybrid electric vehicles (HEVs), which are expected to account for 87% of regional sales by 2035, whilst adapting to the global shift towards electrified vehicles (xEVs). The continued deployment of ICEVs compatible with biofuels, alongside HEVs, represents another important pathway, reflecting diverse market conditions, technological capabilities, and energy endowments, with sustained export demand further reinforcing the case for a varied approach.

Key ASEAN export destinations, including the Middle East, South America, and Oceania, continue to favour ICEVs and HEVs due to infrastructure limitations and affordability constraints (Section 6.4). However, intensifying global decarbonisation pressures, most notably from the European Union (EU) Carbon Border Adjustment Mechanism (CBAM) and the original equipment manufacturer (OEM) Scope 3 emissions requirements, necessitate innovation within ASEAN's ICEV and HEV portfolio alongside sustained investment in xEV capabilities.

Uncertainty surrounding global powertrain trajectories further validates ASEAN's need for a diversified pathway. In the United States (US), for example, projections for xEV sales in 2035 range widely, from as low as 12% to as high as 71%, depending on policy developments, including ongoing debates over e-fuel exemptions in the EU (Section 4.4).

Against this volatile backdrop, ASEAN must contend with its own structural constraints. Vehicle prices exceed median household income by 64% in Indonesia and 26% in Thailand, whilst charging infrastructure remains limited, with an average of 42–64 xEVs per public charger, compared with about 8 in China (Section 4.3.1; Section 5.1).

These affordability and readiness gaps underscore the importance of a balanced transition strategy, one that sustains production volumes and export competitiveness through ICEV and HEV platforms whilst incrementally laying the groundwork for a pragmatic and economically viable xEV transition.

8.1.2. To-Be Vision Pillars

A varied pathway is expected to be sustained by the following five to-be vision pillars:

1a. Establishing ASEAN as a competitive ICEV and HEV export hub
1b. Fostering an advanced, cost-competitive, and integrated supply-chain network
2a. Gradually integrating into the xEV component supply chain
2b. Decarbonising the automotive supply chain
3. Developing innovative mobility services that match the needs of the ASEAN market

Pillar 1a: ASEAN as a Competitive ICEV and HEV Export Hub

Whilst major markets such as the EU, the US, and China are rapidly shifting towards battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs), the rest of the world (RoW) is expected to retain a powertrain mix that remains heavily weighted towards ICEVs and HEVs. In these RoW markets (excluding ASEAN), xEV sales are forecast to rise from 5% to 38% from 2024 to 2035. Nevertheless, HEVs are still projected to account for 27% of total sales, whilst ICEVs are expected to retain a 35% share (Section 4.2).

From a demand perspective, this sustained role for HEVs is driven by persistent infrastructure and economic constraints. High electricity prices and relatively lower fuel costs in many RoW markets reduce the total cost of ownership advantage of xEVs. In developed markets, however, xEVs are estimated to be 14% cheaper to own than ICEVs over a 10-year period (Section 4.2). As a result, HEVs remain a practical transitional solution for the rest of the world, balancing decarbonisation goals with affordability and infrastructure constraints.

From a supply perspective, ASEAN is well-positioned to serve rising global demand for HEVs, supported by its established production scale, cost-competitiveness, and specialised vehicle platforms. In 2023, the region exported US$12 billion worth of passenger vehicles (excluding intra-ASEAN trade) to more than 120 countries, including key markets in the Middle East, South America, and Oceania, where ASEAN-produced vehicles are well-suited to local road conditions and usage patterns (Section 6.4). ASEAN's manufacturing edge lies in its capacity to produce versatile, regionally adapted models, such as pick-up trucks (18.2% of ASEAN sales) and multi-purpose vehicles (15.8%), optimised for durability, high ground clearance, and load-carrying capability.

Digitalisation can further reinforce this export advantage. As global expectations shift beyond powertrain type towards intelligent, connected, and traceable vehicles (Carlson and Walquist, 2025), ASEAN must increasingly equip its ICEV and HEV platforms with digital capabilities. Features such as advanced driver assistance systems, telematics, and software-driven in-vehicle functions are becoming standard expectations, even in non-BEV models. These capabilities offer ASEAN a pathway to differentiate its exports, alongside established strengths in cost-competitiveness and product reliability.

To remain competitive amidst rising global sustainability demands, ASEAN's ICEV and HEV exports must progressively align with evolving decarbonisation expectations. This shift begins with future-proofing ASEAN's manufacturing base, ensuring that export platforms become increasingly efficient, adaptable, and compatible with emerging low-carbon requirements. Detailed strategies for vehicle- and supply-chain decarbonisation are addressed in later sections.

Pillar 1b: ASEAN as an Advanced, Cost-competitive, Integrated Production Hub

ASEAN's automotive industry has long relied on low-cost labour as a core source of competitiveness, similar to China's development model several decades ago. However, whilst China successfully transitioned into a high-technology manufacturing leader by leveraging scale, automation, and digitalisation, ASEAN has struggled to replicate this shift. Low-cost labour, ranging from about US$192 per month in Indonesia to US$766 per month in Malaysia, is no longer a sustainable competitive edge, particularly as competitors such as India (about US$248 per month) narrow the cost gap and global production standards continue to advance.

ASEAN's production network, which remains strong in ICEV and HEV manufacturing, is increasingly constrained by heavy reliance on manual labour and ageing infrastructure. Survey results reveal the depth of these struggles: 46% of respondents reported declining efficiency due to outdated machinery. This issue is particularly pronounced in Cambodia and the Lao People's Democratic Republic (Lao PDR), where 100% of respondents cited inefficiencies, followed by the Philippines at 81%. Low labour productivity was identified as a barrier by 68% of respondents, with unanimous concern in Lao PDR and Myanmar (100%). Furthermore, 47.7% of respondents considered advanced manufacturing tools prohibitively expensive, with 100% of respondents in Cambodia, Lao PDR, and Myanmar expressing this view. These findings underscore ASEAN's lag in adopting modern production methods at a time when global competitors are investing heavily in smart factories and automation, eroding ASEAN's cost-competitiveness. The adoption of digital supply-chain tools offers a pathway to overcome legacy inefficiencies and strengthen ASEAN's position as a responsive and connected production base amidst growing global uncertainty.

In the to-be state, ASEAN operates as a cost-competitive and fully integrated production

network – ASEAN as One – in which national strengths are no longer siloed but interconnected within a cohesive, high-efficiency ecosystem. Thailand leads in final vehicle assembly, Indonesia anchors battery materials and upstream processing, and Malaysia specialises in electronics and power components, with these capabilities linked through a digitally integrated supply-chain architecture. Cloud-based platforms enable seamless coordination of parts, digital manifests, and end-to-end tracking of material flows from suppliers to assemblers.

Upstream, ASEAN increasingly leverages domestic semiconductor production for automotive applications, reducing import dependence and supporting the growth of xEV manufacturing. On the factory floor, automation and artificial intelligence (AI) improve productivity and cost-efficiency, whilst downstream, material traceability and asset tracking support circularity and resource recovery. Strategic coordination underpins this integration. Governments harmonise technical standards, simplify intra-ASEAN trade procedures, and jointly invest in cross-border infrastructure, unlocking logistics efficiency and accelerating intra-regional supply movement. A regional data-sharing framework supports real-time customs clearance, carbon footprint tracking, and supply-chain compliance monitoring. Interoperable systems and shared digital infrastructure improve transparency and traceability across the value chain, creating a unified regional supply chain in which data flow as seamlessly as goods. Establishing common regional frameworks to support knowledge sharing and to equip small and medium-sized enterprises (SMEs) with the capabilities to extract value from data is therefore essential (ASEAN Directors-General of Customs Senior Officials' Meeting, 2021).

This integrated production network allows ASEAN to capture supply-chain realignments triggered by geopolitical shifts, such as the China+1 strategy and the expansion of green industrial policies. More than a collection of national factories, ASEAN positions itself as a digitally connected production hub in which components, data, and materials flow seamlessly across borders. It delivers cost-efficiency without sacrificing scale, agility without fragmentation, and specialisation without duplication, positioning ASEAN as a cohesive, future-ready production base for the ICEV, HEV, and xEV markets.

Pillar 2a: ASEAN's Integration into the Global Electrified Vehicle Component Supply Chain

Global xEV sales are accelerating in leading automotive markets. By contrast, xEV adoption in ASEAN remains comparatively modest, rising from just 7% in 2024 to a projected 16% by 2035 (Section 5.3). Despite this slower uptake, ASEAN must scale up xEV component production to remain relevant within the evolving global automotive value chain. As demand for ICEVs declines, failure to pivot risks marginalising ASEAN's role in the xEV economy and eroding its long-standing export competitiveness.

ASEAN holds distinct advantages that position the region to integrate into the global xEV component supply chain, with Indonesia and Thailand serving as critical starting points. These countries anchor ASEAN's emerging xEV ecosystem and enable the region to function as a regional support hub, capable of supplying key components to global

manufacturers seeking greater supply-chain resilience and diversification.

However, ASEAN faces notable hurdles in scaling xEV component production. Its historical focus on ICEV and HEV manufacturing has resulted in delayed adoption of xEV technologies, compounded by ageing equipment, identified by 47.5% of survey respondents as a major constraint (Section 6.5). Whilst Indonesia and Thailand are attracting xEV-related investments, the region continues to struggle with cohesive scaling. For example, Indonesia's goal of producing 600,000 BEVs by 2030 hinges on closing infrastructure gaps and enhancing regional coordination (Section 6.5). These challenges necessitate a gradual and carefully sequenced ramp-up of xEV capabilities to avoid disrupting existing ICEV and HEV production strengths.

To secure a competitive position in the global xEV supply chain by 2035, ASEAN must pursue a collaborative, region-wide strategy. Individual countries can take on specialised roles: Indonesia focusing on battery production, Thailand on power electronics, and Malaysia on electric motors, together forming a cohesive ecosystem that leverages complementary national strengths. This approach requires phased investments in infrastructure, skills, and digital tools to close technological gaps whilst ensuring steady progress without destabilising current manufacturing bases. Equally important is alignment with global decarbonisation and sustainability standards, as environmental performance increasingly shapes access to export markets. By capitalising on its nickel reserves, supportive policy frameworks, and strategic geographic position, ASEAN can transform into a vital xEV component hub, meeting rising global demand whilst reinforcing its automotive manufacturing legacy.

Pillar 2a: Decarbonising the Automotive Supply Chain

By 2035, whilst ICEV and HEV powertrains are expected to retain a significant share of the automotive market, ASEAN aims to position itself as a pragmatic leader in decarbonisation. Rather than focusing solely on altering vehicle production, this approach emphasises systemic changes that reduce emissions across supply chains and operations. The objective is to build an enabling ecosystem that lowers carbon intensity region-wide, ensuring that ASEAN avoids being perceived as a carbon dumping ground whilst strengthening long-term industrial resilience.

A central component of this strategy is the development of a shared renewable energy network, drawing on solar, wind, and hydropower resources to supply manufacturing facilities, logistics hubs, and supporting infrastructure. Initiatives such as the Asian Zero Emission Community are expected to contribute not only to ASEAN's manufacturing competitiveness but also to the broader decarbonisation of the regional electricity mix. ASEAN plans to establish a region-wide alternative fuel ecosystem by scaling up the production and distribution of biofuels, including E20 and B20 blends, whilst exploring e-fuels as a longer-term option. By leveraging domestic agricultural strengths, such as Indonesia's palm oil resources, this approach can support fuel supply chains sustainably, align with global trends, and complement existing infrastructure.

Decarbonising the supply chain will be a critical focus. By 2035, ASEAN aims to source low-carbon materials such as green steel, taking inspiration from global leaders such as Mercedes-Benz, which has partnered with SSAB to secure near-zero-emission steel. This move will help meet rising Scope 3 emissions expectations in export markets, ensuring that ASEAN remains competitive on the global stage. The region will prioritise circular-economy principles by developing joint facilities to recycle automotive materials, including steel, aluminium, and battery components. With Indonesia's nickel reserves playing a central role in sustainable battery recycling, these efforts will reduce reliance on virgin resources and minimise waste, thereby supporting a more sustainable material life cycle.

To realise this vision, ASEAN Member States (AMSs) will need to work together by aligning policies on renewable energy standards, material traceability, and recycling regulations. Governments can accelerate progress through targeted subsidies for green infrastructure, cross-border research and development (R&D) partnerships, and closer alignment with global trade rules such as the CBAM. Traceability systems, including battery passports and digital product identifiers, can support compliance with increasingly stringent export requirements, especially for HEV and xEV components. Over time, additional mechanisms such as carbon pricing or environmental, social, and governance (ESG)–linked investment incentives may further reinforce decarbonisation efforts. Through these coordinated and practical measures, ASEAN can position itself as a sustainability leader that meets global environmental expectations whilst strengthening the long-term resilience of its automotive industry.

Pillar 3: Servitising Mobility for ASEAN and Global Markets

The third pillar expands ASEAN's value proposition downstream by transforming vehicles into long-lived mobility services rather than one-off products. Empirical work by Genzlinger et al. (2024) traced a sequenced pathway, starting with basic after-sales contracts, moving to usage-based offers such as leasing and rental, and ultimately arriving at results-oriented models in which customers purchase mobility outcomes instead of physical assets. ASEAN can accelerate this shift by closely integrating decarbonisation with digitalisation.

Demand for integrated mobility-as-a-service (MaaS) super-applications is growing faster than private car ownership. The Asia and Pacific vehicle subscription segment alone was valued at roughly US$1.2 billion in 2024 and is forecast to grow at a compound annual growth rate (CAGR) of more than 30% towards 2030, with much of this growth captured through OEM-led or platform-based partnerships (Grand View Research, 2025). Continuous data sharing underpins this model: service providers ingest real-time location, battery, and driver-behaviour data to optimise routing, bundle insurance or carbon-offset add-ons, and trigger just-in-time servicing.

To scale these offers across 10 diverse national markets, and to ensure that export vehicles comply with increasingly stringent data-sovereignty rules, ASEAN is piloting a regulatory pilot space that harmonises cross-border vehicle-data flows for autonomous

and connected mobility (ASEAN, 2024f). Common cybersecurity testing sandboxes will allow Thai-built HEVs, Indonesian battery packs, or Malaysian power-electronics modules to plug seamlessly into EU battery passport systems or Middle Eastern ride-hailing platforms, making ASEAN's digital services as exportable as its hardware.

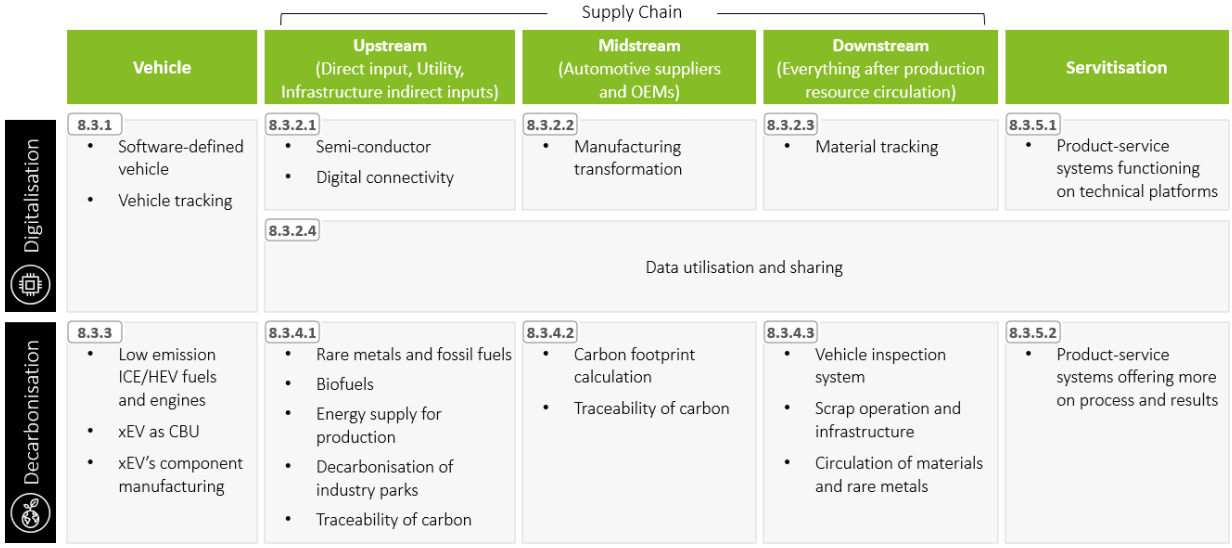
Ride-hailing, car-sharing and subscription services allow a single vehicle to deliver substantially higher passenger-kilometres, thereby cutting embodied carbon dioxide (CO_2) emissions per kilometre. Higher utilisation, however, demands more sophisticated and lower-cost upkeep. Connected-vehicle telematics already enable predictive maintenance that reduces unplanned downtime and energy waste; market analysts project a CAGR of 14.9% for automotive telematics through 2032, driven largely by these efficiency gains (GlobeNewswire, 2025). Regulators can lock in these benefits by mandating digital maintenance passports, recording battery state of health, tyre wear, refrigerants, and repair history in tamper-proof ledgers, to ensure that shared and subscription fleets remain safe, efficient, and export compliant.

By 2035, widespread adoption of shared, hailed, and subscription-based vehicles, each serviced through predictive, telematics-driven maintenance cycles, could lift average vehicle utilisation from today's single-digit levels to well above 30%. This shift would substantially reduce life-cycle emissions per kilometre whilst generating the high-margin service revenues envisioned in the advanced services stage identified by Genzlinger et al. (2024). The same data streams that lower costs and strengthen customer retention also support OEM Scope 3 reporting and compliance with carbon border measures in major destination markets, thereby securing ASEAN's position within the future global mobility ecosystem.

8.2. To-Be State Framework

This section sets out the analytical framework underpinning the envisioned transformation of ASEAN's automotive industry. Anchored in the region's strategic vision and informed by global megatrends, the framework delineates the structural imperatives required to transition from the current state towards a competitive, sustainable, and future-ready automotive ecosystem. It does so by operationalising two foundational transformations – decarbonisation and digitalisation – across three interdependent domains: the vehicle; the supply chain (upstream, midstream, downstream); and servitisation. These domains collectively span the full automotive value chain and are treated not as isolated silos, but as mutually reinforcing levers of systemic change.

Figure 8.1. To-Be State Analysis Framework



CBU = completely built unit, HEV = hybrid electric vehicle, ICE = internal combustion engine, OEM = original equipment manufacturer, xEV = electrified vehicle.

Source: Authors (2025).

The framework begins by segmenting the supply chain into its three stages – upstream, midstream, and downstream – to enable precise diagnosis and targeted policy formulation. Upstream activities encompass both direct inputs (e.g. rare metals, biofuels, semiconductors) and indirect enablers (e.g. energy infrastructure, industrial parks). The midstream refers to the core manufacturing layer, where OEMs and suppliers engage in vehicle assembly and component integration. The downstream captures post-production activities, including vehicle inspection, end-of-life processing, and the circular flow of materials back into the production loop. Overlaying this structure is a fourth domain – servitisation – which reflects the sector's pivot from product-centric manufacturing towards life-cycle value creation through digitally enabled services.

To realise ASEAN's strategic aspirations, each domain must undergo a dual transformation. On the decarbonisation front, the imperative is to embed sustainability across the value chain, from sourcing low-emission fuels and critical minerals to decarbonising industrial parks and enabling circular material flows. Embedding sustainability across the value chain is not merely an environmental agenda but a core competitiveness strategy. ASEAN's integration into global xEV component supply chains hinges on its capacity to meet increasingly stringent carbon and sustainability standards. Meeting these standards requires the development of low-emission ICEV and HEV platforms alongside the localisation of xEV component manufacturing. Within the supply chain, it requires coordinated action on renewable energy adoption, carbon footprint traceability, and the establishment of regional recycling ecosystems. These efforts collectively position ASEAN not as a passive rule-taker, but as a pragmatic leader in industrial decarbonisation.

Digitalisation serves as the connective tissue that binds and accelerates transformation across domains. In the vehicle space, the emergence of software-defined vehicles (SDVs) and advanced telematics enables ASEAN to differentiate through intelligence, functionality, and user experience, rather than cost alone. Across the supply chain, digitalisation manifests through enhanced connectivity, data-driven manufacturing, and real-time traceability, capabilities that are essential for building a resilient, cost-competitive, and regionally integrated production network. A strong digital backbone facilitates cross-border data sharing, enabling ASEAN manufacturers and service providers to plug into global platforms and regulatory standards.

The framework recognises servitisation as a structural shift in value creation. As ownership models evolve and mobility preferences diversify, ASEAN must move beyond vehicle production to deliver integrated mobility solutions. Subscription models, predictive maintenance, and usage-based services respond to shifting consumer behaviour whilst extending vehicle lifespans, deepening customer engagement, and unlocking recurring revenue streams. Through this transition, ASEAN repositions itself from a manufacturing base to a regional hub for smart, service-oriented mobility.

This updated framework provides a coherent blueprint for ASEAN's automotive transformation. It integrates decarbonisation and digitalisation not as parallel tracks, but as interwoven imperatives applied across the vehicle, supply chain, and service layers. The following sections elaborate on the specific policy levers, institutional enablers, and investment pathways required to operationalise this vision.

8.3. To-be State Deep Dives

8.3.1. Vehicle Digitalisation: To-be State

Digitalisation is expected to significantly enhance the competitiveness of the automotive industry, both in the present and over the longer term (Brown, 2024). This transformation is driven by emerging technologies, including comprehensive connectivity, artificial intelligence (AI), and virtualised platforms and services (Khan and Taqi, 2021). These developments are reshaping vehicles into intelligent, connected systems, resulting in a more resilient industry that is better equipped to respond to evolving consumer expectations and environmental demands.

Digital technologies embedded in vehicles account for at least 50% of total vehicle value (Albert et al., 2021). The deepening integration of software and hardware has expanded vehicle functionality whilst also increasing system complexity. The same study notes that digitisation can generate significant improvements across the automotive value chain by boosting operational efficiency, reducing costs, and enabling greater collaboration and innovation amongst industry stakeholders. The growing prevalence of connected vehicles is shifting business strategies away from one-off product sales towards experience-based and service-oriented value offerings.

The following subsections present a deeper analysis of two key digitalisation levers: SDV capabilities and tracking of units in operation (UIO). Each subsection outlines a future-oriented vision and explains how these strategies support ASEAN's goal of strengthening its position as a competitive, connected hub for ICEV and HEV manufacturing.

8.3.1.1 Implementing SDV Technologies at Scale

This section analyses the role of SDVs and their centrality to realising a competitive ICEV and HEV hub, alongside a cost-competitive and integrated production network. Globally, the SDV market is expected to reach US$449.5 billion by 2034, driven by growing demand for advanced in-vehicle experiences, autonomous driving functions, and smart mobility services, and enhanced connectivity (Romanowski, 2025). Deloitte's 2023 European SDV survey underscores this momentum: 89% of surveyed firms confirmed that SDVs already play a substantial role in their corporate strategies, 83% indicated that SDVs reduce time-to-market, and 95% highlighted efficiency gains.

Building on these trends, the following to-be state is proposed.

State #1: Propelling Vehicle Connectivity Through SDVs to Capture Demand

Under this state, ASEAN's automotive sector embeds SDV capabilities across vehicle platforms, enabling real-time connectivity and dynamic software updates without hardware modifications. This vision entails a regionally connected vehicle network that captures live data on usage patterns, driver preferences, and in-market behaviour. Automakers then use these insights to customise features, localise user experiences, and refine software offerings over time. By aligning vehicle functionality more closely with actual customer needs, especially in ASEAN's diverse and fast-evolving market, this approach enables automakers to deliver more cost-effective and competitive vehicles.

Powered by software-driven architectures and embedded connectivity, SDVs function as a continuous feedback engine, transmitting in-use data from vehicles to OEM systems. This feedback loop enables more responsive design, production planning, and product improvement processes across the region.

Why it matters. Adopting SDV capabilities is essential for ASEAN to maintain a competitive edge amidst accelerating global digitalisation in mobility. At its core, SDVs give manufacturers access to real-world, real-time vehicle data that can inform design optimisation, production scheduling, and the targeted rollout of software features. This capability is particularly valuable in ASEAN and other emerging markets, where users tend to be more sensitive to price and exhibit distinct preferences compared with those in mature economies (Grewal et al., 2015).

Through SDVs, OEMs can tailor offerings cost-effectively without proliferating hardware variants (Tactile Mobility, 2025). For example, manufacturers can deploy software feature bundles optimised for dense urban driving in Jakarta, Bangkok, and Kuala Lumpur, or enhance long-distance connectivity for inter-city mobility in Viet Nam. As customer expectations evolve rapidly, over-the-air software updates allow automakers to shorten

innovation cycles and remain responsive to local demand.

Leading global OEMs have already demonstrated these benefits. Tesla, for instance, routinely deploys over-the-air updates to improve battery efficiency, adjust braking performance, and enhance acceleration based on data collected from vehicles in use, reducing the need for recalls and physical service visits (Jayan, 2024). Similar capabilities are now embedded in vehicles produced by other manufacturers, including BMW (Narasimhan, 2024). Stellantis has likewise prioritised SDV development to simplify software architectures by centralising control functions, reducing reliance on multiple electronic control units, and enabling continuous delivery of new features and digital services throughout the vehicle life cycle (S&P Global, 2024).

Beyond individual OEMs, governments in both advanced and emerging economies are actively promoting SDV adoption. In Japan, the Ministry of Economy, Trade and Industry (METI) has launched the Mobility DX Platform to accelerate SDV development in collaboration with major automobile manufacturers (Shimbun, 2024). Toyota, Honda, and Nissan have agreed to collaborate on in-vehicle software development, whilst Suzuki Motor Corp. is partnering with semiconductor and communication companies to advance autonomous driving software. These initiatives support Japan's ambitious targets of selling 12 million SDVs (Nagao, 2024) and capturing 30% of the global SDV market by 2030 (Singh and Horie, 2024).

India has similarly positioned itself as a competitive base for SDV development through strategic partnerships. BMW and Tata Technologies have established a joint software and IT development hub (BMW Group, 2024) whilst Tata Elxsi is collaborating with Mercedes-Benz to strengthen automotive software architectures and SDV capabilities (Singh, 2025). These partnerships not only localise SDV development but also signal India's strategic intent to become a leading SDV ecosystem player.

In parallel, regulatory-led approaches are emerging. China has begun advancing SDV standardisation through a dedicated standards committee, focusing on harmonising technical definitions and strengthening coordination across stakeholders, including alignment with domestic semiconductor ecosystems (Zhu and Huang, 2024). In the EU, the European Commission is working with industry to develop regulatory frameworks addressing SDVs and vehicle-generated data, whilst industry alliances such as the Connected Vehicle Systems Alliance (COVESA), AUTomotive Open System ARchitecture (AUTOSAR), and Scalable Open Architecture for Embedded Edge (SOAFEE), and the Eclipse SDV Working Group, promote standard setting and collaboration.

These global experiences indicate that embedding SDV capabilities is no longer optional. To remain competitive in a rapidly evolving mobility landscape, ASEAN must act decisively to integrate SDVs into its automotive manufacturing ecosystem. The ability to collect, analyse, and act on real-time vehicle data is increasingly a baseline requirement rather than a differentiator.

By adopting SDV technologies at scale, ASEAN can enhance production agility, improve

responsiveness to market signals, and deliver vehicles that evolve continuously through software. This approach enables the region to leapfrog legacy models, offering more localised, adaptive, and value-driven vehicles.

8.3.1.2. Enabling Data-Driven Vehicles Through UIO Monitoring

Building on the SDV capabilities discussed in Section 8.3.1.1, this section focuses on the role of UIO monitoring in enabling data-driven vehicles and supporting ASEAN's ambition to become a competitive manufacturing hub with an integrated production network. The global vehicle monitoring system market was valued at about US$28.1 billion in 2024 and is projected to grow at a CAGR of 13.2% from 2025 to 2033 (Straits Research, 2024).

UIO monitoring refers to the deployment of connected technologies and embedded sensors to collect real-time data from vehicles already in use. A common application is vehicle tracking, which uses global positioning systems (GPS) and wireless data transmission to monitor metrics such as routes, speed, fuel use, and tyre pressure. These features are increasingly embedded in modern dashboards and connected-vehicle platforms, providing manufacturers with live visibility into vehicle condition and operational behaviour (Auliyaa, 2019). This digital shift also requires OEMs to develop integrated data platforms capable of managing vehicle life-cycle information across both physical and digital touchpoints (Gadi, 2019).

Against this backdrop, the following to-be state is proposed.

State #1: Leveraging UIO Monitoring to Extend Life Cycle and Improve Production Planning

In this envisioned state, vehicles across ASEAN are widely equipped with UIO monitoring capabilities, enabling continuous real-time tracking of vehicle condition, operational status, and maintenance needs. Data collected from vehicles in use flow back to OEMs and associated digital platforms to support predictive maintenance, timely parts replacement, and end-of-life forecasting. These insights help extend vehicle lifespan, reduce breakdowns, and improve demand forecasting accuracy. Whilst SDVs primarily focus on dynamic feature updates and market sensing,[1] UIO monitoring concentrates on optimising vehicle operations and life-cycle management for the existing fleet, maximising value from vehicles already on the road.

Why it matters. Embedding UIO monitoring at scale is critical to improving how ASEAN's automotive sector manages vehicle life cycles and aligns production with real-world demand. By capturing real-time data on vehicle health and usage, OEMs can shift from reactive to predictive maintenance strategies, reducing breakdowns, unplanned downtime, and warranty costs (Geotab, 2024).

More importantly, UIO data provide OEMs with clear visibility into when vehicles are approaching the end of their usable life. This enables more accurate forecasting of

[1] Market sensing is the process of understanding customer unique demands within a given market.

replacement cycles and helps manufacturers anticipate future demand, aligning parts supply, assembly capacity, and production timelines accordingly (Omprakash, 2024). Instead of relying solely on historical sales trends, planners can draw on live, usage-based indicators to inform supply-chain decisions and investment planning. This data-driven approach reduces inventory waste, mitigates supply bottlenecks, and supports a transition towards a more responsive and resilient production model.

Leading OEMs have already demonstrated the benefits of integrating real-time operational data. Tesla, for example, applies a multi-faceted UIO monitoring approach. Sensors continuously track the performance of critical components such as batteries, motors, and braking systems, with deviations from normal performance triggering alerts for early intervention (Jayan, 2024). Fleet-wide data are analysed through cloud-based platforms to identify emerging issues and performance trends. This predictive maintenance model helps minimise downtime, extend vehicle lifespan, and prevent minor issues from escalating into major repairs, thereby reducing life-cycle costs for both the manufacturer and consumers.

Other OEMs have adopted similar approaches. Toyota's T-Connect telematics service enhances safety and convenience by connecting vehicles to a digital network and enabling integrated diagnostics that identify maintenance needs (Toyota Connect, 2025). Although not explicitly branded as a UIO monitoring system, these functions effectively contribute to UIO monitoring by providing real-time data insights into vehicle health and usage patterns. Ford's FordPass and SYNC platforms offer vehicle health alerts (FordPass, 2025), whilst Mercedes-Benz's *me connect* provides diagnostic information on battery and fuel systems, maintenance notifications, and driving analytics, capabilities comparable to those offered by Hyundai's BlueLink and General Motors' OnStar.

Although not always framed explicitly as UIO monitoring mandates, several regulatory initiatives indirectly support its adoption by promoting telematics and in-vehicle monitoring technologies. These measures facilitate real-time data collection and provide the foundational infrastructure for large-scale UIO monitoring and life-cycle optimisation.

In the EU, the General Safety Regulation requires all new vehicles from 2026 onwards to be equipped with driver monitoring systems and a suite of advanced driver-assistance systems, both of which rely on continuous data collection and real-time analytics (Wood, 2024). In the US, the regulators have increasingly recognised the role of in-cabin monitoring systems, with the Alliance of Automobile Manufacturers actively supporting federal and state-level measures to ensure consistent deployment across OEMs (Anyverse, 2025).

China has taken a more interventionist approach. Its real-time monitoring programme requires EVs to transmit up to 60 data points, including geo-location, battery state of charge, and component status, every 10 seconds to manufacturers and authorities (Gottwick, 2019). Whilst originally designed to support EV development and infrastructure planning, this architecture also enables robust UIO data flows that support predictive maintenance, fleet analytics, and life-cycle management.

These developments indicate that UIO monitoring is increasingly embedded through broader vehicle digitalisation policies and regulations. For ASEAN, this creates a clear opportunity to advance vehicle digitalisation as a foundation for implementing UIO monitoring at scale. By doing so, automakers can keep vehicles in service for longer, detect issues earlier, and plan more accurately for future demand.

8.3.2. Supply Chain Digitalisation: To-be State

Automation, sustainability, and cost pressures are driving significant changes across the automotive industry, with digitalisation in automotive manufacturing continuing to advance (Automotive Manufacturing, 2025). Globally, the primary motivation for digitalisation amongst automotive manufacturers is to enhance business performance. Following the same strategic trajectory, ASEAN's ambition to become a competitive ICEV and HEV manufacturing hub (Pillar 1) and a cost-competitive and integrated production network (Pillar 2) requires supply chain digitalisation to play a central enabling role.

Successfully implementing digitalisation across the entire value chain, with its diverse requirements, necessitates data standardisation, industry coordination, and strategic partnerships. To achieve this, ASEAN must ensure that digital technologies are deployed consistently across the upstream, midstream, and downstream segments of the automotive ecosystem.

Upstream, securing direct input at an affordable cost, through straightforward and reliable supply chains with sufficient volumes, remains a key priority for strengthening ASEAN's position as an ICEV and HEV manufacturing region. Midstream, transforming manufacturing practices to remain cost-competitive against peer production bases will be central to achieving streamlined, supply chain–efficient operations. Digitalising manufacturing processes enhances operational efficiency, reduces human error, and significantly cuts production costs, making it an indispensable capability for automotive manufacturers aiming to stay competitive (Surya Cipta, 2024).

Downstream, ASEAN should enable region-wide material traceability and establish linkages with global data-sharing platforms that support the recirculation of materials into future vehicle production. Materials used in automotive production often involve rare and critical metals that are costly and difficult to source. Once these materials enter the region embedded in built-up vehicles, it becomes imperative to track their location, condition, and recovery potential, ensuring their reintegration into the supply chain through circular pathways.

Beyond interventions in individual segments of the value chain, fully unlocking the benefits of supply-chain digitalisation and realising ASEAN's ambition to become a cost-competitive and resilient ICEV and HEV manufacturing hub requires leveraging two key enablers: regional connectivity and data utilisation and sharing. These enablers are essential for integrating fragmented supply chain operations, improving resource efficiency through circular practices, and enabling end-to-end coordination across the

region.

8.3.2.1. Upstream

The upstream section focuses primarily on semiconductors. To secure ASEAN's long-term position as a competitive vehicle manufacturing hub, particularly for ICEV and HEV production, the region must evolve towards a more self-reliant and strategically aligned semiconductor ecosystem. The following conditions outline an ideal future state that strengthens semiconductor access and resilience for the automotive sector, together with the rationale for their importance to ASEAN's strategic goals.

State #1: Integration of Semiconductor Manufacturing into the ICEV and HEV Ecosystem

In this state, ASEAN countries leverage existing semiconductor manufacturing capacity within the region as part of a fully integrated supply chain for ICEV and HEV production. This envisions deeper and more formalised linkages between semiconductor fabrication, assembly, testing, and packaging, and automotive component manufacturing, thereby ensuring a more stable supply of critical inputs and supporting greater regional self-sufficiency in vehicle production.

Why it matters. Integrating supply chains within the same regional bloc offers several strategic advantages. First, sourcing semiconductors within the region reduces ASEAN's dependence on external imports and mitigates the risk posed by global supply disruptions. As outlined in the preceding section, this also includes minimising exposure to geopolitical risks arising from trade dependencies on politically sensitive markets. In other major automotive manufacturing regions, similar integration models have increasingly been pursued, reflecting their perceived resilience in sustaining vehicle production during semiconductor shortages.

Regional sourcing enables shorter and more efficient supply chains, resulting in faster lead times, lower logistics costs, and improved coordination between suppliers and manufacturers. At the same time, reliance on local semiconductor inputs helps avoid tariffs, high freight charges, and foreign exchange risks, factors that are critical to keeping the cost-competitiveness of ASEAN's ICEV and HEV production in global markets. Proximity to material supply further allows manufacturers to benefit from more predictable delivery schedules, enhancing production agility and responsiveness to market and customer demand (PanelClaw, 2025).

The EU has long promoted the use of regionally sourced semiconductors amongst its member states. In 2019, the European Commission proposed placing greater emphasis on manufacturing with components and materials sourced within the region. Increasing reliance on regional suppliers has strengthened supply-chain resilience by reducing vulnerability to external shocks, such as trade disputes, natural disasters, and global crises, including the coronavirus disease (COVID-19) pandemic and trade conflicts (Addax Motors, 2023). Even where regional semiconductor production has fallen short of demand,

EU manufacturers have continued to source from nearby countries such as Morocco and Türkiye, reflecting the strategic value of geographical proximity in lowering logistics costs and avoiding trade barriers (Prado et al., 2025).

At the R&D level, Japanese automotive manufacturers have advanced semiconductor integration. Leading OEMs such as Toyota, Nissan, Honda, Mazda, and Subaru have formed partnerships with domestic electronic component producers to conduct joint R&D on high-performance automotive semiconductors (Just Auto, 2024). These collaborations combine the technological expertise of semiconductor manufacturers with the application knowledge of automotive manufacturers, enabling the development of next-generation vehicle architectures, including the integration of multiple semiconductor functions within system-on-chip designs.

These experiences from Japan and the EU reinforce the importance of deepening semiconductor integration within automotive manufacturing in ASEAN. Such integration not only safeguards supply continuity for the region's automotive sector but also strengthens ASEAN's competitiveness as a resilient and globally oriented production base.

State #2: Prioritisation of Domestic Semiconductor Use over Export

ASEAN is expected to allocate a larger share of regionally produced semiconductors to domestic consumption across strategic industries rather than exporting them. This shift reflects a move away from ASEAN's traditionally export-oriented semiconductor sector, which has long supported foreign manufacturing, towards one that increasingly underpins its own industrial expansion. By prioritising domestic use, the region can move towards greater self-sufficiency and generate higher value-added through local manufacturing instead of exporting lower-margin, unprocessed, or semi-processed chips. Aligned with State 1, prioritising domestic use reduces dependency on foreign supply chains, strengthens regional industries, and enables ASEAN to retain more economic value within its borders.

Why it matters. Prioritising regionally produced semiconductors for domestic use bears critical strategic merit, as opposed to continually channelling them towards export markets. First, by redirecting a greater share of regionally produced semiconductors into ASEAN's own industries, countries can move up the value chain. Instead of exporting raw or intermediate chips, which typically yield relatively low margins, integrating them into locally assembled vehicles or electronics allows ASEAN to export finished goods with substantially higher value. This shift supports industrial upgrading, enhances manufacturing's contribution to gross domestic product (GDP), and strengthens ASEAN's trade position through the export of higher-margin products.

By way of comparison, semiconductors are sold at an average price of US$0.61 per unit (Deloitte, 2025), whereas best-selling vehicles in ASEAN markets are priced at US$13,604–US$14,561 on average (Section 5.2.2.1). This stark disparity implies that exporting semiconductors alone does not generate the same scale of economic impact as using them as inputs for high-value products such as automobiles. Ensuring that a sufficient

share of ASEAN-produced semiconductors is retained for domestic use is therefore likely to deliver greater economic returns and help position ASEAN as a higher-value manufacturing hub.

Consistent with State 1, securing an adequate supply through regional production provides greater stability for automotive semiconductor demand, shielding ASEAN from sudden supply shocks or escalating trade tensions. Many countries are now actively protecting domestic semiconductor production, recognising its critical role in sustaining long-term economic resilience.

Japan, for example, has proposed export controls on several semiconductor-related technologies, requiring companies to obtain government approval before exporting such products (Zhihang and Wei, 2024). This approach prioritises domestic supply before meeting overseas demand and is intended to protect supply chains and mitigate the risk of shortages or global disruptions (Togashi, 2022). Similarly, China has restricted exports of certain semiconductor components (Microchip USA, 2024) to preserve sufficient raw materials for domestic supply, whilst expanding smaller-scale suppliers to increase local production capacity and meet domestic demand (Shivakumar et al., 2025). Germany has reportedly considered limiting exports of semiconductor-related chemicals to China, as part of broader efforts to reduce strategic dependence on external markets (The Straits Times, 2024). More broadly, Germany and the EU have stepped up efforts to localise chip production and reduce dependence on external suppliers (Reuters, 2023h).

These developments closely align with earlier observations of the Economic Research Institute for ASEAN and East Asia (ERIA) of a global shift towards prioritising domestic semiconductor needs and reducing import reliance (Parbheesh and Vidya, 2024). It is therefore strategically compelling for ASEAN to pursue a similar trajectory. ASEAN need not adopt extreme measures such as outright export bans, as seen in some countries. Instead, the region can continue to benefit from global trade through technology transfer, GDP growth, and stronger bilateral ties, whilst adopting a more deliberate approach to reserving sufficient semiconductor output for local industries. In practical terms, ASEAN must look inward before looking outward, prioritising domestic demand before exporting semiconductors.

State #3: Prioritisation of ASEAN Semiconductors for Automotive Manufacturing

ASEAN is expected to allocate a defined share of regionally manufactured semiconductors specifically to the automotive industry. This state recognises automotive manufacturing as a strategic priority and seeks to insulate its semiconductor supply from competing demands across other industries. The key difference between State 3 and State 2 lies in this sector-specific focus: whilst State 2 prioritises domestic semiconductor use irrespective of industry, State 3 explicitly directs a portion of regional semiconductor capacity to automotive applications. Implementing State 3 allows automotive manufacturers to concentrate on production continuity and innovation without facing supply bottlenecks arising from semiconductor shortages.

Why it matters. As competition for semiconductors intensifies across electronics, telecommunications, and data centres, automotive manufacturers risk being sidelined in the absence of clear prioritisation frameworks. Semiconductors are critical not only for advanced xEV platforms but also for conventional ICEVs and HEVs. Without a defined allocation, automotive manufacturers may be forced to compete with larger and more dominant sectors that can secure cost-competitive chip supply through superior scale and purchasing power.

No country has enacted formal legislation mandating sector-specific allocation, but several economies have introduced measures to safeguard semiconductor supply for automotive manufacturing. In the US, the American Automotive Policy Council has urged Congress to prioritise semiconductor production essential for domestic vehicle manufacturing, ensuring that OEMs receive a fair share of chips to meet production targets and customer demand (The Economic Times, 2021). Similarly, the EU Industrial Union has lobbied the European Commission to grant the automotive sector priority access to semiconductors to avoid production disruptions during periods of supply stress (Centre for European Studies Indonesia, 2025).

China has adopted a more regulatory-driven approach. Whilst it does not mandate a fixed allocation of semiconductors for automotive use, it requires domestically produced EVs to incorporate at least 15% locally produced chips, a threshold previously expected to rise to 20%–25% by 2025; however, no official update has been provided to confirm its implementation (Trend Force, 2024; Channel News Asia, 2026b). Although this policy operates within a competitive market framework, it effectively channels semiconductor supply towards domestic automotive needs. In the Republic of Korea (henceforth, Korea), the government has committed KRW200 billion (about US$176 million) in grants and proposed low-interest loans through state-owned banks to support next-generation automotive semiconductor research, development, and production (Bcusack, 2021).

Japan's METI brought together its automobile and IT industry divisions with domestic automotive manufacturers to establish the Automotive Semiconductor Supply Chain Working Group in May 2021. Operating under the Automobile Industry Council for Studying Countermeasures, the group focuses on securing stable semiconductor supplies for vehicles and strengthening the resilience of the wider automotive supply chain (METI, 2022).

These examples point to a growing global awareness of the strategic importance of securing semiconductor access for the automotive sector. For ASEAN to emerge as a competitive and resilient automotive manufacturing hub, adopting a similar approach, by defining and safeguarding a fixed share of domestic semiconductor output for automotive use, will be critical. Without such assurance, the region's automotive sector may continue to face supply-side uncertainty even as production capacity and market demand expand.

8.3.2.2. Midstream

The midstream analysis centres on manufacturing transformation, as this is where OEMs are most directly involved and where the bulk of vehicle production and assembly takes place. Strengthening this segment is therefore critical to enhancing ASEAN's cost-competitiveness relative to neighbouring manufacturing regions.

This section outlines the envisaged future states that position ASEAN as a cost-competitive ICEV and HEV manufacturing hub, with manufacturing transformation serving as a critical operational lever. Two complementary layers of transformation are examined. The first focuses on upgrading current manufacturing processes to boost productivity and output. The second reimagines automotive manufacturing by embracing emerging trends that are reshaping the industry.

State #1: Upgrading the Current Manufacturing Process

The first layer of transformation focuses on improving existing operations. This involves upgrading production lines, systems, and workflows to increase productivity, reduce downtime, and raise output. Key measures include digitising legacy processes, enhancing operational visibility through better data use, and integrating leaner manufacturing practices. The goal is to enable ASEAN manufacturers to extract greater value from existing assets whilst maintaining quality and cost control.

Why it matters. Upgrading current manufacturing processes is a vital first step in ASEAN's automotive transformation. Although the specific interventions will vary by manufacturer and local context, the underlying goal is consistent: to enhance productivity, reduce inefficiencies, and increase output in a cost-effective way. Incremental improvements to existing production lines allow manufacturers to stay competitive in the short term whilst building the operational readiness required for deeper transformation. Crucially, these efforts lay the foundation for State 2, in which next-generation technologies fundamentally reshape how vehicles are produced.

Operational excellence in the automotive industry has long relied on efficiency gains and cost-reduction strategies. Eliminating unnecessary process steps and increasing automation can significantly reduce production costs (Lectra, 2024). Reflecting this, leading global OEMs have publicly committed to maximising operational synergies, streamlining workflows, and enhancing productivity across their manufacturing footprints (Lee, 2025).

A prominent example is Hyundai, which has operated a multi-vehicle assembly system at its main plant in Korea since 2022. This manufacturing method allows the production of up to 10 different vehicle models on a single assembly line by placing all required components on a cart that moves alongside each vehicle throughout the production process (Do, 2022). The study found that this system reduces the need to build new plants when demand spikes for specific models. Under the previous mass-production system, assembly lines were typically dedicated to one or two models, with components stockpiled behind the assembly belt. In contrast, the new batch-based system supports quicker

quality control and lets workers install tailored components in response to specific customer requirements.

Several global automakers, including Renault, General Motors, Toyota, and Volkswagen, have adopted similar small-batch, multi-product production systems. These examples demonstrate that upgrading conventional manufacturing processes can increase flexibility, support greater product customisation, and reduce the capital intensity of scaling operations. Such capabilities are essential for ASEAN as it seeks to consolidate its position as a competitive ICEV and HEV manufacturing hub.

State #2: Evolving Towards Next-generation Manufacturing

The second layer of transformation is more ambitious, involving a shift towards fundamentally new approaches to vehicle manufacturing. This includes the adoption of next-generation technologies, such as gigacasting, autonomous robotics, AI, and advanced automation (Section 6.2). These technologies are expected not only to improve efficiency but also to reshape the configuration of the factory floor itself. The aim is to move beyond traditional assembly lines towards smart, adaptive production environments that are faster, more flexible, and more cost-effective over the long term.

Why it matters. Embracing next-generation manufacturing is a strategic imperative for securing ASEAN's long-term competitiveness in the global automotive landscape. Advanced automation enables manufacturers to respond more rapidly to market shifts, optimise production lines, and support sustained growth (Siemens, 2025). To stay competitive, production systems must be adaptable, scalable, and responsive. This new wave of manufacturing transformation extends beyond incremental upgrades, integrating digital twins, AI, and software-defined control systems to create smarter and more precise production environments.

Advanced robotics and AI, for example, are expected to perform up to 75% of production-line tasks (Tata Motors, 2024), whilst the use of augmented and virtual reality in automotive manufacturing is projected to grow at a compound annual growth rate of 18.1% from 2023 to 2028. Leading manufacturers are already deploying these tools to enhance workforce capability, reduce errors, and accelerate production. Assembly teams increasingly use augmented and virtual reality for real-time access to technical data, immersive training, and streamlined inspections, supporting a more adaptive and skilled workforce.

Global OEMs are actively adopting these next-generation trends. Hyundai's plant in the US, for instance, operates with an automation rate of about 40%, four times higher than its global average. The facility deploys more than 950 robots alongside about 880 human workers to produce about 100,000 vehicles annually (The Chosun Daily, 2025). Whilst robots undertake repetitive or physically demanding tasks, human workers focus on programming, monitoring, and quality control, creating a hybrid production model that enhances efficiency without displacing employment. Despite its high degree of automation, the plant continues to employ over 8,500 local staff.

Next-generation manufacturing is being shaped by new production techniques. Tesla has

led innovation through its adoption of gigacasting, which is estimated to reduce the cost of the Model 3 by about US$2,800, or about 7.2% of its 2024 base price of US$39,000 (EV Boosters, 2024). Gigacasting streamlines production by replacing the welding of dozens of smaller components with a single large structural casting. This cuts labour and equipment costs, saves factory space, and enhances structural integrity, benefits that are especially important for xEV platforms. Other manufacturers, including BYD, are adopting similar methods to lower production costs and improve vehicle performance (Spherical Insights, 2025).

Nissan's manufacturing operations are renowned for their extensive use of advanced robotics and automation. Across Nissan's factories, precision-engineered robotic arms equipped with advanced sensors and sophisticated software carry out intricate tasks with unparalleled accuracy and speed (E Auto Export, 2024). This level of automation not only improves production efficiency but also ensures consistent quality control, reducing the risk of human error.

Taken together, these global developments signal a clear industry direction. To stay competitive, ASEAN must begin evolving its manufacturing base, not only to keep pace with global OEMs, but to establish the next generation of cost-efficient, high-quality vehicle production across the region.

8.3.2.3. Downstream

The downstream segment focuses on the traceability and circulation of materials. To ensure material sufficiency across the region, ASEAN must be able to trace materials through connected platforms and establish closed-loop recycling systems that support its vision of becoming a leading ICEV and HEV manufacturing hub. This section advances a trace-and-circulate approach, which is essential for achieving regional sufficiency and supply-chain resilience.

State #1: Material Traceability Integrated with Global Platforms

In this future state, ASEAN enables cross-border material traceability through interoperable platforms aligned with global standards. Materials are digitally tracked from extraction and processing through use, recovery, and reuse, supported by real-time data sharing amongst regional and international stakeholders. ASEAN leverages established platforms and systems for automotive material traceability, allowing data to flow seamlessly across jurisdictions and firms. At the broader supply-chain level, integrating traceability systems enhances data visibility, improves oversight of vehicle locations and embedded materials, and strengthens inventory management whilst optimising logistics and transport. Collectively, these improvements translate into smoother operations, reduced costs, and shorter delivery times.

Why it matters. Traceability across the automotive life cycle, from materials to vehicle end-of-life, is no longer a challenge that individual companies or even single industries can resolve in isolation (Teruyoshi, 2024). Enhanced material traceability provides the

region with comprehensive oversight of finished vehicles and their constituent components. When connected to global platforms, it allows end-to-end tracking across the value chain, improving transparency, accelerating recall processes, and supporting compliance with regulatory and industry standards. It builds trust amongst supply-chain partners, reinforces ASEAN's integration into global production networks, and enables more informed, data-driven decision-making across the value chain.

Recent initiatives provide useful benchmarks. In Japan, METI (2025a) has promoted the Ouranos Ecosystem initiative as part of its Data Free Flow with Trust agenda. Ouranos is a state-led programme designed to establish cross-enterprise, cross-industry, and cross-border data linkages to promote large-scale data sharing and application, in line with Japan's Society 5.0 vision. The initiative encourages interoperability across multiple systems, increasing the value derived from data whilst strengthening industrial competitiveness through public–private cooperation. According to Someya (2025), such data coordination enables faster and more efficient design processes, improved inventory visualisation, and optimised supply chain management. Collaboration across various partners and industries further supports traceability and the creation of new services and social value (Appendix 1).

Earlier, the EU established Catena-X, the first globally trusted and collaborative data ecosystem for the automotive industry. Developed initially as a consortium project funded by the German Federal Ministry of Economics, Catena-X is an open, interoperable, and scalable data ecosystem designed to serve the entire automotive sector (Schuler, 2025). Its core offering is a federated system of data and services that enables companies to shorten time to market, use resources more efficiently, and increase the transparency and resilience of value creation processes (Schmelting and Meyer, 2025). Catena-X brings together manufacturers, suppliers, dealers, recyclers, application developers, and platform and infrastructure providers on equal terms to establish uniform standards for data sharing across the automotive value chain (T Systems, 2025).

Drawing on these two examples, ASEAN is well-positioned to adopt a similar approach by deploying an interconnected platform that enables end-to-end material traceability, aligns with global standards, and integrates diverse systems across countries and industries. Two broad pathways are available: leveraging existing platforms such as Ouranos or Catena-X, or developing a dedicated regional platform tailored to ASEAN's specific needs. Careful and ongoing evaluation will be required, as each option presents distinct merits and trade-offs.

Regardless of the path chosen, the adoption of an integrated global platform is central to achieving ASEAN's to-be state for downstream material traceability. Such a system would enable transparent tracking of automotive materials throughout their life cycle, strengthen cross-border interoperability, and contribute to a more resilient, efficient, and future-ready supply chain.

State #2: Regional Optimisation of Material Use for Strategic Self-sufficiency

In this state, ASEAN maximises the value of its material flows by strengthening circularity, promoting local reuse, and enhancing cross-border coordination. Strategic optimisation ensures that critical materials are retained, recycled, and repurposed within the region, thereby reducing dependence on external supply. Material flows for the automotive sector are managed through closer regional coordination, enabling more efficient reuse of inputs across ASEAN in line with manufacturing demand as the region advances as a leading ICEV and HEV production hub.

Why it matters. Optimising material use is a key driver of resource efficiency and signals a shift away from reliance on finite resources such as rare metals, many of which are essential to automotive production (Ortego et al., 2020). By recycling materials back into the production cycle, the industry can move towards a closed-loop system in which waste is minimised and materials are reused repeatedly. This approach not only improves cost efficiency by reducing dependence on virgin raw materials but also strengthens supply-chain resilience. Over the long term, a coordinated and circular approach to materials management can help ASEAN meet growing manufacturing demand whilst safeguarding access to critical inputs.

To achieve well-grounded circulation systems and ensure that materials remain within the region, several countries have already adopted effective policy and industrial measures. One widely used approach is the implementation of vehicle scrappage policies, which aim to recover valuable materials from end-of-life vehicles (ELVs) and reintegrate them into the production cycle.

Nordic countries provide instructive benchmarks. Finland, for example, has implemented strict regulations governing ELV disposal, mandating that all ELVs be properly dismantled and recycled, with compulsory recovery of valuable materials such as metals and plastics. According to the SHiFT Vehicle Retirement Initiative (2025), Finland has established a network of over 300 authorised dismantling yards and recycling facilities to support this system. The government provides financial incentives to encourage proper ELV disposal, including a tax on new vehicles, the proceeds of which help fund future recycling efforts.

The Finnish automotive recycling industry is highly automated, with many facilities deploying advanced technologies such as robotics and AI to enhance efficiency and precision. As a result, up to 95% of materials from ELVs, including steel, aluminium, copper, plastics, and glass, can be recovered and reintegrated into manufacturing processes. Sweden shows a comparable outcome, with about 95% of vehicles recycled under a well-developed regulatory and industrial framework that ensures systematic recovery and reuse.

In mainland Europe, Germany is recognised for its comprehensive ELV regime under Directive 2000/53/EC, which requires automakers to accept ELVs free of charge through a nationwide collection network. This framework has enabled the recycling of about 97% of metals contained in German ELVs (Umwelt Bundesamt, 2014). In parallel, driven by

regulatory pressure and sustainability ambitions, BMW has committed to increasing the share of secondary materials in its new models from about 30% today to 50% over time (Taylor, 2023).

Asian experiences further reinforce these lessons. Japan implemented the Automobile Recycling Law in 2005, establishing a comprehensive national system that requires vehicle owners to pay a recycling fee upfront and assigns clear responsibilities to automakers, dealers, dismantlers, and other stakeholders. As a result, Japan now recovers 80%–95% of materials from ELVs in the form of reusable parts or reprocessed materials (Japan's Automobile Recycling Promotion Center [JARC], 2025; Auto Recycling World, 2024).

China has accelerated the use of materials recovered from scrapped vehicles in new vehicle production, supported by a series of national scrappage and remanufacturing policies. According to the Ellen MacArthur Foundation (2022), three policy measures have been particularly influential. First, subsidies for enterprises collecting vehicles and components have improved collection rates, whilst consumers receive a 10% discount on remanufactured parts. Second, the State Council set a target to establish 100 industrial zones to facilitate information exchange and best practices in remanufacturing. Third, the Smart Remanufacturing Action Plan (2018–2020) provided funding for skills development and R&D, alongside quality standards to ensure the safety and performance of remanufactured components.

These cases show how coherent national policy, industrial infrastructure, and targeted incentives can enable effective material recovery at scale. Although specific approaches differ, the underlying direction is consistent: coordinated systems linking scrappage, dismantling, and remanufacturing can significantly reduce reliance on virgin imports and keep high-value materials in circulation. For ASEAN, these international experiences highlight the potential of regionally coordinated mechanisms to secure material inputs, reduce waste, and build a more self-sufficient, cost-effective automotive ecosystem.

8.3.2.4. Enabler

This section highlights the cross-cutting enablers that support the entire vehicle supply chain. These enablers comprise foundational capabilities and systems that underpin upstream, midstream, and downstream activities, allowing the overall strategy to function as a connected and coherent whole.

One critical enabler is regional digital connectivity, which provides the underlying infrastructure for linking systems and platforms across the supply chain. Whilst material traceability (Section 8.3.2.3) focuses on tracking the movement and reuse of automotive materials throughout their life cycle, connectivity ensures that such tracking can operate effectively across borders. It enables real-time data exchange, operational coordination, and secure flows of goods, documentation, and certifications between countries and companies. By integrating national systems into a cohesive regional network, connectivity forms the digital backbone of a resilient and interoperable supply chain.

To realise ASEAN's ambitions in supply-chain digitalisation, the development of regionally integrated and interoperable systems is essential. The following analysis sets out the need for such connectivity infrastructure to support efficient, coordinated, and scalable supply chain operations across the region.

State #1: Integrated Connectivity via Real-time, Cross-Border Data Sharing Across ASEAN

In this to-be state, ASEAN establishes a digitally connected framework that enables real-time, cross-border data exchange amongst supply-chain stakeholders, including manufacturers, suppliers, logistics providers, and customs authorities. These systems are interoperable, governed by shared standards, and supported by cloud infrastructure or shared platforms that ensure secure and efficient data transmission across all AMSs.

The data exchanged include shipment status, customs declarations, inventory levels, transport routes, sustainability credentials (such as emissions data and recycled content), and product traceability records (including the origin of raw materials or battery components). This level of visibility ensures seamless coordination across borders and supports compliance with international traceability, ESG standards, and prevailing trade regulations.

Why it matters. Access to real-time, verifiable data is becoming essential for participation in global value chains. Secure and seamless data sharing allows supply chain actors to better coordinate logistics, customs clearance, and sourcing strategies, thereby reducing lead times and costs. Shared data also allow for earlier risk detection and more proactive responses to disruptions across the value chain. As ASEAN positions itself as a next-generation automotive hub, such connectivity is particularly critical given the increasingly modular and cross-border nature of vehicle manufacturing, in which components and subsystems are rarely produced within a single country. Without regionally integrated data exchange, the production network remains vulnerable to delays, cost overruns, and missed market opportunities.

With the rise of connected operations solutions, organisations are increasingly able to collect and analyse real-time data to drive more agile decision-making (Wilkinson, 2020). In complex manufacturing environments such as automotive production, this connectivity enables dynamic scheduling, allowing manufacturers to adjust production plans in response to disruptions or changing conditions (Ding et al., 2022). By integrating real-time insights into strategic and tactical decisions, businesses can optimise operations, reduce downtime, and better coordinate activities across borders. These benefits reflect why real-time, cross-border data sharing is a critical enabler for ASEAN's next-generation supply chain, as seen in emerging global examples.

The EU's Digital Product Passport (DPP) offers a compelling benchmark for how structured, cross-border data exchange can enable greater transparency, regulatory compliance, and operational efficiency across complex supply chains. Introduced as part of the Ecodesign for Sustainable Products Regulation, the DPP requires that nearly all

products sold in the EU carry a digital passport containing detailed information on their origin, material composition, environmental impacts, and ELV handling (EU, 2024). Crucially, the relevance of the DPP lies not only in the type of data collected, but also in how it is made available: openly, in real time, and accessible across borders. By adopting open data principles, the initiative enables standardised product information to be shared amongst manufacturers, regulators, customs authorities, and consumers, thereby reducing administrative friction and supporting data-driven decision-making throughout the product life cycle.

In Japan, efforts to build the Ouranous ecosystem provide another reference point. As part of this initiative, NTT DATA, in collaboration with the New Energy and Industrial Technology Development Organisation, government bodies, and industry associations, is advancing the commercialisation of data space interoperability. In April 2025, NTT DATA (2025a) successfully trialled the first use case of a battery traceability platform developed as a cross-industry ecosystem for EV batteries, with service provision commencing through the Automotive and Battery Traceability Centre Association, Inc. This initiative is expected to enable seamless and secure data exchange amongst companies, across industries, and across international borders.

For ASEAN, embracing similar frameworks could unlock faster movement of goods, reduce compliance-related friction, and deepen trust amongst regional actors. These outcomes are essential enablers for building a unified, resilient, and future-ready automotive supply chain across the region.

State #2: Enhanced Intra-regional Connectivity for a Mature Supply Chain

In this to-be state, ASEAN strengthens digital and operational connectivity across the region to support a more sophisticated and mature automotive supply chain. Rather than each AMS focusing primarily on domestic markets, this future vision emphasises the seamless movement of goods, data, and certifications across borders, enabling smoother intra-regional logistics, deeper collaboration, and more efficient production networks.

Why it matters. For ASEAN to establish itself as a next-generation automotive manufacturing hub, the seamless movement of goods, data, and certifications across borders is essential. Improved intra-regional connectivity underpins just-in-time production, one of the most efficient manufacturing methods (Jenkins, 2024), by reducing inventory holding costs and enabling flexible responses to disruptions. It also strengthens resilience by improving coordination and transparency across production networks. As automotive manufacturing becomes more modular and dependent on cross-border value chains, greater regional integration is critical. Without it, ASEAN risks falling behind regions with more connected, agile, and resilient supply chains.

ASEAN has already taken important steps towards regional integration through the ASEAN Single Window (ASW), which enables the electronic exchange of customs documents amongst AMSs. However, to meet the demands of next-generation automotive manufacturing, the region must move beyond partial digitalisation towards deeper,

system-level integration. This requires linking the ASW with interoperable logistics, inventory, and traceability platforms, supported by more consistent implementation, mutual recognition of procedures, and shared standards across borders.

The EU's Digital Single Market (DSM) offers a compelling benchmark for how regional connectivity can support industrial competitiveness. The DSM combines harmonised technical standards, interoperable digital systems, and mutual trust mechanisms to enable the free movement of goods, services, and data. By reducing fragmentation and aligning national rules, the EU has demonstrated how digital integration can lower compliance costs, lower costs, simplify cross-border procedures, and speed up trade. Harmonised standards and interoperable IT systems allow goods to cross borders with minimal friction, enabling real-time coordination amongst supply chain actors and supporting faster responses to operational disruptions.

The DSM strategy focuses on removing virtual borders and promoting harmonisation rather than fragmentation, whilst adapting the internal market to the digital age (Sadoian, 2025). A key pillar of this approach is environmental and digital readiness, including investment in secure, high-speed digital infrastructure and robust regulatory frameworks covering telecommunications, cybersecurity, and data protection. The EU has continued to simplify rules and reduce administrative burdens by promoting digital submission as the norm for regulatory compliance and encouraging strong coordination amongst member states (European Commission, 2025b).

For ASEAN, the aspiration is not to replicate the EU model wholesale but to adopt its core enablers to regional circumstances: interoperable systems, harmonised procedures, and mutual trust amongst AMSs. Strengthening the ASW into a more comprehensive backbone for intra-ASEAN trade, complemented by shared digital platforms for logistics, inventory management, and regulatory compliance, would allow components, vehicles, and materials to move across borders more efficiently. ASEAN could prioritise the digitisation and exchange of automotive-relevant documents, such as type approval certificates, battery safety declarations, and technical compliance documentation, in addition to existing instruments already exchanged through the ASW. By doing so, ASEAN can unlock faster goods movement, support just-in-time manufacturing, and reinforce its position as a competitive and well-connected production base in the global automotive landscape.

8.3.3. Vehicle Decarbonisation To-be State

ASEAN has long served as a global hub for ICEV and HEV production and exports. However, key customer markets, from Latin America and the Middle East to Oceania, are now imposing tighter fuel and carbon dioxide (CO_2) standards. In practice, these shifts require ASEAN's export models to become cleaner and more efficient well before a full transition to EVs. The envisioned to-be state therefore builds on decarbonising ICEVs and HEVs, whilst adapting these platforms for low-carbon fuels and, in parallel, investing in new EV supply chains.

In the near term, ASEAN producers are expected to prioritise ultra-efficient ICEVs and advanced hybrid systems engineered for higher biofuel and synthetic-fuel blends. Regional fuel policies are already moving in this direction. Thailand is phasing in E20 (20% ethanol) as the primary petrol blend (United States Department of Agriculture [USDA], Foreign Agricultural Service, 2024), whilst Malaysia plans to mandate B30 (30% biodiesel) for heavy vehicles by 2030 (Argus Media, 2023a). Automakers are responding with multi-fuel strategies. Toyota, together with Subaru and Mazda, is developing next-generation engines capable of running on carbon-neutral e-fuels, biofuels, or hydrogen (Toyota Motor Corporation, 2024). Mazda has built a prototype hydrogen rotary engine that can operate on either petrol or hydrogen (Mazda, 2023). These developments show that ICEV and HEV platforms will continue to improve in efficiency and emissions performance, sustaining ASEAN's competitiveness as an export base as fuel standards tighten.

At the same time, ASEAN is scaling up its xEV component industry to capture future growth. The region holds clear advantages, including Indonesia's vast nickel reserves (a key battery input) and a relatively large pool of skilled labour. These strengths are drawing major investments. BYD has opened a US$490 million EV assembly plant in Thailand with a capacity of about 150,000 units per year and is completing a US$1 billion facility in Indonesia (Reuters, 2025d). Tesla has signalled interest in the region, securing approval to sell vehicles in Malaysia and holding discussions on establishing manufacturing operations in Thailand (Reuters, 2024h). These developments suggest that ASEAN is rapidly becoming a focal point for xEV manufacturing and supply-chain localisation.

ASEAN's to-be state for vehicle decarbonisation rests on a dual-track transition. In the short term, the region sustains its role as an ICEV and HEV export hub by deploying fuel-efficient engines and hybrid models compatible with E20, B30, and even synthetic fuels or hydrogen. In parallel, the region rapidly builds out an xEV industrial base, encompassing battery cells and packs, e-axles, and power electronics. This varied pathway, combining existing strength with forward-looking investment, maximises ASEAN's comparative advantages whilst steadily shifting the industry towards zero-emission mobility, thereby supporting resilient growth as global standards continue to evolve.

8.3.4. Supply Chain Decarbonisation To-be State

As outlined in Vision Pillar 3, ASEAN's future competitiveness and growth hinges on its ability to align with tightening decarbonisation demands across the entire vehicle value chain. Decarbonising the automotive supply chain requires a set of mutually reinforcing shifts across upstream, midstream, and downstream segments.

8.3.4.1. Upstream

To support ASEAN's decarbonisation goals whilst sustaining its position in the global automotive industry, the region must strategically enhance its upstream supply chains for

ICEVs, HEVs, and xEVs. First, preserving ASEAN's role as a competitive ICEV and HEV production hub requires secure access to affordable, high-quality fuels that sustain vehicle performance, alongside the development of a robust biofuel ecosystem capable of delivering a reliable renewable fuel supply. At the same time, achieving the to-be vision outlined under Pillar 3 – deeper integration into the global xEV component supply chain – necessitates sustainable and secure access to critical minerals. This dual strategy is vital to ensure compliance with global decarbonisation standards, meet OEM expectations, and enhance regional autonomy and supply-chain resilience.

State #1: Low-carbon Fuels for ASEAN's ICEV and HEV-dominant Automotive Future

ASEAN's automotive industry is expected to remain heavily weighted towards ICEVs and HEVs for both domestic consumption and export in the medium term. Continued growth of the sector, supported by economies of scale from export volumes, alongside a rising middle class and improving affordability across ASEAN, will sustain strong domestic demand for vehicles and fuels. This dynamic is likely to generate a mutually reinforcing growth cycle across the automotive industry and the broader economy. Against this backdrop, ensuring that vehicles operate on reliable, affordable, and low-carbon fuels is essential for ASEAN to maintain global competitiveness whilst meeting its climate commitments in the to-be state.

To-be State – Upstream Fuel Decarbonisation

In the envisioned 2035 landscape, ASEAN commands a secure, diversified, and progressively decarbonised fuel ecosystem that underpins its continued strength in ICEV and HEV exports, whilst aligning with AMSs' net-zero commitments. Although the region continues to rely on imported crude oil, exposure to supply risks is reduced through two complementary strategies: (i) responsibly enhanced domestic extraction in Indonesia, Malaysia, and Viet Nam; and (ii) a broader portfolio of suppliers spanning the Middle East, Africa, and the Americas. Modernised strategic reserves and bilateral swap mechanisms provide an additional buffer, ensuring that short-term disruptions no longer translate into price shocks at the pump.

Running in parallel is a region-wide, certified-sustainable biofuel industry. By 2035, B20–B40 biodiesel and E20+ petrol blends have become standard retail grades, supported by diversified feedstocks, including palm oil, coconut, cassava, molasses, and used cooking oil, and second-generation facilities that convert agricultural residues into drop-in fuels. Harmonised sustainability standards, endorsed under an ASEAN Clean Fuels Pact, ensure deforestation-free supply chains and traceable carbon footprints, thereby preserving access to increasingly climate-conscious export markets. Advanced processing hubs in Singapore and Johor refine waste oils into renewable diesel and sustainable aviation fuel, whilst pilot e-fuel facilities in Sarawak and Brunei Darussalam produce commercial-scale synthetic methanol and ammonia, positioning ASEAN for future ultra-low-carbon fuel niches.

The ecosystem is underpinned by integrated logistics and data infrastructure, including common fuel specifications, interoperable blending terminals, and digital traceability platforms that verify carbon intensity from well to wheel or farm to wheel. As a result, retail fuel prices remain broadly affordable despite higher renewable content, as economies of scale, flexible refinery–petrochemical integration, and regionally pooled reserves help dampen volatility. OEMs, investors, and export customers increasingly view ASEAN as a pragmatic leader in decarbonisation: vehicles built in the region carry clear 'clean-fuel ready' credentials, and life-cycle assessments (LCAs) show that ICEV and HEV models powered by ASEAN's fuel mix achieve material CO_2 reductions relative to 2020 baselines. The to-be state delivers energy security, price stability, and climate credibility, locking in ASEAN's relevance in a carbon-constrained global automotive market whilst setting a foundation for deeper midstream and downstream decarbonisation.

State #2: A Mature Critical Metals Ecosystem as an Entry Point to the xEV Supply Chain

The rapid electrification of transport is driving an unprecedented surge in demand for critical minerals, including lithium, copper, cobalt, nickel, graphite, and rare earth elements (REEs), often described as the 'new oil' due to their indispensable role in modern technology, especially within the automotive sector.

Batteries alone are expected to account for more than 90% of total lithium demand by 2030, whilst requirements for nickel, cobalt, and graphite are all projected to more than double before 2035 (International Energy Agency [IEA], 2024b). Lithium demand is forecast to surge sevenfold by 2040, driven by the expansion of BEVs and PHEVs, with clean energy applications expected to represent over 90% of total lithium demand by 2030. Nickel, which is essential for high-energy-density cathodes, will see similarly strong growth, as higher nickel content is vital for extending vehicle range.

Graphite, used in lithium-ion battery anodes, is expected to grow fourfold by 2040, mirroring the boom in battery production. Yet, with over 90% of battery-grade graphite projected to come from China by 2030, supply diversification has become a strategic priority. Copper, the only critical mineral used across all major clean energy technologies, will see demand rise by about 50%, driven by its extensive use in motors, wiring, and charging systems, with the market projected to reach about US$330 billion by 2040.

Cobalt demand is projected to double by 2040, largely due to its continued role in lithium-ion battery cathodes. Although EV manufacturers are increasingly adopting low-cobalt or cobalt-free chemistries to address ethical and supply chain concerns, cobalt remains essential for battery stability and performance. As a result, EV batteries are expected to remain the dominant driver of cobalt demand despite ongoing efforts to reduce reliance on the metal (IEA, 2024b).

Demand for REEs is expected to double by 2040, reflecting their critical importance in modern technologies underpinning the energy transition. For instance, the permanent magnet motor in a typical EV contains about 600 grams of neodymium. Yet, REE markets

have exhibited pronounced price volatility: neodymium prices fluctuated from about US$65 per kilogram in 2020 to a peak of US$223 per kilogram in 2022, before easing to about US$125 per kilogram in 2023 (Reuters, 2023e). This instability is largely attributable to China's dominance in the REE supply chain. Until 2023, China controlled about 99% of the global supply of heavy rare earths and magnets, which are critical for xEV powertrains and semiconductors (Automotive Manufacturing Solutions, 2025). This reliance became a glaring vulnerability when, in early April 2025, China imposed stringent export restrictions on materials such as dysprosium oxide, which is vital for EV traction motors, in retaliation for US tariff measures. The situation was further exacerbated by the prolonged shutdown of the only notable non-Chinese refinery in Viet Nam due to a tax dispute, alongside inconsistent enforcement by Chinese customs authorities that blocked shipments and intensified the supply crunch (Automotive Manufacturing Solutions, 2025).

These disruptions have forced global automakers across the US, Europe, and Asia to scramble to diversify sourcing, exposing the fragility of the raw material foundations underpinning the energy transition. Whilst the immediate shock centred on REEs, similar vulnerabilities could emerge across other critical metals.

Despite early efforts to diversify supply chains, recent events have underscored how exposed the global energy transition remains to critical mineral disruptions. Automakers have sought alternative sources not only for REEs, but increasingly for lithium, nickel, cobalt, and graphite. Since 2023, companies such as ExxonMobil (which has announced plans for lithium production in the US by 2027), Norway's AkerBP (exploring seabed mineral extraction), and Equinor (investing in AI-enabled exploration through Kobold Metals) have taken steps to reduce dependence on China (Reuters, 2023b; Upstream Online, 2023; Arab News, 2023; Global Corporate Venturing, 2023). Nevertheless, the 2025 export restrictions underscored that these initiatives remain insufficient to withstand abrupt geopolitical shocks and reinforced the need for accelerated investment in more resilient and diversified mineral supply chains.

Compounding these challenges, the availability of low-priced critical metals from China presents a double-edged sword. It has helped lower the cost of clean energy technologies, contributing to a 14% decline in battery prices in 2023. However, persistently low prices discourage investment in alternative supply sources, particularly in emerging resource regions, inadvertently reinforcing China's dominance in global refining and processing (IEA, 2024b).

To-be State – Critical Metal Sourcing

In the to-be state, ASEAN emerges as a critical upstream enabler of the global xEV transition by integrating its mineral wealth, refining capacity, and strategic trade positioning into a cohesive and resilient supply ecosystem. This transformation is not simply aspirational but necessary. The region must reduce its exposure to fragile global supply chains, particularly amidst escalating geopolitical risks and increasingly stringent decarbonisation demands in international markets.

At the heart of this vision is ASEAN's capacity to leverage its unique geological advantages. Indonesia's abundant nickel reserves, Malaysia's rare earth processing expertise, and Viet Nam's emerging rare earth assets position the region as a natural anchor in the global critical mineral landscape. These strengths, however, must be deliberately translated into value through sustainable extraction, responsible refining, and the development of a regional supply ecosystem capable of serving both domestic and global xEV production. ASEAN's role should therefore evolve beyond raw material extraction towards a value-added hub where minerals are mined, refined, and prepared for direct downstream integration.

Achieving this transition requires a clear assessment of strengths and constraints. Whilst ASEAN controls substantial nickel and rare earth reserves, it lacks domestic supplies of other essential inputs, notably lithium and graphite. The to-be state therefore envisages a diversified sourcing strategy that combines enhanced domestic production with long-term supply agreements from multiple international partners. Reducing dependency on any single dominant source will be fundamental to strengthening ASEAN's long-term industrial resilience.

Developing competitive refining capabilities within the region is equally critical. Much of the value in critical mineral supply chain accrues at the refining and processing stages, where ASEAN currently remains underdeveloped. The region must invest in modern, low-emission refining hubs that are closely integrated with upstream mining activities. This includes expanding existing facilities, such as Malaysia's rare earth processing plants and Indonesia's nickel refineries, whilst developing new, regionally distributed capacity across other AMSs. Refining operations must also align with global ESG standards by adopting best-practice technologies, integrating renewable energy, and meeting the decarbonisation expectations of OEMs and export markets.

A supportive regional governance framework will be essential to underpin this transformation. AMSs will need to harmonise regulatory standards, align ESG and material traceability frameworks, and streamline permitting and investment processes. A coordinated ASEAN critical mineral strategy can ensure that national efforts are complementary rather than duplicative, enabling countries to pool resources, share technical expertise, and maximise collective advantage.

The implications of this upstream transformation are profound. Economically, ASEAN can move beyond the role of a low-cost supplier and claim a greater share of the value, generating skilled employment, attracting investment, and enhancing industrial competitiveness. Strategically, a diversified and localised critical mineral ecosystem will reduce exposure to external shocks and strengthen supply security for regional industries and international partners. Environmentally, ASEAN could leapfrog towards sustainable resource development, demonstrating that economic upgrading and alignment with global decarbonisation standards can advance in tandem.

State #3: Decarbonised Industrial Process Ecosystem

ASEAN must accelerate the decarbonisation of its upstream production environment, particularly by developing sustainable industrial parks powered by low-carbon energy and supported by robust carbon traceability, to remain a credible partner for global OEMs and investors.

Investor and OEM scrutiny of upstream emissions is tightening. The 2024 Supply Chain Report of the Carbon Disclosure Project (CDP) notes that 343 corporate buyers, together controlling US$6.4 trillion in procurement spend, now require climate-data disclosure from suppliers and warn that non-reporting or high-emitting vendors risk reduced business (CDP, 2024b). Regulatory pressures add further urgency. From 2026, the EU's CBAM will impose a carbon charge on imported steel, aluminium, and other inputs, with costs cascading down to component manufacturers (Chahim, 2025). In parallel, the EU Battery Regulation mandates cradle-to-gate emissions disclosure for traction batteries from 2024, introduces graded benchmarks in 2026, and sets binding CO_2 caps by 2027 (Kim and Chang, 2023).

Together, these developments make access to low-carbon electricity a prerequisite for market entry. The challenge is substantial: coal still accounted for about 50% of ASEAN's electricity generation in 2023 and contributed roughly 80% of power-sector CO_2 emissions (IEA, 2024c). Even under current policies, the IEA projects that the emission intensity of Southeast Asia's power sector will decline by only about 20% this decade, remaining well above the global average and far higher than in advanced economies. Unless ASEAN's upstream automotive clusters transition to low-carbon production, the region risks eroding its competitiveness under the dual squeeze of investor- and OEM-led decarbonisation mandates and emerging green trade barriers. Policymakers increasingly recognise this imperative: ASEAN's forthcoming energy cooperation blueprint is set to 'highlight decarbonisation and climate change' at its core, signalling a decisive shift towards a low-emissions future (ASEAN Centre for Energy, 2025a).

To-be State – Industrial Process Decarbonisation

By 2035, ASEAN's automotive upstream is envisaged as a global showcase of green industrialisation, characterised by integrated low-carbon energy systems and end-to-end carbon traceability from mine to final assembly.

1. **First,** a secure and scalable supply of renewable energy underpins industrial production. Automotive manufacturers and suppliers source most of their electricity from low-carbon sources through massive on-site solar photovoltaic installations, dedicated off-site renewable power purchase agreements (PPAs), and participation in an expanded ASEAN Power Grid (APC) enabling cross-border clean energy trade. This vision builds on existing momentum. Nine of the 18 APC interconnections are already operational, providing 7.7 gigawatts (GW) of cross-border transfer capacity, about two-thirds supplied by Lao PDR hydropower (ASEAN Centre for Energy, 2024b). Thailand has raised its hydropower import quota from Lao PDR to 10.5 GW by the early 2030s,

securing green electricity for industrial corridors such as the Eastern Economic Corridor (Bangkok Post, 2023a). Manufacturing facilities are already demonstrating feasibility: Bridgestone's Chonburi and Saraburi plants meet 100% of their electricity demand through rooftop solar and renewable energy certificate–backed purchases,[2] reducing emissions by more than 300 kilotonnes of carbon dioxide equivalent (CO_2-eq)[3] annually (Bangkok Post, 2023b). Complementing these efforts, IEA modelling shows that ongoing deployment of solar, wind, hydropower, and geothermal capacity will substantially lower the region's grid-emission factor well before 2035, with deeper cuts under announced pledges (ASEAN Centre for Energy, 2024b). These trends imply that by the mid-2030s, upstream suppliers and assembly plants can operate on electricity with a fraction of today's carbon footprint, sharply reducing Scope 2 emissions whilst locking in stable, low-carbon energy costs.

2. **Second,** ASEAN develops decarbonised industrial parks that synergise energy, waste, and material flows to drive down Scope 3 emissions at scale. In these next-generation automotive supplier parks, co-located firms share circular utilities and advanced low-carbon infrastructure. Common on-site facilities produce green hydrogen at scale via solar-powered electrolysis to supply industrial heat and heavy transport within the cluster. Hydrogen or its derivatives, such as ammonia, are distributed through shared networks, replacing coal- or gas-fired thermal processes. Waste heat from one facility is recovered and redistributed through district thermal loops to provide heat or cooling for neighbouring plants, maximising overall energy efficiency. Shared waste-to-energy systems and water-recycling facilities convert production scrap, biomass, and wastewater into useful inputs for other users. By 2035, several ASEAN automotive hubs have been retrofitted into eco-industrial parks (EIPs) running on closed-loop principles, demonstrating how industrial clustering can unlock economies of scale in decarbonisation. Governments incentivise these transformations through green industrial park programmes, offering infrastructure grants, preferential financing, and streamlined permitting for integrated clean-energy projects. The result is a network of low-carbon manufacturing clusters, across locations such as Indonesia's West Java, Malaysia's Penang, and Thailand's Eastern Economic Corridor, where suppliers achieve far lower emissions per unit of output than in stand-alone facilities. Such hubs attract investment from global OEMs seeking not just cost efficiency but verifiably green supply chains. Drawing on lessons from Europe and North America, where industrial clusters have approached net-zero emissions through shared hydrogen, carbon capture, and microgrid infrastructure (World Economic Forum [WEF], 2024a), ASEAN can leapfrog by adopting and scaling these models regionally. This collaborative approach allows smaller Tier 2 and Tier 3

[2] A renewable energy certificate represents 1 MWh of electricity from renewable sources, used to offset grid emissions.

[3] **CO_2-eq.** A unit expressing the climate impact of all greenhouse gases in terms of the equivalent amount of CO_2.

suppliers, which are often constrained by limited capital, to access low-carbon infrastructure as a shared service, ensuring an inclusive transition.

3. Third, comprehensive carbon traceability and accountability systems form the backbone of the decarbonised supply chain. In the 2035 vision, every major automotive component and battery produced in ASEAN comes with a digital carbon passport that transparently tracks cradle-to-gate emissions. Real-time carbon dashboards are standard features on factory floors and in management systems, drawing on sensors and IoT data that monitor energy usage, process emissions, and material footprints at each production stage. These data streams are secured and shared through industry-wide digital platforms, such as blockchain-enabled automotive networks, supporting standardised, verifiable emission reporting across companies. By 2035, a growing number of ASEAN suppliers are plugged into such systems, allowing near real-time measurement, reporting, and verification of Scope 3 emissions. This transparency is not merely a tool for internal optimisation; it is a licence to operate in global markets. OEMs in Europe and North America increasingly require detailed, authenticated carbon disclosures, whilst regulators demand verified product emission data. Through secure digital passports, ASEAN-made powertrains or batteries can instantly show compliance with stringent regulatory thresholds, supported by third party–verified life-cycle CO_2 data. Early adopters gain a clear competitive edge: reduced border friction, eligibility for green public procurement, and enhanced brand credibility with sustainability-conscious consumers. At the same time, granular emission data enable continuous improvement, allowing suppliers to pinpoint carbon hot spots and collaborate with partners on targeted abatement, reinforcing a virtuous cycle of industrial decarbonisation.

8.3.4.2. Midstream

The greatest decarbonisation pressure within the vehicle value chain will fall on the midstream segment, encompassing OEMs and their supplier networks. Driven by tightening OEM requirements, Tier 1 to Tier 3 parts and component suppliers across ASEAN must adopt robust carbon accounting and traceability systems to remain globally competitive and seamlessly integrated into OEM supply chains. Under current decarbonisation trajectories, by 2035, the carbon footprint of every component is likely to require active measurement and management across the supply chain. To deliver defensible, product carbon figures, ASEAN suppliers must anchor their calculations in internationally recognised protocols. Two pillars dominate this space: International Organization for Standardization (ISO) 14067:2018, which sets principles for cradle-to-gate product carbon footprints, and the Greenhouse Gas Protocol Scope-3 Calculation Guidance, the de-facto standard for value-chain emission reporting (ISO, 2018; Greenhouse Gas Protocol, 2013).

From 1 January 2026, the EU's CBAM will be fully implemented (EnviroSolutions & Consulting, 2024). Carbon measurement and embedded-carbon traceability are therefore

no longer optional; they have become core requirements for OEM sourcing decisions and market access. This shift is already evident in initiatives such as Volkswagen's sustainability rating for suppliers and Mercedes-Benz's responsible sourcing standards, both of which link contract eligibility to environmental performance (Mercedes-Benz Group, 2025). Accordingly, ASEAN suppliers must transparently track and report embodied emissions to meet buyer expectations and regulatory obligations, including CBAM reporting requirements.

To-be State – Carbon Footprint Management Across the Supply Chain

By 2035, the mature midstream ecosystem will feature comprehensive carbon measurement, reporting, and verification (MRV) systems alongside full life cycle traceability. All Tier 1 to Tier 3 parts will carry a DPP recording material composition, mass, origin, and a verified carbon footprint. For example, the EU Battery Regulation requires each EV battery to include a digital passport specifying factory and batch carbon footprint (Circularise, 2025). ASEAN OEMs and suppliers are expected to adopt comparable product passports for motors, plastics, electronics, and other components.

These passports, accessible through QR codes or secure cloud identifiers, will allow buyers or regulators to query a component's full supply-chain history. Embedded-carbon data will be collected in near real time via sensors, enterprise resource planning (ERP) and greenhouse gas (GHG) accounting tools, and primary supplier reports, enabling Scope 3 emissions to be calculated at the product level following ISO 14067/GHG-Protocol Product Standard. In practice, this means that by 2035, every intermediate assembly or subcomponent entering an ASEAN OEM facility will carry a verified carbon label, whilst consolidated dashboards will show the carbon intensity of entire vehicle models. OEMs will increasingly expect zero-defect carbon data, and buyers will select suppliers based on green ratings. Volkswagen's Sustainability Rating (S-Rating), which already excludes non-compliant suppliers from contracts, illustrates this emerging norm.

Digital technology will form the backbone of this system. DPPs will aggregate data from Tier 3 suppliers through to Tier 1 integrators. Each passport will include verified information on material sources, recycled-content percentages, energy mix, and calculated CO_2e per unit (Circularise, 2025). Compliance with ISO 14067 and the GHG Protocol Product Standard will be embedded by design, relying on primary activity data such as material masses, energy use, and transport distances rather than generic emission factors (ERIA, 2023a). Over time, data quality and comparability will improve as suppliers converge on harmonised measurement protocols.

Suppliers will upload footprint data to shared ledgers or secure data spaces where cryptographic verification prevents tampering. For example, Covestro and its partners have demonstrated a blockchain-based digital twin for Porsche vehicles, tracing the provenance and carbon footprint of plastic components from resin production to dashboard assembly (Covestro, 2021). In ASEAN, similar chain-of-custody systems are expected to be deployed for steel, semiconductors, and batteries. These systems will verify the provenance of recycled or low-carbon inputs, enabling buyers to confirm that

materials marketed as 'green' were used.

Digital MRV platforms (often cloud-native applications) will aggregate reported data, flag outliers, and integrate automated measurements such as factory energy metering and gas monitoring. Real-time dashboards will enable rapid corrective action, replacing delayed, periodic reporting cycles. ERP systems will integrate GHG modules so that every purchase order or production order automatically triggers a carbon calculation based on stored LCA data. A mature MRV environment will be bidirectional: suppliers push primary emission data upstream, whilst OEMs communicate decarbonisation road maps and targets downstream. Evidence from WEF Lighthouse plants shows that integrating energy–IoT systems with supplier portals can cut energy consumption per unit by 20%–30% and enable corrective action within 24 hours rather than monthly (WEF, 2024b). Extending this approach, ASEAN OEMs could share anonymised Scope 3 emission hotspot maps with suppliers, enabling benchmarking against peers, whilst suppliers publish forecast emission-reduction trajectories in shared data spaces. This closes the feedback loop and aligns capital expenditure planning across tiers.

ASEAN will not need to build this technological stack from scratch. One pathway is to leverage established global platforms such as Catena-X and Japan's Ouranos. Catena-X has already developed standards for product-level Scope 3 data exchange (Section 8.3.2.3.1) (ERIA, 2023a). Aligning ASEAN's data architecture with these interoperable frameworks would grant suppliers immediate compatibility with European OEM requirements. Collaboration with Japan's Ouranos ecosystem would similarly ensure that Japanese OEMs and suppliers operating in ASEAN remain aligned with global best practice (Catena-X, 2025a).

By 2035, carbon performance will decisively shape procurement and market access. ASEAN OEMs and global buyers will treat emission intensity as a core sourcing criterion. This trend is already visible: Volkswagen's group-wide S-Rating evaluates suppliers' environmental performance and excludes those that fail to meet its standards (Volkswagen Group, 2024), whilst Mercedes-Benz mandates supplier adherence to its sustainability standards and provides structured compliance support (Mercedes-Benz Group, 2025). In practical terms, suppliers with high embedded carbon will see bids downgraded or rejected. ASEAN suppliers will therefore compete on 'green scorecards', where demonstrably lower carbon intensity per component becomes a decisive advantage.

Export regulations reinforce this shift. From 2026, EU's CABM will require importers to document and pay for the embedded CO_2 in goods entering the European market (European Commission, 2025d). As a result, ASEAN-produced automotive steel, wiring harnesses, or chassis components destined for Europe will require a verified CO_2 footprint. Aligning midstream MRV systems and DPPs with CBAM requirements in advance will be essential to avoid cost penalties.

8.3.4.3. Downstream

A critical but often overlooked dimension of vehicle supply-chain decarbonisation in emerging markets is the long tail of emissions accumulated over a vehicle's 10–20-year service life. In Malaysia alone, more than 4 million passenger vehicles are already over 10 years old, whilst the average service life in Indonesia is estimated at 18–20 years (International Council on Clean Transportation [ICCT], 2023; Society of Automotive Engineers Malaysia, 2020). If ASEAN is to remain the world's leading ICEV and HEV export base whilst integrating into the global xEV value chain, it must establish a region-wide system that embeds reuse, recycling, and scrappage from the moment a vehicle leaves the showroom to the moment its materials are reintroduced into production.

By 2035, maintaining ICEV and HEV dominance whilst achieving meaningful decarbonisation will hinge on two core measures. First, ASEAN should implement a harmonised vehicle inspection system, drawing on Japan's forthcoming onboard diagnostics (OBD)–based inspections from October 2024, that captures verified emission data at each inspection. Such a system would discourage prolonged use of high-emitting vehicles and provide OEMs with auditable Scope 3 emission data (Society of Automotive Engineers of Japan, 2022a). Second, licensed scrappage operations and ELV infrastructure must meet EU benchmarks of 85% reuse and recycling and 95% reuse and recovery, ensuring that steel and aluminium are channelled back into vehicle manufacturing rather than disposed of in landfills (European Commission, 2023a).

At the same time, for ASEAN to play an important role in the global xEV supply chain by 2035, two further steps are required. First, the region must establish closed-loop circulation systems for rare metals, including lithium, nickel, and cobalt, to comply with recycled-content thresholds in export markets, such as the EU's requirement of 16% cobalt and 6% lithium by 2031, despite ASEAN's limited indigenous reserves (IEA, 2024d; Asia Society Policy Institute, 2025). Second, ASEAN must roll out dense, interoperable charging infrastructure to support xEV uptake. Thailand already operates 2,658 public charging stations with 9,694 connectors, whilst Malaysia targets 10,000 chargers by 2025 under its Low-Carbon Mobility Blueprint (Malaysian Green Technology and Climate Change Corporation [MGTC], 2021; Krungsri Research, 2024).

Scrappage logistics and closed-loop metal recovery are doubly critical because, without them, ASEAN risks swapping today's dependence on imported crude oil with a future dependence on imported battery minerals. The following sections examine four to-be states – vehicle inspection, scrappage infrastructure, material circulation, and charging networks – outlining the policy instruments, investment requirements, and implementation timelines needed to deliver a genuinely circular, low-carbon downstream ecosystem.

State #1: Vehicle Inspection System as a Digital Carbon Gatekeeper

To reduce tailpipe emissions without undermining ASEAN's cost advantage in ICEV and HEV exports, routine roadworthiness testing must mature into a data-rich emission control

regime. By 2035, every light vehicle should comply with a harmonised ASEAN Vehicle Inspection Protocol (AVIP), under which on-board diagnostic (OBD-III)[4] codes and certified CO_2 readings are uploaded to a regional database at each inspection. Japan's revised Road Transport Vehicle Act, which introduces mandatory OBD inspections for new domestic models from October 2024 and for imported vehicles a year later, demonstrates both the feasibility and the relatively modest administrative burden of implementing a digital inspection regime (Society of Automotive Engineers of Japan, 2022a).

Such a system is particularly relevant for ASEAN's ageing vehicle fleet. In Malaysia, more than 4 million passenger vehicles are already 11–20 years old (Society of Automotive Engineers Malaysia, 2020), whilst the average vehicle in Indonesia remains in service for 18–20 years (ICCT, 2023). AVIP would therefore tighten inspection frequency as vehicles age – biennial inspections during the first decade and annual inspections thereafter – whilst applying progressively higher emission-based road tax surcharges to discourage, rather than prohibit, prolonged use of high-emitting vehicles. This calibrated approach recognises household-budget realities whilst gradually incentivising fleet renewal towards cleaner models.

Implementation would rest on three practical levers. First, ASEAN transport ministers would adopt common test cycles and CO_2 thresholds aligned with the United Nations Economic Commission for Europe (UNECE) Regulations No. (R) 83 and No.101, ensuring that any vehicle compliant with AVIP also meets export-market requirements. Second, inspection centres would require secure cloud connectivity and electronic certification systems. Singapore already mandates a valid digital inspection certificate before road tax renewal, achieving near-universal compliance at minimal public cost (Land Transport Authority, 2025). Third, real-time data transmission would provide OEMs with auditable Scope 3 emission inventories and equip regulators with analytics to identify high-emitting vehicle segments, enabling targeted scrappage incentives or replacement financing schemes.

Combined with the scrappage and material-circulation measures set out in the next sections, a region-wide, OBD-enabled inspection regime would transform a conventional safety check into a strategic carbon gatekeeper. It would reduce lifetime emissions, improve road safety, and establish the digital infrastructure necessary for future battery health monitoring and life-cycle passport verifications for xEVs.

State #2: Licensed Scrap Operations and End-of-life Infrastructure

The inspection regime outlined in State #1 will be effective only if vehicle owners have access to a credible and economically attractive off-ramp for vehicles that fail progressively stricter emission tests. That off-ramp must take the form of a network of licensed ELV hubs: dedicated industrial facilities where vehicles are deregistered, dismantled, and shredded, and their metals remelted under audited environmental

[4] **OBD-III.** Next-generation on-board diagnostics: wireless, real-time transmission of key emission data to regulators, eliminating the need for manual plug-in inspections.

permits.

Each tonne of scrap steel processed through such hubs avoids roughly 1.5 tonnes of CO_2 emissions and reduces iron-ore demand by about 1.4 tonnes (World Steel Association, 2021). Recycled aluminium consumes about 95% less energy than primary smelting (International Aluminium Institute, 2023). At ASEAN's 2024 vehicle-scrappage rate, meeting the EU's 85% reuse and recycling and 95% reuse and recovery targets under Directive 2000/53/EC would reduce emissions by almost 4 million tonnes of CO_2 annually by 2035, whilst injecting well over US$1 billion worth of secondary metals into the regional supply chain.

Formalisation has already proven its viability: Malaysia's pilot Authorised Automotive Treatment Facility (AATF) reached a 90% recycling rate in its first commercial trials, supported by transparent material pricing and a modest take-back payment to vehicle owners (Sulaiman et al., 2023). Scaling this model across ASEAN would enable inspection fees and rising age-based road tax surcharges to channel older, higher-emitting vehicles towards licensed hubs, where residual metal value offsets disposal costs. Digital ELV passports, automatically generated upon deregistration, would record vehicle mass and material composition, providing smelters with predictable scrap streams and equipping regulators with the data needed to verify compliance with the 85% and 95% thresholds.

Strengthened scrappage logistics would therefore reinforce the incentives embedded in AVIP. As inspection frequency increases and emission-based surcharges rise after a vehicle's 10th year of service, the economic calculus would increasingly favour surrendering the vehicle to a licensed hub rather than retaining it in use or abandoning it. These two states would shift ASEAN away from today's informal and environmentally inefficient ELV practices towards a professional circular-economy backbone. This transition would not only reduce Scope 3 emissions associated with ICEV and HEV exports but also establish the material groundwork necessary for the rare-metal recovery systems needed in the xEV era.

State #3: Closed-loop Circulation of Rare Metals for the xEV Era

Whilst the ELV hubs described in State #2 recapture steel and aluminium from legacy vehicles, the electrified fleet expected to dominate after 2035 presents a different material challenge: the lithium, nickel, and cobalt locked inside traction batteries. The IEA estimates that clean-energy demand has already tripled global lithium consumption and increased cobalt demand by 70% since 2017, expanding the critical-mineral market to about US$320 billion in 2022 (IEA, 2023a). Yet ASEAN produces only negligible quantities of lithium or cobalt. A region-wide scoping study concludes that every AMS, apart from Indonesia, remains highly import-dependent for battery metals (International Institute for Sustainable Development, 2023). Such dependence on volatile import streams becomes untenable as regulatory requirements tighten. Under the EU's Sustainable Batteries Regulation, from August 2031, any battery placed on the single market must contain at least 16% recycled cobalt and 6% recycled lithium and nickel (IEA, 2024d).

In the envisioned system, the ELV hubs serve as the primary collection points for spent battery packs. These packs are then routed to hydrometallurgical processing facilities capable of recovering up to 95% of contained metals. Indonesia is already signalling a commercial pathway. The state-owned Indonesia Battery Corporation (IBC) plans to commission a dedicated EV battery-recycling complex by 2031 as part of its US$6 billion integrated nickel-to-battery project with Contemporary Amperex Technology Co., Limited (CATL) (IBC, 2025; Electrek, 2022). Once operational, the facility could supply more than 30 GWh of new cell production a year – enough for roughly half a million BEVs – whilst insulating domestic gigafactories from commodity price volatility, such as the cobalt price surge above US$80,000 per tonne observed in 2022.

A digital battery passport, generated at first vehicle registration and updated at each AVIP inspection, would record chemistry, provenance, and state-of-health data. This information would allow recyclers to optimise feedstock planning and enable regulators to verify compliance with EU recycled-content thresholds. Extended producer responsibility (EPR) fees, applied to new battery sales and reimbursed when battery packs are returned to authorised recyclers, would create the financial incentive structure that ELV hubs already provide for ferrous metals. By 2035, such a regime could redirect an estimated 80–90 kilotonnes of end-of-life battery mass annually into regional smelters, substituting upward of US$1 billion in imported primary metals and cutting embedded CO_2 by roughly 40% compared with virgin supply chains, according to life-cycle modelling by Transport & Environment (2024a).

Together with the digital inspection data flows established in State #1 and the licensed dismantling network in State #2, this rare-metal loop would transform ASEAN's downstream segment from a linear, import-dependent system into a self-reinforcing circular economy. In doing so, it would secure critical inputs for xEV production, meet stringent EU market requirements, and materially lower the carbon footprint of vehicles built within the region.

State #4: Interoperable Charging Infrastructure that Drives xEV Demand

The IEA finds that once a market reaches roughly one publicly accessible charger for every 10 EVs, xEV sales accelerate sharply as range anxiety diminishes and average battery sizes begin to shrink (IEA, 2024a). ASEAN has yet to cross that threshold. Thailand, the regional front-runner, recorded 2,658 public charging stations with 9,694 connectors at the end of 2023, equivalent to a ratio of about one charger for every 18 EVs, based on its 52,000 registered EVs (Fourin, 2024; EVAT, 2023). Malaysia reported roughly 2,020 stations by March 2024, against a government target of 10,000 chargers by 2025 under the Low-Carbon Mobility Blueprint (Malaysian Green Technology Corporation, 2021).

Interoperability must therefore become the norm rather than the exception. Thailand's fledgling Charging Consortium, already linking more than a dozen networks through a single QR code or application (EVAT, 2023), offers a preview of regional seamless access. Europe's Alternative Fuels Infrastructure Regulation demonstrates the potential gains: open roaming together with Combined Charging System (CCS2) and Type 2 standardisation

increased average charger use by roughly 25% within 2 years, lifting investor internal rates of return and reducing subsidy requirements per charging point (Transport & Environment, 2020). ASEAN's to-be state builds on these lessons by mandating a single CCS2 protocol for all direct-current (DC) charging sites, Type 2 for alternating-current (AC) charging, and mandatory real-time data sharing through the same cloud backbone that hosts AVIP inspection logs. This approach ensures that each new charger delivers maximum carbon abatement and financial efficiency.

Taken together, early co-funding and technical interoperability transform charging infrastructure from a potential bottleneck into a powerful accelerator of xEV adoption. They lower the total cost of ownership for first-wave buyers, de-risk private capital, and guarantee the battery throughput required to sustain closed-loop metal recovery systems. State #4 completes the downstream architecture, ensuring that every kilometre driven by ASEAN-made xEVs rolls the region closer to its carbon-neutral ambition rather than further away.

8.3.5. Servitisation To-be State

ASEAN's automotive future hinges on shifting from selling vehicles to delivering MaaS. This to-be state is crucial because it tackles structural challenges on both the demand and supply sides of the market.

On the demand side, consumers in ASEAN's emerging megacities face high costs of vehicle ownership, including fuel, parking, insurance, and taxation, alongside worsening congestion. Many privately owned vehicles remain idle over 90% of their lifetime, representing substantial economic inefficiency (Transport & Environment, 2017). Servitisation, through ride-hailing, car-sharing, and subscription-based mobility, offers the prospect of more affordable and convenient mobility. A survey conducted in Metro Manila found that 84% of respondents were open to using a MaaS application, citing reliability and cost savings as primary motivations (Nikitas et al., 2022). If users can meet most of their travel needs through integrated services, such as ride sharing, short-term rentals, and public transport, they may choose to forego private vehicle ownership, saving significant annual expenditure. This shift would not only benefit household finances but also alleviate congestion and parking pressures in dense urban environments.

However, realising this outcome requires reliability and trust. Services must deliver consistent safety standards, high-quality user experience, and comprehensive first and last-mile connectivity. Without these assurances, private vehicle owners will remain reluctant to switch. Early adopters such as Singapore have already taken steps in this direction, piloting autonomous shuttle services, integrating first-mile ride pooling, and enforcing strict safety standards for ride-hailing drivers. Empirical studies on MaaS adoption consistently show that perceived usefulness, especially cost-efficiency, is the decisive factor influencing consumer uptake (Nikitas et al., 2022). Demand conditions are favourable for service-based mobility, provided it delivers tangible advantages over private ownership.

On the supply side, ASEAN's automotive manufacturers and emerging mobility providers increasingly view servitisation as a pathway to greater and more stable value capture. Traditionally, the regional industry has relied on one-off revenue per vehicle sold. Servitised models, by contrast, generate recurring income streams through subscriptions, usage-based fees, fleet services, and data-driven offerings. Global trends confirm that this transition is underway. In the US, manufacturers ranging from Volvo to Porsche have launched vehicle subscription programmes, whilst technology entrants such as Waymo and Cruise are piloting autonomous taxi services that may reshape vehicle use patterns in the 2030s. In Europe, policymakers actively promote MaaS. Helsinki's Whim application pioneered monthly mobility bundles combining public transport and shared vehicles into a single subscription, whilst cities such as Paris and London support shared e-scooters and car-sharing schemes to reduce traffic. In Japan, Toyota's initiative, including Kinto and the Toyota Mobility Service Platform, aims to reposition the company from a traditional manufacturer to a mobility provider, integrating leasing, ride-hailing partnerships, and logistics services through Toyota-operated fleets (Kinto, 2024).

These global benchmarks demonstrate that servitisation is becoming mainstream. If ASEAN's automotive sector fails to embrace this shift, it risks remaining a hardware-focused supplier whilst foreign platforms capture service revenues, customer relationships, and data ownership.

Envisioning the 2035 to-be state. By 2035, ASEAN can position itself as a regional leader in innovative mobility services tailored to local conditions and potentially exportable to other emerging markets. Achieving this objective requires progression through distinct stages of servitisation.

Initially, manufacturers bundle basic services with vehicle sales, such as maintenance contracts and extended warranties. The next stage introduces usage-based models, including leases, rentals, and flexible subscription schemes. Ultimately, firms evolve towards outcome-based mobility solutions, in which customers pay for mobility results, such as monthly kilometres travelled or assured fleet uptime, rather than for vehicle ownership itself (Transport & Environment, 2017). At this advanced stage, vehicles operate as nodes within an integrated service ecosystem. Customers may no longer choose specific models; instead, they access a digital platform that allocates the most appropriate vehicle for each trip or delivery requirement.

Reaching this stage requires a fundamental transformation of business models and the adoption of an ecosystem-oriented mindset. ASEAN firms must develop or participate in integrated digital platforms rather than operate in fragmented silos.

The following sections outline the digital transformation needed to underpin servitisation (Section 8.3.5.1) and examine how servitisation can accelerate transport decarbonisation (Section 8.3.5.2). These pillars define ASEAN's automotive future: smart, connected mobility services that are both financially resilient and environmentally sustainable.

8.3.5.1. Digitalisation as a Servitisation Enabler: Platforms, Data, and Customer-centric Services

The to-be state for digitalisation within a servitised automotive ecosystem is characterised by technological platforms that facilitate relationship-based, data-driven interactions and support a product-service system focused on outcomes rather than one-off sales. In practice, every vehicle becomes part of a connected platform, and every customer interaction generates data that continuously refine service delivery. The key aspects of this digitalised servitisation model are as follows:

1. Connected platforms and telematics. By 2035, ASEAN vehicles will function as connected IoT devices. Telematics units, embedded sensors, and persistent connectivity will allow real-time monitoring of vehicle location, performance, and usage. This data backbone supports advanced services such as predictive maintenance, where vehicles signal service requirements before breakdown, and usage-based insurance, where premiums adjust according to driving behaviour.
ASEAN policymakers recognise the need for a supportive regional data ecosystem. The region is implementing the Regulatory Pilot Space to harmonise cross-border data flows for digital services (ComputerWeekly, 2024). This initiative is crucial for seamless mobility platforms. For instance, a connected vehicle manufactured in Thailand should be able to transmit telemetry in Singapore or Malaysia without regulatory barriers. The Global System for Mobile Communications Association has described the Regulatory Pilot Space as a precondition for innovations such as cross-border fleet tracking through IoT data (ComputerWeekly, 2024). By establishing common data standards and privacy frameworks, ASEAN can develop a unified digital market in which mobility services scale across a population of about 680 million.

2. Mobility super-applications and ecosystem integration. Southeast Asia is already recognised for its super-application ecosystem, where transport, payments, and ancillary services are integrated within a single digital interface. Grab exemplifies how digitalisation underpins servitisation. Its platform integrates ride hailing, vehicle rentals, shuttle services, and, in selected cities, public transport ticketing. The operational impacts are measurable. Grab operates the largest EV ride-hailing fleets in Indonesia and Thailand, with over 10,000 EVs in each market (Grab, 2025). Through data analytics, Grab optimises EV deployment, identifies peak demand zones, and routes drivers to charging stations during off-peak hours. In 2024, Grab reduced carbon emissions intensity per kilometre by 4.7% within its mobility services, reflecting improvements driven by route optimisation and increased use of low-emission vehicles (Grab, 2025). Super-applications allow service bundling. Grab offers vehicle rental and EV leasing options to drivers through its platform and provides real-time charging location information (Grab, 2025). By reducing two key barriers – high upfront EV costs and charger availability – the digital ecosystem accelerates EV adoption within a servitised model. This dynamic creates a reinforcing feedback loop: digitalisation improves service convenience, expands the user base, generates richer data streams, and enables continuous optimisation.

3. Flexible subscription models. A core tenet of servitisation is offering flexibility beyond traditional ownership, and digital platforms make such flexibility operationally viable. Through a mobile application, users can unlock vehicles for short durations or subscribe monthly, with minimal administrative friction. ASEAN automakers are starting to adopt these models. Toyota's KINTO subscription service, offered in markets including Malaysia and Thailand, provides an all-inclusive monthly fee covering the vehicle, insurance, road tax, and maintenance. Importantly, it allows short minimum commitment periods (3 months in certain markets), after which customers may continue on a rolling monthly basis and cancel with 1 month's notice (Kinto, 2024). In some cases, customers may switch vehicle models to accommodate changing needs. Digital platforms handle the underlying operational complexity, including identity verification, vehicle condition monitoring, and logistics coordination. In Singapore, GetGo allows users to locate, reserve, and unlock vehicles through a smartphone application (Vulcanpost, 2023). Frictionless digital onboarding drastically lowers barriers to adoption, drawing in consumers who value convenience. ASEAN's to-be state may include multiple interconnected platforms, both manufacturer-backed and independent. A regional MobilityPass concept, for example, could enable users to access cars, motorcycles, scooters, and public transport across AMSs through a single digital account.

4. Data use and sharing. Servitisation reaches its full potential when data flows securely and efficiently amongst stakeholders. In the future state, vehicles continuously upload data to manufacturers on component health, to insurers on driving patterns, and to public authorities on traffic flows. This ecosystem enables service optimisation across multiple dimensions.

Aggregated vehicle data can support predictive maintenance scheduling, reducing downtime for customers. Fleet operators can dynamically position vehicles to meet peak demand. Governments can collaborate with mobility providers to develop regional traffic management platforms or EV charging databases fed by real-time inputs. Such a system requires privacy-by-design architecture, incorporating anonymisation techniques and secure data governance to protect personal information whilst enabling analytical value. It will require new forms of collaboration. Automakers may establish data consortia to train AI models for battery performance optimisation or autonomous driving systems, capabilities that individual firms may struggle to develop independently. Data, therefore, becomes a strategic production factor within ASEAN's automotive industry. Servitisation depends not only on vehicles but on digital infrastructure (cloud computing, 5G networks, cybersecurity frameworks, and analytics capabilities) supported by coherent regulatory regimes. When effectively implemented, digitalisation does more than enable servitisation; it continuously enhances it through feedback loops that improve efficiency, cut costs, and elevate customer experience.

In the to-be digital landscape, ASEAN's automotive servitisation model is defined by ubiquitous connectivity and platform-based service delivery. Vehicles, users, and

infrastructure operate within an integrated digital ecosystem. Automakers evolve into software-driven mobility providers, iterating services based on real-time user data. Customer experiences become increasingly personalised. For example, applications may recommend the most cost-effective or time-efficient travel option based on live traffic conditions and dynamic pricing. By optimally matching supply and demand and maximising asset use, digitalisation ensures that servitisation strengthens not only business performance but also sustainability goals across the region.

8.3.5.2. Decarbonisation Through Servitisation: Towards Sustainable Mobility Life Cycles

In the to-be state, ASEAN's mobility services are designed around life-cycle sustainability: from maximising each vehicle's usage (getting more mileage from the resources invested in manufacturing it) to ensuring that vehicles are maintained, powered, and retired in the greenest possible way. Several aspects highlight why servitisation and decarbonisation go together:

1. Higher use, fewer vehicles. For more than a decade, household cars have remained parked for roughly 95% per day (Reinventing Parking, 2013; US Department of Energy, 2024), leaving manufacturing energy and materials underused whilst still emitting CO_2 when driven occasionally. By shifting towards shared fleets that operate more intensively, it becomes possible to serve the same travel demand with far fewer vehicles. European studies show that each shared vehicle can replace 5–15 privately owned vehicles on the road (Transport & Environment, 2017). An Organisation for Economic Co-operation and Development (OECD) simulation in Lisbon found that complete adoption of shared autonomous vehicles could meet the city's travel needs with just 10% of the current vehicle fleet, cutting vehicle numbers by 90% (Transport & Environment, 2017). For ASEAN, which is approaching a period of rapid vehicle boom as incomes rise, servitisation offers a chance to leapfrog to a less car-dependent mobility paradigm. Rather than each household aspiring to own a car (or even multiple cars), the 2035 vision envisages urban residents relying on convenient alternatives: ubiquitous on-demand shuttles, affordable ride-shares, and community car clubs. Fewer vehicles reduce congestion and lower cumulative emissions. It means that vehicles remaining in operation can be newer and cleaner on average, since fleet operators can upgrade vehicles more rapidly than private owners. For instance, when companies such as Grab or Gojek deploy thousands of EVs, the shift from petrol to electric mobility occurs rapidly, something that would otherwise take years if left solely to individual consumer purchases. Singapore already reflects this thinking. The government capped net private car growth at 0% from 2018 onwards (Reuters, 2017), explicitly aimed at reducing strain on land use and meeting environmental goals. Instead of encouraging greater private ownership, Singapore has promoted electric car-sharing programmes, such as BlueSG, launched in 2017, to expand mobility access without expanding the total vehicle fleet (Reuters, 2017).

2. Electrification and cleaner energy integration. Servitisation can significantly accelerate the transition towards EVs and other low-carbon technologies. Fleet operators have strong incentives to adopt EVs once the economics become favourable. Although electric drivetrains involve higher upfront costs, they offer lower operating costs per kilometre due to reduced fuel and maintenance expenses. In high-use scenarios, these savings quickly outweigh the initial premium.

This transition is already underway. Grab's electrification strategy – deploying more than 10,000 EVs in Indonesia and Thailand – is partly driven by operating economics: for drivers travelling about 200 kilometres per day, electricity costs are substantially lower than petrol costs (Grab, 2025). Likewise, battery-swapping and battery-leasing models (pioneered by Nio's 5-minute Power Swap stations in China) have become popular amongst high-mileage taxi and ride-hailing drivers because they provide predictable energy costs whilst minimising downtime (INSEAD Knowledge, 2024). These same economics translate neatly to ASEAN. Grab is already piloting battery-swapping partnerships to further reduce driver downtime (Grab, 2025). Because servitised fleets are centrally managed, operators can optimise charging schedules, shifting charging to off-peak hours or using swap stations that draw power when electricity prices – and carbon intensity – are lower. Smart and bidirectional charging EVs already provide about 10 GW of flexible grid capacity in China, a figure expected to climb as commercial fleets electrify (IEA, 2025a). Applying similar models in Southeast Asia could allow thousands of shared EVs to function as grid-balancing resources, absorbing excess solar generation during midday and reducing evening demand peaks.

3. Life-cycle management and the circular economy. When automotive companies transition from selling products to providing services, they assume greater responsibility for the entire vehicle life cycle. This shift naturally encourages more sustainable practices throughout each stage of operation. For example, when an OEM leases vehicles or operates them within a shared fleet, it has a strong incentive to ensure durability and efficiency. A well-maintained vehicle lasts longer and emits less pollution, directly benefiting the provider's operational costs and reputation.

Technological advances are enabling this life-cycle optimisation. Industry forecasts suggest that the vehicle telematics and IoT market will grow by about 15%–20% annually during this decade (GlobeNewswire, 2024), underlining its growing importance in optimising fleet operations.

Regulatory developments are reinforcing life-cycle transparency. In Europe, from 2027, every traction battery placed on the market must carry a digital battery passport, documenting provenance, chemistry, recycled content, and end-of-life outcomes (German Institute for Standardization [Deutsches Institut für Normung, DIN], 2024). Such systems enable regulators and manufacturers to track environmental compliance whilst also providing data to optimise battery use and second-life applications. ASEAN nations could adopt similar measures, initially targeting commercial fleets or imported EVs, to ensure

that servitisation encourages responsible life-cycle management rather than neglect. The circular-economy element is equally important. Companies such as Renault have already established re-factories dedicated to refurbishing used vehicles and repurposing EV batteries for stationary energy storage (Renault Group, 2023). By 2035, ASEAN automakers and specialised service providers could operate similar facilities, refurbishing high-mileage ride-hailing vehicles for resale in secondary cities or repurposing used bus batteries for solar-energy storage. Such initiatives would create green jobs whilst ensuring that the carbon footprint of manufacturing vehicles and components is amortised over a longer service life.

4. Policy alignment and urban planning. To maximise decarbonisation benefits, servitised mobility must complement public transport and non-motorised transport modes rather than displace them. If ride-hailing becomes excessively convenient or inexpensive, it could divert passengers away from buses or rail systems, increasing vehicle-kilometres travelled. Policymakers must therefore design regulatory frameworks that steer servitisation towards shared rides and first-mile or last-mile solutions that strengthen overall transport system efficiency.

ASEAN cities are already beginning to integrate these approaches. By 2035, congestion pricing and low-emission zones are likely to become more widespread across major ASEAN metropolitan areas. Such policies inherently favour pooled and EVs (many of which will be operated by servitised fleets) over single-occupancy private vehicles powered by ICEs. According to Transport & Environment (2017), these complementary measures are needed to avoid a rebound effect in which cheaper mobility services lead to increased traffic volumes. Ultimately, the environmental benefits of servitisation arise from system transformation: fewer vehicles operating more intensively and powered by cleaner energy sources. Achieving this outcome requires coordinated action amongst businesses, governments, and consumers.

To-be State – Holistic Vision

By 2035, a traveller in ASEAN might use a single application to plan a journey involving an e-scooter to a bus stop, a bus for the long haul, and a shared EV for the last stretch, all booked and paid for through one platform. The vehicles used during this journey are likely to be electric and will serve multiple users throughout the day. As a result, emissions per passenger-kilometre will be only a fraction of those associated with the widespread use of privately owned petrol vehicles.

In this future, ASEAN's automotive companies evolve into mobility providers. Firms such as Proton or Toyota Asia may generate revenue by managing mobility fleets, operating charging infrastructure, and partnering with electricity providers to supply renewable energy for transport services. Mobility becomes more inclusive, as users can pay per journey or subscribe to services without facing the high up-front costs of vehicle ownership. Safety may improve through professional fleet management and advanced vehicle technologies.

These outcomes emerge from the strategic combination of servitisation, digital innovation, and decarbonisation. In such a future, the growth of the automotive sector becomes increasingly decoupled from emissions. Profitability derives from services, efficiency, and system optimisation rather than from the sale of ever greater numbers of polluting vehicles. For ASEAN, a region highly vulnerable to climate change, aligning economic development with environmental sustainability in the automotive sector is not merely desirable, but imperative.

8.4. Business-as-usual and Gap Analysis of Vehicle Digitalisation

To define the policies and steps required to enable full vehicle digitalisation across ASEAN, this section assesses the region's current conditions relative to the to-be state (Section 8.3.1). The analysis focuses on the current adoption of SDV features and the operational use of UIO monitoring. These conditions provide the baseline for understanding the structural constraints that policy and industry action must resolve to support the transition towards a digitalised vehicles ecosystem.

Current State: Vehicle Digitalisation Landscape in the ASEAN Automotive Industry

Business as Usual (BAU) #1: Nascent SDV adoption

SDVs remain an emerging concept globally and are still underdeveloped within the ASEAN automotive market. Nevertheless, according to Lee (2024), technology features and the willingness to try innovations rank amongst the two most important reasons spurring Southeast Asian consumers to switch vehicle brands. Consumers in ASEAN are particularly interested in connected vehicles, especially features that provide updates on maintenance, road safety, and traffic congestion. In most markets in the region, except for Singapore, consumers are even willing to pay extra for such technologies.

Despite this positive sentiment, these expectations have not yet translated into widespread adoption or localisation of SDV technologies within ASEAN's vehicle offerings. The most notable development has emerged from Viet Nam. In 2024, Vietnamese IT company FPT and automotive components manufacturer Denso signed a memorandum of understanding to accelerate SDV development (GlobalData, 2024b). The partnership aims to accelerate the development of next-generation SDVs, particularly by focusing on mass-production solutions for advanced driver-assistance systems. In addition to software development, FPT and Denso will establish an offshore development centre focused on talent development and technical training. FPT will contribute AI engineering expertise, whilst Denso will provide development road maps, training platforms, and personnel exchanges to support collaboration.

Beyond Viet Nam, few other notable local initiatives focus on SDV development, investment, or production. This suggests that SDV adoption within ASEAN's automotive market remains at a nascent stage and is still dominated by conventional hardware-based vehicle architectures. Most vehicles continue to rely on stand-alone electronic control units, and although global OEMs have introduced advanced SDV platforms in other

markets, such developments remain limited within ASEAN.

BAU #2: Underutilisation of connectivity services for UIO monitoring

Growing interest in connectivity and data use in vehicle services is reflected in Southeast Asia's vehicle telematics market, which is projected to grow at a CAGR of 11.4% from 2025 to 2030 (Mordor Intelligence, 2024). This growth is supported by the presence of multiple telematics providers across AMSs offering features essential for in-use vehicle monitoring, such as diagnostic reporting, maintenance status updates, and vehicle life-cycle tracking. However, actual adoption and usage of these services remain limited. Most notably, telematics solutions that provide in-use monitoring are primarily focused on commercial vehicles, whilst adoption in passenger vehicles remains comparatively low.

In Thailand, major telematics providers operate predominantly within the commercial vehicle sector. Companies such as Geotab, Verizon Connect, and Trimble lead telematics integration in this domain (6W Research, 2025a). The emphasis on commercial vehicles is further reinforced by regulatory requirements. In 2015, the Department of Land Transport mandated that vehicles with six wheels or more install telematics systems (Deenadayalan, 2021), whereas no comparable mandate applies to passenger vehicles.

This commercial vehicle orientation is evident in other ASEAN markets, largely driven by the operational needs of fleet management. In Malaysia, for example, ASolute, a telematics and logistics software provider, reports that roughly 99% of its clients are heavy-vehicle operators (Ruptela, 2025). In Indonesia, leading telematics providers such as Lavinta Telematics, TransTRACK, MyFleet Indonesia, Cartrack, and Hino Telematics primarily serve commercial fleet operators. In Viet Nam, key players such as Vintech, CenLand, and MobiFone are advancing telematics-based monitoring solutions focused on commercial vehicles (6W Research, 2025b).

With respect to monitoring trends (Section 8.3.1), several monitoring-enabled offerings from leading OEMs have been introduced in selected ASEAN markets. However, these systems are not yet widely available across the region, which limits seamless connectivity and comprehensive vehicle monitoring across the broader automotive value chain. For instance, Toyota's T-Connect service is available primarily in Thailand, despite Toyota Motor Asia operating across 16 markets. Evidence indicates that not all these markets support T-Connect services. Similarly, Hyundai's BlueLink was reportedly unavailable for the Ioniq 5 in Malaysia, whilst being accessible in Indonesia (Hans, 2023).

These examples suggest that most vehicles in the region still lack active telematics integration, limiting opportunities to support predictive maintenance, extend vehicle lifetimes, and optimise servicing cycles. This limited uptake contrasts with rising consumer openness towards such technologies. Deloitte's Global Automotive Consumer Study (2024) found that consumers in most Southeast Asian markets are willing to share personal data in exchange for updates on vehicle health, maintenance, and road safety, all core functions enabled by in-use monitoring systems.

Gap: Vehicle Digitalisation

Gap #1: Low penetration of connectivity-enabled vehicles in ASEAN

Whilst consumer openness towards connected services is rising, the region still faces a fundamental constraint: the limited number of vehicles equipped with connectivity features that enable in-use monitoring. This gap restricts the ability of automakers and governments to optimise servicing, extend product lifespans, and promote responsible resource use across the automotive value chain.

In the SDV space, the analysis shows that, aside from Viet Nam, few countries in the region have made meaningful progress towards ecosystem development. Even if Viet Nam successfully advances its SDV capabilities, the rest of ASEAN will need to catch up once regional demand surges, as Viet Nam alone will unlikely be able to meet the full scope of SDV requirements.

Although several vehicle telematics providers have entered ASEAN markets, their offerings and adoption remain largely concentrated in the commercial vehicle segment. The passenger vehicle segment continues to lag, with most units still lacking factory-installed systems capable of supporting real-time diagnostics, maintenance tracking, or life-cycle monitoring. As highlighted in the BAU analysis, in-use monitoring services remain primarily fleet-oriented, driven more by regulatory requirements and operational needs than by consumer demand. Consequently, even where consumers express willingness to share data in exchange for benefits such as maintenance alerts or enhanced safety, as highlighted by Deloitte's Global Automotive Consumer Study (2024), these services are not widely available. This situation reflects a disconnect between rising consumer readiness and the deployment strategies of OEMs, contributing to the persistently low uptake of vehicle connectivity across the region.

This disconnect is further shown by the fragmented rollout of OEM connectivity platforms. Services such as Toyota's T-Connect and Hyundai's BlueLink have been deployed selectively in only a few ASEAN countries, even though these manufacturers operate across multiple regional markets. The level of connectivity innovation reaching ASEAN remains limited, typically not surpassing Level 2 connectivity, as defined by the SDV Readiness Level framework developed by S&P Global (2025). By contrast, several vehicles in developed markets such as the US have already reached Level 5 connectivity, with Tesla representing a prominent example.

Level 2 connectivity enables enhanced user experiences such as real-time navigation, predictive maintenance alerts, and basic AI-assisted driver functions (S&P Global, 2025). Level 5 connectivity, by contrast, enables continuous and compliant data collection, supporting advanced machine-learning algorithms and predictive analytics capabilities.

Such data flows not only enhance the in-vehicle experience but also strengthen the broader automotive value chain. Development teams gain visibility into real-world vehicle usage patterns, enabling faster product iteration and software improvements. At the same time, manufacturing facilities can adjust production lines using live operational data rather

than waiting for full model refresh cycles. Supply chains become more predictive and responsive, allowing part production and delivery to align more closely with actual demand. These capabilities are foundational if ASEAN intends to strengthen its position as a high-performing automotive manufacturing hub.

Until a broader base of connected vehicles exists on the road, ASEAN will remain constrained in its ability to implement predictive maintenance programmes, enable circular resource planning, or support vehicle upgrade pathways. These limitations will continue to hold back the region's shift towards a more competitive and future-ready automotive ecosystem.

8.5. Business-as-usual and Gap Analysis of Supply Chain Digitalisation

To define the steps and policies required to advance vehicle digitalisation, this section examines ASEAN's current state in relation to the envisioned to-be state (Section 8.3.1). By clearly understanding the current landscape, this analysis identifies key gaps between the present situation and the desired future direction. These insights will inform the development of effective policies and actions required from governments and industry stakeholders to achieve the desired outcomes.

8.5.1. Upstream

8.5.1.1. Current State: Semiconductor Landscape and Its Role in the ASEAN Automotive Industry

BAU #1: Strong semiconductor capacity, yet fragmented from automotive value chains

The semiconductor market in ASEAN has emerged as a significant global powerhouse in recent years, valued at US$95.9 billion in 2024 and estimated at US$109.6 billion in 2025, and US$212.2 billion by 2032, representing an 8-year CAGR of 9.9% (Fortune Business Insights, 2025). ASEAN countries have primarily established themselves as key actors in downstream processing and assembly, although they continue to face significant barriers to advancing further along the value chain (Liew, 2025). Nevertheless, governments across the region continue to support the sector through national strategies aimed at moving up the semiconductor value chain and participating more actively in advanced manufacturing, chip research, and design. These commitments have helped ASEAN achieve notable progress within the semiconductor industry.

For instance, Singapore's semiconductor ecosystem spans the entire value chain, including R&D, manufacturing activities, wafer fabrication, assembly, packaging, and testing. The semiconductor industry in Singapore currently contributes about 5% of global wafer fabrication capacity, 20% of global semiconductor equipment output, and over 10% of total global semiconductor output (Medina, 2024). Malaysia accounts for 13% of global semiconductor testing and packaging activities and has become the world's sixth-largest exporter of semiconductors (Strangio, 2024). Elsewhere in the region, countries such as Viet Nam, the Philippines, Thailand, and Indonesia consistently export integrated circuits

and related components to China, with manufacturing activities occurring at various stages of the supply chain, particularly assembly, packaging, and testing (Wihardja and Tan, 2025). Overall, ASEAN accounts for 23.6% of global semiconductor exports (Ing and Wijaya, 2024), highlighting the region's significant role in the global semiconductor market.

Despite this strong performance, semiconductor production across ASEAN remains largely disconnected from the region's automotive manufacturing value chains. Most chips produced in ASEAN are exported, with limited allocation to support the growing needs of local vehicle manufacturers. Automotive manufacturers within the region continue to source semiconductors externally, exposing the sector to supply volatility, extended lead times, and geopolitical trade risks. No formal mechanisms exist to integrate semiconductor producers with automakers, leaving both sectors largely siloed and weakening regional resilience within the automotive supply chain.

Although data identifying suppliers' country of origin are not always readily accessible, import statistics from several ASEAN countries provide insight into the persistent disconnect between the semiconductor and automotive sectors. In 2023, about 68% of Thailand's semiconductor imports came from China, valued at US$1.8 billion, followed by Japan (16.8%, US$446 million), and Malaysia (8.1%, US$216 million). (Observatory of Economic Complexity, 2024). Less than 10% of Thailand's semiconductor usage originates within ASEAN. Such a concentration of imports from outside the region, particularly from China, exposes Thailand's automotive sector to supply-chain vulnerabilities and geopolitical risks.

A similar trend is seen in Indonesia. Although Indonesia ranks amongst the world's major chip exporters, the country sources most of its semiconductor imports from China, Japan, and Korea (Volza Global, 2024), with intra-regional imports likely negligible. From 2023 to 2024 alone, chip imports grew by 86% year-on-year, revealing growing reliance on foreign supply chains, a reliance that introduces volatility for semiconductor-intensive industries, including automotive manufacturing. Thailand and Indonesia demonstrate that even in countries with significant automotive manufacturing capacity, semiconductor inputs remain heavily dependent on imports from outside the region. This situation reinforces the disconnect between domestic manufacturing needs and the region's semiconductor production base, which continues to operate largely independently of local vehicle production.

A similar challenge is evident in Viet Nam. Most semiconductor chips used in automobile production and assembly are imported from global corporations based in the US, Taiwan, and Korea. This reliance on foreign chip supply has created a structural vulnerability in Viet Nam's automotive sector. During the global semiconductor shortage (FPT Semiconductors, 2024), the absence of domestic or regional supply alternatives left Viet Nam's automotive manufacturers with limited options. As a result, several brands were forced to postpone vehicle deliveries by several months. Both imported and locally assembled vehicles were affected, and some manufacturers reduced the number of new models introduced to the market.

This scarcity also led to price hikes. One notable example involved VinFast, which had planned to deliver thousands of VF e34 vehicles to customers who had placed deposits by January 2022. However, during the first 2 months of that year, only 93 VF e34 EVs were delivered. VinFast attributed the delays to a shortage of semiconductor components, underscoring how the absence of a resilient and regionally integrated semiconductor supply chain directly impacted production timelines.

ASEAN's current situation reveals a distinct pattern. Although ASEAN's semiconductor industry continues to expand, its output remains largely untapped by regional automotive manufacturers. Instead, vehicle producers continue to rely heavily on semiconductor imports from outside the region, exposing the sector to external supply risks, geopolitical uncertainty, and cost volatility.

BAU #2: Strong export orientation with limited priority for local demand

In comparison with BAU #1, which describes the lack of value-chain integration, BAU #2 describes the export-oriented approach and limited priority given to domestic demand observed in ASEAN. Over the past few years, ASEAN has emerged as a notable global semiconductor exporter. In 2023, the region accounted for 23.6% of global semiconductor exports, contributing US$268.8 billion to the global total of US$1.14 trillion (Ing and Wijaya, 2024).

Further evidence of this export orientation can be seen in ASEAN's semiconductor trade with its major partners, China and the US. The region exported US$58.3 billion in semiconductors to these markets whilst importing US$38.9 billion, resulting in a regional trade surplus of about US$19.3 billion (Appendix 2) (Wihardja and Tan, 2025). Wihardja and Tan found that Singapore, Malaysia, and the Philippines collectively account for about 84.4% of ASEAN's semiconductor exports. Although Viet Nam, Thailand, and Indonesia run semiconductor trade deficits, large surpluses in Singapore, Malaysia, and the Philippines more than offset them. Despite individual country imbalances, ASEAN maintains a positive semiconductor trade position.

Whilst such a trade surplus reflects ASEAN's strong global competitiveness in semiconductor exports, it also indicates that the region's semiconductor output remains primarily geared towards external markets rather than domestic industrial integration. The bulk of semiconductor production is exported, despite the expansion of local industries, such as automotive manufacturing, that increasingly rely on semiconductor inputs. This reinforces the disconnect identified in BAU #1 and suggests that domestic consumption has not yet become a central priority in the region's semiconductor growth trajectory.

BAU #3: Concentration of semiconductor demand in the electronics sector

Within ASEAN, semiconductor consumption is concentrated in the electronics sector. Although both the electronics and automotive industries are designated priority sectors

under the 2004 ASEAN Framework Agreement for the Integration of Priority Sectors,[5] semiconductor demand growth has historically aligned more closely with the electronics industry.

In 2024, electronics for networking and communication alone accounted for about 33% of semiconductor consumption in ASEAN, whilst data processing and consumer electronics increased the total electronics-related share to over 50% (Fortune Business Insights, 2025). By comparison, the share of semiconductors used in automotive applications remains significantly smaller, even relative to networking and communication alone.

This pattern is also reflected globally. In 2024, the global semiconductor end market was dominated by communication and computer chip sales (including data centre chips), which together accounted for 57% of total semiconductor sales. In contrast, the automotive and industrial segments combined accounted for only 31% (Deloitte, 2025).

These trends point to the clear dominance of the electronics sector in shaping semiconductor demand. As a result, semiconductor manufacturers are likely to continue prioritising the needs of electronics-related applications. By contrast, the automotive sector, despite being a designated priority industry, may face greater challenges in securing sufficient semiconductor stock, given the scale, maturity, and commercial influence of the electronics industry across ASEAN.

This prioritisation bias is further reinforced by the profitability and volume advantages associated with the electronics industry. Chip manufacturers earn higher margins on advanced semiconductors supplied to consumer electronics firms than on the lower-margin chips typically produced for the automotive industry (S&P Global, 2021a). Consequently, semiconductor producers have increasingly reallocated production capacity towards high-end chips, favouring the more lucrative demand for 5G smartphones, tablets, video game consoles, and gaming platforms (Ramani et al., 2022).

These higher returns reduce the incentive for manufacturers to adjust their product mix towards automotive semiconductors, especially when operating at full capacity. As a result, the current imbalance in semiconductor allocation is reinforced, further marginalising the automotive sector within ASEAN's domestic semiconductor consumption landscape.

8.5.1.2. Gap: Limited Integration in the Upstream Supply Chain

Gap #1: Lack of formal links between semiconductor output and automotive demand

Despite a strong semiconductor production base, ASEAN has yet to institutionalise mechanisms that channel semiconductor capacity towards automotive manufacturing. This misalignment continues to impede the development of a resilient and regionally self-reliant vehicle production ecosystem.

[5] Under the framework, the 11 priority sectors are electronics, e-ASEAN, healthcare, wood-based products, automotive, rubber-based products, textiles and apparel, agro-based products, fisheries, air travel, and tourism.

Becoming a robust vehicle production hub requires closer proximity to semiconductor supply chains, ideally within the same trading bloc, to minimise tariff exposure and reduce overall production costs. Achieving such integration would further strengthen ASEAN's position as a cost-competitive automotive manufacturing centre. However, automotive manufacturers in ASEAN continue to source most of their semiconductors from outside the region, which in some cases has disrupted production.

In other regions, formal efforts to integrate locally produced semiconductors into automotive supply chains have been observed. For example, coordination between semiconductor producers and OEMs in Korea and the EU has often been facilitated by strong government involvement and industrial policy frameworks. A comparable level of policy coordination or institutional support, however, has yet not yet been identified within ASEAN.

Gap #2: Lack of policies and incentives to encourage local use

ASEAN countries have established a strong foothold in the global semiconductor export market, as shown in the BAU analysis. Nevertheless, a clear gap remains, as formal policies or incentives encouraging manufacturers to prioritise domestic use are largely absent. To achieve the envisioned to-be state, automotive manufacturers would benefit substantially from access to a stable and abundant regional semiconductor supply.

Whilst export markets may offer higher margins, domestic demand remains underserved in part because of the lack of regulatory direction or incentives that encourage domestic sales. Because the semiconductor industry is strategically important, ASEAN countries have introduced numerous semiconductor-related policies. However, most initiatives focus primarily on attracting foreign direct investment, improving the ease of doing business, and developing human capital, with limited emphasis on mobilising domestic demand.

For instance, several initiatives aimed at talent development, including scholarships, cross-border education programmes, vocational training schemes, and salary incentives, have been introduced in Singapore, Malaysia, Viet Nam, Thailand, and Indonesia (ASEAN Briefing, 2024). Financial incentives such as tax breaks, exemption schemes, and other fiscal support measures have been implemented in Singapore and Malaysia, whilst special economic zones have been established in both countries as well as in Indonesia. In R&D, Malaysia has committed to establishing dedicated technology parks (Malaysian Investment Development Authority (MIDA], 2025), and both Malaysia and Singapore have pledged significant investment to strengthen semiconductor innovation. Singapore has made notable progress in strengthening its intellectual property (IP) protection framework.

Despite the breadth of these initiatives, none specifically encourage manufacturers to prioritise domestic markets. Although similar regulations are not always explicitly present in other developed regions, some jurisdictions, including China, Germany, and the EU more broadly, have taken further steps to strengthen domestic supply resilience. These measures include restrictions on chip exports and other policy instruments intended to

reduce dependence on external suppliers. Comparable measures have not yet been observed within ASEAN.

Gap #3: Absence of priority allocation for the automotive sector

Maintaining uninterrupted automotive manufacturing requires OEMs to secure a stable and adequate supply of semiconductors to meet production targets. Even if Gaps #1 and #2 were addressed – creating a more integrated supply chain and greater regional semiconductor availability – the envisioned to-be state would still require a portion of this supply to be deliberately allocated to the automotive sector.

As demonstrated in the BAU #3 analysis, the dominance of the electronics sector, coupled with the profitability bias associated with higher-margin chips, creates a structural imbalance that may lead semiconductor suppliers to prioritise electronics applications over automotive uses.

The absence of a dedicated allocation mechanism means that critical sectors such as automotive manufacturing lack supply security. This limitation reduces ASEAN's ability to compete with global automotive manufacturing hubs that have introduced policy or industry-led initiatives to safeguard semiconductor supply for vehicle production. Only a limited number of countries formally allocate semiconductor supply by sector. Nevertheless, some regions have taken steps to protect automotive chip availability. For example, the US government has called on Congress to prioritise semiconductor supply for the automotive sector, recognising its importance for production continuity and industrial resilience.

To ensure more balanced market allocation, ASEAN governments could support the industry by introducing policy mechanisms that designate a reasonable share of semiconductor output for automotive use. Such measures would help secure supply stability and support higher-value output from the region's automotive manufacturing sector.

8.5.2. Midstream

8.5.2.1. Current State: Automotive Manufacturing Landscape in ASEAN

BAU #1: Reliance on conventional, labour-intensive manufacturing processes

ASEAN's automotive production is characterised by labour-intensive manufacturing processes, resembling the structure of China's automotive industry in the 1990s (International Labour Organization [ILO], 2016). However, as China's workforce has become increasingly educated and wages have risen rapidly, these conditions have driven a strong shift towards automation. As a result, China no longer competes primarily on low-cost production but instead on technological capabilities and value creation.

In contrast, Thailand and Indonesia, as ASEAN's leading automotive producers, continue to rely heavily on human labour for vehicle assembly. Their rapid industrialisation has historically been supported by relatively simple production processes and labour-

intensive manufacturing strategies (Rito, 2017). A similar pattern is observed in Viet Nam, where manufacturing activities, including automotive production, remain concentrated in labour-intensive and low value-added assembly operations (Khalidi, 2024). The Philippines follows a comparable model, having long leveraged its cost advantages through labour-intensive production strategies (Department of Trade and Industry, 2017).

For automotive manufacturing, the appeal of ASEAN's labour pool is considerable: it was ranked the region's most compelling feature for international businesses in a 2023 HSBC survey (HSBC, 2025). In addition to lower labour costs, many ASEAN governments continue to emphasise labour-intensive industries within their national development strategies as a means of reducing unemployment. For instance, the automotive sector is one of the four industries in Indonesia that employ the highest number of workers, contributing to reductions of the country's unemployment rate (Munandar, 2017). Consequently, the Indonesian government continues to encourage foreign investment to further boost labour-intensive industries (Indonesia Business Reports, 2024).

Nevertheless, the competitiveness of low labour costs, which historically has been one of ASEAN's principal advantages, is becoming increasingly difficult to sustain. The region now faces growing competition from other countries offering even lower wages. Amongst the ASEAN-6, Indonesia records the lowest monthly manufacturing wage at about US$192. However, cost-based manufacturing competitiveness is becoming increasingly vulnerable. Bangladesh, for example, has emerged as a potential new entrant in automotive manufacturing (Mashkura, 2023). Historically, Bangladesh's lowest labour costs were identified as its strongest comparative advantage in manufacturing (Hong Kong Trade Development Council [HKTDC] Research, 2016). Today, manufacturing wages in Bangladesh stand at about US$103 per month (Trading Economics, 2024), about 46% lower than Indonesia's. Whilst labour-intensive production models have supported ASEAN's early industrial growth, they increasingly limit the region's ability to climb the value chain and transition towards next-generation manufacturing ecosystems.

Infrastructure constraints remain a challenge despite continued investment in automotive manufacturing. These constraints have slowed industrial transformation and created operational difficulties for vehicle and component manufacturers. Beyond labour-intensive processes, ASEAN's manufacturing productivity is increasingly constrained by ageing infrastructure and slow technology adoption. The ERIA survey found that 47.5% of respondents identified deteriorating efficiency due to ageing equipment as a key concern by 2035, with Thailand reporting the highest level of concern at 55.4% (Chapter 3). This reflects the region's continued dependence on legacy ICEV production systems, which fall behind more advanced manufacturing ecosystems in China and Europe.

Earlier studies have noted that although Thailand's initial infrastructure investments were effective in supporting the development of the automotive industry, they failed to keep pace with the sector's subsequent expansion, resulting in infrastructure gaps relative to industry growth (Rito, 2017). Similarly, Indonesia's ambitions to become a leading automotive hub within the region and beyond will depend heavily on infrastructure

upgrades to increase overall production capacity (Business Indonesia, 2021).

Of the ERIA survey respondents, 36.6% highlighted low operational efficiency stemming from the underutilisation of digital technologies, with Indonesia and Viet Nam reporting levels exceeding 40%. These inefficiencies are further compounded by structural labour force constraints. A shortage of skilled personnel for supply-chain management was identified by 34.6% of respondents, with Viet Nam reporting the highest concern at 78.8%. Of the respondents, 54.5% cited inadequate supply-chain review processes, with Malaysia and Viet Nam again expressing the highest levels of concern at about 80%. Finally, nearly 30% of respondents identified digital infrastructure gaps as a potential obstacle, especially in Viet Nam, the Philippines, and Malaysia.

These findings highlight ASEAN's continued reliance on outdated industrial practices and underscore the urgent need for workforce development, digital investments, and production system upgrades if the region is to remain globally competitive.

BAU #2: Surrounding countries outpace adoption of next-generation technologies

Building on the limitations of conventional processes, ASEAN's automotive manufacturing now faces growing pressure to keep pace with global leaders that are rapidly advancing next-generation production technologies (ILO, 2024).

Despite growing automotive output, the region has yet to showcase notable examples of trends seen in frontrunner economies, such as gigacasting, autonomous robotics, or integrated smart factory ecosystems. Manufacturing facilities across ASEAN largely remain conventional in design and function, lacking the kinds of upgrades that are now considered baseline in more advanced markets. For example, in Indonesian and Vietnamese facilities, inspections are still carried out manually by one or two individuals, and final test drives are conducted entirely by human operators. Workers remain directly involved in key assembly processes, such as attaching engine components and interior fittings, reflecting a continued reliance on partial automation. The absence of next-generation technologies not only signals lost productivity potential but also places ASEAN at risk of falling further behind as the global automotive industry undergoes rapid transformation.

Across the global automotive landscape, however, advanced technologies are being adopted at scale. Countries such as China, Germany, and the US are expanding their use of AI, robotics, and digital systems in manufacturing, whilst India is seeing increased investment by leading OEMs. German automakers such as Volkswagen and Mercedes-Benz are integrating AI throughout their production processes (Techwire Asia, 2024), whilst BMW's innovations such as Car2X and AIQX have enhanced production speed, accuracy, and efficiency (BMW, 2025). Audi applies AI to inspect spot welds, enabling workers to focus only on flagged issues (Audi, 2025). Hyundai Motor India has deployed AI-equipped robots across its Sriperumbudur facility to extend functionality beyond traditional manufacturing roles (Thakkar and Murali, 2025).

Tesla, Renault, and Ford in the US apply digital twin technology for quality monitoring and

design modelling, whilst Nissan uses it for production planning (TxOne Network, 2023). In Korea, smart factories have become a mainstay, driven by strong policy support and a push for greater efficiency and production flexibility (Statista, 2024). Hyundai and Kia operate facilities in which manufacturing processes adapt dynamically through the integration of AI, robotics, and big data systems (Kim and Hun, 2024). Gigacasting has gained traction. First popularised by Tesla, the technology is now widely pursued by General Motors, Ford, Stellantis, and is planned for adoption by Japanese OEMs such as Toyota, Nissan, and Honda (Shirouzu and Piovaccari, 2024).

The absence of such practices in ASEAN reflects more than a simple technology gap; it points to a deeper structural issue within the global automotive value chain. In many cases, innovations such as gigacasting, AI-driven production, and autonomous robotics are pioneered by leading OEMs within their domestic markets. This pattern is evident in the cases of companies such Tesla, BYD, and Volkswagen. Survey results presented further confirm that, across all AMSs, global headquarters retain the ultimate authority over key strategic decisions, including investment decisions, with nearly 100% centralised decision-making reported in most countries and about 60% in Cambodia (Section 3.1.4). As a result, advanced production technologies are typically first deployed and refined within the OEMs' domestic ecosystems, where R&D, skilled labour, and supply-chain partners are deeply integrated.

For ASEAN, which primarily hosts downstream production and assembly facilities, exposure to such innovations often occurs indirectly through gradual knowledge spillovers or when multinational corporations eventually scale their technologies globally.

8.5.2.2. Gap: Constraints in the Midstream Supply Chain

Gap #1: Unclear market direction and growth uncertainties hinder investment

A key factor influencing investment decisions is proximity to markets (Ketokivi, 2017). Whilst ASEAN is expected to maintain a positive growth trajectory at a CAGR of 3.6% from 2024 to 2035 (Figure 5.1; Section 5.2.1), it is important to note that the region accounted for no more than 4% of total global automotive sales in 2024, with its market share projected to reach only 5% by 2035 (Figure 4.1; Section 4.1). Despite the upward trend, the increase of only 1 percentage point may not provide sufficient confidence for OEMs to consider ASEAN's market a priority destination for large-scale investment.

Considering Ketokivi's argument, investments in technological and manufacturing advancement may be less likely to materialise strongly in ASEAN. As a result, the region is unlikely to significantly upgrade – let alone revolutionise – its manufacturing processes through sophisticated production technologies.

This observation is consistent with the survey findings presented earlier. A total of 56% of respondents identified ASEAN's limited decision-making authority as a manufacturing base as the most significant barrier to undertaking necessary investments. Meanwhile, 43% of respondents considered the regional market not large enough to justify such

investments, and about 48% pointed out that highly efficient equipment and technologies remain prohibitively expensive (Chapter 3, Section 3.1.4, Figure 3.12).

Stagnation in automotive sales in ASEAN, driven by the prevailing affordability gap and maturing urban centres that have long sustained demand (Section 5.2.2.1), further dampens expectations for a thriving auto landscape. This suggests that growth is unlikely to be robust, weakening potential returns if OEMs invest in the region.

Investment in manufacturing typically requires substantial capital expenditure, estimated at 4.3%–5.5% of company revenue (Deloitte, 2023a). Rising uncertainty likely reduces firms' willingness to undertake such investments (Banerjee et al., 2015). Because manufacturing investments are closely tied to market demand, fluctuating sales and stagnation in key markets can undermine OEMs' confidence in committing to transformative investments such as digitalisation and automation.

Given the scale and cost of these initiatives, OEMs require clear visibility on expected returns. Current market uncertainty, however, makes firms hesitant to invest heavily in process upgrades and advanced manufacturing technologies within the region. Without greater clarity on market direction, investors may hesitate to commit capital if investment recovery remains uncertain.

Gap #2: Lack of skills to advance manufacturing and adopt next-generation technology

In a scenario where sufficient investment is available to upgrade manufacturing, as defined in Gap #1, it is important to recognise that the skills required to adopt these advanced manufacturing practices are equally critical. Whilst digitalisation and automation are central to the future of manufacturing, ASEAN continues to face major challenges in workforce readiness, as existing training and education programmes remain insufficient to meet the sector's evolving demands (Gideon, 2024).

This skills gap is consistent with the findings of the ERIA survey, in which 49% of respondents identified a lack of expertise amongst personnel in charge as the most significant challenge within the supply chain. This concern is reinforced by additional findings: 37% of respondents noted insufficient personnel dedicated to the issue, 35% indicated that top management does not fully understand the need for investment or personnel allocation, and 32% cited a lack of capital to address the problem (Section 3.1.4; Figure 3.21).

The shortage of digital skills is further reflected in the difficulty of recruiting, developing, and retaining technology talent across the region. According to Technode Global (2024), 9 out of 10 companies in ASEAN face challenges in recruiting, nurturing, and retaining digital talent. This constraint extends beyond the workforce to the education system. Previous ERIA research indicates that digital literacy remains relatively low across many AMSs, with limited integration of digital skills into school curricula. Of individuals aged 10–24, 61% are not taught digital skills in school (Nazara, 2024).

This lack of readiness is evident in practice. As discussed under BAU #2, clear examples

of Industry 4.0 technologies, such as autonomous robotics, smart factories, or AI-assisted systems, being widely adopted across ASEAN's automotive manufacturing facilities remain limited. Without the capacity to adopt and effectively operate such technologies, the region risks missing opportunities for manufacturing transformation and future investment. OEMs and Tier 1 suppliers are less likely to modernise production facilities in environments where the workforce is not prepared to manage or sustain advanced systems. As technologies continue to evolve, the skills gap may further impede progress towards a sovereign manufacturing ecosystem unless targeted interventions are implemented.

8.5.3. Downstream

8.5.3.1. Current State: Tracking, Traceability, and Circulation in the ASEAN Automotive Industry

BAU #1: Sector-limited traceability

Tracking and traceability are not unfamiliar concepts in ASEAN. Nevertheless, material traceability efforts in the region remain mostly concentrated in sectors such as food and beverage, textiles, and steel, rather than in automotive manufacturing. ASEAN has already launched several regional traceability frameworks in sectors such as palm oil (Neo, 2022), aquaculture (ASEAN Secretariat, 2017), and food and feed (ASEAN Secretariat, 2022). These frameworks aim to establish baseline requirements, harmonise regulations, and facilitate intra-ASEAN trade. National traceability efforts have gained greater traction in export-driven industries with complex supply chains. For instance, Viet Nam's trade counsellor has urged businesses to ensure traceability in sectors such as steel and textiles (Vietnam Plus, 2024).

Although traceability has been prioritised in non-automotive sectors, some automotive-related initiatives indicate early efforts towards material tracking. However, where implemented, traceability systems remain largely siloed, confined to individual enterprises or specific national jurisdictions. These systems are typically not built on interoperable global platforms. For example, traceability in manufacturing has been applied to steel used in automotive production in Thailand (Samurai Asia, 2021), the region's largest automobile manufacturing base. However, these efforts are tied to the systems of individual part manufacturers. Steel traceability is managed through Nippon Steel Pipe Thailand's internal system, which tracks materials from raw input to shipment, helping reduce errors and improve traceability accuracy for downstream partners. Nevertheless, the system covers only steel and does not extend to other automotive components, whilst traceability visibility remains limited to customers and OEMs within Thailand.

Another emerging development in this field is the use of laser marking and coding solutions across the region. In Malaysia, AREX provides laser marking services for automotive manufacturers, integrating marked data with backend systems such as systems, applications, and products in data processing to support traceability (ALC Tech

Malaysia, 2018). This programme serves Malaysian automotive manufacturers only (Appendix 3). If Toyota Malaysia were to adopt AREX's system, the company could benefit from precise part identification integrated with its internal manufacturing systems. This would enable tracking of components within Toyota Malaysia's production and after-sales network. However, unless such data are shared beyond Toyota's internal systems and connected to broader platforms, traceability remains confined to the company.

In Thailand, Pryor Marking Technology offers two-dimensional code marking combined with vision systems to enhance part identification and traceability. Like AREX, this approach provides more granular visibility within enterprise boundaries but lacks the infrastructure and governance arrangements needed for cross-OEM or cross-border data interoperability.

Whilst these technologies represent progress, laser marking alone does not enable end-to-end traceability. It must be supported by systems capable of reading, storing, and interpreting data across the broader automotive value chain. Without a regional or global platform linking this information, traceability remains siloed, reducing its potential to support circularity and strengthen regional supply-chain resilience.

BAU #2: Fragmented ecosystem for material reuse

Scrappage and vehicle recycling are critical levers for recovering valuable materials and enabling circularity in the automotive sector. According to an ERIA publication, about 2.4 million motor vehicles were discarded in ASEAN from 2015 to 2020 (Kojima, 2018). To understand the current landscape of material reuse in ASEAN, this section examines national policies, circulation efforts, and how scrap materials are used within domestic markets.

Not all ASEAN countries have vehicle scrappage policies in place. Singapore stands out as the regional leader, having established a structured vehicle retirement scheme, whereas most other AMSs remain in pilot or early regulatory stages. For instance, James et al. (2023) noted that in Singapore, vehicle scrapping is not voluntary but mandatory for every ELV. The policy is driven by a combination of financial incentives and legal requirements (Rafaela, 2024). Vehicle owners may reclaim the unused portion of their certificate of entitlement and receive payment for valuable components recovered from the vehicle. Depending on the vehicle's condition and market value, this compensation can amount to several thousand dollars. Failure to scrap or export a deregistered vehicle may result in hefty fines or other legal penalties under Singapore's strict vehicle regulations. However, such comprehensive frameworks remain largely unique to Singapore. Across the rest of ASEAN, coordinated scrappage policies or shared regulatory standards remain limited.

In contrast, Malaysia does not have a formal vehicle scrappage policy, although policymakers have been urged to consider introducing one to help alleviate road congestion (The Malaysian Reserve, 2025). The decision not to implement an ELV policy has been linked to broader socio-economic considerations, particularly the population's continued reliance on private vehicles for mobility (Malay Mail, 2023). Similarly, in

Indonesia, vehicle scrappage policies have so far only been proposed in Jakarta, where they have faced 49.2% public opposition. Economic concerns, particularly the inability of many households to afford new vehicles every few years, have been the primary source of resistance (The Jakarta Post, 2024a).

Vehicle scrappage policies are absent in several other AMSs. In Thailand, authorities are exploring the possible introduction of a scrappage programme, potentially through a trade-in and scrapping scheme (Setboonsarng and Stapornchamchai, 2025). In the Philippines, no scrappage policy yet exists for passenger cars, although discussions are ongoing (Tipan, 2024). In Viet Nam, no formal policy has been implemented, although discussions are underway to roll out a scrappage programme. Proposals include a target for 2027, when manufacturers would begin fulfilling recycling responsibilities (Kiet, 2021).

In countries where formal scrappage policies are not yet in place, vehicle dismantling and recycling infrastructure tends to remain underdeveloped. By comparison, Singapore has established a well-functioning ecosystem that extends beyond simple vehicle disposal. Scrapping facilities systematically dismantle vehicles, recover usable components, and recycle materials such as metals, rubber, and plastics, supporting a broader circular economy (Bay, 2021). In Thailand, by contrast, suitable scrappage facilities remain limited, with only two operators active, both located in Ayutthaya (Foong, 2022).

Several ASEAN countries have demonstrated early commitment to repurposing discarded materials for vehicle remanufacturing. In Malaysia, the automotive recycling ecosystem remains in its early stages and is expected to grow further under the National Automotive Policy. In March 2021, the Ministry of Natural Resources and Climate Change launched a pilot project for authorised automotive treatment facilities, which focus on dismantling deregistered vehicles and managing waste components for reuse, recycling, or disposal (Auto Recycling World, 2024). The same source notes that since 2018, the government has promoted the development of the automotive part remanufacturing industry. However, most recycled parts used in Malaysia continue to be sourced from Japan and the United Kingdom.

Viet Nam's Ministry of Natural Resources and Environment has introduced requirements for vehicle and motorbike manufacturers to assume responsibility for recycling outdated vehicles (Vietnam Investment Review, 2021). Manufacturers may comply either by directly undertaking recycling activities or by contributing financially to the Vietnam Environmental Protection Fund, which supports waste-recycling initiatives.

Without stronger regulatory frameworks, however, fewer vehicles are formally channelled into proper disposal systems, making it difficult to recover sufficient volumes of automotive scrap to support meaningful resource circulation. Nevertheless, other industries across ASEAN continue to generate scrap materials that may be repurposed for higher-value economic activities. In the absence of a mature domestic market capable of absorbing recycled or remanufactured automotive materials, many ASEAN countries continue to rely on exports as the primary channel for discarded vehicles and components. The Southeast Asia Iron and Steel Institute (SEAISI) (2023) reports that ASEAN countries

still export a significant share of their steel scrap (Appendix 4). According to SEAISI, steel scrap continues to be traded largely through export markets. Singapore exports most of its steel scrap, with 59% destined for other ASEAN countries, whilst the Philippines exports only 20% of its steel scrap within ASEAN, and Viet Nam primarily exports to non-ASEAN markets.

Most of these materials are not reintegrated into domestic value chains (Section 8.5.1). Consequently, even as policies and industries increasingly emphasise remanufacturing using scrapped materials, a large proportion of these materials may ultimately be exported, limiting their availability for regional reuse. This pattern highlights that, despite increasing attention to recycling, a truly integrated regional circulation system for automotive materials has yet to take shape. Most efforts remain fragmented or commercially driven, with limited coordination across countries to retain and reuse materials within ASEAN's own industrial ecosystem.

8.5.3.2. Gap: Disconnects in Traceability and Circular Flows in Downstream Segment

Gap #1: Unsynchronised national efforts to improve traceability and material circulation

As identified under BAU #1, AMSs are progressing at different paces in establishing material traceability systems and ELV policies. Some countries, such as Singapore, have implemented structured scrappage policies, whilst others remain at the pilot or proposal stage. This situation places Singapore ahead in tracking and material recovery capabilities, whilst much of the rest of ASEAN lags due to the absence of clear regulatory guidelines. In many ASEAN countries, such policies are not yet in place and are unlikely to be implemented in the near term, largely due to concerns related to citizen welfare and the high-cost burden associated with vehicle replacement. This lack of alignment creates inconsistencies in how materials are tracked, recovered, and reused. Without a coordinated regional strategy, ASEAN risks missing the opportunity to present a unified approach aligned with global trends in circular manufacturing and responsible sourcing.

Although limited data are available on vehicle scrappage rates across most ASEAN countries, it is reasonable to expect that recovery volumes remain significantly lower than those observed in developed economies with mature ELV systems. This assumption is supported by observations in countries such as Indonesia, where ELVs are often managed informally by private workshops or scrap iron collectors. These operators typically function without formal regulation, and dismantling activities often lack proper environmental or safety standards, reflecting the absence of effective regulatory oversight (Sitinjak et al., 2023). Countries with similarly underdeveloped ELV markets, such as India, illustrate comparable challenges. In such contexts, ELV scrappage remains insufficient to recover materials for sustainable resource circulation despite high material demand and significant untapped recovery potential (The Energy and Resources Institute, 2022).

By contrast, the to-be analysis shows that countries with stronger ELV policy enforcement

consistently achieve higher scrap recovery rates. For instance, Japan and Finland recycle over 95% of materials from ELVs, whilst Sweden recovers 95% of disposed ELVs (Auto Recycling World, 2024). Singaporean scrap yards are able to recover up to 85% of a vehicle's materials (Rafaela, 2024). As these countries are widely recognised as leaders in ELV regulation, the evidence suggests a clear correlation between strong policy frameworks and improved material recovery outcomes. This highlights a critical gap that ASEAN must address.

Like Gap #2 in the semiconductor sector (Section 8.5.1.2.2), ASEAN's reliance on export markets for scrap materials reflects the absence of policies or incentives that encourage local circulation and reuse. In an ideal scenario, where ASEAN's automotive materials are properly disposed of, fully tracked, and traceable, the final requirement would be to ensure that these materials remain available within the region for reuse. Without clear policy direction, however, the region's automotive manufacturing sector may not be able to fully reap the benefits of improved traceability and circularity.

This issue is especially pronounced for countries with high steel consumption that face both cost and trade pressures. For instance, steel accounts for about 69% of an ELV's structure, and Thailand consumes about 19 million tonnes of steel annually (Foong, 2022). Of this amount, about 12 million tonnes (about 63%) must be imported, whilst the remaining 7 million tonnes are sourced domestically. These figures suggest that, if appropriate disposal systems were established through clear regulatory frameworks and scrap materials were systematically recovered and circulated within the region, ASEAN could reduce its reliance on imports whilst strengthening regional material self-sufficiency.

Gap #2: Lack of digital infrastructure for regional traceability and material circulation

If Gap #1 were addressed and materials became fully tracked and traceable, a digital system would still be required to enable regional integrated visibility. As identified under BAU #2, tracking efforts within ASEAN's automotive sector remain fragmented and localised, often led by individual material suppliers such as Nippon Steel Pipe Thailand. In the domain of whole-vehicle marking, examples such as AREX in Malaysia and Pryor Marking in Thailand demonstrate technological progress. However, these systems continue to operate largely within enterprise boundaries and lack cross-border interoperability. In many cases, traceability systems remain confined to internal enterprise solutions or are absent nationally.

By contrast, the to-be state envisages a connected digital ecosystem capable of enabling end-to-end traceability of materials, from vehicle scrappage to reintegration into manufacturing supply chains. Such a system would be essential for maintaining the integrity of recycled materials, ensuring compliance with international standards, and enabling material reuse at scale within the region. Without interoperable digital infrastructure, ASEAN countries risk sustained reliance on more costly material sources, whether due to import levies or upstream supply constraints. The absence of transparent digital systems may exacerbate scarcity and undermine trust amongst regional

stakeholders in the quality and provenance of recovered materials.

This gap becomes particularly evident when compared with global developments. Japan's Ouranos initiative and the EU's Catena-X platform are emerging as leading digital traceability ecosystems, enabling real-time tracking of materials, emissions, and regulatory compliance across supply chains. These platforms also support domestic material recirculation, helping to reduce reliance on imports and primary resource extraction.

ASEAN lacks a shared digital foundation in the form of unified data infrastructure, regional standards, and integrated digital networks capable of supporting traceability at the required scale. Without such capabilities, the region will struggle to demonstrate material provenance, guarantee the quality of recycled content, or develop a resilient and self-sustaining automotive supply chain based on effective material circulation.

8.5.4. Enabler

8.5.4.1. Current State: Regional Connectivity Landscape of the ASEAN Automotive Industry

BAU #1: Disconnected information exchange across automotive supply chains

Automotive manufacturing in ASEAN is increasingly cross-border, with production stages and components often distributed across multiple countries. Despite this high level of interdependence, information exchange amongst supply chain actors remains fragmented. Most manufacturers and suppliers in the region still rely on siloed systems, bilateral data exchanges, and manual document transfers, limiting real-time visibility across borders.

Although some countries and firms have developed domestic digital platforms to track manufacturing, logistics, or compliance-related information, the region has yet to establish a connected infrastructure or common standard capable of linking these systems across ASEAN. At present, data visibility tends to be relatively advanced within individual firms but remains weak across the broader supply chain ecosystem.

One example that illustrates this disconnect in data exchange is the case of Toyota Motor Manufacturing Indonesia (TMMIN), which independently manages its own supply chain traceability through a proprietary platform called ApiHub Enterprise. According to TMMIN (2023), the platform enables end-to-end traceability and allows transaction histories to be transparently shared amongst participating parties. Whilst this represents a notable digital initiative, it remains specific to TMMIN's own operational ecosystem. Data visibility is therefore largely confined to the OEM's internal network, with limited integration or interoperability with other industry players, suppliers, or regional stakeholders.

Beyond TMMIN, no shared or interoperable framework enables real-time, cross-border data exchange across the broader ASEAN automotive supply chain. Although TMMIN's platform demonstrates what is technically possible within a single OEM's ecosystem, such efforts remain isolated and do not translate into system-wide connectivity. As a result,

regional supply-chain visibility and coordination remain fragmented, limiting ASEAN's capacity to function as an integrated, next-generation automotive manufacturing hub.

BAU #2: Nationally driven coordination despite a regional framework

Automotive manufacturing in ASEAN takes place across a diverse set of national contexts, each characterised by its own regulatory frameworks, logistics infrastructure, and trade priorities. Intra-regional connectivity, therefore, depends not only on digital platforms but also on shared standards, aligned processes, and trust amongst countries to enable a unified supply-chain ecosystem.

Since 2019, ASEAN has sought to strengthen intra-regional connectivity through the establishment of the ASW. The ASW represents a key regional initiative aimed at promoting economic integration, facilitating trade, and enhancing connectivity amongst AMSs. Designed to reduce time and costs whilst improving efficiency in customs and trade procedures, the ASW operates by integrating ASEAN national single windows (NSWs). According to Polachai (2023), the implementation of the ASW has helped ASEAN businesses save more than US$6.4 billion, reduced average transit times by about 4 days per transaction, and enabled the exchange of more than 4 million electronic documents.

Nevertheless, rapid developments in digital technology and the growing demand for paperless cross-border trade have revealed certain limitations within the ASW framework. As noted by the Vietnam National Trade Repository (2024b), these challenges include (i) technology synchronisation, where differences in digital maturity amongst ASEAN countries complicate system integration; (ii) regulatory harmonisation, where inconsistencies in document processing procedures and rules across countries reduce the effectiveness of the mechanism; and (iii) limited resources, where some countries lack the financial, human, or technical capacity required to upgrade their NSW systems.

Polachai (2023) also observed that operational practices on the ground continue to prioritise domestic markets over regional integration. For instance, the ASEAN Business Advisory Council initiative launched in 2019, known as ASEAN Digital Trade Connect, is operational only between Singapore and Thailand. Singapore has introduced TradeTrust, a framework designed to enable standards, semantic alignment, and legal interoperability for trusted digital document exchange. However, these efforts remain national or bilateral in scope.

Further evidence of nationally driven coordination can be observed in domestic customs clearance systems. In Malaysia, for instance, a separate customs clearance platform – the Malaysia Maritime Single Window – has been developed for sector-specific use (Subramaniam, 2023). Such fragmentation suggests that different regulatory assessments and procedures may still apply nationally, potentially prolonging the movement of goods and hindering efforts to realise an efficient, integrated supply chain.

These observations suggest that although the ASW provides a foundational platform for connectivity, intra-regional operational integration remains fragmented. Domestic-first priorities, technological disparities, and regulatory misalignments continue to hinder the

seamless cross-border coordination required to support a competitive, next-generation automotive supply chain in ASEAN.

8.5.4.2. Gap: Fragmented Regional Connectivity

Gap #1: Lack of real-time, cross-border data sharing across automotive supply chains

Although certain OEMs in ASEAN have introduced improvements in traceability and data transparency within their own operations, such as Toyota Motor Manufacturing Indonesia's use of blockchain and IoT systems, these efforts remain siloed and proprietary. No shared platform or mechanism exists that allows data to move seamlessly across the region's automotive supply chains. As a result, real-time, cross-border information exchange remains limited, restricting supply-chain visibility across tiers and hindering access to critical data for regulators, partners, and consumers.

Bridging this gap requires more than technical readiness; it also demands policy coordination, system interoperability, and mutual trust amongst AMSs. The envisioned future calls for a regionally integrated digital infrastructure capable of supporting the secure and efficient flow of traceability, carbon, and production data across companies and countries.

This gap becomes more apparent when viewed against global benchmarks. For instance, the EU's DPP, mandated for all products sold within the region, demonstrates how a unified digital system can facilitate transparency, regulatory compliance, and operational efficiency at scale. The DPP enables data from a wide range of stakeholders, including manufacturers, regulators, customs authorities, and consumers, to be accessed and used across borders. This enhances traceability, reduces administrative friction, and supports data-driven decisions throughout the product life cycle.

China's Tianjin Port blockchain pilot project, the world's first initiative to integrate blockchain technology into cross-border trade, illustrates how digital connectivity can strengthen trust, transparency, and efficiency across complex logistics networks. The system enables cargo information to be shared amongst all relevant parties, thereby removing delays and eliminating data silos across stakeholders.

These global examples highlight the growing gap between ASEAN's current operations and the envisioned to-be state of an integrated digital ecosystem capable of supporting a resilient and competitive automotive manufacturing hub.

Gap #2: Limited effectiveness of ASEAN's intra-regional connectivity mechanisms

Whilst the ASW represents a notable starting point for improving regional trade connectivity, its current implementation still falls short of supporting a seamless automotive supply chain. Differences in technology, regulatory frameworks, and national capabilities continue to limit the ASW's reach and effectiveness. Although the platform has helped reduce costs and paperwork, customs processes remain largely country-specific, with many AMSs continuing to prioritise their own systems and procedures. Persistent

implementation challenges, such as inconsistent regulations, difficulties in synchronising digital systems, and uneven institutional capacity, further restrict its impact. As a result, the ASW remains underutilised as a tool for enabling the integrated, frictionless trade needed to support regional manufacturing competitiveness.

The future state requires a higher level of integration, in which trade and logistics systems operate in a more unified and responsive manner. Regional connectivity should support the fast and reliable movement of goods across borders through shared digital systems, consistent regulatory frameworks, and collaborative operational practices. Without stronger coordination, ASEAN risks uneven enforcement of trade standards, which could derail operational efficiency and reduce opportunities to attract global supply-chain investment.

This gap becomes more evident when benchmarked against mature single markets such as the EU, where common technical standards and interoperable systems enable the smooth movement of goods across borders. The EU is deploying a harmonised digital strategy to modernise its internal market for the digital age whilst boosting growth across member states. This approach helps minimise disparities between countries, enabling all members to adopt comparable levels of connected infrastructure to support regional trade. The standardised environment is backed by high-speed, secure, and trusted digital systems, supported by regulatory frameworks that create the conditions for a functioning digitally connected economy (Saidon, 2025).

As identified under BAU #2, comparable harmonised systems are still largely missing in ASEAN. Many of the region's initiatives remain in pilot stages or are limited to a small number of leading countries, particularly Singapore and Thailand. This slow and uneven rollout reflects the absence of a region-wide commitment to building a fully integrated digital trade environment. Without more decisive efforts to improve shared infrastructure and governance, ASEAN's goal of becoming a leading automotive hub may continue to be constrained by operational disconnects in the cross-border movement of goods.

8.6. Business-as-usual and Gap Analysis of Vehicle Decarbonisation

8.6.1 Current State: Vehicle Decarbonisation Landscape in ASEAN

8.6.1.1 BAU #1: Legacy Combustion Pathway and Biofuel Supply Constraints

ASEAN's export proposition still leans on ageing Euro 4 ICEV and mild-hybrid architectures. Thailand's 1-tonne pick-up platform alone accounted for 61% of the country's total vehicle production in 2024, underscoring the limited pace of powertrain renewal in the region (Thailand Automotive Institute, 2024). Destination markets, however, are leaping ahead. Malaysia, for instance, will not roll out Euro 5 petrol nationally until September 2026, with full compliance expected only by 2027, leaving regional assemblers two regulatory steps behind fast-moving buyers in Australia, the Gulf, and Latin America (Malay Mail, 2024; Paul Tan's Automotive News, 2025). In response, OEMs have tended to prioritise lower-risk incremental improvements. General Motors' US$888 million

investment in a sixth-generation V8 engine in May 2025 illustrates how limited engineering budgets are directed towards near-term truck profits rather than breakthroughs in ultra-efficient combustion technologies (Reuters, 2025h).

The region's decarbonisation efforts face equally stiff headwinds. Indonesia's B40 biodiesel mandate failed to meet its planned launch date of 1 January 2025 because the enabling decree and subsidy mechanisms had not yet been finalised. Regulators have now granted fuel distributors up to 12 months to comply, underlining persistent policy fragility (Reuters, 2025h). Even if implementation proceeds as planned, higher blending requirements are likely to tighten feedstock markets. Malaysia forecasts crude palm oil prices to average MYR3,900–MYR4,100 per tonne in 2026, suggesting continued price pressures relative to pre-COVID-19 levels and indicating that biodiesel cost parity remains elusive (Reuters, 2025r). Ethanol faces similar constraints. Thailand's proposal to make E20 the default petrol grade depends heavily on cassava and sugar supplies that are already under pressure from competing food and export demand (USDA Foreign Agricultural Service, 2024).

Outdated combustion platforms, volatile and costly biofuel supply chains, and limited R&D for next-generation ICEV technologies risk trapping ASEAN in a carbon-intensive trajectory. Exports may struggle to meet future homologation standards, whilst domestic vehicle fleets realise only marginal well-to-wheel emissions reductions.

8.6.1.2. BAU #2: Import-led Electriźcation, Thin Local Supply Chains

ASEAN's headline EV growth is driven almost entirely by completely-built-up (CBU) imports. In Malaysia, full import- and excise-duty waivers were in place until 31 December 2025, with no official extension announced as of 2026, a policy that has encouraged brands such as Tesla and BYD to ship finished vehicles rather than assemble them locally. As a result, CBU registrations surged 112% to 6,617 units in the first half of 2024, whilst no high-volume completely knocked-down (CKD) assembly line has yet become operational (MGTC, 2024b; Paul Tan's Automotive News, 2024). Thailand's updated EV 3.5 incentive scheme similarly front-loads imports. Manufacturers may still import one vehicle for every 1.5 units promised for future local production, leaving the market's 2024 EV registrations (about 70,000 units) heavily skewed towards Chinese-built models (Reuters, 2024i; Reuters, 2025h).

The industrial response continues to lag far behind demand. Korea's LG Energy Solution withdrew from the US$8.4 billion Indonesia Grand Package in April 2025, citing market-condition risks, although it maintained a smaller 10 GWh joint-venture battery plant with Hyundai in West Java (Reuters, 2025g; EV Magazine, 2024). Thailand's supply base remains even thinner. Svolt Energy's Chonburi facility can assemble only about 60,000 battery packs per year, enough for less than 5% of projected regional EV demand by 2027 (CnEVPost, 2024). The IEA (2024a) projects global battery demand to increase by 4.5 times by 2030, underscoring the scale at which ASEAN must expand its manufacturing capacity to remain competitive.

Policy signals on localisation remain largely non-binding. Thailand has requested, but not mandated, a 40% local-content share for Chinese EV manufacturers, whilst Malaysia has yet to publish Tier 2 incentives for components such as e-axles, power electronics, or graphite processing (Bangkok Post, 2025). This ambiguity feeds a wait-and-see loop amongst suppliers. Without firm volume commitments or sourcing guarantees, Tier 1 and Tier 2 investors tend to postpone capacity decisions, thereby reinforcing the region's reliance on imports.

Survey results reflect this uncertainty. A significant share of suppliers identified persistent uncertainty in government policy as a key barrier to deeper localisation and supply chain transformation. When asked about challenges to supply chain decarbonisation, 47% of respondents cited a lack of in-house expertise as the most significant obstacle. This was followed by unclear or inconsistent policy signals and strategic ambiguity amongst OEMs, reported by 43% of respondents. These findings reinforce the current pattern of delayed investment and limited localisation. Without clear and enforceable policy frameworks, combined with capacity-building support, suppliers remain hesitant to commit to long-term capital expenditure. This hesitation further entrenches the region's reliance on imported EVs and components, distancing ASEAN from its broader industrialisation and decarbonisation goals.

The current pattern, characterised by high CBU inflows, intermittent battery foreign direct investment, and weak localisation requirements, positions ASEAN more as a retail market rather than as an industrial hub. Absent enforceable local-content milestones, phased removal of duty waivers, and targeted supplier development funds, the region risks capturing only a minimal share of the EV value chain. This outcome would run directly at odds with the dual-track to-be vision (Section 8.3.3).

8.6.2. Gap: Vehicle Decarbonisation

ASEAN's twin aspiration – cleaner ICEV and HEV exports alongside a fully localised xEV supply chain – runs up against two structural gaps. The first is a visibility gap. Production remains anchored in legacy platforms, with pick-up trucks accounting for 61% of Thailand's 2024 output (Thailand Automotive Institute, 2024). Policy signals remain fragmented. Malaysia's duty-free import window for CBU EVs was scheduled to close in 2025, with no official confirmation of any extension as of 2026 (Paul Tan's Automotive News, 2025a), whilst Indonesia's nationwide B40 biodiesel rollout has already slipped beyond its original January 2025 target (Reuters, 2025i). Lacking a synchronised regional road map, OEMs hedge their strategies by stretching Euro 4 platforms and relying on imported CBU EVs rather than investing in next-generation engines or local assembly capacity.

The second gap concerns accessibility to strategic fuels and materials. Biofuel economics remain closely tied to crude palm oil prices, which continue to hover about MYR4,000 per tonne (Reuters, 2023d). The regional battery value chain depends heavily on a limited number of Indonesian nickel and precursor projects, one of which, a US$8 billion venture,

lost its anchor investor in April 2025 (Reuters, 2025g). At the same time, the IEA (2024e) warns that tightening critical-mineral markets are amplifying cost pressures and supply security risks. These fragilities inflate project break-even thresholds, delay final investment decisions for biorefineries and battery cell plants, and leave the region dependent on imported inputs required for its industrial future.

These visibility and accessibility gaps leave ASEAN in a carbon-intensive holding pattern: too emission-heavy to meet tightening export standards, yet insufficiently developed to capture the full value of electrification. The following sections quantify these shortfalls and outline the policy, financing, and capability levers required to bridge them.

8.6.2.1. Gap #1: Uncertainty in Market, Powertrain Transition, and Fuel-usage Road Maps

Investors across ASEAN lack a clear line of sight on future powertrain demand because policy timelines remain poorly aligned. For combustion upgrades, Singapore has enforced Euro 6 petrol since 2017 (Today Online, 2016), whilst Malaysia will continue phasing in Euro 5 petrol until full nationwide coverage by 2027 (Malay Mail, 2024). Indonesia, by contrast, remains on Euro 4 standards and has yet to publish a timetable for upgrading (TransportPolicy.net, 2024). At the same time, biofuel blending targets diverge across the region. Malaysia's B30 mandate for heavy trucks is scheduled for 2030 (Argus Media, 2023a), whereas Indonesia's B40 mandate, originally slated for January 2025, has already been postponed to 'no earlier than March 2025' whilst regulators secure additional subsidy funding (Reuters, 2025i). Without region-wide assurances on Euro 6 fuel availability or stable E20 and B30 supply, OEMs tend to postpone the US$150 million–US$200 million re-engineering programmes needed to make existing engines compliant and flex-fuel ready.

Electrification policies further compound this uncertainty. Incentive timelines vary widely across ASEAN markets. Malaysia's full duty waiver for imported BEVs was scheduled to end in December 2025, with no confirmed extension (Paul Tan's Automotive News, 2025a). Thailand will continue allowing one imported BEV for every 1.5 pledged CKD units until 2026 (Reuters, 2024i). The Philippines has extended zero tariffs on EV imports until 2028 (Reuters, 2024k). For battery pack and e-axle suppliers, which require a decade of stable production volumes to justify new facilities, this creates significant uncertainty. The IEA (2024a) estimates that ASEAN's 2030 BEV sales could range from 1.8 million units (if incentives taper) to 3.6 million units (if they persist).

With fuel standards, blending targets, and localisation requirements evolving along different timelines, investment decisions remain cautious. Automakers continue extending Euro 4 export platforms, refiners add only incremental biofuel capacity, and battery manufacturing projects linger at the memorandum of understanding stage. This dynamic risks locking ASEAN into precisely the carbon-intensive middle ground its long-term decarbonisation strategy seeks to escape.

8.6.2.2. Gap #2: Restricted Access to Low-carbon Fuels and Critical Battery Materials

A closer examination of ASEAN's supply pipelines shows that biofuel-based ICEV and HEV exports and a regionally anchored xEV industry, both pillars of the dual-track strategy, depend on inputs that are scarce, volatile, or concentrated amongst a limited number of suppliers.

Biodiesel illustrates this fragility. Palm oil yields in Indonesia and Malaysia have hovered about 3.3–3.5 tonnes per hectare since 2018, with little sign of the genetic or agronomic breakthroughs needed to lift output materially (USDA Foreign Agricultural Service, 2025). Because production has stagnated whilst blending mandates keep rising, Indonesia's shift from B35 to B40 alone would require about 2 million additional tonnes of crude palm oil per year, effectively absorbing almost all incremental supply projected through 2027 (Reuters, 2025i). Futures prices already trade near MYR4,000 per tonne, and the biodiesel levy has had to be expanded to allow distributors a grace period before full B40 enforcement, pushing the implementation date to March 2025 at the earliest (Reuters, 2025e; Reuters, 2025i). At these feedstock prices, palm oil makes up more than 70% of the ex-gate cost of biodiesel, leaving refiners and truck fleets exposed to fluctuations in commodity markets.

Ethanol faces a different constraint. Thailand relies heavily on cassava and molasses as feedstocks. The 2024 El Niño reduced cassava yields by roughly 9%, and the Thai Ethanol Manufacturing Association has warned that scaling E20 from a premium blend to the nationwide standard would drain the entire feedstock buffer within 2 years (USDA Foreign Agricultural Service, 2024). Spot ethanol prices have already climbed to about THB28 per litre, whilst OEM bench tests indicate up to a two research-octane-number variation between cassava-based E20 batches. This variability forces more conservative ignition calibration strategies, reducing the theoretical CO_2 emissions benefit (US Environmental Protection Agency, 2010).

On the electrification side, nickel appears abundant in headline terms but remains highly concentrated in practice. From 2020 to 2023, Indonesia's share of global mined nickel rose from 34% to 52%, whilst its share of refined Class I nickel rose to 37% (IEA, 2024e). The challenge lies not in overall resource availability but in supply chain depth. Fewer than 10 high-pressure acid leach (HPAL) facilities in Sulawesi and Halmahera supply most of the regional precursor pipeline, meaning that project delays quickly propagate across the value chain. When LG Energy Solution withdrew from the US$8 billion Grand Package project in April 2025, about 140 kilotonnes per year of planned precursor capacity disappeared, prompting financiers to pause financing until Huayou Cobalt could step in as a replacement investor (Reuters, 2025g; Reuters, 2025k). What remains, primarily the Hyundai-LG 10 GWh cell plant in West Java, could supply batteries for only about 120,000 mid-size BEVs a year, far below the IEA's Stated Policies Scenario projection for ASEAN demand in 2030 (IEA, 2024a).

Other elements of the battery bill of materials are even more exposed. China refines more than 90% of the world's graphite anode material and introduced export permit

requirements for spherical and high-purity natural graphite from 1 December 2023 (Reuters, 2023e; Reuters, 2023f). During the first export-permit cycle, several Southeast Asian battery pack plants reported inventory coverage of just 25–30 days. A 2-week shipping delay through Singapore or Port Klang can add US$70–US$90 per tonne in demurrage and handling costs, effectively erasing already thin localisation margins (Reuters, 2024j). Similar single-supplier vulnerabilities affect electrolyte salts such as lithium hexafluorophosphate, none of which are currently produced at a commercial scale within ASEAN.

High and volatile palm oil and cassava prices, single-country dominance in nickel supply, and near-total dependence on Chinese graphite and electrolyte inputs raise break-even costs and intensify perceived supply security risks. These pressures have already stalled several biorefinery and precursor-to-cathode investment projects, constraining the material flows that ASEAN's dual-track decarbonisation strategy presupposes.

8.7. Business-as-usual and Gap Analysis of Supply Chain Decarbonisation

8.7.1. Upstream

To frame the strategic levers that will later shift ASEAN's fuel and materials base towards the 2035 to-be vision, this section first maps the BAU landscape. By diagnosing the structural constraints shaping the current upstream supply chain, the analysis establishes the reference point against which subsequent policy and industry interventions must close the gap.

8.7.1.1. Current State: Green Energy for Manufacturing and Carbon Footprint Control

ASEAN's automotive complex confronts a triple upstream bottleneck: premium-grade fuels remain scarce and costly, renewable-fuel feedstocks are stretched thin, and critical-mineral inputs are both price-volatile and geopolitically concentrated. Five interlocking BAU patterns illustrate the scale of the challenge.

1. Clean fossil fuel quality gap and cost exposure. Only a limited number of regional refineries have completed Euro 5 or Euro 6 upgrades, whilst most continue to produce higher-sulphur fuel grades, forcing automakers and consumers to pay import premiums for compliant fuels.

2. Biofuel feedstock constraints. Rising biodiesel mandates, such as B35 in Indonesia and the planned B30 target in Malaysia, are colliding with tight palm oil supply balances and competing food security priorities. Feedstock volatility and scarcity have already pushed up refined palm oil prices and squeezed discretionary blending margins, stalling further scale-up of low-carbon liquid fuels (ASEAN Centre for Energy, 2024b).

3. Critical mineral concentration and price volatility. Key EV minerals, including nickel and rare-earth elements, are increasingly sourced from a narrow group of suppliers. Indonesia dominates Class I nickel, whilst China controls much of the world's rare earth

magnet processing capacity. This concentration exposes ASEAN OEMs to abrupt export restrictions and price fluctuations, as illustrated by the 2025 magnet-export licensing shock (Reuters, 2025l).

4. Slow renewable energy uptake. Despite accounting for 6% of global GDP, ASEAN attracted only 2% of global clean energy investment in 2023, leaving annual spending at roughly US$72 billion, compared with the US$190 billion required to align with climate goals (IEA, 2025b; IEA, 2024f). Coal still generated about 50% of the region's electricity and accounted for 80% of power sector CO_2 emissions in 2023. As a result, driving grid emission factors remain high, about 650–900 grams of CO_2 per kilowatt-hour, limiting opportunities for Scope 2 emission abatement in automotive manufacturing facilities (IEA, 2024c).

5. Fragmented industrial park planning. Of 893 industrial parks across ASEAN, which host much of the region's automotive supply base, only two are formally recognised as EIPs. Consequently, more than 99% of industrial zones lack shared low-carbon utilities, circular waste management systems, or standardised MRV systems (United Nations Industrial Development Organization [UNIDO], 2024a).

Collectively, these patterns reinforce a cost-heavy, carbon-intensive supply paradigm, underscoring the yawning gulf between ASEAN's net-zero aspirations and its current upstream reality. The following sections examine each constraint in greater depth and quantify the divergence from the to-be state (Section 8.3.4.1).

8.7.1.1.1. BAU #1: Clean fossil fuel quality gap and cost exposure

Regional refinery modernisation landscape. Progress towards cleaner fuels remains uneven across ASEAN. In Thailand, Euro 5 diesel standards took effect in January 2024, following investments of more than THB50 billion by domestic refiners to upgrade facilities and expand capacity (Bangkok Post, 2024). Bangchak Corporation's upgrades reduced sulphur content to below 10 parts per million (ppm), further improving nationwide fuel quality (Bangkok Post, 2024). By contrast, Indonesia still grapples with Euro 4 production standards. The Balikpapan refinery expansion, initially designed to boost capacity from 260,000 to 360,000 barrels per day (bpd) whilst meeting Euro 5 fuel specifications, has experienced repeated delays (Monitoring Oil, 2016). Such postponements leave Indonesia dependent on higher-sulphur diesel and slow the automotive sector's transition towards cleaner engines.

Singapore represents the region's most advanced refining hub. ExxonMobil's 592,000 bpd complex, fully integrated with petrochemical operations, produces a wide range of refined products, including ultra-low-sulphur diesel (ULSD) (ExxonMobil, 2025). The ongoing Resid Upgrade Project, slated for completion in 2025, will further increase ULSD production and output of high-performance lubricants, cementing Singapore's role as a premium fuel exporter to Asia and Pacific markets (ExxonMobil, 2025). Malaysia plans to introduce Euro 5 petrol nationwide by September 2026, although the phased rollout may create

temporary supply gaps and price fluctuations (Motorist, 2024; Paul Tan's Automotive News, 2025).

Economic burden and cost premiums. Because many ASEAN refineries are not yet capable of producing sufficient volumes of Euro 5 petrol and diesel, several countries must import significant quantities of premium fuels. Thailand's switch to Euro 5 standards in early 2024 led to an 8%–12% increase in automotive fuel costs compared with previous domestic output (Bangkok Post, 2024). Global price volatility, shipping costs, import duties, and the price differential between premium and standard fuels all contribute to higher end-user prices. These elevated fuel costs ripple through supply chains: manufacturers and fleet operators face uncertain supply and fluctuating pricing, complicating total cost of ownership calculations. As a result, consumer demand for vehicles requiring ULSD or Euro 5 petrol may weaken, even as regional decarbonisation targets remain unchanged.

Capital allocation and investment challenges. Refinery modernisation demands substantial capital outlays. Thai Oil's Clean Fuel Project, for instance, represents an investment of about US$4.8 billion, expanding refining capacity from 280,000 to 400,000 bpd whilst upgrading fuel output to Euro 5 quality (Bangkok Post, 2024). Initiated in 2019, the project illustrates the multi-year, multi-billion-dollar scale required for meaningful infrastructure upgrades. However, uncertain regulatory environments, volatile refining margins, and the prospect of electrification complicate investment decisions. Refiners must balance compliance with fuel-quality mandates against evolving demand trajectories and long-term energy transition risks, factors that often delay or dilute investment commitments.

Regulatory fragmentation and market inefficiencies. Another defining feature of BAU is regulatory fragmentation. ASEAN markets have not yet harmonised fuel-quality standards, resulting in varying technical specifications and enforcement regimes across countries. Malaysia's mixed policy approach, introducing Euro 5 diesel whilst certain regions continue to rely on Euro 4 petrol, exemplifies this regulatory patchwork (Motorist, 2024). The International Council on Clean Transportation (ICCT) has documented ongoing efforts in Indonesia, Viet Nam, and Thailand to shift from high-sulphur to low- or ultra-low-sulphur fuels, yet coordination challenges remain (ICCT, 2025). As a result, automakers must manage multiple fuel specifications, maintain separate inventories, and adjust engine calibrations across markets. This fragmentation undermines economies of scale and increases administrative overhead.

Environmental and public health consequences. Continued reliance on higher-sulphur fuels limits the effectiveness of modern emission-control technologies. Euro 6 diesel engines require ULSD (less than or equal to 10 ppm sulphur); even 50 ppm sulphur content can impair catalytic converters, degrade particulate filters, and poison selective catalytic reduction systems (ICCT, 2020). These technical limitations translate directly into higher emissions of sulphur dioxide, nitrogen oxides, and particulate matter in urban centres. Over time, such air-quality degradation contributes to respiratory illnesses and

environmental damage, imposing indirect costs on public healthcare systems and local economies.

8.7.1.1.2. BAU #2: Biofuel feedstock constraints

ASEAN's biofuel strategy remains firmly rooted in existing agricultural, market, and policy conditions. Four interrelated challenges define its current trajectory: feedstock availability bottlenecks, economic viability pressures, regulatory inconsistencies, and sustainability trade-offs.

Feedstock supply dynamics and market volatility. Palm oil dominates as ASEAN's primary biodiesel feedstock, accounting for over 80% of regional inputs. Yet climate variability and productivity challenges continue to introduce supply instability. The 2023–2024 El Niño cycle reduced Malaysia's crude palm oil (CPO) output by 7% compared with 2022, prompting a downward revision to 18.2 million tonnes in 2024 (Malaysian Palm Oil Council [MPOC], 2023). At the same time, Indonesia's January 2024 CPO exports rose 14.6% to 2.8 million tonnes, as domestic refining capacity struggled to meet both biofuel mandates and export demand (GAPKI, 2024a).

Price volatility further compounds these challenges. CPO futures on Bursa Malaysia reached MYR3,933 per tonne (US$842) in May 2024, a 25% year-on-year increase that wiped out margins for biodiesel producers, particularly in Malaysia, where B30 production costs ran MYR0.50–MYR0.60 per litre above prevailing diesel prices (The Edge Malaysia, 2024; MPOC, 2025). The Argus UCOME Biodiesel benchmark showed European used cooking oil methyl ester trading at a US$229 per tonne premium over CPO in May 2024 (Argus Media, 2024). These supply and price pressures coincide with competing demand: roughly 60% of ASEAN palm oil exports serve food industries (ASEAN Centre for Energy, 2024c), whilst Indonesia's B35 programme alone consumes 12.26 million kilolitres annually, equivalent to 20% of national production (Gabungan Pengusaha Kelapa Sawit Indonesia [GAPKI], Indonesian Palm Oil Association, 2024b). As a result, CPO prices climbed to US$958 per tonne (cost, insurance, and freight) in January 2024, despite higher output (GAPKI, 2024a).

Economic viability challenges. Indonesia's B35 mandate illustrates the fiscal strain associated with current practices. Although the programme saved IDR512 trillion (US$32.8 billion) in foreign exchange by reducing diesel imports, it relied on IDR68 trillion (US$4.4 billion) in annual subsidies (GAPKI, 2024b). These subsidies obscure operational inefficiencies: biodiesel plants operated at just 65% capacity in early 2024, owing to feedstock procurement shortfalls and blending infrastructure limitations (GAPKI, 2024a). Globally, biodiesel margins deteriorated in 2024, with production costs for palm-based fuels outpacing fossil diesel by US$146–US$229 per tonne (Argus Media, 2024; The Edge Malaysia, 2024).

In Malaysia, the planned B30 rollout hinges on CPO prices remaining below MYR2,800 per tonne (US$600) to maintain refinery viability, a threshold that has been exceeded throughout 2023–2024 (MPOC, 2025; Reuters, 2023g). Under such conditions, refiners

increasingly favour spot sales over blending, despite government directives.

Regulatory and infrastructure barriers. Implementation varies widely across ASEAN. Indonesia has achieved 85% B35 compliance through centralised subsidies (GAPKI, 2024b), whereas Malaysia has yet to fully implement nationwide B20 implementation, due to feedstock shortages (ASEAN Centre for Energy, 2024c), with industry stakeholders continuing to urge accelerated rollout amid feedstock and cost pressures. Thailand continues to rely on B10 blends, despite having the technical capacity for B20 (The Edge Malaysia, 2024). These inconsistencies hinder cross-border feedstock flows. For example, the Indonesian Sustainable Palm Oil certification system does not fully align with Malaysian Sustainable Palm Oil standards (GAPKI, 2024a; GAPKI, 2024b).

Logistics infrastructure remains underdeveloped outside core markets. Indonesia's archipelagic geography increases blending costs by 15%–20% compared with Malaysia's peninsular distribution network (GAPKI, 2024b). CPO distribution is hampered by limited temperature-controlled storage capacity needed to prevent oxidation (GAPKI, 2024a).

Sustainability trade-offs. Expansion of palm oil production for biodiesel risks repeating past deforestation patterns. Indonesia's CPO exports to the EU jumped 104% in January 2024, even as European sustainability criteria threaten to exclude non-certified biofuels (GAPKI, 2024a). Production methods remain carbon-intensive: ASEAN biodiesel life-cycle emissions average 45 grams of CO_2 equivalent per megajoule compared with 33 grams of CO_2 equivalent per megajoule for renewable diesel alternatives (Argus Media, 2024).

Malaysia experienced social pressures when CPO prices exceeded MYR3,800 per tonne in 2024, pushing domestic cooking oil prices up by 25% and disproportionately affecting low-income households (MPOC, 2023; ASEAN Centre for Energy, 2024c). This tension between energy security and food affordability underscores the delicate balance underpinning current biofuel policies.

8.7.1.1.3. BAU #3: Critical mineral concentration and price volatility

ASEAN's metal supply chain sits at the narrow end of a globally concentrated funnel: Chinese refiners dominate the midstream, prices fluctuate sharply, and regional policy frameworks shift frequently. These forces lock the region largely into lower-value roles and threaten its xEV industrial aspirations.

Extreme global refining concentration. The IEA's *Global Critical Minerals Outlook 2024* shows China refining about 65% of the world's lithium and cobalt, 60% of nickel sulphate, and nearly 90% of rare-earth oxides (IEA, 2024e). ASEAN remains largely a raw-ore exporter. Indonesia, despite hosting one of the world's largest laterite resources, currently operates only two battery-grade HPAL lines, both majority-owned by Tsingshan and Huayou (Reuters, 2024m). Malaysia's Lynas Advanced Materials Plant (LAMP) processes about 10% of global light REEs, yet still exports heavier fractions abroad, underscoring the region's downstream processing gap (Reuters, 2020a).

Graphite presents a similar structural vulnerability. The same IEA report warns that more

than 90% of the projected battery-grade supply by 2030 will still come from Chinese processors, highlighting a significant single-point supply risk (IEA, 2024e).

Geopolitical chokepoints driving production risk. China further tightened this grip on 4 April 2025, introducing new export licence vetting requirements for heavy REEs (Reuters, 2025j). Prices responded rapidly: neodymium oxide reached about US$270 per kilogram, double the 2020 average (Reuters, 2025k). The ripple effects were immediate. Suzuki temporarily halted Swift production in Thailand (Reuters, 2025l), whilst global OEMs requested regulatory relief to secure supply licences. (Reuters, 2025m).

Sharp price cycles undermining investment planning. Price volatility further complicates long-term investment decisions. Lithium hydroxide prices fell from about US$85,000 per tonne in 2022 to about US$12,000 per tonne by July 2024 (Reuters, 2024n). Nickel prices fluctuated sharply, rising to US$26,000 per tonne in June 2024 before falling to a 5-year low near US$14,000 per tonne by April 2025 (Reuters, 2025n). Such volatility has disrupted large-scale battery investments. Europe's Automotive Cells Company suspended construction of its Termoli and Kaiserslautern gigafactories (Reuters, 2024l), whilst Northvolt first scaled back expansion plans (Reuters, 2024o) and later placed one subsidiary into bankruptcy (Reuters, 2024p). These developments removed about 30 GWh of planned battery capacity that ASEAN cathode suppliers had expected to serve.

Fragmented regional policy and limited local value capture. Indonesia's ore-export ban stimulated a wave of HPAL project announcements, yet several projects now seek royalty relief and fiscal incentives in response to weaker prices and shifting regulatory frameworks (Reuters, 2025o). Regional policy strategies remain fragmented. The IEA's *Southeast Asia Energy Outlook 2024* flags inconsistent mineral-sector incentives across ASEAN economies (IEA, 2024c), whilst *Business Indonesia* (2025) echoes investor concerns regarding persistent regulatory uncertainty.

As a result, ASEAN continues to capture only a limited share of value within the critical minerals supply chain. Much of the region's concentrate is still exported for further processing abroad, leaving ASEAN with less than 10% of the contained metal value, compared with more than 50% captured in China. This occurs even as declining lithium and nickel prices reduced global battery pack costs by about 14% in 2023 (IEA, 2024a).

Systemic implications for automotive industrialisation. These structural vulnerabilities have already affected automotive production. Rare earth magnet shortages forced temporary shutdowns of motor assembly lines in Thailand and Viet Nam during the second quarter of 2025 (Reuters, 2025l). Delays in European gigafactory investments have postponed precursor offtake agreements that Indonesian HPAL plants had expected to supply. When nickel prices fall below US$15,000 per tonne, the cost gap between Indonesian HPAL production (about US$7,500 per tonne of nickel) and Chinese alternatives widens further, prompting producers to seek for fiscal relief from governments (Reuters, 2025o).

8.7.1.1.4. BAU #4: Slow renewable energy uptake

Coal still supplied roughly half of ASEAN's electricity in 2023 and accounted for about 80% of power sector CO_2 emissions, leaving the average grid-emission factor from 650 to 900 grams of CO_2 per kilowatt-hour, more than twice the OECD median (IEA, 2024c). That level of carbon intensity provides vehicle and parts manufacturers with limited Scope 2 abatement options unless they deploy on-site renewable generation or rely on carbon offsets (IEA, 2024c).

Clean energy investment remains significantly below global levels. Although ASEAN generates about 6% of global GDP, it attracted only 2% of global clean energy investment in 2023, equivalent to about US$72 billion, compared with the US$190 billion annually that the IEA estimates the region will require by 2035 to meet energy transition targets (IEA, 2024g; Reuters, 2024q). In the context of constrained capital availability, many state-owned utilities continue to prioritise extending the operational life of coal-fired power plants rather than investing in large-scale renewable generation.

Corporate renewable procurement pathways remain limited and fragmented. In several ASEAN countries, rigid single-buyer electricity markets and long-term take-or-pay contracts tie utilities to coal-based independent power producers. In Indonesia, such arrangements are expected to cover roughly two-thirds of projected peak demand in the Java–Bali system in 2025, constraining the grid's flexibility to integrate variable renewable energy (IEA, 2023b). A review conducted for the Asian Development Bank (ADB) indicates that most Southeast Asian economies permit industrial users to purchase electricity only from national utilities, meaning that meaningful PPAs for renewable electricity remain limited to pilot programmes in Viet Nam and the Philippines (Watanagase, 2024). Consequently, cumulative corporate renewable PPAs in ASEAN totalled less than 6 GW by the end of 2024, representing less than 5% of the volume contracted in the US during the same year (BloombergNEF, 2025a).

Grid and cross-border infrastructure development lags regional ambitions. Of the 18 interconnection projects envisioned under the ASEAN Power Grid, only 9 are operational, providing a combined transfer capacity of 7.7 GW, equivalent to about 3% of total regional installed generation capacity (ASEAN, 2024e). Plans to expand this capacity to 17.6 GW by 2030 have progressed slowly, hampered by divergent wheeling-charge frameworks and lengthy bilateral talks. Several high-profile initiatives, including Thailand's proposal to increase hydropower imports from Lao PDR to 10.5 GW, remain at the memorandum of understanding stage rather than being supported by binding PPAs (UNIDO, 2024b).

Nascent renewable energy certificates and EIP frameworks remain underdeveloped. Only the Philippines operates a fully functioning compliance renewable energy certificate market. Indonesia is still drafting the legislation, whilst other ASEAN countries rely primarily on small voluntary renewable energy certificate transactions that lack harmonised regional standards (ASEAN Centre for Energy, 2025c). UNIDO reports that fewer than 5 industrial parks in ASEAN align with the International EIP Framework, out of more than 800 registered industrial estates in the region, limiting the availability of verified

low-carbon manufacturing zones (UNIDO, 2023a).

8.7.1.1.5. BAU #5: Fragmented industrial park planning

Across ASEAN, industrial estates host the bulk of upstream automotive suppliers. Nevertheless, the region's industrial park landscape remains a patchwork of conventional zones, with only a small number of genuine eco-industrial exemplars. A recent mapping exercise by UNIDO identified 893 industrial parks and 84 special economic zones, yet only 2 estates fully meet the criteria of the EIP performance framework. This underscores how limited the region's green industrial infrastructure is relative to its broader manufacturing footprint (UNIDO, 2024a). Most industrial estates still follow legacy blueprints: tenants negotiate individual utility contracts, waste streams are handled in silos, and renewable power procurement rarely extends beyond bilateral arrangements to park-wide pooling mechanisms.

Momentum, however, is building. Under the Global Eco-Industrial Parks Programme, retrofit pilots are advancing in several locations, including DEEP C Hai Phong and Amata Dong Nai in Viet Nam, as well as Batamindo and Kendal industrial estates in Indonesia. These projects incorporate shared rooftop solar installations, waste-heat recovery systems, and centralised effluent treatment facilities, financed through development funds from Switzerland and Norway (UNIDO, 2023b; UNIDO, 2023a).

In Malaysia, Kulim Hi-Tech Park already sources part of its electricity from on-site photovoltaic systems and promotes itself as a 'leading global science city', featuring district cooling systems and centralised wastewater recycling integrated into the estate's utility infrastructure (Kulim Hi-Tech Park, 2025). These examples demonstrate that low-carbon industrial park infrastructure is both technically feasible and commercially viable under Southeast Asian conditions.

Despite these developments, the overall scale remains limited. UNIDO's latest annual report shows that fewer than 5 of the region's more than 800 registered industrial estates meet EIP benchmarks for resource efficiency, renewable energy deployment, and MRV transparency (UNIDO, 2024c). Most parks continue to depend on grid electricity with carbon intensities of 650–900 grams of CO_2 per kilowatt-hour. Except for the Philippines, compliance renewable energy certificate markets across ASEAN are either nascent or non-existent, leaving estate managers with limited tools to aggregate tenant demand for verifiable renewable electricity.

Financing constraints further slow progress. Whilst Global Eco-Industrial Parks Programme (GEIPP) pilot projects benefit from concessional funding, mainstream industrial park developers frequently cite regulatory uncertainty and the absence of long-term offtake guarantees as deterrents to investment in shared renewable energy infrastructure, solar, hydrogen production, or waste-to-energy systems.

8.7.1.2. Gap: Upstream Decarbonisation Landscape in ASEAN

A comparison between ASEAN's 2035 upstream vision and current operating conditions reveals two cross-cutting deficits – an economic rationality gap and a capability gap – spanning fuels, minerals, energy systems, and industrial-park development across the region.

1. Economic rationality gap. Most upstream suppliers are small and medium-sized enterprises (SMEs) operating with earnings before interest and taxes margins below 5%. Under such conditions, investments in refinery retrofits, HPAL upgrades, rooftop solar installations, or shared waste-heat recovery systems seldom clear internal payback hurdles.

In the energy sector, single-buyer electricity market structures in countries such as Indonesia, Thailand, and Malaysia continue to restrict direct PPAs, preventing industrial facilities from securing competitively priced renewable electricity even where renewable resources are abundant (Watanagase, 2024).

In the mineral sector, investors frequently cite volatile nickel and cobalt prices, together with shifting royalty regimes, as key reasons why many proposed HPAL projects in Indonesia remain delayed (Reuters, 2025q). Although development banks provide concessional finance for biofuel production and EIP pilots, most SMEs lack the balance-sheet strength and ESG data maturity required to qualify. As a result, access to large-scale transition financing remains constrained (IEA, 2024c).

2. Capability gap. A chronic shortage of engineers, ESG specialists, and plant managers experienced in low-carbon production processes further slows project implementation. A global evaluation by UNIDO of the Eco-Industrial Parks Programme notes that SME tenants often require intensive technical support to adopt shared utilities and MRV systems, yet the regional skills pipeline remains limited (UNIDO, 2024d).

The ILO (2021) warns that ASEAN's manufacturing workforce must rapidly upgrade skills in energy management and digital carbon accounting to meet the increasingly stringent disclosure requirements imposed by global OEMs. With only two industrial parks fully certified as EIPs, opportunities for peer learning remain limited. In many cases, industrial zone authorities still rely on external consultants for carbon reporting rather than developing permanent in-house expertise (UNIDO, 2025).

Weak project economics and limited technical capacity form a mutually reinforcing constraint. SMEs struggle to justify green capital expenditure without access to cheaper finance or shared infrastructure models, whilst financiers and OEMs remain cautious about supporting projects led by teams with limited decarbonisation expertise. The following sections quantify the gap between current performance and the 2035 targets, and outline the financing, market design, and workforce development measures required to close these structural deficits.

8.7.1.2.1. Gap #1: Constrained business case for upstream decarbonisation

ASEAN's upstream decarbonisation efforts stall less because of technological limitations than because of weak economic viability. Across fuels, minerals, electricity systems, and industrial park utilities, thin supplier margins, rigid tariff structures, and volatile commodity prices push most decarbonisation projects below the investment thresholds for the SMEs that dominate the automotive supply chain.

Refinery and fuel-supply retrofits remain net-present-value-negative. For example, installing a Euro 5 desulphurisation unit at a 100,000 bpd refinery in Indonesia requires about US$900 million in capital expenditure, with an estimated payback period exceeding 12 years under current refining margins. This is roughly twice the internal investment threshold typically applied by state-linked refiners (IEA, 2024h).

Second-generation biodiesel facilities face high operating costs. Feedstock inputs, such as palm oil methyl ester or used cooking oil, account for roughly 80% of operating expenditure. When CPO prices exceed MYR3,500 per tonne, earnings before interest, taxes, depreciation, and amortisation can turn negative, even with Indonesia's subsidy support scheme. Under such conditions, independent producers often reduce or suspend production (ASEAN Centre for Energy, 2024e).

Critical mineral processing is constrained by price volatility and fiscal opacity. Benchmark nickel prices fell from US$26,000 per tonne in June 2024 to about US$14,000 per tonne by April 2025. At these levels, the estimated cash production cost of new Indonesian HPAL projects (about US$17,000 per tonne of nickel) exceeds market prices, contributing to the delay of many projects. As a result, about 72% of the 1.4 million tonnes per year HPAL project pipeline is now officially classified as delayed (PwC, 2025).

Policy uncertainty complicates investment decisions. Royalty rates on nickel production were increased from 2% to 4% of gross revenue in 2024 and remain subject to periodic review. Such policy volatility widens financing gaps, as lenders demand longer tenors or sovereign guarantees to mitigate regulatory risk (Reuters, 2024r).

Renewable power procurement remains constrained by single-buyer market structures. In Indonesia, Thailand, and Malaysia, state-owned utilities maintain exclusive retail electricity supply franchises, meaning that factories must purchase electricity from the grid, which often remains dominated by coal-fired grid generation. As a result, industrial consumers are typically unable to sign long-term renewable PPAs that would allow them to hedge both cost and carbon exposure (Asia Clean Energy Forum, 2024).

Even where regulatory reform exists, participation barriers remain high. For example, Viet Nam's pilot direct PPA scheme requires minimum contract capacities of 30 MW and contract tenors of 10 years, thresholds that exceed the electricity demand and credit capacity of most Tier 2 and Tier 3 suppliers. Consequently, total uptake under the scheme remains below 1 GW (Lambe and Yeap, 2021; Tsanova, 2020).

EIP infrastructure struggles to meet shared-cost viability thresholds. A proposed

project in Batamindo Industrial Park, involving 20 MW of aggregated rooftop solar capacity and a 10 MW waste-heat recovery system, is expected to achieve a levelised cost of electricity of about US$0.8.4 per kilowatt-hour, roughly 15% below prevailing grid tariffs. However, the project requires 15 anchor tenants to commit to a pooled take-or-pay contract, whilst only 9 tenants have signed so far, delaying financial closure (UNIDO, 2023a).

A mid-term evaluation of the GEIPP identifies limited credit capacity amongst SMEs as the primary barrier to scaling such projects, even when concessional blended loans with interest rates as low as 2% are available (UNIDO, 2023b).

Capital access mechanisms favour multinationals, sidelining local suppliers. Major programmes such as ADB's Energy Transition Mechanism and the World Bank's Climate Investment Funds typically require audited Scope 1 and Scope 2 emissions baselines, together with 3 years of audited financial statements. Fewer than 30% of ASEAN automotive component SMEs can provide such documentation readily (IEA, 2024c).

As a result, concessional financing is disproportionally accessed by foreign-owned assemblers and large state-linked firms, whilst domestic suppliers, such as casting, machining, and surface-treatment companies, often rely on commercial loans with double-digit interest rates, extending investment payback periods beyond their internal financial limits.

8.7.1.2.2. Gap #2: Capability gap: The talent and know-how deźcit

ASEAN's upstream decarbonisation road map hinges on a talent pool that has not yet developed at the required scale. Whether installing ISO 50001 energy management systems, operating HPAL autoclaves, or configuring MRV dashboards, suppliers often rely on a small number of overextended engineers and external consultants. A diagnostic assessment of Viet Nam's pilot EIPs found that more than 70% of tenant SMEs lacked staff capable of conducting energy audits or LCAs and therefore required intensive technical support (UNIDO, 2023c). Broader labour market indicators confirm this constraint: a recent Reuters (2024s) survey reported that 68% of executives face an 'extreme' shortage of digital skills, which directly hampers corporate sustainability initiatives.

Fuel and bio-energy supply chain. Refinery upgrades and advanced biofuel facilities require process-control engineers trained in hydrogen furnaces, carbon capture and storage systems, and fuel-quality testing. These competencies remain rare within ASEAN polytechnic and technical education programmes. Engineering, procurement, and construction contractors, therefore, frequently add 10%–15% contingency margins to account for 'local skills risk', pushing project bids beyond the financial capacity of many SMEs (UNIDO, 2024d).

Critical mineral midstream sector. Operations such as nickel HPAL processing, rare-earth separation, and battery-grade graphite production require metallurgists experienced in high-purity processing under stringent ESG controls. Indonesia's universities graduate

fewer than 150 extractive metallurgy majors a year, about one-third of the workforce required to support projected HPAL capacity by 2026 (Asia Clean Energy Forum, 2024). The shortage contributes directly to project delays. An analysis by PwC (2025) of 29 announced HPAL facilities found that 72% have been delayed, with the lack of qualified plant managers cited as one of the three primary causes.

Industrial park decarbonisation. Transforming conventional industrial estates into low-carbon clusters requires the integration of waste-heat recovery systems, hydrogen micro-grids, and real-time carbon accounting platforms. However, an evaluation of six GEIPP pilot projects found that most industrial park authorities still outsource carbon accounting functions to short-term consultants, leaving internal institutional capacity at a 'nascent' stage (UNIDO, 2024d). With only two industrial parks in ASEAN fully certified under the EIP Framework, opportunities for peer learning remain limited.

Digital carbon data capability gap. OEMs increasingly require cradle-to-gate CO_2 emission data reported in formats compatible with platforms such as Catena-X, yet fewer than 10% of Tier 2 and Tier 3 suppliers surveyed by UNIDO were familiar with the GHG Protocol Product Standard. The Reuters (2024s) study identifies the shortage of digital sustainability skills as a major barrier to implementing effective corporate decarbonisation strategies.

8.7.2. Midstream

8.7.2.1. Current State: Regional Carbon Footprint Management Landscape in ASEAN

ASEAN's automotive midstream, comprising Tier 1 to Tier 3 component manufacturers and sub-assembly suppliers, entered the 2020s largely unprepared for the increasingly data-intensive transparency requirements emerging in the EU, the US, and Japan. Many suppliers continue to rely on spreadsheet-based estimates for emission accounting, whilst DPP pilots remain limited. Green finance channels barely reach SMEs, and external regulatory requirements are tightening faster than domestic industrial readiness. Four mutually reinforcing BAU patterns illustrate the scale of this capability gap.

8.7.2.1.1. BAU #1: Fragmented, low-rigour carbon accounting

The Asia and Pacific region recorded about 8,000 corporate disclosures to the Carbon Disclosure Project (CDP) in 2023, yet fewer than 1 in 10 originated from ASEAN firms, highlighting the region's limited pool of emissions data (CDP, 2023). Even where disclosure occurs, decision-grade data quality remains uncommon. Only about 20% of companies in emerging markets report product carbon footprints using primary metre or ERP data, and analysts note that the proportion is even lower in Southeast Asia (CDP, 2024a; S&P Global, 2024a). As a result, suppliers frequently rely on grid-average emissions factors or generic material-factor databases, generating carbon estimates that may deviate by 30%–40 % from audited results (S&P Global, 2024a).

Regulatory frameworks remain uneven across the region. Viet Nam is the only AMS with formal national guidance aligned with ISO 14067 for product carbon footprints (Vietnam Briefing, 2023). In other ASEAN economies, adoption remains voluntary and largely unenforced. No AMS has yet incorporated ISO 14067 or the GHG Protocol Product Standard into binding regulatory requirements, leaving national disclosure frameworks misaligned with the emerging International Sustainability Standards Board climate disclosure regime (ISO, 2018; S&P Global, 2024b).

By contrast, OEMs and external regulators increasingly demand far stricter reporting standards. Industry platforms and regulations now require primary data coverage exceeding 70%, the threshold established under the Catena-X Product Carbon-Footprint rulebook and the EU Battery Regulation (Catena-X, 2024). Failure to meet these requirements carries two main costs. First, suppliers may incur third-party verification and restatement expenses of about US$7,000–US$10,000 per component (SGS, 2024). Second, firms risk penalties or exclusion under OEM sustainability scorecards, such as Volkswagen Group's S-Rating system (Volkswagen Group, 2024).

Financial markets are increasingly responding to these transparency requirements. ASEAN SMEs that cannot provide verified product carbon footprints already face an average premium of about 120 basis points on working capital financing (CPA Australia and ASEAN Federation of Accountants, 2024). Once the EU's CABM enters its monetary phase in 2026, any under-reporting or misstatement of embodied emissions will translate directly into higher border levies. Current modelling estimates CBAM-related cost of about EUR75 per tonne of CO_2 equivalent for ASEAN exporters (Institute for Global Environmental Strategies [IGES], 2025).

Limited primary data availability, fragmented reporting standards, and rising verification costs place ASEAN midstream firms at a significant assurance disadvantage. Rapid rollout of ISO 14067–compliant metering systems, LCA tools, and Catena-X–compatible data pipelines is therefore critical to close the widening transparency gap.

8.7.2.1.2. BAU #2: Nascent traceability and digital passport infrastructure

The digital infrastructure required for product carbon traceability remains limited across ASEAN. The ASEAN Digital Integration Index assigns a score of 55 out of 100 to the Digital Trade and Logistics pillar, making it the region's weakest area of digital integration (ASEAN, 2021a). In terms of ERP and sensor adoption, fewer than 40% of Tier 2 and Tier 3 suppliers operate integrated ERP or manufacturing execution system platforms, compared with more than 70% in China and the EU. As a result, many firms continue to track materials using spreadsheets, which prevents automated uploads of product carbon footprint (PCF) data (Fortune Business Insights, 2024).

The region lacks locally developed battery passport pilot programmes. The Global Battery Alliance's 2024 pilot phase covered eight jurisdictions, yet none were led by ASEAN-based firms (Global Battery Alliance, 2024). At the same time, onboarding progress in other

regions is accelerating. In 2025, the Catena-X network and Chinese industry associations agreed to onboard 3,300 mainland suppliers by the third quarter of 2025, giving these firms an early advantage in digital product-carbon data exchange (Catena-X, 2025b).

Regulatory deadlines are approaching rapidly. Beginning in February 2027, every EV or industrial battery with a capacity exceeding 2 kilowatt-hours sold in the EU must carry an interoperable digital battery passport (Circularise, 2025). Legal analyses warn that non-compliant products may face re-labelling requirements or refusal of entry at EU ports, potentially extending logistics timelines by up to 2 weeks (Dudkowiak and Putyra, 2024).

Without accelerated deployment of ERP systems, Catena-X or Ouranos-compatible data infrastructures, and a regional digital passport testing environment, ASEAN suppliers risk border delays, additional re-labelling costs, and the loss of requests for quotations once digital passport requirements become mandatory.

8.7.2.1.3. BAU #3: SME capability and źnance shortfalls

SMEs account for about 99% of enterprises in ASEAN, yet only a minority understand the fundamentals of carbon accounting. A 2024 Certified Practising Accountants Australia–ASEAN Federation of Accountants (CPA Australia and AFA, 2024) focus group survey of regional suppliers identified four systemic barriers: limited awareness, a shortage of ESG talent, fragmented data systems, and high compliance costs. Skills audits reinforce this finding: barely 18% of ASEAN SME employees have received formal LCA or GHG Protocol training, less than half the proportion reported amongst Chinese counterparts (OECD, 2024a). As a result, small plastics-moulding and stamping vendors routinely fail Tier 1 supplier audit portals, which require ISO 14067–aligned product carbon footprints.

Financial shortfalls further compound these capability gaps. The OECD and ERIA *SME Policy Index: ASEAN 2024* assigns a score of 2.9 out of 6 to green finance and sustainable practices, the lowest amongst eight policy dimensions, signalling weak institutional support for decarbonisation capital expenditure (ERIA, 2024a). S&P Global projects US$260 billion in sustainable bond issuance across the Asia and Pacific region for 2025, yet ASEAN's share remains in the single digits and is dominated by Singaporean sovereign and banking issuers (S&P Global, 2025b). Data from the Climate Bonds Initiative confirm this shortage: by the third quarter of 2024, ASEAN issuers accounted for less than 7% of cumulative green, social, sustainability, and sustainability–linked debt, a proportion largely unchanged since 2022 (Climate Bonds Initiative, 2024). Even where concessional financing windows exist, such as the ASEAN Catalytic Green Finance Facility or Singapore's Green Corridor initiative with the People's Bank of China, minimum investment sizes often exceed the requirements of lower-tier automotive suppliers, leaving much of their working capital demand unmet (ADB, 2024; Wall Street Journal, 2023). Independent studies further show that SMEs without verified PCFs pay a 120-basis-point premium on bank credit, as lenders struggle to assess transition risks (Cambridge Institute for Sustainability Leadership and Business for Social Responsibility, 2023).

Ultimately, limited skills and restricted access to finance reinforce one another in a self-perpetuating cycle. Suppliers unable to fund metering systems or ERP upgrades remain excluded from Catena-X data spaces, and this absence in turn prevents them from qualifying for OEM green scorecards and sustainability-linked loans. Unless ASEAN deploys targeted technical assistance programmes and blended-finance instruments that crowd in commercial banks, the region's vast SME backbone will remain locked out from decarbonising global value chains.

8.7.2.1.4. BAU #4: External policy headwinds outpace domestic preparedness

EU policy is advancing faster than regional readiness. An IGES (2025) brief estimates that, at current carbon-credit prices, CBAM could add about EUR75 per tonne of CO_2 equivalent to ASEAN steel or aluminium exports that lack verified low-carbon credentials. Yet only Singapore operates an active carbon tax: SGD25 per tonne of CO_2 equivalent, rising to SGD45 by 2026 (National Climate Change Secretariat, 2024). By contrast, Indonesia's emission trading system remains at the pilot stage, whilst the other eight AMSs are still assessing carbon-pricing options (ASEAN Climate Change and Energy Project, 2024).

Pressure from OEMs is becoming material. Volkswagen's S-Rating has screened suppliers on environmental data since 2022 (Volkswagen Group, 2025), whilst Mercedes-Benz now requires materials aligned with net-zero pathways before 2039 (Mercedes-Benz Group, 2024). Southeast Asian suppliers increasingly report difficulty meeting these audit requirements, with industry media noting missed requests for quotation and the application of 'green discounts' for uncertified components (Asia Manufacturing News, 2025).

If left unaddressed, these BAU dynamics will gradually erode ASEAN's midstream competitiveness. OEM sustainability scorecards already penalise suppliers with unverifiable PCFs, and the EU's CBAM will soon translate these penalties into direct monetary costs. Global green-finance flows are increasingly bypassing firms that cannot quantify climate-related risks. Without a coordinated effort – scaling primary data capture, onboarding suppliers to Catena-X–compliant data spaces, and expanding green-finance mechanisms for SMEs – ASEAN part manufacturers risk progressive exclusion from decarbonising automotive value chains.

8.7.2.2. Gap: Regional Carbon Footprint Management Landscape in ASEAN

ASEAN's midstream automotive base, dominated by Tier 2 and Tier 3 SMEs, remains several steps behind the data-rich, digitally connected carbon-management regime that Europe, North America, and Japan will require by the end of this decade. Survey evidence (Figure 3.3, Figure 3.29, and Figure 3.30) reinforces the external data: only one supplier in five identifies decarbonisation as a core strategy, 'lack of expertise' is cited as the principal barrier, and decision-making authority for investment in carbon-management tools largely resides outside local plants. At the same time, binding regulatory triggers are imminent. The EU's CBAM will monetise embedded emissions beginning in 2026, whilst

the Battery Regulation will require DPPs from 2027. The next section examines five critical gaps – three relating to carbon-footprint calculation and two concerning traceability – and shows how deficits in capability, human capital, and finance could push ASEAN part manufacturers out of global value chains unless remedial action begins within the 2025–2030 window.

If these gaps persist, ASEAN midstream automotive suppliers risk exclusion from global value chains through two channels: near-term delisting by OEMs due to unverifiable carbon data, and medium-term trade penalties under mechanisms such as the EU's CBAM. Competitor regions, especially China and the EU, are moving rapidly to implement digital passports and traceability standards, thereby raising the bar for market access (Grand View Research, 2024a). Without coordinated action across policy, finance, and technology, ASEAN's midstream automotive sector will struggle to maintain its role in the global supply chains as decarbonisation reshapes industrial hierarchies.

8.7.2.2.1. Gap #1: Inadequate carbon-accounting capability

The Asia and Pacific region logged almost 8,000 disclosures to the CDP in 2023, yet fewer than 10% were submitted by ASEAN companies (CDP, 2023). Even where disclosures exist, their methodological rigour remains limited. Only about one-fifth of companies in emerging markets rely on primary metre or ERP data to calculate PCFs, and the proportion is even lower in Southeast Asia (S&P Global, 2021b). Accounting practices aligned with international standards remain rare. Viet Nam is the only AMS with a formal national guideline aligned with ISO 14067 (TCVN 14067) (Vietnam Briefing, 2023).

The envisaged to-be state requires at least 70% primary data coverage, the threshold embedded in Catena-X rules and the EU's DPP requirements. By contrast, current disclosure practices across ASEAN remain closer to 20% primary data coverage. Without rapid improvement, suppliers will struggle to meet the audited PCF requirements imposed through OEM scorecards, including Volkwagen's S-Rating and the Mercedes-Benz Supplier Sustainability Standard, whilst also facing additional costs under the EU's CBAM. Current estimates suggest that CBAM could impose a surcharge of about EUR75 per tonne of CO_2 equivalent on ASEAN steel and aluminium exports lacking verified emission data (IGES, 2025).

Institutional and financial constraints further reinforce this capability gap. The ERIA SME Policy Index: ASEAN 2024 assigns a score of 2.9 out of 6 to green finance and sustainable practices, the lowest amongst the eight policy dimensions assessed (ERIA, 2024a). A CPA Australia–AFA (2024) survey identifies limited awareness, shortages of specialised talent, fragmented data systems, and high compliance costs as the four principal obstacles to ESG adoption. As a result, many Tier 2 and Tier 3 suppliers remain unable to meet the primary-data requirements expected by regulators and OEMs, thereby constraining their access to green financing instruments and participation in OEM procurement contracts.

8.7.2.2.2. Gap #2: Human-resource shortage in LCA and digital MRV

Only 49% of surveyed ASEAN suppliers report having in-house LCA expertise, reflecting a broader skills deficit across the region. Diagnostics from the WEF's (2024b) Lighthouse initiative indicate that factories implementing intensive up-skilling programmes can achieve energy savings of 20%–30%, underscoring the importance of specialised technical capacity. However, regional education systems are not filling this gap. An estimated 61% of ASEAN youth aged 10–24 receive no formal digital skills training, limiting the pipeline of workers capable of supporting digital MRV systems (Nazara, 2024).

Survey evidence reinforces this constraint. 'Lack of expertise' ranks above policy or technology uncertainty as the most significant barrier to decarbonisation (Figure 3-29). Without the development of regional certification pathways and OEM-backed training academies, many SMEs will continue to outsource LCA and digital MRV tasks, an unsustainable cost burden.

8.7.2.2.3. Gap #3: Weak economic case and limited finance

For most ASEAN automotive SMEs, the business case for decarbonisation remains weak. Decarbonisation initiatives tend to become attractive only when they are clearly linked to operational survival, cost savings, or near-term business growth. Although there are examples where external pressures or targeted incentives have encouraged action, most SMEs remain hesitant. This reluctance stems from unclear policy guidance, fragmented regulatory frameworks, and, most critically, limited access to finance for small-scale projects. The absence of unified policy mandates further compounds this hesitation, leaving many SMEs unconvinced of the immediate value of investing in carbon-management systems (United Nations Development Programme [UNDP], 2025).

The financing landscape remains similarly constrained. Although banks across the region have begun piloting sustainability-linked loans and investing in capacity-building programmes, digital outreach, and subsidised access to carbon-accounting software, these efforts are neither sufficiently widespread nor large enough to catalyse broad-based SME engagement. For example, Malaysia's Low Carbon Transition Facility has disbursed over US$225 million, representing about half of its allocated funding. Whilst this indicates progress, it also highlights the scale of unmet demand. Financial institutions report that well-structured green lending programmes can yield returns of up to five times the initial investment, suggesting that a viable business case exists when incentives and institutional support are properly aligned (UNDP, 2025). In practice, however, many SMEs still lack access to practical support mechanisms, such as subsidised carbon-accounting software, simplified benchmarking tools, and concessional finance, leaving adoption rates relatively low (UNDP, 2025; Argus Media, 2023b).

Without stronger commercial incentives and dedicated financing mechanisms, including blended finance instruments or results-based grant schemes, ASEAN's supplier base will struggle to meet emerging international data and sustainability requirements. This shortfall exposes regional automotive suppliers to the risk of losing access to export

markets and facing additional costs under emerging carbon border adjustment mechanisms (ADB, 2023).

8.7.2.2.4. Gap #4: Nascent digital passport and traceability infrastructure

Digitalisation is transforming the global automotive supply chain, with DPPs and traceability platforms becoming central to regulatory compliance and competitiveness. In ASEAN, however, the digital infrastructure required to support traceability remains underdeveloped. Although DPPs are being piloted globally to track the origin and life cycle of automotive components, adoption within ASEAN is still at an early stage. Local pilot programmes remain limited, and the region has yet to establish interoperability standards that would enable seamless cross-border data exchange (SEEBURGER, 2024).

By contrast, China is advancing rapidly in the deployment of DPPs. The country is leveraging blockchain-based traceability systems and government-backed initiatives to strengthen supply-chain transparency and ensure compliance with global sustainability standards. These developments position Chinese suppliers to meet international regulatory and market requirements more effectively than many of their ASEAN counterparts (Grand View Research, 2024a). In the US and Europe, regulatory pressure and corporate sustainability commitments are driving rapid DPP adoption, with the automotive sector emerging as a leading test case for this transformation (Grand View Research, 2024a).

Within ASEAN, digital trade and logistics initiatives, such as the ASW and e-Form D, have improved customs procedures and facilitated regional trade compliance. However, these systems do not yet deliver the end-to-end traceability or data harmonisation needed to support comprehensive decarbonisation compliance across automotive supply chains (Partnership for Open & Neutral Global Automotive Data Exchange, 2025). The absence of a unified, interoperable digital passport system, therefore, leaves ASEAN suppliers vulnerable to future regulatory barriers, such as the EU's mandatory digital passport requirements for automotive components.

8.7.2.2.5. Gap #5: SMEs¿ access to technology and capital for traceability

Even where demand for traceability data exists, most ASEAN Tier 2 and Tier 3 suppliers face prohibitive costs when adopting technologies such as radio-frequency identification (RFID), blockchain platforms, and IoT-enabled inventory systems. Implementing digitalisation and data-security solutions requires significant financial resources and specialised expertise, both of which remain beyond the reach of many SMEs without targeted institutional support (SEEBURGER, 2024). Although some banks and large corporations have begun subsidising access to carbon-tracking software and offering practical support programmes, these efforts have not yet expanded sufficiently to meet the needs of the region's vast SME base (UNDP, 2025).

Access to finance remains similarly constrained. Green capital flows in ASEAN continue to be concentrated amongst large corporations, with SMEs receiving only a small fraction of available sustainable finance (ADB, 2023; Argus Media, 2023b). The absence of strong policy signals, such as carbon pricing mechanisms or mandatory carbon disclosure requirements, further discourages SMEs from investing in traceability infrastructure, as the immediate commercial benefits remain uncertain (UNDP, 2025).

If these gaps persist, ASEAN midstream automotive suppliers risk gradual exclusion from global value chains. In the near-term, firms may face delisting by OEMs due to unverifiable carbon data. Over the medium term, they may encounter trade penalties under mechanisms such as the EU's CBAM. Competitor regions, especially China and the EU, are advancing rapidly in implementing digital passports and traceability standards, thereby raising the bar for market access (Grand View Research, 2024a). Without coordinated action across policy, finance, and technology, ASEAN's midstream automotive sector will struggle to sustain its role in global supply chains as decarbonisation reshapes industrial hierarchies.

8.7.3. Downstream

8.7.3.1. Current State: Regional Carbon Footprint Management Landscape in ASEAN

ASEAN's automotive parts suppliers enter the mid-2020s poorly equipped to meet the increasingly data-intensive carbon-transparency requirements being introduced in Europe, North America, and Japan. Most Tier 1 to Tier 3 firms still estimate product carbon footprints using spreadsheets and generic emission factors. DPP pilots remain extremely limited, whilst green-finance mechanisms and technical advisory programmes reach only a small proportion of the region's SME-dominated supplier base. These conditions illustrate a set of four mutually reinforcing BAU patterns that highlight the scale of the gap.

The ASEAN automotive sector faces broader structural challenges in decarbonising its downstream supply chain. The landscape is characterised by continued reliance on older ICEVs, sustained by economic constraints and extensive informal repair networks, both of which slow the pace of emission reduction. ELV and EV battery-recycling infrastructure remains nascent and fragmented across the region, resulting in inefficient resource recovery and increasing the risk of environmental degradation.

The rapidly expanding xEV market is constrained by uneven and often insufficient charging infrastructure. Investment in charging networks remains concentrated in major urban centres, whilst interoperability standards across charging systems remain limited. These structural constraints, rooted in economic realities, regulatory gaps, and infrastructure deficits, highlight a widening disconnect between ASEAN's decarbonisation ambitions and the current operational realities of its downstream automotive ecosystem.

8.7.3.1.1. BAU #1: Persistent operation of older ICEVs and HEVs

The continued operation of older vehicles presents a significant hurdle to decarbonisation across ASEAN. Although some countries, such as Viet Nam, show a preference for newer used vehicles, with over 60% of buyers in 2024 preferring vehicles under 5 years old (TraceData Research, 2024), a substantial share of the regional fleet still consists of older ICEV models. In Thailand, for example, the number of cars over 10 years old reached 2.98 million units by 2018, representing about 31% of the total registered fleet (Techakanont and Homklin, 2019). A proposal to impose a 10-year vehicle age limit in Jakarta encountered strong public opposition, largely because many households lack the financial capacity to replace vehicles frequently (The Jakarta Post, 2024b).

Vehicle age has a direct effect on emission performance. Remote-sensing tests covering 400,000 vehicles in Jakarta found that in-use diesel cars and light trucks emit 9–10 times more nitrogen oxides than comparable petrol-powered vehicles, with older diesel vehicles performing particularly poorly (ICCT, 2022). At the same time, an extensive network of informal repair shops, identified as the dominant vehicle life-extension channel in both Thailand and Indonesia, allows high-emitting vehicles to remain operational well past their normal retirement age (Techakanont and Homklin, 2019).

Fragmented vehicle inspection regimes further weaken emission control. ASEAN lacks a harmonised, data-driven roadworthiness framework, resulting in large compliance gaps. Malaysia illustrates this issue clearly: inspections conducted by the Computerised Vehicle Inspection Centre (Pusat Pemeriksaan Kenderaan Berkomputer [PUSPAKOM]) are compulsory for commercial vehicles, yet checks for private cars remain voluntary under the ad-hoc Voluntary Vehicle Inspection programme (The Star, 2025). In Jakarta, annual emission tests are formally required for vehicles older than 3 years. However, fewer than 500,000 of the capital's 22 million registered vehicles underwent testing in 2023, largely because only 336 authorised garages and 107 motorcycle workshops provide the service (ICCT, 2022). Viet Nam has announced plans to introduce biennial (and later annual) exhaust checks for motorcycles older than 5 years starting in 2025, but the implementing decree has yet to establish firm timelines for nationwide coverage (Vietnam News, 2024). With standards, testing frequencies, and digital reporting formats differing across cities and vehicle classes, regulators struggle to aggregate reliable regional emissions data.

High grid carbon intensity further limits the emissions benefits of early EV uptake. Even where BEV sales are accelerating, life-cycle emission reductions remain constrained because electricity generation in much of the region continues to rely heavily on coal. The World Bank estimates Indonesia's grid emission factor at 838 grams of CO_2 per kilowatt-hour^{-1}, significantly higher than the EU average of about 250 grams of CO_2 per kilowatt-hour, with similar values observed across several mainland Southeast Asian power systems (World Bank, 2019). Consequently, under current conditions, retiring older diesel vehicles and reducing fossil-fuel consumption can yield greater immediate climate benefits than shifting new vehicles to coal-intensive grid electricity.

Until ASEAN countries can (i) shorten the operational lifespan of the most polluting ICEVs through enforced emission-based inspection regimes, and (ii) capture reliable real-world data for Scope 3 emission reporting, the region's downstream decarbonisation road map – covering reuse, recycling, and circular material flows – will start from a position of persistently high use-phase emissions. The inspection gap, therefore, represents a critical link between an ageing vehicle fleet and the effectiveness of subsequent downstream decarbonisation measures.

8.7.3.1.2. BAU #2: Nascent ELV management and informal recycling dominance

The downstream circular loop for ELVs in ASEAN remains underdeveloped. Regional assessments estimate that about 2.4 million vehicles were scrapped across the region in 2020, yet most AMSs still lacked a formal, nationwide system to manage or recycle them (Regional Resource Center for Asia and the Pacific, 2024; ERIA, 2019a). Field surveys confirm this situation. Across Indonesia, Malaysia, Thailand, and Viet Nam, dismantling, recovery of parts, and scrap trading are conducted largely by informal operators, who typically cut vehicle bodies using gas torches whilst allowing fluids to drain directly onto the ground (ERIA, 2019b).

Indonesia illustrates how regulatory gaps perpetuate informality. An ERIA audit found that the country lacks a licensing or registration framework for dismantling facilities. As a result, ELVs often move through intermediaries before arriving at informal automotive workshops or dismantling shops that operate entirely outside environmental oversight (ERIA, 2019c). Recovery activities, therefore, concentrate on components with immediate resale value, such as wire harnesses, aluminium wheels, and catalytic converters, whilst plastics, shredder residues, and spent fluids are frequently dumped or burned.

The economic losses associated with this system are considerable. Malaysia, for example, is estimated to lose about US$1.1 billion in plastic-resin value annually, as roughly 81% of polyethylene terephthalate, low-density polyethylene, high-density polyethylene, and polypropylene fail to re-enter the supply chain (World Bank, 2022; The Edge Malaysia, 2024a). Steel recovery is similarly inefficient. Studies in Thailand suggest that about one-third of automotive ferrous scrap becomes so heavily contaminated that it can only be down-cycled into low-grade reinforcing bar, thereby eliminating much of the potential energy-saving benefit associated with recycling (ERIA, 2019b).

Formal treatment capacity remains extremely limited by comparison. In Malaysia, the first authorised automotive treatment facility achieved a recycling rate of about 90% in pilot trials, yet its processing capacity extends to only a few thousand vehicles a year, far below the country's estimated annual scrappage volume (Abdullah et al., 2024). Elsewhere in ASEAN, comparable licensed facilities remain either at the planning stage or limited to small-scale demonstration lines.

Weak domestic oversight also increases exposure to illicit trade. A joint study by the United Nations Office on Drugs and Crime and the United Nations Environment Programme (2025)

documents how waste vehicle components and mixed shredder residues are transported illegally across borders. These activities contaminate legitimate metal- and polymer-recycling streams and undercut compliant recyclers. In practice, the region's ELV system continues to be driven more by volatile scrap metal prices than by environmental standards or circular-economy metrics. Until regulators scale licensed recycling capacity, mandate producer take-back obligations, and strengthen enforcement against cross-border waste flows, ASEAN will continue to lose both carbon mitigation potential and recoverable material value at the end of a vehicle's life cycle.

8.7.3.1.3. BAU #3: Immature battery-recycling ecosystem and critical-mineral exposure

Demand for battery metals is surging far faster than ASEAN's ability to recycle them. The IEA (2023a) Critical Minerals Market Review 2023 notes that global lithium demand tripled and cobalt demand rose 70% in 2017–2022, lifting the market for critical minerals to roughly US$320 billion in 2022. Outside Indonesia's nickel ore, however, the region produces virtually no battery-grade lithium, nickel sulphate, or cobalt, so local cell plants still rely on refined inputs shipped from China, Korea, and Australia.

Recycling capacity is too thin to change that equation. Today, formal lithium-ion treatment rests on three commercial operators. SK Tes operates a hydrometallurgical line in Singapore with a nameplate throughput of about 5 kilotonnes per year and recovery yields near 90% (SK Tes, 2024). EcoNiLi has expanded to four plants across three countries with a combined capacity of 86 kilotonnes per year (Eco-Business, 2024). Thailand's Sun-Up facility focuses mainly on solvent recovery, offering only limited cobalt and nickel returns (AsiaOne, 2024). Even at full utilisation, the three operators could process well under 100 kilotonnes a year, an order of magnitude below the 0.8–1.0 megatonnes of end-of-life traction batteries the IEA expects to arise annually in Southeast Asia by 2035 (IEA, 2024a).

Feedstock rarely reaches those plants. A USA-SCP study found that formal e-waste channels capture no more than 5% of discarded batteries in Indonesia, with the rest leaking into informal scrap routes or household storage (Mahanani and Kristianingsih, 2024). Collection logistics are further hampered by hazardous-cargo rules and a December 2020 ban on most used-battery imports, a measure tightened in 2023 to include lithium packs (Global Trade Alert, 2023).

Traceability is another weak link. From August 2031, the EU Battery Regulation will bar packs lacking a digital passport and will require at least 16% recycled cobalt and 6% recycled lithium and nickel in every battery sold in the single market (Regulation [EU] 2023/1542, 2023). ASEAN exporters still rely on paper declarations; no AMS has operational passport databases or recycled-content registries.

The region's rare-metal loop remains embryonic: pockets of hydrometallurgical expertise, scarce feedstock flows, minimal traceability, and heavy dependence on volatile global spot markets for critical inputs.

8.7.3.1.4. BAU #4: Undersized, urban-centric, and fragmented charging network

Public charging in ASEAN is expanding, but the pace and pattern of build-out still fall short of what mass-market xEV adoption needs. Thailand leads in absolute hardware, yet it had only 2,658 public stations with 9,694 plugs at the end of 2023, about one outlet for every 7–8 BEVs and one station for roughly 28 cars, far above the IEA's rule-of-thumb threshold of 1:10 that typically unlocks demand momentum (Fourin, 2024; Royal Thai Embassy, 2023).

Malaysia has made visible progress but remains clustered around the Klang Valley. Only 2,288 charging bays were in service nationwide by March 2024 (MIDA, 2024), whilst EV registrations are approaching 20,000 units (MGTC, 2024a). More than 60% of those chargers sit in Selangor and Kuala Lumpur (Sustainable Development of Energy, Water and Environment Systems [SDEWES], 2023), and three charge point operators – ChargEV, Gentari, and JomCharge – own over 40% of all sockets, each on its own app and tariff ladder (Roland Berger, 2024).

Indonesia's grid utility, State Electricity Company (Perusahaan Listrik Negara [PLN]), dominates the archipelago's rollout. By March 2025, it had built 3,772 four-wheeler public EV charging stations and nearly 10,000 motorcycle public electricity supply stations, but the EV-to-charger ratio is still 21:1, and most fast units hug the main Trans-Java corridor (Segmenty, 2025). Outside Java–Bali, drivers can face 150-kilometre gaps between DC charging hubs.

Singapore is the outlier: about 13,800 public charging points serve about 18,000 electric cars, a 1:1.3 ratio that shows how dense, interoperable networks reduce range anxiety (Land Transport Authority, 2024a). Crucially, its chargers share common CCS2/Type 2 connectors and open roaming protocols, parameters that are still optional elsewhere in the bloc.

Across ASEAN, the technical and user-experience fabric remains patchy. Connector diversity – CCS2, Guobiao/Tuijian [GB/T], Charge de Move [CHAdeMO]) – forces many sites to carry multiple connectors, lowering use; pricing, payment, and roaming vary by operator; and charger uptime is difficult to verify because standardised reliability metrics are rare, echoing findings that reported availability often overstates real-world performance (Electrek, 2024). Hardware skews towards slower AC units: in Malaysia only one in five bays is DC-fast, and Thailand's quick-charger share is under 50 %, limiting turnover at busy sites.

The cumulative effect is a network that is growing, but not yet where it matters or at the pace required. Even optimistic scenarios from BloombergNEF suggest ASEAN will need well over 100,000 public charge points by 2030 to stay on a high-adoption trajectory, an order of magnitude above today's installed base (BloombergNEF, 2025b). Until investment spreads beyond urban cores, roaming becomes seamless, and high-power uptime is verifiable, charging infrastructure remains a brake – not an accelerator – on regional xEV demand.

8.7.3.2. Gap: Downstream Decarbonisation Landscape in ASEAN

ASEAN's downstream ecosystem sits at a decisive inflection point. The region's long-term vision calls for four tightly linked building blocks – a harmonised emission-based vehicle inspection regime; licensed ELV and steel- and aluminium-recycling hubs; a closed-loop battery-metal circuit; and a dense, interoperable public charging network – to turn every kilometre driven into progress towards net zero. Yet today's operating landscape remains fragmented, undercapitalised and data poor. More than 4 million Malaysian cars are already older than 10 years, with no mandatory private car test, whilst Indonesia's average car lasts 18–20 years, evidence that voluntary or patchwork inspection schemes cannot trigger timely fleet renewal (Society of Automotive Engineers Malaysia, 2020; ICCT, 2023). Roughly 2.4 million vehicles were scrapped at the end of life across ASEAN during 2015–2020, yet most dismantling still occurs in informal yards with minimal material recovery (ERIA, 2019a).

The battery era exposes a second structural gap. Formal recyclers – principally SK Tes in Singapore (about 5 kilotonnes per year) and EcoNiLi's tri-country network (86 kilotonnes per year) – can collectively treat under 100 kilotonnes per year, an order of magnitude below the 0.8–1.0 million tonnes of spent packs the IEA expects in Southeast Asia by 2035 (SK Tes, 2024; Eco-Business, 2024; IEA, 2024a). Without a traceable, high-volume secondary supply, ASEAN risks trading its current dependence on imported oil for tomorrow's dependence on imported lithium, nickel, and cobalt.

Finally, charging infrastructure expansion continues to lag mass-market requirements. Thailand's 2,658 stations and 9,694 plugs translate to roughly 1 plug for every 12 EVs – well above the 1:10 density that typically spurs demand acceleration – whilst Malaysia's 2,288 bays and Indonesia's PLN-built 3,772 four-wheeler public EV charging station sites are concentrated in just a handful of urban corridors (Fourin, 2024; MIDA, 2024b; The Jakarta Post, 2025; IEA, 2025a). Varied connector standards, isolated payment applications, and limited DC-fast coverage further dampen use and investor confidence.

These inspection, recycling, battery-metal, and charging gaps expose a single underlying fault line: capital and data do not yet flow where the decarbonisation impact is greatest. The sections that follow quantify the shortfall and map the capability, financing, and governance levers required to align ASEAN's downstream reality with its 2035 ambition.

8.7.3.2.1. Gap #1: From patchy checks to a digital, emission-based inspection regime

ASEAN's inspection architecture remains geared to 20th-century safety checks rather than 21st-century carbon accountability. Fewer than one-third of the region's 55 million in-use passenger cars ever undergo a tailpipe or on-board diagnostics (OBD) reading. Where tests exist, they remain voluntary, such as Malaysia's PUSPAKOM (2024) Voluntary Vehicle Inspection, or city-specific, such as Jakarta's diesel smoke programme and Ho Chi Minh City's motorcycle pilot (ICCT, 2023), with results confined to paper certificates or scattered municipal databases. By contrast, the envisaged AVIP system would log an OBD-III code set and certified CO_2 value for every vehicle at least once every 2 years and upload

each record to a cloud ledger that customs authorities, tax agencies, and OEM sustainability teams could query in real time. The structural gap has three layers.

Coverage comes first. Indonesia tested fewer than 2% of its 22 million registered light vehicles in 2023 because only 336 accredited garages could perform an emission check (ICCT, 2023). Malaysia's voluntary scheme draws barely 40,000 cars a year, about 1% of the ageing fleet that would be audited annually by a vehicle's 11th birthday under the to-be scenario (PUSPAKOM, 2024).

The second layer is data integrity. Where readings are taken, methods vary widely. Thailand's Department of Land Transport (2023) still allows five different idle-speed carbon monoxide, and opacity procedures, none aligned with UNECE R.83, making cross-country benchmarking impossible. AVIP would collapse these variants into a single, export-compliant test cycle and transmit results to a shared application programming interface (API), mirroring Singapore's electronic inspection certificate, which already blocks untested cars from renewing road tax via a live Land Transport Authority (2024b) query.

The third layer involves behavioural incentives. Today's patchwork imposes no escalating penalty for keeping a high-emitting 18-year-old diesel on the road. The proposed design applies progressively higher road-tax surcharges, calibrated to OBD-verified emission bands, to encourage turnover without imposing an outright ban. Japan's 2024 OBD mandate shows that the administrative burden is modest; inspection time rises by only 6 minutes per vehicle (Society of Automotive Engineers of Japan, 2022b). Until these three deficits – coverage, data quality, and behavioural triggers – are closed, ASEAN will struggle to generate auditable Scope 3 inventories for OEMs or to prioritise the most polluting vehicles for scrappage support. The next subsection quantifies the investment needed to retrofit inspection lanes with OBD-III scanners, roll out a region-wide cloud registry, and design a surcharge schedule that remains affordable for lower-income households whilst still accelerating fleet renewal.

8.7.3.2.2. Gap 2: From informal scrap yards to licensed, high-recovery ELV hubs

The inspection reforms outlined above will stall unless owners can dispose of failing vehicles through a transparent, value-returning channel. Today, that channel barely exists. Roughly 2.4 million cars reached end-of-life across ASEAN in 2020, yet fewer than 5% entered a licensed dismantling line; the rest were dismantled in informal yards where fluids leach into soil and recyclable metals are cherry-picked for quick cash (ERIA, 2020). By contrast, the to-be architecture foresees industrial ELV hubs that meet the EU's 85% recycling and 95% recovery benchmark, feeding audited scrap streams back to steel and aluminium smelters (European Commission, 2023a). Three structural gaps block that transition.

Capacity and scale. Malaysia's pilot Authorised Automotive Treatment Facility (AATF) processed about 9,000 cars in 2023: an impressive material-recovery rate of about 90%,

but less than 2% of the nation's annual scrappage need (Universiti Teknologi MARA, 2023). Across Indonesia, Thailand, and Viet Nam, formal capacity is effectively zero. Hitting the to-be target requires 20–25 AATF-scale plants by 2030 – about 150,000 tonnes per year of licensed shredding – or US$600–US$750 million in new capital expenditure at current turnkey prices.

Traceability and compliance. Informal dismantlers operate outside environmental oversight. ERIA's Bandung audit recorded hydraulic-fluid and glycol runoff 12 times above Indonesian Class II water limits within 50 metres of yard perimeters (ERIA, 2020). Without a digital ELV passport that captures the vehicle identification number, weight, and material split at de-registration – mirroring the EU certificate of destruction workflow – regulators cannot verify recovery ratios, and smelters cannot predict scrap chemistry for low-carbon steelmaking (European Commission, 2023a).

Economics and behavioural triggers. Scrap prices alone seldom persuade owners to surrender older cars; the ex-yard value of a 1-tonne sedan in Jakarta averages US$220, barely a third of the about US$600 needed to upgrade to a cleaner used import. The to-be model closes that gap through (i) age-linked road-tax surcharges flagged by the inspection database; and (ii) modest take-back payments funded by dismantler revenues: exactly the mechanism that lifted Malaysia's AATF intake by 40% during its 2023 pilot (Sulaiman et al., 2023).

The cost of inaction is tangible. Every tonne of recycled auto steel avoids about 1.5 tonnes of CO_2 and 1.4 tonnes of iron ore, whilst secondary aluminium cuts energy use by 95% compared with primary smelting (World Steel Association, 2024; International Aluminium Institute, 2024). ASEAN's current leakages, therefore, forfeit nearly 4 metric tonnes of CO_2 a year and more than US$1 billion in recoverable-metal value, losses that will grow as the vehicle parc expands.

Unless the capacity, traceability, and incentive gaps are closed during 2025–2030, the inspection regime cannot deliver fleet turnover, OEMs will lack auditable Scope-3 data, and ASEAN will continue to bleed carbon advantage and raw material value at the very point where circularity should begin. The next subsection quantifies the capital, land zoning, and regulatory milestones required to scale a region-wide network of licensed ELV hubs aligned with both EU recovery thresholds and ASEAN's own decarbonisation timetable.

8.7.3.2.3. Gap 3: From sub-scale battery recyclers to a region-wide, closed-loop circuit

ASEAN's move into xEV manufacturing is colliding head-on with its limited capacity to recapture lithium, nickel, and cobalt. Formal hydrometallurgical lines can treat less than 100 kilotonnes per year[6] of spent cells, only a sliver of the 0.8–1.0 metric tonnes of end-of-life traction batteries the IEA (2024a) projects for Southeast Asia by 2035. The gap is not merely technical; it threatens market access. From August 2031, the EU Sustainable Batteries Regulation will oblige every pack sold in Europe to contain at least 16% recycled

[6] Denotes annual throughput or processing capacity, not cumulative volume.

cobalt and 6% recycled lithium and nickel, with each lot traceable through a digital passport (Regulation [EU] 2023/1542, 2023). No AMS yet issues passports, and exporters still rely on paper declarations that EU customs will soon reject. Three deficits keep the loop embryonic.

Capacity and technology. The region's headline players – SK Tes in Singapore (about 5 kilottones per year, with about 90% metal recovery), EcoNiLi's multi-country network (86 kilotonnes per year), and Sun-Up Recycling in Thailand (focused on solvent recovery) – cannot absorb even 1 year of future scrap (SK Tes, 2024; Eco-Business, 2024). Indonesia's planned US$6 billion CATL–IBC complex could add about 120 kilotonnes per year by 2031 (Nikkei Asia, 2024), but financing has yet to reach close and would still leave the bloc well below the required throughput. Rough estimates indicate that ASEAN needs US$1.5 billion–US$2 billion to build another 300 kilotonnes per year of hydrometallurgical capacity this decade, capital that remains unfunded.

Feedstock mobilisation. Existing plants run at less than 40% utilisation because formal channels capture no more than 5% of discarded batteries in Indonesia and less than 2% in Thailand; most packs are stockpiled or diverted into informal scrap streams (Mahanani and Kristianingsih, 2024). Costly hazardous material permits, fragmented take-back points, and a 2020 Indonesian ban on used-battery imports (Global Trade Alert, 2023) starve facilities of feedstock, raising unit costs and deterring new entrants.

Traceability and market pull. Europe's passport-plus-EPR model guarantees recyclers a paid inflow of homogeneous battery packs, but ASEAN lacks both a battery-passport standard and an EPR fee mechanism to fund collection. OEMs therefore face rising compliance risk: a 45-kilowatt-hour BEV exported to Europe in 2032 will need about 2.8 kilogrammes of recycled nickel and 0.7 kilogrammes of recycled cobalt, volumes the region cannot yet certify. Without digital provenance, local gigafactories will have to import refined metal or outsource recycling to China, perpetuating price exposure that saw cobalt trade above US$80,000 per tonne in 2022 (Trading Economics, 2024).

The opportunity cost is stark. LCA by Transport & Environment (2024b) shows that routing 90 kilotonnes of battery mass through hydrometallurgical loops could displace about US$1 billion in virgin imports and cut embedded CO_2 by about 40% compared with primary supply. Yet ASEAN is on track to recycle barely 12% of that feedstock by 2030.

Unless capacity, feedstock logistics, and traceability gaps close quickly, the bloc risks exchanging dependence on imported oil for an even more volatile dependence on imported cathode metals, whilst forfeiting both EU market access and its own green industrial ambitions. The next subsection sizes the blended-finance envelope and regulatory milestones needed to create a 400 kilotonnes per year closed-loop system, integrated with the ELV hubs discussed under Gap 2 and the AVIP database of Gap 1, so every xEV battery sold after 2031 re-enters the regional supply chain instead of the waste stream.

8.7.3.2.4. Gap 4: From pockets of sockets to a dense, fast-charge xEV infrastructure network

ASEAN's public charging footprint is expanding, but it remains too thin, too slow, and too fragmented to unlock mass-market xEV uptake. Across the bloc, only about 25,000 public plugs serve roughly 250,000 EVs, nominally a 1:10 ratio that worsens to 1:17 once Singapore's dense network is excluded, far outside the utilisation threshold the IEA (2024a) links to demand acceleration. Thailand, the regional frontrunner, has 2,658 stations with 9,694 connectors, leaving whole provinces with fewer than five DC hubs (Fourin, 2024). Malaysia's 2,288 bays sit mainly in the Klang Valley (MIDA, 2024b), whilst Indonesia's 3,772 four-wheeler public EV charging stations trace the Trans-Java spine, creating 150 km 'black zones' beyond Java–Bali (Segmenty, 2025). The shortfall has three dimensions.

Density and power mix. Most hardware is 7–22 kilowatts (kW) AC. In Malaysia, only one in five bays is DC-fast, and Thailand's rapid-charge share is below 50%. Busy sites therefore turn over just one to two cars per plug per day, compared with six to eight in China, where 120 kW is standard (SDEWES, 2023). Low utilisation depresses operator internal rates of return and stalls further build-out, trapping the network in a capital-rationed equilibrium.

Interoperability and user experience. Connector diversity (CCS2, GB/T, CHAdeMO) forces operators to provide multiple charging connectors, yet roaming remains the exception. In the Klang Valley, a driver needs three separate apps – Gentari, JomCharge, and ChargEV – to access 60% of sockets (Roland Berger, 2024). Where roaming pilots exist, such as Thailand's Charging Consortium, they cover less than 15% of plugs and still omit real-time pricing.

Capital allocation. BloombergNEF (2025b) projects the region will need at least 100,000 public charge points by 2030, four times today's inventory. Yet the payback period for a 60-kW charger outside metropolitan cores stretches beyond 9 years at prevailing tariffs, deterring private financiers. Singapore's EV Common Charger Grant, which shoulders up to 50% of hardware capital expenditure (Land Transport Authority, 2023), has accelerated deployment by 2–3 years; no comparable risk-sharing vehicle exists at ASEAN scale.

The result is a patchwork network that creates range-anxiety 'cold spots', confines fleet operators to short-haul duty cycles, and slows the battery-recycling flywheel discussed in Gap 3. Export-oriented OEMs lose the charging behaviour data needed to price value-added services and mobility subscriptions that underpin their xEV profit pools. The next subsection sizes the US$300 million blended-finance envelope and the policy milestones – CCS2/Type 2 mandating, open-roaming APIs, and a regional uptime index – required to convert today's islands of AC sockets into an interoperable fast-charge spine capable of pulling ASEAN xEV demand forward.

8.8. Business-as-usual and Gap Analysis of Servitisation

8.8.1. Current State: Vehicle Servitisation Landscape in ASEAN

Traffic jams remain a daily reality in ASEAN megacities under BAU, as private car use

continues to dominate. Under this trajectory, servitisation in ASEAN's automotive sector advances only incrementally by 2035. Personal vehicle ownership remains the dominant form of mobility, with rising incomes fuelling car sales despite worsening urban congestion. By 2035, many ASEAN households will fulfil their aspiration to own a car as economies grow, keeping privately owned vehicles as the primary mode of transport.

Ride-hailing and new mobility services do expand in this scenario, but in a fragmented, siloed fashion. Operators such as Grab and Gojek remain powerful within their home markets, yet cross-border integration of services across ASEAN countries remains limited. A commuter travelling from Johor Bahru to Singapore or from Bangkok to Kuala Lumpur in 2035 would still need to juggle multiple apps and platforms. No single regional MaaS network has emerged under BAU. National regulations and data localisation laws continue to wall off markets, preventing the emergence of a seamless ASEAN-wide mobility platform. The result is that servitisation remains patchy: concentrated in pockets, mainly large cities, and varying widely across countries rather than becoming the standard model of automotive business across the region.

Crucially, the underlying inefficiencies of the private car paradigm persist. The average car in ASEAN still sits unused for more than 90% of the time (Transport & Environment, 2017), a costly idleness that servitisation was meant to reduce. Despite the proliferation of ride-hailing, most vehicles on the road remain privately owned and spend most hours parked at home or work. Utilisation rates of 5%–10% remain the norm, mirroring global patterns (Transport & Environment, 2017).

As a result, the potential benefits of servitisation – higher asset use and fewer total vehicles – are largely unrealised by 2035 under BAU. Congestion in major cities, therefore, shows little improvement; with more cars overall, traffic delays and parking shortages worsen in many urban centres. Worsening gridlock imposes high economic costs. For example, the EU already loses about EUR100 billion a year to congestion (Transport & Environment, 2017), and ASEAN cities are under similar strain. Transport emissions remain stubbornly high.

Without decisive change, ASEAN continues to lag in the global mobility transition, continuing on a trajectory of growing private car ownership, incremental technology adoption, and only isolated successes in new mobility services.

Change in consumer behaviour is slow under BAU. Whilst younger urbanites show more openness to paying for MaaS rather than owning a car, their options remain limited. In a recent Metro Manila survey, 84% of respondents said they would likely use a unified MaaS app for trips, citing reliability and cost savings as the main reasons (Nikitas et al., 2022). This finding indicates significant latent demand for service-based mobility.

Yet by 2035, most ASEAN consumers still lack access to a comprehensive MaaS that could replace personal car ownership, in stark contrast with global trends. As early as 2000, visionaries such as Jeremy Rifkin foresaw a future 'where access, not ownership, is the dominant market offering' (Baxter and Aurisicchio, 2018). By the 2020s, Western Europe,

China, and Japan had begun to embrace that vision through car subscriptions, shared fleets, and integrated mobility apps. Under a do-nothing scenario, however, ASEAN in 2035 has not fully caught up with this paradigm shift and remains several steps behind the leading markets.

ASEAN's automotive players largely retain the traditional sales-centric business model under BAU. Automakers and dealerships continue to earn revenue mostly from one-off vehicle sales and basic after-sales services (maintenance, spare parts) rather than from innovative mobility services. Toyota's much-touted KINTO subscription service, for instance, has been launched in markets such as Malaysia and Thailand, yet uptake is modest, and it remains a side offering. By 2035 under BAU, no ASEAN-based OEM has transformed itself into a mobility company; profitability still depends overwhelmingly on selling new vehicles.

This situation opens the door for global technology and mobility firms to capture emerging value streams. Companies from outside the region make inroads by offering what local firms do not. Early signs of this trend are already visible. Chinese EV makers are already flooding ASEAN with affordable electric cars and partnering with taxi fleets. In 2024, 85% of electric cars sold in Thailand were imported from China (IEA, 2025a), illustrating how foreign firms can fill market gaps. The value-added, and many of the high-tech jobs associated with digital platforms, fleet operations, and data services, would therefore accrue to these external entrants.

The do-nothing scenario leaves ASEAN as a follower rather than a leader in the evolution of MaaS. The result is more congestion, continued growth in emissions, and economic value flowing to external players that step in to provide services that regional companies and governments have not developed. This sobering outcome underlines the importance of more proactive strategies. The next sections examine the specific BAU shortfalls in digitalisation and decarbonisation that underlie this scenario.

8.8.1.1. Current State: Digitalisation in Servitisation

Under BAU, ASEAN's automotive sector has not fully harnessed technology to enable servitisation. The to-be vision is one of integrated technological platforms that facilitate relationship-based, results-focused product-service systems. By contrast, under BAU, existing digital platforms are largely fragmented, operating as closed ecosystems rather than unified or interoperable networks.

Grab's app, for example, functions as a de facto mobility platform in many cities, but it mainly integrates Grab's own services – ride hailing, food delivery, and some transit ticketing – along with those of selected partners, without a region-wide open data exchange. No equivalent of a pan-ASEAN mobility super-app connects all modes of transport across countries. Each provider, whether an automaker's leasing programme, a transit operator's journey planner, or a car-sharing service, typically runs its own app and data silo, resulting in a fragmented customer experience. The idea of a one-stop MaaS

solution, where users can seamlessly book e-scooters, car shares, trains, and taxis within a single platform, therefore, remains largely aspirational in ASEAN by 2035. Some cities have attempted pilot programmes, but these have not scaled beyond limited trials.

The regulatory environment has not caught up. Concerns over data privacy and sovereignty mean that cross-border data flows remain restricted. ASEAN recognised this challenge and, in 2019, launched the Regulatory Pilot Space as a sandbox for cross-border data transfer (ComputerWeekly, 2024). However, under BAU, progress in implementing region-wide data interoperability is slow. By the mid-2020s, the Regulatory Pilot Space had demonstrated that businesses could safely share data across countries within a controlled 'safe test' sandbox environment (ComputerWeekly, 2024), but scaling this approach into a formal framework adopted by all members is challenging.

Each country's personal data protection laws continue to differ, and some countries impose strict data localisation rules that require even anonymised mobility data to remain within national borders (ComputerWeekly, 2024). This patchwork of regulations stifles digital innovation. For instance, an ASEAN car-sharing start-up cannot easily allow users to drive across borders, such as between Malaysia and Thailand, whilst enabling the platform to track the vehicle seamlessly in both jurisdictions, because data policies and backend systems are not harmonised. As a result, relationship-based digital interaction – the idea that a customer's data travel with them and services adapt to their needs anywhere in the region – remains unrealised. Instead, users face disjointed experiences and must establish new relationships (accounts, IDs, credit top-ups) with each service or city.

Product-service systems on technological platforms remain in their infancy. Most digital services are still based on transactions rather than outcomes. Ride-hailing trips are bought one at a time, car subscriptions (where available) function largely as digital leases rather than flexible usage plans, and automakers' connected services remain mostly limited to infotainment or roadside assistance features.

The advanced telematics and AI-driven personalisation transforming vehicle subscription models in more developed markets (Grand View Research, 2024b) are being adopted only gradually by local players. Globally, telematics already supports applications such as usage-based insurance and predictive maintenance, yet in ASEAN, these services remain confined to a few upscale offerings.

Automakers do embed connectivity in newer vehicle models as part of global designs, generating a flood of vehicle data. However, under BAU, much of these data are underused. Data use is suboptimal: the region has millions of connected smartphones and a growing number of connected vehicles, yet the data are not sufficiently pooled or shared to create the network effects and service innovation seen in a digitally mature servitisation model.

One example of progress under BAU is Singapore's experience, which in many ways stands out as a regional outlier. Singapore has advanced the digital integration of mobility more than its neighbours. For instance, its public transit is highly digitalised, operating

through a unified EZ-Link/SimplyGo payment system, and private mobility services such as GetGo car sharing have expanded rapidly. GetGo, launched in 2021, grew to more than 2,100 cars and 250,000 users within 2 years (Vulcanpost, 2023), using a fully digital platform where users sign up with a national digital ID and unlock cars through a mobile app.

Whilst this experience showcases the power of digitalisation for servitisation – removing the need for physical rental counters and relying entirely on app-based, data-driven systems – it also underscores how isolated such examples remain. Singapore's favourable conditions, including its dense urban structure, high cost of car ownership, and advanced digital infrastructure, are relatively unique. Under BAU, other ASEAN cities have not replicated this model at scale. There may be a car-sharing pilot in Bangkok or a parking app in Jakarta, but these initiatives remain fragmented rather than signal a broad regional transformation.

The gap between ASEAN and the technological cutting edge remains evident. Globally, automakers are turning cars into software-centric devices by delivering over-the-air updates, monetising in-car services, and building platform-based business models. Along ASEAN's BAU path, however, local automakers and regulators are only gingerly exploring these ideas by 2035. For instance, an ASEAN automaker might still be debating how to price connected services or remain hesitant to share vehicle data with third-party developers due to unclear regulations.

BAU's digital foundation is insufficient to support the level of servitisation ASEAN seeks to achieve. Technological platforms exist, but they are not fully leveraged for relationship-based, outcome-oriented services. Data are generated but not broadly shared or optimised. The result is that servitisation efforts remain limited in scope and impact. They do not radically change the customer experience or the industry's revenue model by 2035, leaving a significant digitalisation gap relative to the to-be vision.

8.8.1.2. Current State: Decarbonisation Through Servitisation

Servitisation has the potential to drive substantial decarbonisation of transport. Under BAU, however, this potential is realised only marginally in ASEAN by 2035. The to-be vision described a life-cycle–oriented approach in which new ownership and usage models reduce emissions at every stage. Under BAU, the automotive ecosystem remains largely locked into conventional patterns that are carbon-intensive.

One of the clearest missed opportunities is the persistently low vehicle use rate. Because ASEAN has not shifted substantially towards shared fleets, the region does not reap the benefits of using fewer vehicles to deliver the same level of mobility. Studies show that one shared car can replace 5–15 privately owned cars, and a radical shared autonomous system could reduce urban car numbers by 90% (Transport & Environment, 2017). Under BAU in 2035, nothing approaching this scale of change has occurred. Private cars continue to occupy most roads and parking spaces in cities.

Millions of new vehicles are added to ASEAN roads during the 2020s and 2030s as economies grow, rather than being offset through shared mobility models. Consequently, energy use and emissions from manufacturing and operating these vehicles stay high. The average car is still used for only a small fraction of the day, meaning a huge amount of embedded carbon – in steel, plastic, and battery materials – is tied up in dormant assets. The life-cycle carbon footprint per passenger-kilometre remains substantial. The potential efficiency gains from higher utilisation are lost under BAU.

Car-sharing and ride-hailing services are present, but without strong policy support, they do not significantly reduce private car ownership. In some cases, these services may even increase total vehicle-kilometres travelled. Evidence from several Western cities shows that ride-hailing services can draw passengers away from public transport and place more cars on the road for pick-ups. ASEAN's BAU trajectory may reflect similar dynamics. For example, when ride-hailing services are convenient and cheap, some commuters may choose a GrabCar instead of public transport, potentially increasing congestion.

Without regulatory incentives for shared rides or pooling, many ride-hailing trips remain single-passenger journeys. This reproduces the inefficiencies of private car use whilst adding 'deadhead' kilometres as drivers reposition between rides. Consequently, the contribution of BAU servitisation to cutting congestion or emissions remains limited. In many cases, the outcome resembles one step forward and one step back.

Electrification progresses by 2035, but BAU servitisation does not maximise its impact. Several ASEAN governments, including Thailand, Singapore, and Indonesia, set EV adoption targets and roll out incentives in the 2020s. These efforts contribute to a growing share of EVs in new car sales. For instance, Thailand emerged as the largest EV market in Southeast Asia. Even during a dip in overall car sales, EVs accounted for about 13% of new car sales by 2024 and continued to rise thereafter (IEA, 2025a). Indonesia has seen EV sales climb, supported by tax breaks, reaching mid-single-digit percentages of new sales in the 2020s (IEA, 2025a). By 2035, some ASEAN cities may plausibly have a visible share of EVs on the road.

However, because the servitisation model is not fully embraced, most of these EVs are privately owned and individually used, rather than deployed in high-use shared fleets. An EV that sits idle for most of the day reduces tailpipe emissions, but its contribution to overall emission reduction is far smaller than it would be if the vehicle were used intensively to replace multiple ICEV trips. Under BAU, no coordinated strategy emerges to electrify ride-hailing fleets at scale or build massive electric car-sharing networks. Any such initiatives remain small. Singapore provides a partial exception, as national policy aims to electrify the entire vehicle fleet, including shared mobility services. Across ASEAN as a whole, however, this approach is not the norm.

Consequently, decarbonisation gains from EV adoption are dampened under BAU. Without smart fleet management, EV charging may place additional stress on the grid during peak periods. At the same time, opportunities to integrate EVs into grid-support services, such as vehicle-to-grid applications, are largely untapped. EV adoption proceeds, but without

the efficiency gains that servitisation could deliver. The region, therefore, ends up with a large number of electric cars used only intermittently, rather than a smaller number of EVs serving many users. The latter outcome would have delivered a significantly greener outcome.

Life-cycle–oriented measures, such as rigorous maintenance and end-of-life recycling, lag under BAU. In theory, servitisation encourages better maintenance because fleet operators have incentives to keep vehicles in top condition for customers. However, because servitisation is limited under BAU, most vehicles are maintained – or neglected – by individual owners according to highly variable standards. Many ASEAN countries still lack strong periodic vehicle inspection regimes for emissions and roadworthiness. As a result, older diesel trucks or poorly maintained motorcycles can continue operating whilst emitting high levels of pollutants. This represents a failure to control emissions during the use phase.

In the to-be vision, companies would refurbish cars, reuse batteries, and design products with recyclability in mind. Under BAU, however, these practices are nascent at best. A few pilot initiatives may emerge – for example, battery-recycling centres established between local firms and Japanese technology providers – but these are isolated rather than widespread industry practice. Many used batteries might be stockpiled or disposed of improperly, with valuable materials not recovered efficiently. This situation creates an environmental risk and a missed economic opportunity.

Servitisation implies a circular-economy approach to manufacturing, in which fewer cars are made, and greater emphasis is placed on remanufacturing. Under BAU, the system stays closer to a linear model, with manufacturing expanding continuously to meet growing demand for new cars. Vehicle production across ASEAN continues to ramp up, especially in Thailand, Indonesia, and Malaysia, to supply domestic and export markets.

Without a strong pivot towards servitisation, automakers have limited incentives to design vehicles that are exceptionally durable or easily upgradable, because profitability continues to depend on selling the next generation of models. For example, modular vehicle designs that allow components to be easily replaced or upgraded – an approach that would be highly valuable for service-based fleets seeking to extend vehicle life – are not a priority under BAU. Used vehicles in ASEAN are often resold to secondary markets or exported to neighbouring countries with less stringent standards rather than systematically refurbished by the original maker.

Under another BAU scenario, policy measures linking servitisation with decarbonisation are cautious. Urban and national policies across ASEAN remain conservative. Few jurisdictions adopt bold measures such as congestion pricing, low-emission zones, or strict limits on private car use that could accelerate the shift to shared, cleaner mobility.

Singapore stands almost alone in having capped the growth of private cars through its 0% vehicle growth policy introduced in 2018 and heavy taxes on car ownership (Transport & Environment, 2017). Other ASEAN cities continue expanding road infrastructure – building

flyovers and widening highways – to accommodate more traffic rather than discourage private car use.

Public transport investment continues, with new metro lines built in cities such as Jakarta and Bangkok. However, integration between public transport and new mobility services is ad hoc. For instance, mobility hubs that allow seamless transfers from rail to e-scooters or on-demand shuttles remain uncommon. Instead, travellers must often coordinate these connections themselves. Without stronger integration, servitisation does not reinforce public transport as much as it could. In some cases, the unmanaged proliferation of ride-hailing services may even compete with buses and other mass transit options.

Policymakers under BAU are often reactive. When ride-hailing services first boomed, some governments responded by imposing caps or extra fees on them to protect traditional taxi operators. For example, regulators in Indonesia at one point limited the number of ride-hailing cars and imposed fare controls (CNBC, 2017). Regulations of this kind, aimed at levelling the playing field, can inadvertently stifle innovative models that might have environmental benefits, such as car-pooling services or electric bike-sharing schemes.

Under a do-nothing scenario, these regulatory barriers are not fully resolved. Each ASEAN country maintains different, and often restrictive, rules governing new mobility businesses. What is allowed in one city may be banned in another. For example, motorcycle taxi services are legal in Jakarta but have long been banned in Manila. This regulatory patchwork limits the ability of servitisation-based models, which depend on scale and network effects, to expand across the region and contribute to transport decarbonisation.

8.8.2. Gap: Vehicle Servitisation

ASEAN's automotive sector faces significant gaps in moving from BAU to the ambitious to-be vision of leading in servitisation beyond 2035. One major gap lies in the adoption and integration of mobility services. Despite clear demand signals – for example, in one Metro Manila survey, 84% of respondents said they would likely use a MaaS app, citing cost and reliability (Nikitas et al., 2022) – most ASEAN consumers still lack access to unified, convenient service-based mobility. Car ownership remains the norm, and new mobility services such as ride-hailing, car-sharing, and subscriptions exist only in fragmented pockets. For example, a traveller crossing from Malaysia to Singapore or from Thailand to Viet Nam in 2030 would need multiple apps and accounts, as no seamless regional platform has emerged under BAU. This contrasts sharply with the to-be vision, where ASEAN would operate integrated mobility super-apps and develop exportable service models.

Another critical gap lies in industry capability and innovation. Local automakers and mobility providers have not yet positioned servitisation at the core of their business strategies. By 2025, few ASEAN manufacturers offered flexible leasing or outcome-based mobility services beyond small pilot initiatives. The result is a capability gap, including insufficient investment in software, data analytics, and partnerships needed for service-

centric business models.

Underlying many of these issues is a policy and ecosystem gap. Regulatory and market frameworks across ASEAN are still oriented towards traditional vehicle sales and ownership rather than service-based mobility. Rules are often outdated or inconsistent across countries, creating a fragmented regional environment that hampers scale. The International Transport Forum of the OECD (2022) notes that regulatory frameworks governing app-based mobility in ASEAN are fragmented and need revision. It emphasises that authorities need stronger digital skills and improved data access to mobility data to govern new services.

The region lacks a unifying strategy. Each country is pursuing isolated initiatives or, in some cases, maintaining status quo, car-centric policies, whereas the to-be scenario demands a coordinated push for innovation. Taken together, these gaps indicate that ASEAN still lacks several ingredients to become a leader in servitisation: widespread consumer adoption of mobility services, proactive industry transformation, and a supportive and integrated ecosystem. If unresolved, these shortcomings will leave ASEAN stuck in traffic literally and figuratively whilst other markets speed ahead. The following sections examine in greater depth two pillars of servitisation where the gaps are most acute: digitalisation and decarbonisation.

8.8.2.1. Digitalisation Gaps in Servitisation

A fully servitised automotive ecosystem relies on advanced digital platforms, data sharing, and customer-centric technological innovation, areas where ASEAN's current trajectory falls short.

One gap is the shortage of specialised human capital and R&D for mobility technologies. Developing MaaS platforms and connected vehicle systems requires skilled engineers, data scientists, and continuous innovation. Yet ASEAN's talent pipeline is limited. R&D investment remains low, often well under 1% of GDP in major countries, compared with 2%–3% in advanced economies, and this disparity is evident in skills gaps.

A 2023 ILO study in Thailand, for instance, found critical shortages in high-technology automotive skills, including EV engineering and digital systems, underscoring that the workforce is not fully prepared for smart mobility (Rapid Asia, 2023). This human capital gap hinders local firms from developing homegrown mobility platforms or cutting-edge telematics, leading many to rely on imported technologies or small-scale pilot initiatives. Without significant expansion of R&D investment and cultivation of technical talent, ASEAN will struggle to build the technological platforms envisioned in its servitisation strategy.

A second gap lies in support for open innovation and data sharing across the mobility ecosystem. Servitisation thrives in an environment where automakers, start-ups, telecommunication firms, and government agencies collaborate to build services. This often requires open data standards, APIs, and regulatory sandboxes that allow new ideas

to be tested. ASEAN's environment is not particularly conducive to this form of collaboration.

Data tend to be siloed and tightly controlled. No region-wide open data exchange exists for transport, and even basic integrations, such as linking public transit data with ride-hailing platforms, occur only in isolated cases. ASEAN launched the ASEAN Regulatory Pilot Space in 2019 to create a sandbox for cross-border digital services, enabling companies to pilot solutions spanning multiple countries (ComputerWeekly, 2024). Whilst this initiative was a positive step, progress has been slow and limited to trial projects.

A consistent framework still does not exist that would allow, for example, a mobility start-up in Singapore to access telematics data from cars operating in Malaysia or Indonesia. The lack of support for open innovation is evident in funding and incubation programmes. Outside Singapore, which hosts several government-backed mobility innovation initiatives, few ASEAN countries offer dedicated grants or regulatory sandboxes for new mobility services. As a result, entrepreneurs developing MaaS platforms face a thicket of approvals and uncertain regulatory pathways in each country. Without a friendlier innovation ecosystem, many promising ideas either die early or go elsewhere.

Third, ASEAN's digital servitisation efforts are constrained by limited market scalability resulting from national fragmentation. Even where digital mobility services exist, they typically operate within a single country and are often concentrated in major cities. Grab, for example, operates across Southeast Asia, yet a user in one country cannot seamlessly use the app for cross-border trips, nor is there a unified ASEAN-wide subscription or payment system for mobility services. No regional MaaS platform knits together public transport and private mobility services across national borders.

Each ASEAN market is relatively small when considered individually. Even Indonesia, the largest market in the region, accounts for only a fraction of global vehicle sales. Without regional integration, companies cannot achieve the scale economies or network effects that digital platforms need. The resulting gap is visible in the numbers. Even the most successful ASEAN digital mobility platforms reach a limited share of the population. For example, Singapore's GetGo car-sharing platform, a digital-native service, amassed about 250,000 users and a fleet of 2,100 cars in its first 2 years of launch (Vulcanpost, 2023). Although this represents a notable local success, it is modest compared with Singapore's roughly 600,000 privately owned cars and has no presence beyond Singapore.

In Malaysia, the SOCAR car-sharing platform (backed by a Korean technology company) had about 1.9 million members and 20,000 daily users by 2023 (SK Inc., 2023). Yet its expansion into neighbouring countries is limited. National transit apps and payment systems do not extend across borders.

The lack of a scalable regional platform is a gap that undercuts ASEAN's to-be vision of becoming a global leader in servitisation. Without integration, the region cannot fully leverage its combined market size or create homegrown super-apps that could go global. Instead, ASEAN risks remaining a collection of small digital ponds where big fish from

outside (global technology companies) can enter one market at a time and dominate, or where promising local innovations fail to scale beyond pilot stages.

Companies and investors do not yet see Southeast Asia as a region where cutting-edge mobility solutions can be readily developed and scaled across markets, a perception that must change if ASEAN is to achieve the servitisation to-be state.

8.8.2.2. Decarbonisation Gaps in Servitisation

Servitisation is envisioned as a route to greener, more sustainable transport. The to-be scenario imagines life-cycle–oriented mobility systems, including shared electric fleets, pay-per-use models that maximise efficiency, and rigorous maintenance and recycling practices. The current BAU, however, falls short on several fronts.

First, ASEAN lacks sufficient alternatives to traditional vehicle ownership and usage, limiting the potential environmental gains. Under servitisation, consumers would have many options: subscription plans, car-sharing services, peer-to-peer rentals, and mobility packages that encourage choosing the appropriate transport mode for each trip or avoiding vehicle use altogether where walking or cycling is feasible. In practice, such options remain limited. Most ASEAN residents have two choices for personal mobility: buy a vehicle or rely on public transport and ad hoc ride-hailing services.

New models such as car subscriptions are rare. Car-sharing services operate in only a few cities. Although Singapore and Kuala Lumpur have seen growth in this sector, car sharing accounts for a minuscule fraction of trips. Even ride-hailing services, which are widely used, have not evolved into a MaaS ecosystem. Most users still treat them as occasional taxi substitutes rather than as full alternatives to car ownership.

As a result, private vehicle sales continue to rise, and the expected efficiency gains from servitisation remain largely unrealised. In theory, a single shared vehicle can replace 5–15 privately owned cars (Transport & Environment, 2017). ASEAN remains far from achieving such outcomes. By 2030, personal cars in ASEAN, as in many other regions, will remain idle for about 90% of the time (Transport & Environment, 2017). Consequently, the embodied carbon associated with manufacturing these cars, along with the fuel consumed during their infrequent use, is not meaningfully reduced through service-based mobility models. This gap reflects cultural and structural factors. Car ownership continues to carry status value, and trust in shared services builds gradually. At the same time, affordable and convenient servitised options remain limited, making it difficult for middle-class households to consider abandoning car ownership.

Second, ASEAN's policy and regulatory framework has not yet fully incorporated a life-cycle sustainability approach, particularly in vehicle maintenance and end-of-life management. A fully decarbonised servitisation model would ensure that vehicles on the road are well maintained to maximise efficiency and minimise emissions, whilst older, highly polluting vehicles are retired or retrofitted. In practice, however, many ASEAN

countries do not mandate rigorous in-use vehicle inspections or maintenance standards for private cars.

Unlike regions that require annual or biennial inspections for emissions and safety, several ASEAN countries only require vehicle checks at the time of registration or transfer of ownership, or do not impose inspections after the initial sale. Only two ASEAN countries strictly limit vehicle age or enforce robust inspection regimes. Singapore requires annual inspections after a few years of ownership and effectively retires cars after 10 years through its certificate of entitlement system, and Viet Nam bans private cars older than 20 years and requires more frequent inspections for older vehicles (Solah et al., 2021; AskWonder, 2023).

ELV management is absent except in Singapore. Most ASEAN countries have no formal vehicle scrappage schemes or recycling requirements. As a result, the circular-economy aspect of servitisation, including refurbishing vehicles, reusing batteries, and recycling materials, remains underdeveloped. This gap will become increasingly significant by the 2030s, when waves of first-generation EV batteries reach the end of their operational life. Without adequate recycling facilities or second-life uses, these batteries could create waste and pollution risks. The current regulatory environment remains conventional and reactive. It focuses on standards for new vehicles, such as adopting Euro 5 fuel or setting EV adoption targets, whilst neglecting the in-use fleet and new business models.

To bridge this gap, governments would need to actively reform laws. This would involve creating categories for shared mobility, allowing alternative ownership models, such as companies operating vehicle fleets for subscription or shared use, and setting emission and safety standards tailored to these use cases. Under BAU, such reforms are progressing slowly, if at all. As a result, servitisation-related decarbonisation is held back by rules that favour the status quo of individual ownership and fragmented, informal mobility markets.

Last, the transition to electrified, low-carbon fleets under servitisation is occurring, but not at the speed or scale required, highlighting an implementation gap. In theory, shared and high-use fleets, such as ride-hailing services or rental vehicles, are well suited for electrification because the lower operating costs of EVs generate faster returns when vehicles are used intensively. In ASEAN, however, this synergy remains underdeveloped. Some promising initiatives have emerged. For instance, Grab now operates over 10,000 EVs each in Indonesia and Thailand, representing the largest ride-hailing EV fleets in those markets (Grab, 2024). However, these gains are limited. As of 2024, only 7% of total distance travelled on Grab's platform came from low- or zero-emission vehicles, whilst the remaining 93% still relied on petrol or diesel vehicles (Grab, 2024).

Wider adoption is uneven. Private EV ownership is rising, particularly in Thailand, but often reflects second-car purchases rather than shared or high-use models. Without stronger integration into servitised mobility systems, many EVs risk being underused. ASEAN lacks coordinated plans to electrify fleet services or build charging infrastructure tailored to

shared mobility. Under BAU, efforts remain piecemeal, driven by individual companies or national programmes rather than a region-wide strategy.

The root of these gaps lies in a combination of policy inertia, market fragmentation, and conservative mindsets. These are a continuation of old practices focused on selling more cars and managing pollution through standards, rather than the paradigm shift towards delivering mobility services and managing sustainability through efficiency.

Bridging these gaps requires rethinking incentives. If companies saw profit in keeping a vehicle running cleanly for 15 years rather than selling replacements, or if consumers could conveniently access mobility services without owning ageing cars, behaviours would change. The next section of the masterplan examines the root causes of this situation in greater detail. What is already clear, however, is that without stronger intervention, ASEAN's servitisation will not achieve the seamless digital integration or the deep carbon reductions envisaged in the to-be scenario. Providing these missing pieces is essential if the region is to avoid becoming locked into a high-emission, low-innovation transport future even as the rest of the world advances towards more sustainable mobility systems.

8.9. Root Causes

This section examines the root causes of the gaps identified in Sections 8.4–8.8. In total, 11 root causes have been identified as foundational barriers within the automotive industry. The analysis provides a basis for identifying the organisational and operational factors that must be addressed to realise the vision pillars defined in Section 8.1.2. Figure 8.2 summarises the root causes and their relationship to the identified gaps.

Figure 8.2. Root Causes and Associated Gaps

No	Section	Root Causes	Attributed Gaps
1	8.9.1	Unclear Vision of Regional Automotive Industry and Market Direction	Lack of Clarity in Market Growth, Powertrain Transition, and Fuel Transition Timelines
2	8.9.2	Insufficient Support for Fuel and xEV Material Manufacturing	Lack of Accessibility to Fuel and Materials
3	8.9.3	Unfocused Vehicle Registration and Inspection Regulation to Optimise UIO Replacement	Lack of Vehicle Units with Vehicle Connectivity
4	8.9.4	Insufficient Infrastructure for Carbon Neutral Activities of Manufacturing	Low Economic Rationality for Decarbonisation Activities by SME
5	8.9.5	Limited Experience and Know-How Within the Region	Lack of Human Resources and Know-How to Lead Decarbonisation Activities
			Lack of Human Resources and Know-How to Lead Manufacturing Activities
6	8.9.6	Limited Regional Alignment on Scraping, Disposal, and Tracing for Resource Circulation	Lack of Effective Vehicle Inspection System for Recycle and Scrap
7	8.9.7	Insufficient Support for Regional Semiconductor Manufacturing	Inadequate Semiconductor Supply Within the Region
8	8.9.8	Lack of Regional Direction and Infrastructure for Optimised Supply Chain and Information Sharing	Lack of a Synchronised Efforts as a Region to Align with Global Trends
			Lack of Digital Infrastructure for Traceability and Circulation
9	8.9.9	Conventional Regulations Prevent New Mobility Business Models	Lack of Options for Vehicle Purchase and Usage
10	8.9.10	Unfocused Vehicle Registration and Inspection Regulation to Optimise UIO Condition	Lack of Enforcement for Vehicle Maintenance as a UIO Requirement
11	8.9.11	Unattractive and Regionally Unharmonised Open Innovative Investment Environment	Insufficient Human Resources in Research and Development
			Insufficient Support for Innovative Investment for New Mobility Services
			Insufficient Market Scalability by Country

Source: Authors (2025).

No.	Section	Root Causes	Associated Gaps
1	8.9.1	Unclear regional vision of the automotive industry and market direction	Lack of clarity in market growth, powertrain transition, and fuel transition timelines
2	8.9.2	Insufficient support for fuel and electrified vehicle material manufacturing	Limited access to fuel and critical materials
3	8.9.3	Unfocused vehicle registration and inspection regulations to optimise replacement of units in operation (UIO)	Limited penetration of vehicle connectivity
4	8.9.4	Insufficient infrastructure for carbon-neutral manufacturing	Low economic rationality for decarbonisation activities amongst small and medium-sized enterprises
5	8.9.5	Limited regional experience and technical know-how	Limited human resources and expertise to lead decarbonisation activities and advanced manufacturing activities
6	8.9.6	Limited regional alignment on scrapping, disposal, and traceability for resource circulation	Lack of an effective vehicle inspection system for recycling and scrappage
7	8.9.7	Insufficient support for regional semiconductor manufacturing	Inadequate semiconductor supply within the region
8	8.9.8	Lack of regional direction and infrastructure for supply chain coordination and information	• Lack of synchronised regional efforts to align with global trends

		sharing	• Lack of digital infrastructure for traceability and circulation
9	8.9.9	Conventional regulations preventing new mobility business models	Limited options for vehicle purchase and usage
10	8.9.10	Unfocused vehicle registration and inspection regulations to optimise UIO condition	Lack of enforcement for vehicle maintenance as a UIO requirement
11	8.9.11	Unattractive and regionally unharmonised environment for open innovation investment	• Insufficient human resources in research and development • Insufficient support for innovative investment in new mobility services • Insufficient market scalability across countries

Source: Authors (2025).

8.9.1. Unclear Vision for the Regional Automotive Industry and Market

8.9.1.1. Lack of Clarity on Market Growth, Powertrain Shifts, and Fuel Transition Timelines

The long-term direction of ASEAN's automotive industry remains clouded by uncertainty across several foundational dimensions: market growth, powertrain strategies, and fuel road map standards. This lack of clarity stems from the absence of a clear, unified vision for the regional automotive industry and its future trajectory. As a systemic issue, it continues to hinder policy coordination and long-term planning. As a result, investor confidence weakens, business planning horizons shorten, and the localisation of next-generation automotive technologies and manufacturing systems slows.

Figure 3.29 from the survey illustrates this challenge. Most respondents identified uncertainty over the powertrain transition, together with policy ambiguity, as a key barrier to planning future investment. This finding points to the absence of an overarching regional direction, leaving governments and market players without a shared reference point for navigating the transition.

Despite ASEAN's large consumer base and established manufacturing footprint, the region's overall automotive demand shows signs of volatility and plateauing (Chapter 5). Vehicle sales grew only 4.4% from 2021 to 2024 and are projected to rise just 3.6% through 2035. At the same time, the transition to new powertrains lacks clarity. Whilst ASEAN countries have set electrification targets, adoption remains modest. xEVs make up just 7% of new car sales today and are expected to reach only 16% by 2035, still well behind global peers.

Diverging national policies on powertrain shifts and fuel phase-outs create further uncertainty (Section 8.5.2.1). Investors face mixed signals across the region, with ICEV phase-out timelines, emission standards, and incentive schemes moving at different

paces. These inconsistencies include varying adoption timelines for Euro emission standards[7] and implementation of fuel blending mandates[8] across member states, with no clear path towards regional standardisation.

These uncertainties regarding market potential, powertrain mix, and fuel transition timelines are not isolated issues. Instead, they reflect deeper structural challenges arising from the lack of a shared regional vision and coordinated industry guidance. To accelerate the industry's transformation, ASEAN must articulate a clearer regional direction and provide consistent policy signals on market outlook, transition timelines, and broader industry strategies.

8.9.2. Insufficient Support for Fuel and xEV Material Manufacturing

8.9.2.1. Lack of Accessibility to Fuel and Materials

ASEAN's dual-track strategy – to advance biofuel-based ICEV and HEV exports and a regional xEV industry – is hindered by limited access to critical fuels and materials (Section 8.6.2.2). Across both pillars, supply chains remain fragile, cost intensive, and overly reliant on concentrated sources. This persistent lack of accessibility is rooted in insufficient support mechanisms and limited policy attention directed towards the upstream development of fuel and xEV material manufacturing across the region.

Figure 3.38 from the survey shows that most respondents identified material costs and procurement channels as the most important factors affecting efficiency. These concerns extend beyond cost issues and reflect the broader absence of industrial policies that support robust upstream capacity. Without stronger regional investment and coordination focused on upstream development, material costs continue to rise whilst supply options remain narrow.

Biofuel feedstock supply constraints have already driven up production costs. ASEAN countries continue to grapple with the challenges related to biofuel feedstock availability (Zafira et al., 2024). Stagnant yields of first-generation feedstock, such as palm oil in Malaysia and Indonesia and cassava and molasses in Thailand, have not kept pace with expanding biofuel mandates. Second-generation feedstocks remain underutilised, as the region still relies heavily on first-generation sources that compete directly with food production. As a result, initiatives that rely heavily on crop-based biofuels have shown limited long-term viability (Goh and Lee, 2011). Volatile yields, rising input costs, and infrastructure constraints have created uncertainty for producers and restricted the scalability of biodiesel and ethanol across the region.

In the electrification space, ASEAN faces growing dependencies on a narrow set of upstream sources and external suppliers. Whilst the region has local reserves of critical

[7] Singapore has enforced Euro 6 since 2017. Malaysia is not expected to complete its Euro 5 petrol rollout until 2027, whilst Indonesia remains on Euro 4 with no confirmed upgrade timeline.
[8] Malaysia's B30 mandate for heavy trucks is fixed for 2030, whilst Indonesia's planned B40 launch, originally targeted for January 2025, has since been deferred.

minerals, refining and processing capacity is still developing, and many essential inputs, such as battery chemicals and components, remain heavily reliant on imports from countries such as China. This dependence reflects the broader lack of regional support for developing vertically integrated supply chains.

With limited upstream capability, ASEAN remains exposed to global price fluctuations, policy shifts, and logistical disruptions. Foreign direct investment in battery cell plant factories remains limited, further constraining the region's access to battery production capacity needed to support future BEV demand.[9]

8.9.3. Unfocused Vehicle Registration and Inspection to Optimise UIO Replacement

8.9.3.1. Lack of Units with Limited Vehicle Connectivity

One constraint to optimising vehicle registration and inspection systems is the limited penetration of connectivity-enabled vehicles (Section 8.4.2.1). Without a sufficient base of connected vehicles on the road, implementing intelligent or data-driven UIO monitoring systems becomes more difficult. These systems could track real-world usage patterns, support predictive maintenance, or flag when a vehicle is due for replacement or upgrade. This issue stems from a regulatory starting point in which vehicle registration and inspection regulations are loosely defined and inconsistently enforced. As a result, the existing framework does not sufficiently prioritise or incentivise the integration of connectivity functions as a tool for informing timely vehicle replacement or retirement. Adoption has been slow due to structural market conditions.

Whilst OEMs have introduced selected connectivity platforms in the region (e.g. Toyota's T-Connect, Hyundai's BlueLink), these deployments remain fragmented and often confined to a few markets. Most passenger vehicles still lack built-in telematics capable of sharing diagnostic, mileage, or life-cycle information with authorities or service networks. Even where commercial fleets have adopted connectivity solutions, these systems are primarily used for internal operational needs and do not feed into a broader regulatory or circularity framework. This underscores how current regulatory structures do not yet position connectivity as an enabling tool for life-cycle–based inspection or replacement policies.

The lack of connected units is compounded by underlying market realities of price-sensitive ASEAN consumers (JATO Dynamics, 2025), where embedded connectivity is often perceived as a premium feature. The added cost deters OEMs and buyers, slowing adoption and limiting the overall penetration of connected vehicles across the region.

Cost sensitivity and slower replacement pace limit the region's readiness to adopt data-driven vehicle renewal strategies, as seen in more advanced markets (Section 8.3.1.1.1). Low vehicle connectivity means that registration and inspection regimes operate with

[9] The Hyundai-LG 10 GWh cell plant in West Java could only support production of only about 120,000 mid-size BEVs per year, well below the level ASEAN is expected to need by 2030 based on IEA projections.

limited visibility into actual vehicle use. Without a sufficient base of connected vehicles, shifting towards dynamic inspection and replacement policies becomes more difficult, weakening efforts to manage UIO replacement through life-cycle–based decision-making.

Current efforts to expand vehicle connectivity in ASEAN should continue and scale further. Addressing the root cause through more targeted regulation would help establish a clearer link between digital vehicle functions and public oversight. This would enable more data-driven vehicle registration and inspection systems, ultimately supporting a more resource-optimised automotive ecosystem.

8.9.4. Insufficient Infrastructure for Carbon-neutral Manufacturing

8.9.4.1. Low Economic Rationality for Decarbonisation Activities by SMEs

For many ASEAN automotive SMEs, decarbonisation efforts do not yet present a clear business case (Section 8.7.1.2.1). Most SMEs are unlikely to act unless carbon-reduction activities are directly tied to cost savings, regulatory compliance, or short-term business growth. Wider sustainability goals often fall outside their operational priorities, especially in the absence of clear mandates or sector-specific guidance. This situation reflects a perceived lack of economic rationale for decarbonisation activities, where the benefits do not appear to outweigh the costs or risks from the SME perspective.

The lack of decarbonisation amongst ASEAN automotive SMEs stems in part from insufficient infrastructure to support carbon-neutral manufacturing. The wider SME base lacks access to a standardised framework and consistent policy direction that could encourage or incentivise decarbonisation efforts. In financial markets, green financing instruments remain a critical barrier. Whilst sustainability-linked loans and digital carbon tools are emerging, they are not yet widespread or easily accessible to SMEs. This finding aligns with Figure 3.48 of the survey, which shows that 40% of respondents identified a lack of funds to invest in low-carbon production facilities as a barrier to decarbonising their supply chains. Without accessible finance, tailored support mechanisms, or regulatory clarity, SMEs are left without the ecosystem needed to shift towards greener operations.

Another key challenge faced by SMEs is the complexity of the application process. According to Mertier Solutions (2024), securing green loans or grants often requires detailed project proposals, including assessments of environmental impact and financial viability. Some green finance programmes impose stringent requirements regarding firm size, sector, or eligibility criteria, which may exclude many SMEs from accessing these funds.

This absence of enabling infrastructure – financial, regulatory, and institutional – leaves most SMEs unable to justify investments in decarbonisation. Without intervention to lower costs, reduce risk, and build capacity, SME participation will remain limited, weakening the foundation for an inclusive and scalable transition to carbon-neutral manufacturing in ASEAN.

8.9.5. Limited Experience and Know-how Within the Region

8.9.5.1. Lack of Human Resources and Know-how to Lead Decarbonisation Activities

Most ASEAN automotive players lack the in-house capability to lead or manage decarbonisation efforts (Section 8.7.1.2.2). Key roles such as carbon accounting; LCA; and monitoring, reporting, and verification (MRV) are typically outsourced, and most employees still require intensive technical handholding. This capability gap reflects not only dependence on external expertise but also a broader shortage of skilled personnel in upstream decarbonisation activities across technical and operational functions. The skills shortage spans multiple areas, including fuel and bioenergy value chains, midstream mineral processing, industrial park operations, and digital carbon data management.

Figure 3.50 of the survey aligns with regional workforce data, showing that this skills deficit is linked to foundational weaknesses in the region's talent pipeline. Over 60% of ASEAN youth aged 10–24 receive no formal digital skills training (Nazara, 2024), suggesting the talent pipeline is not yet equipped to meet future industrial needs. WEF (2024) found that only 49% of ASEAN suppliers had in-house LCA expertise, with lack of expertise ranked as the leading challenge to decarbonisation, ahead of policy or technology constraints.

These challenges reflect a structural issue in the region, where a fundamental shortage of skilled human resources and technical know-how persists. Where skills are available, they are concentrated amongst a small pool of consultants and engineers in multinational firms. Local contractors and suppliers often lack the in-house expertise to install, operate, or maintain energy and carbon management systems. Digital capability for MRV reporting is especially scarce. As leading OEMs increasingly require carbon footprint data in standardised formats such as Catena-X, many Tier 2 and Tier 3 suppliers are unable to comply due to limited familiarity with these protocols.

Efforts to expand this talent base are at an early stage. No region-wide certification track exists, OEM-backed academy networks are limited, and public–private coordination to scale training programmes across priority decarbonisation domains is still developing. Strengthening ASEAN's decarbonisation efforts will therefore require more targeted action to expand education and upskilling initiatives and to build a stronger, more capable workforce across the automotive supply chain.

8.9.5.2. Lack of Human Resources and Know-how to Lead Manufacturing

It can be inferred that the shortage of skilled personnel in ASEAN's automotive manufacturing sector stems from deep-rooted structural issues in workforce development systems (Section 8.5.2.2.2).

First, technical training programmes have not kept pace with the rise of automation, digitalisation, and smart factory operations, resulting in a shortage of workers capable of adopting advanced manufacturing practices. Curricula often remain theoretical, with limited focus on the hands-on technical competencies required to operate and maintain

Industry 4.0 systems such as autonomous robotics, connected data platforms, and advanced process controls. This gap between training and real-world skills clearly reflects the region's limited experience and know-how in advanced manufacturing.

The shortage of digital skills compounds this issue. Many firms face difficulty retaining and developing technology talent across the region, limiting the pool of workers able to support digital transformation on the ground. As a result, the digital skills shortage creates a persistent mismatch between graduate capabilities and industry needs.

Second, Figure 3.46 of the survey indicates that many management personnel do not fully recognise the need to invest resources in training. As a result, these foundational gaps in technical readiness prevent companies from effectively adopting advanced technologies and discourage further investment in production upgrades. Without targeted reforms in education systems and enterprise talent development, the region's ability to lead next-generation manufacturing will remain constrained.

These challenges stem from a root cause: limited regional experience in advanced manufacturing environments, which weakens both the supply of skilled workers and the demand for workforce development. With targeted reforms in education systems and enterprise talent development, ASEAN can strengthen its ability to advance next-generation manufacturing capabilities.

8.9.6. Limited Regional Alignment on Vehicle Scrappage, Disposal, and Material Traceability

8.9.6.1. Lack of Efiective Vehicle Inspection Systems for Recycling and Scrappage

ASEAN is constrained by the lack of a robust vehicle inspection regime for its ELVs (Section 8.5.3.2.1). This challenge stems from a combination of public resistance, fragmented enforcement, and limited systems designed with circular-economy goals in mind. Where programmes do exist, they are often standalone and not connected with other countries' initiatives. As a result, tracing efforts remain disconnected from national databases and yield no actionable data on carbon emissions or material recovery potential.

The lack of inspection systems for recycling and scrappage highlights a systemic absence of regional coordination on scrappage, disposal, and material traceability frameworks. Without a shared regulatory foundation, ASEAN governments lack both the information and the institutional levers to regulate vehicle decommissioning or to support the emergence of an industrialised dismantling and recycling sector. In the absence of such frameworks, most old vehicles are either resold in second-hand markets or dismantled informally in unregulated yards, leading to environmental degradation and significant under-recovery of usable materials.

This fragmented approach not only limits progress towards circular-economy goals but also risks leaving ASEAN behind global standards. Without a verified inspection record or scrappage certificate, used vehicles cannot be tied to verified carbon footprints or integrated into digital material passports. For decarbonisation efforts, the disconnect will

pose compliance risks under emerging global regulations such as the EU's Sustainable Battery and CABM. From a supply-chain perspective, a non-aligned inspection regime disrupts the development of traceable, circular, and resource-efficient material flows.

8.9.7. Insufficient Support for Regional Semiconductor Manufacturing

8.9.7.1 Inadequate Semiconductor Supply Within the Region

ASEAN has a strong presence in global semiconductor exports, but this has not translated into sufficient domestic availability, particularly for the automotive industry. The gap is largely caused by insufficient government support to build a regionally balanced and resilient semiconductor ecosystem that serves both domestic and export-oriented needs (Sections 8.5.1.2.2 and 8.5.1.2.3).

Whilst ASEAN countries have introduced policies to attract foreign direct investment and develop talent, these efforts are largely geared towards promoting export competitiveness rather than strengthening domestic supply chains. As a result, domestic supply chains remain underdeveloped and poorly integrated with national industrial needs. Much of ASEAN's semiconductor activity remains concentrated in testing, packaging, and assembly, which are lower-value-added segments and offer limited strategic control over supply. By comparison, advanced economies lead in upstream design, R&D, and advanced manufacturing, enabling stronger alignment between semiconductor output and national industrial priorities.

The lack of upstream capacity is compounded by the absence of policy instruments or coordinated incentives to direct semiconductor output towards regional industrial use. OEMs in ASEAN remain reliant on imports and exposed to global supply shocks. No mechanisms are in place to prioritise allocation for critical sectors such as automotive manufacturing.[10] Therefore, even if overall regional production increases, the mismatch between supply and demand is likely to persist without targeted government action.

Resolving this root cause requires a strategic shift from an export-oriented approach towards policies that build local supply resilience, support upstream capabilities, and ensure semiconductor access for high-priority domestic sectors. With appropriate interventions, ASEAN will be better positioned to realise its ambition of becoming a next-generation automotive manufacturing hub.

8.9.8. Lack of Regional Direction and Infrastructure for Information Sharing on Traceability and Circular Supply Chains

8.9.8.1. Lack of Synchronised Regional Efiorts to Align with Global Trends

ASEAN's fragmented efforts to develop traceability systems and circular material use reflect a deeper lack of regional direction. Whilst some countries, such as Singapore, have

[10] Consumer electronics offer higher margins for semiconductor suppliers, causing them to favour these segments over the automotive sector (Section 8.5.1.1.3).

advanced policies for ELV management and material tracing, others remain in pilot or planning phases. This uneven progress reflects the absence of a shared regional strategy or institutional mechanism to guide AMSs towards common standards and implementation timelines. Without such alignment, national policies continue to evolve in silos, resulting in inconsistencies in how materials are traced and circulated across the region.

Developed economies recycle over 90% of materials from ELVs through strict regulatory enforcement, whilst most ASEAN countries continue to operate informal or loosely regulated recycling systems, often without adequate environmental and safety oversight (Section 8.5.3.2.1). These discrepancies highlight the need for region-wide standards and coordinated enforcement to achieve consistent material recovery outcomes.

This fragmentation is not confined to material circulation systems but signals a broader challenge in ASEAN's regional coordination mechanisms (Section 8.5.4.2.2). For instance, ASEAN-wide platforms such as the ASW remain underused due to inconsistent rules, varying national priorities, and limited political commitment to harmonised standards. This situation illustrates the region's difficulty in forming a cohesive response to global supply-chain shifts, leaving ASEAN fragmented and less competitive compared with more unified blocs such as the EU.

With a cohesive and forward-looking regional approach, ASEAN could stay ahead of global trends in circular manufacturing, digital traceability, and responsible sourcing. It could strengthen its competitiveness and reinforce its ambition to build a sustainable and strategically self-reliant automotive manufacturing base.

8.9.8.2. Lack of Digital Infrastructure for Traceability and Circulation

The underdevelopment of traceability and circulation systems stems from the absence of coordinated digital infrastructure grounded by shared regional direction and standards. Although isolated enterprise or national initiatives exist, such as AREX in Malaysia, Pryor Marking in Thailand, and material tracking by Nippon Steel Pipe Thailand, these remain siloed within company or country boundaries and are not designed to operate across borders. ASEAN lacks an overarching infrastructure to connect these efforts and enable seamless, multi-country visibility of material flows (Section 8.5.3.2.2). Consequently, this fragmentation limits the region's ability to achieve full end-to-end traceability across the automotive supply chain.

Even amongst leading OEM deployments, Toyota Motor Manufacturing Indonesia's use of blockchain and IoT for vehicle monitoring (Section 8.5.4.2.1) remains proprietary and limited to the Indonesian entity. In the absence of shared platforms and governance mechanisms, no consistent method exists for exchanging traceability, carbon, or production data across countries or firms. This gap in interoperability continues to prevent the development of regional systems capable of supporting cross-border transparency in material flows.

This issue is particularly stark when benchmarked against global leaders. Japan's Ouranos and the EU's Catena-X platforms have emerged as foundational digital ecosystems for material traceability within their automotive sectors. These systems enable real-time tracing of materials, emissions, and compliance across supply chains, whilst also supporting the reuse and reintegration of recovered materials into domestic production, helping reduce reliance on imports and virgin extraction.

To date, ASEAN lacks a comparable platform. No equivalent digital backbone exists in the form of unified data infrastructure, common standards, or regionally agreed frameworks that can support traceability and material circulation at scale. This shortcoming reflects not merely a technical gap but also a broader lack of coordination and commitment to build shared digital systems for a connected and circular automotive supply chain.

The lack of regional digital infrastructure remains a key barrier, not just in digital infrastructure availability but also in the absence of a common framework to connect initiatives. With stronger coordination, ASEAN can begin laying the digital foundations needed to support more connected traceability systems and unlock regional opportunities for circular manufacturing.

8.9.9. Conventional Regulations Limiting New Mobility Business Models

8.9.9.1. Lack of Options for Vehicle Purchase and Usage

ASEAN's vehicle regulations have historically been shaped around traditional ownership models, which have limited the development of alternative modes of vehicle access such as subscriptions, car sharing, or peer-to-peer rentals. These emerging options remain rare or receive limited support (Section 8.8.2.2). Car subscription services, such as Toyota Kinto, are available in only a few markets and have seen limited uptake. Car sharing is confined to a handful of urban centres and accounts for only a small share of travel. Even widely used ride-hailing services have not evolved into fully integrated MaaS ecosystems capable of replacing private car ownership.

The limited diversification of mobility options is closely tied to ASEAN's regulatory landscape, which remains rooted in conventional vehicle ownership models and has yet to evolve in step with new mobility business models. Despite the rise of app-based mobility services in Southeast Asia in recent years, most countries have yet to establish sector-specific regulatory frameworks (International Transport Forum, 2023). As a result, the lack of targeted regulation restricts market experimentation, discourages innovation, and leaves consumers without access to more flexible, low-emission mobility options.

Because regulatory structures remain static and misaligned with the pace of innovation, consumers still face a narrow set of choices: purchasing and owning a vehicle or relying on public transport and ad hoc ride-hailing. This situation suggests that regulatory frameworks have not evolved to support new mobility business models. As a result, most consumers continue to rely on private vehicle ownership, which reduces asset use and slows progress towards more efficient, low-emission transport systems. Without

regulatory updates that enable new business models, ASEAN is likely to fall short of benchmarks set by advanced economies, such as the OECD's shared autonomous transport scenarios, which could meet 10% or more of total travel demand.

According to the International Transport Forum (2023), AMSs broadly agree that app-based mobility services improve consumer welfare by offering more convenient options than traditional services. However, without a clearer national vision and supportive regulation, these services remain too fragmented or underdeveloped to provide a viable alternative to conventional vehicle purchase and ownership.

Ultimately, ASEAN needs a more formalised and responsive public sector approach. According to Ho and Tirachini (2024), this includes regulating shared mobility platforms, formalising the work of drivers, and establishing pricing and subsidy mechanisms that reflect the broader social costs of motorised traffic. These actions are essential to improving the uptake for future MaaS systems and expanding vehicle use options beyond private ownership for consumers. Strengthening the enabling environment for alternative mobility choices will be key to realising the environmental and economic benefits of servitisation.

8.9.10. Weak Vehicle Registration and Inspection Systems to Optimise the Condition of Units in Operation

8.9.10.1. Lack of Enforcement of Vehicle Maintenance Requirements for Units in Operation

A core reason ASEAN has been unable to optimise its vehicle replacement cycle lies in the absence of effective enforcement mechanisms to ensure regular vehicle maintenance throughout a vehicle's lifespan (Section 8.8.2.2). Apart from Singapore, ASEAN countries do not mandate vehicle maintenance standards for private vehicles. Even when AMSs set inspection standards for new vehicles, follow-up checks to ensure that those vehicles remain roadworthy over time are often lacking. Consequently, vehicle safety, efficiency, and emission performance degrade without regulatory intervention.

In most AMSs, private vehicles are not required to undergo regular inspections. Vehicles require inspection only at the time of registration or change of ownership, or none at all after the initial sale. In some cases, emission testing may be expected, but these requirements are either voluntary or weakly enforced. As a result, vehicles can operate for decades without being checked for safety or environmental performance.

It can be inferred that this issue stems from registration and inspection regulations that do not sufficiently enforce or account for the ongoing condition of vehicles throughout their use. Because regulation treats vehicle approval as a one-time administrative process rather than a life-cycle obligation, many ageing and poorly maintained vehicles remain on the road long after they should have been upgraded or retired. This observation suggests that vehicle regulation in many ASEAN countries is still treated as a one-time administrative step rather than an ongoing responsibility throughout a vehicle's life cycle. Inspection and renewal policies lack the formal mechanisms needed to proactively

manage the condition of UIO, limiting efforts to prolong vehicle lifespans where viable or remove high-risk units on time.

To support broader goals related to decarbonisation and circularity, enforcement of in-use maintenance requirements should be strengthened. This includes formalising regular inspections as a basic condition for maintaining registration and ensuring that vehicles remain roadworthy.

8.9.11. Unattractive and Regionally Unharmonised Investment Environment for Open Innovation

8.9.11.1 Insuij cient Human Resources in R&D

A key barrier to ASEAN's advancement in new mobility services is the limited availability of specialised talent to support R&D and innovation. Whilst the development of smart mobility platforms, connected vehicle systems, and data-driven services requires a strong base of engineers, data scientists, and digital automotive specialists, workforce capacity across the region remains insufficient.

This gap stems from historically low national investment in R&D, often below 1% of GDP, compared with 2%–3% in advanced economies (Section 8.8.2.1). The issue reflects a broader regional pattern in which limited coordination and an unharmonised innovation environment between AMSs constrain the flow of investment into future-facing sectors. The absence of shared platforms for mobility-related innovation restricts collaboration and cross-border talent development. These include academic programmes, training pipelines, and industry–university research partnerships tailored to new mobility technologies. As a result, critical skills such as EV engineering, automotive software development, and telematics remain underdeveloped. For example, a 2023 ILO study in Thailand identified major shortages in advanced automotive skills, underscoring a wider regional challenge (Rapid Asia, 2023).

Such an underinvestment environment not only limits funding but also weakens the talent pipeline needed for innovation. A lack of skilled human resources constrains the region's ability to create and scale local innovations. Many ASEAN firms remain dependent on imported platforms or conduct only small-scale pilot projects, leaving them unable to compete with countries such as China that invest heavily in automotive IT and AI. To build stronger human capital for mobility innovation, ASEAN could expand partnerships with universities, the private sector, and international institutions to strengthen R&D capabilities and develop a more skilled talent base.

8.9.11.2. Insuij cient Support for Innovative Investment in New Mobility Services

Another key challenge is the limited development of open innovation ecosystems to support new mobility services (Section 8.8.2.1). Servitisation requires collaborative platforms where automakers, start-ups, telecommunication companies, and public agencies can co-develop and test new service models. However, this level of innovation

has been difficult to achieve across most of ASEAN. From another perspective, the challenge reflects the absence of a conducive regional environment that encourages innovative investment and cross-sector collaboration.

The limited development of open innovation ecosystems stems from a profound root cause: an unattractive and regionally unharmonised innovation environment. Across much of the region, dedicated funding, incubation schemes, and regulatory sandboxes to promote the development and scaling of new mobility solutions remain limited. Apart from Singapore, few countries have government-backed programmes that specifically target mobility innovation.

Disharmony is also evident in ASEAN's data sharing for mobility-related information, which is limited by fragmented and protective regulatory environments and has not been widely adopted (International Transport Forum, 2023). For example, the same publication reported that Indonesia faced major challenges in data gathering, with mobility service providers not reporting data on basic operational indicators. Without even the most basic data, it is difficult to determine how many drivers and delivery personnel provide app-based services or to assess whether supply is sufficient to meet travel demand.

The International Transport Forum (2023) highlights challenges in Myanmar, where app-based mobility services still face hurdles because they are regulated by different ministries, with no single national regulatory body overseeing the sector. This case illustrates how, even within a single country, the mobility environment is not yet aligned, creating uncertainty that discourages the formal development of a healthy, open innovation ecosystem.

The conditions reflect an innovation environment that remains fragmented and underdeveloped, making it difficult to attract the cross-border investment and experimentation required to scale new mobility services across ASEAN. As a result, mobility start-ups and service innovators operate in an uncertain environment where unclear rules and limited support make regional expansion difficult. A company developing a platform in one country cannot easily scale it regionally or access the data needed to refine its service. Promising innovations are often delayed or diverted to more supportive ecosystems outside the region. Tackling these regulatory and institutional limitations will be essential for ASEAN to foster a more supportive environment for mobility innovation.

8.9.11.2. Limited Market Scalability Across Countries

Digital mobility innovation in ASEAN remains limited in scale compared with the global market (Section 8.8.2.1). With an estimated revenue of US$69.6 billion (Statista, 2025e), ASEAN's share of the shared mobility market accounts for only 4.5% of global revenue, which totals US$1.6 trillion (Statista, 2025f). The limited market scale points to a deeper structural issue: ASEAN remains an unattractive and unharmonised environment for innovation to scale.

Despite the region hosting super-app giants such as Grab and GoJek that operate across

multiple AMSs, these platforms remain constrained by country regulations, technical standards, and data protocols. Each national market operates largely as a silo, limiting firms' ability to scale operations across borders. The lack of regional coherence reflects the absence of a unified innovation and investment framework across the region. Without alignment on key enablers such as standards, payment systems, and cross-border service rules, firms cannot deliver seamless user experiences or achieve the level of scalability required for servitised mobility models.

A common example of this fragmentation is the lack of interoperability in digital payment systems for mobility services. For instance, Indonesian users cannot directly use their OVO balance for Grab rides or services in Singapore, where Grab operates GrabPay as a separate e-wallet and payment system. Such fragmentation prevents firms from capturing the scale efficiencies and network effects needed to sustain and expand MaaS models.

Regulatory and operational siloing reinforces a cycle where services stay small, preventing the region from building integrated platforms capable of competing globally. The situation weakens the case for private investment and slows the emergence of globally competitive, regionally integrated platforms. Without clear pathways for cross-border expansion, many promising solutions remain confined to pilot projects or niche user bases. Resolving this challenge will require ASEAN to move towards harmonised digital standards and regulatory frameworks that support the seamless expansion of mobility services across borders.

8.10. Policy Recommendations

This chapter translates the gap and root cause analysis into action. Using a four-layer policy stack – strategy and policy, schemes and regulations, resources, and operations and infrastructure – it identifies the levers ASEAN must pull to turn today's BAU trajectory towards a low-carbon, digitally enabled, service-oriented automotive ecosystem.

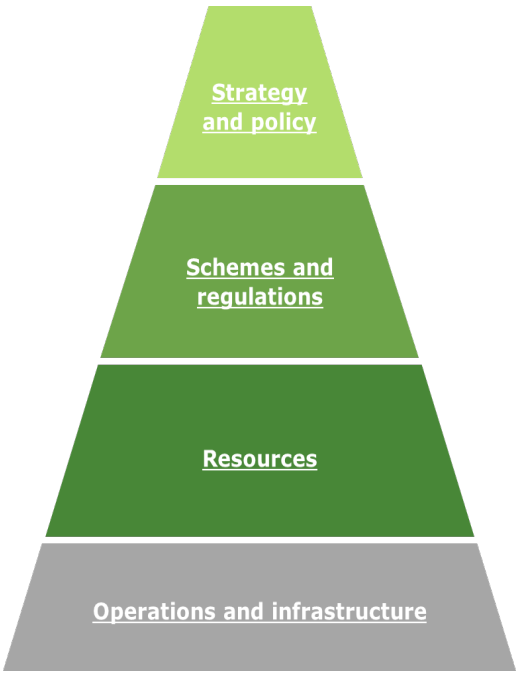
8.10.1. Policy Recommendation Framework

The analysis laid bare a consistent pattern: ASEAN's automotive system is rich in aspiration yet riddled with structural gaps, ranging from patchwork rules to underpowered investment (Sections 8.4–8.9). Without intervention, these gaps risk locking the region into a BAU trajectory that fails to achieve any of the three strategic goals:

1) a low-emission ICEV and HEV export engine that keeps ASEAN relevant to growth markets in Africa, South Asia, and the Middle East;
2) an indispensable node in the global xEV supply chain, supplying critical materials, components, and recycled metals; and
3) a vibrant mobility service marketplace that turns connected, shared, or even autonomous vehicles into new profit pools.

The gap diagnostics reveal that each obstacle ultimately reflects a policy failure: either the vision is unclear, rules are inconsistent, resources are thin, or enabling infrastructure is missing. ASEAN's masterplan adopts a four-layer intervention stack that sequences action from the overarching strategy to physical infrastructure (Figure 8.3).

Figure 8.3. Four-layer Intervention Stack Policy Development Framework



Layer 1. Strategy and policy establish an investable compass: for example, a regional commitment to varied-pathway growth (ICEV and xEV).

Layer 2. Schemes and regulations translate vision into enforceable standards and fiscal signals.

Layer 3. Resources cover finance, skills, and data, including blended finance windows, mobility innovation funds, human-capital pipelines, and shared data trusts.

Layer 4. Operations and infrastructure deliver the hard and soft assets: green industrial parks, battery-recycling facilities, fast-charge corridors, and Catena-X-compatible ledgers.

Source: Authors (2025).

8.10.2. Policy Recommendation Overview

This section links diagnosis to prescription. It explains how the 11 root causes identified in Section 8.9 are mitigated by the 15 headline interventions that populate the four-layer policy stack. In doing so, it provides the overview, guided by the high-level framework (Section 8.10.1), of the layer-by-layer analysis that follows.

Table 8.1. Policies to Support the ASEAN Automotive Industry in Achieving the To-Be State

	Root Cause	Policy Recommendation
Strategy and policy	• Unclear regional vision for the automotive industry and market direction	• This masterplan
Schemes and regulations	• Unclear regional vision for the automotive industry and market direction	• Promote regional biofuel and e-fuel use and circulation • Support regional digital

	Root Cause	Policy Recommendation
	• Lack of regional alignment on vehicle scrappage, disposal, and material traceability • Weak vehicle registration and inspection systems for units in operation (UIO) • Conventional regulations limiting new mobility business models • Unattractive and regionally unharmonised environment for open innovation investment	transformation (DX) and green transformation (GX) initiatives • Reform vehicle inspection systems • Develop regional recycling and vehicle scrappage regulations • Establish regulatory frameworks for diverse vehicle ownership and use models • Harmonise regional regulations for open innovation investment
Resources	• Insufficient support for fuel and xEV material manufacturing • Limited support for regional semiconductor manufacturing • Lack of regional experience and technical know-how • Insufficient data collection and connectivity	• Provide fiscal incentives for biofuel, e-fuel, and semiconductor manufacturing • Establish programmes to attract and develop DX, GX, and open innovation talent • Promote regional data connectivity and information sharing • Provide fiscal support for innovation investment
Operations and infrastructure	• Insufficient infrastructure for carbon-neutral manufacturing • Insufficient regional infrastructure and systems to optimise supply chains	• Develop green energy industrial parks • Establish material and carbon footprint traceability platforms • Develop regional human capital databases and education systems • Strengthen regional connectivity through the ASEAN Single Window • Reduce tariff and non-tariff barriers

Source: Authors (2025).

Table 8.1 groups each root cause under its governing layer and pairs it with the policy lever best suited to close the gap.

Layer 1. Strategy and policy. The root cause is the absence of a shared, forward-looking vision for ASEAN's automotive future. The cure is development and endorsement of this regional automotive masterplan. Once adopted by AMSs and Japan, the plan crystallises the region's varied-pathway ambition – low-carbon ICEV, HEV, and xEV – and establishes measurable key performance indicators (KPIs). This single act of collective commitment provides the foundation for the layers that follow, giving investors, regulators, and industry a common reference point for long-term planning.

Layer 2. Schemes and regulations. Vision is translated into regulations. Five regulatory gaps must be closed: misaligned scrappage and material traceability rules, an unfocused vehicle inspection regime, fragmented biofuel and e-fuel standards, legacy statutes that box in new mobility business models, and a patchwork of investment and IP norms that discourage open innovation. Six regulatory actions are proposed to resolve these shortcomings: a region-wide biofuel and e-fuel circulation scheme, a harmonised framework for DX and GX standards, an upgraded AVIP 2.0 inspection system, an ASEAN ELV and battery-passport law, flexible ownership codes for MaaS, leasing and autonomous vehicle fleets, and an open innovation framework with clear, cross-border rules. Together, these measures translate the strategic direction of Layer 1 into predictable and enforceable market signals.

Layer 3. Resources. The focus is on finance, skills, and data. Four root causes dominate this layer: weak fiscal incentives for low-carbon fuels and xEV materials, a shortage of inducements for semiconductor manufacturing, an acute deficit of DX and GX talent, and siloed information flows that thwart cross-border optimisation. The policy response is four-pronged. Targeted tax credits and concessional loans mobilise private investment in biofuel and e-fuel refineries and cathode-active-material plants. Complementary IP incentives and capital expenditure allowances can strengthen the attractiveness of ASEAN for semiconductor investment. Talent visa and fellowship pipelines can bring in global expertise whilst developing local capability. Finally, a regional data-trust framework can integrate customs, origin, and carbon-footprint information, creating the data foundation needed for supply-chain traceability.

Layer 4. Operations and infrastructure. Two physical bottlenecks threaten to hinder transformation: the shortage of green, utility-ready industrial land and the absence of a digital spine capable of tracking materials and emissions across borders. Five infrastructure initiatives are proposed to close these gaps: construction of renewable-powered industrial parks, deployment of Catena-X–compatible material- and carbon-traceability platforms, establishment of modular training hubs linked to a regional human-resource database, an upgraded ASW that merges digital customs with logistics APIs, and the selective removal of tariff and non-tariff barriers for low-carbon automotive inputs. Together, these investments turn policy commitments into operational capacity. Plants are built, data flow, goods move, and skilled people find productive work.

Each layer resolves a discrete family of root causes, yet none can succeed in isolation. Layer 1 provides credibility, Layer 2 certainty, Layer 3 capability, and Layer 4 permanence.

Sections 8.10.3–8.10.6 examine these layers in greater detail so that every root cause is mitigated and the to-be vision becomes attainable on schedule.

8.10.3. Layer 1. Strategy and Policy

A robust transformation rarely fails because of a lack of technology; it fails because of the absence of a clear-sighted compass. Across the survey (Chapter 3), the signal is unambiguous: manufacturers, suppliers, and investors hesitate not because they doubt ASEAN's end-market potential but because the region's long-term direction remains unclear. The survey revealed several key findings. More than 70% of firms in five major AMSs report having 'no declared powertrain strategy beyond 2030' and an overlapping majority identify 'policy uncertainty' as the main obstacle to product diversification.

These findings point to a single root cause identified surfaced in Section 8.9: unclear vision of the regional automotive industry and market direction. Layer 1 would remove this ambiguity once and for all.

The masterplan is the instrument of Layer 1. Once endorsed, it will achieve the following:

- Lock in the three strategic endpoints – a low-emission ICEV and HEV export engine, an indispensable xEV supply-chain node, and a region-wide mobility-service marketplace – giving investors a 10-year line of sight on policy intent.
- Institutionalise measurable KPIs, including (i) a regional ICEV-efficiency target indexed to biofuel and e-fuel penetration, (ii) a recycled-content share for batteries and ferrous metals, and (iii) a cross-border data roaming index for mobility platforms
- Mandate a biennial ASEAN–Japan GX and DX council to publish progress scorecards and recommend course corrections, ensuring that the strategy remains a living document rather than a static proclamation.

By turning aspiration into a publicly monitored commitment, the region signals that the wait-and-see era is over. The masterplan therefore becomes the north star reference for capital allocation, similar to the role the EU's 2035 zero-emission mandate played in catalysing EUR170 billion of battery-cell investment within 6 years.

Strategy without alignment remains rhetoric. Layer 1 guides line ministries and regulators in cascading the vision through a varied powertrain pathway. AMSs commit to complementary – not identical – trajectories. Under the masterplan, each AMS aligns with one of four production archetypes based on its current strengths and future potential. The framework is designed to harness the distinctive strengths and unique characteristics of each country, ensuring that every member makes a distinct and valuable contribution. This grouping is dynamic and may evolve over time as supply chains progress.

- Group 1: Leading export hubs safeguard CBU and component exports.
- Group 2: Emerging manufacturing hubs deepen supply chains and reach export scale.
- Group 3: Strategic supporting hubs contribute niche resources and logistics.

- Group 4: Tech and mobility hubs supply the region's digital innovation and servitisation backbone.

To support this structure, policymakers may align industrial strategies with each country's demonstrated strengths. Some members may consolidate leadership in complete vehicle production and export, whilst others develop policy frameworks to capitalise on local metal resources and attract investment in BEV batteries and upstream components. Some economies may prioritise scaling up capabilities in auto electronics and innovative vehicle components, whilst others focus on upgrading production of parts.

Members with limited manufacturing capacity may instead benefit from regional trade facilitation and support services rather than direct vehicle manufacturing. These services enable such economies to benefit from regional integration, create jobs, build human capital, and lay the groundwork for future industrial upgrading without requiring immediate large-scale manufacturing capacity.

Clear national specialisations reduce duplication and establish region-wide comparative advantage. The masterplan introduces a common GHG accounting backbone and a shared data interoperability protocol, forming the basis of the Catena-X–compatible ledger described in Layer 4.

The strategic clarity generated in Layer 1 is not an academic exercise; it is a risk-pricing event. Bond investors can price sovereign guarantees for green industrial park debt, corporations can lock in site decisions for cathode material plants, and mobility start-ups can raise Series B funding against a region-wide sandbox licence rather than nine separate ones. Layer 1 lowers the discount rate applied to ASEAN projects, creating the conditions needed for the blended finance and infrastructure corridors introduced in Layers 3 and 4.

The masterplan embeds an accountability architecture. Each KPI is assigned to a lead AMS ministry, supported by the ASEAN Secretariat's Industry and Energy Division. Annual dashboards are published on an open portal, enabling scrutiny by civil society and capital markets. The reporting cycle responds to the survey finding that 55% of firms identify the lack of review processes as a key constraint on supply-chain efficiency (Figure 3.32).

With the strategic compass established, the report turns to Layer 2 (schemes and regulations) (Section 8.10.4), which outlines the six cross-border rulebooks that translate the regional vision into enforceable standards and fiscal signals. These measures carry weight because Layer 1 has already reduced strategic uncertainty and because the KPIs introduced here will serve as the yardstick against which subsequent policies, budget allocations, and infrastructure investments are assessed.

8.10.4. Layer 2. Schemes and Regulations

Layer 1 establishes the regional vision; Layer 2 gives that vision legal and fiscal force through schemes and regulations. The objective is straightforward: translate the masterplan's varied-pathway commitments into a framework of rules that remove ambiguity for investors, align national actions, and accelerate private sector delivery. Five

root causes (Section 8.9) define the policy agenda, whilst six region-wide regulations provide the response.

Individually, each regulation targets a specific root cause; collectively, they form a coherent operating system for the ASEAN automotive economy. Biofuel and e-fuel standards boost certainty for low-emission ICEVs, inspection reform improves fleet renewal, circularity rules secure feedstock for recycling investments, and innovation statutes unlock the data and capital needed to expand new mobility services. In applying these measures, the masterplan balances regional integration with domestic supply stability, safeguarding local production whilst scaling regional initiatives. By sequencing adoption – standards first, compliance mechanisms next, innovation enablers in parallel – Layer 2 establishes the stable and harmonised rulebook that industry stakeholders have flagged as the most urgent requirement.

8.10.4.1. Regional Biofuel and E-fuel Usage and Circulation Enhancement

The objective of the regional biofuel and e-fuel usage and circulation enhancement scheme is twofold: first, to secure stable demand within ASEAN's export-oriented automotive industry; second, to scale up sustainable production and regional distribution of low-carbon fuels. By strengthening demand certainty and expanding supply, ASEAN automakers will have greater incentive to manufacture ultra-efficient ICEV and HEV models that support the varied-pathway transition. This approach enables ASEAN to remain competitive as a hub for next-generation vehicles and cut transport emissions pragmatically as the EV ecosystem matures.

Enhancing biofuel and e-fuel usage and circulation across ASEAN requires an integrated policy approach that spans the entire value chain, from upstream feedstock collection to midstream fuel verification to downstream cross-border market adoption. Based on the existing policy landscape and current initiatives on biofuel and e-fuel development (Appendix 5), this masterplan recommends three mutually reinforcing regional measures grounded in proven international practices and adapted to ASEAN's unique needs.

1) **Establish region-wide incentives that reward smallholder farms and mills for collecting and delivering feedstock raw materials and agricultural wastes into regional supply pools and production hubs.** The scheme converts low-value agricultural harvest surplus and by-products (such as palm oil mill effluent, cassava waste, and sugarcane molasses) into monetisable commodities, broadening feedstock availability (WIREs Energy and Environment, 2024). This approach draws on the US Biomass Crop Assistance Program, which provides matching payments for the collection, harvest, storage, and transport of eligible feedstock materials to biomass conversion facilities. Payment levels depend on eligibility and the quantity of materials delivered. Eligible materials receive up to US$20 per tonne for 2 years, with payments issued within 24 months (National Sustainable Agriculture Coalition, 2019). Through direct payments, smallholders gain clear financial incentives to collect, sort, and transport feedstock materials. ASEAN could operationalise a

similar mechanism through a unified levy–rebate scheme, whereby a modest levy on fossil fuel consumption or export earnings funds payments to participating smallholders. Pilot hubs could first be launched in high-supply AMSs (Indonesia, Malaysia, and Thailand), and later expand to emerging producers (Philippines and Viet Nam). Over time, this integrated network would encourage the aggregation of feedstock into regional supply pools, lower biofuel production costs, and expand ASEAN's biofuel supply, supporting the shift to low-carbon fuels.

2) Implement a single, region-wide LCA framework and carbon-intensity labelling system to certify biofuel and e-fuel eligibility and eliminate cross-border trade barriers. With standardisation, a fuel certified in one AMS will be recognised across the region. The EU's Renewable Energy Directives (RED I–III) provide a useful reference. These directives apply a common LCA standard under the EU Common Agricultural Policy, ensuring that biofuel and bioethanol feedstocks comply with the strict ESG safeguards of all member states (Official Journal of the European Union, 2023). Because feedstocks in Europe must comply with the Common Agricultural Policy's sustainability and land management standards, certified feedstocks can move more easily across national borders (World Energy Council, 2010). Harmonised biofuel and bioethanol production policies therefore ensure sustainability at the source whilst enabling fluid trade within the region. ASEAN could adopt a similar approach by establishing a regional technical group to define common LCA baselines for various biofuel and e-fuel supply chains. A complementary digital registry could verify carbon-intensity levels and issue tradable low-carbon fuel certificates. Pilot projects with early-adopting refiners would test mutual recognition mechanisms, develop auditing systems, and allow certified biofuels to move freely across ASEAN markets.
3) Enforce a regional blending mandate supported by a flexible credit trading mechanism to secure predictable demand and smooth supply variations. Under this scheme, AMSs would agree to a minimum share of biofuels and e-fuels in their transport fuel mix, with the option to bank, borrow, or trade credits to balance over- or underachievement of blending targets. The mechanism would allow surplus production in more developed biofuel markets (Indonesia, Malaysia, and Thailand) to offset shortfalls in markets with more limited capacity (Cambodia, Lao PDR, and Myanmar). By allowing surplus supply to flow to countries with lower production capacity, the system would reduce biofuel and e-fuel costs and enable less developed markets to participate in the varied-pathway transition without bearing the full cost of domestic blending compliance. Japan offers a useful benchmark. By expanding market access for US corn-based ethanol imports, from 44% in 2018 to 60% in 2021 to 100% in 2025, Japan has diversified supply sources and reduced procurement costs. The policy has supported plans to increase the national blending target to E10 by 2030 and E20 by 2040, whilst imported volumes have risen from 95.5 million gallons to 217 million gallons (Advanced Biofuels USA, 2023; Biofuels International, 2018; Ethanol Producer Magazine, 2025). To build an integrated ASEAN

biofuel and e-fuel market, AMSs could agree on a phased blending road map targeting, for instance, a minimum B10 and E5 share by 2030 and progressively scaling up to B20 and E10 by 2040. A unified regulatory framework for issuing, trading, and banking blending credits would support this system. Such a mechanism would reduce price volatility and ensure supply distribution.

These measures would create a region-wide system that strengthens every link of ASEAN's biofuel and e-fuel supply chain, securing sustainable feedstock upstream, ensuring transparent LCA and carbon accounting midstream, and enabling cross-border trade downstream. As a result, ASEAN would be better positioned to meet stricter global fuel quality and carbon standards, boosting its competitiveness as a hub for next-generation vehicles.

8.10.4.2. Regional Support for DX and GX Actions

Regional support for DX and GX actions aims to establish ASEAN-wide standards and incentives that achieve three objectives: (i) equip automotive OEMs and suppliers with a playbook for adopting Industry 4.0 and green manufacturing practices, (ii) introduce cross-border standards for data management and carbon accounting, and (iii) create factory programmes that make digital and green upgrades bankable.

With clear Industry 4.0 and green manufacturing guidelines, OEMs and suppliers can boost productivity and meet global buyer expectations for low-carbon vehicles. Harmonised standards for data management and carbon accounting would allow firms to comply once and operate seamlessly across multiple markets, reducing compliance costs and accelerating cross-border production. Region-wide programmes that reward the use of advanced and low-carbon technologies could improve access to affordable financing for industrial modernisation. As DX and GX supports the development of innovative next-generation vehicles, ASEAN could strengthen its competitiveness as a global automotive hub of the future.

To realise this ambition, ASEAN must move beyond fragmented national actions and adopt coordinated DX and GX measures. Three policy directions are recommended to help firms meet stricter global market requirements, lower compliance costs, and unlock economies of scale.

1) Develop a factory DX and GX playbook, similar to Malaysia's Industry4WRD and Singapore's Smart Industry Readiness Index, but expanded into a region-wide guide. The playbook would help factories plan, implement, and assess Industry 4.0 and green manufacturing upgrades, including automation, data integration, energy efficiency, and carbon reduction, using standardised checklists and maturity levels. The concept is benchmarked against Japan's Smart City Reference Architecture, which provides a clear guide for cities to adopt digital systems whilst ensuring that APIs and IoT devices connect smoothly. Under this model, initiatives are organised into special zones according to the level of regulatory and financial support needed. This approach has

enabled pilot deployment of advanced DX solutions, such as the Next-Generation Energy and Mobility Creation Special Zone in Toyota City and the Next-Generation Automobile and Smart Energy Special Zone in Saitama City (Cross-ministerial Strategic Innovation Promotion Program, 2020). AMSs could link compliance with this playbook to eligibility for DX and GX incentives as means to unify diverse national strategies into one interoperable system.

2) Establish standardised data management and carbon accounting standards to create a fair ASEAN market for digital and low-carbon automotive supply chains. The policy would define uniform requirements for data management and carbon reporting across all AMSs, drawing lessons from the EU Data Act and the Intelligent Transport Systems (ITS) Directive for DX, and the EU Emissions Trading System (ETS) for GX. The EU Data Act and the ITS Directive build on the General Data Protection Regulation (GPDR) and strengthen Europe's data economy by clarifying usage rights for data generated by connected products and services. The framework maintains strict oversight to prevent misuse. National data coordinators are appointed to (i) help businesses navigate compliance, (ii) resolve disputes through certified settlement bodies, and (iii) cooperate in cross-border cases. These processes are backed by a public registry and enforcement mechanisms that impose penalties system for violations (European Commission, 2025e). The EU ETS relies on the GHG Protocol and enforces a single cap-and-trade market. The system applies robust monitoring, reporting, and penalties to ensure that all member states comply with emission limits (European Commission, 2025e). ASEAN could begin by harmonising national standards with basic global frameworks such as the GPDR for DX and the GHG Protocol for GX, and continue reinforcing these systems with penalties and sector-specific rules as AMS markets progress. MRV passports could be introduced so that once a factory's data management and carbon accounting practices are verified in one AMS, the certification would be recognised in other AMS markets.

3) Launch a fiscal programme that makes DX and GX investments bankable for OEMs and suppliers. The programme would mobilise private capital for digitalisation and decarbonisation projects, supported by a voluntary ETS scheme. Japan's GX League is a leading benchmark. Under this initiative, the government brings together participating companies as GX League members that voluntarily set GHG reduction targets, disclose their results annually, and either earn carbon credits when targets are exceeded or purchase carbon credits when targets are missed (METI, 2025). ASEAN could adopt a similar approach by pooling support from development banks, enabling even lower-income AMSs to participate without straining domestic budgets.

To position ASEAN as a next-generation automotive hub, AMSs must unify their fragmented schemes and regulations into a coordinated regional DX and GX framework. A factory playbook, common data management and carbon accounting rules, and supportive financing mechanisms can enable OEMs and suppliers to adopt digital and low-carbon

technologies. By acting collectively, ASEAN could future-proof the automotive sector and position it as a global leader in digital and sustainable mobility.

8.10.4.3. Revision of Vehicle Inspection System

The objective of revising vehicle inspection regulations is to achieve net-zero emissions targets by reducing CO_2 emissions from vehicles already in use. The regulation should emphasise the effectiveness of vehicle renewal cycles, as older vehicles typically emit higher levels of pollutants due to ageing technologies and declining efficiency. Strengthening inspection and renewal policies could stimulate demand for cleaner ICEVs, HEVs, and various forms of xEVs, thereby accelerating the transition to a low-emission transport sector (see 8.3.4.3, State #1: Vehicle Inspection as Digital Carbon Gatekeeper for the end-state picture).

To strengthen current inspection regulations, ASEAN countries may consider several approaches based on insights gained from successful regulatory initiatives worldwide. Building on existing regional initiatives related to vehicle inspection systems (Appendix 6), two policy directions are recommended to support a harmonised inspection system across the region:

1) Tax adjustment based on vehicle age. Introduce a progressive tax structure that increases with vehicle age, thereby imposing a higher financial burden on older, higher-emitting vehicles. Provide tax incentives or exemptions for new xEVs. This dual approach discourages the prolonged use of ageing ICEVs whilst encouraging fleet renewal and accelerating the transition towards zero-emission mobility. Japan provides a relevant example. The government applies higher tax rates to vehicles that are 13 and 18 years beyond their initial registration (Appendix 7). For privately owned light motor vehicles, the annual tax is set at a flat rate of about JPY10,800 (US$74).[11] Vehicles first registered before April 2015 are subject to a lower rate of JPY7,200 (US$49). However, petrol-powered private cars that exceed 13 years since initial registration face a higher annual tax of JPY12,900 (US$88), reflecting an age-based surcharge designed to encourage replacement with newer, more environmentally efficient models. These higher tax burdens create a financial disincentive for retaining ageing vehicles and support the transition towards cleaner alternatives.
2) Enhancement of OBD capability. For countries that have not yet implemented OBD systems, strengthening OBD capability, particularly OBD-III, would improve vehicle inspection effectiveness. OBD inspections help detect vehicle malfunctions through diagnostic error codes and ensure that safety systems meet regulatory standards. These systems monitor emission-related components, including compliance with carbon monoxide limits. Japan provides a useful reference, having fully implemented OBD testing for new domestic vehicles and planning to extend the requirement to new imported vehicles from October 2025.

[11] Exchange rate based on XE Currency Converter data as of 22 June 2025.

8.10.4.4. Development of Regional Recycling and Scrappage Regulations

The development of regional recycling and scrappage regulations would increase the formal recycling rate of ELV components and secure stable secondary flows of steel, aluminium, and other critical metals needed for the EV battery supply chain. Higher ELV recycling rates would improve the cost-effectiveness of ASEAN's automotive manufacturing by providing access to high-quality secondary materials and reducing reliance on imported inputs. Stable secondary flows of battery metals could slow the depletion of critical minerals, helping position ASEAN's automotive sector to thrive within a circular economy.

Building on the current regulatory landscape for recycling and scrappage policies in ASEAN (Appendix 8), this masterplan proposes four regulations and supporting schemes to strengthen sustainable vehicle life-cycle management. The measures aim to tap into the economic value of circular resource use whilst ensuring that ASEAN remains competitive in increasingly green-conscious export markets. By promoting material traceability and reliable secondary flows, the proposed regulations would support the broader goal of encouraging vehicles that use critical minerals sourced from stable and sustainable supply chains.

1) Establish region-wide recycling standards for ELV components and used EV batteries, with mandated minimum recycling rates. This approach would build on the EU's ELV Directive and Type Approval Directive, which clearly define which materials can be reused, recycled, recovered, or disposed of (European Commission, 2025f; EU Monitor, 2015). The regulations would require new vehicles to meet minimum targets of 85% reuse or recycling and 95% reuse or recovery by vehicle mass (European Commission, 2025f). ASEAN could transition to a similar framework by drafting regional standards and minimum recycling targets for ELV components and EV batteries. The process could be supported by the ASEAN Working Group on Environmentally Sustainable Cities and the ASEAN Working Group on Chemicals and Waste, helping align national automotive and waste-management regulations and targets.
2) Create a digital passport registry for vehicle and EV battery materials to improve traceability and support proper handling across AMSs. A digital passport would store key information on material composition, recyclability, and handling procedures, ensuring interoperability across borders. The concept draws on the EU Battery Passport introduced under the New Batteries Regulation, which applies strict labelling and traceability requirements. Manufacturers must provide verified documentation detailing recycled materials and their sources, Conformité Européenne marking to demonstrate compliance, physical labels on batteries and associated devices, and digital QR codes linking to detailed product information. These requirements inform consumers, operators, and authorities about battery composition, safe use, and end-of-life management (Flash Battery, 2025). ASEAN could begin by expanding existing national vehicle registration databases to capture

data needed for digital vehicle and battery passports, before gradually linking national systems through a regional interoperable platform.

3) Enforce EPR regulations to aggregate ELV and used EV battery-recycling facilities into a single formal scheme. AMSs could collectively enforce EPR regulations requiring OEMs, suppliers, and EV battery manufacturers to organise recycling activities under one formal scheme. Given the limited national budgets of most AMSs, EPR is suitable because it places recycling responsibility on the private sector. JARC is an industry-wide organisation jointly created by automotive industry players. It coordinates the collection and recycling of ELVs from vehicle owners to recycling facilities, outsourcing recycling activities to licensed facilities. OEMs and suppliers typically charge vehicle owners JPY7,000 to JPY18,000 in ELV recycling fees at the time of a new vehicle purchase (JARC, 2018). By embedding EPR schemes into regional ELV and used EV battery-recycling standards, automotive companies would be encouraged to jointly form and/or participate in government networks of authorised recycling centres. Simultaneously, AMSs could support implementation by providing a playbook with clear operational standards, licensing requirements, and oversight mechanisms harmonised regionally.
4) Introduce a vehicle trade-in scheme to incentivise vehicle owners to recycle and scrap their ELVs and used EV batteries. AMSs could introduce a region-wide vehicle trade-in scheme that encourages vehicle owners to properly retire ELVs through recycling and scrappage initiatives. The policy is inspired by China's Vehicle Trade-in Scheme, which provides cash subsidies of up to US$2,730 for replacing a scrapped ELV with an EV and up to US$2,047 for a small-engine ICEV replacement (Rho Motion, 2025). AMSs could tailor the scheme to available budgets, starting with modest tax rebates and scrappage fee discounts.

These four interconnected regulations and schemes – ELV components and used EV battery-recycling standards, material traceability, a formalised collection and recycling system, and incentives to support scrappage – would help ASEAN establish itself as a competitive player in sustainable mobility and resource-efficient manufacturing.

8.10.4.5. Development of Regulation for Various Vehicle Ownership and Usage Options

In the ASEAN context (Appendix 9), vehicle ownership policy frameworks remain underdeveloped in many countries. The policy would aim to support subscription-based services, MaaS platforms, and autonomous fleet operators in optimising asset utilisation and unlocking new revenue streams by reducing regulatory barriers.

Enhancement of MaaS platforms

To optimise fleet utilisation, MaaS platforms represent one of the most effective approaches for development in Southeast Asia. These platforms provide customers with a seamless solution for planning, booking, paying for, and receiving support during and after travel across a wide range of mobility options. For further development, several factors should be considered in an ideal regulatory framework, including collaboration

amongst stakeholders, sustainability that promotes eco-friendly travel options, and data openness and standardisation. Within the MaaS ecosystem, standardised technical specifications are essential to ensure both interoperability and scalability. One prominent example is the Transport Operator to Mobility Provider Application Programming Interface (TOMP-API), initiated by the Dutch government and still actively developed and maintained. The open standard defines MaaS platform access across a comprehensive set of functionalities, including general operator identification, registration and onboarding, trip planning, booking, trip execution, payment, support, asset information, and other optional services. The government requires the use of TOMP-API in all seven national MaaS pilot projects to ensure seamless integration between MaaS providers and transport operators. Whilst TOMP-API is not yet legally mandatory in other countries, several, such as Belgium and Switzerland, have already incorporated it into their national MaaS frameworks. This example could serve as a valuable benchmark for ASEAN in developing standardised technical specifications tailored to regional mobility needs. Developing a MaaS application that operates seamlessly across Southeast Asia would support cross-border mobility and enhance user experience through integrated planning, booking, and payment features.

Dynamic data exchange between transport operators and MaaS platforms is strongly encouraged. This includes real-time information on routes, schedules, vehicle availability, and service disruptions such as congestion. To maintain public trust, such data sharing must be supported by robust data privacy policies that safeguard users' personal information. One notable MaaS application in the EU region is Whim, which integrates multiple modes of transport, including public transit, city bikes, e-scooters, ferries, taxis, and affordable rental cars, into a single user-friendly platform. Whim's ambitious goal is to replace 1 million private cars with MaaS subscriptions by 2030. The app is primarily used in Finland and is available in other countries, including Belgium, the United Kingdom, and Japan.

MaaS platforms should be complemented by usage-based insurance (UBI), a model in which insurance premiums are calculated based on individual usage patterns and driving behaviour. UBI is particularly relevant for vehicles used in rental services, car sharing, and other shared mobility models, where traditional fixed-premium insurance is often inefficient. UBI systems collect real-time data on key driving metrics such as speed, acceleration, braking behaviour, and distance travelled. The data are then analysed to generate a detailed risk profile for each driver, enabling insurers to offer more accurate and personalised pricing.

8.10.4.6. Regionally Harmonised Regulations for Open Innovation Investment Life Cycle

Regionally harmonised regulations for the open innovation investment life cycle are necessary to propel ASEAN as a leading global innovator for mobility technologies. This entails creating regulations and schemes that (i) support the establishment of sandboxes for IP development; (ii) establish regional frameworks to strengthen IP protection; (iii) ease

IP commercialisation (regulatory reforms, data flows, capital repatriation); and (iv) provide incentive schemes to boost private investment and/or foreign direct investments.

Based on the existing landscape of the open innovation investment life cycle (Appendix 10), this masterplan proposes four policies to improve the open innovation ecosystem. These aim to close regulatory gaps that hinder ASEAN from becoming the preferred destination for global mobility investments.

1) Create a unified open innovation framework to safeguard industry-focused sandboxes with minimum establishment standards. The policy would ensure that all AMSs have the tools needed to build successful sandboxes, such as a clear industry focus, a multi-stakeholder ecosystem, and minimum invested capital, providing mobility technology firms a level playing field to test projects in the real world. In 1986–2016, China established 189 national demonstration zones (NDZs) intentionally clustered around targeted high-technology industries (The State Council of the People's Republic of China, 2017). As a result, 65% of China's top 20 smart manufacturing hubs originate from NDZs (Mercator Institute for China Studies, 2019). One success factor is the consortium of industry-related government institutions, companies, universities, research centres, and international organisations within the NDZs. Start-ups can consult these actors to solve operational problems, fast-tracking IP development (Xinhang, n.d.). With a unified sandbox framework, OEMs and suppliers could simultaneously develop and test innovations in mobility-focused sandboxes across AMSs, resulting in more market-resilient mobility technologies.
2) Establish ASEAN start-up nations standards to harmonise IP systems, data flows, and capital repatriation to improve open innovation. The benchmark is the Startup Nations Standards developed by Europe Startup Nations Alliance (ESNA). The Startup Nations Standards standardise market entry procedures, IP systems, stock options, capital financing schemes, and data sharing across member states. However, ESNA recognises such regulatory complexity and continues to support European policymakers in identifying, sharing, and implementing best policy practices for start-ups (ESNA, 2025). One example is the development of the Capital Markets Union, Europe's integrated single capital market to increase financing availability (European Commission, 2025g). ASEAN could start by forming an alliance to facilitate the co-creation of region-wide regulations and schemes suited to the start-up landscapes of all AMSs, enabling ASEAN to emerge as a borderless hub for scaling mobility innovation.
3) Offer an ASEAN open innovation policy facility as a pathway to commercialisation. AMSs should institutionalise clear road maps to convert sandboxes into real market entries via adaptive regulatory frameworks. Japan's Regulatory Sandbox, established under the Act on Strengthening Industrial Competitiveness, demonstrates that regulatory reform is an integral part of start-up commercialisation. If a start-up perceives that existing regulations do not support its growth, it can apply to the Committee for Evaluating the Effectiveness

of New Technologies and related ministries, together with data gathered during the pilot, to deliberate on potential regulatory reforms to support its growth (Cabinet Secretariat, 2023). The EU adopts similar policies for its innovation hubs through the Horizon Policy Support Facility, which provides services such as country assessments of innovation systems, policy recommendations, and policy reforms for national authorities (European Commission, 2025g). ASEAN could establish an ASEAN open innovation policy facility under the Unified Open Innovation Framework to act as an intermediary between AMSs and start-ups during commercialisation. By formalising this feedback loop, sandboxes would become not standalone experiments but catalysts for regulatory improvement.

4) **Define clear requirements for establishing foreign-funded sandboxes within open innovation regulations and schemes to attract high-quality foreign direct investment.** The policy would involve setting clear investment thresholds, IP systems, and partnership schemes. China has tiered requirements to determine eligibility; for example, minimum R&D investment is at least US$2 million for foreign-funded R&D centres and open innovation platforms, but at least US$10 million for global R&D centres (Shanghai Municipal People's Government, 2025). Similarly, the ASEAN R&D hub framework could set baseline standards, such as minimum R&D investment, number of R&D projects committed, and number of R&D sites. The scheme would strengthen ASEAN's appeal as a competitive innovation hub.

The four regulations and schemes address issues across ASEAN's open innovation life cycle, from IP development to commercialisation.

8.10.5. Layer 3. Resources

Layers 1 and 2 have clarified the destination and set the rulebook; Layer 3 now ensures that the journey can be financed, staffed, and monitored. In this report, the term 'resources' spans the fiscal firepower that lowers the cost of capital for low-carbon fuels and semiconductors; the pools of GX and DX talent that design and run smart, green factories; and the trusted data rails that allow thousands of suppliers to prove origin, carbon footprint, and circular content in real time. In deploying these resources, measures would be designed to balance support whilst maintaining domestic supply stability, ensuring that local production capabilities are safeguarded as regional initiatives scale. Together, these monetary, human, and informational assets would turn legislation into projects and projects into cash flow.

The chapter is organised around four complementary resource packages:

- targeted fiscal incentives and risk-sharing tools that crowd private money into biofuel and e-fuel refineries, critical-mineral processing, and front-end fabs (Section 8.10.5.1);
- resolution of the talent deficit through a region-wide visa, credential, and co-investment system that imports scarce know-how whilst accelerating the training

of local engineers, auditors, and data scientists (Section 8.10.5.2);

- connection of national pilots to the ASEAN Automotive Data Space, giving regulators, lenders, and OEMs a single window on traceability and ESG performance and cutting compliance costs for SMEs (Section 8.10.5.3); and
- widening of the capital funnel for frontier mobility and circular-economy ventures through blended-finance vehicles, super-deductions, and a green-bond fast-track (Section 8.10.5.4).

By aligning money, skills, and data with the same set of regional standards, Layer 3 provides the practical capability that complements the credibility secured in Layer 1 and the certainty delivered in Layer 2. The measures would create an investable pipeline today whilst retaining the flexibility to accommodate evolving technologies and business models as the masterplan moves from paper to pavement.

8.10.5.1. Fiscal Incentives for Biofuel, E-fuel, and Semiconductor Manufacturing

To support ASEAN's commitments to creating a low-carbon transport sector, targeted fiscal incentives should be introduced to drive biofuel, e-fuel, and semiconductor manufacturing as enablers for next-generation vehicle growth. For biofuels and e-fuels, the objective is to support refiners and plants in scaling up production to ensure a stable supply and affordable pricing whilst shifting consumer preference from fossil fuels to low-carbon alternatives.

Building on existing fiscal incentives related to biofuel and e-fuel (Appendix 11), the masterplan outlines three policy recommendations that aim to help AMSs strengthen performance across the biofuel and e-fuel supply-chain ecosystem.

1) Introduce performance-based incentives for low-carbon fuel producers to optimise production capacity whilst conserving limited public spending. Fiscal rewards would be calculated based on performance indicators linked to production level, blending rate, energy content, and carbon intensity (Section 8.10.4.1). The EU Energy Taxation Directive, which seeks to align fuel taxation with energy content and environmental performance rather than volume, is a prime example. The directive introduced tiers by setting minimum tax rates that favour advanced biofuels, feed-crop biofuels, and fossil fuels, in that order. Consequently, fossil fuel taxes are estimated to be 2 times higher than feed-crop biofuels and 70 times higher than advanced biofuels (European Court of Auditors, 2023). AMSs could implement a similar performance-based scheme to distribute fiscal incentives, such as subsidies, grants, and tax incentives. For example, if a biofuel producer achieves a 10% reduction in carbon intensity compared with the industry standard, the producer would be eligible to receive a tax allowance equivalent to the market value of the carbon credits for reduced emissions. Each AMS should identify its biofuel and e-fuel strategic goals in coordination with this masterplan and determine key performance indicators to measure progress. As a result, public financial resources could be directed towards high-performing biofuel and e-fuel producers.

2) Expand the scope of biofuel and e-fuel fiscal incentives to push forward all segments of the supply chain, from feedstock to biofuel production. To ensure feedstock availability, AMSs should provide fiscal incentives to boost feedstock production. Without considering the entire biofuel supply chain, AMSs could risk facing feedstock shortages that inflate biofuel production costs and undermine existing biofuel fiscal incentives. In Brazil, the National Biodiesel Production Program (PNPB) provides subsidies and tax incentives for biofuel producers that source feedstock from certified smallholder farms; maintain diversified feedstock (castor bean, palm, sunflower, rapeseed, jatropha); and/or source feedstock from the poorest parts of the country. Evidence shows that the PNPB improves biofuel production profitability: 7.43% for soybean, 5.53% for sunflower, and 3.88% for rapeseed. Biofuel production derived from soybeans yields the highest profitability because soybeans are the most abundant feedstock, which pushes costs down (Alves et al., 2017). AMSs could start offering fiscal incentives for feedstock producers to increase production capacity and lower biofuel production costs, whilst diversifying feedstock crops to minimise risks from failed harvests. Fiscal incentives would help existing feedstock producers scale up production and gradually integrate smallholder farms into the programme.
3) Implement fossil fuel disincentives to enhance the cost-competitiveness of biofuels and e-fuels and reinvest earnings into a central ASEAN biofuel and e-fuel fund. AMSs could introduce a fossil fuel surcharge, levied based on the carbon intensity of imported and/or domestically produced fossil fuels, to reduce competitiveness and improve cost parity for biofuels and e-fuels. A benchmark is Japan's GX Promotion Act, which imposes a carbon-based surcharge on fossil fuel imports. The fossil fuel surcharge is estimated to generate JPY20 trillion in revenue and will be used to finance GX initiatives that require JPY150 trillion investments (USDA Foreign Agricultural Service, 2023). Similarly, each AMS could contribute a portion of fossil fuel surcharge revenue into a central fund to support the development of biofuels and e-fuels throughout the region. The ASEAN biofuel and e-fuel fund could facilitate cross-border financing to encourage refiners and plants to expand to other markets, invest in low-carbon infrastructure in underdeveloped markets, and subsidise upstream feedstock production.

For semiconductors, the focus is to attract high-value investments for xEV-tailored semiconductor manufacturing facilities. Such fiscal incentives would help correct underinvestment in the next-generation vehicle ecosystem, supporting ASEAN's varied-pathway approach to achieve net-zero in the transport sector. Based on existing fiscal incentives (Appendix 12), two policies are recommended to improve the integration of ASEAN's semiconductor incentives, targeting the end-to-end value chain to support the self-sufficiency of the automotive sector.

1) **Co-create an integrated ASEAN semiconductor development plan and fiscal incentive strategy, assigning each AMS a value-chain specialisation.** ASEAN could adopt a coordinated regional semiconductor strategy that designates specific segments of the value chain – R&D; front-end fabrication; and back-end assembly, testing, and packaging – to each AMS based on its comparative advantages. An example is the EU Chips Act, which allows member states to channel state aid into Important Projects of Common European Interest (IPCEI) (European Parliament, 2022). From 2014 to 2018, the IPCEI raised EUR8.4 billion from member states and EUR1.9 billion from the private sector. The IPCEI fund was distributed amongst 32 participants across five member states, helping them build integrated production facilities and open EU foundries (European Commission, 2022b). ASEAN could replicate this approach by creating a regional mechanism to coordinate national strategies, design incentives, and pool funding to realise a region-wide semiconductor manufacturing network.
2) **Integrate performance-based R&D and human capital development incentives into semiconductor support packages.** AMSs should shift away from purely investment value–based semiconductor incentives towards performance-based schemes that explicitly reward outcomes in R&D and workforce development. A strong benchmark is Japan's semiconductor revitalisation strategy, under which the government committed US$27 billion from 2021 to 2023, linking support to tangible performance requirements. After funding 40% of Japan Advanced Semiconductor Manufacturing's Kumamoto production plant, the government required the firm to guarantee 10 years of domestic manufacturing and prioritise supply to the domestic market. The government funded 20% of next-generation microchip manufacturer Rapidus' costs to mass-produce 2-nanometre chips by 2027 in collaboration with IBM and Interuniversity Microelectronics Centre (ASEAN+3 Macroeconomic Research Office, 2024). Japan's model ties funding to commitments such as domestic upskilling, R&D targets, and international collaboration. AMSs could adapt this approach by introducing tiered subsidies, grants, and tax incentives based on indicators that help close the knowledge and innovation gap.

Fiscal incentives that integrate the ASEAN semiconductor supply chain whilst improving innovation and manufacturing talent would make ASEAN the top choice for semiconductor investors.

8.10.5.2. Attracting DX, GX, Open Innovation Talent from Outside the Region whilst Strengthening Domestic Human Resources and Know-how

Attracting foreign DX, GX, and open innovation talent across the globe is vital for ASEAN's transition towards becoming a hub for smart, low-carbon, next-generation mobility technologies. However, AMSs must keep these objectives in mind as they bring talent from outside the region whilst strengthening domestic capabilities. Highly skilled foreign

workers would not be brought in to replace domestic talent but to help upgrade domestic skills. They could catalyse innovation when given opportunities to engage with local communities, including companies, educational institutions, and local talent. However, the inflow of highly skilled foreign workers could have negative impacts on local communities, including rising rents, food prices, and service costs (ERIA, 2023c). With more DX, GX, and open innovation talent, ASEAN could accelerate the deployment of large-scale smart and green innovation.

Given the existing landscape (Appendix 13), the masterplan recommends three policies to address ASEAN's key issues in attracting foreign DX, GX, and innovation talent.

1) Launch an ASEAN knowledge co-creation programme to organise domestic talent upskilling workshops with foreign experts as educators across AMSs. The region-wide programme would systematically attract top foreign experts and connect them with domestic talent to jointly solve DX, GX, and mobility challenges. The Japan External Trade Organization (JETRO) created J-BRIDGE to support local companies in finding overseas partners to drive innovation, whilst the Japan International Cooperation Agency (JICA) runs Knowledge Co-Creation Programs, which invite foreign specialists and officials to joint problem-solving workshops with Japanese counterparts (JETRO, 2025a; JICA, 2024). ASEAN and its development partners could set aside programme budgets to fund fellowships, R&D grants, and accommodation for global experts, as well as finance sector-specific talent matching hubs and co-creation platforms across AMSs. This arrangement would ensure that foreign experts actively mentor and upskill ASEAN talent pools.
2) Develop ASEAN-wide local talent repatriation and long-term visa programmes with pathways to residency. AMSs could establish a coordinated local talent repatriation and long-term visa framework – an ASEAN regional talent visa – to attract high-skill, high-income diaspora and foreign experts in priority industries such as DX, GX, and mobility technologies. This recommendation draws on China's Thousand Talents Program for the local talent repatriation scheme, which aims to attract over 2,000 overseas Chinese scientists from developed countries over 5–10 years. The Thousand Talents Program repatriated 326 Chinese overseas talents within 1 year of its launch by providing competitive salaries, living subsidies, accommodation, and tenure opportunities (Chinese Academy of Sciences, 2009; Southern University of Science and Technology, n.d.). The long-term visa programme is benchmarked against Japan's Startup Visa, under which foreign entrepreneurs are granted a 6- to 8-month stay, with extensions of up to 12 months, to set up their business domestically (JETRO, 2025b). Japan attracts high-skill, high-income foreigners through special programmes; foreign engineers with annual incomes of at least JPY20 million can apply for permanent residency, and graduates of top-ranked overseas universities can be granted a 2-year stay (JETRO, 2023). Applicants for the ASEAN regional talent visa would be directed to one AMS based on their top preference to work and/or establish their businesses. The

designated AMS would review the applicants' qualifications and/or business plans as part of the approval process. To optimise this new talent pool, all AMSs could exempt visas for ASEAN regional talent visa holders.

3) **Establish an ASEAN student and staff exchange programme to provide continuous cross-border learning opportunities through talent mobility.** The programme is inspired by the European Union's Erasmus+ International Credit Mobility and Marie Skłodowska-Curie Actions (MSCA) Staff Exchange programmes. Whilst Erasmus+ International Credit Mobility primarily targets students studying at foreign universities for 3–12 months (European Commission, 2020a), MSCA Staff Exchange targets R&D professionals seconded to foreign organisations within the same sector for up to 4 years (MSCA, 2025). Post-programme requirements stipulate that student and staff participants return to Europe to facilitate knowledge sharing. ASEAN could adopt a similar approach by creating a coordinating unit to manage the programme's budget, match participating local and international organisations, and organise workshops for returning participants to share their experiences. Over time, the programme would increase the mobility of the regional talent pool, boosting the innovation capacity of all AMSs to the same target level.

These three policies would strengthen the DX, GX, and innovation capacity of ASEAN's workforce and help propel the automotive sector forward.

8.10.5.3. Regional Information Connection and Sharing

The creation of a single-source ASEAN automotive data space is needed to integrate critical information horizontally across AMSs and vertically across the supply chain. The objective of this regional data infrastructure would be to aggregate data and provide real-time visibility across areas such as manufacturing energy traceability, carbon accounting, vehicle LCA, tracking of ELV and used battery–recycling materials, and innovative mobility project pipelines. Such tools could help industry players, regulators, and investors make well-informed decisions that reduce market inefficiencies and promote responsible industry practices contributing to nationally determined contribution targets. As the ASEAN automotive data space opens access to AMS markets, the automotive ecosystem would become more resilient, transparent, and sustainable.

Given the existing landscape (Appendix 14), this masterplan proposes three policies to increase interoperability, standardise datasets, and improve cybersecurity. These measures aim to prepare ASEAN's data ecosystem for the ASEAN automotive data space.

1) **Develop the ASEAN automotive data space with an open data architecture.** The recommendation draws on the US Open Data initiative, which has aggregated about 300,000 datasets from more than 100 organisations since 2019 (Data.gov, 2025). The open data platform is equipped with data analysis tools that allow real-time analysis of custom datasets (Resources.data.gov, 2025). Because the US Open Data system is developed as a software package, participating organisations can upload compliant datasets, and software developers can add data analysis tools if they

share the same APIs (Fedscoop, 2012). Similarly, the ASEAN automotive data space could adopt an open data architecture to enable OEMs and suppliers to upload their data easily into the system. The built-in data dashboard would analyse important indicators in real time. Additional features could be added with minimal service disruption when software packages using the same APIs are connected to the open data architecture.

2) **Strengthen the implementation of the ASEAN Framework on Personal Data Protection and waive data localisation requirements to enable cross-border data flows between AMSs.** Mutual agreements on data protection and localisation standards would remove regulatory barriers that hinder international data transfers. The concept draws on the EU Common European Data Space, a single-source database covering priority sectors, that is open to the participation of all European organisations and individuals. Data owners can choose whether to grant access to their personal and non-personal data and whether to make their data available free of charge or at cost (European Commission, 2025h). However, they are subject to data-sharing rules outlined in the European Data Act (European Commission, 2025i). As ASEAN works to harmonise data frameworks, AMSs could use the ASEAN Framework on Personal Data Protection as a guide. Mutual agreements to waive data localisation requirements amongst AMSs would be needed to foster cross-border data flows.
3) **Strengthen cybersecurity measures and limit government access to personal data, especially in cross-border contexts, through the ASEAN Cybersecurity Cooperation.** ASEAN could agree on baseline safeguards to minimise cybersecurity risks and prevent unjustified government access to personal data; both actions could restore automotive industry players' trust in the region's data ecosystem. For instance, China recently eased compliance requirements for cross-border data transfers. Generally, Measures for Data Export Security Assessment stipulate that security assessments must be conducted only when companies plan to conduct a cross-border personal data transfer. Non-compliance may result in penalties, business license revocations, and other sanctions (China Briefing, 2024). ASEAN could formalise similar provisions within the ASEAN Framework on Personal Data Protection, requiring legal warrants and independent oversight for government access, whilst protecting business confidentiality. Penalties and fines could be built into the framework to strengthen compliance across the region.

As ASEAN's digital ecosystem strengthens with quality datasets, cross-border insights, and industry-wide data protection, the automotive sector can unlock data-driven growth.

8.10.5.4. Fiscal Support for Innovative Investment

Fiscal support for innovative investment is essential to pave the way for ASEAN's next-generation mobility markets. Smart factories, low-carbon supply chains, next-generation fuelling infrastructure, and MaaS and SDV pilots are amongst the investments that AMSs

need to finance. These DX, GX, and innovation investments require high upfront capital, so ASEAN must crowd in private investment through targeted fiscal incentives to realise them.

Given the existing landscape (Appendix 15), three policies are presented to address ASEAN's under-resourced innovation ecosystem. They aim to strengthen the region's ability to attract meaningful private sector participation in the mobility sector.

1) Establish an ASEAN centre of innovation fund for high-impact innovation projects. This fund would address the capital intensity of innovative projects that create regional impact by offering subsidies, grants, and co-financing beyond the limits of public budgets. The structure of the fund would be benchmarked against the European Structural and Investment Funds (ESIF), which pool EUR731 billion from the European Regional Development Fund, European Social Fund, Cohesion Fund, European Agricultural Fund for Rural Development, and European Maritime and Fisheries Fund. By aggregating the funds, ESIF reduces duplicative processes, expands deal size, and reallocates idle capital. For example, temporary flexibility was introduced into the Cohesion Fund's policy that allowed member states to redirect unused funds towards health emergency responses during the COVID-19 pandemic (European Commission, 2023b). ASEAN could replicate this model by launching a centre of innovation fund to pool contributions from AMSs, development partners, and private capital. The fund would prioritise projects with regional spillover effects, creating a scalable mechanism to drive innovation growth.
2) Offer project management office oversight and guidance from the start to the end of the open innovation life cycle. The policy requires cross-ministerial governance to guide companies through every stage of the open innovation life cycle. The governance structure could be modelled on Japan's Cross-ministerial Strategic Innovation Promotion Program, which oversees innovative programmes under the Council for Science, Technology and Innovation. Each programme has its own project management office governance consisting of a programme director; a promotion committee consisting of experts from related ministries; and a working group made up of government research institutes, universities, and private companies (Secretariat of Science, Technology and Innovation Policy Cabinet Office, 2024). For ASEAN, a similar innovation governance hub could help oversee cross-border innovative projects and facilitate knowledge exchange. This approach would ensure that innovation progresses from R&D through to commercialisation.
3) Offer co-financing at early stages of innovation and performance-based incentives at later stages of innovation as self-sustaining fund mechanisms. AMSs could provide co-financing for capital expenditure and operating expenditure during pilot phases, but gradually shift to performance-based incentives after the pilot stage. As a benchmark, China's National Demonstration Zone Support Fund provides subsidies of up to 30% of capital expenditure and operating expenditure during pilot stages and subsidies of 10% of aggregate economic contribution

beyond the pilot stage (The People's Government of Beijing Municipality, 2021). Only firms that succeed commercially and contribute to the economy receive continued fiscal support, gradually reducing dependency on public budgets. AMSs could start embedding performance indicators, such as IP-related incomes and the number of jobs created, into existing subsidies, grants, and tax incentives. This approach could be implemented regionally in the proposed ASEAN centre of innovation fund, ensuring high graduation rates of innovative start-ups from sandboxes and generating real economic contributions.

To transform innovative investments into region-wide growth engines, AMSs should design centralised, well-governed, performance-driven fiscal support that can accelerate uptake.

8.10.6. Layer 4. Operations and Infrastructure

Layers 1–3 have lit the runway: ASEAN now knows where it is going, which rules apply, and which resources are on tap. Layer 4 turns that strategic momentum into bricks and mortar (and code). It lays the rails that allow capital deployed in Layer 3 to cut emissions, raise productivity, and circulate materials.

Five flagship programmes would structure the chapter: (i) a network of renewable-powered green energy industry parks that would give suppliers plug-and-play access to low-carbon utilities; (ii) a federated material and carbon footprint tracing platform that would record every gram of metal, molecule of CO_2, and kilowatt-hour as parts flow across borders; (iii) a human resource database and education system, an ASEAN skills and talent hub that would ensure that the right engineers are on the ground when new plants switch on; (iv) an upgraded ASW 2.0 that fuses customs, logistics, and sustainability data into a single API layer; and (v) a targeted rollback of tariff and non-tariff barriers for low-carbon inputs and circular materials. Together, these assets would neutralise two bottlenecks: the infrastructure gap that makes decarbonisation uneconomic for SMEs, and the digital connectivity gap that keeps traceability pilots stuck in national silos (Section 8.9). By 2030, each programme would have bankable project lists, pooled financing envelopes, and measurable KPIs, anchoring Layer 4 within the broader masterplan.

8.10.6.1. Green Energy Industry Park Programme

Upstream decarbonisation stalls because individual suppliers cannot finance on-site renewables, waste-heat loops, or zero-liquid-discharge plants (Section 8.9). To overcome insufficient infrastructure for carbon-neutral manufacturing in ASEAN, a coordinated green energy industry park programme is proposed. The concept is to develop clusters of automotive suppliers and assemblers in EIPs equipped with shared low-carbon utilities (renewable power, green hydrogen, circular water systems, and waste recycling) and digital energy management systems. By pooling resources and demand, these parks would radically reduce the cost and complexity for individual firms, especially SMEs, to decarbonise operations. The park would provide plug-and-play access to carbon-neutral

infrastructure that no single small or medium-sized enterprise could afford on its own, making green manufacturing economically rational. This approach would address the current situation where 4% of surveyed ASEAN automotive firms cited lack of funding for low-carbon facilities as a key barrier (Section 8.9.4.1). With government backing and regional coordination, green industry parks could turn decarbonisation into a competitive advantage rather than a cost burden.

Given global best practices and the current landscape in ASEAN (Appendix 16), the masterplan proposes that ASEAN pursue a three-pronged strategy to implement green energy industrial parks across the region.

1) Adopt a regional EIP standard and accreditation. AMSs could jointly develop an ASEAN EIP standard aligned with the international framework set by UNIDO. The standard would define performance criteria on energy (e.g. percentage of renewable share), emissions, water reuse, and waste recycling for industrial parks. For instance, parks could be required to achieve at least 50% renewable energy use and 90% safe waste recycling by 2030 to qualify for ASEAN green park certification. A regional accreditation board could ensure consistency. Notably, the UNIDO (2021) framework emphasises providing sustainable utilities and minimising environmental footprints through measures on water, waste, and resource efficiency. An ASEAN-wide EIP label would give developers access to special support, much as Japan's Eco-Town approval unlocked national funds. An ASEAN-wide EIP certification system would create peer pressure for lagging countries to catch up, addressing current fragmentation where some AMSs have world-class green zones, whilst others have none.
2) Coordinate incentives and a green utilities fund. Layered incentives would be needed to attract investors and lower the upfront cost of park infrastructure. Governments should designate EIP projects as strategic and offer packages such as 15-year corporate tax holidays, import duty waivers on renewable technology, fast-track permitting, and public co-investment in common facilities. ASEAN with partners (e.g. ADB, Asian Infrastructure Investment Bank, and Japan–ASEAN Integration Fund) could establish a green industrial infrastructure fund to provide low-interest loans or guarantees for park developers that meet the ASEAN EIP standard. The fund could, for example, finance a park's centralised solar farm, biomass cogeneration plant, or wastewater recycling unit, with repayment partly through user fees. By pooling projects, all AMSs would be able to achieve scale and tap global climate finance. The impact of such support is evident in other regions: Brazil's RenovaBio programme, funded by a levy, has used credit incentives to attract billions in biofuel refinery investments, and in Europe, the EU Innovation Fund (financed by carbon permit revenues) is disbursing EUR3 billion to first-of-a-kind industrial decarbonisation projects (Reuters, 2025p). An ASEAN equivalent could take the form of a dedicated window that blends public and private capital to de-risk green industrial park utilities, ensuring that even SMEs in the park would gain access to stable, affordable green power. Notably, the EU is also simplifying

state-aid rules and fast-tracking permits for clean energy infrastructure by 2025. ASEAN could similarly streamline approvals for microgrids, solar plants, and waste facilities in these parks, possibly through an EIP one-stop shop in each country.

3) Aggregate SME off-take through a pooled-demand scheme. The primary purpose of a green energy industrial park is to help SME suppliers that lack the balance-sheet strength to fund their own decarbonised utilities. Instead of relying on a few anchor OEMs, the park operator (or a public utility) should act as an aggregator, bundling smaller firms' electricity and steam purchase commitments into a single bankable contract. Governments could underwrite this pooled demand, much like EU Commission–European Investment Bank (EIB) guarantees for SME renewable PPAs, by offering a minimum off-take guarantee or by directing state-owned utilities to buy any surplus. Governments could play a matchmaking role. For instance, they could broker arrangements under which an OEM that commits to sourcing a share of its energy or materials from the park's facilities receives preferential treatment, such as higher import quotas or co-branding as a green supplier. The approach has precedent: in energy markets, utility consortiums often sign long-term PPAs to guarantee demand for new renewable plants. In the EU's pilot scheme, the EU Commission–EIB guarantees effectively make the public sector the backstop buyer of renewable power for SMEs (Reuters, 2025p). ASEAN could adopt a similar approach by encouraging cross-border corporate PPAs within the region's power grid or by using state-owned enterprises to purchase excess green power or waste steam from parks, thereby assuring investors of stable revenues. Policies such as green power wheeling – allowing a company in one AMS to contract renewable electricity from a park in another AMS – and a regional renewable energy certificate market would expand the customer base for these parks. The goal is to integrate these parks into supply chains so that participation becomes a competitive requirement. If global automakers commit to Scope 3 emission cuts, they would preferentially source components from suppliers in verifiable low-carbon parks. ASEAN could reinforce this trend by marketing certified parks in trade promotion efforts (e.g. ASEAN Green Automobility Hub branding) and by requiring multinational assemblers benefiting from investment incentives to incorporate local green suppliers (Vietnam Briefing, 2024). Most importantly, the approach shifts the paradigm for SMEs: compliance with carbon-neutral production would no longer be a costly individual endeavour but rather a built-in feature of the manufacturing ecosystem. With clear standards, smart incentives, and regional cooperation on financing, ASEAN could deploy more green industry parks, each serving as a node of sustainable growth that anchors the region's automotive supply chain in the net-zero era.

8.10.6.2. Material and Carbon Footprint Tracing Platform

Another key policy recommendation is the development of a material and carbon footprint tracing platform for ASEAN's automotive supply chain. This responds to the lack of regional infrastructure for optimised supply-chain traceability and information sharing identified in the gap analysis. In today's automotive industry, data have become as vital as steel or semiconductors; manufacturers worldwide face increasing pressure to document the origin, carbon footprint, and recycled content of every component, from battery metals to plastic trim. Advanced economies are already mandating DPPs (e.g. Europe's battery passport by 2026) and requiring proof of sustainability for imports. Without a unified ASEAN platform to collect and exchange such data, the region's suppliers risk being locked out of greener value chains or facing higher transaction costs to comply with each buyer- or country-specific systems. Therefore, an ASEAN-wide traceability digital backbone is needed to connect companies, countries, and regulators with a single source of truth on materials and emissions. ASEAN could then unlock cross-border efficiencies, enable circular-economy practices (such as part reuse and recycling across AMSs), and meet the rising demands of customers and trade partners for transparency.

Deriving from the existing landscape of the tracing approach (Appendix 17), four key components would form the ASEAN platform. The policy recommendation is to establish a regional material and carbon footprint tracing platform as a federated data space connecting all AMSs. This would entail several coordinated actions.

1) Common data standards and governance. ASEAN should convene a technical working group, including industry and IT experts, to adopt a unified data model for traceability. This would specify how to represent each part's identity, its manufacturing history, material composition, carbon emissions at each process stage, and end-of-life disposition. Leveraging proven standards would accelerate this step, for instance, using carbon accounting for products that are compliant with ISO 14067 and ISO 14083, and the Catena-X data schema for part identification and event records. A shared ASEAN traceability ID (ATID) could be introduced, analogous to a vehicle identification number but for components and materials, encoded in QR or RFID tags on products. Each ATID would link to a secure record in the platform's ledger. In governance terms, a regional body, possibly under the ASW framework or an ASEAN automotive data alliance, could oversee the system rules, ensuring data confidentiality and equal access. Modern data space technology allows a decentralised architecture in which each country or large firm can host a node of the blockchain-like ledger, with agreed protocols for querying data without exposing business secrets. For example, Catena-X uses zero-knowledge proofs to verify claims such as 'X part has < Y kg CO_2 footprint' without revealing all proprietary data (NTT DATA, 2025b). ASEAN could establish a legal safe harbour for data sharing, harmonising privacy and cybersecurity laws so that companies can participate without violating national laws. The aim is a single digital spine where, for example, a battery recycled in Singapore can be tracked as it is reprocessed in

Malaysia and then incorporated into a new module in Thailand, with each step recorded and visible to authorised users.

2) Integration with trade and compliance systems. To maximise adoption, the platform should integrate with existing trade processes and upcoming regulations. The upgraded ASW 2.0 could be expanded to include sustainability data fields alongside customs data. For instance, when a component is shipped across borders, its digital manifest could automatically include the ATID and a link to its footprint record. This would reduce duplicate reporting and make border clearance smoother for data-compliant goods. Regulators could require that any vehicle or battery sold in ASEAN (or exported from the region) have an ASEAN material passport entry on the platform, similar to the EU's approach. A starting point could be critical parts such as high-voltage EV batteries or engines. By mandating a digital material passport that records composition (for recycling) and origin (for supply-chain security), ASEAN would lay the groundwork for future ELV and battery-recycling policies. The recommended regional ELV and battery-recycling regulation proposed in Layer 2 would rely on this platform to register and track scrapped vehicles and recovered materials. If a vehicle were deregistered in Indonesia and its battery sent to a recycling facility in Viet Nam, the platform would log that transfer and update the material's status, ensuring compliance with recycled content targets and preventing illegal dumping. Over time, the platform could integrate carbon trading or product carbon credit systems. For example, a company exceeding low-emission benchmarks could generate credits recorded on the ledger and sell them to others needing to offset emissions, similar to how California's Low Carbon Fuel Standard uses a central registry (Reuters, 2025p). Linking the platform to such economic incentives would drive participation.

3) SME onboarding and capacity building. A major challenge would be bringing thousands of smaller suppliers (Tier 2 and Tier 3) onto the digital platform, since they often lack IT systems for traceability. Policy support would be needed to ensure that these firms are not left behind. ASEAN could launch a traceability starter kit grant programme that subsidises essential tools: cloud-based ERP subscriptions, QR code or RFID tagging systems, and staff training. For example, Korea's Smart Factory initiative provided vouchers covering 70% of costs for SMEs to adopt digital production systems, resulting in significant efficiency gains. ASEAN could adopt a similar approach by offering, for instance, US$15,000 per eligible supplier to fund software integration and the first year of platform fees. In parallel, a network of certified implementation partners, such as large technology firms or local start-up integrators, could be established in each AMS to help onboard SMEs in their local languages. Another important element is developing human capital to operate and audit the platform. The system would generate demand for traceability officers or sustainability data managers at companies to manage the data input and quality. ASEAN should anticipate this need by setting up training courses and micro-credentials, as proposed in the Layer 3 talent measures. For instance, a regional

skills pass programme could include a digital badge for LCA auditors or blockchain data specialists, allowing companies to identify qualified candidates. The platform itself could serve as an educational tool; once SMEs start logging their material flows and reviewing their carbon footprints, they could discover inefficiencies, such as waste or energy hot spots, that could be fixed. In Europe, many small suppliers that joined Catena-X found opportunities to cut costs after measuring their processes. ASEAN could amplify these benefits by providing analytics and benchmarking within the platform. For example, a supplier could compare its carbon emissions per part against an anonymised average of peers, spurring competitive improvement.

4) Pilot and scale approach. ASEAN could identify a priority pilot use case to start. A strong candidate could be an EV battery supply-chain pilot involving mining and refining (Indonesia, the Philippines), component manufacturing (Thailand, Malaysia), pack assembly (Singapore, Thailand), and vehicle integration (various AMSs). The pilot would register a batch of EV battery components and track them along the supply chain, capturing data such as nickel origin, cell factory emissions, and transport emissions. This could be done in partnership with existing initiatives. For example, Thailand and Indonesia might partner with Japan's Ouranos or the EU's Global Battery Alliance to trial dual reporting. Success in the pilot could create a template for other products, including engines, electronics, and steel parts. In parallel, ASEAN could establish a policy requirement that, by a target year, all major automotive manufacturers and importers operating in the region participate in the platform by reporting certain key data, such as annual carbon footprints or verified recycled material content. Early signalling of such requirements would prompt companies to join voluntarily rather than delay compliance. Scaling the platform would require continuous improvement and funding. A sustainable financing model could be a small digital service fee on each transaction, much like trade facilitation fees, or support from the ASEAN Infrastructure Fund, given the platform's regional public-good function. Donor agencies, including JICA, Deutsche Gesellschaft für Internationale Zusammenarbeit [GIZ], and the World Bank, have shown interest in funding digital trade and circular-economy projects and could support initial development costs. Once operational, the ASEAN traceability platform could revolutionise supply-chain management by enabling real-time tracking of carbon and materials across Southeast Asia's automotive network, simplifying compliance with international regulations, and opening new business models such as MaaS or carbon footprint labels.

8.10.6.3. Human Resource Database and Education System

ASEAN's core challenge is a chronic skills mismatch in the automotive supply chain (Section 8.9). SME plants lack easy access to engineers trained in EV powertrains, battery recycling, or digital supply-chain tools, whilst workers' qualifications often lose value outside their home country. Firms cannot justify clean-tech investments when they cannot

hire or verify the necessary talent. The region needs a shared data infrastructure for skills and credentials. ASEAN should build a centralised talent portal that aggregates vocational and academic certificates into a cloud-based database. This ASEAN skills passport would mirror successful models such as the EU's European Skills, Competences, Qualifications and Occupations (ESCO), a multilingual taxonomy of skills, qualifications, and occupations; and the Europass Digital Credentials Infrastructure (European Commission, 2024). ESCO has demonstrated the value of a common language of occupations and skills across borders. An ASEAN taxonomy would tag each worker's résumé with standard skill codes, such as EV battery maintenance, IoT diagnostics, and LCA.

All credentials, from a Thai vocational certificate in electronics to a Philippine bachelor's degree in data science, could be stored in secure digital wallets. These wallets use cryptographic signatures (such as e-Seal) to make credentials tamper-evident, reducing fraud and allowing employers to verify them instantly (European Commission, 2022a). The Europass Digital Credentials Infrastructure demonstrates how this works in practice: over 2.5 million Europass wallets now hold electronic certificates in 29 languages. ASEAN could build a similar system through a federated platform in which authorised training institutes and certifying bodies upload digital records to a centralised portal. The portal could then issue ASEAN-wide credentials. Employers would be able to search the portal to confirm qualifications and view candidates' skill profiles. For instance, a Vietnamese part maker could look up 'EV assembly-certified technicians' and find verified workers from Indonesia or Malaysia. By making both skills and talent visible, the platform would help companies plan investments with confidence, knowing that a trained regional workforce is available.

Five key policy elements are recommended for this system:

1) Common ASEAN skills taxonomy. Adopt or build a common language of competencies (modelled on ESCO) so that each skill and occupation is defined consistently across the region. This would ensure that a 'mechatronics technician' in Brunei Darussalam or Singapore would be recognised identically in other AMSs.
2) Digital ASEAN skills wallet. Establish a secure cloud repository for each worker's credentials. Vocational certificates, micro-credentials, and degrees (e.g. EV safety training, robotics certification, battery-recycling LCA courses) could be uploaded with e-signatures. Employers would be able to verify authenticity instantly and assess skills (ASEAN, 2022).
3) Cross-border training hubs and mobility. Establish regional technical and vocational education and training (TVET) and apprenticeship programmes focused on EV and smart manufacturing skills. For example, Toyota's ASEAN–Republic of Korea mobility scheme (TMP Tech) sent 21 students from nine AMSs to the Philippines for a hybrid and electric powertrain course (Carmudi, 2023). ASEAN could expand such models by rotating cohorts amongst ASEAN training centres and industry academies, such as Thailand's Automotive Human Resource Development Academy, Malaysia's Institut Latihan Perindustrian dan Teknologi Lanjutan, and Singapore Institute of Technology. Graduates of these programmes

would automatically receive ASEAN-recognised credentials recorded into the skills wallet.

4) Standardised curriculum and micro-credentials. Harmonise green technology modules across national colleges. Develop short courses and micro-credentials in priority areas such as high-voltage battery servicing, IoT automation, industrial data analytics, and circular-economy practices. National qualifications should be mutually recognised under the ASEAN Qualifications Reference Framework. By stacking micro-credentials on the portal, workers across AMSs could upskill and carry certifications between countries.

5) Recognition and oversight. Introduce certification audits to enforce trust in the system. Like the EU's e-Seal for diplomas (Europass, 2024), ASEAN should leverage digital ID infrastructure – many AMSs already have national e-ID systems (ASEAN, 2022) – so that uploaded credentials carry legal authenticity. Governments could require accredited certificates to be issued through the portal, gradually replacing paper-only diplomas that cannot be verified.

This integrated talent system addresses the two root gaps simultaneously. By quantifying and tracking ASEAN's skills stock, policymakers can identify shortages (e.g. countries lacking battery technology instructors) and launch targeted programmes. A Thailand–Japan labour study, for instance, advocates similar measures – comprehensive skills needs assessments, occupational mapping, and in-company trainer development – to manage the EV transition (Nation Thailand, 2024).

Other key actions to consider include establishing an ASEAN skills portal and skills wallet supported by a common taxonomy, accrediting regional EV and robotics training centres, launching cross-border TVET exchange programmes, and embedding interoperable credential standards (digital signatures or e-Seals) to guarantee trust. These steps would build the critical skills and data infrastructure needed to enable ASEAN's supply chains to decarbonise and digitise on schedule.

8.10.6.4. ASEAN Single Window 2.0: Trade and Sustainability Spine

ASW 2.0 is the next-generation upgrade of the current ASW, incorporating sustainability-related data such as carbon emissions, circular materials, and supply-chain risks. For the ASEAN automotive sector, this would help facilitate the trade of responsibly sourced biofuels and e-fuels, recycled ELVs and EV batteries, and semiconductors, positioning the region as a digital, green, and innovative hub. The objective is to strengthen coordination for regional data exchange that streamlines trade flows, enables communication amongst trade stakeholders, and improves supply-chain traceability.

Compared with the existing ASW (Appendix 18), the ASW 2.0 would present three interlinked challenges across national and regional systems. First, although most AMSs maintain national reference data for traded goods related to customs clearance, ASEAN-wide reference data have not been centralised. Second, inter-agency data exchange within

AMSs is limited to e-permit issuance and does not provide data visibility on carbon emissions, circular materials, and supply-chain risks. Third, existing NSW frameworks remain narrowly focused on trade facilitation without end-to-end supply-chain traceability and ESG verification. Without interoperable legal, technical, and governance structures, ASW 2.0 cannot evolve to be a sustainability-focused trade backbone for ASEAN's next-generation automotive export network (ASEAN Single Window, 2025). Three proposed policies aim to add layers of sustainable compliance, accountability, and traceability into the flow of ASEAN goods, helping propel the region as a leading hub for next-generation vehicle manufacturing.

1) Establish a regional data service (RDS) for sustainability-aligned trade codes. ASEAN could embed harmonised classifications and codes for carbon intensity and circular materials into the existing RDS, serving as the technical foundation for sustainability-linked trade across AMSs. This approach draws on the EU CBAM, which requires importers to report embedded carbon emissions using a standardised form for products and pay carbon-related customs duties starting in 2026 (European Commission, 2023c). CBAM uses the Authorisation Management Module as its RDS, issuing e-permits, facilitating communication between CBAM declarants and government agencies, and managing internal workflows across EU member states (European Commission, 2025i). CBAM will be integrated into the EU customs single window – the Customs Electronic Certificates Exchange System (CERTEX) – creating a single service point for trade and carbon verification (Livingston, 2025). ASW 2.0 could adopt a similar model to encourage AMSs and their trading partners to strengthen sustainable practices, which are increasingly demanded in the automotive sector. ASEAN could begin by forming a regional working group to define shared metadata fields for sustainability reporting aligned with extended Harmonised System codes or digital attachments. These standards should be integrated into the existing RDS and gradually adopted within each NSW. Implementation could start with high-impact sectors such as automotive, energy, and mining, which would enable ASEAN to respond proactively to carbon-based trade requirements and build credible green export systems.
2) Streamline the paperless customs clearance, e-permit issuance, logistic services, and payment processes across all NSW ecosystems into a single AWS common portal. ASEAN should integrate inter-agency processes within NSWs into the interoperable ASW platform. Japan's Nippon Automated Cargo and Port Consolidated System (NACCS) provides a leading example. Under the first initiative implementing the Convention on Facilitation of International Maritime Traffic, Japan reduced 16 forms and 600 data terms across ministries to 8 forms and 200 data terms and consolidated 5 separate port entry forms from four ministries into a single standardised declaration. The second initiative, the Asian Gateway Initiative, mandated full digital integration between NACCS, seaport systems, and airport systems within a single portal that provides logistics services for international trade (United Nations Economic and Social Commission for Asia and the Pacific,

2018). Similarly, ASEAN could encourage AMSs to standardise metadata and business processes across NSWs within a shared regional framework. In parallel, AMSs could launch an ASW common portal to streamline access for all NSW stakeholders. This transformation would reduce administrative burdens, enable seamless reuse of submitted data, and significantly improve efficiency and user experience in ASEAN's cross-border trade environment.

3) Launch the ASEAN trace-ID portal to enhance end-to-end supply-chain visibility across all AMSs. The concept involves establishing a region-wide traded goods tracking system that enables secure cross-border verification of product traceability, origin, and sustainability claims across sectors. The policy draws on China's International Trade Single Window, which offers a one-stop, free-of-charge platform integrating over 25 regulatory agencies and providing 495 service items, including traceability support for bonded goods, processing trade, and cross-border e-commerce across different categories of traded goods. The platform supports core applications such as cargo, manifest, and transport vehicle declarations and enables tracking across major trade routes (World Customs Organization, 2019). ASEAN could adopt a similar approach by first defining common trace-ID metadata fields, such as origin, material flows, and ESG claims, and linking them to trade documentation, including invoices and certificates, through the ASW. This system could be piloted in strategic sectors through public–private partnerships and later scaled through a regional funding mechanism supported by AMSs and development partners to ensure open access and system interoperability.

By standardising sustainability-related RDS, integrating inter-agency compliance systems across AMSs, and launching the ASEAN trace-ID portal, the ASW could be transformed into a platform that encourages other trading partners to engage in low-carbon supply chains as well.

8.10.6.5. Reduce Tarifi and Non-Tarifi Barriers

The objective of removing tariffs and non-tariff measures (NTMs) in the ASEAN automotive sector is to eliminate trade frictions that hamper the flow of automotive goods. ASEAN's success in the automotive sector will depend on more than national competitiveness; it will require regional coordination to foster specialisation, reduce duplication, and build resilient, integrated value chains that serve internal and global markets. A supportive and coherent policy environment will serve as a critical enabler of industrial upgrading and regional integration. Whilst most tariffs have declined under regional free trade agreements (FTAs), tariffs on vehicles remain higher than those on intermediate goods, reflecting efforts to promote local value addition. However, NTMs remain pervasive and fragmented. Technical barriers to trade, especially conformity assessments, account for over half of NTMs in ASEAN and East Asia. This indicates a strong focus on safety and standards, but often results in high compliance costs due to lack of harmonisation.

More ambiguous or potentially trade-restrictive NTMs, such as non-automatic licensing,

price controls, and export restrictions, constitute nearly 40% of ASEAN's automotive-related NTMs. Without transparent and predictable application, these measures may discourage deeper participation in regional value chains. Countries such as Indonesia, the Philippines, Thailand, and Viet Nam are more active in deploying NTMs, whilst others such as Brunei Darussalam, Cambodia, and Lao PDR tend to have limited regulatory frameworks, often due to capacity gaps.

Regional initiatives, including the ASEAN Trade in Goods Agreement (ATIGA), the Regional Comprehensive Economic Partnership, and ASEAN+1 FTAs, can play a catalytic role by reducing policy fragmentation, improving trade facilitation, and encouraging regulatory convergence. Platforms such as the ASW, mutual recognition arrangements, and coordinated EV ecosystem policies provide opportunities to streamline procedures, strengthen testing and certification capacity, and build trust in cross-border production processes. Accelerating trade and investment facilitation, including regulatory harmonisation, streamlined customs procedures, and investment-friendly policies, will not only enhance competitiveness but also foster a more cohesive and resilient regional production base.

To realise ASEAN's ambition of becoming an integrated production base for next-generation vehicle manufacturing, the region must move beyond its current regulatory landscape of tariffs and NTMs (Appendix 19). Four policies are proposed.

1) Appoint a central ASEAN tariff monitoring mechanism for CBU, CKD, and auto parts to ensure AMSs' ATIGA compliance and provide support mechanisms for businesses. The central tariff monitoring mechanism could be institutionalised under the Coordinating Committee on the Implementation of the ATIGA, with responsibility for conducting annual audits of automotive goods and other products subject to 0% tariff obligations. Each AMS could designate national representatives to support exporters and importers in navigating tariff schedules, complying with certificates of origin, and applying preferential trade rules. This approach draws on Japan's success using economic partnership agreements (EPAs) and FTAs. Through business needs assessments, information dissemination through customs websites, and workshops educating businesses on new EPAs and FTAs, as well as irregularity cases, Japan drove down tariffs on non-agricultural products to only 2.4% (World Customs Organization, 2023; HKTDC Research, 2024). In addition to setting up a regional central tariff monitoring mechanism, ASEAN could gradually publish needs assessment surveys, tariff schedules, and workshop materials in the ASEAN Trade Repository.
2) Mandate the development and harmonisation of AMS national automotive technical standards through UNECE regulations and accelerate the ratification of the ASEAN Mutual Recognition Arrangement on Type Approval for Automotive Products. ASEAN should make the development of national automotive technical standards obligatory and enforce UNECE regulations for safety, labelling, and emission standards, helping standardise the technical specifications of

manufactured vehicles that previously made some models difficult to export. The EU Single Market provides a strong benchmark. By eliminating technical barriers, firms operate as if within a single country, boosting competition and lowering consumer costs (European Union, 2025). For instance, lower airfares and telecommunication costs were direct results of regulatory alignment and market liberalisation (European Commission, 2020b). Similarly, ASEAN could use the ASEAN Consultative Committee on Standards and Quality to draft and enforce an ASEAN automotive technical rulebook aligned with UNECE regulations. This effort should be coupled with a transition road map that includes technical assistance and phased compliance timelines.

3) Develop a sector-specific digital trade facilitation platform as an extension of ASW 2.0, starting with the automotive sector. Whilst ASW 2.0 focuses on government-to-government interoperability for trade document exchange, this extension would place greater emphasis on business-to-government services by allowing OEMs and suppliers to directly interact with government agencies through integrated portals. The platform would consolidate automotive-specific requirements across AMSs, such as import and export licensing, product registration, technical inspection, value-added tax (VAT) exemptions, and customs fee schedules. It would provide real-time traceability, pre-clearance tools, and dispute resolution functions for businesses, extending support beyond customs procedures into broader market entry processes. Lessons can be drawn from China's national demonstration zones, where sector-specific digital infrastructure has enabled faster customs releases – often within 6 hours – and eased access to financial services for sector participants (China Briefing, 2023). ASEAN could design a user-centric interface and pilot the automotive platform in countries with complex NTMs, such as Indonesia, Myanmar, and the Philippines, before scaling the system across the region.
4) Eliminate non-technical NTMs through binding transparency and peer review protocols. Non-technical NTMs, such as VAT measures, minimum local content requirements, and import or export licensing, should be subject to a binding NTM transparency and peer review protocol modelled after the OECD Trade Facilitation Indicators (TFIs) framework. The OECD TFIs consist of several variables reflecting actual border and regulatory practices, including the time between publication and entry into force of new trade rules, the share of trade processed before goods arrive, and the availability of certified trader programmes. The TFIs help policymakers identify bottlenecks, benchmark progress, and design reforms to reduce friction in border operations (OECD, 2023). By implementing a regional automotive TFI dashboard, AMSs could track NTMs imposed across the sector and monitor the extent to which NTMs affect trade flows.

These four policies tackle tariffs and NTMs that impede automotive trade integration across ASEAN by promoting tariff discipline, harmonising technical standards, supporting businesses in trade facilitation, and eliminating disguised protectionism. The reforms

would unlock the region's automotive manufacturing potential and strengthen ASEAN's trajectory as a leading automotive hub.

Chapter 9
Co-Creation Areas

9.1. Objective and Introduction

At the Association of Southeast Asian Nations (ASEAN)–Japan Commemorative Summit in December 2023, both sides reaffirmed their shared vision for Co-Creation for the Future. A notable outcome of the summit was Japan's commitment to strengthen the ASEAN–Japan Comprehensive Strategic Partnership in a way that is meaningful, substantive, and mutually beneficial, under three key pillars that embrace ASEAN's unity and centrality. The three pillars are heart-to-heart partners across generations, partners for the co-creation of the economy and society of the future, and partners for peace and stability.

Japan expressed its intention to be a proactive partner in ASEAN's development, with a particular focus on green growth, digital innovation, and enhanced connectivity (Government of Japan, 2024). In this context, efforts will be made to deepen public–private partnerships, strengthen connectivity, promote climate action, and support small and medium-sized enterprises (SMEs) and startups.

The summit marked the launch of the ASEAN–Japan Co-Creation Initiative for the Next-Generation Automotive Industry, a joint effort to formulate and implement strategies to enable ASEAN to remain a leading global automotive production and export hub. In alignment with this shared agenda, the ASEAN Automotive Masterplan directly contributes to the ASEAN–Japan initiative, positioning co-creation as a key implementation modality to unlock shared opportunities in innovation, decarbonisation, and regional integration.

For more than half a century, Japan has been an indispensable partner in harnessing ASEAN's potential, with both sides possessing distinct strengths and demonstrating strong complementarity (Economic Research Institute for ASEAN and East Asia [ERIA], 2023). ASEAN Member States (AMSs) envision the region as a key internal combustion engine (ICE) and hybrid electric vehicle (HEV) production and export hub for both vehicles and components, whilst gradually shifting supply chains towards electrified vehicle (xEV) component manufacturing. Japan's strength in HEV technologies (EOS Intelligence, 2024) is not only complementary but also strategically aligned with ASEAN's intended trajectory. Such technological overlap is especially relevant, as many key HEV components share technological commonalities with xEVs (Al Sharif et al., 2021; Veza et al., 2023), making early collaboration a stepping stone towards deeper electrification. A strategic partnership between Japan and ASEAN in the automotive sector provides a strong basis for co-creation, as leveraging Japan's expertise supports ASEAN's dual goals of maintaining strength in ICE and HEV whilst preparing for the global pivot to xEVs.

To realise the policy recommendations defined in Section 8.10, this section proposes

potential co-creation areas to be jointly pursued. These pathways aim to strengthen collaboration and achieve the region's ambitions for its automotive sector, serving not only to operationalise ASEAN's to-be state but also to ensure that international partnerships deliver concrete value for the region. The proposed areas also reflect the domains where mutual strengths and strategic priorities are most likely to generate practical and regionally meaningful impact.

In continuation of the stated objectives and contextual rationale, the subsequent framework provides a structured view of these potential areas, which are then explored in greater detail through targeted deep dives.

9.2. Co-creation Framework and Areas

The co-creation areas are structured based on their relevance to each corresponding policy topic. During this study, it was observed that the Government of Japan had previously been involved in several of these areas. Upon closer examination, these proposed initiatives appear to align closely with the Ministry of Economy, Trade and Industry (METI) original co-creation concepts under this masterplan, which encompass the following:

- A: Supporting transition of suppliers and human resources
- B: Reducing life-cycle carbon dioxide emissions, including decarbonisation of the power sector
- C: Developing stable xEV supply chains, including resource circulation
- D: Developing biofuels and e-fuels for the local economy

The alignment indicates the relevance of Japan's experience and capabilities in supporting the masterplan's implementation. In total, 10 co-creation areas are proposed. Table 9.1 summarises these areas, highlighting their linkages to specific policy topics and their consistency with METI's co-creation framework, which is elaborated in the subsequent section.

Building on this framework, each co-creation area is further assessed across two key dimensions. First, it identifies the expected value and relevance of each initiative. Second, it reviews Japan's prior engagements in similar efforts as reference points to assess feasibility. Table 9.1 maps each co-creation area to its corresponding use case to illustrate the potential modes of collaboration. The outcome of this chapter offers a clear view of how ASEAN and Japan can effectively co-create and which areas present the most practical and strategic opportunities to pursue.

Table 9.1. Policy Recommendations Mapped to Co-Creation Areas and METI's Ideas

Policy Recommendation		Section	Co-creation Area	Reference
Strategy and Policy	Development of ASEAN Automotive Masterplan	9.2.1	Platform or Forum of Stakeholders	AMEICC Working Group on Automotive Industry
Scheme and Regulation	Biofuel and E-fuel Usage Enhancement for ICE and HEV	9.2.2	Bilateral Collaboration for Biofuel and E-fuel Economy Development	Initiative for Sustainable Fuel and Mobility of Japan and Brazil Biofuel Co-creation Task Force Meeting with Indonesia
	Regional Support for DX and GX Actions	9.2.3	Education System Development and Human Resource Exchange Support	ASEAN–Japan 50th Anniversary Project: Mutual Recognition Arrangements and Digital Skill Standard of METI
	Revision of Vehicle Inspection System	9.2.4	Automotive-Related Regulations Commonalisation	JICA's Support to Cambodia on Inspection Scheme and Myanmar for Automotive TVET Maintenance Programme
	Development of Regional Recycle and Scrap Regulation	9.2.5	Support for Developing Recycling and Circular Economy Rules	JICA's Support to the Philippines on End-Life-cycle–Vehicle Disposal System
Resource	Develop Biofuel and E-fuel Manufacturing	9.2.6	Biofuel and E-fuel Manufacturing and Technical Support	NEDO's Activities on 2G Biofuel Technology Promotion
	To Bring DX and GX Human Resource and Know-How from Outside the Region and Develop Internally	9.2.3	Education system development and human resource exchange support	
	Regional Information Connection and Sharing	9.2.7	Information and Data Standardisation Development	Ouranos Ecosystem
Operations and Infrastructure	Green Industry Park	9.2.8	Green Energy Industrial Park Model Development	METI's Global South Project on the Masterplan

Policy Recommendation		Section	Co-creation Area	Reference
				Development for Patimban Deep Sea Port Green Transformation Corridor
	Material and Carbon Footprint Platform Development	9.2.7	Information and Data Standardisation Development	
	Human Resource Database and Education System			
	Strengthen Connection of the Region through ASEAN Single Window	9.2.9	Support for Strengthening the ASEAN Single Window System	Japan's Support for the Establishment of the ASEAN Single Window System
	Reduce Tariff and Non-Tariff Barriers	9.2.10	Support for Policy and Regulatory Development	JICA's Activities Supporting Policymaking in Developing Countries

2G = second generation; AMEICC = ASEAN Economic Ministers–METI Economic and Industrial Cooperation Committee; ASEAN = Association of Southeast Asian Nations; DX = digital transformation; GX = green transformation; JICA = Japan International Cooperation Agency; METI = Ministry of Economy, Trade and Industry (Japan); NEDO = New Energy and Industrial Technology Development Organization (Japan); TVET = technical and vocational education and training.
Source: Authors (2025).

9.2.1. Platform or Forum of Stakeholders

At the core of this masterplan is the need to translate high-level policy recommendations into coordinated, actionable steps that mobilise ASEAN as a next-generation automotive hub (the to-be states). To support these goals, it is proposed that ASEAN and Japan co-create a dedicated stakeholder platform or forum to serve as a mechanism for implementation follow-up and policy coordination.

The primary function of this forum would be to facilitate structured dialogue, enable information sharing, and monitor the progress of the masterplan. It would monitor how individual policy actions are implemented. To achieve this, a follow-up mechanism should be established. This could take the form of a working group, task force, or coordinating secretariat comprising representatives from government, industry, and relevant institutions.

In doing so, the ASEAN Economic Ministers–METI Economic and Industrial Cooperation Committee (AMEICC) Automotive Working Group serves as a useful reference, having

functioned as a platform for policy dialogue, technical cooperation, and information exchange between AMSs and Japan. In this forum, public and private-sector automotive experts from ASEAN and Japan have discussed how ASEAN and Japan can cooperate to strengthen ASEAN's role as a production and export hub, whilst also pursuing sector decarbonisation goals (AMEICC, 2024).

Establishing such a forum represents one of the most practical and immediately actionable steps under the masterplan. Unlike long-term policy or infrastructure changes, a stakeholder platform can be initiated early and expanded over time. Its role would be not only to monitor progress but also to identify implementation challenges, support mid-course policy adjustments, and ensure that co-creation between ASEAN and Japan continues in a structured, transparent, and results-oriented manner. The platform should not be seen as external to the masterplan but as an integral part of its delivery mechanism. It would help institutionalise co-creation beyond the planning phase, foster accountability, and lay the groundwork for future iterations or upgrades based on shared insights and evolving priorities.

9.2.2. Bilateral Collaboration for Biofuel and E-fuel Economy Development

One way to realise regional biofuel and e-fuel usage at scale is to first develop the biofuel and e-fuel economy. In this case, a potential collaboration area would be the establishment an ASEAN–Japan co-working group to develop a biofuel and e-fuel economy in the region and secure supply for the automotive industry and to increase utilisation in road transport.

Co-creating a biofuel and e-fuel economy builds on the strong alignment between ASEAN and Japan in energy and decarbonisation ambitions. Both sides share robust climate commitments, with Japan aiming for net zero by 2050 and AMSs advancing national energy transition strategies (Ministry of Foreign Affairs of Japan [MoFA], 2024a). Their complementary energy profiles provide a basis for joint leadership in advancing clean energy transitions whilst strengthening energy security and economic resilience. Both regions are already undertaking biofuel and e-fuel initiatives, providing a practical foundation for coordinated action. Strengthening this partnership will help accelerate innovation and foster resilient supply chains across the biofuel and e-fuel value chains.

Similar co-creation in biofuel and e-fuel economy development has been established between Japan and Brazil. The two countries launched the Initiative for Sustainable Fuel and Mobility (ISFM) to achieve carbon neutrality through partnerships that combine Brazil's potential in decarbonised fuels with Japan's high-performance mobility technologies, such as hybrid engines (MoFA, 2024b). Both sides agreed to promote and strengthen cooperation through the development and use of high-performance mobility equipment, such as hybrid and flex-fuel engines and next-generation aircraft, as well as sustainable fuels, such as biofuels, biogas, low-carbon hydrogen, and its derivatives, including e-fuels. As part of an initiative under the International Framework for Sustainable Fuels (IFSF), Japan and Brazil co-hosted the inaugural Ministerial Meeting on Sustainable Fuels in Osaka, Japan, in September 2025. Ministers and delegates from 34

countries and organisations discussed the critical importance of expanding the production and utilisation of sustainable fuels, such as biofuels, biogases, e-fuels, and e-methane, across various sectors, including road transport. The participants also emphasised the necessity of global cooperation and public–private partnerships to achieve these goals. Ahead of the 30th Conference of the Parties (COP30) to the United Nations Framework Convention on Climate Change in Brazil, the co-chairs issued a summary of the ministerial discussions (METI, 2025a).

The Brazil case shows that a strengthened ASEAN–Japan partnership in biofuel and e-fuel economy development could contribute to establishing a regionally integrated low-carbon fuel supply base. Such a foundation would directly support the broader goals of the ASEAN Next-Generation Automotive Masterplan by ensuring access to clean, diversified, and secure fuel sources for the future of the automotive industry.

9.2.3. Education System Development and Human Resource Exchange Support

In the pursuit of building an automotive industry capable of driving both digital (DX) and green (GX) transformations, ASEAN must equip its workforce with the skills needed to operationalise these initiatives at scale. Existing support for DX and GX capacity building across the region remains fragmented, resulting in significant disparities amongst AMSs (Section 8.10.4.2). To address this, the proposed co-creation area emphasises a collaborative approach in which Japan supports education and training initiatives to build a skilled workforce aligned with the future needs of the ASEAN automotive sector.

As part of the ASEAN–Japan 50th Anniversary Project, Japan has proposed the development of mutual recognition arrangements (MRAs) and the standardisation of digital skills based on METI's Digital Skill Standard. These initiatives aim to promote mobility and consistency of skilled labour across ASEAN by aligning educational outcomes and qualification frameworks with emerging industrial demands. A concrete step towards addressing workforce readiness through MRAs could involve the development of technical and vocational education and training (TVET) curricula aligned with company demand for DX and GX human resources, supported by mutual qualification recognition mechanisms.

Prior proposals related to the anniversary project through ERIA (2023) have outlined several dimensions of education system development relevant to this collaboration. First, educational qualifications and professional standards should be standardised across the region through MRAs, whilst also expanding the range of recognised personnel with specialised skills. The ASEAN–Japan credit transfer system should be enlarged to facilitate this process. Second, mutual recognition of credits and harmonised study plans for training programmes should be implemented, building on the existing ASEAN Credit Transfer System and linked to MRA-approved qualifications. Third, a joint ASEAN–Japan framework should define future skill requirements to inform human resource development. Japan's Digital Skill Standard, which integrates digital literacy with business applications, offers a practical model for adoption. Fourth, ASEAN and Japan should incorporate common skills into educational programmes by engaging with multiple

education providers, including Japan's National Institute of Technology (Kōtō Senmon Gakkō [KOSEN]) colleges, to ensure better alignment between education and evolving labour market demands.

These education system development initiatives are closely linked to direct human resource exchange efforts that enhance practical, on-the-ground skills transfer and real-time industry alignment. The deployment of Japanese technicians to ASEAN plays a key role in bridging the gap between classroom-based instruction and industry needs. These experts can provide targeted training aligned with evolving production technologies, supporting local upskilling in areas such as automotive electrification, diagnostics, and mechatronics. Conversely, the dispatch of ASEAN personnel to Japan enables structured skill acquisition in high-standard operational environments, helping build a workforce capable of contributing to local and regional industrial upgrading.

In addition to the MRA and digital skills standardisation initiatives under the ASEAN–Japan 50th Anniversary Project (Section 9.3.3), Japan has demonstrated a long-standing commitment to this form of technical cooperation through the AMEICC framework. To support ASEAN economic integration, Japan has implemented various initiatives, such as the Dispatch of Roving Automotive Experts to Indonesia, Malaysia, the Philippines, and Thailand. It has provided technical support for the development of road maps for the integration of automotive and electronic sectors through expert dispatch (MoFA, n.d.). Japanese experts are routinely dispatched to developing countries to share applied technical knowledge with government officials and engineers through Japan International Cooperation Agency (JICA) cooperation schemes. When appropriate, JICA employs a third-country dispatch model, sending experts from countries other than Japan or the partner country and drawing on regional talent pools to deliver technical assistance more efficiently and in a contextually appropriate manner.

In Indonesia, Japan has sent 22 experts in welding to support training in management techniques and standard curriculum certification to enhance welding engineering skills and training capacity (Mursitama et al., 2019). In Thailand, the emphasis on building a high-quality workforce to support Automotive Industry 4.0 has led to stronger collaboration with Japan. For example, Japan's Ministry of Health, Labour and Welfare has been requested to send experts and co-organise training sessions aimed at enhancing technician and engineer competencies (Vietnam Plus, 2017). In Malaysia, the Japan External Trade Organization (n.d.) dispatched experts from Nissan to train master trainers and assist in developing a standardised syllabus for a new skill training centre. These trainers are expected to transfer knowledge to vocational school instructors and workers in private industry, with the facility envisioned as a model institution that can help raise training quality and better align public vocational schools with industry needs.

Complementary initiatives have been introduced to improve the mobility of skilled professionals between ASEAN and Japan (ASEAN, 2023). These include (i) training of local Japanese language teachers to prepare foreign workers for life and work in Japan; (ii) providing Japanese language tests and skills development programmes tailored to key

target sectors; and (iii) exploring mutual recognition of skills between ASEAN and Japan, particularly in technical and professional fields.

Through the METI (2022) report on the ASEAN Economic Ministers–METI consultation, both sides agreed to enhance the quality of TVET in Cambodia, the Lao People's Democratic Republic, Myanmar, and Viet Nam, including the development of an internationally recognised curriculum in industrial electronics and the provision of vocational training aligned with regional industrial standards. The curriculum covers core modules such as circuit design, microcontroller programming, and digital systems, using training equipment and teaching materials that meet Japanese industrial specifications. In Cambodia, the curriculum includes automotive mechanic training, with a focus not only on repair but also on inspection and preventive maintenance to help reduce vehicle breakdowns.

From the cases above, it can be deduced that Japan's experience in aligning education, skills certification, and industry demand offers ASEAN a valuable partner in closing workforce gaps in DX and GX. Existing frameworks such as MRAs, credit transfer systems, and skill standards offer practical starting points for co-creation. To operationalise these efforts, academic and training qualifications should be systematically linked to MRAs, and curricula should be adapted to ensure compatibility with Japanese occupational standards and emerging automotive sector demands.

9.2.4. Automotive-related Regulations Commonalisation

A vehicle inspection and maintenance regulation scheme is needed to promote vehicle renewal and improve fleet efficiency, thereby supporting net-zero emission targets through in-use vehicle carbon dioxide reductions (Section 8.10.4.3). In line with this policy direction, the proposed co-creation areas focus on aligning key regulatory frameworks in ASEAN with established Japanese practices, particularly in vehicle inspection and automotive maintenance certification, to support environmental and safety outcomes.

Two key areas of collaboration are proposed. First, ASEAN could enhance its vehicle replacement mechanisms by introducing a vehicle inspection system modelled on Japan's, which has proven effective in ensuring roadworthiness and encouraging timely vehicle renewal. Second, the co-creation initiative could involve adopting Japan's automotive maintenance certification framework to support high-quality technical training and facilitate the development and mobility of skilled maintenance professionals across the region.

Establishing regulatory frameworks for vehicle inspection and maintenance, aligned with Japan's proven systems, offers ASEAN multiple benefits. According to RevvedUp Ride (2025), Japan's regulatory landscape is evolving rapidly, with growing emphasis on sustainability, stricter emission standards, and the adoption of safety technologies such as advanced driver-assistance systems. Central to this shift is Japan's legally mandated vehicle inspection and maintenance framework, established under the Road Transport

Vehicle Act and in operation for over 70 years. The system ensures regular checks to uphold vehicle safety, environmental performance, and roadworthiness. In Japan, maintenance is not merely a technical requirement but a deeply embedded norm that reflects a national commitment to precision, safety, and operational excellence. As ASEAN seeks to build more structured inspection and maintenance regimes, Japan's long-standing approach offers a credible and adaptable model for regulatory co-creation.

The feasibility of this co-creation area is further supported by preliminary initiatives in Cambodia and Myanmar, where Japan has begun providing institutional and technical support. In Cambodia, Japan has supported the development of a vehicle inspection system modelled on its own regulatory framework. According to JICA (n.d.), the Ministry of Public Works and Transport of Cambodia formally requested support through the Administrative Reform Project for Cambodia's Vehicle Registration and Inspection System. In response, JICA conducted a detailed planning survey in December 2015 and, in coordination with Cambodian stakeholders, identified a set of cooperation components. As part of the project, Japanese experts were dispatched to reinforce Cambodia's vehicle registration and inspection systems, including support to upgrade the IT infrastructure underpinning these functions (NTT Data, 2016). Japan's engagement in Cambodia is considered part of a broader effort to expand vehicle registration and inspection systems to other emerging markets, in line with the Japanese government's infrastructure cooperation strategy.

In Myanmar, co-creation efforts have focused on strengthening automotive maintenance capabilities through collaboration with TVET institutions. On 10 January 2020, JICA officially began construction of the Japan–Myanmar Aung San Vocational Training Institute. As a government technical institute, the school is expected to become a model of Japanese-standard TVET in the fields of automobile maintenance and electrical engineering. Since August 2018, four long-term experts from Japan have been supporting Myanmar's Ministry of Education in developing curricula, textbooks, and training for teachers and management staff. The 3-year programme in automobile maintenance and industrial electrical engineering will accommodate up to 20 trainees per batch and is expected to foster highly skilled labour and expand employment opportunities in Myanmar's automotive sector (Eleven Myanmar, 2020).

To operationalise this co-creation area, AMSs must adopt inspection and maintenance frameworks that reflect local needs and international best practices, such as those Japan has supported in several AMSs. These initiatives should be expanded and scaled up. Taken together, these collaborations illustrate feasible and scalable entry points for advancing vehicle regulatory harmonisation in ASEAN through structured co-creation with Japan.

9.2.5. Support for Developing Recycling and Circular Economy Rules

To secure a stable secondary flow of rare metals and key inputs for the ICE, HEV, and xEV supply chain, recycling and scrappage regulations should be introduced to increase the formal recycling rate of end-of-life vehicle (ELV) components (Section 8.10.4.4). In

response, the proposed co-creation area involves supporting the development of automotive recycling regulations modelled on Japan's system to help establish an effective resource circulation framework across the region.

Establishing regulatory frameworks for recycling and circulation aligned with Japan's proven systems is expected to offer ASEAN multiple benefits. For one, Japan has a long-standing tradition of recycling and resource conservation, rooted in cultural practices and reinforced by comprehensive government policies (Tamaki and Wada, 2023). Japan maintains one of the highest automotive recycling rates globally. Under the Automotive Recycling Law, most of ELVs are recycled, including through the recovery of heat energy from the incineration of unrecyclable waste (Marklines, 2024), surpassing countries such as the Republic of Korea, where the overall ELV recycling rate stands at 89.1% (Lee et al., 2025). Given Japan's mature legal and operational framework, co-creating recycling and resource circulation rules with Japan would enable ASEAN to develop a regionally coherent policy approach, avoid the inefficiencies of fragmented national systems, accelerate the transition to a circular economy in the automotive sector, and strengthen material security and sustainability throughout the vehicle life cycle.

The feasibility of this co-creation area is further reinforced by Japan's prior involvement in supporting ELV regulatory development, such as its collaboration with the Philippines to introduce a structured vehicle disposal system. In 2024, JICA and the Japanese automotive recycling manufacturer Tsuruoka Co., Ltd. held a grand launch of the Philippines' first Japan-standard ELV dismantling facility, established by local partner EN-Tsumugi in Pampanga province (JICA, 2024). The facility aims to reuse recycled parts from ELVs, promote proper disposal and waste reduction, and contribute to the circular economy. In addition to improving resource efficiency, the project seeks to evaluate the economic and employment potential of ELV recycling, beginning in the Philippines and expanding through regional partnerships with Japan and other interested countries.

As part of the programme, JICA is bringing in innovative Japanese technology to promote modern, environmentally sustainable production and consumption patterns in the automotive industry. In doing so, JICA partnered with Toyota Motor Corporation and Mitsui & Co., Ltd., which provided business development and technical assistance (Desiderio, 2024). Toyota Motor Philippines Corporation contributed technical support in key areas such as environmental compliance, facility design, dismantling methodology, equipment standards, and hazardous waste management (Toyota, 2024). The Philippines' case illustrates how this collaboration translates into practical implementation and highlights its potential for broader application across the region.

9.2.6. Biofuel and E-fuel Manufacturing and Technical Support

To scale up biofuel and e-fuel usage, ASEAN must advance its manufacturing capabilities at scale in a way that strengthens sustainable energy security, incorporates technology, and remains cost-competitive. First-generation feedstock is becoming increasingly limited, and ASEAN has the opportunity to expand its use of second-generation (2G) resources to

scale up the regional biofuel economy (Section 8.9.2.1). 2G biofuels, derived from non-edible biomass, offer a viable pathway to decarbonise hard-to-abate sectors such as transport and heavy industry, whilst minimising competition with food production.

It is imperative to consider ASEAN's regional strength as an abundant provider of 2G feedstock. This area holds strong potential due to the availability of residual biomass from palm oil, sugarcane, cassava, and other regionally abundant crops. A potential co-creation area lies in deploying technology transfer mechanisms and joint manufacturing capabilities from Japan, whilst leveraging ASEAN's biomass resources for 2G biofuel production.

In line with ERIA's earlier publication, Japan has long held an advantage in the research and development of 2G biofuel production in Asia (Yamaguchi, 2013). As early as 2013, Japan promoted the production of biofuels from cellulose and unused resources, with research and development in 2G biofuels remaining highly active (Koizumi, 2013). Verification tests and large-scale demonstration projects have been launched, with continuous innovation aimed at reducing production costs and improving the logistics of feedstock procurement. Most ASEAN countries possess an abundance of biomass resources due to their agriculture-based economies and expansive forest sectors (Tun et al., 2019).[1] The total annual volume of biomass potential from the agriculture and forestry sectors is estimated at over 500 million tonnes per year, equivalent to more than 8,000 million gigajoules of total energy potential. Given this untapped supply base, a co-creation approach focused on converting ASEAN's biomass into transport-grade fuel is both timely and technically feasible.

The feasibility of this approach is supported by use cases such as the activities of the New Energy and Industrial Technology Development Organization (NEDO) to promote biofuel development in Southeast Asia. Since 2023, NEDO has been studying the feasibility of 2G biofuel production, particularly using palm oil residues in Indonesia. The Japanese government, through METI and NEDO, has expressed its intention to deepen cooperation with Indonesia in this area. At the 2024 Japan–Indonesia Automotive Policy Dialogue, the two governments reached a basic agreement to consider establishing a task force to promote the use of bioethanol in the Indonesian transport sector, with the first session held in November 2025. Earlier, in February 2025, NEDO conducted the Business and Technology Introduction and Exchange Meeting on Non-Edible Biomass-Based Biofuels. This initiative aimed to facilitate a demonstration project involving Japanese and Indonesian companies to explore commercial-scale production of 2G biofuels using non-edible feedstock.

In Thailand, the National Energy Technology Center and NEDO have launched H-FAME, a premium biodiesel that reduces engine wear and is suitable for heavy-duty trucks (Bangkok Post, 2025). H-FAME was first developed in 2017 with the support of JICA and

[1] Tun et al. (2019) found that major biomass sources in the region include fuelwood, wood residues, rice husk, rice straw, sugarcane residues, oil palm residues, and coconut residues.

the Japan Science and Technology Agency. The fuel has since undergone extensive testing and is now ready for mass production. Its performance is comparable to B7, a commonly used diesel blend, but with significantly lower particulate emissions. By leveraging Japanese technology, H-FAME is expected to help Thailand's firms comply with the European Union's Carbon Border Adjustment Mechanism whilst also contributing to Thailand's national targets of carbon neutrality by 2050 and net-zero greenhouse gas emissions by 2065.

Under NEDO's leadership, the Japanese packaging firm Rengo has launched a demonstration project targeting production of 20,000 kilolitres per year of 2G ethanol by 2027, using unused biomass resources such as construction waste (Maeda, 2024). The resulting bioethanol will be directed towards the production of sustainable aviation fuel, further demonstrating the technological scalability of Japan's 2G biofuel ecosystem.

It can be inferred that the Japanese government is not only committed to advancing 2G biofuel technologies domestically but has also demonstrated experience and active engagement in facilitating their deployment across ASEAN. Even for technologies developed and used by Japanese companies, the government has demonstrated openness and willingness to support knowledge transfer and adapt these solutions to the ASEAN context.

To build on this momentum, ASEAN should focus on expanding local 2G biofuel production by leveraging its abundant biomass resources. In parallel, Japan can continue supporting these efforts through targeted technology transfer, technical cooperation, and the joint development of scalable production models, particularly for strategic sectors such as automotive.

9.2.7. Information and Data Standardisation Development

To achieve data standardisation, connectivity, and digitalisation in the automotive sector, efforts must go beyond national strategies and establish regionally interoperable data systems. The proposed co-creation area centres on the joint development of institutional and regulatory foundations to operationalise the ASEAN automotive data space. Developing such a regionally unified data platform from scratch to meet global traceability standards would require substantial investment, coordination, and technical capacity. As an alternative, the proposed co-creation area considers the potential use of Japan's Ouranos Ecosystem as a cost-effective and immediately scalable foundation.

By leveraging Japan's experience with the Ouranos Ecosystem, particularly in data standardisation, real-time traceability, and cross-border data governance, this collaboration aims to support ASEAN in building interoperable protocols, aligning regulatory frameworks, and designing secure, scalable systems that connect stakeholders across AMSs and supply-chain tiers. Given the strong presence of Japanese automotive and battery-related companies operating across ASEAN, exploring connectivity with this existing system offers strategic advantages in feasibility and industry alignment. For

instance, one way to use the platform would be to enable traceability through an EV battery passport to monitor battery material origin, life cycle, and sustainability compliance.

Japan's development of the Ouranos Ecosystem provides a foundation for this co-creation (Section 8.3.2.3.1). Initiated by METI, Ouranos promotes the realisation of Data Free Flow with Trust by integrating multiple systems to facilitate data use across industries, thereby advancing the interoperability of data, systems, and business functions (METI, 2025b). The ecosystem is continually expanding its use cases to support integrated sharing of critical data and services across economic activities. The Ouranos digital framework presents various use cases across the automotive supply and value chain, from which ASEAN can draw valuable insights (Figure 8-3.1).

One of the Ouranos Ecosystem's use cases is the automotive and battery carbon footprint traceability centre, which plays a central role in material and carbon footprint tracking. The platform provides traceability services that securely link data between companies across the automotive and battery supply chains (ABtC, 2025). The centre is exploring approaches to ensure interconnection and interoperability with global data infrastructures through public–private collaboration. Data exchanged through the centre include Carbon Footprint of Products (CFP) and due diligence information across the battery value chain. The CFP encompasses carbon dioxide emissions generated at each stage, from raw material procurement to manufacturing, transport, and use (METI, 2025b).

This traceability capability is increasingly critical for ASEAN in light of evolving international regulatory requirements, particularly the European Union Battery Regulation. For instance, Article 7 of the regulation is expected to mandate CFP disclosure for batteries within the next few years, whilst Article 48 introduces supply-chain due diligence obligations (METI, 2025b). In the longer term, compliance with Article 8 on recycled content and Article 77 on battery passports will be required. ASEAN's potential collaboration with Japan, particularly through strengthening connectivity with the Ouranos Ecosystem, presents a promising pathway for accelerating traceability preparedness and aligning with key international markets.

The Ouranos Ecosystem is being considered for overseas deployment, particularly in Southeast Asia (METI, 2025b). As this expansion proceeds, ASEAN has an opportunity to tap into Japan's expertise in data governance and system integration to accelerate the development of its own cross-border data-sharing architecture. Ultimately, the Ouranos Ecosystem initiative highlights Japan's advanced capabilities in constructing interoperable data ecosystems and its ongoing commitment to scaling them globally. As regional momentum grows around trusted digital integration, such platforms offer ASEAN a practical foundation to align with international traceability standards and strengthen its digital infrastructure for global supply-chain transparency.

9.2.8. Green Energy Industrial Park Model Development

To overcome gaps in enabling infrastructure for carbon-neutral manufacturing in ASEAN,

the development of a coordinated green energy industrial park programme was identified as a recommended policy direction (Section 8.10.6.1). This approach seeks to concentrate decarbonisation-enabling infrastructure and services within designated industrial zones to optimise resource use, facilitate investment, and accelerate net-zero transitions at scale.

For this topic, the proposed co-creation area focuses on the development of a green energy industrial park model to support the decarbonisation of SMEs in ASEAN. This model serves as a replicable demonstration of how low-carbon infrastructure, energy services, and technical assistance can be concentrated within industrial zones to improve efficiency and reduce emissions. Through the green energy industrial park model, ASEAN and Japan can jointly resolve SMEs' challenges by aggregating energy demand,[2] facilitating shared infrastructure, and establishing support mechanisms tailored to SME capacities and constraints.

By jointly developing a green energy industrial park model, ASEAN and Japan can create a platform for co-creation that delivers collective economic, environmental, and social benefits. As noted by the United Nations Industrial Development Organization (2025), industrial parks enable cost-effective access to shared environmental infrastructure such as wastewater treatment and pollution control, particularly benefitting SMEs that lack the capacity to adopt such systems independently. The Green Industry Platform (2025) further highlights that these parks foster resource productivity, technological synergies, and socially responsible practices, resulting in more competitive and resilient industrial zones. By leveraging Japan's technical expertise and ASEAN's local resource base, the model supports energy security and creates value chains rooted in local communities. Co-developing such parks not only accelerates regional decarbonisation but also ensures that the approach is practical, scalable, and regionally grounded.

The feasibility of this co-creation area is reinforced by Japan's involvement in the development of the Patimban Port Green Corridor in Indonesia. Through METI, a memorandum of understanding was signed between Pertamina and Toyota Tsusho Indonesia to jointly explore carbon-neutral fuel solutions for the Eastern GX Corridor, an initiative aimed at decarbonising logistics and industrial zones in eastern Jakarta (METI, 2024). For the automotive industry, Patimban Port plays a central role as a strategic hub for export–import logistics. The establishment of a green corridor at this site highlights its potential to become a regional centre for international trade, as noted by the Indonesian minister of industry (Industri Kontan, 2021). As of June 2025, the project has entered detailed discussions with private sector stakeholders to evaluate implementation feasibility beyond the government level. The masterplan is scheduled for adoption by the end of 2026, with feasibility studies and demonstration activities expected to proceed in parallel as the groundwork for phased commercialisation starting in 2028.

The Patimban Port collaboration reflects Japan's active role in promoting industrial

[2] Many SMEs face structural barriers to climate action, including limited financial incentives, weak regulatory enforcement, and a lack of access to decarbonisation technologies or expertise (Section 8.9.4).

decarbonisation through green industrial park development. Given the scale and reach of such initiatives, this model of co-creation offers a practical pathway that should be continued and extended to other countries as the region collectively advances its low-carbon transition.

9.2.9. Support for Strengthening the ASEAN Single Window

To enhance connectivity, efficiency, and the resilience of regional supply chains, strengthening the ASEAN Single Window (ASW) remains a key co-creation priority. The proposed co-creation area involves Japan's support for the further technical and institutional enhancement of the ASW, aimed at enabling more seamless cross-border transfer of goods across the region.

The feasibility of this co-creation area is demonstrated by Japan's long-standing involvement in the establishment and development of single window systems throughout ASEAN. Japan has supported Viet Nam customs for over 2 decades, particularly in the development of the Vietnam Automated Cargo Clearance System (VNACCS) and the Vietnam Customs Intelligence Information System (VCIS), along with technical assistance, training, and human resource development (Viet Nam Chamber of Commerce and Industry, 2021). VNACCS/VCIS is an electronic customs system, deployed since April 2014 as part of the Japanese government's aid package to Viet Nam (HML Supply Chain, 2025). Viet Nam adopted Japan's customs model, recognising Japan customs as a reference authority with one of the most advanced and modern management systems globally. To facilitate this collaboration, Japan provided technical expertise and capacity building to Viet Nam customs, including the upgrade of the VNACCS/VCIS system, and its integration with the national single window (NSW) to streamline import and export processes.

Drawing on its experience in supporting Viet Nam, Japan is well positioned to assist ASEAN in achieving greater regional digital connectivity and institutional alignment under the ASW framework. Japan's engagement in ASEAN's digital integration efforts has been long-standing. As early as 2015, Japan, through the Ministry of Finance and JICA, provided technical assistance to streamline customs processes and simplify cross-border procedures, particularly through the ASW and NSWs, with a focus on facilitating trade and improving physical connectivity (Nguyen and Vo, 2015).

In 2020, Japan reaffirmed its support for strengthening ASEAN's connectivity by aligning with the Master Plan on ASEAN Connectivity 2025 and committing to continue both infrastructure and institutional support (MoFA, 2020). The support included more than JPY2 trillion in infrastructure investments and capacity-building projects that complement ASW efforts, reflecting a mature foundation for expanding ASW cooperation under a shared ASEAN–Japan framework.

More recently, several forward-looking proposals have emerged from the 50th Anniversary project in 2023. The first proposition is to scale the digitisation of trade operations, including the online processing of bills of lading and certificates of origin

through NSWs and the ASW, across ASEAN and Japan. Second, system connectivity between the ASW, NSWs, and private sector platforms must be strengthened to enable interoperability and broader trade facilitation. The ASEAN secretary general noted that a major step would be to integrate Japan into the ASW digital platform (Jakarta Globe, 2023).

Finally, ASEAN's ongoing study on the next-generation ASW in 2024 is expected to yield substantial gains, including shorter customs clearance times, more reliable trade data, and deeper regional integration (Vietnam National Trade Repository, 2024). To maximise the impact of this initiative, ASEAN and Japan could build on their existing institutional linkages and technical foundations to jointly advance the next-generation ASW. In doing so, both sides must prioritise actionable steps such as aligning digital protocols, transferring technical assistance, enabling cross-border system interoperability, and piloting connectivity to support wider inter-regional integration.

9.2.10. Support for Policy and Regulatory Development

Effective implementation of the masterplan's strategic directions requires not only technical projects but also actionable and feasible national policy frameworks. The proposed co-creation area involves Japan's continued support for policymaking processes in ASEAN through capacity building, regulatory planning, and advisory cooperation, drawing on Japan's institutional experience and long-standing track record in policy-oriented development assistance.

Japan's approach to legal and regulatory development is particularly valuable for ASEAN. Whilst Japan has incorporated advanced legal systems from other developed countries, it has also customised and adapted these laws to the cultural and societal contexts within its existing system (JICA, 2012). Consequently, this adaptive approach offers ASEAN countries concrete insights into how to localise global standards without sacrificing coherence or enforceability. Japan's experience in drafting, revising, and upgrading laws in response to national development stages has proven instrumental in achieving both social stability and economic growth. These strengths highlight the value of Japan's support as ASEAN seeks to operationalise the masterplan's policy directions through locally grounded yet internationally aligned regulations.

One key avenue for this support is through JICA's assistance, which has played a central role in supporting policy and regulatory development across various sectors in ASEAN. Based on the Basic Principles of JICA's Cooperation Planning (2022), co-creation is expected to take place through Technical Cooperation for Development Planning. Under this scheme, JICA conducts studies needed to support recipient countries in formulating policies and masterplans, typically by dispatching JICA missions. In turn, recipient countries are expected to formulate sector or regional development plans, rehabilitation or reconstruction programmes, and institutional reform strategies using the study results. These plans may then be implemented by mobilising funding from international organisations or other partners and by carrying out the organisational or policy actions recommended through the cooperation.

Such a co-creation approach is already reflected in JICA's extensive track record of supporting legislative and regulatory formulation across Asia, including AMSs. Since 2012, JICA's cooperation in this field has primarily involved assistance with drafting basic civil laws (Viet Nam, Lao People's Democratic Republic, Uzbekistan, Cambodia, Nepal, China, Timor-Leste); economic laws such as competition law (Viet Nam, China, Indonesia); and the development of civil dispute resolution mechanisms (Mongolia, Indonesia).

Another example is JICA's support to the Philippines in preferential taxation systems. Recognising that many of the country's tax exemption and deduction schemes lacked oversight and effectiveness, JICA conducted a comprehensive utilisation survey and found that about 40% of the schemes were not being used, with no mechanisms in place to estimate revenue losses. Based on these findings, JICA co-developed policy reform proposals and action plans, including measures such as auditing, inter-agency information sharing, and increased transparency through tax expenditure reporting, to improve the system's efficiency and alignment with policy objectives. The deputy minister of finance at the time said that the assistance helped shape the core framework of the preferential taxation system, leading to improved oversight and more effective use of the country's tax incentives.

ASEAN and Japan should build on this strong foundation by institutionalising structured policy support mechanisms under the masterplan framework. As ASEAN countries begin implementing national strategies aligned with regional goals, Japan's adaptive and locally sensitive policymaking expertise can serve as both a guide and partner in designing responsive, evidence-based regulations. By anchoring co-creation in real policy cycles (planning, reform, and implementation), this approach is expected to deliver high-impact, scalable governance solutions that enable the masterplan's strategic directions to materialise across diverse national contexts.

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Annexes

Annex 1: Survey Results

Table 1.1. Breakdown of Respondents by Location Type across ASEAN Countries

Countries	Country Office	Global HQ	Regional HQ	Grand Total
Cambodia	5	-	-	5
Indonesia	335	-	-	335
Lao PDR	3	-	-	3
Malaysia	268	-	-	268
Myanmar	2	-	-	2
Philippines	74	-	1	75
Singapore	88	-	-	88
Thailand	1,187	6	4	1,197
Viet Nam	61	16	83	160
Grand Total	2,024	22	88	2,133

Source: Authors, 2025.

Table 1.2. Direct Business Relationship with OEMs, by Country

Countries	Yes	No	OEM	Grand Total
Cambodia	3	2	0	5
Indonesia	1	330	4	335
Lao PDR	3	0	0	3
Malaysia	0	260	8	268
Myanmar	2	0	0	2
Philippines	14	60	1	75
Singapore	0	88	0	88
Thailand	462	725	10	1,197
Viet Nam	148	8	4	160
Grand Total	633	1,473	27	2,133

Source: Authors, 2025.

Table 1.3. Breakdown of Company Establishment Timeline in ASEAN by Country

Countries	<1949	1950-1959	1960-1969	1970-1979	1980-1989	1990-1999	2000-2009	2010-2019	2020-2024	Grand Total
Cambodia	2	1	0	2	0	0	0	0	0	5
Indonesia	7	6	5	39	41	85	72	71	9	335
Lao PDR	0	0	0	0	1	0	1	1	0	3
Malaysia	1	4	6	23	62	108	38	25	1	268
Myanmar	0	0	0	2	0	0	0	0	0	2
Philippines	13	2	3	5	4	29	10	8	1	75
Singapore	3	1	4	24	12	26	12	5	1	88
Thailand	29	16	51	86	158	337	289	200	32	1,197
Viet Nam	1	1	2	6	4	28	49	63	6	160
Grand Total	56	31	71	186	282	613	471	373	50	2,133

Source: Authors, 2025.

Table 1.4. Breakdown of Company Ownership in ASEAN, by Country

Countries	Domestic Company	Foreign-Affiliated Company	Grand Total
Cambodia	1 (20%)	4 (80%)	5
Indonesia	331 (99%)	4 (1%)	335
Lao PDR	0 (0%)	3 (100%)	3
Malaysia	260 (97%)	8 (3%)	268
Myanmar	0 (0%)	2 (100%)	2
Philippines	61 (81%)	13 (19%)	75
Singapore	88 (100%)	0 (0%)	88
Thailand	1,171 (98%)	26 (2%)	1,197
Viet Nam	57 (36%)	103 (64%)	160
Grand Total	1,969	163	2,133

Source: Authors, 2025.

Table 1.5. Breakdown of Total Company Sales in ASEAN by Country (US$ million, 2023)

Countries	<5	5-10	10-50	50-100	100-250	250-500	500-750	750-1,000	1,000–2,500	2,500–5,000	>=5,000	Grand Total
Cambodia	0	0	1	1	0	0	0	0	0	0	0	5
Indonesia	22	10	13	6	5	9	3	0	2	2	0	335
Lao PDR	0	0	0	0	0	0	0	0	0	0	0	3
Malaysia	58	43	27	7	24	11	2	2	2	1	0	268
Myanmar	0	0	0	0	0	0	0	0	0	0	0	2
Philippines	11	3	2	0	0	0	0	0	0	0	0	75
Singapore	2	5	5	2	4	2	2	1	4	1	1	88
Thailand	216	81	159	33	21	14	4	0	3	1	53	1,197
Viet Nam	15	14	24	22	9	8	5	3	3	2	1	160
Grand Total	324	156	231	71	63	44	16	6	14	7	55	2,133

Source: Authors, 2025.

Table 1.6. Breakdown of Total Company Profit in ASEAN by Country
(US$ million, 2023)

Countries	<5	5-10	10-50	50-100	100-250	250-500	>500	Total Respondents
Cambodia	0	0	0	1	0	0	0	5
Indonesia	4	0	2	0	0	0	0	335
Lao PDR	0	0	0	0	0	0	0	3
Malaysia	0	2	3	1	2	0	0	268
Myanmar	0	0	0	0	0	0	0	2
Philippines	9	3	2	0	0	0	0	75
Singapore	0	0	1	1	1	0	0	88
Thailand	80	5	5	1	0	0	33	1,197
Viet Nam	28	9	32	16	6	4	3	160
Grand Total	121	19	45	20	9	4	9	2,133

Source: Authors, 2025.

Table 1.7. Breakdown of Company's Total Capital Size in ASEAN by Country
(US$ Million, 2023)

Countries	<5	5-10	10-50	50- 100	100-250	250-500	>500	Total Respondents
Cambodia	0	0	0	0	0	0	0	5
Indonesia	14	2	9	2	0	0	0	335
Lao PDR	0	0	0	0	0	0	0	3
Malaysia	4	1	1	0	0	0	1	268
Myanmar	0	0	0	0	0	0	0	2
Philippines	7	3	3	0	0	0	0	75
Singapore	0	1	0	0	0	0	0	88
Thailand	78	15	21	3	1	1	27	1,197
Viet Nam	14	11	30	21	4	9	4	160
Grand Total	117	33	64	20	9	4	9	2,133

Source: Authors, 2025.

Table 1.8. Breakdown of Vehicle and Vehicle Parts Produced by Companies, by Country

Countries	Passenger Vehicle	Commercial Vehicle
Cambodia	5 (100%)	5 (100%)
Indonesia	319 (95%)	52 (16%)
Lao PDR	3 (100%)	3 (100%)
Malaysia	259 (97%)	29 (11%)
Myanmar	0 (0%)	2 (100%)
Philippines	67 (89%)	19 (25%)
Singapore	82 (93%)	10 (11%)
Thailand	1,176 (98%)	568 (47%)
Viet Nam	157 (98%)	125 (78%)

Source: Authors, 2025.

Table 1.9. Breakdown of Powertrain Vehicle Types Produced by Companies, by Country

Countries	ICE	HEV	PHEV	BEV	FCEV	Biofuel	Other	Not Sure
Cambodia	3 (60%)	5 (100%)	3 (60%)	5 (100%)	2 (40%)	1 (20%)	0 (0%)	0 (0%)
Indonesia	115 (34%)	10 (3%)	0 (0%)	17 (5%)	0 (0%)	0 (0%)	3 (1%)	210 (63%)
Lao PDR	2 (67%)	3 (100%)	2 (67%)	2 (67%)	1 (33%)	0 (0%)	1 (33%)	0 (0%)
Malaysia	11 (4%)	7 (3%)	1 (0%)	10 (4%)	0 (0%)	0 (0%)	2 (1%)	254 (95%)
Myanmar	0(0%)	2 (100%)	2 (100%)	2 (100%)	0 (0%)	0 (0%)	1 (50%)	0 (0%)
Philippines	34 (45%)	3 (4%)	8 (11%)	5 (7%)	0 (0%)	1 (1%)	6 (8%)	29 (39%)
Singapore	50 (57%)	7 (8%)	1 (1%)	3 (3%)	0 (0%)	0 (0%)	0 (0%)	35 (40%)
Thailand	115 (10%)	55 (5%)	60 (5%)	83 (7%)	52 (4%)	14 (1%)	9 (1%)	928 (78%)
Viet Nam	43 (27%)	119 (74%)	122 (76%)	117 (73%)	78 (49%)	0 (0%)	9 (6%)	8 (5%)
Grand Total	373	211	199	244	133	16	31	1,464

Source: Authors, 2025.

Table 1.10. Breakdown of Product Types Produced by Companies by Country

Countries	Vehicle Assembly	Powertrain and Related Components	Electric and Electronic	Interior	Exterior	Chassis	Body	General/ Small Parts	Other	Total Respondents
Cambodia	0	0	3	0	0	0	0	2	0	5
Indonesia	148	60	60	24	19	66	24	47	33	335
Lao PDR	1	0	2	0	0	0	0	0	0	3
Malaysia	83	26	98	26	11	28	7	40	11	268
Myanmar	0	1	1	0	0	0	0	0	0	2
Philippines	29	8	24	5	6	3	3	9	4	75
Singapore	51	13	33	1	4	9	3	7	0	88
Thailand	439	112	161	87	45	116	60	163	250	1,197
Viet Nam	8	20	62	25	11	29	21	38	10	160
Grand Total	759	240	444	168	96	251	118	306	308	2,133

Source: Authors, 2025.

Table 1.11. Powertrain-Related Products Produced by Companies

Countries	Main Engine Parts	Valve Train System	Fuel, Injection System	Intake, Exhaust System	Ignition System	Lubrication System	Cooling System	Starter	Transmission, Clutch	Drive Battery	e-Axl, traction motor	Electric powertrain related parts	Other
Cambodia	0	0	0	0	0	0	0	0	0	0	0	0	0
Indonesia	28	1	1	5	0	0	2	0	15	14	0	10	0
Lao PDR	0	0	0	0	0	0	0	0	0	0	0	0	0
Malaysia	5	0	4	2	0	0	1	0	5	6	0	6	0
Myanmar	0	0	0	0	0	0	0	0	0	1	0	0	0
Philippines	5	1	0	2	0	0	0	0	1	2	0	2	1
Singapore	6	0	1	2	0	2	2	0	1	4	0	1	0
Thailand	56	3	10	13	0	1	8	0	18	13	0	8	6
Viet Nam	5	3	1	2	0	2	0	0	3	2	0	11	0
Grand Total	105	8	17	26	0	5	13	0	43	42	0	38	7

Source: Authors, 2025.

Table 1.12. Breakdown of Current Supply Distribution by Country

Countries	SEA	Other Asia	Middle East	Europe	America	Africa	Australia	Others
Cambodia	3 (60%)	3 (60%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	2 (40%)
Indonesia	335 (100%)	15 (4%)	1 (0%)	3 (1%)	9 (3%)	0 (0%)	0 (0%)	3 (1%)
Lao PDR	3 (100%)	2 (67%)	0 (0%)	1 (33%)	1 (33%)	0 (0%)	1 (33%)	0 (0%)
Malaysia	268 (100%)	8 (3%)	2 (1%)	4 (1%)	2 (1%)	1 (0%)	1 (0%)	0 (0%)
Myanmar	2 (100%)	2 (100%)	0 (0%)	0 (0%)	1 (50%)	0 (0%)	1 (50%)	0 (0%)
Philippines	75 (100%)	4 (5%)	0 (0%)	0 (0%)	5 (7%)	0 (0%)	1 (1%)	1 (1%)
Singapore	88 (100%)	2 (2%)	0 (0%)	0 (0%)	1 (1%)	0 (0%)	0 (0%)	0 (0%)
Thailand	1,187 (99%)	40 (3%)	7 (1%)	14 (1%)	25 (2%)	5 (0%)	8 (1%)	6 (1%)
Viet Nam	152 (95%)	82 (51%)	1 (1%)	10 (6%)	45 (28%)	5 (3%)	2 (1%)	1 (1%)
Grand Total	2,113 (99%)	158 (7%)	11 (1%)	32 (2%)	89 (4%)	11 (1%)	14 (1%)	13 (1%)

Source: Authors, 2025.

Table1.13. Breakdown of Current Supply Distribution within SEA Countries, by Country

Countries	Brunei	Cambodia	Indonesia	Lao PDR	Malaysia	Myanmar	Philippine	Singapore	Thailand	Viet Nam
Cambodia	0 (0%)	2 (40%)	1 (20%)	0 (0%)	2 (40%)	0 (0%)	0 (0%)	1 (20%)	3 (60%)	3 (60%)
Indonesia	0 (0%)	0 (0%)	334 (100%)	0 (0%)	5 (1%)	0 (0%)	8 (2%)	2 (1%)	8 (2%)	5 (1%)
Lao PDR	0 (0%)	0 (0%)	1 (33%)	3 (100%)	1 (33%)	1 (33%)	0 (0%)	0 (0%)	2 (67%)	2 (67%)
Malaysia	2 (1%)	1 (0%)	3 (1%)	1 (0%)	265 (99%)	2 (1%)	4 (1%)	2 (1%)	6 (2%)	5 (2%)
Myanmar	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (50%)	2 (100%)	0 (0%)	1 (50%)	2 (100%)	2 (100%)
Philippines	0 (0%)	0 (0%)	1(1%)	0 (0%)	1 (1%)	0 (0%)	75 (100%)	1 (1%)	1 (1%)	0 (0%)
Singapore	0 (0%)	0 (0%)	1 (1%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	87 (99%)	0 (0%)	0 (0%)
Thailand	1 (0%)	0 (0%)	16 (1%)	1 (0%)	12 (1%)	1 (0%)	4 (0%)	12 (1%)	1,186 (99%)	22 (2%)
Viet Nam	0 (0%)	0 (0%)	40 (25%)	1 (1%)	20 (13%)	2 (1%)	33 (21%)	26 (16%)	39 (24%)	145 (91%)

Source: Authors, 2025.

Table 1.14. Breakdown of Current Manufacturing Locations by Country

Countries	Brunei	Cambodia	Indonesia	Lao PDR	Malaysia	Myanmar	Philippine	Singapore	Thailand	Viet Nam
Cambodia	0 (0%)	5 (100%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Indonesia	0 (0%)	0 (0%)	333 (99%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	2 (1%)	0 (0%)
Lao PDR	0 (0%)	0 (0%)	0 (0%)	3 (100%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (33%)	0 (0%)
Malaysia	0 (0%)	0 (0%)	1 (0%)	0 (0%)	265 (99%)	1 (0%)	0 (0%)	0 (0%)	2 (1%)	0 (0%)
Myanmar	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	2 (100%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Philippines	1 (1%)	1 (1%)	1 (1%)	1 (1%)	1 (1%)	1 (1%)	75 (100%)	1 (1%)	1 (1%)	1 (1%)
Singapore	0 (0%)	0 (0%)	1 (1%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	87 (99%)	1 (1%)	0 (0%)
Thailand	0 (0%)	0 (0%)	2 (0%)	0 (0%)	2 (0%)	0 (0%)	1 (0%)	0 (0%)	1,194 (100%)	5 (0%)
Viet Nam	1 (1%)	0 (0%)	1 (1%)	0 (0%)	2 (0%)	0 (0%)	4 (3%)	3 (2%)	5 (3%)	151 (94%)

Source: Authors, 2025.

Table 1.15. Breakdown of Respondents' Views on BEV and PHEV Penetration Rate Forecast, by Country

Countries	Yes		No	
	Total Respondents	% Total Respondents	Total Respondents	% Total Respondents
Cambodia	3	60%	2	40.0%
Indonesia	194	57.9%	141	42.1%
Lao PDR	1	33.3%	2	66.7%
Malaysia	257	95.9%	11	4.1%
Myanmar	1	50.0%	1	50.0%
Philippines	42	56.0%	33	44.0%
Singapore	59	67.0%	29	33.0%
Thailand	1,070	89.4%	127	10.6%
Viet Nam	146	91.3%	14	8.8%
Grand Total	1,773	83.2%	360	16.9%

Source: Authors, 2025.

Table 1.16. Breakdown of Revenue Projection by 2035, by Country

Countries	Decrease up to 100%	Decrease up to 75%	Decrease up to 50%	Decrease up to 25%	Remain Steady	Increase up to 25%	Increase up to 50%	Increase up to 75%	Increase up to 100%	Not Sure	Grand Total
Cambodia	0	0	0	0	1	3	1	0	0	0	5
Indonesia	0	0	0	0	158	30	6	0	0	141	335
Lao PDR	0	0	0	0	2	1	0	0	0	0	3
Malaysia	0	0	1	0	81	28	2	0	0	156	268
Myanmar	0	0	0	0	1	1	0	0	0		2
Philippines	0	0	0	1	9	1	1	0	0	63	75

Countries	Decrease up to 100%	Decrease up to 75%	Decrease up to 50%	Decrease up to 25%	Remain Steady	Increase up to 25%	Increase up to 50%	Increase up to 75%	Increase up to 100%	Not Sure	Grand Total
Singapore	0	0	0	0	38	13	0	0	0	37	88
Thailand	0	0	0	1	253	109	15	0	423	396	1,197
Viet Nam	1	2	2	5	20	34	52	13	6	25	160
Grand Total	1	2	3	7	563	220	77	13	429	818	2,133

Source: Authors, 2025.

Table 1.17. Breakdown of Powertrain Vehicle Types Companies Plan to Focus on in Response to the Above Forecast, by Country

Countries	ICE	HEV	PHEV	BEV	FCEV	Biofuel	Other	Not Sure	Total Respondents
Cambodia	0	0	0	2	0	0	0	3	5
Indonesia	21	5	4	9	1	0	0	304	335
Lao PDR	1	2	0	3	0	0	0	0	3
Malaysia	0	7	6	8	0	1	1	259	268
Myanmar	0	2	2	2	0	0	0	0	2
Philippines	12	2	3	1	0	2	5	57	75
Singapore	10	0	0	0	0	0	0	78	88
Thailand	7	55	61	76	39	10	4	1,023	1,197
Viet Nam	5	83	82	83	73	3	7	44	160
Grand Total	56	156	158	184	113	16	17	1,768	2,133

Source: Authors, 2025.

Table 1.18. Breakdown of Product Types Projection Produced by Companies, by Country

Countries	Vehicle Assembly	Powertrain and Related Components	Electric and Electronic	Interior	Exterior	Chassis	Body	General/ Small Parts	It is not decided yet	Other
Cambodia	0	0	3	0	0	0	0	2	0	0
Indonesia	38	16	29	14	11	23	7	12	205	4
Lao PDR	1	0	2	0	0	0	0	0	0	0
Malaysia	25	2	28	7	3	11	0	9	189	0
Myanmar	0	1	1	0	0	0	0	0	0	0
Philippines	11	1	13	4	0	0	0	1	48	0
Singapore	3	0	7	1	1	2	0	1	75	0
Thailand	199	21	59	40	14	39	12	34	792	10
Viet Nam	8	15	35	14	12	17	20	31	54	0
Grand Total	285	56	177	80	41	92	39	90	1,363	14

Source: Authors, 2025.

Table 1.19. Breakdown of Product Types Projection (Specific to Powertrain and Related Companies) Produced by Companies, by Country

Countries	Main Engine Parts	Valve Train System	Fuel, Injection System	Intake, Exhaust System	Ignition System	Lubrication System	Cooling System	Starter	Transmission, Clutch	Drive Battery	e-Axl, traction motor	Electric Powertrain Related Parts	Not Decided Yet	Other
Cambodia	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Indonesia	8	0	0	1	0	0	1	0	5	3	0	0	0	0
Lao PDR	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Malaysia	0	0	0	0	0	0	0	0	2	0	0	0	0	0
Myanmar	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Philippines	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Singapore	0	0	0	0	0	0	0	0	0	2	0	0	0	0

Countries	Main Engine Parts	Valve Train System	Fuel, Injection System	Intake, Exhaust System	Ignition System	Lubrication System	Cooling System	Starter	Transmission, Clutch	Drive Battery	e-Axl, traction motor	Electric Powertrain Related Parts	Not Decided Yet	Other
Thailand	9	1	1	2	0	1	1	0	8	1	1	7	0	0
Viet Nam	2	2	2	0	3	2	1	0	0	0	0	0	0	0
Grand Total	20	3	3	3	3	3	3	0	15	7	1	7	0	0

Source: Authors, 2025.

Table 1.20. Markets Where Companies Intend to Distribute Supplies in the future, by Country

Countries	SEA	Other Asia	Middle East	Europe	America	Africa	Australia	Others	Not Decided
Cambodia	3 (60%)	2 (40%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (20%)	1 (20%)
Indonesia	121 (36%)	6 (2%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	9 (3%)
Lao PDR	1 (33%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	2 (67%)	0 (0%)
Malaysia	78 (29%)	7 (3%)	0 (0%)	1 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Myanmar	2 (100%)	2 (100%)	0 (0%)	0 (0%)	1 (50%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Philippines	28 (37%)	2 (3%)	0 (0%)	0 (0%)	1 (1%)	0 (0%)	1 (1%)	0 (0%)	0 (0%)
Singapore	12 (14%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (1%)
Thailand	385 (32%)	14 (1%)	4 (0%)	6 (1%)	7 (1%)	1 (0%)	5 (0%)	8 (1%)	12 (1%)
Viet Nam	96 (60%)	73 (6%)	0 (0%)	8 (5%)	33 (21%)	3 (2%)	1 (1%)	2 (1%)	5 (3%)
Grand Total	726 (34%)	106 (5%)	4 (0%)	15 (1%)	42 (2%)	4 (0%)	7 (0%)	13 (1%)	28 (1%)

Source: Authors, 2025

Table 1.21. Breakdown of Future Supply Distribution within SEA Countries

Countries	Brunei	Cambodia	Indonesia	Lao PDR	Malaysia	Myanmar	Philippine	Singapore	Thailand	Viet Nam
Cambodia	0	3	0	0	2	2	0	2	2	2
Indonesia	0	0	120	0	2	0	1	0	1	1
Lao PDR	0	0	0	1	0	0	0	0	0	0
Malaysia	0	0	0	0	78	0	1	1	1	0
Myanmar	0	0	1	0	2	2	0	0	2	2
Philippines	2	1	1	1	1	1	27	1	1	1
Singapore	0	0	0	0	0	0	0	12	0	0
Thailand	1	0	5	0	10	0	3	5	385	9
Viet Nam	0	0	41	1	23	2	25	23	29	90
Grand Total	3	4	168	3	118	7	57	44	421	105

Source: Authors, 2025.

Table 1.22. Comparison of Current and Planned Supply Distribution

Countries		SEA	Other Asia	Middle East	Europe	America	Africa	Australia	Others	Not Decided Yet
Cambodia	Current	60%	60%	0%	0%	0%	0%	0%	40%	0%
Cambodia	Future	60%	40%	0%	0%	0%	0%	0%	20%	20%
Indonesia	Current	100%	4%	0%	1%	3%	0%	0%	1%	0%
Indonesia	Future	36%	2%	0%	0%	0%	0%	0%	1%	3%
Lao PDR	Current	100%	67%	0%	33%	33%	33%	0%	0%	0%
Lao PDR	Future	33%	0%	0%	0%	0%	0%	67%	0%	0%
Malaysia	Current	100%	3%	1%	1%	1%	0%	0%	0%	0%
Malaysia	Future	29%	3%	0%	0%	0%	0%	0%	0%	0%
Myanmar	Current	100%	100%	0%	0%	50%	50%	0%	0%	0%
Myanmar	Future	100%	100%	0%	0%	50%	0%	0%	0%	0%
Philippines	Current	100%	5%	0%	0%	7%	1%	1%	0%	0%
Philippines	Future	37%	3%	0%	0%	1%	1%1	0%	0%	0%
Singapore	Current	100%	2%	0%	0%	1%	0%	0%	0%	0%
Singapore	Future	4%	0%	0%	0%	0%	1%	0%	0%	0%
Thailand	Current	99%	3%	1%	1%	2%	0%	1%	1%	0%
Thailand	Future	32%	1%	0%	1%	1%	0%	0%	1%	1%
Viet Nam	Current	95%	51%	1%	6%	28%	3%	1%	1%	3%
Viet Nam	Future	60%	46%	0%	5%	21%	2%	1%	1%	3%

Source: Authors, 2025

Table 1.23. Breakdown of Planned Manufacturing Locations by Country

Countries	Brunei	Cambodia	Indonesia	Lao PDR	Malaysia	Myanmar	Philippine	Singapore	Thailand	Viet Nam
Cambodia	0 (0%)	5 (100%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Indonesia	0 (0%)	0 (0%)	126 (38%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (0%)	0 (0%)
Lao PDR	0 (0%)	0 (0%)	0 (0%)	2 (67%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Malaysia	0 (0%)	0 (0%)	1 (0%)	0 (0%)	78 (29%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Myanmar	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	2 (100%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Philippines	1 (1%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	28 (37%)	0 (0%)	0 (0%)	0 (0%)
Singapore	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	13 (15%)	0 (0%)	0 (0%)
Thailand	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	400 (33%)	1 (0%)
Viet Nam	2 (1%)	1 (1%)	0 (0%)	0 (0%)	1 (1%)	0 (0%)	2 (1%)	0 (0%)	3 (2%)	88 (55%)
Grand Total	3	6	154	2	84	2	32	15	432	139

Source: Authors, 2025.

Table 1.24. Comparison of Current and Planned Manufacturing Location

Countries		Brunei	Cambodia	Indonesia	Lao PDR	Malaysia	Myanmar	Philippine	Singapore	Thailand	Viet Nam
Cambodia	Current	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%
Cambodia	Future	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%
Indonesia	Current	0%	0%	99%	0%	0%	0%	0%	0%	1%	0%
Indonesia	Future	0%	0%	38%	0%	0%	0%	0%	0%	0%	0%
Lao PDR	Current	0%	0%	0%	100%	0%	0%	0%	0%	33%	0%
Lao PDR	Future	0%	0%	0%	67%	0%	0%	0%	0%	0%	0%
Malaysia	Current	0%	0%	0%	0%	99%	0%	0%	0%	1%	0%
Malaysia	Future	0%	0%	0%	0%	29%	0%	0%	0%	0%	0%
Myanmar	Current	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%
Myanmar	Future	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%
Philippines	Current	1%	1%	1%	1%	1%	1%	100%	1%	1%	1%
Philippines	Future	1%	0%	0%	0%	0%	0%	37%	0%	0%	0%
Singapore	Current	0%	0%	1%	0%	0%	0%	0%	99%	1%	0%
Singapore	Future	0%	0%	0%	0%	0%	0%	0%	15%	0%	0%
Thailand	Current	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%
Thailand	Future	0%	0%	0%	0%	0%	0%	0%	0%	33%	0%
Viet Nam	Current	1%	0%	1%	0%	1%	0%	3%	2%	3%	94%
Viet Nam	Future	1%	1%	0%	0%	1%	0%	1%	0%	2%	55%

Source: Authors, 2025.

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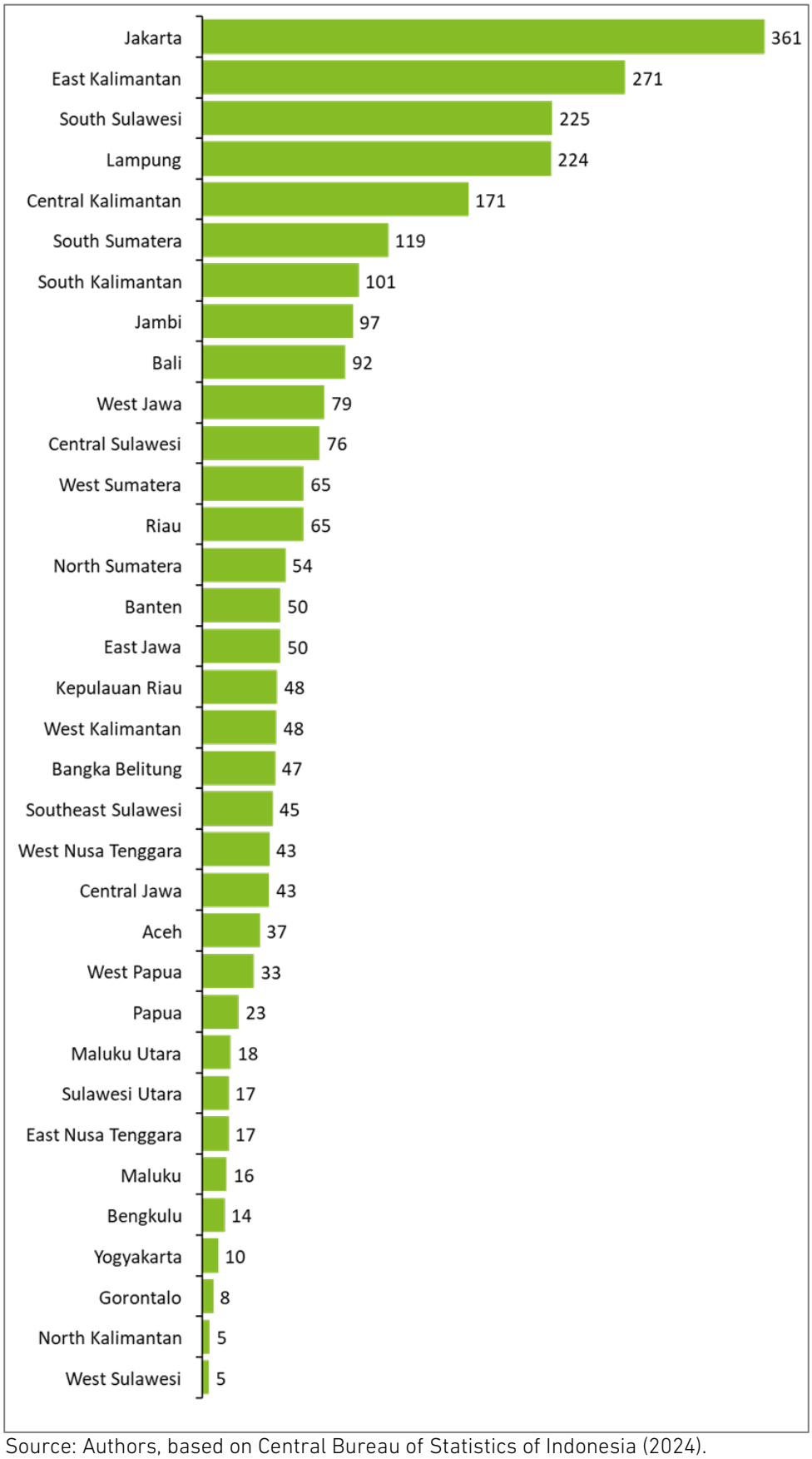
Annex 2: Vehicle Stocks per 1,000 Population in Indonesia (2023)



Source: Authors, based on Central Bureau of Statistics of Indonesia (2024).

Annex 3: TCO Comparisons of ICE vs xEV

Table 5.1. Differences in Vehicle Cost After Subsidy between ICE vs xEV (in US$, 2023)

Country	ICE	xEV	xEV Premium or Discount	
			In US$ Value	In %
Indonesia	33,327	49,167	15,840	47.5%
Malaysia	28,217	34,797	6,580	23.3%
Thailand	30,107	34,454	4,347	14.4%
Philippines	19,601	28,696	9,095	46.4%

Source: Maybank Investment Banking Group's Publication on ASEAN Mobility.

Table 5.2. Differences in Total Fuel Cost per 50,000 km per Year between ICE vs xEV (in US$, 2023)

Country	ICE	xEV	xEV Premium or Discount	
			In US$ Value	In %
Indonesia	3,937	1,242	(2,695)	-68.5%
Malaysia	3,289	863	(2,427)	-73.8%
Thailand	10,210	8,351	(1,858)	-18.2%
Philippines	2,108	848	(1,260)	-59.8%

Note: Value in parentheses indicate negative amount or discounts relative to xEV
Source: Maybank Investment Banking Group's Publication on ASEAN Mobility.

Table 5.3. Gap Between Fuel Cost Savings and Additional xEV Price to ICE

Country	(A) Additional Vehicle Price of xEV	(B) Fuel Cost Savings of xEV	(A-B) Remaining Costs from Vehicle Price	(B/A) % of Costs Offset by Fuel Savings
Indonesia	15,840	2,695	13,145	17.0%
Malaysia	6,580	2,427	4,153	36.9%
Thailand	4,347	1,858	2,489	42.8%
Philippines	9,095	1,260	7,835	13.9%

Source: Maybank Investment Banking Group's Publication on ASEAN Mobility, Deloitte Analysis.

Table 5.4. Gap Between Maintenance Cost Savings/Year and Additional xEV Price to ICE (US$)

Country	ICE	xEV	xEV Premium or Discount (in US$ Value)
Indonesia	153	0	(153)
Malaysia	183	0	(183)
Thailand	55	0	(55)
Philippines	340	0	(340)

Note: In Indonesia, xEVs are assumed to have no maintenance costs up to 45,000 kilometers. In Malaysia, Thailand, and the Philippines, maintenance costs for xEVs are considered to be covered under warranty provisions, based on prevailing industry practices and warranty policies.
Source: Maybank Investment Banking Group's Publication on ASEAN Mobility, Deloitte Analysis.

Table 5.5. Gap of Fuel Cost and Maintenance Cost Savings and Additional xEV Price to ICE (US$)

Country	(A) Additional Vehicle Price of xEV	(B) Fuel Cost Savings of xEV	(C) Maintenance Cost Savings of xEV	(A-(B+C)) Remaining Costs from Vehicle Price	((B+C)/A) % of Costs Offset by Fuel Savings
Indonesia	15,840	2,695	153	12,992	18.0%
Malaysia	6,580	2,427	183	3,970	40.0%
Thailand	4,347	1,858	55	2,434	44.0%
Philippines	9,095	1,260	340	7,495	18.0%

Source: Maybank Investment Banking Group's Publication on ASEAN Mobility, Deloitte Analysis.

Annex 4: Affordability of Car Purchase using Loan

Table 5.6. Calculation of 20/4/10 Rule of Thumb

(Amount in US$)	(A) ICE	(B) xEVs
Average Car Prices	27,183	36,779
Down Payment (20% of Average Car Prices)	5,563	7,356
Monthly Car Loan Payment [A]	502	663
Monthly Maintenance and Fuel Costs [B]	40	20
Monthly Income	819	819
Monthly Transportation Cost [A+B]	541	683
% Transportation Cost to Total Income	66%	83%

Note: Monthly Car Loan Payment is calculated using loan calculator.
Source: Maybank Investment Banking Group's Publication on ASEAN Mobility, Deloitte Analysis, Euromonitor (2024a).

Annex 5: Summary of ASEAN EV Policies

Table 5.7. Summary of EV Policies

Countries	BEV Policies
Brunei Darussalam	Key Targets: • 2025: Installation of 500 public charging stations • 2030: i) Electrification of 50% of government fleet, ii) a 10% of EV market penetration • 2035: EVs to represent 60% of new vehicles sales
Cambodia	• Imported electric motorcycles are subject to special tariff rate of 10% which is lower than the rates for conventional motorcycles 150 cc to above 800 cc to which tariff is at 15 to 25% depending on engine size • Reduced import duties on EVs, approximately 50% lower than those for traditional vehicles • Reduced the tax on pure EVs from 30% to 10%, aimed at making EVs more affordable for consumers. Key Targets: • 2030: To achieve 30,000 electric cars, 720,000 electric scooters, and 20,000 three-wheeler electric vehicles traversing its roads • 2050: To achieve 40% EV usage of all cars on the road
Indonesia	• VAT reduction from 11% to 1% for EVs purchase with a minimum of 40% local content. • BEVs produced domestically (CKD) will be subject to only 1% Value-Added Tax (PPN), as the government will cover 10% of the tax (PPN DTP) to make EVs more affordable.

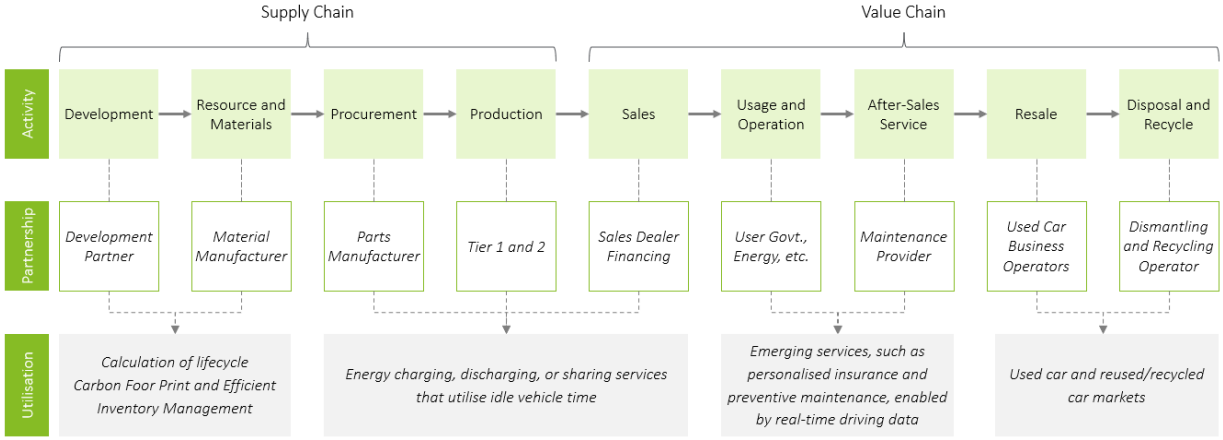
Countries	BEV Policies
	• 15% Luxury Goods Tax (PPnBM) exemption for BEVs, applicable to both imported (CBU) and domestically assembled (CKD) models. • Import duty exemption for CBU BEVs to reduce costs and enhance market competitiveness. • Foreign OEMs establishing factories in Indonesia are eligible for import tax exemptions on machinery and equipment, as well as a reduced luxury sales tax rate of 15%. • Issuance of Ministerial Decree No. 182.K/ TL.04/MEM.S/2023, which regulates electricity tariffs for fast and ultra-fast charging - The Ministry of Energy and Mineral Resources (MEMR) of Indonesia • The ease of charger-permitting process through MEMR Regulation No 5/2021 – The ministry of Energy and Mineral Resources
Lao PDR	• 30% reduction in the annual road tax for EVs • Battery Management under the decree of Ministry of Industry and Commerce: EV batteries must be replaced every seven to 10 years for
Malaysia	• Individuals can claim up to RM2,500 ($ 590) per year in income tax relief for installing, renting, or subscribing to EV charging facilities at home. • Corporate tax exemptions and 70% of statutory income exempted from income tax for 3 years for companies involved in the manufacturing of xEVs, and related critical components - Malaysian Green Technology and Climate Change Corporations • Charging Point Operators (CPOs) that meet specific criteria are eligible for a 100% Investment Tax Allowance for five years. • Charging Site Operators (CSO) are eligible to benefit from a 100% Investment Tax Allowance for five years, with this allowance allowing deductions of up to 100% of statutory income annually - Ministry of Investment, Trade, and Industry (MITI), • Full income tax exemptions on statutory income from 2023 to 2032 for companies producing xEV charging equipment. • Full exemption of import duties for imported CBUs until the end of 2025 while duties and sales tax exemption apply until the end of 2027 for domestically produced xEVs (primarily BEVs) • Key Target: Establish 10,000 EV charging bays nationwide by 2025
Myanmar	• Zero tariffs on EV imports • Tax exemptions for EVs and chargers arriving at Yangon Port, Htee Tan Port in Yangon, and the Muse 105-mile trade zone • Reduction in import duties on Battery Electric Vehicles (BEVs) under Myanmar's 2022 Customs Tariff to 0% for CBU, CKD, and SKD units • Myanmar citizens working abroad who remit at least US$50,000 annually can import one EV per year, with the vehicle's value capped at 5% of the total remittance
Philippines	• Tariffs on various EVs, including HEVs and PHEVs, are reduced to 0% until 2028.

Countries	BEV Policies
	• EV-related businesses are eligible for a 4 to 7-year income tax holiday under the Corporate Recovery and Tax Incentives for Enterprises (CREATE) Act • The Philippine government provides a 100% excise tax exemption and a 30% registration fee discount for BEVs, and a 50% excise tax exemption with a 15% registration fee discount for HEVs.
Singapore	• The EV Early Adoption Incentive (EEAI) offers up to a 45% rebate on the Additional Registration Fee for new fully electric cars and taxis, capped at SGD 15,000 until 2025. • Plan to deploy 60,000 charging points by 2030 encompassing both public and private sectors. • The government aims for all new car registrations to be cleaner-energy models by 2030.
Thailand	• Vehicles priced up to US$58,000 with battery capacities of at least 50 kWh qualify for subsidies ranging from US$1,450 to US$2,900 per unit. • The excise tax on imported battery electric vehicles (BEVs) has been reduced from 8% to 2%. • The Energy Policy and Planning Office plans to install over 500 charging stations and 1,400 battery-swapping stations by 2030 • The Thailand Board of Investment (BOI) offers a 5-year corporate income tax exemption, with up to 3 additional years for businesses investing in EV charging stations that meet specific criteria. • A US$48 million green loan from the Asian Development Bank and Energy Absolute supports the nationwide EV charging network • To promote BEV production, manufacturers and importers receive up to 40% import duty cuts on completely built-up units (CBUs) for vehicles priced up to B2 million ($61,303) • From 2024 to 2027, the Thai government offers subsidies of B50,000 to B100,000 ($ 1,397– $2,794) for each new EV purchase.
Viet Nam	• From March 1, 2022, battery-powered cars are exempt from registration fees for three years, then receive a 50% reduction for the next two years.

Source: Clean Air Asia (2020), SokSiphana & Associates (2025), The Phnom Penh Post (2025), Khmer Times (2024), Maybank (2023), Kristiana T., et al (2024), The Laotian Time (2023), Vietnam Investment Review (2023), ASEAN Center for Energy (2024), MIDA (2024), Myanmar Energy Monitor (2023), The Global New Light of Myanmar (2023), ASEAN Briefing (2023), Reuters (2023).

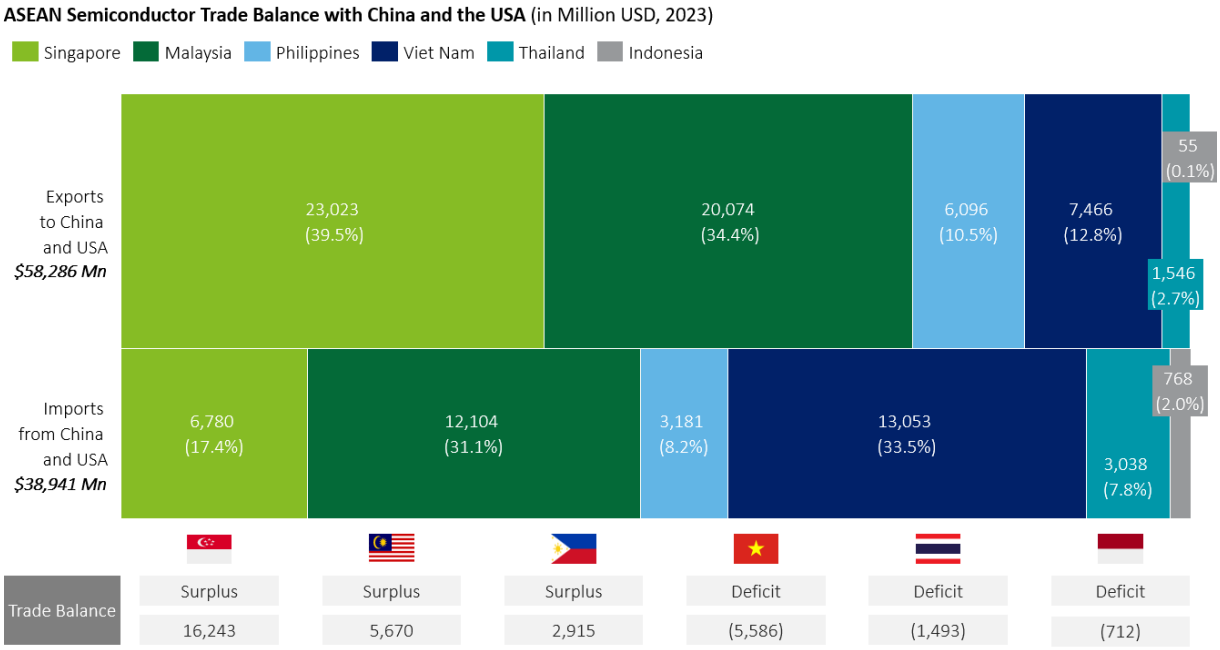
Appendices

Appendix 1: Various Use Cases of Data Utilisation in the Automobile Life Cycle



Source: Mobility Digital Transformation Strategy in Japan, Presentation by METI (2025a).

Appendix 2: ASEAN's Semiconductor Trade Balance with China and the US



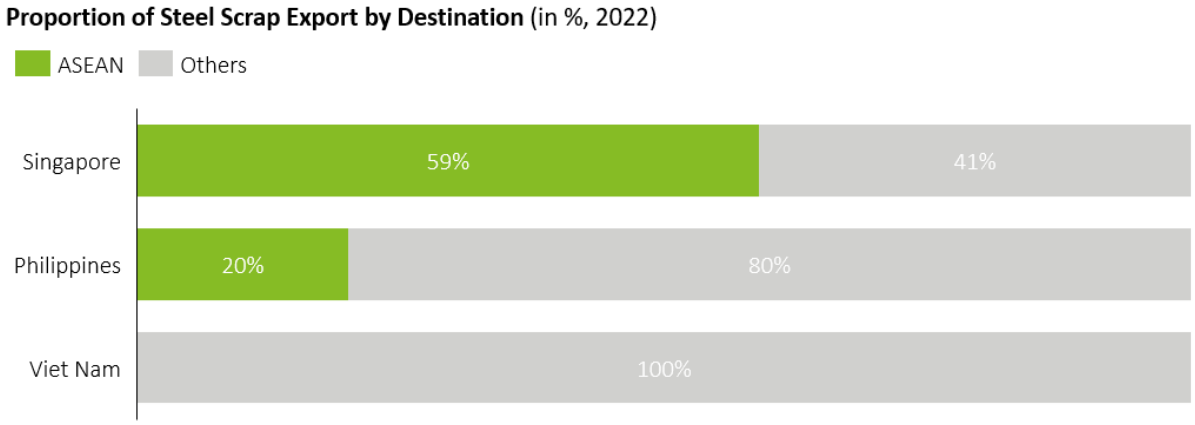
Source: Yusof Ishak Institute - Will ASEAN Countries Pass the US' Heightened Export Controls? (2025).

Appendix 3: Malaysian Manufacturers Involved in Laser Marking Services

Malaysian Manufacturers involved are: Bei Ben, Bison, BMW, CAMC, Changan, Chery, Citron, DFSK, Dong Feng, Foday, Grand Tiger, Hino, Honda, Hyundai, Isuzu, JAC, JBC, Jinbei, Joy Long, Kia, Land Rover, Mazda, Mercedes-Benz, Mini, Mitsubishi Fuso, Naza, Nissan, Peuguot, Perodua, Proton, Renault, Scania, Subaru, Suzuki, Toyota, Tuah, View, Volkswagen,

Volvo, and YoungMan.

Appendix 4: ASEAN Steel Scarp Export



Note: For Viet Nam, 72% of steel scrap exports went to India, while the rest of exports to other unidentified countries remain minimal.
Source: Southeast Asia Iron and Steel Institute (2023).

Appendix 5: Existing Landscape and Policies on Biofuel and E-Fuel Usage in ASEAN

ASEAN Member States (AMS) are currently at different stages of biofuel and e-fuel utilisation, resulting in an uneven regional landscape. As leading CPO producers in ASEAN, Indonesia and Malaysia have progressive blending mandates – Indonesia enforces B40 biodiesel nationally with B50 target by 2026 (Kementerian Energi dan Sumber Daya Mineral Republik Indonesia, 2025), while Malaysia requires nationwide B10 and runs a B20 pilot for the transport sector in select states (Biofuels International, 2025). Moreover, they are key players in the global biodiesel trade – Indonesia exports to China, the Netherlands, Peru, while Malaysia exports to EU, China, US (ASEAN Centre for Energy, 2024f). Contrastingly, partial adopters, including Thailand, the Philippines, and Viet Nam, struggle to implement their mandates – Thailand is scaling down the E85 and B20 subsidies and switching back to E20 and B10 (USDA Foreign Agricultural Service, 2023), the Philippines has been suspending the B4 mandate since the 2020 pandemic, and Viet Nam is struggling to incentivise gas stations to supply the mandated E5. Nascent markets of Brunei Darussalam, Cambodia, Lao PDR, Myanmar, and Singapore either focus mainly on biomass or biogas for power generation or have limited infrastructure for biofuels production (ASEAN Centre for Energy, 2024f). The fragmented status quo leads to underutilised feedstock potential and missed opportunities for economies of scale, making it harder for AMS to guarantee stable prices and reliable supply in the face of tightening global low-carbon fuel requirements.

Current biofuel and e-fuel policies in ASEAN fall short because they do not aggregate the region's supply chain into an integrated system. An ERIA study on 'Biofuel Market Outlook for Integration: Case of ASEAN' finds that the projected 2035 biodiesel demand of 49,425.3ktoe and bioethanol 37,479.4ktoe can be adequately supplied 'under the

precondition that biofuels be traded cross countries' (ERIA, 2013). However, trade barriers persist because firstly, abundant feedstocks like palm oil mill waste remain underutilised due to lack of incentives for smallholders to collect them into market-ready volumes (WIREs Energy and Environment, 2024). Secondly, national blending mandates rely heavily on fragmented domestic feedstocks like CPO and cassava, which raise feedstock prices and 'have in turn eaten into profit margin of biodiesels' pushing down production levels (The Edge Malaysia, 2025). Meanwhile, surplus cannot be credited or traded regionally because each AMS follows different Life Cycle Assessment (LCA) standards in calculating sustainability scores and lacks a harmonised carbon intensity label. For instance, the Indonesian Sustainable Palm Oil (ISPO) and Malaysian Sustainable Palm Oil (MSPO) certifications have different scoring criteria that hinder trade between the two countries – CPO certified for Malaysia's B30 cannot count towards Indonesia's target (European Forest Institute, 2022). Lastly, the lack of a regional mechanism to pool fragmented domestic feedstock, align standards, and enable cross-border flows also forces biofuel producers to manage feedstock risks in isolation, face rising production costs, and discourage investments in large-scale production facilities. Ultimately, ASEAN risks falling behind export market requirements – undermining its position as a global hub for cleaner ICE, HEV, and EV exports.

Appendix 6: Existing Policies on Vehicle Inspection System in ASEAN

In the ASEAN region, most countries have implemented mandatory periodic inspection policies for private passenger vehicles. The frequency of vehicle inspection typically increases with vehicle age, with Singapore and Viet Nam requiring annual inspection after ten years of use. Thailand and Brunei mandate inspections from seven years of use, while Cambodia and the Philippines begins after two years and three years of operation. Myanmar and Lao PDR apply stricter standards, requiring annual inspections from the first year (Solah, S.M et al., 2021). Malaysia and Indonesia are still formulating their regulatory frameworks for private vehicle inspection. Although periodic vehicle inspections are mandatory in many ASEAN countries, there is a lack of stringent regulatory frameworks promoting the replacement or retirement of older vehicles. Consequently, passenger vehicles often remain in operation for extended periods, with the average vehicle age typically ranging between 11 and 12 years (World of Statistics, 2024).

In addition, emission testing is generally incorporated into the periodic inspection process across the region. Countries such as Singapore and Viet Nam have adopted On-Board Diagnostic (OBD) Level 2 systems, which enable real-time monitoring of vehicle diagnostic functions, including the performance of emission-related components. In contrast, most other ASEAN countries continue to rely on conventional emission testing methods. For example, Thailand uses a basic smoke opacity test for diesel vehicles, with a maximum allowable opacity of 45% under no-load conditions. However, the current in-use vehicle emission inspection processes in such countries are often ineffective, as the opacity test measures only visible particulate emissions and fails to account for other pollutants such as NO_x and CO. Moreover, traditional laboratory-based or static emission tests do not capture real-time, on-road performance, leading to a significant gap between tested and actual environmental impact.

Appendix 7: Vehicles Taxation Rate in Japan

Type of Vehicles	Classification	Taxation Rate	Remarks
Light Vehicles	Private Passenger Cars with total displacement of 660cc or less	¥10,800	Newly Registered Vehicles after April 1, 2015 (Standard Tax Rate)
		¥7,200	Vehicles other than those listed on the above (former taxation Rate)
	Private Passenger Cars after 13 years have passed since the vehicle first received its number plate	¥12,900	-

Source: Funabashi City, 2025.

Appendix 8: Existing Landscape and Policies on Biofuel and E-Fuel Usage in ASEAN

The current states of ELV recycling and scrap processes show wide disparities in regulatory maturity and scheme effectiveness across AMS. These processes are not currently in place in Brunei Darussalam, Cambodia, Lao PDR, and Myanmar. Malaysia and Singapore are most advanced in laying down standards on ELV management, enabled by centralised collection and recycling systems authorised by the governments. Malaysia has the Authorised Automotive Treatment Facilities (AATF) scheme licensed by the Department of Environment under Section 18, Environmental Quality Act 1974. The network of AATFs is required to adhere to ELV recycling standards set by the Department of Environment, Road Transport Department, and the Ministry of Transport. Additionally, AATFs must record the input and output of waste into the Electronic Scheduled Waste Information System to maintain traceability of secondary materials and environmental pollutants. Singapore has similar regulations and schemes, whereby ELV disposal occurs at Land Transport Authority-appointed scrapyards or export processing zones. Moreover, Singapore also introduced an Extended Producer Responsibility (EPR) scheme on e-waste which will likely impact automotive OEMs and suppliers shortly. Following them, Thailand is in the process of setting up 'an efficient and appropriate resource circulation system for ELV in Thailand' under a public-private partnership between the Industrial Estate Authority of Thailand and the Japanese funding agency New Energy and Industrial Technology Development Organization. Viet Nam is in the process of introducing its own EPR scheme through the issuance of Decree No. 02/20022/ND-CP and 08/2022/ND-CP. The remaining adopters (Indonesia and the Philippines) rely on broad waste regulations and informal sectors to manage ELV recycling and scrap (ERIA, 2025b). Across most AMS, the ELV management industries remain unregulated, undermining the quality and traceability of recovered materials.

The same can be said about used EV battery recycling and scrap regulations across AMS, given that Indonesia is the only country to have a formal framework in place. Indonesia's Presidential Regulation No.55/2019 requires used EV batteries to be recycled under licensed waste management companies. The regulation enables companies like PT Puqin Recycling Technology to invest in large-scale battery waste treatment plants. However,

there are still regulatory inconsistencies because used batteries are still classified as hazardous waste under Government Regulation No.101/2014 and imports of such waste are prohibited under Law No.32/2009. In Malaysia, the used EV battery recycling regulation is still under formulation – including discussions around EV battery passports development (ERIA, 2023b; ERIA, 2025b). Meanwhile, in Singapore and Viet Nam, used EV battery recycling are indirectly stipulated by the EPR schemes (ERIA, 2025b). The Philippines still has not enacted any regulation on used EV battery recycling (ERIA, 2023b). Consequently, ASEAN's patchy regulatory landscape on used EV battery recycling limits the region's ability to secure sustainable critical mineral resources toward a closed-loop battery value chain.

Currently, the fragmented regulatory landscape deters AMS from creating an end-to-end next-generation vehicle supply chain within the region. Despite some country-level efforts, there is no single ASEAN-wide directive to define standards that classify eligible ELV and used EV battery materials to reuse, recycle, recover, or dispose of. Additionally, there is no traceability system for auto parts and batteries to maintain materials information for future users. Collection and recycling companies are not formalised into a government scheme resulting in ineffective and unsafe handling of materials. Finally, the lack of recycling and scrap schemes to facilitate proper ELV and used EV battery treatments prevents the flow of valuable secondary materials. These four key issues will prevent ASEAN from becoming a self-sufficient automotive manufacturer.

Appendix 9: Existing Landscape on Regulation for Various Vehicle Ownership and Usage Options in ASEAN

Singapore has taken significant steps toward regulating shared mobility. The Parliament of Singapore passed the Point-to-Point Passenger Transport Industry Bill, which took effect in June 2020. This law mandates that all ride-hailing and street-hailing service providers operating fleets of over 800 vehicles must obtain a license. the new ride-hailing licenses prohibit such exclusive contracts, allowing drivers to operate on multiple networks at once because some operators like Grab disallow their drivers from operating on other networks. This can make it challenging for smaller and new operators to attract drivers and compete. On the other hand, Ministry of Transportation in Malaysia had introduced the regulations related to the e-hailing services in which all e-hailing providers are required to register with the Land Public Transport Agency (APAD) – formerly known as the Land Transport Commission (SPAD) – as well as with the Companies Commission of Malaysia (SSM) or the Cooperative Commission of Malaysia (SKM) to operate legally. In addition, since October 2019, additional regulations have been enforced which include annual vehicle inspection, mandatory medical and criminal background check, Public Service Vehicle (PSV) license issuance, e-hailing add-on insurance purchase, and contribution to the Social Security Organization (SOSCO). The enforcement of regulations promotes efficiency in the operations of traditional taxis and operations of Transportation Network Companies (TNC) or online taxis as these services face challenges such as ensuring fair competition with traditional taxi drivers and implementing adequate safety measures. Currently, each country in the Southeast Asia (SEA) region has its own policies regarding vehicle usage, with no unified framework. As of now, there is no integrated MaaS platform that enables seamless cross-border mobility or connectivity between countries

within the region.

Appendix 10: Existing Landscape and Policies on Open Innovation Investment Lifecycle

The regulatory environment for open innovation varies widely regionally, mirroring each AMS' R&D infrastructure, strength of IP system, and readiness for cross-border cooperation. All AMS are members of the World Intellectual Property Organization (WIPO), whereby memberships help strengthen national IP systems and enable registration of certain IPs on a global basis versus country-by-country (Smith and Perry, 2023). However, the Global Innovation Index developed by WIPO reflects the uneven innovation capacity of AMS (Athens Journal of Law, 2023) (Table 8.11).

Table 8.1. Global Innovation Index Rankings of AMS 2020-2024

Country	2020	2021	2022	2023	2024
Brunei Darussalam	71	82	92	87	88
Cambodia	110	109	97	101	103
Indonesia	85	87	75	61	54
Lao PDR	113	117	112	110	111
Malaysia	33	36	36	36	33
Myanmar	129	127	116	NA	125
Philippines	50	51	59	56	53
Singapore	8	8	7	5	4
Thailand	44	43	43	43	41
Viet Nam	42	44	48	46	44

NA = not available.

Note: The Global Innovation Index is scored 1 (best) to n (worst), where n = number of participating countries. There are 131 countries in 2020, 132 countries in 2021, 132 countries in 2022, 132 countries in 2023, 133 countries in 2024.

Source: WIPO (2020), WIPO (2021), WIPO (2022), WIPO (2023), WIPO (2024).

Singapore leads with well-structured regulatory sandboxes and IP frameworks, exemplified by the Open Innovation Platform that has connected more than 16,000 innovators to solve more than 400 local startup challenges (IMDA Open Innovation Platform, 2025). In Malaysia, Thailand, and Viet Nam, growing investments in innovation spaces demonstrate meaningful progress – Malaysia's Automotive Robotics & IoT Institute, Thailand's Eastern Economic Corridor of Innovation, and Viet Nam's National Innovation Center – although IP protection and enforcement still lag. Indonesia and the Philippines are starting to launch their own government-backed innovation programmes, but these remain sector-specific and disconnected from national IP commercialisation pathways (Smith and Perry, 2023). For instance, Indonesia's digital financial innovation sandbox participants dropped from 108 fintechs in August 2023 to only 52 fintechs in March 2024. The cause was a limited programme budget that forced the Indonesian Services Authority to filter out unlikely fintechs (Bisnis.com, 2024). Meanwhile, the innovation landscape of Brunei Darussalam, Cambodia, Lao PDR, and Myanmar continue to be stagnant (Smith and Perry, 2023). Despite foundational efforts, the fragmented regulations and schemes

related to open innovation across AMS limit the region's ability to establish border-agnostic automotive innovation hubs.

As a region, ASEAN's open innovation ecosystem suffers from critical gaps that undermine its ability to attract global mobility investments. First, many sector-specific sandboxes lack the reach to facilitate multi-stakeholder engagement (governments, firms, educational and research institutions), limiting the ability to foster innovative knowledge transfer. Second, there is no unified IP protection and enforcement regulations across the region – Indonesia, Malaysia, the Philippines, and Thailand still have no international agreements related industrial IP registration (Table 8.2).

Table 8.2. AMS Membership of International Patent and Mark Treaties

	Brunei Darussalam	Cambodia	Indonesia	Lao PDR	Malaysia	Myanmar	Philippines	Singapore	Thailand	Viet Nam
World Intellectual Property Convention	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Paris Convention for the Protection of Industrial Property	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Hague Agreement Concerning the International Registration of Industrial Designs	✓	✓	-	-	-	-	-	✓	-	✓
Geneva Act (1999) [of the Hague Agreement Concerning the International Registration of Industrial Designs]	✓	✓	-	-	-	-	-	✓	-	✓
Patent Cooperation Treaty	✓	✓	✓	✓	✓	-	✓	✓	✓	✓
Protocol Relating to the Madrid Agreement Concerning the International Registration of Marks	✓	✓	✓	✓	✓	-	✓	✓	✓	✓
Agreement on Trade-Related Aspects of Intellectual Property Rights	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Source: Smith and Perry (2023).

This raises concerns because when AMS assemble vehicles for foreign automotive companies such as Toyota, Honda, and Mitsubishi, the IPs remain with those foreign companies and must be registered and protected in the country of assembly (Smith and Perry, 2023). Third, these sandboxes merely function as testing grounds rather than IP commercialisation zones that systematically assist proven innovations through regulatory reforms, preventing startups to scale. According to an ASEAN Socio-Cultural Community Policy Brief, Singapore's ecosystem value and early-stage funding is approximately 126% and 216% larger than the total value of Bangkok, Ho Chi Minh, Jakarta, and Kuala Lumpur combined (ASCC Research and Development Platform on the Future of Work, 2024).

Fourth, the weak FDI ecosystem risks ASEAN access to mobility technologies. As seen in the number of IPs registered in ASEAN (Table 8-6), all AMS rely heavily on foreigners from abroad (Smith and Perry, 2023).

Table 8.3. Number of Patent Grants, Patents in Force, Trademark Registrations, and Industrial Design Registrations in AMS 2014-2023

Country	Patent Grants (2014–2023)		Patents in Force (2023)	Trademark Registrations (2014–2023)		Industrial Design Registrations (2014–2023)	
	Resident	Abroad		Resident	Abroad	Resident	Abroad
Brunei Darussalam	15	50	66	638	462	1	3
Cambodia	-	19	25	6,116	284	133	18
Indonesia	5,041	297	356	519,875	12,705	16,752	340
Lao PDR	-	7	10	1,517	95	2	-
Malaysia	6,127	5,188	9,043	122,666	29,780	4,206	1,710
Myanmar	-	6	12	-	240	-	15
Philippines	441	975	1,018	128,771	7,300	6,603	201
Singapore	3,679	29,952	40,956	59,344	123,602	4,897	6,136
Thailand	1,580	2,711	4,654	171,119	27,500	19,673	1,530
Viet Nam	1,420	593	1,323	200,870	15,966	11,080	842
Total	**18,303**	**39,798**	**57,463**	**1,210,996**	**217,934**	**63,347**	**10,795**

Note: WIPO statistics database, last updated in May 2025.
Source: WIPO (2025).

This highlights the need to smoothen cross-border data flows and capital repatriation amongst others. As a result, ASEAN needs to harmonise regulations for innovation and support systems to build a borderless open innovation ecosystem for global mobility investments.

Appendix 11: Existing Fiscal incentive for Biofuel and E-Fuel Manufacturing

The maturity of biofuel and e-fuel usage and circulation amongst AMS can be reflected in the differences between their fiscal incentive support levels. Large biofuel economies like Indonesia, Malaysia, and Thailand employ various fiscal incentives to drive the biofuel

production costs down. The Indonesian government sets aside public budget to subsidise biodiesel production as mandated in the Presidential Regulation No.45/2009. Malaysia provides three major tax incentive schemes for biofuel refiners: the Pioneer Status income tax exemption for five years (partial exemption nation-wide and 100% exemption for companies located in priority zones), R&D tax allowance equal to the investment amount, R&D commercialisation 100% income tax exemption scheme for ten years (EAS-ERIA, 2010). Thailand uses a more complex approach of reallocating tax revenues from gasoline excise duties paid to the Oil Fund to subsidise high-blended bioethanol that ranges from E10 to E85, but B100 biodiesel is still exempted from paying taxes to the Oil Fund (EAS-ERIA, 2010; ERIA, 2024b). Both Philippines and Viet Nam have no direct fiscal incentives related to biofuels, relying on broad policies for renewable energy and high-value investment. For instance, even though Philippines planned to offer biofuel fiscal incentives through the Biofuels Act, the implementation was suspended due to limited public budget, so biofuel refiners rely on tax incentives provided under the Renewable Energy Act. While Brunei Darussalam still focuses on fossil fuel asset optimisation and Singapore does not need to incentivise low-carbon alternatives, Cambodia, Lao PDR, and Myanmar still lack financial capacity to offer biofuel incentives (EAS-ERIA, 2010). Therefore, AMS need to financially support biofuel and e-fuel development beyond their own borders to enhance usage and circulation throughout the region.

There are some cross-cutting issues limiting the effectiveness of biofuel and e-fuel fiscal incentives across ASEAN. Firstly, most fiscal incentives are not tied to performance-based indicators that reward refiners and plants based on measurable outcomes, limiting innovation and efficiency. Secondly, the biofuel fiscal policies across AMS do not offer enough coverage to incentivise upstream industries to increase availability and mobilisation of biofuel feedstock. Finally, most AMS do not provide enough support to close the cost gap between biofuels and fossil fuels, preventing the shift to low-carbon alternatives. Therefore, biofuel and e-fuel fiscal incentives still need to be expanded and optimised to enhance their distribution across ASEAN.

Appendix 12: Existing Fiscal Incentive for Semiconductor Manufacturing

Singapore has the crucial role as the central economy in ASEAN's semiconductor hub, integrating Indonesia, Malaysia, the Philippines, Thailand, and Viet Nam into its network. Brunei Darussalam, Cambodia, Lao PDR, and Myanmar show weak connections to this hub (ERIA, 2024c). Even for Indonesia, Malaysia, the Philippines, Thailand, and Viet Nam, the semiconductor value chain is limited to back-end assembly, testing, and packaging (ATP) activities, not high-value R&D and front-end fabrication. Malaysia and Singapore have the most advanced end-to-end semiconductor value chains thanks to their comprehensive fiscal incentives. Under Singapore's Economic Development Board (EDB), semiconductor firms undergoing R&D are eligible to receive grants, subsidies, co-financing, such as the IP Development Incentive, Partnerships for Capability Transformation Scheme, and Research and Innovation Scheme for Companies (EDB, 2025a). From 2021 to 2025, the Singaporean government has invested approximately S$28 billion into the Research, Innovation and Enterprise plan and distributes a portion of the fund to explore key semiconductor research pillars (EDB, 2024). One example is the joint laboratory between the US-based Applied Materials and Singapore's Agency for Science, Technology and Research – the Centre of Excellence in Advanced Packaging – that was set up to develop

advanced 3D chip packaging capabilities (The Strait Times, 2024). Furthermore, Singapore also provides tax incentives for semiconductor manufacturing in schemes such as Refundable Investment Credit, Pioneer Certificate Incentive, and Development and Expansion Incentive (EDB, 2025a). Malaysia offers the same Pioneer Status tax incentives used to develop biofuel and e-fuel industries for semiconductor manufacturing (EAS-ERIA, 2010). Additionally, the Malaysian Investment Development Authority also spent RM800 million to build the Kulim Hi-Tech Park that has attracted an estimated RM23 billion in investments from international companies (MITI, 2010), by providing tax breaks, grants, and other preferential treatments for semiconductor manufacturers (MIDA, 2025). Emerging players such as Thailand, Philippines, and Viet Nam have sizeable share in ASEAN's semiconductor back-end ATP value chain but aim to move upstream to R&D and front-end fabrication as well. For instance, Thailand's Board of Investments offer tax holidays for R&D, human resource development, and capital investments of advanced semiconductor manufacturing and smart packing – ranging from three to five years depending on the investment value (ASEAN Briefing, 2021). The Philippines' CREATE and proposed CREATE More Act provide corporate income and VAT tax exemptions for semiconductor companies (OECD, 2024b). Viet Nam's Decree 182 also declares that the government will subsidise up to 50% of the initial investment costs for businesses engaging in semiconductor R&D (Viet Nam News, 2025). Although the remaining ASEAN countries do not have targeted fiscal incentives for semiconductor manufacturing, Indonesia is starting to pivot. The Ministry of Trade Regulation No.18/2021 bans the export of raw silica – a critical mineral resource abundant in Indonesia – and plans to fully ban silica export (raw and processed) by 2027. Therefore, front-end fabrication companies shall invest and build smelters in Indonesia to access the resource (HHP Law Firm, 2021). Clearly, each AMS has its own competitive advantage within the semiconductor value chain. Unless ASEAN-co-ordinated fiscal incentives are introduced, each AMS will continue competing to attract investors and risk creating isolated semiconductor hubs rather than an integrated network.

The lack of regional integration limits AMS to effectively deploy financial incentives in targeted areas of the value chain, preventing ASEAN from having a robust end-to-end network. Two core challenges persist: firstly, a fragmented regional approach leads AMS to compete for the same high-profile investments, straining resources and weakening ASEAN's collective bargaining power; secondly, most AMS are still narrowly targeting manufacturing-centric fiscal incentives with insufficient support for R&D and human capital. Consequently, each AMS risks remaining dependent on major economies to play a part in the global semiconductor value chain instead of reaping benefits from the self-sufficiency of the integrated ASEAN network.

Appendix 13: Existing Landscape and Policies to Attract DX/GX/Open Innovative human resource/know-how from outside of the region and develop internally

Each AMS' ability to attract DX, GX, and open innovative talent varies significantly. Indonesia, Singapore, and Thailand lead ASEAN with comprehensive, long-term visa schemes that target top-tier professionals with high-income. The advanced visa schemes filter the eligibility of foreign talent pool using two screening criteria: firstly; quality of talent based on priority industry experiences (AI, digital, technology, research, etc.); secondly, potential investment value based on minimum investment and/or annual

income. These 'residency-by-investment-style' visas facilitate long-term stays and long-term investments, boosting economic growth. Following them, Malaysia, Philippines, and Viet Nam build innovative-focused programmes, such as Malaysia's DE Rantau Nomad Pass that provide ready-to-live accommodations alongside the 1-year visa; Philippines' three visas for startup owners, startup employees, and startup investors; Viet Nam's Investment Visa for foreigners establishing or investing in a local company. However, the shortfall is the visa schemes broadly target the foreign talent pool with relatively low-cost visa fees and lack of criteria on the talent quality. The remaining Brunei, Cambodia, Laos, and Myanmar only provide typical business visas (ERIA, 2023a) (Table 8-4). While AMS are ramping up efforts to attract foreign workers, more skilled talent in DX, GX, and innovation are needed to realise the region-wide ambition to become the leading automotive hub of the future.

Table 8.4. Global Talent Visas across AMS

Country	Type of Visa	Visa Eligibility	Visa Validity	Quality of Talents	Applicant Minimum Requirements
Brunei Darussalam	Professional Visit Pass	Professionals or companies looking to open and operate business venture	3 months	NA	NA
Cambodia	E-class Ordinary Visa	Business owners and individuals who received invitation for business purposes	3 months	NA	NA
Indonesia	Golden Visa	High-skilled and high-earning individuals and companies	10 years	Talent in the field of digitalisation and AI, health, research and technology	Companies must invest at least US$50 million; individuals must invest at least US$350,000
Lao PDR	Business Visa for Foreign Investors	Foreign investors and stockholders	Up to 1 year	NA	NA
Malaysia	DE Rantau	Open to a relatively wide scope of professionals	1 year	Targeted to both foreign and local digital nomads, tech entrepreneurs, business owners, freelancers, and industry players	Individuals must have a minimum annual income of US$24,000

Country	Type of Visa	Visa Eligibility	Visa Validity	Quality of Talents	Applicant Minimum Requirements
Myanmar	Business Visa	Foreign talent who works in a company registered in Myanmar or a registered Chamber of Commerce Association	70 days	NA	NA
Philippines	Special Investor's Resident (SRV) Visa	For startups and startups enablers	5 years	Business creators, innovators, and technology talents	Individuals must invest at least US$75,000
Singapore	Entre Pass	For entrepreneurs who have incorporated a private limited company in Singapore	2 years	Business creators, skills development	Individuals must hold at least 30% ownership of registered company
	Tech.Pass	Tech professionals with certain track record achievements	2 years	Tech enabler in AI, data science, cybersecurity, and fintech	Individuals must have a minimum fixed month salary of S$22,500 for 12 consecutive months AND have a minimum 5-year experience in leading a tech company or venture capital firm with valuation or asset under management of at least US$500 million
	Overseas Network and Expertise (ONE) Pass	High-skills professionals and high-income earners	5 years	Top talents in business, arts and culture, sports, science and technology,	Individuals must have a minimum fixed month salary of S$30,000

Country	Type of Visa	Visa Eligibility	Visa Validity	Quality of Talents	Applicant Minimum Requirements
				academia and research	under an employer for 12 consecutive months
Thailand	Long-Term Residence (LTR) Visa	High-skills professionals, high-income earners, and pensioners	10 years	Talents who belong to companies or Research institutions that are involved in more than 10 industrial or technological categories (EVs, electronics, medicine, defence, etc.)	Individuals must have a minimum annual income of US$80,000
Viet Nam	Startup Visa	Foreign investors with certain amount of capital contribution	Up to 5 years	NA	NA

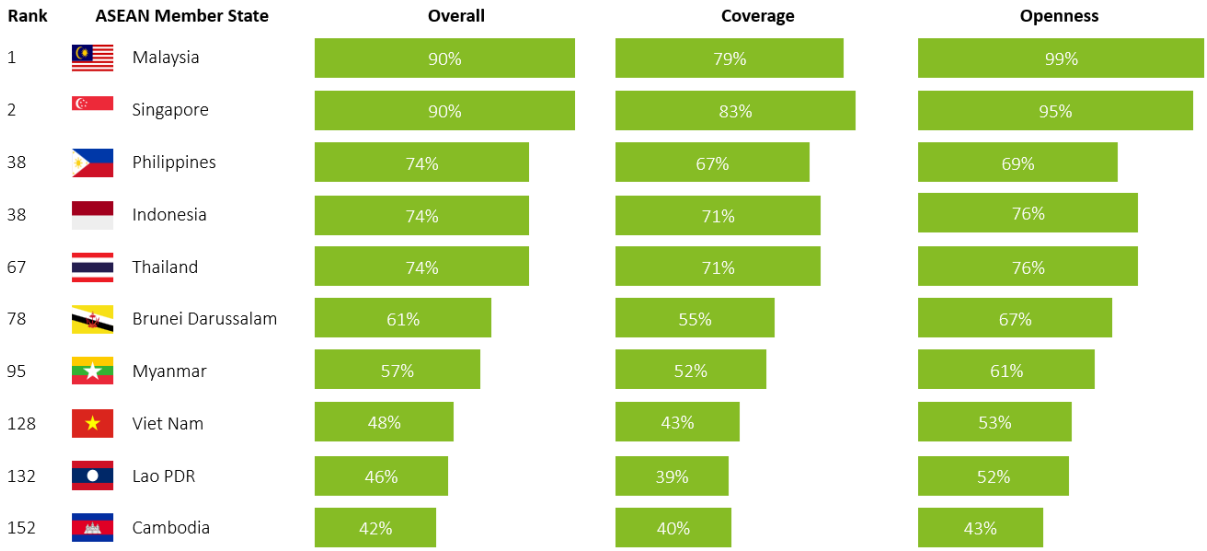
NA = not available.
Source: ERIA (2023e), Investment Promotion Department (2025), The Digital Nomad Asia (2025), Ministry of Immigration and Population of Myanmar (2024), Ministry of Manpower of Singapore (2025a), EBD (2025c) Ministry of Manpower (2025b), Visas Philippines (2025).

Bridging the gaps in DX, GX, and open innovative talent and knowledge across AMS is a critical challenge ASEAN shall overcome to position itself as the top automotive exporter. Firstly, the domestic talent remains underdeveloped due to the absence of robust knowledge transfer mechanisms, creating over-reliance on foreign experts. Secondly, visa schemes across AMS are not well integrated with their respective DX, GX, and innovation hubs, limiting the extent to which visa holders can engage with the local communities. Finally, the lack of AMS' participation in global student and staff exchange programmes highlights the opportunity costs of talent immobility, limiting DX, GX, and innovation learning within the nuances of those specific economies. Addressing these key issues is critical in building ASEAN's future-ready workforce to remain competitive as the world's largest automotive sector.

Appendix 14: Existing Landscape and Policies on Regional Information Connection and Sharing

Currently, ASEAN's data infrastructure remains highly fragmented with disparities in digital standards, infrastructures and tools, interoperability, and cybersecurity across the region. The 2024 Open Data Inventory rankings reveal the contrasting landscape of national data systems across AMS – Malaysia and Singapore ranked first and second globally, while Cambodia ranked 152nd out of 197 countries (Open Data Watch, 2024) (Figure 8a).

Figure 8a. Open Data Inventory Global Rankings of AMS 2024



Source: Open Data Watch (2024).

Malaysia and Singapore led the region with robust open data ecosystems exemplified by high-quality and extensive datasets, user-friendly data visualisation tools, and frequent data update schedules. Additionally, both AMS are actively working to facilitate cross-border data flows – Singapore co-developed the ASEAN Model Contractual Clauses guidelines to implement the region-wide standards of the ASEAN Framework on Personal Data Protection and joined the APEC Cross-Border Privacy Rules System, Malaysia allows cross-border transfer with an adequacy decision from the Personal Data Protection Committee and approval from the Malaysian Communications and Multimedia Commission (ERIA, 2025a). Although their local data-sharing ecosystems are strong, regional interoperability is still limited to the current state of other AMS. Brunei Darussalam, Indonesia, Philippines, and Thailand have shown significant progress towards strengthening their national data infrastructures. Open data platforms have been created, but metadata standards are weak, data visualisation tools are static, and data updates are infrequent. Furthermore, cross-border data flows are limited since local databases do not comply with regional frameworks and data localisation requirements drive up compliance costs (ERIA, 2025a). Out of ten AMS, there are four AMS without open data systems – that is, Cambodia, Lao PDR, Myanmar, and Viet Nam (ASEAN-ROK Cooperation Fund, 2019). Additionally, they lack comprehensive and sector-specific data privacy frameworks and

have strict data localisation requirements. For example, Viet Nam imposes Decree No.53/2022 that requires storage of both personal and non-personal data within its territory even for foreign digital service providers. However, in terms of cybersecurity, governments have access to all personal and non-personal data across all AMS. This is why most AMS are strict about international data transfers, given that surrounding governments are legally allowed to examine them (ERIA, 2025a). Consequently, low open data readiness and regulatory restrictions that inflate compliance costs often discourage cross-border data-sharing.

Crucially, ASEAN's fragmented data frameworks hinder regional data integration, especially for sector-specific systems that require lower-level datasets. Variations amongst AMS' open data systems reflect the need to unify data structure standards. Additionally, region-wide data transfers are rare due to complex data privacy and localisation regulations that drive compliance costs up. Governments are legally given permission to access private personal and non-personal data, increasing cybersecurity risks. These key issues hamper the possibility of establishing the ASEAN Automotive Data Space.

Appendix 15: Existing Fiscal support for Innovative Investment

Only Indonesia, Malaysia, the Philippines, Singapore, Thailand, and Viet Nam provide fiscal support for innovative investments, revealing contrasting financing capacities amongst AMS. Singapore stands over all AMS, maintaining an average of approximately 201% of GDP in R&D spending (GERD) over the last decade within 2014-2023. Fiscal support to attract innovative investments is disbursed amongst different government agencies based on the open innovation lifecycle: the National Research Foundation for R&D support, EDB for IP development support as mentioned in section 8.10.5.1, and Enterprise Singapore for IP commercialisation support (NRF, 2025; EDB, 2025a; Enterprise Singapore, 2025). These three government agencies share similar fiscal support structures, which are mainly co-financing and performance-based incentives – for instance, the EDB's Partnerships for Capability Transformation scheme co-finances up to 50% of equipment costs and 70% of manpower costs, while its IP Development Initiative offers concessionary tax rates of 5% to 15% depending on the proportion of the IP-related income to total income (MTI, 2024; EDB, 2025b). Consequently, Singapore can effectively encourage collaboration with innovation companies across the open innovation lifecycle.

Mid-tiered Malaysia and Thailand have an average GERD of 199% and 98% in 2014-2023, respectively. Their strategies are to build multi-ministerial fiscal support – Malaysia offers R&D incentives, subsidies, and grants from seven ministries (Ministry of Science, Technology and Innovation, Ministry of Higher Education, Ministry of International Trade and Industry, etc.), Thailand relies on R&D tax incentives from the Ministry of Science and Technology and the Board of Investment. As the multi-ministerial perspective focuses more on sector than enterprise development, both fiscal schemes fail to target the right businesses that can optimise them. However, they show commitments in improving the innovation ecosystem – Malaysia's upskilling programme and Thailand's joint automotive R&D between assemblers and local tier-1 suppliers – will attract investment opportunities as well (ERIA, 2018). Additionally, the remaining three countries (Indonesia, Philippines, Viet Nam) operate under fragmented and underfunded frameworks, as average GERD in 2014-2023 remains at 25%, 24%, and 40% respectively. Indonesia offers diverse R&D fiscal

support (subsidies, grants, tax incentives), but faces poor co-ordination and uptake. Meanwhile, the Philippines and Viet Nam have limited R&D budgets that are divided amongst many fiscal tools – too small to create impact (ERIA, 2018). In ASEAN, only Singapore has fully institutionalised innovation as a core economic driver.

Despite progress, ASEAN continues to grapple with common barriers that hinder the effectiveness of fiscal support for innovative investments. While most AMS have already introduced various forms of fiscal support to accelerate innovation, limited public budgets are spread too thinly across fragmented schemes, making it difficult to bring meaningful impact. Furthermore, fiscal incentives are often distributed without proper governance for AMS to guide and oversee innovation activities. Instead, fiscal support is granted for weak pipelines that result in minimal private sector uptake. Finally, only Singapore has linked fiscal incentives to performance-based outcomes beyond the R&D phase. Other AMS are missing the opportunities to help startup commercialise, earn revenue, and contribute back to the system. Without such performance-based mechanism, fiscal incentives will remain dependent on limited public budget rather than evolving into self-sustaining fund. Therefore, AMS shall rethink how fiscal resources are allocated, governed, and sustained.

Appendix 16: Existing Landscape and Policies on Green Energy Industry Park Programme

Global best practices underscore the efficacy of this approach. Japan's Eco-Town programme is a case in point. Launched in 1997, it established 26 eco-industrial parks nationwide to drive urban-industrial symbiosis. Approximately US$1.65 bn was invested in 61 innovative recycling and energy-efficiency projects under this programme, with the government subsidizing about 36% of the capital costs (Sakai et al., 2009). Crucially, the Japanese central government provided technical and financial support to local authorities once a park development plan was approved, creating a strong incentive for green industrial initiatives. The result was a network of zones where waste from one industry becomes input for another and shared facilities (e.g. waste-to-energy plants, advanced recycling centers) cut overall emissions. The success factors included ambitious recycling laws with quantified targets and public–private technology partnerships. This ensured that by 2009, at least 107 additional recycling facilities were built even without subsidies, as the business case for resource efficiency had been proven (Sakai et al., 2009). ASEAN policymakers can draw from Japan's model by offering capital subsidies or tax holidays for certified 'eco-park' projects and by enacting strict standards (e.g. requiring 90%+ recycling of industrial waste) that guarantee demand for green utilities.

In Europe, decarbonising industry at scale has become a strategic imperative, backed by substantial public finance. The EU's new Clean Industrial Deal provides a template for turning climate action into industrial renewal. For example, the European Commission has proposed a dedicated Industrial Decarbonisation Bank with €100 billion in funding from carbon market revenues to catalyze private investments in clean manufacturing (Reuters, 2025p). In addition, a €500 million pilot with the European Investment Bank will guarantee long-term renewable power purchase agreements (PPAs) for industrial SMEs (Reuters, 2025p). By de-risking 10–15 year renewable energy contracts, this measure directly lowers electricity costs for manufacturers and makes relocating to a green industrial cluster more attractive. The Clean Industrial Deal also includes an EU-wide circular

economy law by 2026 to cut feedstock costs and incentivise recycling of critical materials (Reuters, 2025p), which complements the infrastructure effort by ensuring recycled inputs (e.g. steel scrap, battery materials) flow into factories at scale. These policies recognize that clarity of direction plus patient capital can transform decarbonisation from a cost into a growth catalyst. ASEAN should likewise consider a blended finance facility (with development banks and green funds) that offers 15-year, low-interest loans or guarantees for on-site solar, bioenergy, and waste-recycling infrastructure in certified green parks. By aggregating projects regionally, smaller AMS can access financing on terms usually reserved for large EU projects.

China is moving even more aggressively in deploying near-zero-carbon industrial zones as engines of innovation. In Changzhou (Jiangsu province), a 100-hectare zero-carbon industrial park began operations in 2024 and showcases what's possible: it has 77,000 m^2 of solar PV panels generating 5.2 million kWh of green electricity annually and is now adding wind and hydro sources to hit net-zero emissions (Beijing Review, 2025). These parks integrate clean energy, green building design, smart grids, and circular economy practices by default. Early results indicate not only environmental benefits but also economic gains. One tenant, NR Electric, leveraged AI and IoT systems to monitor real-time energy use and cut its CO_2 emissions by 21,000 tonnes, saving ¥20 mn (~US$2.8 mn) in energy costs within a year (Beijing Review, 2025). Such examples demolish the myth that decarbonisation is antithetical to profit – when supported by proper infrastructure, efficiency pays. The city of Changzhou plans to build 10+ near-zero-carbon parks by 2026, alongside dozens of zero-carbon 'lighthouse' factories.

ASEAN industrial hubs (e.g. Eastern Seaboard in Thailand, Java's manufacturing corridor in Indonesia, or Malaysia's Proton City) could be prime candidates for pilot green parks that, like Changzhou's, combine on-site renewable generation, microgrids, electric vehicle charging, and closed-loop waste systems. Government action plans should set clear targets and provide matching grants or land concessions to kick-start development.

Beyond major economies, even emerging ASEAN members have proven the eco-industrial concept at pilot scale. Viet Nam's Eco-Industrial Park (EIP) initiative, run with UNIDO support, retrofitted 3 existing industrial zones (in Ninh Binh, Da Nang, Can Tho) between 2015–2019. The outcome was striking: 72 factories implemented resource-efficient technologies that save 22,000 MWh of electricity, 600,000 m^3 of water, and 3,600 tonnes of waste annually, yielding US$3 million in cost savings per year (Vietnam Briefing, 2024). These green upgrades (e.g. heat recovery, water recycling, biomass boilers) were co-financed by the private sector, which invested over US$10.6 million during the pilot, and in return the parks collectively cut CO_2 emissions by 32,000 tonnes per year (Vietnam Briefing, 2024). Such results convinced Viet Nam's government to formalize EIP incentives in a new decree, offering tax breaks, import duty exemptions and streamlined permits for park developers and 'eco-enterprises.' Moreover, Viet Nam is scaling up the programme with Swiss and World Bank funding, expanding to additional provinces and requiring every new industrial park to assess EIP conversion potential (Vietnam Briefing, 2024). This ASEAN experience demonstrates that green industrial parks are not a luxury, but a practical development strategy that improves productivity and environmental compliance simultaneously. It also shows the importance of a supportive policy framework: clear EIP certification criteria, fiscal incentives, and integration into urban planning were key to Viet Nam's success.

Appendix 17: Existing Landscape and Policies on Material & Carbon Footprint Tracing Platform

At present, traceability efforts in ASEAN are fragmented and nascent. A few large firms have proprietary systems – for instance, Toyota Indonesia uses blockchain/IoT for internal tracking of parts and vehicle emissions, and some Thai and Malaysian suppliers tag and trace materials within their own operations (e.g. using QR codes or basic RFID) (Reuters, 2025p). However, these are isolated islands of data. There is no common platform or data standard linking, say, a steel recycled in the Philippines to a component made in Thailand and then assembled in Indonesia. Even the ASEAN Single Window, while effective for exchanging customs documents, does not capture sustainability or production data. This contrasts starkly with developments elsewhere. Japan's 'Ouranos' ecosystem, an interoperable data infrastructure championed by METI and NEDO, is creating a unified ledger for automotive and battery supply chains (NTT DATA, 2025b). Europe's Catena-X, a consortium of OEMs and suppliers, has already onboarded thousands of companies onto a federated data exchange network, enabling multi-tier visibility of parts and their attributes. In fact, a recent pilot demonstrated that sharing standardized data through Catena-X cut the time and cost of carbon footprint (PCF) calculations by 3–5×, saving about €10,000 per analysis for suppliers by eliminating manual spreadsheets (Catena-X, 2025c). Such gains illustrate the efficiency dividend of a shared platform – a dividend ASEAN firms are currently missing out on. Moreover, the regulatory clock is ticking: All EV and industrial batteries over 2 kWh sold in the EU must carry a digital battery passport by 1 Jan 2026 (DNV, 2024), containing data on the battery's materials, manufacturing history, carbon footprint, and recyclability. By 2027, those batteries will be graded by carbon performance, and by 2030 they must include minimum levels of recycled content (DNV, 2024). This means any ASEAN battery or vehicle exporter will soon need to feed verified data into global data spaces or be barred from major markets. The absence of an ASEAN system puts the region at a disadvantage – without ASEAN-level traceability, suppliers could be locked out of EU and other regulated markets once digital-passport rules take effect. It is therefore a strategic imperative for ASEAN to build its own Catena-X-compatible ledger that interfaces with global systems but remains under regional governance.

Global benchmarks for traceability. Both policy and technology trends abroad can guide ASEAN's platform development. Europe's new Battery Regulation provides a blueprint for a full-stack approach: it couples legal mandates (e.g. requiring carbon footprint disclosure and a QR-code passport for each battery) with the creation of data standards and repositories to implement them. The EU is finalizing a standardized methodology for life-cycle carbon footprint calculation and a format for battery passports, and will enforce third-party verification of the data (DNV, 2024). In parallel, industry groups in Catena-X have settled on open standards (such as the GS1 EPCIS 2.0 data model for supply-chain events and W3C decentralized identifiers for companies) to ensure interoperability across software providers. The result is an emerging 'digital ecosystem' where any compliant data can flow between companies securely, enabling, for example, a German OEM to trace an ASEAN-made part's journey and carbon impact with a few clicks. Japan's Ouranos is pursuing a similar path. In April 2025, NTT Data and partners successfully demonstrated interoperability between Japan's battery traceability platform and Catena-X, by building an intermediate layer that reconciled differences in authentication and data models (NTT DATA, 2025b). This is a crucial proof-of-concept: it shows that if ASEAN adopts global

standards from the start, its data space can seamlessly connect to others (e.g. allowing ASEAN battery exports to plug into EU's system). On the policy side, China has begun piloting a Product Carbon Footprint (PCF) labeling and certification programme across 11 key industries (including lithium batteries, steel, cement, etc.) (Climate Cooperation, 2024). Over a 3-year pilot (2024–2027), select cities and companies will apply unified carbon accounting rules and get certified labels for their products, in hopes of creating best practices that can scale nationally. The aim is to harmonize data methods and encourage enterprises to compete on low-carbon performance. Notably, Chinese regulators explicitly intend to 'promote convergence and mutual recognition of domestic and international standards' for carbon footprint accounting (Climate Cooperation, 2024) – a recognition that global supply chains demand common languages. These international moves suggest that ASEAN should not reinvent the wheel but rather embrace and adapt existing frameworks (like the WBCSD/GHG Protocol for carbon data, and EU Circular Economy standards for recycled content) to regional needs. Doing so will ease compatibility and make it simpler for multinationals to integrate ASEAN suppliers into their digital supply chains.

Another instructive innovation is China's Corporate Carbon Accounting and Rating Platform for green finance. This government-backed digital system automatically pulls companies' energy and output data and generates a carbon score or rating, often color-coded, that banks use to adjust loan terms (Su, 2025). Since 2021 it has been piloted in at least six provinces to guide lower-interest green loans for SMEs based on their carbon performance. This shows the spillover benefits of a robust data platform: once firms' carbon metrics are transparent and trusted, financial institutions can incentivize decarbonisation (e.g. via cheaper credit for low-carbon suppliers). An ASEAN traceability platform could similarly feed into sustainability-linked financing – for example, a parts maker that fully reports its material flows and shows reduced footprint might automatically qualify for an interest rebate from a regional green fund. In short, reliable data unlocks policy tools (like green procurement, carbon pricing, and investment incentives) that currently are stymied by information gaps.

Appendix 18: Existing Landscape of the ASEAN Single Window

As of now, the implementation of the ASW only encompasses basic paperless customs limited to the varying maturity levels of each AMS' National Single Window (NSW) (ASEAN Single Window, 2025). Based on the United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP), the maturity levels of Single Windows could expand to up to a regional information exchange system (Level 5), yet to be achieved in ASEAN (Table 8.5).

Table 8.5. Five Evolutionary Stages of Single Window

Stage	Key Characteristics
Level 1	Paperless Customs + e-Payment for Customs Duty + e-Container Loading List + Electronic risk-based inspection
Level 2	Connecting other government back-end IT systems and e-Permit exchange with paperless custom systems

Stage	Key Characteristics
Level 3	Port-Communication Information Exchange: e-Documents Exchange amongst stakeholders within the air and seaport community
Level 4	An integrated national logistics platform with traders and logistics-service providers information exchange (e.g., banks for various kinds of e-payment, insurance companies, freight forwarders and logistic service providers)
Level 5	A regional information-exchange system or cross-border paperless trade

Note: Based on UNESCAP's five stages of NSW's evolution; in many countries, L3 was developed before L2
Source: ADB (2022).

At country level, Singapore's TradeNet is recognised as the global gold standard, or the most advanced, (Level 5) with various key milestones – paperless customs reduces trade documents processing from 2-4 days to 15 minutes, e-permit issuance streamlines 20 paper forms into one single digital form, logistics e-documents exchange saves freight forwarders 25% to 35% in document handling costs, integrated payment system completes transactions in less than 10 minutes, inter-agency data exchange improves staff productivity by digitalising trade documents distribution to various agencies, and operates Networked Trade Platform to interact with foreign NSWs (ADB, 2022; Singapore Customs, 2025). Brunei Darussalam, Indonesia, Malaysia, the Philippines, and Thailand have built relatively advanced NSWs but limited in their regional interoperability (Level 3 to Level 4). Indonesia, Malaysia, the Philippines, and Thailand already integrate paperless customs and e-permits services, National Logistics System, inter-agency applications, and tax payment system (ASEAN Single Window, 2025). Brunei Darussalam launched a smaller-scale Maritime Single Window in 2025, centralising communications between shipping lines, port authorities, customs, and logistic services providers (Port Technology, 2025). Meanwhile, Cambodia, Lao PDR, Myanmar, and Viet Nam are still focusing paperless customs and launching NSW efforts (Level 1 to Level 2). Regionally, all ten AMS can digitally exchange ASEAN Trade in Goods Agreement (ATIGA) e-Form D and the ASEAN Customs Declaration Document (ACDD) through ASW (ASEAN Single Window, 2025). However, ASW still needs to evolve to higher maturity levels to improve regional trade.

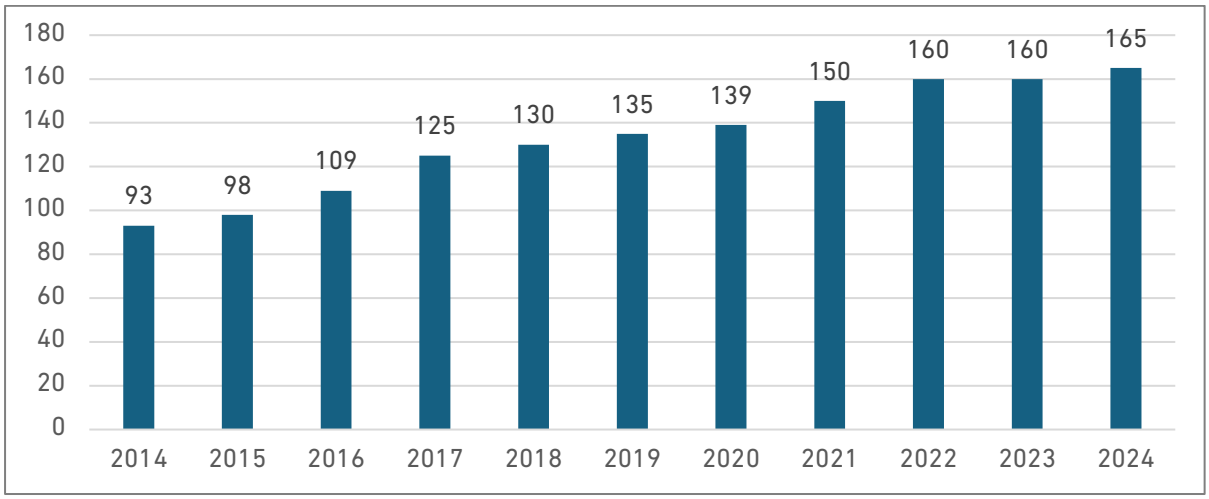
Appendix 19: Existing Landscape on the Tariff and Non-Tariff Borders

The automotive trade flow in ASEAN is limited by tariffs and NTMs, preventing OEMs and suppliers across AMS to benefit from the economies of scale of an integrated hub. Significant strides in tariff liberalisation are made through the 1992 Common Effective Preferential Tariff (CEPT) Scheme under the ASEAN Free Trade Area (AFTA) and 2010 ATIGA – enabling 98.6% of ASEAN's traded goods to be tariff-free including CBU vehicles (ASEAN, 2025). However, implementation of ATIGA on CKD vehicles and auto parts tariffs is harder to oversee. An ERIA study on the 'Impact of the ASEAN Trade in Goods Agreements (ATIGA) on the Inter-ASEAN

Trade' reveals that there were still more than 100 ATIGA tariff lines in automotive that had not been implemented in Thailand and Viet Nam by the tariff reduction deadline in 2018 (ERIA, 2021).

Nevertheless, Despite the ATIGA tariff elimination, intra-regional trade of automotive goods remains stagnant at 24% to 22% (US$608 billion to US$759 billion) throughout the decade of 2014-2023 (ASEANstats, 2025). Contrarily, the number of NTMs on vehicles under HS 87 codes increased 77% from 93 measures in 2014 to 165 measures in 2024 – signifying that AMS continues to employ trade protectionism via NTMs instead of tariffs (TRAINS, 2025), as shown in Figure 8c.

Figure 8c. Number of Automotive NTMs Employed by AMS to Other AMS 2014-2024



Note: Detailed search query is Economies applying the NTMs = ASEAN, Affected Markets = ASEAN, Products affected = 87 Vehicles, Type(s) of NTMs = All NTM Types.
Source: TRAINS (2025).

Brunei Darussalam, Malaysia, Singapore, and Thailand implement the lowest number of NTMs at 6 measures, 5 measures, 3 measures, and 7 measures respectively (Figure 8-34). The NTMs cover basic technical measures, such as vehicle product registration, vehicle importer licensing, etc. However, vehicle product registration is dependent on vehicle labelling, safety, and emissions standards that remain largely unharmonised across ASEAN – AMS must standardise them based on 19 United Nations Economic Commission for Europe (UNECE) regulations but AMS 'who does not have national standards is not obliged to develop a standard' (TRAINS, 2025; ASEAN, 2015). Meanwhile, the ASEAN Mutual Recognition Arrangements for Automotive Products (APMRA) are in the process of ratification for most AMS, except Malaysia, Myanmar, and Viet Nam (MARii, 2023). Cambodia, Lao PDR, and Viet Nam employs 10 NTMs, 15 NTMs, and 20 NTMs as of 2024 (TRAINS, 2025) – these barriers are more nuanced such as, Cambodia, Lao DPR, and Viet Nam requiring additional custom fees for export and import vehicles (Viet Nam charges ₫20,000 per declaration); Cambodia prohibiting the imports of ozone depleting substances and Lao DPR requiring additional permits and inspection of products containing the substances. Crucially, Viet Nam places more stringent barriers for vehicle imports that inflate costs significantly – limiting the presence of foreign vehicle traders and requiring custom duties to be paid immediately instead of previous 275-day grace period. The remaining Indonesia, Myanmar, and the Philippines impose 27 NTMs, 35 NTMs, and 37

NTMs each (TRAINS, 2025). Indonesia limits EV imports mostly through luxury car VAT taxes ranging from 15% to 70%, a mandated minimum local content requirement of 35% by 2019 up to 80% by 2030, SNI marking requirements, and numerous authorisation processes on automotive goods under the Ministry of Trade (TRAINS, 2025; Taxprime, 2022; CNN Indonesia, 2023). Myanmar has the vehicle export prohibition, VAT of 5% for imported vehicles, ATIGA self-certification system for foreign OEMs and suppliers, advanced export tax collection at 2% of exported value, and restrictions on the production years of imported vehicles. Philippines imposes VAT of 10% on imported vehicles, limits direct exports and imports of vehicles to socialist countries (Lao PDR, Myanmar) through the Philippine International Trading Corporation, extensive fees under customs clearance processing (custom transit fee of ₱50,000, handling and storage fees, container security fees, etc.) (TRAINS, 2025). Since growing NTMs are placed across AMS to replace tariffs, automotive trade remains isolated and stagnant, going against the ambition of an integrated manufacturing hub.

Cross-cutting issues related to tariffs and NTMs continue to hinder automotive trade across AMS, keeping them as isolated economies. Firstly, tariffs on CBU, CDK, and auto parts are not monitored closely resulting in non-zero ATIGA tariff lines. Secondly, there is no obligation to create national safety, labelling, emission standards and APMRA are still in development amongst most AMS causing vehicle non-compliance that restricts market access. As an example, vehicles that are manufactured in Indonesia may not pass the safety, labelling, and emission testing in Malaysia. Thirdly, most AMS are not transparent in their export/import licensing requirements and customs processing that drives up costs and lead-times when intra-regional trade is involved. Finally, non-technical NTMs also affect liberalisation of automotive trade such as the VAT taxes to replace tariffs, as well as minimum local content requirements and import/export licensing that disrupts integration.