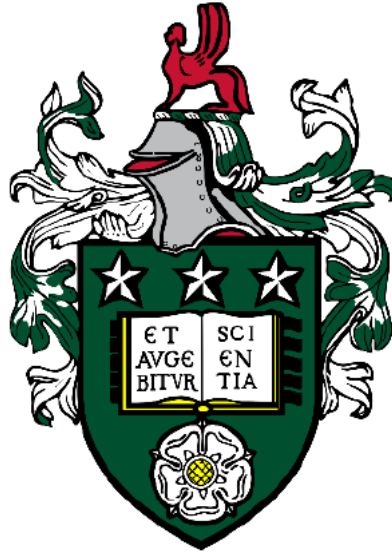


Eco-innovation Driven Energy Transition: A Case Study of the Energy for Transportation Sustainability in Indonesia



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Submitted in accordance with the requirements for the degree of
Doctor of Philosophy
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School of Geography

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Details of jointly authored publications and corresponding thesis chapter

Chapter 4

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Chapter 5

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Chapter 7

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Details of authorship contributions

A Multi-Level Perspective on Transition to Renewable Energy in the Indonesian Transport Sector

1. Ferry Fathoni: Designing the research; collecting and analysing data; writing the first draft of the article, and revising during the peer review process.
2. Jon C Lovett: Providing supervision during the research design, first draft-writing, and revisions; providing guidelines for responding to reviewers' comments; and proofreading.
3. Muhammad Mufti Rifansha: Involved in the data analysis (transcribing), providing valuable insights related to Indonesia's energy policies.

Power Relations in Indonesia's Transport Transition: A Multi-Theoretical Analysis of Actor Dynamics in the Adoption of Alternative Fuel Technologies

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Estimating Lifecycle Management of Retired Electric Motorcycle Batteries into Total Cost of Ownership Modelling in Indonesia

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2. Kang Li: Supervising the research design, first draft-writing, data processing and analysis; providing guidelines for responding to reviewers' comments; and proofreading.
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Statement on the Impact of Covid-19 Pandemic

My PhD journey went through the COVID-19 pandemic, which was impacted by social restrictions and other COVID-19 prevention measures. This impact affected the early and middle stages of this research. I started my PhD journey in October 2019 under normal circumstances. I prepared the research matrix, the research questions, reviewed the literature, analysed initial data, and took part in in-person academic training.

In the third week of March 2020, the COVID-19 pandemic began to spread in the UK. The announcement of the first lockdown, followed by several rounds of extensions until August 2020, has resulted in the limitations of this research due to limited access. All activities in the initial period of the dissertation were moved from my office at the University to my home. However, thanks to technological advances, especially video conferencing, FFPR and viva transfers can occur amid the pandemic. This period has provided significant challenges because the primary data source comes from my country, Indonesia. My company's overseas travel restriction policy has limited primary data collection. To overcome this challenge, the thesis ethics document was adapted to collect primary data remotely via video conference or online survey. The potential participant recruitment process experienced obstacles due to the difficulty of obtaining contact information from various stakeholders in Indonesia's transportation energy sector, which was very private for some people. This condition resulted in an amendment to the research ethics document, especially on eco-innovation, using a multi-level interview approach in December 2022. The amendment to the research ethics document was approved in February 2023.

Collecting data remotely, especially video conferencing, was carried out via an online platform. Even though all information can be obtained, this approach reduces the involvement of informants. This limited participant involvement has prevented me from constructing a more cognitive relationship between the observed phenomena and recent literature.

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Abbreviations

AAPRESID	<i>Asociación Argentina de Productores en Siembra Directa</i> (Argentine Association of Direct Seeding Producers)
AC	Alternating Current
ADB	Asian Development Bank
Directorate	<i>Direktorat Aneka Energi Baru dan Energi Terbarukan</i> (Directorate of New and Renewable Energy)
AEBET	
AEML	<i>Aliansi Elektrifikasi Mobilitas Listrik</i> (Electric Mobility Ecosystem Association)
AISI	<i>Asosiasi Industri Sepedamotor Indonesia</i> (Indonesian Motorcycle Industry Association)
ANTAM	<i>Aneka Tambang</i> (Indonesian State-Owned Mining Enterprises)
APROBI	<i>Asosiasi Produsen Biofuel Indonesia</i> (Indonesia Biofuel Producer Association)
ASEAN	Association of Southeast Asian Nations
ATD	Annual Traveling Distance
AF	Alternative Fuel
BBN-KB	<i>Bea Balik Nama Kendaraan Bermotor</i> (Transfer of Motor Vehicle Title Fee)
BCG	Boston Consulting Group
BESS	Battery Energy Storage Systems
BEV	Battery Electric Vehicle
BKPM	<i>Badan Koordinasi Penanaman Modal</i> (Investment Coordinating Board)
BLDC	Brushless Direct Current Motors
BMS	Battery Management System
BPDPKS	<i>Badan Pengelola Dana Perkebunan Kelapa Sawit</i> (Oil Palm Plantation Fund Management Agency)
BPPT	<i>Badan Pengkajian Dan Penerapan Teknologi</i> (Agency for the Assessment and Application of Technology)
BRIN	<i>Badan Riset dan Inovasi Nasional</i> (National Research and Innovation Agency)
BRT	Bus Rapid Transit
BSN	<i>Badan Standardisasi Nasional</i> (National Standardisation Body)
BSS	Battery Swap System

BTU	British Thermal Unit
CBR	Cost of Battery Replacement
CE	Cost of Energy
CI	Cost of Insurance
CM	Cost of Maintenance and Repair
CNG	Compressed Natural Gas
COP	Conference of the Parties
COPEX	Cost of Operational Expenditure
COVID-19	Corona Virus Disease 2019
CPO	Crude Palm Oil
CREA	<i>Consorcios Regionales de Experimentación Agrícola</i> (Association of Regional Consortia for Agricultural Experimentation)
CT	Cost of Taxes
DC	Direct Current
DDT	Double-double Tracks
DEN	<i>Dewan Energi Nasional</i> (National Energy Council)
DG Move	Directorate-General for Mobility and Transport
DOI	Diffusion of Innovations Theory
DPD	<i>Dewan Perwakilan Daerah</i> (Regional Representative Council)
DPR	<i>Dewan Perwakilan Rakyat</i> (House of Representatives)
DG EBTKE	<i>Direktur Jenderal Energi Baru, Terbarukan, dan Konservasi Energi</i> (Directorate General of New, Renewable Energy, and Energy Conservation)
EI	Eco-Innovation
EIA	Environmental Impact Analysis
EMC	Electric Motorcycle
EN	European Norm
ERP	Electronic Road Pricing
ESG	Environmental, Social, and Governance
ESS	Energy Storage System
EU	European Union
EV	Electric Vehicle
FAME	Fatty Acid Methyl Ester
FAO	Food and Agriculture Organisation
FFB	Fresh Fruit Bunches
GAIKINDO	<i>Gabungan Industri Kendaraan Bermotor Indonesia</i> (Association of Indonesia Automotive Industries)

GAPKI	<i>Gabungan Pengusaha Kelapa Sawit Indonesia</i> (Indonesian Palm Oil Association)
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GW	Gigawatt
HEV	Hybrid Electric Vehicle
HI	Historical Institutionalism
HVO	Hydrotreated Vegetable Oil
IAA	<i>Instituto de Álcool e Açúcar</i> (Institute of Alcohol and Sugar)
IBC	Indonesia Battery Corporation
ICEV	Internal Combustion Engine Vehicle
IDR	Indonesian Rupiah
IEA	International Energy Agency
IEC	International Electrotechnical Commission
ILUC	Indirect Land Use Change
IMF	International Monetary Fund
INTA	<i>Instituto Nacional de Tecnología Agropecuaria</i> (National Institute of Agricultural Technology)
IPP	Independent Power Producer
ISCC	International Sustainability and Carbon Certification
ISO	International Organisation for Standardisation
ISPO	Indonesian Sustainable Palm Oil
IUCN	International Union for Conservation of Nature
JICA	Japan International Cooperation Agency
JPOI	Johannesburg Plan of Implementation
KAI	<i>Kereta Api Indonesia</i> (Indonesian Railways)
KCI	<i>Kereta Commuter Indonesia</i> (Indonesian Commuter Railways)
KEN	<i>Kebijakan Energi Nasional</i> (National Energy Policy)
KL	Kilolitres
KPK	<i>Komite Pemberantasan Korupsi</i> (Commission for Eradication of Corruption)
KUBE	<i>Kebijakan Umum Energi</i> (General Policy on Energy)
LEVD	Low Emission Vehicle Development
LFP	Lithium Iron Phosphate
LIB	Lithium-ion Battery
LRT	Light Rail Transit
MBPD	Million Barrels per Day

MEF	Ministry of Environment and Forestry
MEMR	Ministry of Energy and Mineral Resources
MLP	Multi-level Perspective
MoA	Ministry of Agriculture
MoF	Ministry of Finance
MoI	Ministry of Industry
MPR	<i>Majelis Permusyawaratan Rakyat</i> (People's Consultative Assembly)
MRT	Mass Rapid Transit
MRU	Mobile Refueling Unit
MSAEBR	<i>Kementerian Pendayagunaan Aparatur Negara dan Reformasi Birokrasi</i> (Ministry of Administrative and Bureaucratic Reform)
MSME	Micro, Small, and Medium Enterprises
MSOE	Ministry of State-Owned Enterprises
MTOE	Million Tonnes of Oil Equivalent
NDC	Nationally Determined Contributions
NEV	New Energy Vehicle
NGO	Non-Governmental Organisation
NIE	New Institutional Economic
NIEO	New International Economic Order
NODA	Notice of Data Availability
NRE	New and Renewable Energy
NZE	Net Zero Emission
OECD	Organisation for Economic Co-operation and Development
OPEC	Organisation of Petroleum Exporting Countries
OPEX	Operational Expenditure
OTR	On the Road
PERIKLINDO	<i>Perkumpulan Industri Kendaraan Listrik Indonesia</i> (Indonesian Electric Vehicle Industry Association)
PHEV	Plug-in Hybrid Electric Vehicle
PIMG	Plug-in Motorcycle Grant
PLI	Production-Linked Incentive
PLN	<i>Perusahaan Listrik Negara</i> (State Electricity Company)
PPA	Power Purchase Agreement
PV	Photovoltaic
RAN-GRK	<i>Rencana Aksi Nasional Penurunan Emisi Gas Rumah Kaca</i> (National Action Plan for Reducing Greenhouse Gas Emissions)

RB	Battery Resale Price
RED	Renewable Energy Directive
REDD+	Reducing Emissions from Deforestation and Forest Degradation
RFS	Renewable Fuel Standard
RIPIN	<i>Rencana Induk Pembangunan Industri Nasional</i> (National Industrial Development Plan)
RIPNAS	<i>Rencana Induk Perkeretaapian Nasional</i> (National Railway Master Plan)
RSPO	Roundtable on Sustainable Palm Oil
RUED	<i>Rencana Umum Energi Daerah</i> (Regional General Energy Plan)
RUEN	<i>Rencana Umum Energi Nasional</i> (National Energy General Plan)
RUPTL	<i>Rencana Usaha Penyediaan Tenaga Listrik</i> (Electricity Supply Business Plan)
RV	Resale Value
SAF	Sustainable Aviation Fuel
SBZ	Special Biofuel Zone
SDGs	Sustainable Development Goals
SLA	Sealed Lead Acid
SLR	Systematic Literature Review
SNI	<i>Standar Nasional Indonesia</i> (Indonesian National Standard)
SOE	State-Owned Enterprise
SPBG	Stasiun Pengisian Bahan Bakar Gas (Natural Gas Refuelling Station)
TCO	Total Cost of Ownership
TJ	Terajoule
TM	Transition Management
TOD	Transit Oriented Development
UCO	Used Cooking Oil
UK	United Kingdom
ULEZ	Ultra-Low Emission Zone
UN	United Nations
UNCED	United Nations Conference on Environment and Development
UNDESA	United Nations Department of Economic and Social Affairs
UNDP	United Nations Development Program
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UPP	Upfront Purchase Price

UPS	Uninterruptible Power Supply
US	United States
US EPA	United States Environmental Protection Agency
USD	United States Dollar
UUD	<i>Undang-undang Dasar</i> (Constitution)
VAT	Value Added Tax
VRE	Variable Renewable Energy
WCED	World Commission on Environment and Development
WTO	World Trade Organization
WWF	World Wildlife Fund

Chapter 1 Introduction

1.1 Background

The diffusion and uptake of eco-innovation is one of the main policy agendas for supporting the socio-technical transition towards sustainability in emerging economies. Eco-innovation (EI) refers to innovations that reduce environmental risks while generating economic and social value, representing a fundamental departure from conventional innovation pathways (Carrillo-Hermosilla et al., 2010; Horbach et al., 2012; Paipa-Sanabria et al., 2025). EI continues to evolve both technical and non-technical aspects applied to products, processes, services, organisational, marketing, business models or even regulatory approaches to reduce environmental impacts and/or optimise resource use (Demirel and Kesidou, 2019; OECD, 2011). Eco-innovation plays an important role in reducing ecological risks, improving resource efficiency, and mitigating negative environmental impacts while maintaining or even enhancing market competitiveness (Kemp and Pearson, 2007; Carrillo-Hermosilla et al., 2010; Bossle et al., 2016). Unlike traditional innovation, eco-innovation is inherently systemic. EI requires not only technological breakthroughs but also support for changes in policy, institutions and user behaviour to promote its adoption and diffusion (Hojnik and Ruzzier, 2016; Kaenzig and Wüstenhagen, 2010).

Aragon-Correa and Leyva-de la Hiz (2016) emphasise that compliance with increasingly stringent environmental regulations, environmental technology push, market pull for more environmentally friendly products, and the improvement of institutional capabilities have become EI's internal determinants within firms. On the other hand, environmental externalities and knowledge spillovers are external determinants of EI (Demirel and Kesidou, 2019; Orjuela-Ramirez et al., 2023). Meanwhile, studies on EI also demonstrate that the role of government is crucial for harmonising environmental and innovation policies so that innovative products can continue to have a market share (Rennings, 2000; Orjuela-Ramirez et al., 2023).

The process of EI begins with the idea generation and mobilisation phase, which is followed by the screening phase. During the screening phase, EI ideas are evaluated to determine their potential compliance with environmental policies while still being profitable (Sadler, 2020; Sovacool et al., 2018). Once an idea is screened, experimentation and development are carried out on EI projects to advance them toward commercialisation and widespread diffusion (Sadler, 2020; Sovacool et al., 2018). The diffusion of EI offers a useful perspective for analysing how sustainable technologies

emerge, spread, and transform socio-technical systems. "The framework for exploring consumer acceptance of new products is drawn from the area of research known as the diffusion of innovations" (Schiffman et al., 2012, p.403). In contrast to the diffusion process, which is macro, there is also the adoption of innovation which is a micro process that focuses on the stages that individual consumers go through in deciding to accept or reject a new product as a result of innovation (Desouza et al., 2009; Glover et al., 2019). For EI to diffuse effectively, it requires further adaptation and ongoing experimentation to achieve social acceptance from customers who are already acquainted with the existing system. Social acceptance is not just a function of technological rationality; it also involves discourse, power, and identity. Therefore, understanding the cultural and institutional contexts of eco-innovations is crucial for achieving equitable and inclusive transitions (Jammes et al., 2025; Pineda et al., 2023).

The diffusion of EI is a constantly evolving subject, particularly regarding the socio-technical transitions toward sustainability (Eitan and Hekkert, 2023). According to Rogers (2003), diffusion is defined as the process by which innovation is communicated among members of a social system over time through specific channels. Geels (2002) further emphasises that the diffusion of EI in sustainability transitions occurs through multi-level interactions among niches, regimes, and landscapes (Geels and Turnheim, 2022). In the context of EI, diffusion is not a linear process; rather, it is influenced by the interests of various actors, governance frameworks, market structures, and social acceptance (Markard et al., 2012; Schot and Steinmueller, 2018). This complexity underscores why developing countries like Indonesia offer valuable opportunities to study how eco-innovations are adopted, rejected, or transformed within their unique institutional and socio-political contexts.

The socio-technical transition framework catalyses the diffusion of innovation theory while addressing a wider range of desires. Socio-technical transitions focus on long-term, multi-dimensional shifts within systems such as energy and transportation (Geels, 2018; Wu, Z. et al., 2021). These transitions involve not only technological advancements but also changes in regulatory frameworks, market structures, user practices, and cultural adaptations (Geels, 2002; Markard et al., 2012). In this context, the diffusion of EI extends beyond just applying a technological solution; it is part of a larger transformation of the social system. For instance, biofuels have emerged not only as a technical alternative but also as products shaped by global commodity chains, sustainability certification, and local socioeconomic equity (Astari et al., 2025; Choiruzzad et al., 2021; Ichsan et al., 2025). Similarly, electric vehicles (EVs) in Indonesia are distributed not only through consumer acceptance but also influenced by state-led industrial policies, global mobility trends, international trade relationships, and cultural perceptions of mobility (Sunitiyoso et al., 2023; Waluyo et al., 2022).

The focus of this research on socio-technical transitions lies in the normative framework of sustainability and sustainable development. Sustainability refers to a system's ability to meet present needs without compromising the needs of future generations by integrating ecological, social, and economic dimensions (Purvis et al., 2019; WCED, 1987). Sustainable development, as described by Barbier (1987) and Sachs (2015), expands on this concept by outlining a strategic path that seeks to reconcile growth with environmental conservation (Barbier, 1987; Sachs, 2015). In this study, sustainability is approached not as an abstract goal but as a contested and negotiated process in which various actors mobilise different forms of knowledge, power, and institutional arrangements to either promote or resist pathways toward decarbonisation. Transportation is the third-largest sector of global energy consumption, accounting for about 25% of both fuel production and consumption (Lindstad et al., 2023). This sector accounts for 22.96% of total emissions, approximately 7.98 gigatons of carbon dioxide (IEA, 2023a). It heavily relies on petroleum products, which still account for 91% of its energy sources (IEA, 2023a). Within transportation, the road sector is the most significant contributor, responsible for about 74.5% of overall emissions (Our World in Data, 2020).

Global initiatives for sustainable development include the decarbonisation of transportation systems as an essential policy priority. EI plays an essential role in achieving the United Nations Sustainable Development Goals (SDGs) (Sipos and Ionescu, 2024; Fatma and Haleem, 2023; Sadiq et al., 2023). SDGs are a universal initiative aimed at eliminating poverty, encouraging environmental conservation, and fostering inclusivity, with a target for completion by 2030. The SDGs comprise 17 global objectives adopted by all United Nations (UN) member states in 2015 as part of the 2030 Agenda for Sustainable Development (UNDESA, 2023). Intensive decarbonisation of the transportation sector involves eco-innovation, alternative vehicle fuels, electrification of mobility, and integrated mass transit systems. These efforts directly contribute to achieving the seventh SDG, which focuses on providing affordable and clean energy (Xia and Li, 2022; Panoutsou et al., 2021).

The implementation of transportation decarbonization varies significantly between countries, particularly between developed and developing nations. The complexities involved in formulating, diffusing, and adopting environmentally friendly transportation technologies provide an opportunity to discuss the role of EI in fostering sustainable development (Singh, J. and Clough, 2024; Costa et al., 2021). Recent studies have explored the impact of the EI diffusion on the sustainable development of the transport sector in emerging economies, with a particular focus on mass public transport (Nadeem et al., 2021; Nikitas and Karlsson, 2015), biofuels (Kirshner et al., 2022; de Vos et al., 2023; Grandis et al., 2024), and EVs (Abbasi et al., 2021; Pandita et al., 2024; Waluyo et al., 2022) at national, subnational, and rural levels. There are also comparative studies

on the EI of biofuels and EVs across various countries (Nikas et al., 2022; Shamsuddoha and Nasir, 2025; Abbasi et al., 2021).

This study aims to fill the gap in comprehensive research concerning the socio-technical transition in developing countries, emphasising the importance of path dependence for sustainability from a multilevel perspective. This multilevel perspective is required to analyse the impact of power relations in cross-border actor interactions related to the diffusion of EI. Additionally, it is crucial to deeply explore how stakeholders tackle key issues regarding the social acceptance of green technologies, such as biofuels and EVs, as they compete with the dominance of the fossil fuel regime.

This dissertation aims to understand the complexities involved in the diffusion of EI and social acceptance of low-carbon technology that contribute to achieving sustainable development in Indonesia's transportation sector as a developing country. The motivation that triggers this dissertation includes four aspects. First, the efforts to promote sustainable transportation in emerging economies are challenged by institutional inertia and fragmented governance. Long-established institutional structures can both facilitate and hinder the transition to sustainability. This study examines the evolution of sustainability policies, highlighting that this process is not linear but is shaped by historical path dependence, power asymmetry, and hybrid governance structures. Utilising the Multilevel Perspective (MLP) framework, this study has identified the impacts of various landscape pressures—such as the global environmental agenda, environmental issues, trade disputes, and energy security concerns—along with the diffusion of environmentally-friendly innovations on the stability and development of the transportation regime's institutions (Geels, 2012; Klitkou et al., 2015; Cameron and Geels, 2019; Geels, 2024). Through a combination of historical institutionalism (HI), this research examines how long-lasting institutions—formed through past policy choices and bureaucratic norms—can reinforce existing transportation regimes or create opportunities to support the diffusion of EIs (Lockwood et al., 2017; North, 1995; Karaulova et al., 2017).

Second, the socio-technical transition to sustainability is embedded in contested power relations. This study uses Indonesian policies regarding the diffusion of biofuels and EVs as a case study to explore how different governance structures, discursive frameworks, and institutional power impact EI pathways in transportation. The transportation sector in developing countries provides an interesting context for analysing power relations. The advancement of biodiesel and the increasing adoption of EVs have demonstrated how dominant actors—such as government agencies, state-owned enterprises (SOEs), large multinational palm oil companies, and global automotive manufacturers—utilise structural and instrumental power to shape policy decisions (Ichsan et al., 2025; Astari et al., 2025; Dwi, 2024). Furthermore, the global narratives on decarbonisation and

sustainability certifications serve as discursive and disciplinary mechanisms to legitimise specific technological power (Newell and Bray, 2025; Choiruzzad, 2019). However, these established power relations often deepen social inequalities and marginalise other groups, including smallholder farmers, local startup SMEs, lower-middle-class urban populations, and rural communities (Djarmika et al., 2024; de Vos et al., 2023; Kirshner et al., 2022; Sovacool et al., 2022).

Third, the diffusion of eco-innovation to comply with stricter environmental regulations has encountered various drivers and challenges, particularly between developed and developing nations. This different diffusion advancement is primarily due to the complexity of institutional frameworks and ineffective bureaucracy. Therefore, it is essential to examine the adoption of technology, particularly among users in rural areas, using the framework of propositions, encounters, dispositions, and responses (Glover et al., 2019). The adoption of biofuels and EVs requires further analysis of their impacts on environmental conservation and social justice, especially concerning smallholder farmers, rural communities, and low- to medium-income urban populations (Ichsan et al., 2025; Hasan et al., 2022). Additionally, the introduction of second-generation biofuels processing technology, which is more compatible with conventional vehicle engines and does not compete with the food sector, has posed challenges in terms of technology mastery and investment (Kirshner et al., 2022; Sugiyono et al., 2020). However, the diffusion of second-generation biofuels has also raised concerns about equitable welfare for marginalised groups, including small farmers and rural communities (Kirshner et al., 2022). Furthermore, it was crucial to understand how stakeholders tackle the environmental externalities associated with the diffusion of EI through biofuels and EVs (Klitkou et al., 2015; Singh, J. and Clough, 2024).

Fourth, despite the government of a developing country's efforts to implement various fiscal and non-fiscal policies to promote EV adoption, social acceptance and adoption of this environmentally friendly mobility technology remain low compared to those in developed countries. Several key factors influence emerging market consumers' adoption decisions. These include the upfront purchase price, operational and maintenance costs, the availability of charging infrastructure, driving range, and compatibility with daily mobility needs (Shamsuddoha and Nasir, 2025; Pandita et al., 2024; Abbasi et al., 2021). However, EV adoption in developing countries is hindered by high upfront purchase prices, limited charging infrastructure, and slow battery charging times, which reduce public interest (Abdul Qadir et al., 2024; Pandita et al., 2024; Abbasi et al., 2021). From a socio-technical transitions perspective, the patterns of adoption reveal the power relationship between niche innovations and the incumbent regime (Geels et al., 2020; Grin et al., 2010). EVs necessitate significant transitions in infrastructure, business model strategies, and user social approaches. Institutional factors such as institutional inertia, vested interests, and fragmented policies have

hindered the necessary reconfiguration of the transport system for decarbonisation through the adoption of EVs (Sovacool et al., 2022; Newell and Bray, 2025).

This study focuses on the diffusion of EI in Indonesia's transportation sector as a case study. This study aims to analyse theoretical aspects and examine the reasons behind the need for socio-technical transitions, along with their impact on achieving sustainability targets established by the government. Four reasons determine the choice of this sector as a case study. First, global landscape dynamics—such as the oil crisis, geopolitical conflicts, environmental initiatives, and trade disputes—have significantly shaped regime sustainability policies. The need for alternative fuels has become evident, particularly after Indonesia transitioned to being a net oil importer, which, coupled with rising fuel consumption and soaring subsidies, contributed to a current account deficit in 2004 (BPPT, 2018; Varela and Zangrandi, 2015). The initiative to develop biodiesel in Argentina, which spread globally in the early 2000s (Nikas et al., 2022; Tomei and Upham, 2009), has inspired policymakers in Indonesia. This fuel shift effort was marked by the issuance of Presidential Instruction No. 1/2006 concerning the provision and utilisation of biofuels as alternative fuels for motor vehicles (Sembiring, 2025; Ichsan et al., 2025; Suhara et al., 2024). This eco-innovation policy has been influenced by path-dependence, particularly in the determination of biofuel feedstocks, which are currently dominated by palm oil-based biodiesel compared to sugarcane molasses-based ethanol (Ichsan et al., 2025; Choiruzzad et al., 2021). Simultaneously, initiatives have been made to improve mass public transportation. The successful development of the EI bus rapid transit (BRT) system in Curitiba, Brazil, has diffused worldwide (Nadeem et al., 2021; Nikitas and Karlsson, 2015; Wright, 2011). BRT systems began to gain traction in Asia in the early 2000s and were subsequently adopted by the local government of Jakarta, the capital of Indonesia (Hasibuan and Mulyani, 2022). The enactment of Jabodetabek Governor Regulation No. 48/2006 marked the beginning of a new era for the adoption of EI BRT systems in the Jakarta metropolitan area (PPID PT Transportasi Jakarta, 2020).

Second, power relations between local and global agencies have caused contestation that influences structural power, institutional change, the emergence of dominant discourses, and the implementation of disciplinary mechanisms. These factors have significantly shaped the formulation of eco-innovation policy trajectories for transportation sector sustainability. Despite the advancements in the diffusion of Indonesian biodiesel EI, the issue has sparked debates among various stakeholders. These debates were mainly due to the supply chain's frequent intersection with global concerns, including politics and trade (Sembiring, 2025; Astari et al., 2025), the adoption of environmentally friendly technologies (Farobie and Hartulistiyoso, 2022; Sugiyono et al., 2020), and environmental degradation (Ichsan et al., 2025; Choiruzzad et al., 2021). Challenges such as deforestation, land conversion, land tenure disputes, and social welfare inequality hinder the ability to align the sustainable development of low-emission

transportation eco-innovation with biodiversity conservation efforts (Ichsan et al., 2025; Astari et al., 2025; Choiruzzad et al., 2021).

Third, the landscape dynamics of the global sustainability agenda, especially following the Paris Agreement at COP 21 in 2015, have placed pressure on the Indonesian government to commit to decarbonization. The transportation sector has been a primary focus of the government's decarbonisation program. However, power contestation between agencies has tended to prioritise path dependencies over sustainability, crystallising in the MEMR Regulation No. 12/2015 which mandated use of B20 biodiesel and was implemented in 2016 (Suhara et al., 2024; Farobie and Hartulistiyoso, 2022). Despite this, several years later, the global trend towards EVs and the niche innovations fostered by the presence of local EV brands have encouraged the government to promote EV adoption. This institutional shift in focus resulted in the enactment of Presidential Regulation No. 55/2019, which aims to accelerate the development of battery-based electric vehicles (BEVs) for road transportation (Hakam and Jumayla, 2024; Afraah et al., 2021). Nevertheless, the widespread adoption of EVs, as seen in the EU, US, China, Japan, and South Korea (Greitemeier et al., 2025; IEA, 2025; Helveston et al., 2015), has not yet been realised in Indonesia (Afraah et al., 2021; Hakam and Jumayla, 2024). Several key barriers hinder this advancement, including unclear regulations, high upfront purchase prices, and inadequate charging infrastructure. Addressing these barriers required the development of effective socio-technical transition strategies by stakeholders (Abdul Qadir et al., 2024; Pandita et al., 2024; Abbasi et al., 2021).

Fourth, despite the Indonesian government's ambitious targets, the adoption of EVs remains low. Therefore, it is essential to analyse the social acceptance of Indonesian consumers regarding the transition to EVs (Waluyo et al., 2022; Afraah et al., 2021). To address the significant barrier of the high upfront purchase price of EVs, it is essential to study the power dynamics among key actors in coalitions that develop fiscal and non-fiscal policies, particularly incentive and subsidy schemes (Afraah et al., 2021; Lazuardy et al., 2024). This investigation examined how the dominant agencies collaborate to attract investment to expand charging infrastructure and battery swapping stations (BSS) (Sunitiyoso et al., 2023; Waluyo et al., 2022). Furthermore, a more in-depth examination is required to understand the narrative that dominant agencies construct to promote sustainability to the public and facilitate the socio-technical transition towards EVs .

The advancement of biofuel adoption in Indonesia requires further analysis, particularly concerning its effects on farmers' welfare and job creation in rural communities (Ichsan et al., 2025; Hasan et al., 2022). Additionally, the introduction of second-generation biofuels processing technology, which is more compatible with conventional vehicle engines and does not compete with the food sector, has presented challenges in terms

of technology mastery and investment (Kirshner et al., 2022; Sugiyono et al., 2020). However, the second-generation biofuels diffusion has also raised concerns about equitable welfare for marginalised groups, including small farmers and rural communities (Kirshner et al., 2022).

The limited adoption of EVs is particularly notable, given the substantial market potential due to a large vehicle population and the ambitious national targets set for EVs (Afraah et al., 2021; IEA, 2024a). The adoption of EVs in developing countries, including Indonesia, remains limited due to several factors, such as unclear policies (Shamsuddoha and Nasir, 2025; Wu, J. et al., 2018), high upfront purchase prices (Abdul Qadir et al., 2024; Pandita et al., 2024; Abbasi et al., 2021), and inadequate infrastructure support (Shamsuddoha and Nasir, 2025; Zarazua de Rubens et al., 2020) for widespread EV adoption. This study also conducted a thorough analysis to assess the effectiveness of various stakeholders in absorbing knowledge transfers from licensors and foreign institutions. The exploration of collaboration networks and corporate strategy development is conducted to address the barriers to innovation diffusion (Hakam and Jumayla, 2024; Shamsuddoha and Nasir, 2025). This analysis was particularly focused on overcoming the affordability challenges of EVs and attracting investment for the development of charging points and battery swap stations (BSS) infrastructure particularly in rural areas (Shamsuddoha and Nasir, 2025; Waluyo et al., 2022).

1.2 Scope of The Study

This study aims to analyse how institutional arrangements for eco-innovation can contribute to a socio-technical transition toward sustainability in the transportation sector by providing affordable and clean energy. The research focuses on examining the socio-technical transition to sustainable transportation in Indonesia, a developing country, by investigating three main areas: the diffusion of mass public transportation systems based on TOD, the diffusion of biofuels—particularly palm oil-based biodiesel—and the promotion of EV adoption. These three areas were selected because they are critical to the government's efforts to reduce dependence on fossil fuels, enhance energy security, and environmental conservation, while also generating complex institutional, political, social, and technological dynamics.

Furthermore, this research has focused on examining the EI of biofuels and EVs in Indonesia, due to the complexities inherent in the diffusion of these two low-carbon technologies. The diffusion of biofuel involves utilising existing distribution infrastructure and conventional internal combustion engine vehicles (ICEVs) (Bonaiuto et al., 2024). Key attention is given to the compatibility of fuel storage tanks and the combustion system of vehicles. Furthermore, Indonesia's biodiesel supply chain is closely linked to

environmental degradation issues, trade disputes, and land tenure disputes. In Indonesia, the diffusion of EVs is slower than that of biofuels. This condition primarily stems from the fact that vehicles and their supporting infrastructure are powered by electricity, which differs from the existing ICEV framework. Recent literature indicates that consumer social acceptance poses challenges to EV adoption in Indonesia, particularly considering regulatory, economic, infrastructure, and sustainability awareness factors.

This study utilises an analytical framework that integrates the multilevel perspective (MLP) proposed by Geels (2010) with the historical institutionalism approach (Lockwood et al., 2017; North, 1990; Porter, 1991) to analyse the evolution of sustainability policies and institutional changes in the transportation sector's socio-technical transition. By combining these two approaches, the study explores the interactions across different levels between landscape pressures—such as global climate commitments, energy market volatility, geopolitical tensions, trade disputes, and national energy security demands—and the diffusion of niche innovations like sustainable biodiesel and disruptive electric vehicle (EV) technology. These interactions significantly influence how the entrenched transportation regime responds to emerging challenges and opportunities (Geels, 2024; Sembiring, 2025; Astari et al., 2025).

Furthermore, this research utilises a power relations analysis framework to investigate the power contestation between various agencies. This power relations analysis focuses on dominant coalitions that establish structural power to control over technology and financial capital, institutional power through regulations and public policies, discursive power through narratives surrounding energy security, energy self-sufficiency, environmental sustainability, and rural development, as well as disciplinary power through mechanisms of sustainability certifications and regulation of the behaviour of other actors (Newell and Bray, 2025; Newell, 2008; Allen, 2011b; Foucault, 2007). The narratives created by these dominant agencies often justify policies that favour established entities, such as state-owned enterprises, energy conglomerates, and multinational corporations involved in palm oil and automotive manufacturing. In contrast, vulnerable groups—such as smallholder farmers, rural communities, local MSME startups, and urban low- to middle-income communities—face marginalisation in their access to and participation in the socio-technical transition (Ichsan et al., 2025; Djatmika et al., 2024; Choiruzzad et al., 2021).

This study focuses on the diffusion of biodiesel in Indonesia, with a focus on the implementation of the B20 mandate¹ policy introduced in 2016 (Sembiring, 2025; Astari et al., 2025; Suhara et al., 2024). This policy emerged in response to environmental conservation concerns and trade disputes, and it has evolved into the B40 mandate², which was set to take effect in 2025 (Candra, 2025). Biodiesel diffusion policies represent a space for negotiation between decarbonization goals and state interests (Ichsan et al., 2025; Choiruzzad et al., 2021). The power relations among various agencies significantly influence the trajectory of EI diffusion (Eitan and Hekkert, 2023). Furthermore, this study also investigates the adoption of advanced technologies, specifically second-generation biodiesel and ethanol, to explore the challenges related to knowledge spillovers and investment risks in the energy industry (Kirshner et al., 2022; Sugiyono et al., 2020). Additionally, research on social justice has been conducted to assess the impact of EIs on small farmers and rural development, considering sustainability throughout the entire life cycle of Indonesia's biofuels (Kirshner et al., 2022; Djatmika et al., 2024; Choiruzzad et al., 2021).

The adoption of EVs in Indonesia was analysed using the MLP framework, which considers several key barriers. These key barriers include regulatory uncertainty, the high upfront EV purchase price, inadequate charging infrastructure, and lack of public awareness of sustainability discourses (Waluyo et al., 2022; Afraah et al., 2021). This study also investigates consumer preferences in urban areas like Jakarta Greater Area and Bandung Greater Area regarding the social adoption of electric vehicle technology to meet their daily mobility needs. A social acceptance analysis of EV technology has been conducted among the public in these two main Indonesian cities, Jakarta and Bandung, which differ significantly in topography and demographic characteristics. The goal of this approach was to understand how social, economic, and infrastructure factors influence consumer acceptance of electric motorcycles (EMCs), which present lower entry barriers compared to four-wheeled electric passenger vehicles (E4Ws). Additionally, it aims to explore how varying local contexts lead to different adoption patterns.

Overall, this study focuses on analysing multi-level institutional interactions, the power dynamics of cross-border actors, the distribution of social benefits, and the impacts of policy. This study has also examined the factors influencing the advancement or slow

¹ The B20 mandate promotes the blending of 20% palm oil-based biodiesel with fossil diesel fuel (MEMR, 2025a).

² The B40 mandate promotes the blending of 40% palm oil-based biodiesel with fossil diesel fuel (MEMR, 2025a).

diffusion of transportation eco-innovation towards sustainability in Indonesia. Consequently, this study enhances the understanding of sustainable transportation transitions in emerging economies and their role in achieving net-zero-emission (NZE) targets.

1.3 Research Questions

This research is specially designed to answer the following overarching question:

How does the diffusion of low-carbon eco-innovations shape the transition towards sustainable transportation in Indonesia?

An empirical study on the diffusion and social adoption of environmentally friendly technologies for the transportation sector in Indonesia was undertaken by formulating three specific research questions to address the overarching question.

1. How have multi-level interactions influenced critical junctures in the institutional dynamics of socio-technical transitions toward sustainability in the Indonesian transport sector?
2. How does the power contestation between global and local actors influence the development of sustainable transport policies in Indonesia?
3. How can multilevel stakeholder interactions enhance drivers and address key barriers in the diffusion of eco-innovation within the transportation sector of emerging economies?
4. How the interaction between regimes and niches affects the socio-technical transition process of EV adoption in emerging economies?

Figure 1.1 presents the intercorrelation between empirical Chapters 4, 5, 6, and 7, addressing the overarching research question and sub-research questions.

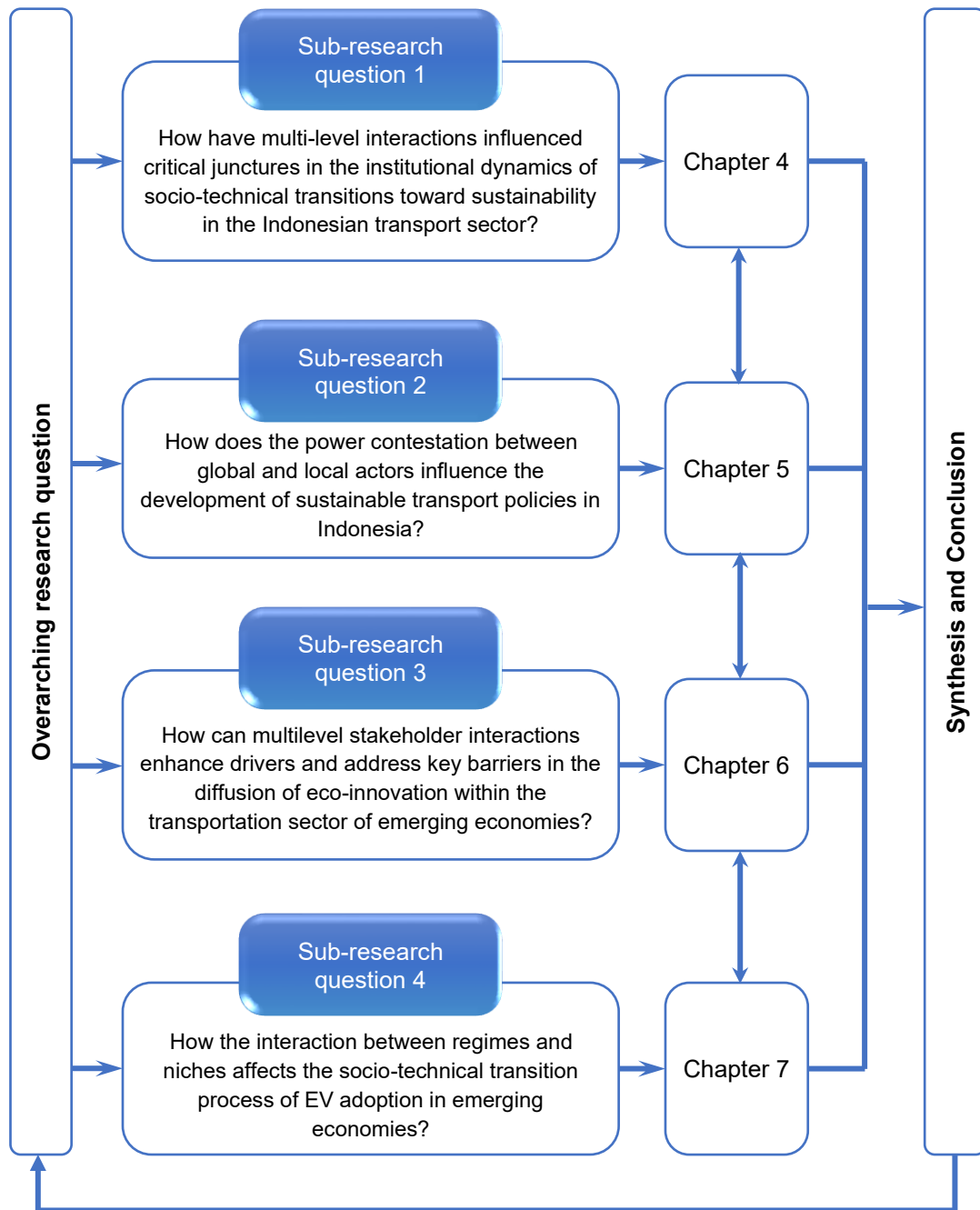


Figure 1.1 Correlation between the research questions in this dissertation

1.4 Thesis Structure

This thesis is structured as follows:

Chapter 1 Introduction

Chapter 1 introduces this thesis by elaborating on the research background and the motivation for conducting this research. This dissertation selects the sustainability of Indonesia's transportation sector as an empirical case study. To maintain the discussion's focus, this chapter describes the objectives and scope of the research.

Further, the overarching research questions and sub-questions are briefly described in this chapter.

Chapter 2 Literature review

In Chapter 2, a comprehensive review of relevant literature is presented, which includes various topics covered by the research. The study is based on institutions and institutional theories as the underlying framework. This chapter reviews both theoretical and practical research conducted on the dissertation topic. Discussions start with institutional theories, institutional changes, sustainability, power relations, and socio-technical transitions, as a function of institutional arrangement. The institutional regulatory framework for sustainable development integrates a multilevel perspective with historical institutions, highlighting their critical role in the diffusion of eco-innovation amid increasingly stringent environmental regulations. The power dynamics among agencies also affect the development of structural power, functional power, discourse formation, and disciplinary mechanisms within the socio-technical transition toward sustainability. Additionally, the public social acceptance of new environmentally-friendly technologies significantly influences the diffusion process of eco-innovation. Furthermore, this chapter provides a brief overview of sustainable development in the transportation sector, focusing on institutional regulation and the socio-technical transition of Indonesia's transportation system. Finally, this chapter has identified knowledge gaps and highlights specific research topics relevant to Indonesia, focusing on the diffusion of biofuels and EVs eco-innovations.

Chapter 3 Research methods

The methodology chapter outlines the research approaches used to address the identified knowledge gaps and research questions. Both qualitative and quantitative methods are utilised to address research questions. Each empirical chapter explains the approaches used to address each research question. This chapter describes the relationship between the empirical chapters to ensure a coherent research development.

Chapter 4 Empirical chapter 1

This empirical chapter has utilised a combination of multilevel perspective and historical institutionalism concepts to identify multilevel stakeholder interactions that triggered the macro-level landscape pressures and the diffusion of EIs at the niche level. The dynamics of the landscape and the diffusion of niche innovations create pressures that affect both the stability and institutional change of the entrenched meso-level regime and create critical junctures that influence path dependence in the formulation of sustainability policies within the Indonesian transportation sector. Additionally, this

chapter explores the types of institutional changes that have taken place and assesses whether the influencing factors are external (exogenous) or internal (endogenous).

Chapter 5 Empirical chapter 2

Chapter 5 analyses the power relations among agencies in the formulation of eco-innovation trajectories within the Indonesian transportation sector. This study explores the networks of actors, highlighting how elite alliances create both structural and functional power through discourse and disciplinary mechanisms that influence the path dependence of EI diffusion. Additionally, the analysis examines the outcomes of these power dynamics, assessing whether they are inclusive or exclusive, and what benefits dominant agencies gain. The study also investigates whether narratives and stakeholder groups have been marginalised during the socio-technical transition.

Chapter 6 Empirical chapter 3

Chapter 6 utilises a qualitative approach to explore the interactions among various actors involved in the diffusion of EI for sustainable transportation in emerging economies. Using a multilevel perspective framework, this study examined the collaborative network of niche-level actors to enhance technological capabilities by leveraging knowledge spillovers. In addition to fostering socio-technical development, this network advocates for a meso-level regime that provides regulatory support for the adoption of low-carbon technologies. Furthermore, the chapter conducts a thorough analysis to understand how this collaborative network addresses barriers to eco-innovation, particularly environmental externalities, in the diffusion of biofuels and EVs in Indonesia.

Chapter 7 Empirical chapter 4

Chapter 7 employed mixed methods to investigate public social acceptance of EVs. An online survey was conducted with respondents from two urban areas, Jakarta and Bandung, which differ in topology and demographics. This study explored how consumer perceptions influence the transition to electric motorcycles (EMCs) for meeting daily mobility needs. Additionally, a thorough analysis was performed to examine the economic gap in EV adoption between Indonesia and several other developing countries, with particular focus on the challenge posed by high upfront purchase prices for EVs. The study also explored collaborative network efforts aimed at addressing investment risks that hinder infrastructure deployment. This study has also explored the total cost of ownership (TCO) calculation by comparing conventional ICE and EMC across different segments in Indonesia, including lifecycle management for retired EV batteries. Furthermore, this study analysed sustainability considerations throughout the entire lifecycle of EVs.

Chapter 8 Discussion and conclusion

The final part of this dissertation elaborates on the key findings from empirical chapters and describes conclusions that answer the overarching research question and the sub-research questions. This chapter also holistically reflects on the analysis of the findings to understand the institutional arrangements for environmentally friendly emerging technologies. Furthermore, the final section discusses the study's policy implications and limitations and provides directions for future research.

Chapter 2 Literature Review of Energy Transition in the Transportation Sector

2.1 Introduction

This chapter provides an overview of the conceptual underpinning of the dissertation. A critical review of the literature was conducted, analysing key approaches and concepts to explain socio-technical transition in the transportation sector, particularly in emerging economies. The low-carbon transition, as the diffusion of eco-innovation, is often promoted as a panacea for transportation issues in both developed and developing countries to achieve sustainability goals (Mavi et al., 2019; Rennings, 1998). However, recent literature reviews on transportation transitions highlight political contestation (Wågsæther et al., 2022; Mutter and Rohrer, 2022). This power contestation involves the interests of state agencies, large corporations, and global actors, leading to the formation of coalitions focused on biofuels and electric vehicles that significantly shape eco-innovation trajectory policies toward sustainability (Ichsan et al., 2025; Kirshner et al., 2022; Mutter and Rohrer, 2022).

This chapter reviews literature from a variety of disciplines—political science, ecological economics, science and technology studies (STS), and business and management—to develop an integrated framework for analysing Indonesia's transition to sustainable transport. Political science and historical institutionalism provide insights into institutional arrangements, the evolution of regulations, and the path-dependent nature of policy changes (Eitan and Hekkert, 2023; Lockwood et al., 2017; North, 1990). Ecological economics adds perspectives on sustainability constraints, resource governance, and the socio-environmental implications of adopting new technologies (Billanes and Enevoldsen, 2021; Bonaiuto et al., 2024; Del Río González, 2005). Science and technology studies (STS), particularly the socio-technical transition framework and the multilevel perspective (Dutt, 2023; Geels, 2024; Grin et al., 2010), offer analytical tools for examining how technologies, stakeholders, and institutions evolve in tandem, creating environments in which power dynamics play out. Additionally, business and management scholarship contributes theories on the diffusion of eco-innovation, firm strategies, and consumer acceptance (Del Río et al., 2016; Demirel and Kesidou, 2019; Hojnik and Ruzzier, 2016; Jammes et al., 2025). These various strands of literature collectively inform the discussion on institutional change, power relations (Allen, 2011b; Foucault, 2007; Newell and Bray, 2025), discursive formations, and disciplinary mechanisms that influence sustainability transitions. By exploring the intellectual

foundations of these key concepts, this chapter positions Indonesia's efforts to decarbonise its transport sector—especially concerning biofuels and electric vehicles—within a broader interdisciplinary context, identifies gaps in current knowledge, and emphasises the importance of institutional regulation, socio-technical structures, and public acceptance in understanding the diffusion of eco-innovation in Indonesia.

This literature review begins by establishing the context of the recent low-carbon transition by examining how entrenched institutional arrangements, lock-in effects, and path dependencies influence the pace and direction of the socio-technical transition. It combines a framework from the multilevel perspective (MLP) with historical institutionalism to analyse the historical trajectories of transport transitions in emerging countries. This review then examines the power relations involved in sustainable transport transitions (Ichsan et al., 2025; Nikas et al., 2022; Cameron and Geels, 2019). The power relations analysis examines how dominant coalitions—comprising government agencies, industry associations, multinational corporations, and international development organisations—mobilise resources, set agendas, and shape narratives to either reinforce or challenge existing transport systems (Ichsan et al., 2025; Cameron and Geels, 2019; Klitkou et al., 2015).

The chapter then reviews socio-technical transitions related to the concepts of eco-innovation (EI) diffusion and the social acceptance of low-carbon transport technologies, explicitly focusing on biofuels and EVs. The diffusion of EI theory and the adoption of technology frameworks help to highlight the drivers and barriers to EI uptake in developing contexts (Aloise and Macke, 2017; Wang et al., 2023). Finally, this chapter reviews the literature on consumer preferences and social acceptance of EVs as environmentally friendly technologies emerging in developing countries. In this context, consumer decisions are shaped by environmental concerns (Wang et al., 2023; Han, M.S. and Chen, 2021; Aloise and Macke, 2017) as well as socio-technical factors, including upfront purchase price (Abbasi et al., 2021; Pandita et al., 2024; Abdul Qadir et al., 2024), accessibility of charging infrastructures (Shamsuddoha and Nasir, 2025; Waluyo et al., 2022), and alignment with local mobility practices (Schot and Geels, 2008; Singh, V. et al., 2021).

2.2 Socio-Technical Transition

Socio-technical transition is an analytical framework designed to understand the mechanisms involved in sustainability transitions (Markard et al., 2012; Köhler et al., 2019). Socio-technical transitions involve an interdisciplinary approach that examines

how new technologies arise, evolve, or replace older technologies within the framework of broader social and structural systems (Calvert et al., 2017; Geels and Schot, 2007). The socio-technical transition approach emphasises the two-way interaction between technology and the social environment (Rip and Kemp, 1998). Socio-technical transition highlights how the development of advanced technology is shaped by social, economic, and political forces, while conversely, technology and technological systems impact human relationships and society (Geels, 2011). Socio-technical transitions refer to significant structural changes that occur over the long term (Grin et al., 2010; Geels, 2024). These transitions involve multiple actors, encompass various dimensions, and are characterised by non-linearity. Additionally, socio-technical transitions are significantly influenced by historical context and path dependence (Geels et al., 2020; Geels, 2012; Rip and Kemp, 1998).

The socio-technical transition framework has been widely used to promote sustainability in the transportation sector (Wu, Z. et al., 2021; Cameron and Geels, 2019). This approach provides a comprehensive understanding of the significant shift from transportation systems that rely heavily on fossil fuels to more sustainable, low-carbon mobility solutions (Wu, Z. et al., 2021; Cameron and Geels, 2019). The transition process in transportation involves technological advancements, changes in institutions, infrastructure development, and changes in societal behaviour (Geels, 2012; Geels, 2024).

The socio-technical transition of the transportation sector in developing countries faces significant challenges, including limited access to investment financing, inadequate technological capabilities, and resistance from dominant actors who benefit from the existing system (Wu, Z. et al., 2021; Ghosh and Schot, 2019). Despite these obstacles, there are opportunities for diffusing sustainable transportation technologies, mainly due to external pressures such as fluctuations in crude oil prices, the impacts of climate change, and global commitments to reduce emissions (Grandis et al., 2024; Pandita et al., 2024; Doumax-Tagliavini and Sarasa, 2018). The socio-technical transition theory provides a valuable framework for understanding why eco-innovation and sustainable transportation technologies diffuse more slowly in developing countries than in developed ones, despite the governments in emerging economies facing social urgency, sustainable goals, achievement targets, and environmental conservation (Wu, Z. et al., 2021; Ghosh and Schot, 2019).

2.2.1 Multi-Level Perspective

The Multi-Level Perspective (MLP) has become an essential framework for observing socio-technical transitions towards sustainability (Geels, 2024; Hansmeier et al., 2021). MLP examines transitions in socio-technical systems through interactions between three

levels: niche, regime and landscape (Geels, 2020; Lockwood et al., 2017). The first level involves radical technological innovations in micro-level niches that are the precursors of the sustainability transition (Geels, 2024; Geels et al., 2020; Geels, 2002). Micro-niches are the levels where new experiments and innovations take place (Geels, 2024; Geels et al., 2020; Geels, 2002).

Radical technical innovations at the niche level occasionally struggle with existing systems at the second level that do not support the transition. The second level comprises established rules, policies, technologies, and institutions forming meso-level 'regimes'. Meso-level 'regimes' with established structures, interests and stability entrenched various 'lock-in mechanisms' that make change difficult (Geels, 2024; Klitkou et al., 2015). Eitan and Hekkert (2023) elaborate that economic and financial lock-ins in dependence on fossil fuel infrastructure have perpetuated the regime. So, the sustainability transition faces a steep path marked by economies of scale, sunk costs in infrastructure, and financial risk or uncertainty (Eitan and Hekkert, 2023). Technology lock-in has been a major challenge to radical green innovation by favouring entrenched technologies (Męczyński and Ciesiółka, 2024). Foxon (2014) and Xu, W. and Mo (2024) have examined how the lock-in of existing techno-institutional systems, such as high-carbon energy systems, has created barriers to innovation and adoption of more sustainable systems (Xu, W. and Mo, 2024). Moreover, a considerable number of consumers and businesses perceive innovative green technologies as unproven or risky, which has delayed their adoption (Goerzen et al., 2023).

Cognitive lock-ins, such as stakeholders' perceptions and mindsets influenced by the historical success and stability of the existing system, act as barriers to the sustainability transition (Nikas et al., 2022). Social lock-ins give rise to shared norms of energy use that may inhibit or enable certain technologies (Helmrich et al., 2023; Nguyen Long et al., 2024). Rigid policies that favour conventional industries and the lobbying activities of dominant actors can be attributed to the mechanisms of political and institutional lock-in. These policies collectively maintain the status quo and impede the advent of radical innovation (Helmrich et al., 2023).

The third level of analysis is the socio-technical landscape, which can be defined as the broader exogenous environment that forms the trajectory of the socio-technical system (Geels, 2024; Geels et al., 2020; Geels, 2002). The interaction between the macro-level landscape gives origination to trends and pressures that shape and influence the dynamics of innovation and transition along regimes (meso-level) and niches (micro-level) (Geels, 2024; Geels et al., 2020). The landscape can trigger rapid shocks such as pandemics, wars, or economic crises. Likewise, exogenous landscape influences can be gradual changes such as global megatrends and macroeconomic or macro-cultural shifts

(Geels et al., 2020). The MLP approach is characterised by a broad scope, encompassing technological to socio-technical regimes (Geels, 2024; Geels et al., 2020; Geels, 2002). It places significant emphasis on aligning emerging eco-innovations with prior developments at the regime and landscape levels. The socio-technical transition in MLP conceptualisation comprises of four distinct phases (Geels, 2020; Lockwood et al., 2017), described below.

The emergence of radical innovations within the boundaries of the existing system characterises the first phase (Apostolopoulou et al., 2022; Geels and Turnheim, 2022). The emergence of radical innovations is typically initiated by enterprising individuals, start-ups or external parties (Geels, 2024; Smith and Raven, 2012; Schot and Geels, 2008). These niches provide a protective barrier against the mainstream market and serve as hubs for the research and development of radical innovations. At the same time, the evolution of the existing system and regime follows a predictable trajectory (Geels, 2024; Smith and Raven, 2012; Schot and Geels, 2008).

The second phase is marked by the advent of radical innovation in one or more niche markets, leading to a reliable stream of resources (Apostolopoulou et al., 2022; Geels and Turnheim, 2022). The R&D process gradually stabilises towards a dominant design that meets manufacturing and mass production specifications. At this stage, niche innovations face challenges from intensely entrenched socio-technical systems that maintain the stability of the existing technological trajectory. Furthermore, consumers still need to trust the presence of niche innovations, making their prices even higher than those of existing technologies (Geels, 2024; Geels, 2002).

In the third phase, innovations are diffused into the mainstream market, competing with the existing system. Geels and Johnson (2018) examined the degree of diffusion as contingent upon several factors, including performance improvements, cost efficiency, economies of scale, the development of support systems, and the participation of dominant actors. On the other hand, the dynamics of the landscape exert external pressure on the existing regime, creating and opening 'windows of opportunity' for novelty (Geels and Johnson, 2018). The dynamics of innovation diffusion trigger adjustments to the socio-technical regime filled with multidimensional struggles. Incumbents struggle to maintain business dominance against new players. The literature shows that many incumbents fall or reorient their businesses in the innovation diffusion phase. Regulators also face political struggles in the third phase that require adjustments to policy targets and instruments such as regulations, incentives or subsidies. In addition, discursive struggles take place in framing the problem and its solution, as well as the rationale for action or inaction (Geels, 2024; Geels, 2002).

In the final phase, the new regime becomes firmly established and institutionalised, transitioning the pathway of the old socio-technical system. The new regime is

institutionalised regarding regulations, standards, technical capabilities, usage habits, and normalised views (Geels, 2024; Geels, 2002). As Geels and Turnheim (2022), the transition does not merely concern a single technology perspective. Instead, it encompasses a multitude of concomitant innovations, infrastructural adaptations, market and business model developments, and shifts in consumer habits (Geels and Turnheim, 2022).

Recent scholars have broadened the investigation of the types of system transitions in the conceptualisation of MLP, in addition to substitutions that replace existing socio-technical systems. Geels and Schot (2007) emphasise that the system transition can also take place as transformation, reconfiguration, as well as de-alignment and realignment (Geels and Schot, 2007). The institutional transformation involves dominant actors gradually adjusting the existing system while the regime accommodates pressures from the landscape (Geels and Turnheim, 2022; McMeekin et al., 2019). According to McMeekin et al. (2019), reconfiguration involves niche innovations within existing socio-technical systems that collaborate and gradually impact the system architecture (Geels and Turnheim, 2022; McMeekin et al., 2019). Meanwhile, the transitions of de-alignment and realignment result from significant pressure from the landscape, a key factor that destabilises the existing socio-technical system and creates fertile ground for niche innovations to flourish (Geels, 2024; Geels and Schot, 2007). Subsequently, the new socio-technical system undergoes realignment (Geels and Turnheim, 2022; McMeekin et al., 2019).

2.2.2 Historical Institutionalism

While the socio-technical transition and MLP frameworks focus on analysing the dynamics of the interaction between technology and social context in contemporary terms, the Historical Institutionalism (HI) approach examines the temporal dimension, emphasising that past decisions influence current development path dependencies and limit future choices (Pierson, 2000a). Historical institutionalism is a complement to sociological institutionalism or socio-technical analysis in energy transition studies (Lockwood et al., 2017) towards sustainability while balancing national energy security interests and environmental conservation concerns (Ullah et al., 2017; Sembiring, 2025).

Institutional understanding and institutional change are core agendas in political, economic, and social sciences for analysing a case study of the sustainability of the transportation sector in Indonesia. Scholars across disciplines have used diverse definitions and interpretations of institutions (Iyer, 2016; March and Olsen, 2006; Scott, 2008; Lockwood et al., 2017). This dissertation defines the term institution as it is used

by scholars of New Institutional Economics (NIE), namely "Institutions are the rules of the game in a society, or more formally, are the humanly devised constraints that shape human interaction" (North, 1990, p.3). Institutions can be classified as formal, such as laws and regulations, or informal, like social norms (North, 1990). There is a difference between institutions and organisations that is "Conceptually, what must be clearly differentiated are the rules from the players" (North, 1990, p.4) in that the institutions provide the rules and organisations are the players (North, 1990).

Organisations are groups of individuals with several general goals that aim to achieve specific goals (Lounsbury and Gehman, 2024). North (1990) states that the institutional framework of an organisation will affect its emergence and development. Decision-making and routine choices by individual actors and organisational entrepreneurs lead to exchange restructuring, which can impact economic and political change (North, 1993). Meanwhile, institutions have formal rules, informal rules, and enforcement mechanisms (Hodgson, 2025; Greif and Kingston, 2011). Formal rules, for example, constitutions, laws, regulations, contract law and property law, have mechanisms of law enforcement and affect changes in the formal rules of an institution (North, 1990; Lockwood et al., 2017). In contrast, informal rules, such as norms of behaviour, social values, social rules, and conventions, have enforcement mechanisms that differ from those of formal rules. Even so, formal rules and informal rules cannot work alone efficiently. However, the two rules are interdependent for each transaction that occurs between several actors (Ollila, 2009).

The Historical Institutionalism (HI) approach views institutions—both formal ones like regulations and policies, and informal ones like norms and habits—as frameworks that shape actors' behaviour. Institutions are not static; they evolve through processes influenced by critical moments known as 'critical junctures'. In the context of transportation in many emerging economies, significant past road infrastructure development, fossil fuel subsidy policies, and regulations that have made the automotive industry the backbone of transportation has created a 'lock-in' effect that is challenging to change (Thelen, 1999; Helmrich et al., 2023).

Institutional development typically occurs gradually between these critical junctures and is influenced by path dependence and the 'lock-in' effect (Thelen, 1999; Lockwood et al., 2017). In HI, the 'lock-in' effect refers to a situation in which previous institutional choices restrict current and future policy options, even if those previous choices are no longer the best or most efficient. Lock-in is influenced by path dependence, where initial decisions or developments create reinforcing mechanisms, making it increasingly challenging to implement institutional changes over time (Eitan and Hekkert, 2023;

Klitkou et al., 2015). This institutional development is evident in the global dominance of ICEVs, which can be attributed to past infrastructural, regulatory, and industrial commitments that have created a strong momentum that hinders the rapid adoption of EVs (Sovacool et al., 2022; Klitkou et al., 2015). Additionally, in several developing countries, the centralised electricity system, managed by SOEs, reflects a governance structure that continues to influence the current low-carbon transition despite increasing pressure to integrate renewable energy (Apriliyanti et al., 2024; Eitan and Hekkert, 2023).

Path dependence significantly influences political phenomena by 'locking in' past experiences and limiting the available choices for institutional development (Eckersley, 2017). Initially, the inheritance of institutional policies addressed prior institutional problems. However, dominant actors have derived numerous benefits from these policies, leading them to strive for institutional stability by maintaining the existing policy (Pierson, 2000b). HI approach to long-term institutional stability has established a dichotomy concerning institutional change. On one hand, institutional change tends to occur slowly and gradually within limited boundaries (Eckersley, 2017), yet it remains transformative (Streeck and Thelen, 2005; Van der Heijden, 2011). On the other hand, radical exogenous shocks at critical junctures can disrupt this balance and lead to the emergence of new institutional arrangements (Fioretos et al., 2016).

Lockwood et al. (2017) examined the gradual development and change of institutions through four mechanisms: layering, drift, conversion, and displacement. The term 'displacement' refers to the process of eliminating existing institutional rules and replacing them with new ones (Lockwood et al., 2017; Streeck and Thelen, 2005). In contrast, 'layering' involves adding new rules alongside existing ones, rather than replacing them (Van der Heijden, 2011; Lockwood et al., 2017). Meanwhile, 'drift' occurs when there are no formal changes to the rules, but the influence of the existing rules changes due to wider environmental changes (Hacker et al., 2015; Lockwood et al., 2017). Lastly, 'conversion' refers to a situation where the formal rules remain unchanged, but they are interpreted and enforced in a new way (Lockwood et al., 2017; Streeck and Thelen, 2005).

2.3 Diffusion of Eco-Innovation and Social Acceptance of Technology

The term innovation is frequently used today, and its definition continues to evolve. Kahn (2018, p.453) states that innovation can be seen from three perspectives which the first perspective elaborates:

“Innovation as an outcome emphasizes what output is sought, including product innovation, process innovation, marketing innovation, business model innovation, supply chain innovation, and organizational innovation” (Kahn, 2018, p.453).

Secondly, innovation is the process of pursuing new ideas to achieve results, encompassing the entire innovation process and the development of a new product (Mont, 2008; Tellis et al., 2003). Third, innovation as a mindset involves implementing creativity in individual members of an organisation within a culture that fosters innovation (Ringberg et al., 2019). This mindset includes defining the elements needed, consideration and local wisdom that enables innovation to succeed (Ringberg et al., 2019; Chang and Huang, 2022).

The term eco-innovation (EI) was introduced by Klemmer et al. (1999) as the measurement of all relevant actors which conduct innovations and contribute to reduce environmental impacts or to achieve specific ecological sustainability targets. The policies of several countries and across countries provide an overview of eco-innovation definition (OECD, 2011; Rennings, 2000). EI covers technological and non-technological aspects that “applies to goods, services, manufacturing processes or business models” (OECD, 2011, p.29). The US also comprises the regulatory innovation practice for environmental preservation. EI can be done radically and systemically, for example, replacing polluted goods with environmentally friendly products, or enhancements such as increasing the efficient use of sources of a product (OECD, 2011). Even though eco-innovation has been implemented for decades it is still challenging to standardise its definition. Although there are various definitions of the term EI, this study adopts a broader definition: “all forms of innovation that reduce environmental impacts and/or optimise the use of resources throughout the lifecycle of related activities” (OECD, 2011, p.29). The term EI is often used interchangeably with sustainable innovation, environmental innovation, and green innovation (Pansera, 2011). López and Montalvo (2015) categorised EI into four types: product innovations, process innovations, organisational (institutional) innovations, and marketing innovations.

EI starts with generating and mobilising ideas. This process is followed by screening and evaluating these ideas to ensure compliance with environmental regulations and profitability potential (Sadler, 2020; Sovacool et al., 2018). The chosen EI initiatives proceed to the experimental and development stage, which ultimately leads to commercialisation and dissemination across the entire social system (Sadler, 2020; Sovacool et al., 2018). This process, known as technology diffusion, involves the gradual dissemination and integration of technology at both the market and population macro levels (Rogers, 2003; Lee et al., 2020).

Although the EI approach aims to balance environmental, technological, social, and economic perspectives, not all EI activities are effectively implemented to support sustainability due to various drivers and barriers. One key feature of EI is the presence of dual externalities, which include knowledge spillovers and environmental externalities (Rennings, 2000; Branstetter, 2006; Arora, A. et al., 2021). Arora, A. et al. (2021) emphasised that firms that perform EI may not fully recover their investment returns due to knowledge spillovers, where their innovations also benefit other companies (Arora, A. et al., 2021). Although this knowledge spillover can enhance the diffusion of green technology, it may reduce companies' motivation to invest in EI (Arora, A. et al., 2021). Meanwhile, firms are performing to minimise adverse environmental externalities, such as pollution and carbon emissions, through EI (Carchano et al., 2024; Samarina et al., 2021; Centemeri, 2009). However, the literature points out that the neoclassical approach often treats environmental concerns as externalities, meaning that society ultimately bears the costs (Carchano et al., 2024; Centemeri, 2009). This perspective leads to reduced interest from companies in investing in EI. To address this, the government must implement incentive schemes or subsidies that enhance the competitiveness of EI outputs in the market (Wang et al., 2023; Costa et al., 2021).

E.M. Rogers introduced the Diffusion of Innovations Theory (DOI) in his book, "Diffusion of Innovations" (Rogers, 2003.p1). This theory emphasises the crucial role of convincing people to adopt new ideas, concepts, processes, business models, products, and particularly through media, in promoting the acceptance of innovations (Zanello et al., 2016; Pineda et al., 2023; Rogers, 2003). The process of EI diffusion typically requires ongoing adaptation (Karaulova et al., 2017) and experimentation (Sadler, 2020), which customers subsequently accept. The macro-level adoption of the DOI theory emphasises the analysis of overall diffusion trends and the societal factors that influence them (Sadler, 2020). This analysis underscores the government's crucial role in formulating policies for technology diffusion at the macro level (Rogers, 2003; Schot and Geels, 2008). By fostering interest in and readiness to adopt emerging technologies, the government can promote technological adoption (Abbasi et al., 2021; Rezvani et al., 2015).

The sustainability of innovation diffusion is significantly influenced by the adoption stage at the individual or organisational micro-level. The ongoing debate regarding technology adoption is continually evolving among scholars. Supporters of the conventional approach often simplify the process of technological change, suggesting it can be universally transferred and adopted. However, this perspective tends to overlook the complex social, cultural, and institutional aspects that affect consumers' acceptance and technological adoption (Ali et al., 2022; Pacheco et al., 2018). In contrast, Glover et al.

(2019) propose an alternative framework that breaks down technological change into four key aspects. The first aspect, known as the proposition, emphasises the initial design of the technology provided to users and the values it represents. This alternative framework suggests that the technology or innovation introduced by external actors is not final or perfected. Instead, it is an open proposal that requires testing and reinterpretation by the users (Glover et al., 2019).

Second, the encounter highlights the interaction between new technology and its users. It underscores the importance of dialogue between technological values and local realities. Users assess how relevant, practical, and suitable the new technology is for their needs. This evaluation often involves comparing the results achieved by the new technology with those produced by traditional or existing technologies. The third aspect is disposition, which refers to a user's initial standpoint toward new technology. Disposition is shaped by individuals' diverse backgrounds and other factors, including socioeconomic status, social considerations, past experiences with technology, and personal risk assessments (Glover et al., 2019).

Lastly, the response to new technology is shaped by internal analysis and social evaluation. Users may fully adopt, partially adopt, modify locally, or reject the technology. Additionally, user responses can sometimes lead to the development of new innovations. Whether at the individual or institutional level, these responses are typically influenced by social norms, community attitudes, and local power dynamics rather than entirely personal decisions (Glover et al., 2019).

The technological adoption requires more than just transferring knowledge from innovators to users. Many promising innovations fail to be adopted, particularly in emerging economies, not because of inferior technology but because top-down policies often do not provide users with the necessary space and support to adopt technology in ways that suit their needs. The process of adopting technology involves users gradually experimenting with it and making choices based on their specific requirements (Bardhi and Gashi, 2025; Douthwaite et al., 2001).

Recent studies show that social interactions among actors, including innovators, producers, regulators, investors, and end-users, are crucial for the effective adoption of technology (Tarei et al., 2021; Dutt, 2023; Gonçalves Montenegro et al., 2021; Cagno et al., 2013). End-users participate in a collaborative learning process, which helps them adapt the technology to fit their socio-economic circumstances (Kesidou et al., 2023; King et al., 2018). This local experiment involves end-users from the start of innovation development, enabling modifications that enhance the probability of local adoption (Régner et al., 2022; King et al., 2018). By adopting this approach, end-users become

co-creators of the technology, ensuring that the innovation is relevant and beneficial to their specific needs (Régnier et al., 2022). Meanwhile, Billanes and Enevoldsen (2021) identified and examined the main elements that affect users' choices to accept and adopt emerging technologies. The ten main factors they identified include policy support, knowledge understanding, awareness, societal impact, demographic conditions, trust level, self-confidence, satisfaction level, risk assessment, and the compatibility of the technology with users' necessities and values. These factors significantly impact users' decisions regarding the adoption of energy technology (Billanes and Enevoldsen, 2021).

2.4 Socio-Technical Transition in the Global Transportation Sector

The socio-technical transition in the transportation sector is a technology-intensive process. Geels and Turnheim (2022) identified that socio-technical transitions in the transportation sector encompass complex interactions across three analytical levels: niche innovations, socio-technical regimes, and landscapes (Geels and Turnheim, 2022; Cameron and Geels, 2019). Micro-niche innovations act as testing grounds for developing and experimenting with new technologies (Geels, 2012). In the transportation sector, several niche innovations can be observed, such as pilot projects for bus rapid transit (BRT) systems (Nikitas and Karlsson, 2015; Prestes et al., 2022), tests of biofuel compatibility with conventional ICEVs (Klitkou et al., 2015; Bonaiuto et al., 2024), trials of EVs (Geels and Turnheim, 2022; Wu, Z. et al., 2021), and the advancement of charging infrastructure (Zarazua de Rubens et al., 2020; Wu, Z. et al., 2021). This level is essential because it facilitates technical learning, fosters collaborative networks among supporting actors, and allows for the examination of perspectives on new technologies (Geels and Turnheim, 2022; Wu, Z. et al., 2021; Johnson and Silveira, 2014).

Cameron and Geels (2019) emphasise that the meso-regime level consists of a stable configuration of dominant technologies, regulations, infrastructure, markets, and social norms that shape the transportation sector (Cameron and Geels, 2019). The transportation sector in many developing countries is significantly influenced by the historical development of extensive road infrastructure, fossil fuel subsidy policies, and a focus on prioritising private vehicles over public transportation systems (Sefriyadi et al., 2023; Syafruddin, 2024). This socio-technical regime is deeply entrenched, leading to technological lock-in that maintains the status quo (Pye, 2019; Ferreira et al., 2021). This situation arises from the economic and political interests that benefit key actors, including automotive manufacturers and fossil fuel producers (Cameron and Geels, 2019; Johnson and Silveira, 2014; Nikas et al., 2022).

Meanwhile, landscape dynamics at the macro level are significantly influenced by external factors such as climate action, international pressure to reduce emissions, fluctuations in energy prices, geopolitical developments, and trade disputes (Johnson and Silveira, 2014; Kuyper et al., 2018; Sembiring, 2025). Additionally, domestic dynamics play a crucial role, including uncontrolled urbanisation, energy resilience, dependence on fuel imports, increasing fuel subsidies, and rural development (Foster et al., 2023; Sovacool et al., 2022). Moreover, EI in low-emission technologies—such as biofuels, EVs, and mass public transport systems—have diffused globally and fostered niche innovations (Cameron and Geels, 2019; Wu, Z. et al., 2021). These landscape dynamics and the emergence of niche innovations might exert pressure on the transportation regime, leading to instability, and providing a window of opportunities for these niche innovations to enter the market (Cameron and Geels, 2019; Eitan and Hekkert, 2023). In developing countries, the socio-technical transition often requires a combination of policies that foster niche innovations, minimise institutional barriers, and counteract resistance from dominant agencies (Nikas et al., 2022; Wu, Z. et al., 2021).

The process of socio-technical transition demands considerable investment in physical infrastructure, the availability of resources, and mastery of specific technologies (Geels and Turnheim, 2022; McMeekin et al., 2019). Transitioning to new transportation technologies, such as electric vehicles and mass public transport, requires not only replacing existing technologies but also restructuring political institutions, which may threaten the interests of established dominant players. In developing countries, where radical change can be challenging due to limited resources and resistance from dominant agencies, it is essential to implement relevant institutional change strategies gradually within the socio-technical transition toward sustainable transportation policies (Geels and Turnheim, 2022; McMeekin et al., 2019).

Recent literature emphasises that the energy transition involves more than just technology and efficiency; it must also consider social justice and the transformation of societal behaviours, particularly in emerging economies. A heavy emphasis on technology can overlook structural and social inequalities. Consequently, technological innovation may exacerbate inequality unless it is accompanied by redistributive and participatory policies. Sovacool et al. (2022) emphasise that effective decarbonisation is influenced by the interplay of three key pillars: technological innovation, human behaviour, and social justice. The success of the low-carbon transition relies on aligning all three pillars, rather than focusing solely on technological efficiency. Ignoring any one aspect could undermine the legitimacy and effectiveness of climate change mitigation

efforts. Therefore, climate policy design must be inclusive and grounded in principles of justice. Technology should be developed and disseminated with consideration for local contexts and social vulnerabilities. Additionally, governments need to implement incentives and regulations that promote sustainable behaviours without placing undue burdens on disadvantaged populations (Sovacool et al., 2022; Eitan and Hekkert, 2023).

Bonaiuto et al. (2024) highlighted the factors affecting the societal adoption of biofuels in the EU. These factors include technological beliefs, contextual elements, and psychosocial factors related to users. The analysis of technological beliefs focuses on how users perceive the efficiency, safety, and environmental impact of biofuels. Contextual beliefs are influenced by external factors, including regulations, supporting infrastructure, and social norms associated with this sustainable technology Bonaiuto et al. (2024). Additionally, the study examines psychosocial factors, which encompass individual attitudes, personal values, and beliefs about new technology (Bonaiuto et al., 2024; Jansson et al., 2011). Meanwhile, Köhler et al. (2019) emphasised that sustainability transitions necessitate long-term changes to achieve environmentally friendly and socially just systems. They emphasise interdisciplinary approaches and the importance of addressing social justice, power dynamics, and global implications in transition research (Köhler et al., 2019; Singh, J. and Clough, 2024; Klitkou et al., 2015). Recent studies underscore the significance of overseeing transportation transitions through niche innovations and adaptive policies (Ichsan et al., 2025; Kirshner et al., 2022). This approach facilitates system change during disruptions while promoting inclusive governance that combines bottom-up participation and top-down guidance. However, if not managed inclusively, these transitions can exacerbate inequalities affecting marginalised groups, such as smallholder farmers, rural communities, MSMEs, and lower-middle-class urban customers. (Ichsan et al., 2025; Kirshner et al., 2022; Newell, 2021).

2.4.1 Socio-Technical Transition in the Mass Public Transportation

Bus Rapid Transit (BRT)

Mass public transportation is essential for transitioning in the transportation sector as urban populations grow. In response to citizens' mobility needs, governments are advancing the EI of public transport systems, particularly the Bus Rapid Transit (BRT) system (King et al., 2018; Nikitas and Karlsson, 2015). In 1974, the BRT system emerged as a solution to rapid population growth, limited funding for a metro system, and the urgent need for efficient urban transportation in Curitiba, Brazil (Prestes et al., 2022; Wright, 2011).

The Curitiba BRT system offers several key value propositions, including dedicated bus lanes, underground stations that reduce waiting times, high-capacity buses, and the integration of land use with transit along high-density corridors (Prestes et al., 2022; Wright, 2011). The BRT offers greater flexibility than traditional rail by efficiently servicing residential areas with feeder services (Nikitas and Karlsson, 2015; Prestes et al., 2022). Moreover, Nadeem et al. (2021) highlight that the BRT system reduced travel times, increased capacity, ensured reliable service, and provided inclusive accessibility. Additionally, BRT delivers further benefits, including increased in passenger numbers, more efficient investment costs, support for regional development, and reduced GHG emissions (Nadeem et al., 2021; Rabinovitch and Leitman, 2015).

However, the diffusion of BRT systems has seen significant growth since the 1990s, particularly in cities like Quito and Bogotá in Ecuador, as well as Los Angeles in the US. In 2000, Bogotá implemented a larger corridor scale and a complex trunk-feeder system. The success of the BRT in Bogotá led to a global trend of BRT adoption, with systems being adapted to fit local contexts (Duarte and Rojas, 2012; Hidalgo et al., 2024). In 2005, Mexico City and Brazil upgraded their bus rapid transit systems for main events, including the 2014 FIFA World Cup and the 2016 Summer Olympics (Hidalgo et al., 2024; Prestes et al., 2022). In Asia, the diffusion of BRT systems was initially limited, with notable examples in Nagoya (Japan) and Taipei (Taiwan) in the late 1990s. However, since 2004, the adoption of BRT systems has become more widespread in Asia, including cities such as Seoul (South Korea), Beijing (China), and Bangkok (Thailand) (Hasibuan and Mulyani, 2022; Wright, 2011).

Recent debates have revealed several sustainability challenges despite widespread adoption of BRT. Key issues include service quality problems, such as overcrowding, unreliability, and safety concerns, which have reduced public interest in BRT in some cities (Alberti and Pereyra, 2021). High rates of fare evasion and vandalism are also issues in cities like Santiago and Bogotá. Political factors significantly impact BRT development. For example, sustainability policies have prompted the expansion of BRT in Mexico City, whereas changes in government leadership in other cities have stalled projects (Hidalgo et al., 2024; Hidalgo and Gutiérrez, 2013). Furthermore, service barriers arise from inadequate management, limited technical skills, and financial constraints. While BRT offers high capacity and fast travel, it needs ongoing support and investment. Adequate regulatory backing is essential for technological innovation, transit-oriented development (TOD), and public participation, all of which are crucial for a sustainable mobility network (Hidalgo et al., 2024).

Rail-based Mass Public Transportations

Urban rail mass transportation began with London's underground metro in 1863 and rapidly diffused across Europe and North America in the late 19th century and the early 20th century. Cities like Budapest, Paris, Berlin, and New York adopted subway systems to improve mobility and reduce downtown congestion at this period. Early subways established key standards for tunnel design and signalling (Chen, Z. et al., 2021; Zhao et al., 2025; National Academies of Sciences, 2025). After a period of stagnation in the mid-20th century, interest in underground metros surged again, driven by urbanisation, the energy crisis, and environmental concerns since the 1970s. Meanwhile, expansion has been remarkably rapid in Asia, especially in China, since the 2000s. However, behind the rapid development of increasingly extensive subway networks lies a challenge to structural efficiency as the scale of this adoption grows (Zhao et al., 2025; Lin et al., 2024; Pei et al., 2022).

Commuter rail lines have been electrified on busy routes since the early 1900s and are still in use today (National Academies of Sciences, 2025). These lines were essential to contemporary urban transport networks at the end of the 20th century due to expansion in new regions during the previous decade (Gao et al., 2024; National Academies of Sciences, 2025; Nelson and O'Neil, 2019). Several countries in Asia have developed local eco-innovation heavy rail metro systems known as Mass Rapid Transit (MRT) (Fouracre et al., 2003). The branding for these metro lines was first established in Singapore in 1987, followed by Hong Kong (Fouracre et al., 2003). While the system is technically classified as a metro, the literature emphasises regional adoption and institutional arrangements for the MRT (Fouracre et al., 2003; Diao, 2019).

Light rail transit (LRT) is an eco-innovative transportation service that evolved from trams, providing a cost-effective solution between buses and metro systems (Ravensbergen et al., 2023; Thompson and Brown, 2012). Developed in Germany and the U.S. during the 1970s and 1980s, LRT addresses urban modernisation and reliance on private vehicles (Thompson and Brown, 2013). Key features include dedicated lanes and integration with other transportation modalities, enhancing the efficiency and productivity of LRT (Ravensbergen et al., 2023; Thompson and Brown, 2012). Since the 1980s, LRT has expanded in Southeast Asia, starting with Manila in 1984, followed by Kuala Lumpur (mid-1990s), Singapore (late 1990s), and Macau (late 2019) (Diao, 2019; Gulcimen et al., 2021).

Transit-Oriented Development (TOD)

Recent studies have emphasised that the global transition in mass transit during the 2020s is characterised by a shift in focus from simply achieving mobility to prioritising decarbonisation, inclusive access, and digital transformation. This change is primarily driven by climate commitments and the need to tackle congestion and disparities in urban accessibility (Papa and Bertolini, 2015; Hasibuan and Mulyani, 2022). Some metropolitan areas have implemented a transit-oriented development (TOD) approach to reduce dependence on private vehicles by enhancing public transportation accessibility (Papa and Bertolini, 2015; Gu et al., 2019; Hasibuan and Mulyani, 2022). This TOD approach focuses urban planning on regional development centred around transit systems, connecting hubs like train stations and BRT stops with walkable, multifunctional areas (Papa and Bertolini, 2015; Gu et al., 2019; Hasibuan and Mulyani, 2022).

Recent research indicates that many cities have positioned the MRT/metro as the backbone of high-density corridors and a key driver of modern TOD growth. Current policy focuses on integrating TOD by highlighting the benefits of regional economic development around train stations. The TOD concept provides a solution for urban transportation challenges, particularly traffic congestion. By aligning land use with transportation, TOD improves mobility and shortens travel distances (National Academies of Sciences, 2025; Hasibuan and Mulyani, 2022; Gu et al., 2019).

Recent discussions have revealed several obstacles and criticisms related to the implementation of TOD, particularly concerning social justice (Yip et al., 2024; Kim, 2021). One significant issue is that TOD can lead to gentrification, which often results in high-income residents moving into city centres. This displacement exacerbates inequality, especially for low-income urban communities. Moreover, there is a frequently overlooked concern regarding equitable community engagement and representation in the design stage. When policymakers fail to address these issues, the TOD planning may not result in inclusive transportation solutions (Yip et al., 2024; Kim, 2021).

2.4.2 Socio-Technical Transition in Alternative Vehicle Fuels Technology in Developing Countries

The development of biofuels has become a significant focus in eco-innovation as countries seek alternative vehicle fuels to reduce their reliance on fossil fuels. Ethanol has been utilised as an alternative vehicle fuel since the early 20th century (Hira and de Oliveira, 2009; Grandis et al., 2024). However, following World War II, its usage declined

sharply due to the low price of petroleum. The oil crisis in the 1970s triggered a global energy shortage, which led many countries to reconsider ethanol as a viable option (Manuel, 2021; Schot and Steinmueller, 2018; Hira and de Oliveira, 2009).

The Brazilian government initiated Pró-Álcool as the national alcohol-based biofuel program in 1975, which significantly promoted the development of ethanol derived from sugarcane (Grandis et al., 2024; Nikas et al., 2022). The Brazilian government implemented subsidy schemes to make ethanol more affordable. Additionally, Petrobras, the state-owned oil company, played a crucial role by purchasing ethanol production, further enhancing ethanol's position as an alternative fuel. Brazil's flex-fuel vehicle³ policy, introduced in 2003, has led to these vehicles dominating the new car market since 2008 (Mosquera et al., 2024; Grandis et al., 2024; Nikas et al., 2022).

Meanwhile, the US government has enacted tax incentives to boost corn-based ethanol production and promote its use in gasohol⁴. The Energy Tax Act of 1978 provides tax benefits for ethanol producers and distributors (Sajid et al., 2021). Furthermore, the Renewable Fuel Standard (RFS) established by the Energy Policy Act of 2005 mandates blending renewable fuels into gasoline, leading to a significant increase in ethanol production in the US (Chen, M. and Smith, 2017; Ponte, 2014; Sajid et al., 2021).

Argentina has been a key player in developing biodiesel from soybean oil. Nikas et al. (2022) and Tomei and Upham (2009) highlighted that the establishment of biodiesel industry was marked by the enactment of Biofuel Law 26.093 in 2006. This regulation mandates a 5 per cent blend of biodiesel in fossil diesel fuel (B5), with plans for a gradual increase in this ratio over time (Nikas et al., 2022; Tomei and Upham, 2009). Biodiesel production in Argentina significantly increased following the EU's Renewable Energy Directive in 2009, which created a demand for biofuels, including biodiesel (European Union, 2013).

During the first decade of the 21st century biofuel development gained momentum in Europe, following gradually opening its markets since the 1990s. Several countries, including the Czech Republic, Germany, and Sweden, established facilities for producing biodiesel. Additionally, France has started local production of rapeseed-based biodiesel to blend with fossil diesel fuel (Kupzok, 2020; Doumax-Tagliavini and Sarasa, 2018).

³ Flexible-fuel technology, introduced by Henry Ford in 1908, enabled the blending of ethanol with gasoline as a fuel for vehicles. To reduce carbon emissions, Brazil began selling ethanol-powered flex-fuel vehicles with a 27% ethanol-to-gasoline ratio (Grandis et al., 2024).

⁴ Gasohol refers to a blending of ethanol and gasoline (Murachman et al., 2014).

However, European biofuel policies have faced criticism from various stakeholders. Kupzok (2020) highlights that some scientists and economists advocate for sustainability and emphasise the importance of EU biofuel policies addressing indirect land use change (ILUC). Land conversion often causes emission miscalculations and raises concerns about deforestation in the biofuels value chain (Kupzok, 2020; Neslen, 2011; Fargione et al., 2008).

The diffusion of biofuels is not limited to the Americas and Europe; it has also occurred in various emerging economies in Asia and Africa. The establishment of cross-regional technical collaboration networks has enabled knowledge spillovers, equipment support, and investment flows (Kirshner et al., 2022; Ponte, 2014). The diffusion of biodiesel largely relies on the availability of feedstock, price stability, and policy support (Suhara et al., 2024; Nikas et al., 2022). The broader adoption of biofuels encounters barriers, particularly due to external factors such as limited availability of raw materials, fluctuating petroleum prices, and insufficient regulatory support (Suhara et al., 2024; Singh, J. and Clough, 2024).

Recent research has examined several factors driving the EI diffusion of biofuels in emerging countries as shown in Table 2.1. Key aspects include regulatory support (Suhara et al., 2024; Farobie and Hartulistiyoso, 2022), particularly through incentives (Astari and Lovett, 2019; Farobie and Hartulistiyoso, 2022). The availability of feedstock (Singh, J. and Clough, 2024; Nikas et al., 2022) also plays a crucial role, as financial benefits for large companies can enhance the diffusion of biofuels and improve the wealth of rural farmers (Astari and Lovett, 2019; Farobie and Hartulistiyoso, 2022). Additionally, collaborative networks facilitate knowledge spillovers, enabling the transfer of biofuel technology from developed countries (Wang et al., 2023; Chandran, 2020). These collaboration networks are crucial for ensuring that biofuels are compatible with existing vehicles (Chandran, 2020; Kahn Ribeiro et al., 2007). Furthermore, improving green market sensing can help meet local consumer requirements and facilitate the broader adoption of emerging low carbon technologies (Gupta and Barua, 2018a).

Despite some progress in certain countries, the widespread adoption of biofuels in emerging economies faces several challenges. Key barriers are insufficient regulatory support and a lack of incentive schemes, which hinder the advancement of biofuel technologies (Breetz, 2020; Ebadian et al., 2020). Additionally, fluctuations in crude oil prices—affected by global trade dynamics and geopolitical events—have led to instability in biofuel prices (Suhara et al., 2024; Mosquera et al., 2024). There are also compatibility issues that pose technical barriers to the adoption of biofuels (Chandran, 2020; Kahn

Ribeiro et al., 2007). Moreover, the development of second-generation biofuels⁵ requires substantial investment and access to technology, which is often limited to large corporations (Kirshner et al., 2022; Ichsan et al., 2025).

The diffusion of biofuels in developing countries presents opportunities to enhance energy security, generate employment, and foster local economic growth, particularly in rural areas (Justiari, 2021; Suhara et al., 2024; Singh, J. and Clough, 2024). However, discourses about the role of biofuels in rural development have led to debates among scholars. Kirshner et al. (2022) examined the social, economic, and institutional dynamics encompassing the socio-technical transition to second-generation (2G) biofuels in Alagoas, Brazil. This state has traditionally depended on the sugarcane industry and first-generation (1G) ethanol production. While the aim of developing second-generation biofuels is to provide a low-carbon solution that fosters environmental sustainability and does not compete with the food sector, the process of this socio-technical transition reveals significant disparities. There are gaps in access to knowledge, technology, and economic benefits between large companies and local communities (Kirshner et al., 2022). Therefore, this socio-technical transition is not fully inclusive and fails to promote social justice. Many smallholder farmers and rural communities are often marginalised in terms of social justice due to challenges imposed by dominant entities, influential agribusiness conglomerates and energy companies. Additionally, this lack of social justice is exacerbated by biofuel regulations that are not inclusive for smallholder farmers and rural residents (Ichsan et al., 2025; Kirshner et al., 2022).

⁵ Carriquiry et al. (2011) classified biofuels into three generations. First-generation biofuels sourced from sugar, grains, or seeds are converted through a relatively simple process into fuel. Second-generation biofuels are sourced from vegetable oils from plants that can grow on critical lands (including *jatropha*), non-edible lignocellulosic biomass (such as rice husks, corn cobs, sawdust, and forest thinning), and biomass from plant (for example, switchgrass and poplar). Meanwhile, third-generation biofuels derived from the process of extracting oil from algae. Based on the use of environmentally friendly and economic benefits, second-generation biodiesel is better than the first-generation biofuel (Köhler et al., 2014).

Table 2.1 Drivers and barriers facing emerging markets in the diffusion of biofuels EI

Drivers and barriers facing emerging markets in the diffusion of biofuels eco-innovation		References
Drivers	Regulatory support, particularly incentives and subsidies	Suhara et al. (2024) Farobie and Hartulistiyoso (2022)
	Feedstock availability offers financial benefit for large companies and enhances wealth of rural farmers	Singh, J. and Clough (2024) Nikas et al. (2022) Suhara et al. (2024) Farobie and Hartulistiyoso (2022)
	Collaborative networks for optimising knowledge spillovers and enhance compatibility	Wang et al. (2023) Chandran (2020)
	Green market sensing capabilities	Gupta and Barua (2018a)
Barriers	Insufficient regulatory support and the absence of incentive schemes for advanced biofuels	Breetz (2020) Ebadian et al. (2020)
	Price vulnerability and high investment risks	Suhara et al. (2024) Mosquera et al. (2024)
	Compatibility and technology mastery concerns	Chandran (2020) Kahn Ribeiro et al. (2007)
	Social welfare gap concerns between large companies and rural farmers	Kirshner et al. (2022) Ichsan et al. (2025)

Source: Author

2.4.3 Socio-Technical Transition of Electric Vehicles Technology in Emerging Countries

By the late 19th century, electric vehicles (EVs) were commercially produced and began competing with gasoline- and steam-powered vehicles due to their ease of use and environmental cleanliness (Kirsch, 2000). However, the rise of cheaper and more efficient internal combustion engine vehicles (ICEVs) in the 20th century led to a decline in EV usage. Although the oil crisis of the 1970s revived interest in EVs, models like the GM Electrovair and Enfield 8000 faced limitations in range and speed (Ehsani et al., 2018).

Since the late 1990s, research has significantly improved battery performance (Zhuge et al., 2021; Singh, V. et al., 2021). Concerns about climate change have accelerated the adoption of EVs (Steinhilber et al., 2013; Kern and Rogge, 2016). Advancements in lithium-ion battery (LIB) technology and government subsidies have supported China's shift to EVs (Kalthaus and Sun, 2021; Zhuge et al., 2021). The Toyota Prius hybrid, launched in 1997, marked a key milestone of EV commercialisation, followed by the Tesla Roadster in 2008, a high-performance LIB-powered vehicle (Kalthaus and Sun, 2021; Zhuge et al., 2021).

The socio-technological transition to EVs has been progressing in major regions, especially in the EU and the US. Since 2004, Germany has implemented tax reductions for low-emission vehicles, including Hybrid Electric Vehicles (HEVs), based on their carbon dioxide emissions (Rong et al., 2017). The Energy Policy Act of 2005 introduced advanced vehicle credits for HEVs in the US (Borenstein and Davis, 2016). Throughout the 2010s, the adoption of EVs surged in the US, the EU, China, Japan, and South Korea, driven by regulatory support and subsidy programs that made EVs more competitive with ICEVs in the market (IEA, 2025; Department for Transport, 2025; Nair et al., 2024). The popularity of EVs has continued to grow rapidly, especially in the 2020s. Global sales of plug-in vehicles reached over 10 million units in 2020 and increased to 17 million by the end of 2024 (IEA, 2025).

Currently, China is the largest global market and producer of EVs, making up over 70% of worldwide production (IEA, 2025). Since 2010, the government has promoted EV adoption through subsidies, tax incentives, sales quotas, and investment in charging infrastructure. These measures have been key to the widespread use of EVs (Greitemeier et al., 2025; Fraunhofer FFB, 2025). Despite phasing out subsidies in 2022, China continues to have a robust supply chain for lithium, cobalt, batteries, and vehicle manufacturing, which provides it with a cost advantage over other producers (Greitemeier et al., 2025; Fraunhofer FFB, 2025).

The transition to EVs differs between developed and developing countries. Developed countries experience significant growth in EV adoption, while emerging markets show varied rates. Countries in Latin America, Asia, and Africa face barriers in adopting EVs, especially emerging economies that struggle with high purchase costs and inadequate charging infrastructure (Pandita et al., 2024; Abbasi et al., 2021). In response, India implemented subsidies for HEVs and BEVs based on their battery capacity and efficiency through the Faster Adoption and Manufacturing of Electric Vehicles (FAME) I program, which was launched in 2015 (Singh, V. et al., 2021; IEA, 2025). Since 2019, the FAME II program has been focused on promoting BEVs (Dutt, 2023; Singh, V. et al., 2021).

IEA (2024a) indicates that Thailand is leading the way in promoting the adoption of HEVs in Southeast Asia. From 2007 to 2017, the country implemented a lower tax rate of 10–15% for HEVs based on their carbon dioxide emissions, while ICEVs faced higher tax rates of 20–30% (IEA, 2024a; Gabriel et al., 2021). Additionally, the Eco Car Program Phase II, introduced in 2015, classified HEVs as low-emission vehicles. Beginning in 2017, the focus shifted towards plug-in hybrid electric vehicles (PHEVs) and BEVs, with the EV Roadmap 2030 aiming for 30% of car production to be electric (IEA, 2024a; Gabriel et al., 2021).

Zhuge et al. (2021) analysed the factors influencing EV diffusion at macro and micro levels. At the macro level, their analysis highlights societal trends affecting adoption and

emphasises the critical role of policymakers in developing national strategies for EV promotion (Zhuge et al., 2021). Initiatives aim to boost interest and purchasing power among lower- and middle-class populations, while the growth of the EV industry and its infrastructure rely on the government's ability to attract investment (Pandita et al., 2024; Zhuge et al., 2021).

At the micro-niche level, the utilisation of DOI theory examines individual adoption behaviours regarding new green energy technologies. Research by Hakam and Jumayla (2024) and Zhuge et al. (2021) identifies several factors that influence consumer preferences for adopting EVs. These factors include the upfront purchase price (Shamsuddoha and Nasir, 2025; Abdul Qadir et al., 2024; Afraah et al., 2021), operational and maintenance costs (Saputra et al., 2023; Wu, Z. et al., 2021), product performance (Tiwari et al., 2020; Yang et al., 2023), psychological influences (Hakam and Jumayla, 2024), consumer behaviour (Hakam and Jumayla, 2024; Zhuge et al., 2021), government policies (Pandita et al., 2024; Abbasi et al., 2021), and the availability of infrastructure (Pandita et al., 2024; Zhuge et al., 2021). In several emerging markets, the electric two-wheelers (E2Ws) were growing faster than that for electric four-wheelers (E4Ws), primarily due to their more affordable upfront purchase prices and lower operating costs (IEA, 2025; Afraah et al., 2021).

EVs represent a new form of green energy that has gained traction in several developing countries, driven by supportive environmental regulations and incentive schemes, particularly subsidies (Helveston et al., 2015; Singh, V. et al., 2021). The public is increasingly acknowledging the advantages of EVs, which include cheaper long-term operating and maintenance costs (Ji and Gan, 2022; Afraah et al., 2021) and lowered emissions compared to ICEVs (Abdul Qadir et al., 2024; Afraah et al., 2021; Singh, V. et al., 2021). Additionally, networks for technological collaboration have facilitated the knowledge spillovers to meet public mobility needs better (Hakam and Jumayla, 2024; Shamsuddoha and Nasir, 2025). Intensive promotional campaigns can further promote EV adoption (Abbasi et al., 2021; Pandita et al., 2024), potentially increasing the integration of clean energy sources in the transportation sector's (Costa et al., 2021; Ehsani et al., 2018).

Despite policies in some countries encouraging EV adoption, consumers in emerging economies face significant obstacles, primarily the high upfront purchase price, which limits widespread adoption (Abdul Qadir et al., 2024; Pandita et al., 2024; Abbasi et al., 2021). Additionally, unclear regulatory frameworks and a lack of coordination among institutions have slowed the socio-technical transition to low-emission mobility (Shamsuddoha and Nasir, 2025; Wu, J. et al., 2018). The broader of EVs adoption beyond major cities was further obstructed by the limited availability of charging infrastructure, which requires significant investment (Shamsuddoha and Nasir, 2025;

Zarazua de Rubens et al., 2020). Consumers also expect EV performance to match that of ICEVs in their class, presenting technological challenges (Yang et al., 2023; Singh, V. et al., 2021). Furthermore, there is a growing demand for a shift away from reliance on polluting energy sources for electricity generation, particularly coal (Sadiq et al., 2023; Jaramillo et al., 2009). Table 2.2 outlines the factors that promote and hinder socio-technical transition through the EVs diffusion in developing countries.

Table 2.2 Drivers and barriers facing emerging markets in the diffusion of EVs EI

Drivers and barriers facing emerging markets in the diffusion of electric vehicles eco-innovation		References
Drivers	Supportive regulations and incentive schemes, particularly subsidies	Singh, V. et al. (2021) Helveston et al. (2015)
	Lower long-term costs and emission compared to ICEVs	Ji and Gan (2022) Afraah et al. (2021) Abdul Qadir et al. (2024) Singh, V. et al. (2021)
	Technological collaboration has facilitated the knowledge spillovers	Hakam and Jumayla (2024) Shamsuddoha and Nasir (2025)
	Promotional campaigns	Abbasi et al. (2021) Pandita et al. (2024)
	Enhance the utilisation of clean energy sources	Costa et al. (2021) Ehsani et al. (2018)
Barriers	Unclear regulatory frameworks and a lack of coordination among institutions	Shamsuddoha and Nasir (2025) Wu, J. et al. (2018)
	Low affordability due to expensive upfront purchase cost	Abdul Qadir et al. (2024) Pandita et al. (2024) Abbasi et al. (2021)
	Limited availability and high investment risk of charging infrastructure	Shamsuddoha and Nasir (2025) Zarazua de Rubens et al. (2020)
	Technological challenge to improve performance	Yang et al. (2023) Singh, V. et al. (2021)
	Dependence on fossil fuel electrical power plant	Sadiq et al. (2023) Jaramillo et al. (2009)

Source: Author

2.5 Socio-Technical Transition in the Indonesian Transportation Sector

As global awareness of decarbonisation increases and the urgency for a socio-technical transition toward sustainability grows, the Indonesian government faces an energy

trilemma⁶ when formulating sustainability strategies, particularly for the transportation sector (Setyowati, 2020; Gunningham, 2013). In 2022, Indonesia had the highest energy consumption in Southeast Asia, with its primary energy supply primarily sourced from coal, which made up 42%. Oil accounted for 31%, gas for 14%, and renewable energy (NRE) contributed 12.3% as shown in Figure 2.1 (DEN, 2023). In 2022, the industrial sector consumed 45% of total energy, more than the transportation sector's 37% (DEN, 2023). Carbon dioxide emissions totalled around 696.7 million tonnes, with transportation accounting for 22.3% of emissions, following power generation and industry (DEN, 2023).

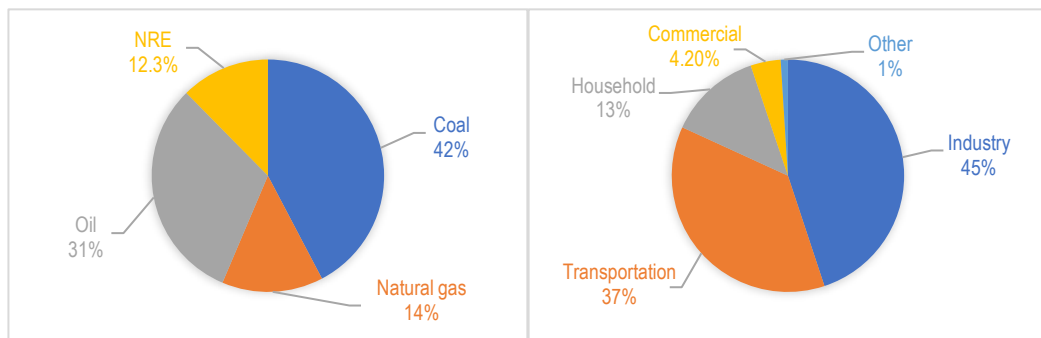


Figure 2.1 Indonesian final energy consumption in 2022
Adopted from source: DEN (2023)

Inadequate planning for mass public transport and uncontrolled urbanisation have significantly increased the reliance on private vehicles (Dimitriou, 2022; Sefriyadi et al., 2023). Motorcycles have become the preferred choice for many Indonesians due to their affordability (Fevriera et al., 2021). The number of motorcycles escalated rapidly, growing from 2.67 million units in 1980 to 120.10 million units in 2018. In comparison, passenger cars increased from 639,464 units in 1980 to 16.44 million units in 2018. Buses, on the other hand, experienced the slowest growth, rising from 86,284 units in 1980 to 2.54 million units in 2018 (Katadata Media Network, 2017). Figure 2.2 shows the growth in the population of motorised vehicles in Indonesia from 1949 to 2018.

In 1980, motorcycles represented about 69% of all motor vehicles, increasing to 82% by 2018, showcasing their growing dominance. Motorcycles have become the most significant fuel-consuming vehicle type in Indonesia. Although their per-unit fuel consumption is lower than that of cars or trucks, the total number of motorcycles has

⁶ The energy trilemma, developed by the World Energy Council since 2010, focuses on energy security, affordability, and environmental sustainability (World Energy Council, 2011). This framework is used worldwide to evaluate a country's energy system (Setyowati, 2020; Wibisono et al., 2023).

made them the most significant contributor to overall fuel consumption (Katadata Media Network, 2017).

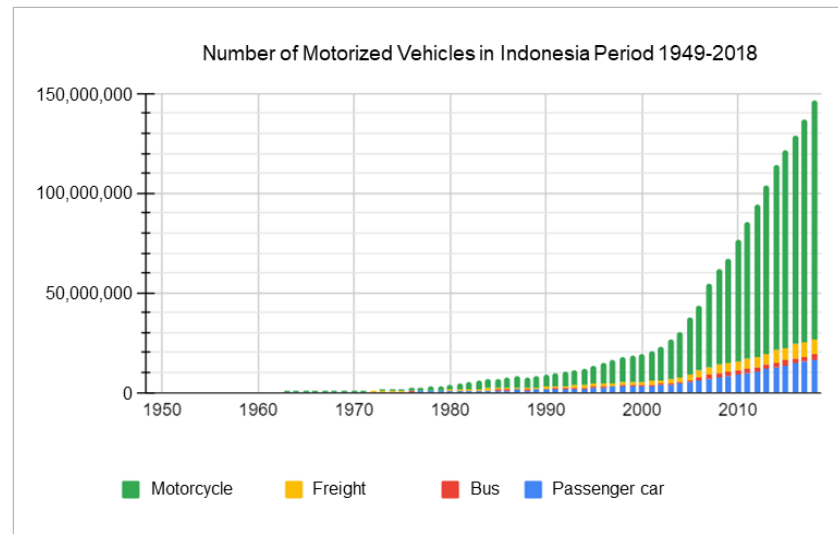


Figure 2.2 Number of motorised vehicles in Indonesia period 1949-2018
Adopted from source: (Katadata Media Network, 2017)

The development of public transportation in Indonesia has highlighted the role of TransJakarta, the country's first BRT system, which began operations in 2004 (PPID PT Transportasi Jakarta, 2020; Nurhaliza, 2024). The TransJakarta BRT design draws inspiration from the BRT system in Curitiba, Brazil, featuring dedicated lanes, off-bus payment options, and level boarding platforms (Wright, 2011; Nikitas and Karlsson, 2015). Supported by subsidies from the Jakarta regional government, TransJakarta has provided inclusive, high-capacity urban mobility at a relatively low cost, making it affordable for all segments of the public. For nearly two decades, the BRT network, along with commuter rail services, has served as the backbone of public transportation in metropolitan Jakarta (PPID PT Transportasi Jakarta, 2020; Nikitas and Karlsson, 2015; Nurhaliza, 2024).

Recent developments are focused on two key strategic directions. First, intermodal integration is achieved through the JakLinkGo microbus feeder scheme, which connects the BRT system with commuter trains, MRT, and LRT (Nurhaliza, 2024; Setijowarno, 2023). The second direction emphasises the implementation of environmentally friendly transportation modes aimed at reducing GHG emissions. TransJakarta has become a promotional platform for low-carbon transportation alternatives by utilising compressed natural gas, biodiesel, and electric vehicles. This diversity in fuel types and drivetrain technologies not only supports environmental conservation but also enhances the user experience with eco-friendly transportation options (Difa and Sulistiyandari, 2021; PPID

PT Transportasi Jakarta, 2020). Recent debate has emerged regarding the trade-off between the acceleration of implementing road-based solutions and the potential reduction in mixed traffic capacity. Additionally, several parties express concerns about the importance of service quality and perceived reliability in attracting passengers. In the context of TOD, the focus is on enhancing last-mile connectivity, improving pedestrian accessibility, and ensuring spatial integration with the surrounding land use (Yip et al., 2024; Hasibuan and Mulyani, 2022).

Decarbonisation of the transportation sector through electrification is significantly affected by the lifecycle of Indonesia's electricity system. This system is highly centralised under the electricity SOE, PLN, which operates under a single buyer model. This structure centralises both investment and operational decisions (Apriliyanti et al., 2024; Setyowati, 2020). Recent discussions surrounding the low-carbon transition focus on the debate between maintaining a centralised system for stability and equity versus promoting decentralisation to facilitate the integration of renewable energy (Gulagi et al., 2025; IRENA, 2019).

However, this transition has encountered significant challenges, particularly due to overcapacity in coal-fired power generation, which has obstructed the entry of variable renewable energy (VRE). Furthermore, the current infrastructure has limitations in flexibility to manage the intermittency of VRE (IEA, 2024b; Hamdi and Adhiguna, 2021). While the electrification ratio was almost universal, at approximately 99.8% in 2023 (MEMR, 2024), the quality of supply remains inconsistent in remote areas (Hasjanah, 2023).

To address these challenges, policymakers have implemented regulations focused on infrastructure development, accelerating the VRE mix through pumped storage, battery energy storage systems (BESS), and reforms in rooftop photovoltaic policy (Pramadya and Kim, 2024; IEA, 2024b). The effectiveness of these initiatives largely depends on policy synchronisation, enhanced incentives, and the creation of opportunities for innovation in distribution and microgrids. Additionally, some stakeholders have pointed out that the green electrification of the transportation sector has increased the demand load, which must be balanced by decarbonising the upstream supply within the sector (Pramudya et al., 2024; Hasjanah, 2023).

From an energy security perspective, Indonesia's transportation sector has encountered increasing pressure from rising energy consumption, averaging approximately 4.5% per year, primarily due to the prevalence of private vehicles (Wardhana and Marifatullah, 2020). In response, the government has implemented mandatory biofuels (including

B40⁷ and E5⁸) and promoted electric vehicle policies to ensure a stable domestic energy supply while fostering long-term energy stability (Sembiring, 2025; Candra, 2025). In terms of energy equity, subsidy policies have been essential for governments to keep fuel prices affordable. However, the increasing cost of these subsidies has put significant financial pressure. reliance on subsidies has increased the number of private vehicles, leading to greater environmental impacts. While there have been some efforts to redirect subsidies towards supporting clean fuels—such as reducing sulphur content and banning subsidised fuel for certain vehicles—the primary focus remains on maintaining affordability (Helveston et al., 2015; Skovgaard and van Asselt, 2019).

The transition to biofuels, electrification, and mass public transport projects represents a significant effort toward environmental sustainability. Mass public transport systems, including the TransJakarta BRT and commuter line trains, have contributed to reducing GHG emissions (Sembiring, 2025; Andistya and Dwi Ratna Indri, 2025; BPPT, 2018). However, a significant challenge in this sector is the reliance on coal-fired power generation within the EI diffusion chain (Hamdi and Adhiguna, 2021; Koplitz et al., 2017). Additionally, there are concerns regarding the impacts of deforestation, threats to biodiversity, and land tenure disputes associated with the expansion of oil palm plantations as the primary feedstock for Indonesian biodiesel (Ichsan et al., 2025; Astari et al., 2025; Choiruzzad et al., 2021).

However, there is considerable debate among scholars about the trade-offs involved in the energy trilemma. While low-cost policies, such as fuel subsidies, can promote equity, they may pose a risk to sustainability. While increasing the share of coal-based electricity generation can enhance energy security and reduce costs, it also exacerbates emissions and leads to environmental degradation (Ichsan et al., 2025; Hamdi and Adhiguna, 2021; Koplitz et al., 2017). Nevertheless, the decarbonisation in the transportation sector, including the diffusion of biofuels and EVs, faces challenges such as regulatory uncertainty, insufficient infrastructure, and limited investment in green initiatives (Suhara et al., 2024; Lazuardy et al., 2024).

2.6 Gaps in knowledge

The previous section reviewed literature and studies on socio-technical transitions, institutional change, power relations, the diffusion of innovation, and social adoption of technology towards sustainability in the transportation sector in Indonesia. While

⁷ B40 refers to a blend of 40% biodiesel in diesel fossil fuel.

⁸ E5 refers to a blend of 5% ethanol in gasoline fossil fuel.

research on socio-technical transitions for the sustainability of the transportation sector in developing countries has grown rapidly, several knowledge gaps remain relevant to the Indonesian context.

First, recent research that combines the multilevel perspective (MLP) and historical institutionalism (HI) to analyse the trajectory of Indonesia's transportation sustainability policies (Sembiring, 2025; Ichsan et al., 2025) requires further in-depth study. This research framework is particularly important for mapping the interrelation between the dynamics of the domestic transportation regime with low-carbon technology niche innovations, and pressures at the landscape level (Geels, 2024; Xu, W. and Mo, 2024). These landscape pressures include the energy trilemma, the global climate agenda, international trade disputes, environmental degradation, and social welfare equity (Setyowati, 2020; Gunningham, 2013). Recent studies have generally addressed these factors in a fragmented manner, often focusing on a single area such as mass public transport (Cameron and Geels, 2019; Klitkou et al., 2015), biofuels (Sembiring, 2025; Ichsan et al., 2025; Nikas et al., 2022), or EVs (Dutt, 2023; Xu, W. and Mo, 2024). However, they have not thoroughly examined how historical interactions and institutional arrangements influence the unique transition pathways among these areas, which are crucial for understanding transportation sustainability in Indonesia as a developing country (Geels, 2019; Nikas et al., 2022).

Second, research examining power relations between local and global actors in determining Indonesia's transportation sustainability policies is still limited conducted in-depth using a comprehensive power analysis framework in the context of competition between different types of green transportation technologies in developing countries. Recent studies have examined the significant influence of global actors and asymmetric relationships within the technology supply chain at both national and subnational levels (Newell, 2021). In Indonesia, some studies have concentrated on central government policies and the role of foreign investors (Choiruzzad, 2019; Astari and Lovett, 2019). However, the analysis needs to be deepened by exploring power negotiations, policy coalitions, the formation of dominant discourses, and the institutional mechanisms that affect implementation at both national and regional levels (Allen, 2011b; Foucault, 2007; Newell and Bray, 2025). Additionally, it is crucial to thoroughly examine the emergence of dominant coalitions that advocate for their interests while also investigating the marginalisation of other stakeholder groups within the context of socio-technical transitions (Newell, 2008; Kirshner et al., 2022; Ichsan et al., 2025).

Third, the recent research on the diffusion of EI and the social adoption of technology often separates the discussion of the main pillars of sustainable transportation

development in Indonesia, particularly focusing on biofuels (Ichsan et al., 2025; Suhara et al., 2024; Farobie and Hartulistiyoso, 2022) and electric vehicles (Afraah et al., 2021; Lazuardy et al., 2024). Therefore, a comparative analysis is needed to connect the EI drivers and obstacles of diffusion in both subsectors. Consequently, there is a limited understanding of integrative strategies to accelerate cross-technology adoption. Cross-technology integration for environmental sustainability is crucial to optimising the impact of the socio-technical transition. This socio-technical transition is essential for addressing the energy trilemma, enhancing energy resilience, providing inclusive transportation, and reducing greenhouse gas emissions (Magnani, N. and Cittati, 2022; Xu, S., 2021).

The adoption of EVs as an emerging low-carbon technology is progressing at a different pace in Indonesia compared to biodiesel (Gulagi et al., 2025). Numerous studies have focused on the social acceptance of EVs, examining consumer preferences and their willingness to pay for EVs (Hakam and Jumayla, 2024; Xue et al., 2015). Furthermore, research has analysed the total cost of ownership associated with EVs (Ji and Gan, 2022; Afraah et al., 2021; Kumar and Chakrabarty, 2020). Key barriers to adoption have been identified, including unclear regulations, high purchase prices, significant infrastructure investments, and limited public understanding of sustainability (Shamsuddoha and Nasir, 2025; Pandita et al., 2024; Abdul Qadir et al., 2024; Abbasi et al., 2021). On a global scale, literature has highlighted pilot projects for second-life applications and the development of efficient recycling methods for retired EV batteries (Altuntas Vural et al., 2025; Kampker et al., 2023; Rufino Júnior et al., 2023). However, there is a need for further research that integrates government policy strategies, addresses consumer acceptance from multiple perspectives, and explores the potential for second-life utilisation and recycling methods for retired EV batteries. This comprehensive approach is necessary to overcome barriers to EV adoption in Indonesia, particularly given its status as an emerging economy (Safarzadeh and Di Maria, 2025; Altuntas Vural et al., 2025).

Chapter 3 Methodology

3.1 Introduction

The methodology chapter outlines the interrelationships between the overarching research questions, the sub-research questions, the identified knowledge gaps, and the approaches to address those knowledge gaps. The methodological design of this dissertation acknowledges that sustainable transportation in Indonesia is a complex socio-technical challenge influenced by political, cultural, institutional, and economic factors. Instead of focusing solely on the technical aspects of vehicles, alternative fuels, or supporting infrastructure, this research situates transportation within a broader context that includes institutional arrangements, path dependencies, power dynamics, the diffusion of eco-innovation, and consumer social adoption. Consequently, the methodology moves beyond the strict measurement of transport sustainability indicators typically associated with positivist approaches. Instead, it adopts interpretive, critical, and socio-technical transition-based frameworks.

This research adopts critical realism as its guiding philosophy at the ontological level (Sayer, 2010; Easton, 2010; Brunson et al., 2025). Critical realism posits that social phenomena arise from underlying generative mechanisms, such as institutional rules, power asymmetries, and the dynamics of global transportation markets, which may not be directly observable. These mechanisms are reflected in the events, discourses, and actions of various actors, but understanding their causal influence necessitates interpretive reconstruction. This ontological perspective is essential for comprehending the socio-technical transition toward sustainability in Indonesia's transportation sector. Phenomena like the diffusion of mass public transport, the adoption rates of electric vehicles and the implementation of mandatory biofuel usage policies stem from deeply entrenched institutional legacies, the interests of various agencies, pressures from the global landscape, and disruptions caused by low-carbon technologies (Ayuriany et al., 2023; Djatmika et al., 2024; Ichsan et al., 2025; Hakam and Jumayla, 2024).

This study is grounded in interpretivism and constructivism at the epistemological level. Interpretivism emphasises the importance of meaning, narratives, and the discourse of dominant actors, acknowledging that knowledge is socially constructed rather than an objective truth (Bryman, 2016). On the other hand, constructivism illustrates that terms such as "sustainability," "energy resilience," "diffusion of eco-innovation," and "social adoption of green technologies" are not neutral labels; instead, they represent contested

social constructs that are deeply rooted in political struggles (Guba & Lincoln, 1994). For instance, in Indonesia, framing palm oil biodiesel as a means to achieve "energy sovereignty" reflects both political narratives and environmental concerns (Ichsan et al., 2025; Astari et al., 2025; Choiruzzad, 2019).

This research follows a primarily qualitative design, enhanced by quantitative methods. Qualitative approaches, including semi-structured interviews, document analysis, and discourse analysis, enable the exploration of meaning and power dynamics among stakeholders. Meanwhile, online surveys and cost modelling provide empirical data and triangulation, particularly regarding consumer acceptance of EVs. This mixed-methods approach reflects pragmatic pluralism (Mingers, 2001; Morgan, 2014), which recognises that no single method can fully capture the multifaceted reality of socio-technical transitions.

The choice of research methods aligns with each research question. Chapters 4 and 5 examine how interactions among multilevel actors, institutional legacies, and power relations affect the diffusion of eco-innovation in the Indonesian transportation sector. This inquiry requires a qualitative approach that examines the narratives and discourses of these actors. Chapter 6 focuses on the role of collaborative networks in diffusing low-carbon transportation technologies, with biofuels and EVs as case studies. This empirical chapter utilises structured coding methods, including Gioia's methodology (Gioia, D.A. et al., 2013) and framework analysis. In Chapter 7, this research investigates the social acceptance of EVs, utilising a mixed-methods design that integrates online surveys, cost-structure modelling, lifecycle analysis, and secondary data analysis. Overall, these methodological choices create a theory-based mixed-methods design suitable for addressing the complexities inherent in the socio-technical transition to sustainable transportation.

The chapter is divided into four sections covering the phases of the research process: research methods and design, data collection and analysis methods; research access and ethical concerns; methodological limitations and critical reflection; and study site. Each section is discussed in detail to provide a comprehensive understanding of the research process.

3.2 Conceptual Framework, Research Methods, and Analysis

This research was conducted in four stages, as illustrated in Figure 3.1, which provides a detailed overview of the research methodology and design.

Table 3.1 Conceptual framework, research methods, and analysis

Research Question	Chapter	Conceptual Framework	Data Source and Collection Technique	Methodology	Analytical Technique
1. How have multi-level interactions influenced critical junctures in the institutional dynamics of socio-technical transitions toward sustainability in the Indonesian transport sector?	4	Multilevel perspective; historical institutionalism; landscape, regime and niche levels; socio-technical transition; institutional change; critical junctures; and path dependence.	- Primary data: Transcripts from Interviews. - Secondary data: Indonesian transport energy regulation documents, historical institutional records, national environmental policies, corporate annual reports, academic journals, and local/international NGO reports that impacted sustainability pathways from 1945 to 2025, especially from 2006 to 2025.	Qualitative method: - Semi-structured online interviews, the interviews were recorded, transcribed, and processed using NVivo. - Systematic literature review on secondary data.	Multilevel perspective analysis; Historical institutional analysis, secondary data analysis, content analysis and tenet of triangulation on regulation, institutional records, academic journals, and interview transcripts.
2. How does the power contestation between global and local actors influence the development of sustainable transport policies in Indonesia?	5	Power relation; structural power; discursive contestation; disciplinary mechanism; dominant coalitions; and political economy.	- Primary data: Transcripts from Interviews. - Secondary data: The power relation between agencies including discourse contestation, formation of coalition, and political economy in the diffusion of eco-innovation records, academic journals, media (websites, newspapers), and scientific publications.	Qualitative method: - Semi-structured online interviews, the interviews were recorded, transcribed, and processed using NVivo. - Systematic literature review on secondary data.	Power relation analysis, power/knowledge analysis, discourse and disciplinary analysis, and political economy analysis, secondary data analysis, and tenet of triangulation.
3. How can multilevel interactions between	6	Diffusion of eco-innovation; user innovation; social	Primary data: Transcripts from Interviews.	Qualitative methods: Semi-structured online interviews, the interviews	The framework analysis and Gioia analysis on primary data transcript,

Research Question	Chapter	Conceptual Framework	Data Source and Collection Technique	Methodology	Analytical Technique
stakeholders enhance drivers and address key barriers in the diffusion of eco-innovation within the transportation sector of emerging economies?		adoption of low-carbon technology; multilevel interaction impact on drivers and barriers of eco-innovation.	Secondary data: diffusion of eco-innovation, adoption of low-carbon technology, drivers and barriers on the diffusion of biofuels and EVs in developing countries documents, academic journals, media (websites, newspapers), and scientific publications.	were recorded, transcribed, and processed using NVivo. Systematic literature review on secondary data.	secondary data analysis, content analysis and tenet of triangulation on regulation and interview transcripts.
4. How the interaction between regimes and niches affects the socio-technical transition process of EV adoption in emerging economies?	7	Social acceptance of technology approach; customers' preferences; institutional arrangements, and total cost of ownership.	- Primary data: Interview transcripts and internet-based questionnaires. - Secondary data: social acceptance of technology approach, key challenges, and EV consumer preference documents, media (websites, newspapers), and scientific publications in transportation energy technology trajectory.	Qualitative and quantitative methods: - Internet-based questionnaires data related to customers' preferences on willingness to buy electric motorcycle were analysed using descriptive statistical analysis with SPSS. - Total Cost of Ownership (TCO) analysis on EMC and ICE motorcycles over ten years period. - EV lifecycle assessment - Secondary data review.	Descriptive statistical analysis, secondary data analysis, content analysis and tenet of triangulation on regulation and interview transcripts.

3.2.1 Socio-Technical Transition

The first empirical chapter utilises a qualitative method that combines the Multi-Level Perspective (MLP) framework (Geels, 2024; Geels and Turnheim, 2022; Geels, 2002) with Historical Institutionalism (HI) (Lockwood et al., 2017; Mahoney and Thelen, 2010; Pierson, 2004). MLP conceptualises sustainability transitions as the result of interactions among three analytical levels: the niche, where radical innovations occur; the regime, which represents the dominant socio-technical configuration; and the landscape, which exerts exogenous pressures such as climate change and trade disputes. In contrast, HI focuses on institutional legacies, path dependence, and the mechanisms that maintain stability or facilitate gradual institutional change.

The methodological integration of MLP and HI optimises the strengths of both approaches to complement each other. MLP is effective at mapping dynamic interactions across levels and actors, but has faced criticism for being overly descriptive and sometimes narrative rather than explanatory (Genus & Coles, 2008). HI addresses this limitation by providing greater analytical precision, particularly concerning critical junctures, feedback loops, and institutional constraints (Thelen, 1999). The resilience of the fuel subsidy regime in Indonesia can be explained through HI's concept of increasing returns (Skovgaard and van Asselt, 2019; Büthe, 2016). In contrast, the diffusion of biofuels and electric vehicles can be analysed within the MLP framework, which emphasises inter-agency contestation (Sembiring, 2025; Xu, W. and Mo, 2024; Nikas et al., 2022).

However, critically, both frameworks have notable limitations. MLP is often criticised for being overly structuralist (Upham et al., 2018; Fuenfschilling and Truffer, 2014) and Eurocentric (Arora, S. and Stirling, 2023; Fernandes de Freitas and Jehling, 2023). On the other hand, HI faces criticism for being excessively deterministic and for its slow pace in explaining rapid changes. Recent discussions have encouraged the combination of these two frameworks to better capture the complexity of the sustainability transition (Pye, 2019). This thesis addresses these criticisms by integrating both approaches, with MLP mapping dynamic multi-level interactions and HI focusing on the reasons why specific institutional arrangements maintain stability or undergo change. Table 3.1, specifically the row for Phase 1 in column 3, outlines the conceptual framework for examining the socio-technical transition towards sustainability in Indonesian transport.

3.2.2 Power Relations

The second empirical chapter uses a qualitative method that emphasises power relations as the primary analytical framework. Measuring power relations is complex due to their diffuse and relational nature. To operationalise the concept of power, this study

integrates three perspectives. First, relational modalities of power, as described by Allen (2011b), encompass power over, power to, power with, and power through, which manifest in routine interactions among agencies. Second, Foucault (1980) conceptualised power as embedded in the discourse and practice of discipline, highlighting how knowledge and expertise serve as mechanisms of control. Third, Newell (2008) and Newell (2021) situate power within the global political economy, emphasising how alliances between states, corporations, and international organisations influence the diffusion of eco-innovation. Furthermore, this approach explores the formation of dominant alliances and the marginalisation of narratives or interests from other stakeholder groups. This framework allows an analysis of how dominant coalitions in Indonesia—such as state-owned enterprises, multinational automotive manufacturers, and conglomerates of palm oil and coal—utilise both structural and discursive power to shape the adoption of eco-innovation policies. By combining these concepts of power relations, the framework has explored the dominant discourse that legitimises the sustainable expansion of biodiesel and electrification, despite concerns regarding environmental conservation (Astari et al., 2025; Verma et al., 2021; Pye, 2019). Table 3.1, particularly the Phase 2 row in column 3, presents the conceptual framework for analysing the power contestation among actors shaping sustainable transport policy development in Indonesia.

3.2.3 Diffusion of Eco-Innovation

The third empirical chapter of this thesis employs a qualitative case study design to examine the diffusion of eco-innovation in sustainable transportation in Indonesia, specifically focusing on the factors that influence the spread of biofuels and EVs. The choice of a qualitative methodology allows for a deeper understanding of the nuanced, context-specific interactions among actors, institutions, technology, and environmental conservation in the Indonesian context (Astari et al., 2025; Djatmika et al., 2024). This chapter incorporates insights from Glover et al. (2019) regarding the pathways of technological change negotiation and from Douthwaite et al. (2001) concerning the significance of user innovation. By doing so, it moves beyond simplistic deterministic diffusion models to emphasise the roles of agency and contestation.

This phase of the study uses two complementary sources of textual material. Primary data comes from semi-structured interviews, while secondary sources include policy documents, regulations, company reports, survey reports, news articles, public records, and relevant academic literature. For analysis, the Gioia methodology and framework analysis are integrated; each serves a specific role. The Gioia methodology provides a systematic approach to inductive qualitative analysis, focusing on developing new

conceptual categories grounded in informants' perspectives. Framework analysis, in contrast, structures and organises data according to predetermined themes, facilitating systematic comparison across sources. Table 3.1, focusing on Phase 3 in column 3, presents the conceptual framework for examining multilevel interactions that influence the diffusion of eco-innovation and technology adoption.

Interview data were analysed using the Gioia methodology, enabling a systematic, transparent progression from participants' perspectives to theoretical interpretation (Gioia, D.A. et al., 2013; Magnani, G. and Gioia, 2023). Unlike general qualitative coding, this method maintains participants' meanings before abstract interpretations, aligning directly with the study's goal (Gioia, D. et al., 2022; Magnani, G. and Gioia, 2023). The iterative data analysis process adhered to the three core stages of the Gioia methodology: identification of first-order concepts, development of second-order themes, and construction of aggregate dimensions (Gioia, D.A. et al., 2013; Magnani, G. and Gioia, 2023). The Gioia method is especially valuable when the objective is to generate conceptually robust categories rather than merely descriptive summaries (Gioia, D. et al., 2022; Magnani, G. and Gioia, 2023).

To enhance analytical rigour and facilitate systematic comparison across multiple sources of evidence, the Gioia methodology was combined with framework analysis. Framework analysis is a structured qualitative approach that organises data through coding, summarising, and charting evidence into a matrix, allowing systematic comparison across cases, actors, documents, and themes (Gale et al., 2013; Klingberg et al., 2024). While framework analysis shares with thematic analysis an interest in identifying patterns across qualitative material, it places greater emphasis on matrix-based organisation, transparency, and cross-source comparison (Braun and Clarke, 2023; Gale et al., 2013). In this study, framework analysis was primarily used to integrate interview findings with secondary documentary evidence, enabling comparison of how themes emerging from interviews were reflected, reinforced, qualified, or challenged by policy and institutional documents. The combination of the Gioia methodology and framework analysis thus served complementary purposes: the Gioia methodology facilitated inductive concept development from interview data (Gioia, D. et al., 2022; Magnani, G. and Gioia, 2023), whereas framework analysis provided the analytical structure for organising, comparing, and triangulating findings across the broader case study dataset (Braun and Clarke, 2023; Gale et al., 2013). This methodological combination is well-suited to the present research as it supports both conceptual depth and cross-source analytical consistency in examining the diffusion of EI in Indonesia's biofuel and EV sectors.

This analysis supports advocacy with the government to formulate fiscal and non-fiscal policies, especially incentives and subsidies, that foster green markets and encourage the adoption of biofuels and EVs. Additionally, the examination assesses the impact of the carbon emission reduction agenda, global market pulls effect, and energy price fluctuations. The analysis also identifies key barriers to the further adoption of ethanol, second-generation biofuels, and EVs. These barriers include high production costs, ineffective policy implementation, competition with fossil fuels, a lack of technological capability or expertise, and concerns about environmental conservation.

3.2.4 Social Acceptance of Low-Carbon Technologies

This empirical chapter utilises a mixed methods approach to examine the social acceptance, economic viability, and sustainability impacts of EV adoption in Indonesia, with a specific focus on electric motorcycles (EMCs), which are the primary mode of transport in urban areas. The decision to apply a mixed methods design is based on the understanding that consumer perceptions of EVs are influenced not only by socio-cultural attitudes but also by economic factors, regulatory clarity, infrastructure availability, and technological challenges. A purely qualitative exploration may effectively capture the discourse surrounding EV adoption, but it risks overlooking quantitative aspects such as upfront purchase price, mobility usage patterns, and lifecycle implications. On the other hand, solely quantitative surveys can provide broad statistical generalisations but may miss the deeper socio-technical context that influences consumer decision-making (Creswell and Poth, 2018).

This chapter aims to provide a comprehensive understanding of the factors influencing electric vehicle adoption in Indonesia by triangulating survey analysis, secondary document reviews, and life cycle sustainability assessments. This study has examined both demand-side factors, such as consumer acceptance and affordability, and supply-side factors, including infrastructure and life cycle impact. This hybrid methodology is especially relevant for sustainability transitions in developing countries, where systemic transformations are greatly impacted by changes in public behaviour and institutional restructuring (Sovacool et al., 2018). Table 3.1, Phase 4, column 3, outlines the conceptual framework for analysing social acceptance of low-carbon technologies, focusing on the emergence of EVs in Indonesia.

3.3 Data Collection and Analysis Methods

3.3.1 Data Collection

3.3.1.1 Semi-Structured Interviews

Dynamics of Institutions and Power Relations in Socio-Technical Transitions

This study employs both primary and secondary data. The primary data were collected to verify the secondary data and to explore institutional developments in the socio-technical transition toward sustainability. As shown in Table 3.1, the rows for Phase 1 and Phase 2 in column 4 indicate that primary data were collected through semi-structured interviews. To gather primary data, semi-structured interviews were conducted with twenty-nine actors representing various stakeholders in the transportation sector. Participants were selected through purposive sampling to ensure diverse representation of key actors, avoid dominance by any particular group, and cover a broader range of transportation sustainability-related institutions. The stakeholders included government agencies, oil and gas companies, electric power companies, biofuel corporations, automotive manufacturers, green suppliers, transport providers, global institutions, energy associations, smallholder farmers, members of the public involved in transportation, NGOs, standardisation bureaus, research institutions, academics, and media representatives. Appendix A provides the semi-structured interview format used in this study. The semi-structured interviews explored several themes, including:

1. The roles and involvement of stakeholders in developing institutions for socio-technical transition.
2. The impact of landscape-level factors on national transition policies.
3. The interactions between niche actors and existing regimes within collaborative innovation networks for the diffusion of emerging mobility technologies.
4. Power relations in the contestation between actors in determining the policy development trajectory of eco-innovation diffusion and low-carbon technology adoption.

The study adopted gatekeepers and stratified snowball sampling to ensure diverse representation among stakeholders involved in Indonesia's transportation energy transition. Access to potential stakeholders for semi-structured interviews and online questionnaires was carried out through gatekeepers and snowball sampling to expand representation across various parties in the research. Seidman (2006) states that gatekeepers are actors who represent an institution that has the authority to grant or withhold access to a person or a condition of research. Gatekeepers inform and invite various energy sustainability activities in transportation, especially biofuels and

electrification. Gatekeepers are also a source of access to other relevant stakeholders. Purposive sampling was used to obtain gatekeepers from the MEMR, energy associations, NGOs, the transportation community, and academicians. Furthermore, snowball sampling was conducted among participants to ensure representation of the full range of stakeholder groups.

This research phase has approached potential stakeholders for semi-structured interviews, and online questionnaires are carried out using gatekeepers and snowballing techniques to expand the representation of various parties in the research. Seidman (2006) states that gatekeepers are actors who represent an institution that has the authority to grant or withhold access to a person or a condition of research. Gatekeepers inform and invite various energy sustainability activities in transportation, especially biofuels and electrification. Gatekeepers are also a source of access to other relevant stakeholders. Purposive sampling was conducted to obtain gatekeepers from government agencies, energy associations, NGOs, and the transportation community. Furthermore, snowball sampling conducted among participants to ensure representation of the full range of stakeholder groups. Facilitated the identification of additional participants, particularly from informal or less-documented networks, such as local NGOs and members of the public engaged with transportation issues. This approach recognises that many relevant actors may not be formally represented in policy documents but still have significant influence in practice (Mason, 2017).

Several participant groups were excluded during the first and second phases of this research, including international NGOs, smallholder farmers and EV startup SMEs. Representatives of international NGOs were contacted multiple times, but did not respond. As a result, the perspectives and aspirations of this stakeholder group were gathered through a secondary data analysis of reports published by international NGOs. This analysis focused on the intersection of various Indonesian biofuel and electric vehicle supply chains, as well as on environmental concerns, particularly deforestation and threats to biodiversity. Meanwhile, smallholder farmers and EV startup SMEs were interviewed in the third phase to gain a deeper understanding of the diffusion of eco-innovation and technology adoption, specifically regarding biofuels and EVs. The goal was to identify the driving factors behind their involvement in the socio-technical transition chain, as well as the constraints that marginalise their aspirations and roles in promoting sustainability within Indonesian transportation (Ichsan et al., 2025; Choiruzzad et al., 2021).

Participants were contacted via email, phone, and LinkedIn and given one week to accept or decline the invitation. Response times ranged from two days to three weeks.

Interviews typically took place in focus groups, but during the COVID-19 pandemic, they were conducted online using Microsoft Teams, Zoom, and WhatsApp from August 2020 to May 2023. All interviews were conducted in Indonesian, recorded, and then transcribed and translated into English for analysis with NVivo. This software helped track themes in the transcripts and determine when data saturation occurred, indicating that no new themes emerged.

Diffusion of Eco-Innovation and Adoption of Low-Carbon Transport Technologies

The third phase of this study has adopted a qualitative research design to investigate the diffusion of eco-innovation and the adoption of low-carbon transportation technologies in Indonesia. It specifically focuses on the sustainability trajectory of biofuels as a reference for EVs, which are emerging technologies for the Indonesian public. Primary data collection for Phase 3, shown in column 4 of Table 3.1, involved multi-level semi-structured interviews with 62 respondents representing various stakeholders actively engaged in the diffusion of eco-innovation biofuels and EVs in Indonesia. The participants were carefully selected to include actors at the micro-niche level of eco-innovation diffusion and technology adoption. This group included representatives from Pertamina, PLN, biofuel companies, independent power producers (IPPs), automotive manufacturers (including local EV MSME startups), small-scale palm oil farmers, spare parts suppliers, and providers of charging points and battery swap system infrastructure. This research stage involved participants from various job levels and fields of work to gain a comprehensive understanding of the challenges faced by actors promoting the diffusion of biofuels and EVs in developing countries. Appendix B presents list of interview topics on the diffusion of eco-innovation and social acceptance of low-carbon transportation technologies.

This purposive stratified snowball sampling ensured a diverse range of perspectives, capturing insights from both established companies and emerging innovators across the entire value chain, from upstream to downstream. The semi-structured interview questions were designed to be open-ended, allowing respondents to articulate their experiences and perspectives while maintaining comparability across cases. These questions were oriented around three thematic categories that align with the conceptual framework guiding the research: (1) analysis of the processes occurring during the eco-innovation diffusion stage, (2) examination of consumer technology adoption processes driving user innovation, and (3) identification of the drivers and barriers faced by collaboration networks in achieving wider adoption of advanced biofuels and EVs, particularly regarding regulatory clarity and consistency, economic acceptability, and accessibility to supporting infrastructure.

This study used stratified snowball sampling to engage various stakeholders in the biofuels and EVs in Indonesia. Participants were recruited via emails, phone calls, and LinkedIn, with responses collected over one week. Online interviews were conducted from February to November 2023. In July 2025, data were collected from smallholder farmers to assess the impact of biofuel diffusion on rural residents near oil palm plantations.

3.3.1.2 Surveys

The fourth stage of the study focused on observing public responses to the introduction of electric motorcycles (EMCs) as a new transportation mode in Indonesia, examining their social acceptance within the broader context of low-carbon technologies. As shown in Table 3.1, the Phase 4 row in column 4 indicates that data were collected via a survey. An online survey was conducted with 600 respondents from Jakarta and Bandung; two cities selected for their contrasting demographic and topographical characteristics. Jakarta, the capital and megacity of Indonesia, is characterised by coastal lowlands, high-density urbanisation, and a heavy reliance on private vehicles. However, Jakarta has begun implementing TOD based mass public transportation policies. In contrast, Bandung is a medium-sized city situated in hilly highlands. Its demographic profile features lower education and income levels, with high dependence on private vehicles and a lack of public mass transportation infrastructure, making it a suitable comparison location.

The survey sample was designed to ensure representation across various age groups, family sizes, monthly family income levels, educational backgrounds, and motorcycle ownership. While online surveys can be subject to self-selection bias, they offer advantages such as cost-effectiveness, broad reach, and timely data collection—particularly relevant during the restrictions on social activities due to the COVID-19 pandemic. To mitigate bias, recruitment efforts combined social media outreach with targeted invitations through community groups, local educational institutions, employment organisations, and other relevant participant groups.

The survey consisted of three sections: travel preferences, key considerations for purchasing EMCs, and the main barriers respondents faced in their desire to adopt EMCs. Additionally, the survey explored the reasons for low EV ownership by asking participants whether they preferred conventional EVs or ICEVs. This design reflects the pragmatic approach of this thesis, combining quantitative generalisation with qualitative depth. Appendix C provides the online survey design on customer willingness to buy an EMC.

3.3.1.3 Secondary Data

Alongside primary data from interviews and surveys, secondary data came from various sources. These secondary data provided a broader context, supporting an understanding of low-carbon transportation in Indonesia. In qualitative case studies, they offer background, help identify key events and policies, and place interview findings within broader social, political, and organisational settings (**Bowen, 2009; Kayesa and Shung-King, 2021**). Thus, secondary documents enriched the empirical base and supported a comprehensive understanding of the case. Column 3 in Table 3.1 identifies the secondary data sources used across all phases.

In this research, the secondary documents focused on five main dimensions:

1. **Government Regulatory Documents:** This includes policies and official reports from key ministries such as MEMR, MoF, MoT, MSOE, MoA, and MEF. These documents provide insight into the institutional framework and regulatory logic behind the development of low-carbon transportation.
2. **Corporate Reports:** Annual reports, sustainability reports, and press releases from state-owned enterprises and corporations, including Pertamina, PLN, biofuel producers, IPPs, automotive manufacturers, and infrastructure enablers, were reviewed. These documents contain data about corporate strategies, investments, and commitments towards decarbonisation.
3. **Publications from International Organisations:** Reports from international entities such as IEA, World Bank, OECD, FAO, UNFCCC, UNDP, and RSPO were analysed. These publications facilitate a comparative analysis and explore the connections between global agendas and national dynamics.
4. **Scientific Publications:** Published research academic journals, books or book chapters, conference proceedings, and thesis published that examine socio-technical transitions towards sustainability was included. This literature addresses power relations, advancements in low-carbon transportation technology, the diffusion of eco-innovation, and ongoing debates regarding the social adoption of green technologies.
5. **NGO and Civil Society Reports; and News:** Reports and publications from NGOs and civil society organisations often critique state policies and corporate strategies. Additionally, news coverage from national and international media presents public perspectives on mass transportation, biofuels, and electric vehicles.

A comprehensive body of secondary documentary sources was compiled, totalling 603 documents, which constituted the full corpus for documentary analysis. These materials were classified into five categories of secondary sources. Specifically, 88 documents were government regulatory documents, 39 were corporate reports, and 44 were publications from international organisations. An additional 62 documents were sourced from NGO and civil society reports, as well as news outlets, offering contextual and contemporary insights into the development of low-carbon transportation. The largest component comprised 370 scientific publications, including 312 academic journal articles, 56 books or book chapters, one conference proceeding, and one PhD thesis. Collectively, these sources established a broad and systematically assembled documentary foundation for the analysis. The complete distribution of these secondary data sources is presented in Table 3.2.

The collection of secondary data was designed to provide a broad documentary base for the study. Sources were selected for their relevance to the regulatory, corporate, international, academic, and societal dimensions of the case. Instead of relying solely on primary sources, the study used a diverse range of documentary materials, each offering insights into specific aspects of low-carbon transportation in Indonesia. This approach builds a richer understanding of the actors, institutions, and developments shaping the field.

Table 3.2 Overview of secondary data sources included in the documentary analysis

Type of Secondary Data Source		Quantity
1	Government regulatory documents	88
2	Corporate reports	39
3	Publications from international organisations	44
4	Scientific Publications	370
5	NGO and civil society reports	62

3.3.2 Analysis Methods

A mixed-methods analytical design was employed to examine low-carbon transport transitions in Indonesia. This phenomenon encompasses discursive, institutional, socio-technical, and economic dimensions. This study analysed semi-structured interviews, survey responses, and documents, finding that integrated documentary evidence provided greater explanatory depth, triangulation, and richness than qualitative or quantitative methods alone (Creswell and Clark, 2017; Denzin, 2012; Guetterman and Fàbregues, 2025). Qualitative analysis focused on interpreting interview transcripts and

documentary materials as textual data. Policy documents, corporate reports, media texts, and organisational records were recognised as codable and comparable with interview narratives (Grant, 2018; Bowen, 2009). Content analysis structured and interpreted the qualitative data through the lenses of the MLP, HI, and power-relations analysis of socio-technical transitions. The analysis remained open to emergent categories from the empirical material (Capoccia, 2016; Geels, 2024; Newell and Bray, 2025). The Gioia methodology supported iterative movement from first-order informant-centric concepts to second-order themes and aggregate dimensions of the diffusion of eco-innovation. This process enhanced conceptual rigour and clarified how empirical interpretations became theoretical insights (Gioia, D.A. et al., 2013; Magnani, G. and Gioia, 2023). Framework analysis integrated interview findings with secondary documentary evidence, enabling comparison of interview themes with policy and institutional documents (Gioia, D.A. et al., 2013; Magnani, G. and Gioia, 2023).

The quantitative strand analysed survey data using descriptive statistics to identify socio-economic patterns, attitudinal tendencies, and adoption preferences across respondent groups. TCO analysis examined the economic competitiveness of alternative vehicle technologies (Afraah et al., 2021; Ji and Gan, 2022; Kumar and Chakrabarty, 2020). Together, these qualitative and quantitative procedures formed a robust mixed-methods strategy. Statistical patterns and cost calculations were interpreted alongside interview and documentary evidence. This approach examined trends and considered factors—such as policy changes, new technologies, or market shifts—that shaped them within broader socio-technical transitions.

3.3.2.1 Documentary Data Analysis

Dynamics of Institutions and Power Relations in Socio-Technical Transitions

The first phase of data analysis examined the characteristics of the HI (Lockwood et al., 2017; North, 1990; Porter, 1991) and MLP (Geels, 2011; Geels, 2024; Schot and Geels, 2008) frameworks in energy and transportation policy. The MLP framework has been applied to analyse how landscape dynamics and the development of environmentally friendly niche technologies affect the socio-technical regime within Indonesia's transportation energy sector (Mori and Halimatussadiah, 2023; Sembiring, 2025). The HI analysis examined path dependencies, critical junctures, and contingencies in shaping energy-sector institutions (Astari et al., 2025; Geels, 2024; Sembiring, 2025). This phase also identified the types of changes and assessed the main sources of change, whether from global agendas or national environmental policies. Interviews gathered respondents' views on how energy institutions affect transportation. Indonesian mass public transportation, biofuels, and electrification served as case studies. The

second phase shifted to analysing power relations, using frameworks by Allen (2011b), Foucault (2007), and Newell and Bray (2025). It examined interview data to examine power among agencies, including discourse contestation, coalition formation, and the political economy of spreading low-carbon EI technologies in Indonesia.

Stakeholder responses were recorded with a digital voice recorder, and transcripts processed in NVivo. This was done after the two main analytical phases. NVivo helped track themes across transcripts and marked when data saturation was reached, with no new themes emerging. After completing the primary data analysis, secondary data analysis was subsequently performed. The row for Phase 3 in the fifth and sixth columns of Table 3.1 lists the methodologies and analytical techniques used in the third phase of the study.

Diffusion of Eco-Innovation and Adoption of Low-Carbon Transport Technologies

The third phase of this study has adopted a qualitative research design to investigate the diffusion of eco-innovation and the adoption of low-carbon transportation technologies in Indonesia. It specifically focuses on the sustainability trajectory of biofuels as a reference for EVs, which are emerging technologies for the Indonesian public. This methodology integrates both primary and secondary data sources, utilising an analytical framework developed from established conceptual models related to eco-innovation diffusion (Glover et al., 2019), technology adoption (Douthwaite et al., 2001; Bonaiuto et al., 2024), and the identification of drivers and barriers in the socio-technical transition toward transportation sustainability (Machado et al., 2015; Kirshner et al., 2022). This approach is effective for capturing the complexity of socio-technical change processes, where various actors, governance levels, and market-policy interactions converge to shape the diffusion pathways of eco-innovation.

The first analytical category refers to the work of Glover et al. (2019), who reconceptualised socio-technical transition and diffusion processes, moving beyond the traditional linear model. They highlighted how social, institutional, and political contexts influence the diffusion of innovations. In this phase of the study, interview data were coded to identify the narratives related to the diffusion of biofuels and EVs in Indonesia. This analysis traced how collaborative networks absorbed knowledge spillovers from green technology developed abroad, leading to initial adoption, wider dissemination and integration into institutional frameworks. By situating the trajectories of biofuels and EVs within this context, the research explores the dynamics of knowledge spillover, institutional learning, and the construction of legitimacy across various actor networks.

The second category of analysis uses the technology adoption concept of Douthwaite et al. (2001), which highlights the important role of user-driven innovation and adaptation in determining the success or failure of environmentally friendly technologies. Instead of treating adoption as a passive process, this perspective emphasises how users—from smallholder farmers and vertically integrated large companies producing biofuel raw materials to consumers using biofuel and electricity companies distributing power to EV users—modify and reshape technologies to fit their social and economic contexts. Thus, this analysis examines how micro-niche actors in Indonesia reconfigure biofuel blending practices, engine compatibility development, energy purchasing culture adaptation in EV charging or battery replacement systems, and vehicle maintenance routines. This perspective is crucial in revealing the gap between formal policy design and practical implementation, as well as uncovering how user innovation contributes to the localisation of global low-carbon technologies.

The third category of analysis is based on the work of Kirshner et al. (2022), who identified the structural drivers and barriers affecting the adoption of second-generation biofuels in Brazil. They emphasised the broader political and economic conditions that shape the sustainability transition. This framework has been adapted to the Indonesian context to explore how eco-innovation drivers—such as mandatory policies, incentive schemes and subsidies, international certification regimes, corporate investments, and consumer awareness of sustainability—interact with key barriers, including regulatory uncertainty, cost structures, and infrastructure limitations. Additionally, this analysis considers the contestation between the interests of the biofuel and EV coalitions, the marginalisation of smallholder farmers and low-to-middle income urban consumers, and the homologation of local startup products from MSMEs. This approach enabled the identification of systemic barriers and opportunities to advance both biofuel and EV adoption. In parallel, Machado et al. (2015) were referenced to contextualise socioeconomic indicators and their roles in assessing the broader impacts of the raw material production chain, particularly regarding palm oil for biofuels and the dominance of coal in electricity generation. This contributes to a more nuanced understanding of how both technological and socioeconomic dimensions influence sustainability transitions.

The fourth category of analysis is utilised a combination of Gioia methodology and framework analysis (Gioia, D.A. et al., 2013; Klingberg et al., 2024; Magnani, G. and Gioia, 2023). During the initial stage, interview transcripts and field notes were reviewed multiple times to identify recurrent statements and similarities and differences in informants' descriptions of factors influencing the diffusion of EVs and biofuels. The analysis at this stage remained closely aligned with the informants' language and

interpretations, grouping these recurrent meanings into first-order concepts. In the subsequent stage, related first-order concepts were compared, refined, and synthesised into broader second-order themes. This stage involved cross-referencing emerging themes from the primary data with company reports, public records, and existing academic literature. Several second-order themes were identified through this process, including regulatory support, implementation of incentives and subsidy schemes, financial considerations, technological capabilities, external collaboration, market acceptance, infrastructure availability, sectoral competition, and supply sustainability. In the final stage, these second-order themes were distilled into five aggregate dimensions: regulatory, financial, technological, market, and environmental. These dimensions formed the basis of the final data structure and provided the analytical foundation for explaining the key drivers and barriers of EI diffusion in Indonesia's sustainable transportation sector (Farobie and Hartulistiyo, 2022; Fathoni et al., 2025; Setiawan, A.D. et al., 2022). The row for Phase 3 in the fifth and sixth columns of Table 3.1 lists the methodologies and analytical techniques used in the third phase of the study.

Social Acceptance of Low-Carbon Technologies

The fourth phase of this study has adopted a mixed methods approach to investigate the social acceptance and economic viability of EVs in Indonesia, with a specific emphasis on EMCs, which are the predominant mode of transportation in the country (Fevriera et al., 2021). The motivation for utilising a mixed methods design is based on the understanding that consumer perceptions of EVs are shaped not only by socio-cultural behaviours. However, economic factors and the availability of infrastructure also influenced the adoption of emerging low-carbon technologies. A purely qualitative exploration could provide insight into the discursive framework of EV adoption; however, it may overlook quantitative aspects such as mobility patterns, initial purchase price, operational and maintenance costs, and life cycle impacts. On the other hand, a solely quantitative survey can yield broad statistical generalisations but might miss the deeper socio-political context that influences consumer decision-making (Creswell and Clark, 2017).

This research phase has integrated survey research, secondary data analysis, and life cycle assessment. It aims to provide a comprehensive understanding of both the demand-side dimensions (such as consumer acceptance, affordability, and mobility patterns) and the supply-side dimensions (including infrastructure accessibilities and life cycle impacts) of electric vehicle adoption. This hybrid methodology is particularly well-suited for socio-technical transitions in developing countries, where systemic change

requires shifts in consumer behaviour towards new technologies and institutional adaptations to encourage EV adoption (Sovacool et al., 2018; Pandita et al., 2024).

The survey questionnaire data were analysed to examine consumers' purchase preferences and intentions regarding EMCs in Indonesia. The analysis revealed that respondents' socio-economic characteristics and travel preferences were associated with their interest in adopting EMCs. Specifically, income level, demographic profile, and daily mobility patterns influenced perceptions of affordability, practicality, and technological suitability. These findings demonstrate broad tendencies in consumer attitudes and adoption preferences for EMCs in Indonesia, as identified through descriptive statistical analysis using SPSS (Waluyo et al., 2022; Withayaruksun et al., 2025). Additionally, the survey data were analysed to identify the primary considerations influencing respondents' willingness to purchase EMCs and the principal obstacles to adoption. The analysis addressed a range of factors related to consumer decision-making. These included economic evaluation, perceived utility, and mobility needs. Potential barriers, such as cost, infrastructure limitations, and uncertainty about technological performance, were also considered. These factors have been widely recognised in previous studies as central to the adoption of EV in Indonesia and other developing countries (Ayetor et al., 2023; Reddy et al., 2024; Setiawan, A.D. et al., 2022). By focusing on these dimensions, the descriptive statistical analysis established an empirical basis for interpreting the extent to which EMCs are perceived by prospective users as feasible, desirable, and relevant within the broader transition to low-carbon transportation in Indonesia (Hakam and Jumayla, 2024; Balijepalli et al., 2023). The row for Phase 4 in the fifth and sixth columns of Table 3.1 lists the methodologies and analytical techniques used in the fourth phase of the study.

Secondary Document Analysis

Secondary document analysis is a crucial aspect of this research methodology as it offers a comprehensive framework for understanding the dynamics of transportation sustainability in Indonesia. This understanding is derived from various written sources produced by government agencies, global institutions, corporations, research institutions, NGOs, and the public. This approach aligns with Grant (2018) assertion that documents should not be viewed merely as passive data sources. Instead, they are considered social artefacts that contain power relations, ideologies, and discursive practices, all of which contribute to the construction of both policy realities and technological progress. Therefore, secondary documents do more than fill gaps in primary data; they also provide an analytical foundation for this research. This secondary data analysis enables this study to trace how the narrative of transportation sustainability was constructed, debated, and legitimised in both public and institutional arenas. This

organised approach provides a comprehensive understanding of the various factors influencing low-carbon transportation development.

As Grant (2018) emphasised that documents must be thoroughly examined as products of actors with specific interests. This analysis aims to identify potential biases, rhetoric, and exclusionary practices within the text. This approach is relevant to both the multilevel perspective framework (Geels, 2024; Geels, 2002; Grin et al., 2010; Schot and Geels, 2008) and historical institutionalism (Lockwood et al., 2017; North, 1990; Pierson, 2000a; Thelen, 1999). Documents not only convey factual information but also reveal how landscape pressures and niche-level innovations influence the stability and dynamics of socio-technical regimes. These influences are discussed and channelled through policy instruments, sustainability reports, or corporate campaigns. Therefore, analysing secondary documents enhances the understanding of power relations in inter-agency contestation (Allen, 2004; Foucault, 1980; Newell, 2021), particularly in promoting or hindering the diffusion of eco-innovation in the transportation sector in Indonesia.

This research uses the systematic literature review (SLR) method to select and analyse scientific publications. The purpose of using the SLR method is to enhance the academic rigour of the document studies. This study has adopted SLR because it offers a transparent procedure, enables replication, and minimises subjective bias in the literature selection process (Tranfield et al., 2003; Snyder, 2019). The SLR process is carried out in three stages: identification, screening, and synthesis. During the identification stage, this study gathered articles from major academic databases, including Web of Science, Scopus, and Google Scholar, using relevant keywords such as "low-carbon transport in Indonesia," "biofuels diffusion," "EV adoption in emerging economies," and "sustainable transport governance." In the screening stage, inclusion criteria were applied (articles from peer-reviewed journals published between 2015 and 2025, relevant to the Indonesian context or emerging economies), along with exclusion criteria (duplicate articles and non-academic reports that did not meet established standards). Finally, in the synthesis stage, a narrative synthesis was conducted by grouping the literature based on analytical themes such as the diffusion of eco-innovation, the adoption of low-carbon technology, power relations in energy policy, and institutional dynamics in transportation sustainability.

This study utilised a SLR approach alongside an analysis of institutional and regulatory documents, facilitating data triangulation across academic, policy, and public discourses. Methodologically, combining documentary analysis (Bowen, 2009; Grant, 2018) and SLR (Kraus et al., 2020; Snyder, 2019) allowed this research to not only reveal the content of the documents but also to understand the relative positions of various actors

involved in the debate over sustainable transportation transition in Indonesia. By treating documents as social constructs and systematically reviewing academic literature, this research provides a more comprehensive understanding of the factors that drive and hinder the socio-technical transition to low-carbon transportation in a developing country.

In this study, the analysis of secondary documents serves two key purposes: first, as an empirical data source that complements the outcomes of in-depth interviews, and second, as an object of analysis reflecting the contestation of discourse, power, and legitimacy in the development of low-carbon transportation. This approach enables the research to create a detailed mapping of the factors influencing the spread of eco-innovation and technology adoption toward sustainable transportation in Indonesia, framed within the theoretical contexts of the multilevel perspective, historical institutionalism, and studies of power relations. The sixth column of each phase row in Table 3.1 details the methodologies and analytical techniques for secondary data used throughout all study phases.

3.3.2.2 Total Cost of Ownership and Lifecycle Sustainability Analysis

To enhance the social acceptance analysis, this study conducted a comparative analysis of the prices of EMC and batteries, which are the most significant cost components. The analysis included data from several countries in the EU, the US, China, and other developing nations that have implemented varying incentive and subsidy schemes. Additionally, a Total Cost of Ownership (TCO) analysis was performed to assess the economic viability of EV adoption across different subsidy scenarios and categories of two-wheeled vehicles. The TCO model considers upfront purchase costs, fuel/electricity consumption costs, operational and maintenance costs, battery replacement costs, and potential resale value (Hakam and Jumayla, 2024; Afraah et al., 2021). The scenarios analysed included a non-subsidised baseline reflecting current market prices and targeted subsidies for low-income groups, accompanied by an EMC model that complies with local content regulations.

The inclusion of TCO is established on the observation that the high upfront purchase price is one of the key barriers to EV adoption in Indonesia and other emerging markets (Abbasi et al., 2021; Pandita et al., 2024). This perspective aligns with Douthwaite et al. (2001) argument that technology adoption frequently fails to meet the needs of end-users, particularly due to the oversight of affordability issues for urban lower- and middle-income consumer groups and remote rural areas (Douthwaite et al., 2001). By modelling various scenarios, this study investigates how the design of subsidies can either alleviate

or worsen equity challenges in electric vehicle adoption. Furthermore, integrating TCO calculations has connected survey data with economic modelling, facilitating triangulation between stated consumer preferences and their financial feasibility. As shown in Table 3.1, the row corresponding to Phase 4 in the fifth column summarises the quantitative methodology, including TCO calculations, used in this phase of the study.

TCO Model Development

Previous studies have used the Total Cost of Ownership (TCO) model to calculate the actual costs of buying a motorcycle (Afraah et al., 2021; Kumar and Chakrabarty, 2020). TCO examines cost considerations beyond price (Ellram, 1995) and analyses the expenses involved in owning a product throughout its economic lifespan (Bickert and Kuckshinrichs, 2011). The model used to calculate TCO in this research has been used by (Kumar and Chakrabarty, 2020) and (Afraah et al., 2021) is shown in Equation (1). Meanwhile, the cost of operational expenditure (COPEX), vehicle residual value (RV), and cost of battery replacement (CBR) models are shown in equations (2), (3), and (4), respectively.

$$TCO = UPP + \sum_{t=1}^n C_{OPEX}(1+r)^{-t} - R_V(1+r)^{-n} + C_{BR} \quad (1)$$

$$C_{opex} = C_E + C_M + C_I \quad (2)$$

$$R_V = (1 - d_V)^n \times UPP \quad (3)$$

$$C_{BR} = \sum_{t=i}^{f_i < n} \frac{(C_B - R_B)}{(1+r)^t} \quad (4)$$

Total Cost of Ownership (TCO)

The upfront purchase price (UPP) refers to the on-the-road (OTR) price, which encompasses the EMC purchase price, taxes, import fees, and other administrative costs. A discount rate (r) is applied to assess the impact of price fluctuations. Consequently, costs incurred at a specific time (t) can be converted into their present value.

Resale Value (RV)

As the life of the vehicle increases, the price of the vehicle will continue to decrease. This decrease in selling price is influenced by the depreciation value (dV), which occurs during usage (n). Besides that, battery resale price (RB) has also decreased and is calculated like RV.

Cost of Operating Expenditure (COPEX)

COPEX is the cost of all annual operational expenses consumers incur in mobility. This research adds up energy consumption costs (CE), maintenance and repair costs (CM), insurance costs (CI), and taxes (CT). The CE and CM components are greatly influenced by travel intensity as measured by Annual Traveling Distance (ATD).

Cost of Battery Replacement (CBR)

This research assumes a service life of an EV battery of 1,000 cycles. EV batteries continue to degrade until they reach 80% capacity before entering a second life cycle, for example, for storage systems in stationeries, UPS, and laptops, or being recycled to extract materials that can be reused. The period for EV battery replacement is calculated by dividing the economic lifespan by the frequency of charging, which is affected by annual mileage (ATD) and the maximum range achievable on a single battery charge.

Lifecycle Sustainability Analysis

This phase of the study has been completed with a life cycle sustainability assessment of EVs in the Indonesian context. The assessment focuses on three key dimensions: integration with variable renewable energy (VRE), second-life applications for EV batteries, and recycling pathways. It also evaluates Indonesia's institutional readiness to recycle EV batteries and minimise environmental externalities. The analysis draws on insights from Rufino Júnior et al. (2023) and Kampker et al. (2023), who examined the second-life options for retired EV batteries. Additionally, this study phase references the findings of recent studies that address efficient engineering pathways for EV battery recycling (Safarzadeh and Di Maria, 2025; Perdana et al., 2025; Ferreira et al., 2021). These studies tackle environmental impacts, address the scarcity of precious raw materials, and potentially reduce costs for battery replacement.

This research argues that Indonesia must proactively consider the sustainability challenges associated with the diffusion of EVs, particularly concerning battery waste. It emphasises that EV adoption should not be viewed as a purely environmentally friendly solution. The integration of life cycle analysis ensures that this methodology can address criticisms of EV research, often seen as overly technology-focused and neglectful of its life cycle impact on environmental conservation (Hawkins et al., 2012).

3.3.2.3 Triangulation

This research employs a triangulation method to enhance the validity, reliability, and credibility of the findings by integrating primary and secondary data sources from various actors, documents, and institutional contexts. The triangulation process involved

comparing narrative patterns, discourse, and quantitative data obtained from interviews and surveys with documentary evidence gathered from secondary sources. This approach facilitates cross-checking between different sources, thereby deepening our understanding of the multilevel interactions among actors, power relations, institutional capabilities, the diffusion process of eco-innovation, and the social adoption mechanisms of low-carbon technologies in Indonesia's transportation sector.

Document analysis not only complements the primary data but also provides a broader context for understanding Indonesia's role within the global dynamics of energy transition and low-carbon transportation. According to Bowen (2009), document analysis is a significant strategy in qualitative and mixed methods research because it can uncover hidden meanings behind institutional practices and public policies. This approach is increasingly pertinent in the context of decarbonisation, as more research emphasises the need to integrate document data with field data to comprehend the complexities of socio-technical transition policies aimed at sustainability in the transportation sector (Fusch et al., 2018; Guetterman and Fàbregues, 2025). The sixth column in each phase row of Table 3.1 summarises the triangulation analytical techniques applied throughout the study.

3.4 Research Access and Ethical Concern

Access to potential stakeholders for semi-structured interviews and online questionnaires is carried out using gatekeepers and snowballing techniques to expand the representation of various parties in the research. Seidman (2006) states that gatekeepers are actors who represent an institution that has the authority to grant or withhold access to a person or a condition of research. Gatekeepers inform and invite various energy sustainability activities in transportation, especially biofuels and electrification. Gatekeepers are also a source of access to other relevant stakeholders. Purposive sampling was conducted to obtain gatekeepers from MEMR, MSOE, energy associations, representatives of NGOs, the transportation community and academicians. Furthermore, snowball sampling was carried out on a group of participants to ensure representation of the range of stakeholder groups.

Under normal conditions, these interviews were conducted in person, either face-to-face or in a roundtable setting. However, during the COVID-19 pandemic, a social distancing policy required interviews to be conducted via the internet and telephone using Microsoft Teams, Skype, or WhatsApp. Participant candidates were approached via e-mail and/or by letter sent to available contacts, who were asked to advise relevant participants and

to follow up via telephone or e-mail. Participants were given one week to decide whether to participate in this study. The interview started with the consent form and the right to withdraw. The documentation process for stakeholder responses was recorded using a digital voice recorder. The purpose of the audio recording is to produce an accurate transcript of the interview. The audio recording was destroyed after an accurate transcription of the interview was made using NVivo.

Ethical practices outlined in the University of Leeds (UoL) guidelines have been followed in this study. The Business, Earth & Environment, Social Sciences, and Area Faculty Research Ethics Committee (FREC) has approved this study to collect primary data through interviews and surveys, as recorded in AREA FREC Reference 2023-0418-300 – 2 16/12/2022. All information collected about the participants during the research was kept confidential using anonymisation. Participant personal data was stored only in the appropriate University-approved secure storage. Participant identities are not traceable in all research reports and publications. The results of this research data, which form the basis of the thesis, will be submitted to the School of Geography, a copy of which will be sent to the University of Leeds library database. The research will be sent for publication to peer-reviewed journals or presented at conferences.

3.5 Study Site

This section outlines Indonesia's geographical, political, and economic conditions as the study site.

3.5.1 Geography

Indonesia is an archipelago located between the Asian and Australian continental plates. Its strategic position between the Pacific and Indian Oceans makes Indonesia open to trade, politics, and cultural interactions (Figure 3.1). Indonesia lies on the equator, spanning from 6° 04' 30" N to 11° 00' 36" S latitude and from 94° 58' 21" E to 141° 01' 10" E longitude (BPS, 2024b). Indonesia is an archipelago with 16,056 islands, as registered by the United Nations (2017) (BPS, 2024b). As of the 2020 Population Census, Indonesia had a population of about 270 million, projected to grow to around 281 million by 2024 at an annual growth rate of 1.11%. More than 56% of this population resides on Java, which accounts for only 7% of the country's land area (BPS, 2024b).

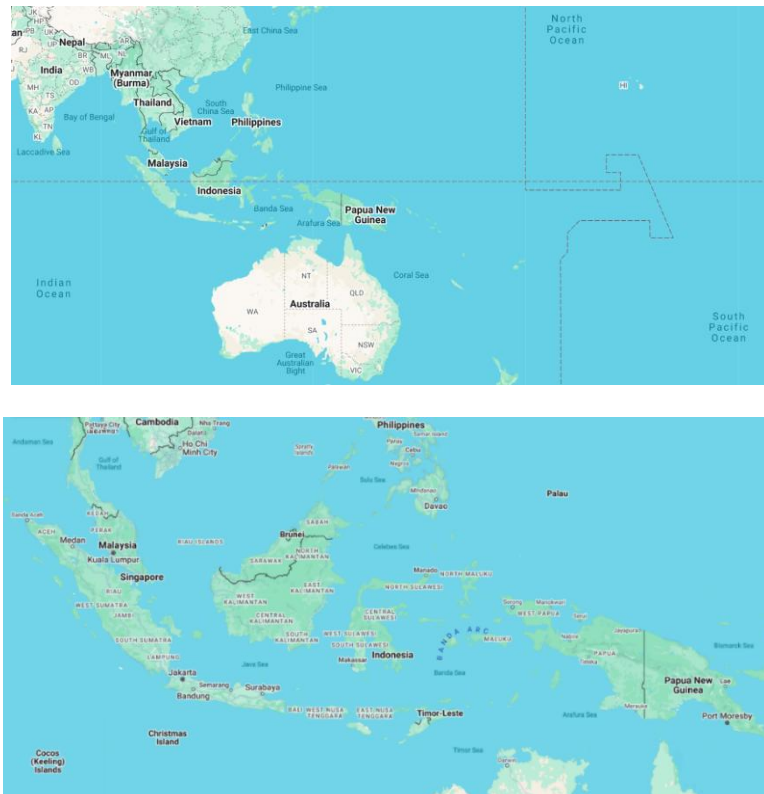


Figure 3.1 Indonesian Map

3.5.2 Political

Indonesia gained its independence on 17 August 1945, ending three years of Japanese occupation during World War II. After several centuries, nearly all kingdoms in Indonesia came under Dutch colonial control. In addition to governing the society and economy, Dutch colonialism established socio-technical energy institutions, including the transportation sector.

Indonesia's government adheres to a presidential system under the 1945 constitution, which delineates three pivotal organs: the executive, the legislature, and the judiciary. The executive consists of the president, vice president, and cabinet, with ministers directly accountable to the president. The local government in Indonesia is structured at two levels: provincial and district or city. In 1945, the Indonesian government restructured local administrations, including eight provinces and about seventy districts or cities inherited from the colonial administration. Population growth and socio-economic activities have driven regional development in Indonesia, resulting in 38 provinces and 514 cities as of June 2023 (BPS, 2024b).

The People's Consultative Assembly (MPR) is Indonesia's highest legislative body. Its membership was revised after the 1945 Constitution was amended between 1999 and 2004. The MPR includes all members of the Indonesian House of Representatives (DPR) and the Regional Representative Council (DPD), both elected in general elections for

five-year terms. Since the constitutional reforms, the Supreme Court has been responsible for the judiciary and the management of judges (BPS, 2024b).

3.5.3 Economic

The country's growth rates fluctuated in the early 2020s due to the COVID-19 pandemic but stabilised at around 5% per annum by 2023. In that year, Indonesia's exports totalled USD 258.8 billion, while imports were USD 221.9 billion. As a developing country, Indonesia's GDP was reported by the IMF at approximately USD 45.38 trillion in October 2024, with a GDP per capita of USD 6,650 (BPS, 2024b).

Indonesia has a diverse range of natural resources that can serve as feedstock for transportation energy. Currently, palm oil-based biodiesel and petroleum dominate the transportation energy sector. However, there is significant potential to develop bioethanol from sugarcane and utilise natural gas. Additionally, generating electricity from renewable sources is crucial for decarbonising the transportation sector, particularly through geothermal and hydropower (MEMR, 2024).

The agricultural sector is vital to Indonesia's economy, contributing about 12.53% to GDP in 2023, making it the third largest sector after Manufacturing at 18.67% and Wholesale and Retail Trade at 12.94% (BPS, 2024a). One of the key plantation commodities is palm oil, which is crucial to Indonesia's economy due to its ability to produce vegetable oil. The vegetable oil product is in high demand by the industrial sector.

Oil palm plantations are continuing to expand, with the land area increasing from 14.33 million hectares in 2018 to approximately 15.93 million hectares in 2023 (BPS, 2024a). Large private enterprises primarily hold control of these extensive oil palm plantations. Specifically, private plantations account for 8.61 million hectares (54.08%) of the total area; smallholder plantations control 6.74 million hectares (42.29%), while state-owned large plantations manage the remaining 0.58 million hectares (3.63%) (BPS, 2024a). According to the Directorate General of New, Renewable Energy and Energy Conservation in the MEMR (2024), biodiesel production capacity in 2023 was 20,264,521 KL⁹, compared to 40,000 KL of ethanol. This contrasting situation arose because developing sugarcane plantations has not yet become a government priority, with only 513.08 thousand hectares under cultivation in 2023 (Ministry of Agriculture, 2023).

⁹ KL refers to kilo litres.

3.5.4 Historical Development of Energy Institutions in the Transportation Sector

The literature notes that the early history of transportation in Indonesia marked a significant milestone in introducing energy technologies and institutions, beginning with the establishment of the Oranje Nassau coal mine in the 19th century. The mine officially commenced operations on September 28, 1849, in Pegaron, within the Riam Kiwa District of the Sultanate of Banjarmasin. The technology and mining experts associated with the Oranje Nassau coal company were from the UK (Arif, 2014; Inagurasi, 2015). Coal mining in the Ombilin area near the Durian River in Sawalunto, West Sumatra, started in 1888, with official operations beginning in 1892. Later, in 1919, the Bukit Asam coal mine commenced operations in Tanjung Enim, South Sumatra and began commercial production in 1938 (Arif, 2014). PMI Indonesia Chapter (2012) reported that coal production in Indonesia steadily increased, reaching 2 million tons in 1941, but it declined to 1 million tons during World War II.

Inagurasi (2015) stated that the development of coal mining technology in Indonesia paved the way for further technological advancements, including industrialisation and transportation. The railway sector emerged as Indonesia's first land transportation system to utilise fossil fuels. Proposals for railway infrastructure began in the 1840s during the Dutch colonial period in Java. The first train in Indonesia started operating on August 10, 1867, in Semarang, covering a distance of 26 kilometres from Samarang Station to Tanggung Station (KAI, 2017). During this period, trains were powered by coal steam locomotives (Inagurasi, 2015). Initially powered by coal steam locomotives, rail construction later expanded to Aceh (1876), North Sumatra (1889), West Sumatra (1891), South Sumatra (1914), and Sulawesi (1922) (KAI, 2017). In contrast, only feasibility studies were conducted in Kalimantan, Bali, and Lombok, with no construction occurring (KAI, 2017).

Fuel diversification for railway transport in Indonesia began in 1918 with the introduction of an electric tramway connecting Jakarta and Bogor. The network expanded to cities such as Surabaya, Semarang, Bandung, and Medan, serving as the primary mode of transportation for commerce and urban mobility until the 1960s (Adryamarthanino and Nailufar, 2022). The Dutch prioritised railway and tramway development for commodity transport and mining support, leading to 7,464 kilometres of infrastructure by 1928. During the Japanese occupation from 1942 to 1945, railway construction increased on the Saketi-Bayah and Muaro-Pekanbaru routes to transport coal for war machinery. While 473 kilometres of tracks were dismantled for use in Burma (KAI, 2017).

Petroleum was an important energy source in Sumatra by the 8th century, used in sea battles (Haryata, 2019). Haryata (2019) highlighted that the Netherlands began drilling for lamp oil in 1871, and by 1883, A.J. Zylker extracted oil at Brandan Base, with

additional finds in Ledok, Muara Enim, and Riam Kiwa. The Dutch colonial government intervened significantly, supporting Dutch companies while restricting foreign, particularly American, operations. Production mostly relied on concessions held by Royal Dutch and Shell (Haryata, 2019).

In the 1920s, Dutch colonial intervention underwent significant changes due to the US government's General Leasing Act. This law banned land leasing to non-US companies from nations that discriminated against American businesses. As a result, Shell's operations in the US faced disruptions because of the Dutch discriminatory policies towards US companies in Indonesia. Consequently, the Dutch colonial government adopted a more lenient approach, allowing U.S. oil companies like Stanvac and Caltex to operate in Indonesia. After World War II, oil refineries were established in Plaju, Sungai Gerong, Balikpapan, Cepu, Wonokromo, and Pangkalan Brandan (Haryata, 2019).

According to GAIKINDO (2020), petroleum utilisation as fuel led to the entry of motorbikes into Indonesia in 1893, followed by the import of cars in 1894. These vehicles were initially used by the elite, Dutch colonial officials, and plantation entrepreneurs in big cities such as Jakarta, Surabaya, Bandung and Semarang. Due to limited road infrastructure, the prevalence of cars was not very widespread during the late 19th century (GAIKINDO, 2020).

As the number of cars grew, the Dutch colonials began to improve and expand the road network, including the modernisation of postal highway in Java. The first bus company in Indonesia, Pengangkutan Djawatan Automobil (PDA), was established in 1912 by the Dutch colonial government. PDA operated the route between Bandung and Lembang using Dutch-made 'Auto Tram' buses. Since then, the bus industry in Indonesia has continued to grow and has become an essential mode of transportation, connecting various regions across the country (SindoNews, 2023).

In the 1920s, main roads in Jakarta, Surabaya and Semarang were paved to accommodate motorised vehicles (Khusyairi and Colombijn, 2015). The establishment of an automobile assembly plant by General Motors in Jakarta in 1927 marked a significant milestone for Indonesia's automotive industry, which included producing cars, trucks, and buses. In 1932, Aneka Motor was founded in Bandung, becoming the first private bus company to contribute to developing this road transport mode (SindoNews, 2023). The rise of petroleum-fuelled vehicles facilitated various socio-economic activities and contributed to urbanisation. The growth of the automotive industry and road infrastructure continued until it faced a slowdown in the 1940s due to World War II when Japan mobilised its military resources in Indonesia (GAIKINDO, 2020).

3.6 Methodological Limitation and Critical Reflection

This research on the sustainability of the transportation sector began during my time at Pertamina. This role has provided both advantages and challenges. As a researcher closely affiliated with a state-owned energy company, I have gained privileged access to key informants across government agencies, state-owned enterprises, and private-sector actors. This insider perspective enables me to gain valuable insights into Pertamina's strategic role in supporting Indonesia's biofuel mandate, its collaboration with PLN to build EV charging stations and battery swap systems networks, and its innovative contributions to geothermal and solar photovoltaic projects. This access has significantly enriched my understanding of institutional logic, policy trajectories, and infrastructure investment in the sector.

However, this position raises critical methodological reflections. My proximity to Pertamina could influence the formulation of questions and the interpretation of findings, potentially reinforcing the narrative that emphasises the role of large companies, mainly state-owned enterprises, in Indonesia's transportation sector's socio-technical transition. While this connection enabled me to capture the perspectives of key stakeholders, it unintentionally marginalised alternative or critical voices from small and medium-sized enterprises, NGOs, rural community groups, or lower-middle-class urban residents. To address this issue, this study utilised triangulation with secondary data and conducted a series of diverse interviews; however, the possibility of bias still exists. Acknowledging these limitations is essential for ensuring transparency and reflexivity in the research process and its interpretation.

The linkage between the global agenda and national regulations on environmental preservation and eco-innovation in Indonesia is an important topic for study. Exogenous and endogenous influences are prominent phenomena that actors can be address differently. These views, perceptions and discussions have been researched and published by many scholars, both in Indonesia and globally. This topic has encouraged me, as an Indonesian scholar, to examine the dynamics of the energy transition eco-innovation in my country and its relation to the global sustainability agenda. I hope to contribute insights from the Indonesian domestic sphere, which may have unique characteristics compared to the global perspective.

Research on energy supply in the transportation sector began when I worked at an Indonesian energy company, Pertamina, particularly in the development of renewable energy sources and EV adoption. I feel called to include the influence of national

environmental policies and global agendas, and how domestic resources and local technological maturity need to be considered for the sustainability of transportation energy supply. When I started my PhD, my background working with producers affiliated with several innovation institutions encouraged me to study social sciences so I could understand the Indonesian energy transportation sector as a whole. Furthermore, I chose to conduct my research case study in the Indonesian transportation energy sector because the sustainability of this sector has become a global concern, particularly concerning efforts to reduce environmental impacts.

Transport energy in Indonesia is a sensitive that involves among business entities, political institutions, and groups interested in environmental and social conservation. As a researcher, I always strive to maintain a neutral position despite the diverse responses provided by stakeholders during data collection.

Chapter 4 Critical Junctures at the Crossroads: Multilevel Interactions as Catalysts for Institutional Development in Indonesia's Transport Energy Sector¹⁰

4.1 Introduction

The transition to sustainable transport in Indonesia should not be viewed as a linear or purely technological process. Instead, the transition is a complex outcome of multi-level interactions shaped by institutional, political, and socio-technical dynamics. This empirical chapter addresses the first research question of this thesis: How have multi-level interactions create critical junctures that influence the institutional dynamics of the socio-technical transition toward sustainability in the Indonesia's transportation sector? To examine this question, the analysis combines the multi-level perspective (MLP) framework (Geels, 2024; Geels, 2002; Grin et al., 2010; Schot and Geels, 2008) with approaches from historical institutionalism (HI) (Lockwood et al., 2017; North, 1990; Pierson, 2000a). This integration of frameworks enables a deeper understanding of how landscape-level pressures—such as the global oil crisis, climate change agendas, and international trade disputes—interact with the diffusion of niche-level eco-innovations, including mass public transportation systems, biofuels, and electric vehicles (EVs). These landscape pressures and the diffusion of niche-level eco-innovations have created pressures that impact the stability of entrenched socio-technical regimes, resulting in critical junctures that have shaped the policy trajectories and institutional arrangements in Indonesia's transportation sector.

The utilisation of MLP provides a systematic framework for understanding the interactions between the landscape (macro), regime (meso), and niche (micro) levels, particularly in how radical innovations emerge and diffuse in response to external pressures and opportunities (Geels, 2011; Cameron and Geels, 2019; Smith et al., 2005). Meanwhile, HI emphasises the roles of institutional path dependence, lock-in mechanisms, and critical junctures in explaining why specific policy trajectories persist or change (North, 1990; Pierson, 2004; Thelen, 2004). By integrating these perspectives,

¹⁰ This chapter has been published in the journal *Energies* with the following reference:

Fathoni, F., Lovett, J.C. and Rifansha, M.M. 2025. A Multi-Level Perspective on Transition to Renewable Energy in the Indonesian Transport Sector. *Energies*. 18(21), p5723. <https://doi.org/10.3390/en18215723>.

this chapter identifies events in which interactions among global and domestic actors, technological disruptions, and institutional constraints converge to shape the trajectories of sustainable transport development in Indonesia. In particular, the analysis considers whether institutional change is the result of exogenous shocks—such as oil crises or the commitment to the global climate agenda—or endogenous incremental changes and endogenous critical junctures driven by domestic governance reforms, bureaucratic politics, and evolving social acceptances (Mahoney and Thelen, 2010; Streeck and Thelen, 2005).

This chapter examines Indonesia's transport sector from 1945 to the present, highlighting the various global and local pressures it has faced and the gradual diffusion of eco-innovations. The transport system in Indonesia has experienced several phases of evolution. It began with rebuilding infrastructure after gaining independence, transitioned to a phase characterised by a dependency on fossil fuels, heavily influenced by oil revenues, and is currently focused on diversifying transportation methods. This diversification typically occurs through a process of layering, wherein institutional change unfolds gradually without completely replacing existing institutions (Lockwood et al., 2017; Van der Heijden, 2011). Over time, this approach exerts pressure and facilitates transitions. For instance, the policy requiring the use of biodiesel (B20 to B40) was integrated into the existing framework, which was still primarily based on fossil fuels. As a result, the existing actors, led by Pertamina, the oversight corporation of the oil distribution system, remain in place but are enhanced by new regulations and incentives for biofuels (Ichsan et al., 2025; Suhara et al., 2024). A similar trend is observed in the development of mass public transportation systems based on TOD in Jakarta, such as BRT, commuter trains, MRT, and LRT, which are layered onto the existing road transportation system dominated by private vehicles (Hasibuan and Mulyani, 2022; Difa and Sulistiyandari, 2021).

The methodological approach involves conducting semi-structured interviews with 28 respondents from various stakeholder groups. These groups encompass government agencies, state-owned enterprises, local governments, international organisations, industry associations, corporate entities, NGOs, academics, and media representatives. An extensive analysis of secondary data complements this primary data collection. The open-ended questions in the semi-structured interview focused on the respondents' experiences, involvement, and roles within the transportation sector. Additionally, this interview explores the influence of the global climate change agenda, geopolitical conditions, leadership changes, domestic socio-political dynamics, and the emergence of eco-innovation on the direction of transportation sector policy development.

The secondary sources include government policy documents, corporate annual reports, NGOs publications, peer-reviewed academic journals, and media coverage. To enhance the validity of the findings, data triangulation was systematically applied. This method helps to address potential biases and capture a wide range of perspectives within the socio-technical transition process (Denzin, 2012; Flick, 2018; Yin, 2003).

Overall, this chapter contributes to a nuanced understanding of how Indonesia's transport sector is being reshaped by the interaction of institutional dynamics and the diffusion of eco-innovations in response to landscape pressures. This analysis situates Indonesia within broader debates about socio-technical transitions in emerging economies. In these contexts, the interaction between global sustainability agendas, domestic political economies, and local actors' coalitions creates unique transition trajectories (Sovacool et al., 2022; Rosenbloom, 2020; Schot and Geels, 2008). Thus, this chapter emphasises the significance of identifying critical moments when institutional changes take place, offering insights into broader conditions that can accelerate the diffusion of eco-innovations and foster sustainable mobility transitions in developing countries.

4.2 The Socio-Technical Landscape of Energy in Indonesia's Transportation Sector

Following World War II, there was a significant shift in energy policy among developing countries, primarily driven by decolonisation, post-war economic recovery, and geopolitical factors. Many emerging economies gained independence during this time, prompting their governments to take control of natural resources. A common trend during this period was the nationalisation of energy assets, particularly in resource-rich regions such as parts of Asia, Latin America, and Africa (Bucheli and Decker, 2021; Andreasson, 2015). After gaining independence in 1945, Soekarno, Indonesia's first president, adopted a nationalist approach to managing natural resources, particularly energy, by nationalising colonial-era institutions. Coal remained the primary energy source for the transport sector at that time.

Railways experienced a shift towards diesel power in the 1940s and 1950s, particularly in the United States and Europe. By 1960, diesel locomotives had replaced steam engines on nearly all US railroads, and this transition was primarily complete in Europe by the 1970s. In Asia, dieselisation began in the 1950s, with Japan leading the way. The Japanese phased out steam trains in the 1970s. China introduced diesel locomotives in

the 1950s and 1960s, with widespread adoption in the 1980s. Indonesia introduced railway dieselisation in 1952 (Setiawan, I., 2010).

This significant increase in diesel rail transport during the 1950s contributed to the global discovery and production of oil, especially in the Middle East. In 1960, the spirit of nationalism again found momentum when the world's major oil companies unilaterally lowered oil prices. This action was carried out without consultation with oil-producing countries and resulted in a decrease in national royalty revenues. Several oil and gas-producing countries formed the Organisation of Petroleum Exporting Countries (OPEC), which aimed to control oil prices by implementing a production control system (Mabro, 1992).

The United Nations (UN) resolutions represented the spirit of developing countries to achieve equality with developed countries in sovereignty over natural resources and economic assets extracted from within a country's territory. First, UN General Assembly Resolution No. 1803 (XVII) in the year 1963 concerning Permanent Sovereignty over Natural Resources. Second, UN General Assembly Resolution No. 3201 (S-VI) in 1974 concerning the Declaration on the Establishment of the New International Economic Order (NIEO). Both resolutions aimed to establish national sovereignty over the management of countries' natural resources (Sunarya and Taufik, 2018).

In 1968, Soeharto became the second president of Indonesia. At the beginning of his presidency, Suharto faced a challenging economy due to the failure of Soekarno's Guided Economy and concerns about defence and territorial issues, which had not revitalised the nation for two decades. Soeharto's leadership led to rapid transport infrastructure development, supported by the production and export of natural resources. Petroleum exports became a crucial source of revenue for the state, bolstering Indonesia's economic growth (Lindblad, 2010).

In October 1973, there was an oil crisis when the Organisation of Arab Petroleum Exporting Countries implemented an oil embargo. The 'oil shock' caused oil prices to increase fourfold from USD 2.8 per barrel to nearly USD 12 per barrel in 1974. The second oil crisis occurred in 1979 due to the decline in oil production during the Iranian Revolution. The second oil crisis event boosted oil prices by 100%. The oil crisis of the 1970s led many countries to seek alternative energy sources, including the Indonesian government, which has significant geothermal and natural gas reserves (Corsello et al., 2023).

Several countries have pioneered the adoption of biofuels, such as ethanol and biodiesel, as alternative fuels for vehicles. Concerns regarding energy security, environmental policies, and government mandates have primarily driven this shift.

Although biofuels have been used since the early 1900s, their expansion and institutionalisation began in Brazil with the launch of the Pró-Álcool Program in 1975. The Pró-Álcool Program initiative, led by the Institute of Alcohol and Sugar (Instituto de Álcool e Açúcar-IAA), marked the first large-scale ethanol fuel program and utilised sugarcane ethanol as an alternative vehicle fuel. In 1978, the effectiveness of Pró-Álcool enabled the sale of cars powered exclusively by alcohol. The following year, the Brazilian government invested in ethanol during the second oil crisis. However, this strategy did not account for falling oil prices, and ethanol production could not keep up with domestic demand, further declining as sugar demand increased. The decline in production and the subsequent closure of the IAA in 1990 marked the end of the government's incentive program. Brazil's ethanol production experienced a significant recovery beginning in 2008 (Grandis et al., 2024; Nikas et al., 2022). Meanwhile, the United States has developed ethanol since the enactment of the Energy Tax Act in 1978. This policy promotes blending 10% ethanol with 90% gasoline. The significant growth of ethanol production in the US after the 2000s was driven by the Renewable Fuel Standard (RFS), followed by the implementation of subsidies and the widespread use of corn as feedstock (Sajid et al., 2021).

Since the 1980s, due to the increasing demand for affordable and cleaner alternative fuels, many countries have successfully implemented compressed natural gas (CNG) in public transport, heavy-duty trucks, and taxis. CNG was considered an alternative fuel that supports energy security, offers low emissions, and is more economical than petrol (Shamsapour et al., 2020; Aguilera and Aguilera, 2020). Iran has led the global adoption of CNG vehicles due to government support for conversion programs, abundant natural gas reserves, and networks of refuelling stations in major cities and along highways (Shamsapour et al., 2020). In addition, Pakistan and China have embraced CNG on a large scale due to its economical pricing and commitment to reducing air pollution in urban areas. Strong government policies have fostered the growth of CNG refuelling stations in these countries. Similarly, Argentina, India, and Brazil have implemented incentives for converting vehicles to CNG to reduce emissions. These policies have boosted CNG adoption not just in public transport but also among private vehicle owners. Furthermore, the growth of CNG usage has been supported by well-established refuelling networks in these countries (Yeh, 2007; Shamsapour et al., 2020).

The global agenda associated with natural resource extraction developed a new approach in the early 1980s. The World Conservation Strategy, formulated by three NGOs, namely IUCN, WWF, and UNEP, for the first time introduced the term 'sustainable development' in 1980. This term was taken to mean conserving the earth's natural resources by limiting exploitation which harms the environment. The United Nations

formed the World Commission on Environment and Development (WCED), which held its first meeting in 1984. In 1987 the WCED announced its report, which became known as the Brundtland Report. The report makes a substantial contribution to understanding the relationship between development and environmental management in the framework of sustainable development. The report discusses several issues related to energy, especially the potential utilisation of renewable energy as an alternative source of energy from fossil fuels and the impact of long-distance transportation on air pollution (Keeble, 1987). Then, through the United Nations Conference on Environmental Development (UNCED), discussions on sustainable development continued in 1992 in Rio de Janeiro. The Rio de Janeiro Declaration 'Agenda 21' produced a new concept of environmentally sustainable development (Eco-sustainable development). The conference also produced several legally binding agreements, one of the most relevant to this thesis being the United Nations Framework Convention on Climate Change (UNFCCC). In 1997, UNFCCC delegates held a conference in Kyoto to discuss global warming caused by various human activities. This conference agreed on the signing of the Kyoto Protocol which binds developed countries to reduce overall emissions from some GHG. In 2002, UNCED held the next World Summit on Sustainable Development in Johannesburg. The Johannesburg Plan of Implementation (JPOI) emphasises the integration of economic, ecological, and social elements based on good governance (Kuyper et al., 2018).

Infrastructure development has bolstered the Indonesia's economy and improved citizens' welfare. However, the government's emphasis on road infrastructure, without adequately planning for mass public transport, has resulted in a rise in private vehicles. Additionally, a decline in oil production and increased fuel consumption have caused the government to allocate more subsidies. Between 2003 and 2008, oil prices fluctuated due to several factors, including a surge in global demand, geopolitical tensions—particularly the war in Iraq—and limited spare production capacity. Additionally, the situation worsened due to underinvestment in exploration and production following the oil price collapse in the post-1990s period. This oil crisis led to a significant increase in oil prices, causing fuel subsidy costs to soar by 168%, from USD 4.4 billion to USD 7.4 billion (U.S. Energy Information Administration, 2020b).

The conflict-driven oil crisis of the 2000s became a critical issue for energy security, prompting both European and Asian countries to integrate renewable energy considerations into their economic policies. As a result of these challenges, mainly developed nations actively worked to decrease their reliance on oil. There was a significant increase in research and innovation to accelerate energy diversification through investments in renewable energy sources such as wind, solar, biofuels, and biomass.

Biodiesel is another variant of biofuel, and it is interesting to briefly examine the case of Argentina which became one of the leading producers and exporters of biodiesel for decades after being locked into a natural gas-based innovation path. The Argentine government developed biodiesel, primarily supported by the soybean industry. The development of biodiesel in Argentina started with organisations that support farmers through research, networking, training, and knowledge sharing. Key organisations include the National Institute of Agricultural Technology (INTA), the Association of Regional Consortia for Agricultural Experimentation (CREA), and the Association of No-Till Producers (AAPRESID). These collaborations have led to rapidly adopting new technologies and techniques, helping farmers achieve a competitive edge through innovative practices (Tomei and Upham, 2009). The institutionalisation of biodiesel in Argentina was marked by the passage of Biofuels Law 26.093 in 2006, which mandated a 5% biodiesel blend (B5) in diesel fuel, with plans for future increases. Furthermore, tax incentives and investment support were implemented to foster the development of biofuel production facilities (Nikas et al., 2022). As the EU biodiesel market expanded due to the Renewable Energy Directive (RED) in 2009, Argentina's biodiesel exports increased, making it the largest exporter in 2010. However, the development of Argentine biodiesel faced challenges, including trade barriers from the EU, which imposed anti-dumping tariffs between 2012 and 2013, and countervailing duties from the US in 2017. Domestically, Argentina faced the challenge of balancing exports with local demand, alongside the need for diversification in feedstock due to competition between fuel and food production (Nikas et al., 2022).

The development of biofuels expanded to include countries in Southeast Asia. Thailand diversified its feedstocks using sugarcane and cassava. It has widely adopted E20¹¹ and E85¹² ethanol blends in gasoline-fuelled vehicles, as well as B20¹³, a palm oil-based blend, for heavy-duty vehicles. In contrast, the Philippines opted for an E20 implementation strategy based on sugarcane, and as the world's largest coconut producer, it started to implement B5¹⁴. The Philippine government is also promoting domestic coconut-based biodiesel production to reduce crude oil imports (ERIA, 2021b; OECD, 2024).

¹¹ E20 refers to a blend of 20% ethanol in fossil gasoline.

¹² E85 refers to a blend of 85% ethanol in fossil gasoline.

¹³ B20 refers to a blend of 20% biodiesel in fossil diesel oil.

¹⁴ B5 refers to a blend of 5% biodiesel in fossil diesel oil.

Awareness of climate change and scientific certainty increased in the socio-technical landscape during the early 2000s, which contributed to the international commitment known as the Paris Agreement under the UNFCCC in 2015. The primary aim of the Paris Agreement was to limit the rise in global temperature to below two degrees Celsius, capped at 1.5°C compared to pre-industrial levels. The agreement also encourages countries to improve their adaptive capacity to climate change's impacts and direct financial resources toward low-emission and climate-resilient development (Fankhauser et al., 2022).

Indonesia's economy and infrastructure were developing as it recovered from the oil crisis of the 2000s. According to the National Energy Council (DEN), DEN (2024), Indonesia's final energy consumption increased by 5% annually from 2010 to 2023, from 94 million TOE to 178 million TOE. In 2023, the industrial sector dominated Indonesia's final energy consumption at 46%, followed by the transportation sector at 35%, households at 13%, and commercial sectors at 4%. Other sectors, including agriculture, mining, and construction, collectively represented about 1% of the total energy consumption. Fossil-based energy accounted for 75% of final energy consumption in 2023. Oil is the largest contributor at 38%, followed by coal at 25% and gas at 12%. Electricity contributed 15%, while NRE made up 9% as shown in Figure 4.1 (DEN, 2024).

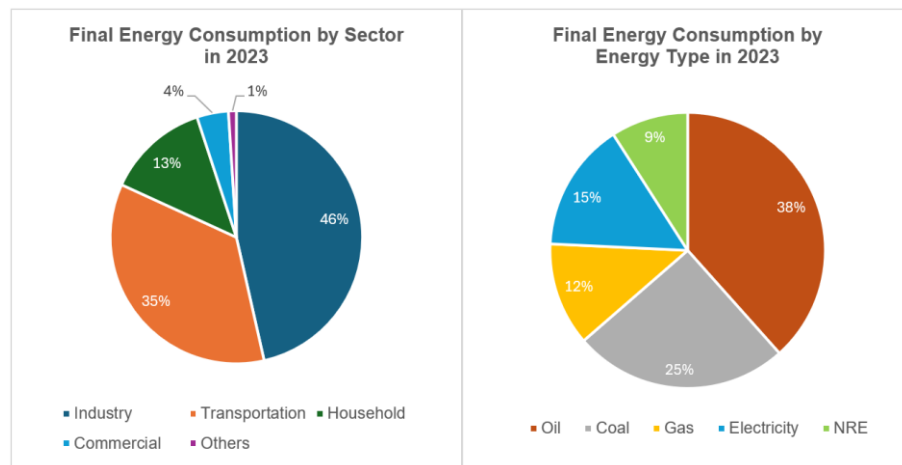


Figure 4.1. Final Energy Consumption by Sector and Energy Type in 2023

Source: DEN (2024).

4.3 The Socio-Technical Regime of Energy in Indonesia's Transportation Sector

Transportation is one of the most energy-intensive sectors in Indonesia. Landscape developments and niche innovations have significantly influenced the institutional dynamics of the energy socio-technical regime, particularly in the transport sector. The evolution of the energy regime has undergone several policy and institutional changes, which can be categorised into three stages, as illustrated in Figure 4.2 and described in Table 4.1, as follows:

1. First stage: The early development of transportation energy institutions and the rise of fossil-based energy (1945-1979).
2. Second stage: The establishment of fossil-based energy and the emergence of environmental protection (1980-2003).
3. Third stage: The institutional development of sustainable alternative fuel (2004-present).

4.3.1 First Phase: The initial Indonesian transportation energy institutions and infrastructure development (1945-1979)

The events leading up to Indonesia's independence on 17 August 1945 played a pivotal role as critical junctures in shaping the nationalistic orientation of the energy, including the transportation sector. The regime of Indonesia's energy sector reflected an institutional 'displacement' from the colonial era to the nationalisation era. The Soekarno administration established nationalist institutions across various sectors. The establishment of Djawatan Kereta Api Republik Indonesia (DKARI) and Jawatan Listrik dan Gas in 1945 marked the initial energy for transportation sector institutions and infrastructure development. Furthermore, in 1950, the Bukit Asam Arang State Company (TABA) were established for coal mining. By 1952, the demand for coal as the primary energy source for trains and ships had reached 750,000 tonnes (Arif, 2014).

On road transport, the government established Djawatan Angkoetan Motor Repoeblik Indonesia (DAMRI) on 25 November 1946, which operates buses and trucks to serve passenger and freight transport throughout the country. Private bus companies began operating on various routes, including Aneka Djaja in Surabaya (1946), Haryanto in Solo (1946), Sumber Alam in Sumedang (1955), and Gunung Harta in Jakarta (1960) (SindoNews, 2023).

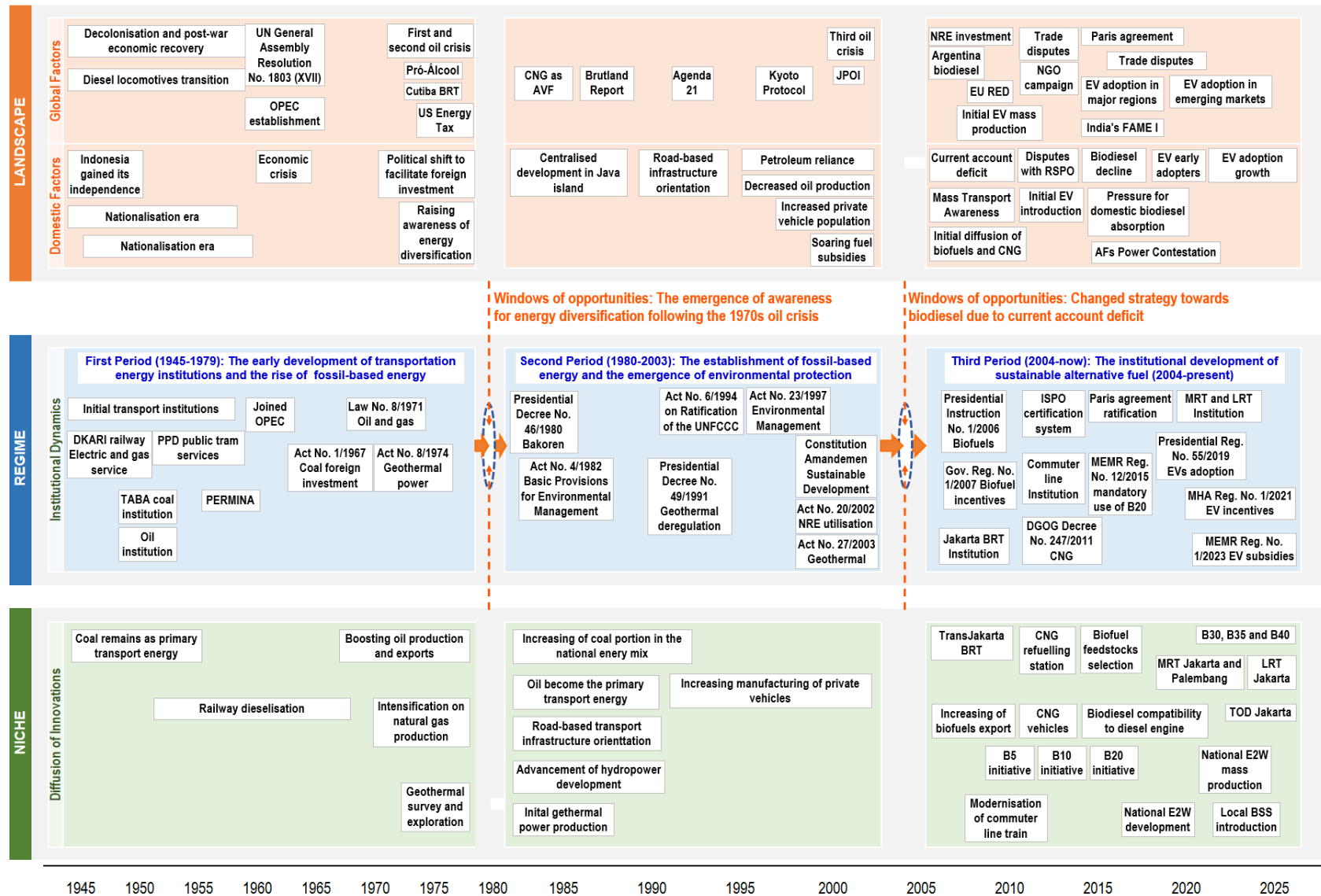


Figure 4.2. Historical development of institutional arrangements toward transportation energy sustainability in Indonesia.

Table 4.1 Key events and dynamics of Indonesian transport energy sustainability institutions

Stage	Key Events	Global (exogenous) factors	Domestic (endogenous) factors	Institutional stability or change type
First phase: The initial Indonesian transportation energy institutions and infrastructure development (1945-1979)	Initial institutional and infrastructure development in the transportation energy sector.	• UN General Assembly Resolution No. 1803 (XVII)/1963 concerning Permanent Sovereignty over Natural Resources. • Declaration on the New International Economic Order (NIEO) establishment. • The first oil crisis in 1970s.	• The shift from the colonial era to the nationalisation era during early independence. • The initial development of nationalistic institutions for energy and transport infrastructure. • The transition in energy sources for the railway sector from coal to oil. • Shift through layering from tram era to bus era in Jakarta. • Shift in political approach during the early Soeharto regime, characterised by facilitated foreign investment in the energy sector. • Awareness of energy source diversification policy.	Endogenous changes in the form of displacement begin the path formation, and then exogenous effects accelerate institutional change.
Second phase: The encouragement of energy diversification and raising awareness of environment preservation (1980-2003)	• Presidential Decree No. 46/1980 concerning Bakoren. • Act No. 4/1982 on Basic Provisions for Environmental Management. • Act No. 23/1997 on the Environmental Management. • Fourth amendment of UUD 1945 (the Indonesian Constitution). • Act No. 20/2002 on NRE source utilisation.	• Global Sustainable Development conferences and agreements (including Brundtland report in 1987, Agenda 21 in 1992, Kyoto Protocol in 1997, and JPOI in 2002). • Oil price fluctuation (the third oil crisis in 2003-2008).	• The infrastructure development policy has shifted to prioritize road-oriented transport over rail-based systems. • Unbalanced growth in vehicle number with road capacity and inadequate public mass transport. • Increase in crude oil consumption when national crude oil production decreases. • Indonesia's transportation landscape shifted favouring private	• Energy institutions have aimed to maintain stability by continuing reliance on oil and coal, and beginning to establish the groundwork for alternative, cleaner energy sources. • The institutional change was exogenous and

Stage	Key Events	Global (exogenous) factors	Domestic (endogenous) factors	Institutional stability or change type
			vehicles over the public transportation system. • Geothermal and hydropower plants operation were critical junctures for advancing national renewable energy policies. • Ratification of global agreements on the sustainable development in national policies. • Aligning policies to increase energy production by reducing environmental pollution.	occurred incrementally. • Involvement of new private institutions and are side by side with state institutions.
Third phase: The energy transition towards affordable and clean transportation energy sustainability (2004-now)	• TransJakarta BRT service launched in 2004. • Presidential Instruction No. 1/2006 on Biofuel. • Decree No. 10/2006 on Timnas BBN for Biofuel Development and Biofuel Roadmap. • Presidential Regulation No. 26/2008 on the Establishment of DEN. • ISPO certification system publishing. • Ministerial Regulation No. 12/2015 on the mandatory use of biofuels. • Presidential Regulation No. 16/2016 on RUEN. • Presidential Regulation No. 55/2019 on the EV. • Ministry of Industry Regulation No. 6/2023: limited subsidies for EV.	• Adoption of the Renewable Energy Directive (RED) by the EU. • Global and NGOs institutions campaign on biofuel sustainability. • Several global institutions trade campaign. • Several NGOs campaign on biofuel sustainability. • Global emerging technologies development and adoption on EV	• Current account deficits have become a critical juncture that causes energy institutions to shift through layering for the transition toward sustainable energy institutions. • Sustainable mass public transport through BRT, commuter line electric train, MRT and EV. • Diversification of energy sources and energy conservation through developing biofuels as alternative vehicle fuels. • Implementation of mandatory biofuel use regulations in the fuel mix for transportation, industry, commercial and power generation. • Introduction of natural gas and electric vehicles in the domestic market.	• Institutional changes occur in the combination of endogenous and exogenous factors. • Reproduction with adaptations that result in stability elements and lock-ins.

Source: Author

In 1954, the government enacted Emergency Law 10 to nationalise the Dutch colonial tram transport company, which led to the establishment of Perusahaan Pengangkutan Djakarta (PPD) to operate tram public transport in Jakarta. The first city bus in Jakarta was operated by PPD in 1956. However, in 1960, President Soekarno ordered the abolition of trams. These events marked critical junctures that led to an institutional shift through layering that ended the tram era as the primary mode of street transport in Jakarta and ushered in the bus era (Arbi, 2022).

The global development of railway dieselisation and the rise of oil-fuelled vehicles led to changes in transport energy institutions in Indonesia through a process of layering. Layering is one of the mechanisms of institutional change that is incremental (Mahoney and Thelen, 2010; Streeck and Thelen, 2005). Instead of completely replacing steam locomotives, the policy of transitioning railway main propulsion from steam locomotives began in 1952. While diesel trains gained popularity and became the preferred choice, steam trains remained in operation on limited routes until they were finally retired in 1981 (Setiawan, I., 2010).

The rising demand for petroleum led the government to create an organisation responsible for managing petroleum exploration, production, and distribution. Fuel oil management in Indonesia began in 1950 when the Indonesian government designated the Army Forces to establish PT. Eksplorasi Tambang Minyak Sumatera Utara (Pertamina, 2020; Sunarya and Taufik, 2018) (Pertamina, 2020; Sunarya and Taufik, 2018). On December 10, 1957, the company developed into PT. Perusahaan Minyak Nasional (PERMINA) (Pertamina, 2020). Indonesia, as one of the petroleum-producing countries, joined OPEC in 1962. Diesel locomotives still dominate train prime-movers in Indonesia until now (KAI, 2017).

In late 1960s, Soeharto adopted a different approach by conducting an institutional shift to alleviate the constraints of Sukarno's nationalist policies and open the economy to increased foreign investment. Additionally, his government focused on leveraging natural resources as a key strategy for economic recovery, particularly by boosting oil production and exports. Indonesian crude oil extraction reached its peak of production in 1977 at 84.9 MTOE¹⁵ (OECD, 2020). The Indonesian government encouraged acceleration of coal mine development through Act No. 1 year 1967 concerning Foreign Investment. Coal mining was growing, so the government established the State Coal Company (PN Batubara) based on Government Regulation no. 23 of 1968 (Arif, 2014).

¹⁵ MTOE stands for million tons of oil equivalent.

The energy sector experienced a significant shift during Soeharto's early years, driven by two key events that occurred nearly simultaneously: the increase in foreign investment and the global oil crisis of the 1970s. The combination of these events marked a critical juncture that profoundly altered the institutional landscape of Indonesia's transport energy sector. The socio-technical regime has experienced institutional change through layering with energy source diversification, including geothermal and natural gas.

Government through Presidential Decree No. 64/1971, Act No. 8/1974, and Presidential Decree No. 16/1974 gave an assignment to Pertamina to survey, conduct exploration and exploitation of geothermal sources to produce electricity (Pertamina Geothermal Energy, 2019).

The search for other energy sources in the form of natural gas was carried out by several companies that work under Production Contract Sharing with Pertamina. Law No. 8 of 1971 established Pertamina to manage oil and gas. In 1971, Mobil Oil Indonesia discovered natural gas fields in Arun and Lho Shukun, North Aceh. In 1972, Huffco Inc. discovered the second natural gas field, Badak, in Bontang, East Kalimantan. To increase energy security, the Directorate of Mineral Resources in the late 1970s carried out an exploration program and found large coal deposits in several potential basins in Sumatra and Kalimantan (PMI Indonesia Chapter, 2012).

4.3.2 Second Phase: The encouragement of energy diversification and raising awareness of environment preservation (1980-2003)

During the second phase, the Soeharto regime aggressively pursued economic development, concentrating in major cities, particularly on Java Island. This centralised development led to urbanisation, with rural residents moving to large cities, thereby increasing population density in urban areas. Economic development in Indonesia has led to increased economic activity, rising per capita income, and accelerated population growth, all of which have created a greater demand for transportation support.

The regulatory approach to transportation infrastructure development has shifted from rail-based systems to road-oriented systems. Over the 78-year period (1939-2017), the length of the operating railway line decreased significantly. The railroad that operated in 2017 was 5,434 km long (Java was 3,890 km and Sumatra was 1,544 km). This railway length has decreased compared to 1939, when it was 8,157 km (Java is 6,324 km and Sumatra is 1,833 km) (Directorate General of National Railways, 2018). In contrast to railways, the length of roads has increased significantly from 79,357 km in 1957 to 542,310 km in 2018 (BPS, 2019).

The emphasis on road construction, along with the growth of private car manufacturing, increased private car usage, as Interviewee 10 describes below:

“The [extensive infrastructure] development occurred during the Soeharto government's regime... As we began to build infrastructure, we were also introduced to private vehicle technology... We recognized the importance of mobility... We were spoilt by private cars. During that time, many of our graduates were oriented toward the US, which was dominated by private cars.” (Interviewee 10, Academician)

Our findings confirm the OECD/IEA (2015, p.138) statement regarding Indonesia's transportation challenges during this period, which are outlined as follows:

“The growth of the transport industry offers great potential for energy efficiency measures in Indonesia. In particular, the country's increasing population and economic growth is linked to an increase in motor vehicle ownership, which, combined with rapid urbanisation, is leading to greater traffic congestion. Motorcycles account for 80% of the country's private transport vehicles, and the modal share of motorcycles is increasing at the expense of public transport. Indonesia places no fuel efficiency or emissions restrictions on the light vehicle fleet at present.” (OECD/IEA, 2015, p.138)

The government's emphasis on road-based transportation, combined with poor planning for transport infrastructure, has resulted in insufficient development of public transportation. Additionally, the lack of regulations governing private vehicle ownership and uncontrolled urbanization patterns (Dimitriou, 2022) shifted Indonesia's transportation landscape, favouring private vehicles over the public transportation system (Sefriyadi et al., 2023). This condition contrasts with developed countries, such as the US, EU, and Japan, which have integrated transport systems supported by urban planning policies that ensure road and infrastructure capacity develops in line with vehicle growth.

The unbalanced growth in private vehicle ownership with the growth in road capacity and inadequate public mass transportation caused congestion in urban areas (BPPT, 2018). Congestion has an impact on the decline in environmental quality in the form of air and noise pollution. In addition, this congestion reduces the transport energy efficiency. These factors led to increased fuel oil consumption, the primary energy source, particularly in the land transportation sector. Significant increases in fuel consumption began in the late 1980s. Whereas in 1987 fuel consumption was 0.493 MBPD and increased at an average rate of 4.53% to 1.72 MBPD in 2013. Along with the decline in

Indonesian crude oil production, the government imported fuel oil to meet the needs of domestic fuel oil.

Indonesia's crude oil production began to decline and fluctuated in the 1980s between 80.69 MTOE and 66.44 MTOE. During the 1990s, crude oil production returned to a range of 72.12 MTOE to 74.34 MTOE. After that, starting in 2000, Indonesia's crude oil production has gradually decreased until 2017 to 39.17 MTOE (OECD, 2020) (See Figure 4.3). Meanwhile, natural gas production continues to increase significantly, especially starting from 1984 of 1.14 quad BTU¹⁶ to 260 quad BTU in 1996. Furthermore, the level of natural gas production fluctuated in the period from 1999 to 2005 in the range of 2.06 quad BTU up to 2.18 quad BTU (U.S. Energy Information Administration, 2020a) (See Figure 4.4).

The Indonesian government continues to strive to maintain energy supply security through several policies. Since the 1980s, the government has operated geothermal and hydropower plants, marking a critical juncture for developing renewable energy policies at the national level. Kamojang PLTP Unit 1, with a capacity of 250 kW, became the first geothermal power plant in Indonesia, starting operations in 1983. The government enacted Presidential Decree No. 49/1991 to deregulate and attract foreign investment, promoting the private sector's role in geothermal development (Pertamina Geothermal Energy, 2019).

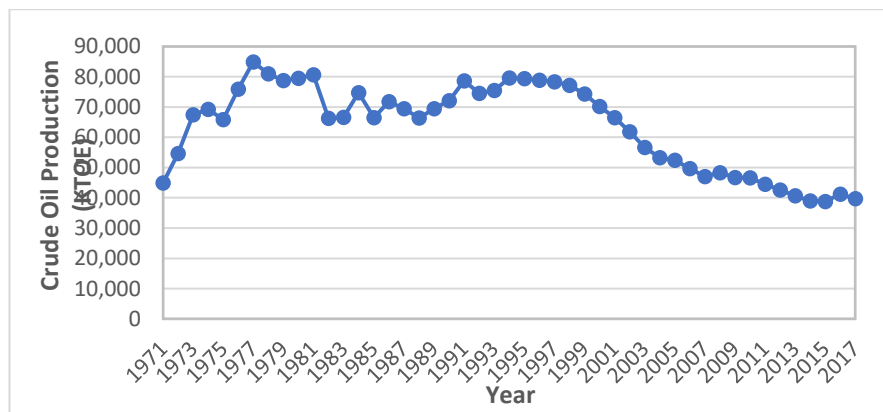


Figure 4.3 Indonesian crude oil production (1971-2017).

Source: OECD (2020)

The initiative to promote the energy mix began with Presidential Decree No. 46/1980, which established the National Coordinating Board (Bakoren). Bakoren issued the General Policy on Energy (KUBE) in 1981 (Dharmawan et al., 2018). However, the

¹⁶ BTU stands for British thermal unit.

presidential decree was still focused on improving the fuel oil efficiency and increasing the portion of coal in the national energy mix. Energy policy institutions in the second stage have aimed to maintain stability by providing affordable energy, continuing reliance on oil and coal, and beginning to establish the groundwork for alternative, cleaner energy sources.

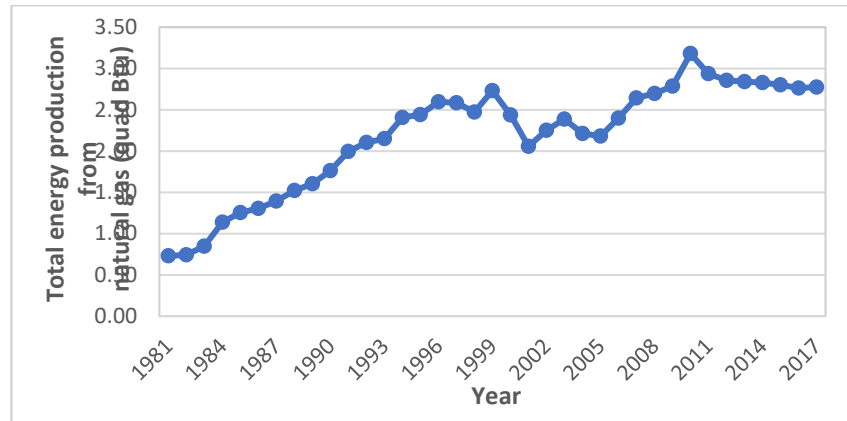


Figure 4.4 Indonesian natural gas production (1981-2017)

Source: U.S. Energy Information Administration (2020a)

Various global agendas and agreements related to sustainable development influenced Indonesia's energy institutions landscape. The government responded by ratifying, endorsing, or incorporating these sustainable development agendas into national regulation. The development of these laws also addressed the energy industry generally and transportation specifically. In 1982, the government enacted Act No. 4/1982, concerning Basic Provisions for Environmental Management. Furthermore, to elaborate the law, Government Regulation No. 29/1986, concerned Environmental Impacts Analysis (EIA) (Caroko et al., 2011). National legislation related to sustainable development includes ratification of the UNFCCC in Act No. 6/1994, the definition of sustainable development with environmental insight in Act No. 23/1997 concerning Environmental Management, and ratification on the Kyoto Protocol to Act No. 17/2004 (Kuyper et al., 2018). Furthermore, Article 33, sub-Article 4 of the fourth amendment of UUD 1945 as the Indonesian Constitution in 2002, regarding the national economy, refers to the principles of togetherness, equitable efficiency, sustainable development, environmental awareness, and maintaining advancement and harmony in the nationwide economy (Astari and Lovett, 2019).

Government Regulation No. 31/2003 encourages the transformation of the management of the oil and gas business from upstream to downstream to PT Pertamina (Persero) (Pertamina, 2020). Act No. 15/1985 concerning Electricity describes that energy sources

for electricity generation should be determined by paying attention to aspects of security, balance, and preservation of environmental functions. Furthermore, through Act No. 20/2002, the government prioritises local energy source utilisation with an obligation to prioritise using renewable energy sources (Arsita et al., 2021). By enacting Act No. 27/2003, the State accelerated the exploration and production of geothermal energy to enhance the mix of NRE sources (Pertamina Geothermal Energy, 2019).

4.3.3 Third Phase: The institutional development of sustainable alternative fuel (2004-present)

In 2004, Indonesia's crude oil consumption reached 1.23 million barrels per day (MBPD), surpassing the production level of 1.10 MBPD (BPPT, 2018). Therefore, Indonesia became a net oil-importing country. Figure 4.5 illustrates Indonesia's crude oil production and consumption profile from 1980 to 2013. The third oil crisis, between 2003 and 2008, led to a significant increase in oil prices. This crisis resulted in fuel subsidy costs soaring by 168%, from USD 4.4 billion to USD 7.4 billion (U.S. Energy Information Administration, 2020b). "Indonesia's current account deficit due to imports... Most of this deficit was attributed to fossil fuel imports, particularly petrol" (Interviewee 2, Energy Corporation). Rising fuel consumption and the increased subsidies contributed to current account deficits, marking critical junctures for the transition toward sustainable energy institutions. This shift has been evolving through layering, which involves developing a socio-technical framework for sustainable mass public transportation and advancing the diffusion of environmentally friendly alternative fuels.

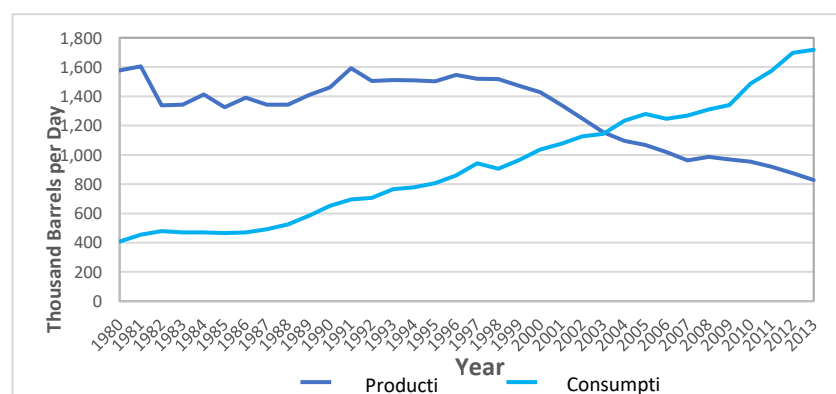


Figure 4.5 Indonesian crude oil production and consumption (1980-2013).

Source: U.S. Energy Information Administration (2020b)

Adequate mass public transport infrastructure was highlighted during Susilo Bambang Yudhoyono's (SBY) tenure as the sixth President of Indonesia from 2004 to 2014. After

struggling to find modalities for successful mass public transport, the government found inspiration in the effective implementation of Bus Rapid Transit (BRT), which was first introduced in Curitiba, Brazil, in 1974 (Wright, 2011). The BRT concept offers greater flexibility than rail systems, as it can extend residential areas through feeder services (Nikitas and Karlsson, 2015). Furthermore, Nadeem et al. (2021) emphasised that the advantages of BRT systems include performance factors such as travel time, reliability, capacity, and accessibility, as well as benefits like increased ridership, lower capital costs, support for area development, and improved environmental quality.

The effectiveness of BRT systems began to emerge in North and South America in the 1970s on a limited scale. However, their adoption significantly expanded in the 1990s, particularly in cities like Quito, Ecuador; Los Angeles, US; and Bogotá, Colombia. In Asia, the introduction of BRT systems was initially limited to Nagoya (Japan) and Taipei (China) in the late 1990s. Since 2004, the implementation of BRT systems in Asia has become more widespread, including Seoul (South Korea), Beijing (China), and Bangkok (Thailand) (Wright, 2011; Hasibuan and Mulyani, 2022).

The Greater Jakarta regional government established the Transjakarta Busway Management Agency (BP Transjakarta) through Governor Decree No. 110/2003. BP Transjakarta commenced BRT service in the Greater Jakarta Region on January 15, 2004. Following the Greater Jakarta Governor Regulation No. 48/2006, the BRT institution was restructured and became the Transjakarta Public Service Agency under the DKI Jakarta Transportation Agency on May 4, 2006. The government has adopted a socio-technical approach by developing adequate infrastructure, including dedicated road networks, procuring comfortable buses, and providing subsidies to ensure accessibility for all community segments. As a result, BRT has evolved into a mass transit platform designed to offer punctuality, safe, comfortable, and affordable mobility that meets the needs of the people of Jakarta (PPID PT Transportasi Jakarta, 2020).

The SBY administration revitalized rail-based transport systems for intra-city and inter-city connections. Regulatory reforms were introduced through Law 23/2007 on railways, which permitted private investment. Additionally, modernization and improvement of infrastructure were achieved by rehabilitating previously abandoned railway lines in Java and Sumatra and developing a double track along the main Jakarta-Surabaya route. A socio-technical approach was used to emphasize enhanced service quality and safety, such as extension subsidies for economy class, implementation of electronic ticketing, prohibiting passengers from riding on train roofs, and elimination of level crossings to reduce accidents (Andistya and Dwi Ratna Indri, 2025).

The SBY administration also revitalised rail-based transport institutions for urban areas mobility. In addition to road transportation options, the electric rail management entity evolved from the former Jabodetabek Division under PT KAI into a limited liability company known as PT KRL Commuter Line on September 15, 2008, as stipulated by Presidential Instruction No. 5/2008. The government has also developed a rail-based mass rapid transit (MRT) mode of transportation through the Regional Regulation of Greater Jakarta Province Number 3 of 2008 concerning the Establishment of Regional Owned Enterprises PT Jakarta MRT (MRT Jakarta, 2020).

In 2018, Joko Widodo, the seventh president of Indonesia, enacted Presidential Regulation No. 55, which addressed the Greater Jakarta Transportation Master Plan. This regulation has significant implications for transportation development, integrating it with spatial planning, engineering management, traffic control, transport safety and security, and financing systems. The Master Plan also supported the construction of infrastructure networks that integrate road-based and rail-based transport systems while promoting environmentally friendly modes of transportation (Syafuruddin, 2024). The government formed a light rail transit system to connect Jakarta with its surrounding satellite areas, establishing the regional company PT LRT Jakarta on April 16, 2018. The Jabodetabek LRT began operations after being inaugurated by Joko Widodo on August 28, 2023 (LRT Jakarta, 2024).

In addition to improving mass public transport infrastructure, enhancing energy security necessitates institutional changes to support the development of low-emission alternative fuels. Fuel diversification was essential to reduce dependence on petrol and lower emissions. Many countries were undergoing institutional shifts by layering in their transport energy sectors. These changes involved developing and diffusing various alternative fuels, such as biofuels, natural gas, and electric energy (BPPT, 2018).

Significant policy interventions to promote biofuels, driven by environmental movements and concerns about GHG emissions, occurred in various regions, including the US and the EU. The US government introduced the Renewable Fuel Standard (RFS) in 2005 and expanded it in 2007 to provide a framework for increasing the portion of biofuel blended into vehicle fuels (Manuel, 2021). Similarly, through the Biofuels Directive (2003/30/EC), the EU aimed to have 5.75% of transport fuels derived from biofuels by 2010. Additionally, countries such as Sweden and Germany, have implemented policies encouraging biodiesel and ethanol use (Kupzok, 2020).

In the early 2000s, the Indonesian government started observing the transitions in the global socio-technical landscape concerning biofuel technology development and the export markets. This biofuel opportunity was significant due to established industries for

agricultural export commodities, such as crude palm oil (CPO) and ethanol derived from sugarcane. The EI development for Indonesian biofuel highlights the socio-technical regime transition of biodiesel and ethanol. The Indonesian government began to focus on developing biofuel EI in 2005, aiming to improve the export balance and potentially reduce dependence on fossil fuels. Furthermore, the development of biofuels creates additional market opportunities for palm oil products beyond the food and oleochemical sectors (Farobie and Hartulistiyoso, 2022).

The diversification of CPO to biodiesel in Indonesia has triggered debates about its environmental impact. Recent studies have examined the benefits of biodiesel, especially in terms of reducing GHG emissions in the transportation sector. However, the expansion of palm oil cultivation has raised controversies regarding land conversion, deforestation, and potential threats to biodiversity (Mori and Halimatussadiah, 2023; Astari et al., 2025).

In 2006, Presidential Instruction No. 1/2006 was implemented to regulate the supply and use of biofuels as a substitute for fossil fuels. Furthermore, the government, through Presidential Decree No. 10/2006 formed the National Team for Development of Biofuels (Timnas BBN) which had the task of formulating policies to accelerate the adoption of national biofuels. The regulator implemented Presidential Regulation No. 5/2006 on National Energy Policy (KEN) to provide a nationwide energy management blueprint. The regulator's blueprint summarises the strategy for managing and utilising diverse energy sources, including biofuels. The government encouraged investment by guiding potential investors on obtaining licences for the production, purchase, sale, export, and import of biofuel under Ministerial Regulation No. 051/2006 (BPPT, 2018).

These include income tax deductions, accelerated depreciation and amortisation, and guarantees for operational losses, as outlined in Government Regulation No. 1/2007. At the initial stage, the government implemented a mandatory program on the use of biofuels in fuel oil, starting in 2008 with a 2.5% biodiesel content in the fuel-oil mixture. Gradually the proportion of biofuels in fuel oil increased to 7.5% in 2010. The government regulates the biofuels procurement, distribution and the pricing of petroleum and biofuel markets through Presidential Regulation No. 45/2009, which replaced Presidential Regulation No. 71/2005 (BPPT, 2018).

In 2009, the Indonesian government committed to reducing GHG emissions at the fifteenth Conference of the Parties (COP) conference in Copenhagen, leading to the implementation of this policy. GHG emission reductions are carried out through various policies including increasing energy savings; the use of cleaner fuel (fuel switching); enhanced utilisation of new and renewable energy (NRE) sources; the use of clean

technology in power plants and transportation facilities; and the development of national mass transportation that is low in emissions, sustainable and environmentally friendly. In 2011, the government issued Presidential Regulation No. 61/2011 concerning the National Action Plan for Reducing Greenhouse Gas Emissions (RAN-GRK). The RAN-GRK strategy establishes goals and plans for decreasing greenhouse gas emissions in five key sectors: agribusiness, forestry and peatlands, energy, transport, industrial, and waste handling (APROBI, 2022).

The consistency of increasing alternative fuels production capacity sustainability has received attention from various parties, including environmental NGOs. For instance, Greenpeace released a report called 'Caught Red-Handed' in March 2010. The report revealed the efforts of the largest producer of Indonesian palm oil, Sinar Mas, a Nestlé supplier, to take unsustainable action. Sinar Mas expanded cultivation land to rainforest and peatlands which are orang-utan habitat (Greenpeace, 2010). In October 2013, Greenpeace (2013) published a report entitled 'Licence to Kill', revealing that Wilmar International sourced palm oil from plantations in Tesso Nilo National Park, Riau, Sumatra. Greenpeace produced maps indicating that oil palm plantations threaten the rainforests, which provide habitats for the Sumatran tiger, an endangered species.

In November 2013, the EU imposed anti-dumping measures on Indonesian biodiesel (European Union, 2013). The Indonesian government brought this dispute to the World Trading Organization (WTO) in 2014. Following this, the United States government also imposed anti-dumping on Indonesian biodiesel because the price of Indonesian biodiesel was subsidised so that it was cheaper than world prices (US Department of Commerce, 2017). After going through a three-year dispute resolution process, in January 2018, the Panel of Dispute Resolution at the WTO won the Indonesian lawsuit over the EU (Dharmawan et al., 2018). Another concern arose from the European Parliament's decision on 17 January 2018 to stop using biodiesel from palm oil starting in 2021. The claim underlying this decision is that some of the CPO that supplies the biodiesel industry cannot be guaranteed traceability (Dharmawan et al., 2018). This claim was based on the expansion of oil palm plantations triggering deforestation and carbon emissions. The Indonesian government opposed the European Parliament's decision, through the Ministry of Foreign Affairs stated that the European Parliament consistently ignores the fact that oil palm has high efficiency, productivity, and the potential to create long-term environmental conservation when compared to other vegetable oils (Ministry of Foreign Affairs, 2019).

Changes in the socio-technical landscape of Indonesian biofuels, driven by environmental concerns and trade disputes, have led to abandoned oil palm harvesting.

At the same time, there was an urgent necessity to reduce reliance on petroleum imports. These events have created critical junctures that prompted the government to implement a policy mandating the use of biofuels across several sectors. In 2014, the government issued Government Regulation No. 79/2014 concerning KEN, which replaces Presidential Regulation No. 5/2006. The government revised the KEN by improving the national energy mix, implementing energy conservation, and accelerating the construction of generators. This policy raised the target of using biofuels, as part of bioenergy, where the share of renewable energy is 23% in 2025 and at least 31% in 2050 (Dharmawan et al., 2018). To implement this policy, the government imposed Presidential Decree No. 1/2014 concerning the Compilation of the National Energy General Plan (RUEN), Provincial Regional National Energy General Plan (Provincial-RUED), and Regency/City Regional National Energy General Plan (RUED-Regency/City). Furthermore, the MEMR Ministerial Regulation No. 12/2015 has become the basis of the energy policy to integrate biofuel production into mandatory usage in transport, commercial, industry, and electric generation sectors (BPPT, 2018).

The Indonesian government has continued the decarbonization program by promoting CNG utilisation since the 2010s. This initiative was formalised through Decree No. 247/2011 issued by the Director-General of Oil and Gas, which outlines the specifications for CNG fuels used in domestic transportation. The MEMR has assigned the provision and distribution of gas fuel for road transportation to PT Pertamina, as stated in Ministerial Decree No. 2435/2014, and to PT Perusahaan Gas Negara (PGN), under Ministerial Decree No. 2436/2014. Based on this policy framework, both companies established a Gas Fuel Filling Station in Greater Jakarta. Subsequently, the MEMR enacted Ministerial Regulation No. 25/2017, which governs using natural gas for road transportation. Several public vehicles, including TransJakarta buses, taxis, and motorised rickshaws, use this gas fuel (BPPT, 2018).

Indonesia ratified the Paris Agreement through Law Number 16 of 2016. As a result, the State has committed to reducing its greenhouse gas emissions by 29% independently and up to 41% with international support by 2030 (IESR, 2022). The global EV trend, prominently highlighted in mainstream and social media, has attracted the attention of various groups in Indonesia. Early adopters have formed brand enthusiast groups to share knowledge about EVs' latest updates and operational experiences. These early adopters indirectly promote the benefits of EVs to the public, contributing to their increasing population.

Changes in the socio-technical landscape, driven by the growing population of EVs and President Jokowi's political orientation to China, have created critical junctures in the

development of EV adoption in Indonesia. The socio-technical regime has shifted its approach to EV diffusion by prioritising technology transfer through investments from foreign manufacturers such as Hyundai and Wuling. The implementation of Presidential Regulation No. 55/2019 has led to the formation of an institution that promotes the acceleration of the battery electric vehicle (BEV) program for road transportation. This regulation signified the advent of EV production era in Indonesia (Sasongko et al., 2024).

After the COVID-19 pandemic, the government launched several fiscal and non-fiscal policies to encourage EV adoption. The government has provided yearly tax and title transfer fee reduction (Ministry of Home Affairs Regulation No. 1/2021), luxury goods sales tax exemption (Government Regulation No. 74/2021), and exemption from vehicle title transfer fee and vehicle tax (Law No. 1/2022). EV adoption increased significantly after implementing a limited subsidy scheme through the MoI Regulation No. 6/2023 (DEN, 2023).

The increase in the EV population has stimulated the development of charging infrastructure through charging points and battery swap systems. High investment costs remain a challenge for the deployment of charging networks. The government offered an infrastructure charging business scheme through MEMR Regulation No. 1/2023 (Rokadiya et al., 2021). Apart from that, the government's seriousness in developing the EV industry is supported by the implementation of standardisation. In July 2023, BSN had stipulated 38 Indonesian National Standards (SNIs) related to electric vehicles and charging infrastructure. The government designed an ICE vehicle transition program to a more environmentally friendly EV at RUEN with the target to stop ICE vehicle production in 2040 (DEN, 2023). Regulatory support has contributed to the growth of the EV population in Indonesia. In addition to fiscal policy, the Jakarta local government also facilitates EV users by exempting them from even-odd regulations in major areas (Sasongko et al., 2024).

4.4 Niche Innovations of the Transport Energy in Indonesia

4.4.1 Developing a Socio-Technical Framework for Sustainable Mass Public Transportation

The mass public transport niche in Indonesia began to grow in the 2000s, particularly after the current account deficit was triggered by the uncontrolled increase in private vehicles and the oil crisis. The road sector was revitalised through the implementation of BRT, which had expanded into Asia by this period. The initial phase of the EI niche BRT began in 2004 in Jakarta, with one route covering 12.9 km and serving 15.93 million passengers. TransJakarta BRT has effectively addressed the public's needs for

punctuality, safety, and comfort through the development of dedicated lane infrastructure.

Implementing a flat fare for all journeys and subsidies has further boosted public interest in utilising this affordable mode of transport. By 2010, the network grew to 10 routes spanning 183.05 km, accommodating 86.93 million passengers. TransJakarta BRT services have expanded and become a favourite among the public of Jakarta and supporting areas for their daily mobility necessities. The Greater Jakarta regional government's efforts to integrate BRT with microbus feeder services further increased capacity, allowing 264.65 million passengers in 2019. Microbus feeders have interconnected the first miles from residential areas to the nearest BRT station, thereby further expanding service coverage. The service capacity of TransJakarta BRT decreased during the COVID-19 pandemic due to social distancing policies and declining socio-economic activities. After the post-pandemic recovery, TransJakarta BRT services continued to increase, serving 280 million passengers in 2023 (Nurhaliza, 2024).

The implementation of niche innovations that enhance mobility capacity, promote energy efficiency, and support decarbonisation through the revitalisation of public transport has spread to major cities across the country. While the scale of these developments may not be as extensive as in Jakarta, local governments in cities such as Surabaya, Semarang, Yogyakarta, Medan, and Makassar have initiated BRT projects. Additionally, Bandung and Tasikmalaya were in the planning stages for their BRT systems. In the rail-based sector, commuter line systems have been established in Surabaya and Yogyakarta, and further planning for commuter lines is underway in Bandung and Medan.

Before the 2000s, Indonesia's commuter trains faced significant challenges, including severe delays, poor service, and overcrowding. Inadequate scheduling, poor station infrastructure, and inefficient manual ticketing contributed to a struggling legacy system. Since 2008, modernisation has also been carried out through electrification and standardisation of the system adopting the loop line system as a commuter line to improve travel time, the import of electric train units, and the renovation and expansion of stations (KCI, 2018).

In 2013, a socio-technical approach was introduced to enhance passenger discipline. This involved implementing an electronic ticketing system and measures to limit the number of passengers on trains to prevent overcrowding. Initially, the ticketing system operated on a single-trip basis, but it later expanded to include multi-trip cards. Service improvements have been implemented by gradually eliminating class-based train services, such as economy and express options, and replacing them with standardized

services. Regarding infrastructure, upgrades were made by retiring old non-air-conditioning diesel trains and replacing them with fully air-conditioned electric multiple units (EMUs). These niche innovations addressed the overcrowding of commuter line trains before the 2000s when many passengers resorted to climbing onto the roofs of carriages, leading to frequent accidents (KCI, 2018).

Niche innovations that have revitalised commuter rail lines in the Greater Jakarta area expanded nationally. By the end of 2017, PT Kereta Commuter Jakarta rebranded itself as PT KAI Commuter Indonesia (KCI), focusing on transforming commuter rail systems in major cities nationwide (KCI, 2018). To alleviate bottlenecks, double-double tracks (DDT) on the Manggarai-Cikarang route were completed in the 2020s. The commuter line electric trains increasingly became the preferred mode of transportation for the Greater Jakarta public (Syafuruddin, 2024). This mode of transport served 104.43 million passengers in 2006, rising to 124.31 million in 2010 and reaching 504.64 million by 2024 (BPS, 2025).

The government has initiated niche innovations through the development of MRT and LRT to enhance the capacity and quality of mass public transport services. The Japan International Cooperation Agency (JICA) conducted the initial feasibility study for the construction of the MRT in Jakarta in 2005. This study continued during Governor Fauzi Bowo's leadership from 2007 to 2012. After a lengthy process, the State established the institutional framework for the LRT and MRT systems through Presidential Regulation No. 03/2016, which aimed to accelerate national strategic projects, including the MRT and LRT. This initiative was further supported by Presidential Regulation No. 65/2016, which focused on implementing an integrated LRT system in the Greater Jakarta area. The 16 kilometres MRT Phase 1 began operating in March 2019 and has served the mobility of 33 million passengers in 2023 (MRT Jakarta, 2024). The stimulation for developing the Light Rail Transit (LRT) system was bolstered by the upcoming 2018 ASEAN Games, which were held in Palembang and Jakarta. Additionally, there was a compulsory need to reduce reliance on private vehicles by enhancing public mass transportation efficiency. The initial planning for the Palembang LRT began in 2012-2013, and construction commenced in 2015. 2018 President Joko Widodo inaugurated the Palembang LRT, which connects Sultan Mahmud Badaruddin II Airport to Jakabaring Sports Station. This LRT network spans a total track length of 23.4 kilometres and includes 13 stations (LRT Jakarta, 2024).

The Japan International Cooperation Agency (JICA) conducted the initial feasibility study to construct the MRT in Jakarta in 2005. This study continued during Governor Fauzi Bowo's leadership from 2007 to 2012. Nevertheless, after a lengthy process in 2013, Joko Widodo, then the Governor of Jakarta, performed the groundbreaking. There are

two LRT lines: the Cibubur Line, which is 25.94 kilometres long, and the Bekasi Line, which stretches for 29.54 kilometres (LRT Jakarta, 2024). In its first year of operation, the Jabodetabek LRT served 7.25 million passengers, which rose significantly to 21.06 million in 2024 (Kompas, 2025).

The development of various modes of mass transportation relies on the multi-dimensional integration of both infrastructure and fare structures. This integration was expected to encourage a shift from private vehicle users to public transport, as noted by Interviewee 27 below:

"Integration is indeed the key aspect to consider... First, operational integration relates to the collaborative routes establishing numerous feeder lines for rail transportation. [Second, this niche innovation also] includes the integration of tariffs, which is crucial for making it easier for passengers to switch between different modes of transport. This seamless experience encourages people to transition from private vehicles to public transportation. As the quality of service improves, public transport becomes more accessible and affordable, attracting more users. Additionally, integrating fare systems contributes to making public transportation more accessible." (Interviewee 27, Transport Provider Company)

The development of MRT Jakarta and LRT Jabodetabek aims at more than just transportation infrastructure. MRT Jakarta and LRT Jabodetabek seeks to shape the city's new character and culture. The MRT and the LRT development complements the integration between the TransJakarta BRT, commuter line electric trains and microbus feeders to form Transit-Oriented Development (TOD) areas across Greater Jakarta. The TOD concept addresses urban transportation challenges, particularly severe traffic congestion, by integrating urban land use with transportation systems. TOD enhances public mobility by reducing travel distances and maximising the efficiency of transport services, concentrating urban development around transit stations (Hasibuan and Mulyani, 2022). The key characteristics of TOD are often referred to as the 5Ds: density, diversity, design, destination accessibility, and distance to transit (Ewing and Cervero, 2010). The local government of Jakarta has paid attention to the development of TOD to integrate urban spatial development with public mass transport infrastructure. As reported by (Jones, 2024):

"TOD is becoming increasingly important in major cities worldwide, and Jakarta is no exception. It is an urban development concept that integrates urban design with public transport. Jakarta must take the TOD seriously. Currently, five TOD projects are operating in the city... I believe that TOD will continue growing as more people increasingly rely on public transport." (Jones, 2024)

Our findings align with recent literature, which emphasises that TOD policy focuses on integrating sustainable land use with transportation systems. It aims to improve accessibility by providing efficient transport connections and encouraging people to use public transport. This shift will reduce traffic congestion, lower energy consumption, and decrease air pollution (Gu et al., 2019). The map of the TOD concept implementation through the integration of MRT, LRT, and BRT in the Greater Jakarta area is presented in Appendix D.

The TransJakarta BRT system became a reference for other regions seeking to develop sustainable mass public transportation systems. Secondary sources highlighting the TransJakarta impact on public transportation policies and its role in reducing emissions, as stated by Setijowarno (2023) as follows:

"Starting operations on January 15, 2004, the TransJakarta Busway has influenced policies at the national level... The development of TransJakarta has been recognised throughout Indonesia as a historic milestone in the emergence of a mass public transport system that will revolutionise urban landscapes... The BRT TransJakarta Busway, in addition to changing transportation traditions and culture within the community, has also become a leading force in improving air quality in urban areas." (Setijowarno, 2023)

Despite implementing various pull policies, the advancement of public transport in Indonesia remains hindered by a lack of push policies. The government still faces challenges implementing several environmental policies that have gained popularity in many developed countries. These include the Ultra-Low Emission Zone (ULEZ), Electronic Road Pricing (ERP), and tax incentives or disincentives for private vehicle ownership, as stated by Interviewee 27.

"In Jakarta, the focus has generally been on implementing pull rather than push policies. For instance, the ERP system and progressive parking have not yet been implemented... While incentivising EVs may contribute somewhat to reducing pollution, the impact in Jakarta is limited, as the electricity supply is still largely dependent on coal. The [condition] means that the congestion problem persists. Due to the EVs incentives for [private users], people may still own ICE cars at home and purchase more EVs. The relaxation of odd-even regulations for private EV users further complicates this situation" (Interviewee 27, Transport Provider Company).

4.4.2 Streamlining Biofuels as Low Emission Vehicle Fuels

Timnas BBN has led the development of niche biofuel innovations in Indonesia since 2006. Key organisations involved in the national biofuel initiative include various

government ministries and agencies, including the Ministry of Energy and Mineral Resources (MEMR), the Ministry of Agriculture (MoA), the Ministry of Transportation (MoT), the Ministry of Finance (MoF), and the National Development Planning Agency (Bappenas). Additionally, state-owned companies such as Pertamina, Perkebunan Nusantara, and Rajawali Nusantara Indonesia were significant contributors. Research and academic institutions, including the Agency for the Assessment and Application of Technology (BPPT), the National Research and Innovation Agency (BRIN), Bandung Institute of Technology, Gadjah Mada University, and the University of Indonesia, also play a vital role. Moreover, the Indonesian Palm Oil Association (GAPKI), the Association of Biofuel Producers (APROBI), and various non-governmental organisations (NGOs) were actively engaged in the biofuel sector.

The biofuel niche innovation program utilises a triple-track strategy emphasising pro-growth, pro-job, and pro-poor initiatives. The pro-growth strategy required the biofuel program to increase economic activity to drive national economic growth. In the pro-job context, the biofuel program was labour-intensive and involved cooperation among all levels of government, from the state level to the province and down to the village level. The biofuel program was developed as a cross-sectoral initiative encompassing cultivation, industry, and the private sector. Meanwhile, through a pro-poor strategy, kerosene was replaced with biofuels (MEMR, 2014; Agency for the Study and Development of Trade Policy, 2013).

The KEN roadmap guided the development of EI biofuels in Indonesia, with the goal of achieving a biofuel mix constituting 2% of the country's national energy consumption by 2010 and increasing this target to 5% by 2025 (BPPT, 2018). Besides, the regulator issued additional policies related to biofuel development zones and dedicated 6 million hectares of land for biofuel cultivation. The government provided the Special Biofuel Zone (SBZ) based on an evaluation to measure the potential of the region for development. There are three potential crops as the primary raw material for biofuels, including oil palm, jatropha and sugarcane. SBZ followed conservation guidelines by distinguishing zoning for industry, planting, and conservation (Mori and Halimatussadiah, 2023).

In 2006 the National Standardisation Agency enforced SNI 04-7182-2006 as a standard quality standard for biodiesel and bioethanol in Indonesia. This biodiesel and ethanol standard refer to the same standard and applies in the US and EU. Ministerial Regulation No. 051/2006 guided potential investors on licensing for production, trade, export, and import biofuels to support investment stimulation. The regulation requires the socio-technical transition to ensure a continuous supply of biofuels for domestic needs. The government assigned Pertamina and PLN to guarantee biodiesel consumption targets

and strengthen the market for biodiesel in Indonesia through its role as a standby purchaser. With this decision, Pertamina was permitted to start selling biodiesel and bioethanol biofuels in mid-2006.

At the end of 2006, biofuel producers formed the Indonesian Biofuel Producers Association (APROBI). APROBI is a facility that accommodates the interests of biofuel producers in Indonesia. APROBI aims to bring together industrial companies and bring together actors in the biofuel business industry. APROBI acts as a partner for the government in the process of formulating policies to improve the competitiveness of Indonesian biodiesel products in the domestic and international markets (Dharmawan et al., 2018).

Since 2007, biofuels have received fiscal incentives as innovative products to assist them compete with existing fossil fuels. These incentives support the companies involved in producing biofuels and those that use biodiesel in their operations. The government continued to support biofuel development through MEMR Regulation No. 32/2008 concerning the regulation produce, trade, and utilise biofuels. This regulation aims to gradually introduce biofuels into several sectors, including transport, industrial, and electric power generation, by 2025. The industrial sector was required to use biodiesel for at least 5% of 2010 total fuel consumption. Besides, this gradually increased to 10% of the biodiesel in 2015. Finally, in 2020, the target is set up for 15% of total industrial fuel consumption (Caroko et al., 2011).

As other countries also shifted to biofuel use, the Indonesian government took advantage of opportunities to meet the increasing global demands for biofuels. APROBI (2022) emphasised that one of the targeted global biofuel export markets was the EU which on 23 April 2009 adopted the Renewable Energy Directive (Directive 2009/28/EC). Indonesian biofuel companies moved to meet EU requirements through international certification of biofuel products to be exported to the EU market. Several international certifications focus on biofuel sustainability based on a carbon calculation mechanism to ensure the accuracy of biofuel sustainability by documenting energy inputs and GHG outputs. Some of these international certifications included the International Sustainability and Carbon Certification (ISCC), which was based on the Renewable Energy Guidelines (RED) of the European Union and the German Sustainability Ordinances (BioNachV). Indonesian biofuel exports in 2005 were 6.82 million litres and increased to 607 million litres in 2008 (APROBI, 2022). The worldwide crisis led to a significant decline in CPO prices in 2008 (Indonesia Investments, 2017). The decline in CPO prices triggered a decrease in biofuel exports in 2009 to 270 million litres.

Indonesia's biofuel exports increased again in 2010 to 520 million litres (OECD-FAO, 2024).

The global certification system of palm oil product was marked by the development of the Roundtable on Sustainable Palm Oil (RSPO) in April 2004. The RSPO initiation promoted the development and use of sustainable palm oil products through credible global standards and stakeholder engagement (RSPO, 2013). Interestingly, from an HI perspective, the RSPO penetration into the Indonesian palm oil sector resulted in sudden institutional changes. Most Indonesian biofuel companies adhere to the RSPO system to be able to access global markets, but the institutional changes have impacted Indonesian regulations.

Indonesian company representatives expressed their disappointment at the RSPO's inability to persuade the global market of Indonesia's sustainability commitment. The certification provided by the RSPO was viewed as having the potential to contribute to carbon emissions, raising concerns about its economic implications. Additionally, some stakeholders, particularly farmers, have voiced concerns about the RSPO's lack of engagement with the needs and challenges faced by local producers. For smallholders and small to medium-sized enterprises, RSPO certification was seen as prohibitively expensive (de Vos et al., 2023).

The dynamics of the socio-technical landscape, shaped by differing perspectives between palm oil producers and the RSPO, alongside government commitment to environmental sustainability and the protection of small and medium enterprises, have formed critical junctures for the sustainability of biofuels in Indonesia. As part of its commitment to the REDD+ policy, the Ministry of Agriculture has established the Indonesian Sustainable Palm Oil (ISPO) certification under MOA Regulation No. 19/2011. ISPO serves as an institution responsible for the sustainability certification of the Indonesian palm oil industry, aiming to reduce GHG emissions. ISPO emphasizes inclusiveness across all sectors of the palm oil industry by maintaining affordable certification costs and not charging membership fees (Astari et al., 2025). This strategy was in contrast to the RSPO certification, which was often considered too expensive for smallholders and small to medium enterprises. The Indonesian government has been promoting ISPO certification as an alternative to the RSPO in collaboration with the GAPKI. They have also engaged in diplomacy with palm oil-importing countries to recognise ISPO (Astari et al., 2025).

The ISPO certification obligation for all palm oil companies came into force in May 2012, with a completion deadline by the end of 2017 (Astari et al., 2025). At the beginning of implementing the sustainability commitment, Indonesia's biofuel production capacity

rose from 1,800 million litres in 2011 to 3,000 million litres in 2014. The production proportion in the past four years was still dominated by exports to meet demand from the world market (OECD-FAO, 2024).

However, the international community was still worried about the unsustainability of Indonesian biofuel production despite the ISPO implementation. The US EPA (2011) released a Notice of Data Availability (NODA) and conducted the Renewable Fuel Standard (RFS) programme to examine the greenhouse gas life cycle of palm oil used for biodiesel. The US EPA analysis concluded that oil palm oil fails to achieve the minimal requirement of 20% of the GHG life cycle for renewable fuels (US EPA, 2011). The Indonesian government, as per the 2012 Embassy of Indonesia Press Release, disputed the accuracy of the conclusions in NODA, claiming that the data was outdated as it only included information up to 2009. The Indonesian government claimed that the updated records, thorough procedures, and unbiased models accurately represent the situation (Astari et al., 2025). The inaccurate report not only has a negative impact on the Indonesian palm oil sector but distorts the trade in palm oil based-biofuels (Kovacevic, 2012).

Some of the environmental issues and trade disputes led to a sharp decline in Indonesia's biofuel production to 1,180 million litres in 2015 (OECD-FAO, 2024). APROBI (2022) analyses that the Indonesian government encouraged downstream applications of palm oil production through three channels: the oleo food industry channel, the oleochemical industry channel and the biofuel channel. This downstream diversification has two main objectives to increase added value and reduce dependence on world palm oil markets. In the downstream path for biofuels, the government issued a mandatory policy on the use of biofuels. With the implementation of the downstream lane, the government is trying to reduce Indonesia's dependence on imported fossil fuels while reducing emissions from fossil fuels. The implementation of the mandatory policy is carried out by increasing the production of fatty acid methyl ester-based biodiesel (FAME) both to meet domestic and export demands.

The domestic market has rapidly expanded due to policies mandating the use of biofuels in the transport, industrial, commercial, and power generation sectors. The policies mandated the share of biofuel in diesel fuel to be 20% by 2016 (BPPT, 2018). Besides, the government, through Presidential Regulation No. 61/2015 to form institutions in the financial sector, namely the Palm Oil Plantation Fund Management Agency (BPDPKS). This institution managing funds from palm oil export levies to develop human resources, research and development, plantation promotion, plantation rejuvenation, infrastructure development and biodiesel supply (Dharmawan et al., 2018). The level of biodiesel

production then gradually increased again in 2016 to 2,700 million litres and 3,872 million litres in 2023 (OECD-FAO, 2024) as shown in the Figure 4.6.

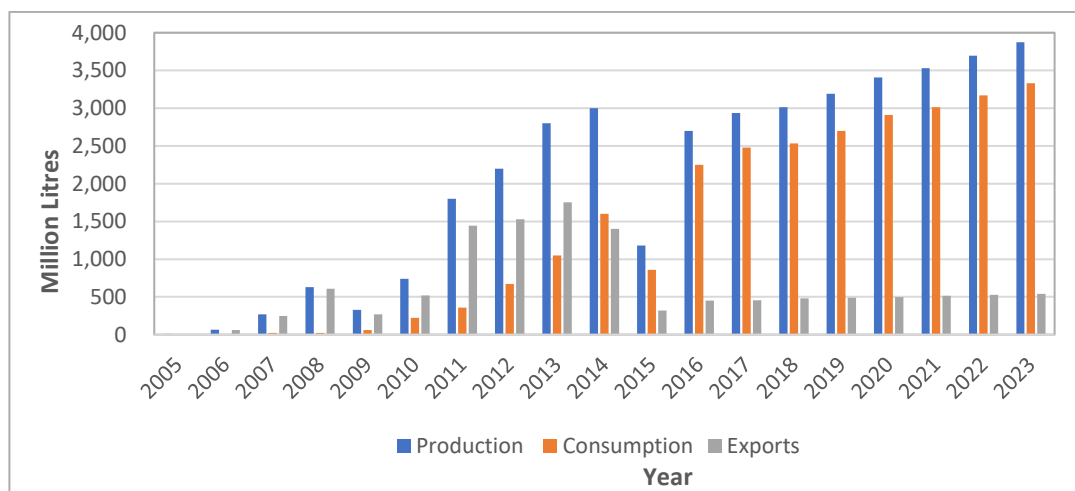


Figure 4.6 Indonesian biodiesel production, consumption, and export capacity (2005-2023)

Source: (OECD-FAO, 2024)

The implementation of Indonesia's commitment, at the signing of the Paris Agreement at COP 21 in 2015, to reduce greenhouse emissions was implemented in Presidential Regulation No. 22/2017 concerning RUEN. The RUEN targets biofuel production of 15.6 million kilolitres in 2025 and 54.2 million kilolitres in 2050, as well as a blending target of 30% biodiesel and 20% bioethanol. There was a shift in the absorption of biofuel products, from what was initially export-oriented, to meet domestic demand during this stage (OECD-FAO, 2024).

Prabowo Subianto, the eighth President of Indonesia, advanced the development of E1 biofuels by increasing biodiesel production from B35 to B40 through MEMR Decree No 341.K/EK.01 /MEM.E/2024, starting in early 2025. This socio-technical energy policy strives to enhance energy security, conserve foreign exchange by reducing diesel imports, and create jobs. Besides, this transition emphasises reducing GHG emissions to achieve the net zero emissions (NZE) target by 2060, as stated in the following secondary source:

“MEMR Bahlil Lahadalia explained the increase in biodiesel production from B35 to B40... This [initiative] aligns with President Prabowo Subianto's Asta Cita agenda, which focuses on energy security and self-sufficiency, and the government's goal of achieving NZE by 2060... The mandatory biofuels program aims to reduce petrol imports, thereby saving foreign exchange... The B40 program has delivered significant benefits in various social and environmental aspects, including an increase in the value of crude palm oil

(CPO)..., the creation of over 14,000 off-farm jobs, and approximately 1.95 million on-farm jobs. Additionally, it has contributed to a reduction in GHG emissions by 41.46 million tonnes of CO₂ equivalent per year.” (Candra, 2025).

4.4.3 Fuel-Switching Program through Natural Gas Utilisation

The Indonesian government was diversifying alternative fuels by utilising natural gas in the transport sector. Establishing four natural gas refuelling stations in Palembang in 2011 marked a significant milestone in utilising CNG. The following year, additional CNG refuelling stations were constructed in East Java, including two in Surabaya, one in Sidoarjo, and one in Gresik. MEMR also built two pilot workshops for natural gas vehicles. By 2013, four CNG refuelling stations, four mobile refuelling units (MRUs), and a gas distribution pipeline were established in the Greater Jakarta area. Four more CNG refuelling stations were built that same year in Balikpapan, East Kalimantan (MEMR, 2013).

The natural gas supply was managed through contracts between Pertamina and seven business entities. The Greater Jakarta area receives natural gas from Pertamina EP, Pertamina ONWJ, Medco E&P, and Pertamina-Talisman Jambi Merang. In East Java, the supply comes from Pertamina WMO and Santos, while Pertamina EP supplies the Palembang area (MEMR, 2013).

The distribution of converter kits for public vehicles and official fleets further supported the shift to using natural gas as a fuel source. In 2011, 500 units were distributed in Greater Jakarta and Palembang. This distribution expanded significantly, with 1,000 units delivered to Greater Jakarta, Surabaya, and Palembang in 2012 and 2,000 units in 2013 (MEMR, 2013). Since its introduction as an alternative low-emission vehicle fuel, the use of CNG increased from 1,159 TJ¹⁷ in 2011 to 2,349 TJ in 2012. It then fluctuated between 1,300 TJ and 1,500 TJ from 2014 to 2019. However, CNG consumption dropped to 983 TJ in 2022 following the pandemic (IEA, 2023b).

Despite the high natural gas production, its use in domestic transportation remains limited. In Indonesia, natural gas utilisation in 2022 was predominantly in the industrial sector, accounting for 69.06%, with non-energy use making up 29.73%. In contrast, the transportation sector accounted for only 0.14% of natural gas use (IEA, 2023b). The limited adoption of CNG in the transportation sector is primarily hindered by three main obstacles: unclear government regulations, insufficient infrastructure, and significant

¹⁷ TJ refers to terajoule

price differences between petrol and gas (Putra, Y.M.P., 2013). As of 2024, Indonesia has only 72 gas refuelling stations and mobile refuelling units (MRUs). This situation highlights a lack of government support for developing natural gas in the transportation sector, as noted by Panolih and Baskara (2020):

"The development of the number and management status of CNG refuelling station and mobile refuelling unit in the capital city, to some extent, reflects the government's weak commitment to promoting the use of natural gas for transportation. National-level data also indicates that the government's efforts to adopt this energy source widely are still suboptimal." (Panolih and Baskara, 2020)

The low market interest in private vehicles using CNG has resulted in a lack of automotive manufacturers willing to produce CNG-fuelled vehicles. Energy regime policies that favour biodiesel as an alternative fuel have also hindered the adoption of CNG. Moreover, the emergence of EVs has further decreased the uptake of CNG in this sector.

4.4.4 Decarbonisation through Electric Vehicle Diffusion

A key initiative for decarbonising the transport sector was the shift from internal combustion engine vehicles (ICEVs) to electric vehicles (EVs). The rebirth of EVs globally has been greatly influenced by advancements in lithium-ion battery technology, mainly through enhanced capacity that increases EV range and reduces costs (Zhuge et al., 2021). China began its transition to EVs in the early 2000s through substantial investment in battery production and strong government support through subsidies (Kalthaus and Sun, 2021; Zhuge et al., 2021). Developed countries like Germany and the United States are pursuing electrification for the energy transition. In 2004, Germany reduced taxes for low-emission vehicles, including Hybrid Electric Vehicles (HEVs), based on CO₂ emissions. The U.S. followed with the Energy Policy Act of 2005, providing advanced vehicle credits for HEVs (IEA, 2024a).

The mass adoption of EVs was introduced in the market with the launch of the Tesla Roadster in 2008, followed by the introduction of the Nissan Leaf in 2010. Subsequently, governments in major regions, such as the EU, the US, and Japan, promoted the socio-technical transition to EVs by implementing subsidies, offering incentives, and tightening emission policies. The 2020s have seen high EV penetration rates in countries like Norway, Germany, and the Netherlands, establishing the EU as the global leader in the transition to EVs (IEA, 2024a).

In the 2010s, several emerging economies, particularly China, introduced strict policies to encourage EV adoption (Kalthaus and Sun, 2021; Zhuge et al., 2021). This strong government support has allowed companies like BYD and NIO to dominate the EV market since 2019. Meanwhile, India has promoted electric two-wheelers and e-rickshaws as part of its decarbonisation efforts since 2013. Furthermore, India launched the FAME I program in 2015 to offer subsidies for HEVs and Battery Electric Vehicles (BEVs) based on battery capacity and vehicle efficiency. This program was replaced by FAME II in 2019, which focused primarily on transitioning to Battery Electric Vehicles (BEVs). Some limited EVs have emerged in some parts of Latin America, Asia, and Africa; however, these emerging markets face challenges due to high upfront purchase prices and limited charging infrastructure (IEA, 2024a).

While the adoption of EVs was spreading globally, Indonesia was experiencing a slower transition than other countries. The EV diffusion for Indonesian public highlights the socio-technical transition of new emerging clean alternative vehicle fuel. Since 2012, the government has encouraged research into EV technology. In 2013, an Indonesian-made EV prototype was introduced through a collaboration between universities and state-owned enterprises. However, the further development of this prototype has been hindered by a lack of clear regulations and insufficient financial support (Fakhriansyah, 2023).

One respondent noted that a key factor hindering niche innovations in EVs was the automotive market leaders' lobbying network, which ultimately influenced the government to shift toward biofuels.

"From 2015 to 2017, the [lobby network of automotive market leaders] unified to oppose EV adoption. As a result, they were seeking to survive by transitioning to biofuels" (Interviewee 18, NGO).

The global trend of EVs gained momentum through news and social media, particularly following Tesla's mass production. This green transition inspired a small group of Indonesians to import and test the EVs. These early adopters subsequently formed enthusiast groups to share their experiences with EV operation and troubleshooting. The exchange of EV-related experiences on social media became an indirect pathway to promote the benefits of EVs in the late 2010s (Sasongko et al., 2022).

As the number of EVs grew, the energy industry noticed the potential for new business opportunities. Unlike the E4W, which still depends on technology from global brands, electrification has fostered collaborative research and niche innovations in the E2W sector among automotive manufacturers, universities, suppliers, and the government. Between 2017 and 2019, local brands like Viar and Gesits emerged as pioneers of

Indonesia's commercial electric motorbike market. Following the issuance of Presidential Regulation No. 55/2019 and the provisions for limited subsidies tied to a minimum local content requirement since 2023, a growing number of local manufacturing brands have entered the E2W sector (Deloitte and Foundry, 2023; BCG and AEML, 2022).

The government has implemented fiscal and non-fiscal incentives to encourage transport providers and infrastructure developers to promote EV adoption. EVs have been introduced through the transition of fleets used by TransJakarta BRT, ride-hailing, and taxis. With growing public interest, PLN has partnered with various energy companies, including Pertamina and Shell, to expand the charging point infrastructures. Additionally, several companies have established battery swap networks by directly adopting foreign systems, such as Gogoro from Taiwan, and developing local innovations like Swap Energi and Volta (Deloitte and Foundry, 2023; BCG and AEML, 2022).

Furthermore, from a financial perspective, EVs provide lower charging costs than petrol (Saputra et al., 2023). While electricity generation in Indonesia primarily relies on coal, the shift toward electrification has allowed for the inclusion of renewable energy sources in the transportation sector's energy mix (Maghfiroh et al., 2021). Additionally, the public was becoming more aware of the lower operational and maintenance costs associated with this eco-friendly mode of transport (Novizayanti et al., 2021).

The evolving niche innovation has fostered the adoption of EVs. In addition to targeting private vehicle users in urban areas, EV manufacturers were also cultivating niche green markets in remote areas where petrol filling stations were inadequate. In 2017, only 32 electric two-wheelers (E2W) were registered in the country. However, by 2024, the population has expanded significantly to include 160,578 units of E2W and 34,504 units of electric four-wheelers (E4W) (Deloitte and Foundry, 2023; Agustiar, 2024; Abdurrahman, 2025).

Despite the growing population of EVs, many people were still deterred by the high upfront purchase prices (Sasongko et al., 2022) and the inadequate charging stations and battery swapping stations (Setiawan, A.D. et al., 2022). The incumbent automotive manufacturers have attempted to address these challenges by introducing hybrid electric vehicles (HEVs) while favouring ICEVs (Sasongko et al., 2024). In 2024, 127,243 electric hybrids (HEVs) were on the market, almost comparable to the popularity of E2Ws (Deloitte and Foundry, 2023; Agustiar, 2024; Abdurrahman, 2025). However, the government has not enhanced regulatory support for HEVs as a transitional approach towards electrification as stated by a secondary data:

“Cars with hybrid technology are expected to be in higher demand if the government provides subsidies. Additionally, they are considered to support

reducing emissions. Unfortunately, in its efforts to transition to an electrification era, the government has not recognized hybrids as a goal." (Putra, D.L.E., 2024)

Another challenge the State faces in increasing the adoption of EVs is the lack of public awareness regarding sustainability (Sasongko et al., 2024). Additionally, several stakeholders have underlined the importance of using clean energy sources for EV charging. For instance, one respondent noted, "Our movement demands that there be no new investments in coal-fired or dirty fuels power plants" (Interviewee 18, NGO).

4.5 Key Events and Institutional Policy Changes on Indonesian Transportation Energy Sustainability

The previous sections describe the historical evolution of the transport energy regime in Indonesia, focusing on the pressures and opportunities shaped by the socio-technical landscape that has led to the development of sustainable transport energy technologies. This section highlights the dynamics of key events in the socio-technical landscape — such as energy crises, political turbulence, fiscal depressions, trade disputes, and environmental initiatives—that have profoundly impacted institutional changes within the transport energy regime. These key events are analysed to identify critical junctures that can lead to either continuity or change and to determine the nature of the institutional changes required to respond to these pressures. Additionally, this section discusses the policies adopted within the energy regime that have fostered the emergence of niche innovation path dependencies to achieve sustainability in the transport sector.

The energy development of Indonesia's transport sector can be traced back to the Dutch colonial era, marked by significant state involvement and complementary relationships between the government and private companies. Coal production was the dominant energy source during this time, particularly for rail-based transport. Alongside advancements in oil-fuelled vehicle technology, there was also exploration and production of petroleum. This early period saw an increase in coal and petroleum production capacity, reflecting the growing energy demand.

In the first stage, the critical juncture for energy institutions in Indonesia's transportation sector emerged after the country gained independence in 1945. The end of Japanese occupation and Dutch colonisation allowed the Soekarno government to establish initial institutions in this sector. During Soekarno's presidency, the growing desire for independent management of natural resources across parts of Asia, America, and Africa significantly influenced the socio-technical landscape. This dynamic led to institutional change characterised by the 'displacement' of Dutch colonial energy and transport

companies through nationalisation, reflecting a prolonged process of endogenous change. As a result, the socio-technical regime established several state-owned enterprises to oversee the production and utilisation of energy in this sector, a trend that continued until the 1960s.

Following the critical juncture of independence, the Indonesian energy sector experienced path dependence and incremental change, primarily driven by the state's focus on energy security and the need to increase production capacity. Energy sources were still predominantly based on fossil fuels, especially coal, with oil also playing a significant role. This reliance has created a path dependence in the energy regime. Increased mobility and electricity demand have led to a rise in coal production.

In the 1950s, the dieselisation became widespread across Asia, including Indonesia. The niche innovation of diesel locomotives resulted in a shift through layering the institutional regime. During this period, diesel locomotives were introduced, while steam trains remained in widespread use. The intensification of oil exploration and production made Indonesia a member of OPEC in 1962. At the global level, the UN General Assembly adopted Resolution No. 1803 (XVII) of 1963 on Permanent Sovereignty over Natural Resources. This resolution aligned with the Soekarno regime's guided economic policies, which emphasised state control over natural resources. During this socio-technical regime, the private sector was positioned to complement and support the state's objectives.

In 1965, political upheaval led to an economic downturn. By the late 1960s, Soeharto emerged as the new energy regime leader, aiming to restore economic conditions through the production and export of natural resources, mainly petroleum. Domestic events and the NIEO Declaration in 1974 became critical junctures that influenced the socio-technical landscape and prompted institutional change in energy regime policies. The Soeharto government shifted from the nationalistic approach of the previous regime by inviting foreign investment to boost energy production.

Global agendas, such as the 1970s oil crisis (Leal Filho et al., 2021), have prompted countries to seek alternatives to petroleum. These exogenous changes have promoted awareness of the necessity of diversifying energy sources, particularly in Indonesia's transportation sector landscape. The government has implemented policies that mark a milestone in developing other energy sources with substantial potential reserves, such as geothermal energy and natural gas. The institutional shift in the socio-technical regime through layering has prompted several companies to pursue niche innovations in the exploration, exploitation, and production of natural gas in North Aceh and East Kalimantan. Additionally, progress has been made in geothermal development as part

of these niche innovations. Meanwhile, the government has continued to exploit substantial coal deposits to enhance energy security.

In the second stage, ongoing development has stimulated economic activity and raised per capita income. This improvement in living standards and population growth has increased the demand for mobility support. Changes in the socio-technical landscape have influenced institutional change in the transport energy regime, leading to a shift in infrastructure development towards road-based systems, away from the previous reliance on railways.

The shift in infrastructure development orientation was not backed by effective planning for adequate public transport, regulations to limit private vehicle ownership and control over urbanisation. As a result, these factors have altered the socio-technical landscape, leading the public to prefer private vehicles and increasingly abandon public transport. The rising number of private vehicles, mainly motorcycles and cars, not balanced by the growth in road capacity, has resulted in congestion in urban areas. This increase in congestion, leading to energy waste, has exerted an incremental endogenous influence, prompting the government to import oil to compensate for the decline in domestic production. Furthermore, the congestion has contributed to air and noise pollution, negatively impacting environmental quality.

Several global agendas have emerged at this stage, highlighting the importance of sustainable development. Global events and domestic issues marked by energy waste and rising pollution levels have transformed the landscape and significantly influenced the institutionalisation of Indonesia's energy policies. These global events have become critical junctures that have prompted the government to balance national energy production growth, particularly in coal, natural gas, and oil, with environmental conservation efforts. Presidential Decree No. 46/1980 regarding Bakoren marked the beginning of the development of renewable energy sources in the national energy mix. Additionally, the government promoted environmental preservation through Law No. 4/1982. The implementation of this law was further detailed in the Environmental Impact Assessment (EIA) requirement established by Government Regulation No. 29/1986. During this stage, niche innovations in the geothermal energy sector began to transition into the commercialisation phase. Coupled with the increase in hydropower capacity to enhance the renewable energy mix. Furthermore, the government introduced mandatory policies in the transportation sector to set threshold levels for exhaust emissions and noise to minimise environmental pollution.

The development of policies in the transportation energy sector during the second stage was influenced by incremental exogenous influences. These exogenous influences

stemmed from a combination of global agendas emerging from various international environmental conferences. The Indonesian government incorporated the global agreement on sustainable development into its national policies. In 2004, the government ratified the Kyoto Protocol through Law No. 17/2004 and made a fourth amendment to the Indonesian Constitution. This constitutional change paved the way for new institutional arrangements in Indonesia's future development, emphasising the principles of sustainability and environmental awareness.

The third stage involved developing institutional policies to promote energy diversification as a crucial measure to ensure energy security and sustainability. Endogenous influences prompted institutional changes as fuel consumption exceeded domestic production capacity, requiring the government to provide higher subsidies. Additionally, exogenous influences related to the oil crisis of the 2000s worsened oil subsidy overruns. The evolving socio-technical landscape has reached a critical juncture in shaping energy regime policies, highlighting the necessity of a framework that supports sustainable public transportation and initiatives for affordable, clean alternative fuels.

The global success of BRT as an efficient urban transport system has inspired the Indonesian government. Exogenous influences have played a significant role in shaping the development of BRT institutions, which take a socio-technical approach to creating adequate infrastructure and providing subsidies that ensure affordability for all segments of society. In 2004, the socio-technical regime launched the TransJakarta BRT service, marking a significant milestone in providing efficient public transportation. This initiative aimed to address energy waste and reduce air pollution. By implementing dedicated lanes and supporting microbus feeder services, the system effectively met consumer needs for punctuality, safety, comfort, and accessibility to various socio-economic activity centres. Additionally, local government subsidies and niche innovative fare systems have further improved the affordability of public transportation in this urban area.

The socio-technical landscape of urban-centric development requires more than just improved road public transportation. There was also a necessity to revitalize rail-based transportation to support urban areas through commuter lines, MRT, and LRT systems. 2008 marked the establishment of institutions to restore commuter line electric train services. Alongside enhancing the physical infrastructure and train quality, e-ticketing systems and passenger capacity restrictions have been introduced to improve public discipline. Additionally, the construction of MRT and LRT, which began operations in 2019 and was supported by integrating the JakLinkGo feeder service, has become a key event in Indonesia's TOD development.

Continued institutional and policy developments characterised the third stage to encourage diversification by creating environmentally friendly vehicle fuels, particularly biofuels. The evolution of the socio-technical landscape surrounding global biofuel development, particularly the successful ethanol programs in Brazil and biodiesel initiatives in Argentina, has influenced the formulation of Indonesian government policy. The Indonesian government established the Timnas BBN in 2006 to facilitate the rapid adoption and implementation of biofuels. This organisation was responsible for compiling the National Energy Policy, a comprehensive biofuel development blueprint. This blueprint addresses various aspects, including land allocation for cultivation, industry involvement, private sector participation, and fiscal policies. Additionally, the government has implemented quality standards for biodiesel and bioethanol products in Indonesia. With the support of these institutions and cross-sectoral policies, Indonesia's biofuel industry was beginning to develop.

The Indonesian government was capitalising on the growing global demand for biofuels, particularly from the EU. Through its Renewable Energy Directive, the EU mandates a requirement for 10% of renewable sources to be included in transportation fuels. To support this, the establishment of the RSPO introduced a certification system for palm oil products, including biofuels. While the RSPO initiative promotes sustainability, its implementation in the Indonesian palm oil sector has led to sudden institutional changes. Most Indonesian biofuel companies comply with the RSPO system to access global markets, but these changes can sometimes undermine existing Indonesian regulations.

In the third stage, I argue that endogenous influences prompted the government to create sustainable institutions by publishing the ISPO national biofuel certification policy, demonstrating Indonesia's authority and institutional capacity in managing policies related to superior alternative fuel commodities. The growth of downstream biofuel as an alternative vehicle fuel is expected to increase oil palm production and enhance Indonesia's presence in global markets. During this stage, exogenous influences played a significant role, particularly in campaigns by environmental NGOs and trade actions by developed countries that highlighted unsustainable practices among Indonesian palm oil companies. These external pressures have motivated the Indonesian government to reaffirm its commitment to sustainability in the downstream biofuel sector. This commitment was reflected in sustainable biofuel management agreements with Norway. Additionally, the influence of external factors has led to the establishment of a domestic market through mandatory policies requiring biofuels in the transportation, industrial, and power generation sectors in 2015. Furthermore, the establishment of the BPDPKS institution has fostered mutual collaboration between the State and the private sector in providing incentive mechanisms to ensure biodiesel remains competitive in the domestic

green market. The mandatory biodiesel policy and incentive mechanisms have established a path dependence for developing niche innovations in alternative vehicle fuel in Indonesia.

As a natural gas producer, Indonesia has implemented a fuel-switching program promoting the utilisation of CNG, reducing GHG emissions. The widespread adoption of CNG has received substantial government support in countries such as Iran, Pakistan, China, Argentina, India, and Brazil, and this success has inspired other nations. In Indonesia, the institutionalisation of CNG usage in transportation was guided by Decree No. 247/2011, issued by the Director-General of Oil and Gas. In 2014, the State initiated fuel-switching by appointing Pertamina and PGN to manage the supply and distribution infrastructure for CNG. In 2017, the State encouraged the private sector to innovate in CNG transport applications, including its utilisation in TransJakarta's BRT system, taxis, and motorised rickshaws. Despite Indonesia's relatively high natural gas production, the CNG fuel-switching program has been limited to public transportation.

The global EV trend gained significant attention after the launch of the Tesla Roadster in 2008 and the Nissan Leaf in 2010, which has influenced the Indonesian public. Although research on developing locally made EV prototypes began as early as 2012, intensive niche innovations primarily occurred between 2017 and 2019. The socio-technical landscape's pressures, along with these niche innovations, prompted the government to enact Presidential Regulation No. 55/2019 to support EV adoption. The government also promoted EVs by transitioning its official fleet, followed by TransJakarta BRT, ride-hailing services, and taxis. Furthermore, it has provided fiscal and non-fiscal incentives to the private sector to encourage EV manufacturing and the development of charging infrastructure. However, the notable growth in the EV population was only observed following the implementation of limited subsidies in 2023.

4.6 Discussion

This chapter explores the historical evolution of institutional development in Indonesia's transport sector's energy sustainability, focusing on the interactions between socio-technical institutions. The study utilised a combination of historical institutionalism and a multi-level perspective to analyse how multiple interactions drive change while maintaining institutional stability. It also examined how critical junctures, path dependencies, and incremental changes have shaped state involvement in the transport energy sector. Additionally, the research analysed the relationship between the state and industry-specific companies, assessing their influence on transforming energy policy towards sustainable development.

The institutional framework of Indonesia's energy transport sector originated in the colonial era's legacy. During this time, the sector's energy institutions included the Dutch colonial ruler, who acted as the State's representative in the transport sector energy and a collaborative relationship between the State and private companies. During the colonial period, the state played a significant role in coal production, electricity generation, and railway services, while the private sector was more prominently involved in oil production and road-based transport services. Despite this complementary relationship, the strategic importance of Indonesia's energy sector to the Dutch economy prompted the Dutch colonial government to adopt an interventionist approach. This was evident when the government-imposed restrictions on private-sector involvement, prioritising Dutch companies' participation in the oil industry. As a result, coal and petroleum production capacity increased during this period of colonisation, reflecting the growing demand for energy to support mobility.

Indonesia's independence in 1945 marked a critical juncture in the country's energy transport sector. Since 1945, Indonesia's transport energy institutions have undergone various phases of stability and change from the post-independence era to the present. Our findings highlight the transformation of the socio-technical landscape during the post-World War II period, shaped by decolonisation movements, geopolitical shifts, and post-war recovery. These socio-technical landscape dynamics shape the orientation of the early socio-technical regime. Motivated by a strong sense of nationalism, Indonesia's first president, Soekarno, initiated the nationalising of the transportation and energy institutions established during the Dutch colonial era. This institutional displacement involved replacing control of colonial railway, bus, and truck companies with state-owned enterprises.

In the 1950s, this nationalisation continued, and the socio-technical regime also took control over primary energy resources such as coal and petroleum. The nationalisation process, which took nearly two decades to complete, strengthened the State's involvement in the transport energy sector. As a result, this sector was recognised as a significant area of strategic interest and priority for the State. The State's significant involvement in this sector has positioned the private sector to complement and advance the State's objectives.

Our findings indicate that after gaining independence, Indonesia's transport energy institutions have exhibited path dependency, characterised by gradual increments primarily driven by state interests and priorities. The socio-technical regime observed during this period has adopted a path of dependence on fossil fuels to ensure the sector's energy security. A significant layering transition has occurred, shifting from an initial reliance on coal to a greater dependence on petroleum since the 1950s. This change

can be attributed to the evolution of the landscape and the niche innovation of diesel locomotives. Although coal and oil production increased during the Soekarno period, overall conditions were less favourable for development. This unfavourable socio-technical landscape was primarily due to the regime's focus on a guided economic system and concerns about defence and territorial issues.

The country's reliance on fossil fuels persisted throughout the Soeharto era, as oil production and exports were used to fund national development. However, during this socio-technical regime, there was a notable shift in resource management policies, which included inviting foreign investment. The abundance of Indonesia's fossil fuel reserves has placed the country's energy diversification agenda, including developing renewable energy, particularly from the energy security perspective.

The global oil crisis of the 1970s and the increase of foreign investment became a critical juncture, mainly triggering the State's awareness of the necessity to diversify energy sources. In addition, diversification has also been aimed at anticipating the depletion of petroleum reserves. The State implemented institutional changes to explore and exploit geothermal energy as a renewable source, recognizing its potential reserves through the assignment of Pertamina. While there was an emerging awareness of renewable energy sources, the regime continued to rely heavily on fossil fuels. This dependence was further entrenched by increasing coal production capacity. Additionally, the state has attracted investment from several foreign companies through the Production Sharing Contract scheme to enhance natural gas production.

The findings highlight that the socio-technical landscape has evolved due to several global sustainability agendas established during the 1980s and 1990s, which influenced the development of environmental policies at the national level. These global sustainability initiatives included the Brundtland Report in 1987, Agenda 21 in 1992, and the Kyoto Protocol 1997. As a result of adopting these global agendas, significant changes occurred within the socio-technical regime, exemplified by the enactment of Act No. 4/1982 on Basic Provisions for Environmental Management, Act No. 23/1997 on Environmental Management, and the fourth amendment to the 1945 Constitution. Recent events have created critical junctures to align policies for increasing energy production with environmental preservation through developing renewable energy sources, particularly geothermal and hydropower.

From the 1980s to the 1990s, urban-centred development led to population growth and economic improvement, but urbanisation was not effectively managed. Moreover, there was a shift in transport infrastructure development from rail-based systems to road-based systems. This focus on road transportation has promoted an increase in private

vehicle use, which has not been matched with adequate road infrastructure planning and improvements in public transport capacity. As a result, congestion has become a significant issue. Despite the government ratifying various global sustainability initiatives into national environmental policies, enforcing fuel efficiency measures and emission restrictions remains ineffective. The research confirms that population growth in emerging economies, when not paired with proper transportation infrastructure planning, uncontrolled urbanisation, and effective enforcement of vehicle emission regulations, has resulted in congestion and increased pollution (OECD/IEA, 2015).

Since 2005, Indonesia has been facing an energy trilemma that presents challenges in balancing the three main dimensions of energy policy: energy security, environmental sustainability, and energy equity/affordability. This challenge was characterised by the transition to becoming a net oil importer and the oil crisis of the 2000s, which has placed a significant burden on the country's finances due to fuel subsidies. The analysis aligns with literature that fossil fuel subsidies have promoted over-consumption, leading to congestion that worsens climate change mitigation (Gunningham, 2013; Skovgaard and van Asselt, 2019). Additionally, Indonesia has started to face a current account deficit. Changes in the socio-technical landscape, driven by internal and external factors, have led the State to implement energy diversification policies. Energy diversification policies, particularly in the transportation sector, are aimed at finding a solution by balancing supply security (through the diffusion of biofuels and EVs), energy affordability (by maintaining fuel subsidies for vulnerable communities), and sustainability (through new and renewable energy policies). However, the trade-off between these three aspects remains a key energy policy issue for Indonesia to this day (Gunningham, 2013; Setyowati, 2020; Wibisono et al., 2023). The analysis reveals that the State's aim for resource diversification was primarily motivated by concerns over improving energy affordability and security. However, the regulatory enforcements related to climate change, emissions, and other environmental issues still requires greater attention from stakeholders.

The dynamics of the socio-technical landscape, shaped by various crises such as the oil crisis, trade disputes, current account deficits, political turmoil, and global sustainability agenda, have significantly impacted the transportation energy regime. Additionally, technological advancements in mass public transportation—including BRT, commuter line trains, MRT, and LRT—and the development of clean alternative fuels like biofuels, CNG, and EVs have contributed to the emergence of niche innovations. As these innovations aligned and stabilised, particularly with a substantial focus on BRT and biodiesel, their improved performance and economic viability led the government to introduce fiscal and non-fiscal regulations to support their growth. In the third phase,

especially during the 2010s, these niche innovations took advantage of ‘windows of opportunity’, triggering adjustments within the socio-technical system.

The third phase has become crucial in transitioning to affordable and clean transportation energy in Indonesia. The increasing fuel subsidies, primarily benefiting private vehicle owners, have led the government to reformulate the socio-technical framework for mass public transportation. Seeking inspiration from successful implementations of BRT, which was first introduced in Curitiba, Brazil, in 1974 and later expanded to the Americas in the 1990s and Asia in the late 1990s, the government was formulating strategic mass public transportation policies.

The Jakarta Governor's Decree No. 110/2003 institutionalised the management of the Transjakarta BRT system, marking a significant milestone in developing a mass transportation system. This policy has encouraged niche innovation practices implemented by BP TransJakarta since 2004, including the construction of dedicated lanes, the provision of appropriate vehicles, the improvement of ticketing systems, and integration with micro feeders and other modes of public transportation. These niche innovations have transformed Indonesia's public transportation system from a state of degressive to a punctual, safe, comfortable, and affordable one. Furthermore, BRT TransJakarta serves as a hub for various modes of transportation, enhancing spatial value and improving accessibility, catalysing the development of Transit-Oriented Development (TOD).

After decades of neglect, rail-based transportation institutions have begun revitalisation in phase 3. Law 23/2007 has institutionalised railway restoration efforts with a focus on improving service quality and safety. Our findings highlight PT KAI's innovative approach to managing commuter line passengers through a socio-technical strategy, which has increased public interest in this mode of public transportation. Additionally, improvements in commuter line services have been supported by infrastructure expansion, carriages' modernisation, and ticketing system enhancements. According to secondary sources, Indonesia's railway system was restored under Jonan's leadership at PT KAI from 2009 to 2014; as Siswanto (2024) reported, “Mr. Jonan performed the first transformation, reorganising the previously chaotic and unregulated railway culture. This [approach] marked the beginning of the transformation” (Siswanto, 2024).

The government has also focused on expanding rail-based services by developing MRT (Mass Rapid Transit) and LRT (Light Rail Transit) systems. While these modes effectively enhance public transportation capacity and services, our study indicates that the construction of MRT and LRT infrastructure has faced significant delays. The MRT and LRT systems were institutionalised through Presidential Regulation No. 03/2016,

which aimed to accelerate national strategic projects, including MRT and LRT developments. This policy was further supported by Presidential Regulation No. 65/2016, which focused on implementing an integrated LRT system in the Jakarta, Bogor, Depok, and Bekasi areas. Consequently, the construction of the MRT began in 2015, while the LRT construction commenced in 2019. Analyses of secondary sources indicate that Indonesia continues to face significant challenges in implementing public transport policies such as the MRT and LRT. These challenges include critical issues related to inter-agency coordination, infrastructure funding, and the necessity of managing rapid urban growth (BPPT, 2018; Ilham, 2024).

Our research identified several factors hindering mass transportation advancement in Indonesia, including the absence of emission control zone regulations. Furthermore, there are no access restriction policies or tax disincentives for private vehicle ownership. Our findings align with secondary data regarding barriers to public transportation development in developing countries, including the lack of emission zones and the absence of policies limiting access or tax disincentives for private vehicle ownership (Alves et al., 2023).

Our study also analyses how the State has made institutional changes through 'layering' by simultaneously developing alternative fuels to address the energy trilemma. The effectiveness of the *Pró-Álcool* program in promoting ethanol development in Brazil and implementing mandatory biodiesel policies in Argentina has transformed the socio-technical landscape. This shift has encouraged the State to institutionalise biofuel development. The institutional framework for biofuels in Indonesia took a significant turn with the implementation of Presidential Instruction No. 1/2006. Initially, the government identified three types of crops as potential raw materials for biofuel: palm oil, jatropha, and sugar cane. The biofuels initiative was followed by a policy that mandated a 2.5% biodiesel content in fuel oil mixtures beginning in 2008. The 2009 Renewable Energy Directive expanded the EU biodiesel market, creating opportunities for Indonesian palm oil companies to develop niche innovations that add value to their existing operations. These institutional developments have become critical junctures for advancing biodiesel in Indonesia.

Our findings indicate that the proliferation of biodiesel production in Indonesia is closely linked to several issues related to sustainability, environmental concerns, and trade disputes. The RSPO certification, which represents the interests of diverse stakeholders, has raised concerns regarding the environmental and social impacts of Indonesia's palm oil industry. The introduction of sustainability certification systems, such as the RSPO and other non-governmental mechanisms, has disrupted existing institutions. While Indonesian enterprises can use this certification to access global markets, many small

and medium-sized entrepreneurs believe the costs of meeting certification requirements are too prohibitive. This tension has prompted the government to implement the ISPO certification system to showcase its ability to regulate the domestic sector. This institutional change in palm oil sustainability occurred through a 'conversion' process, presenting that not all institutions were changed entirely but instead redirected towards new goals and rules (Lockwood et al., 2017). Despite implementing ISPO to demonstrate its commitment to sustainability, our findings align with secondary sources, indicating that international NGOs and global markets remain sceptical (Astari et al., 2025; Choiruzzad et al., 2021).

The emergence of obstacles to Indonesian biodiesel in several export markets has resulted in socio-technical landscape changes, prompting the government to implement policies to absorb production into the domestic market. Our findings align with recent literature highlighting the essence of MEMR Regulation No. 12/2015 on mandatory biodiesel use policies, particularly in the transport sector, and establishing incentive mechanisms through the BPDPKS to develop the domestic market since 2015 (Farobie and Hartulistiyo, 2022; BPPT, 2018).

The stability of biodiesel institutions in Indonesia has been bolstered by the shared interests of various stakeholders, including the government, palm oil companies, oil companies, and ICEV manufacturers. Additionally, the availability of incentive mechanisms derived from export profits has supported maintaining biodiesel's competitiveness compared to traditional petroleum fuels (Farobie and Hartulistiyo, 2022). These institutional developments represent critical junctures that encourage the industry to capitalize on 'windows of opportunity' for expanding domestic market penetration. These niche innovations were crucial in the gradual increase in biodiesel production, which reached the B40 composition level by 2025. The government's focus on biodiesel has created a path of dependence on developing alternative fuels in Indonesia (Astari et al., 2025).

Our findings indicate that, despite adequate natural gas production, institutional support has failed to promote the widespread adoption of CNG in Indonesia's transport sector. The success of CNG usage in countries like Iran and Pakistan has faced challenges due to technical issues during the initial implementation phase, which have delayed the conversion of conventional vehicles to CNG. Consequently, private vehicle owners in Indonesia have lost interest and moved away from CNG. Only public transport options, such as some BRT buses, taxis, and motorised rickshaws, continue to rely on CNG. Our study reinforces previous research showing that the growth of CNG use in public transport is still obstructed by the high costs investments associated with refuelling stations and distribution infrastructure (Igbojionu et al., 2019; Mitrică, 2023).

The advancement of battery technology and the mass production of the Tesla Roadster in 2008, followed by the Nissan Leaf in 2010, have significantly disrupted the socio-technical landscape of alternative fuel development. This global EV trend has influenced policy changes in developed countries and several emerging economies, especially China. Our study reveals that although the Indonesian government has focused on EV technology research since 2012, institutional development has lagged compared to other Southeast Asian countries. Significant obstacles to EV adoption in Indonesia, especially a lack of regulatory clarity and financial support, have kept the country reliant on biodiesel development.

Collaborative innovation among energy companies, EV manufacturers, and brand enthusiast groups has pressured the government to provide regulatory support. Through niche innovations from E2W, industries have leveraged 'windows of opportunity' that have prompted adjustments in socio-technical systems. The change in the transport energy regime orientation in 2019 led to the enactment of Presidential Regulation No. 55/2019, laying the institutional framework for introducing and diffusing EVs. This regulatory support has fostering niche innovations, particularly in the E2W sector. Our study aligns with existing literature that emphasises the crucial role of regulation, along with incentives and subsidy schemes (Abdul Qadir et al., 2024; Afraah et al., 2021; Singh, V. et al., 2021), in reducing the EVs high upfront costs. These incentives policies also include investments in EV manufacturing, green supplies, charging infrastructure, and battery swap systems. The reduction of financial barriers has encouraged the public to switch to EV (Costa et al., 2021; Lazuardy et al., 2024).

The diffusion of EVs in Indonesia, as an emerging economy, faces several challenges, including remarkably high upfront purchase prices and inadequate infrastructure. Furthermore, our findings align with recent research, indicating that the adoption of EVs in developing countries is hindered by a lack of public awareness regarding EV's financial and sustainability benefits. Although electricity generation in Indonesia is still primarily reliant on coal, the growth of EVs has begun to gain momentum since 2023, allowing for greater utilization of renewable energy in the transportation sector. Additionally, the transition to electrification will be more effective if the government implements fiscal and non-fiscal policies to support HEV users. These measures could lower investment barriers for infrastructure development and also help reduce GHG emissions compared to ICEVs (IEA, 2024a; Dutt, 2023; Shamsuddoha and Nasir, 2025).

The energy transition in Indonesia's transportation sector has experienced significant changes due to the evolving global socio-technical landscape. This evolution has led to the development of institutional changes that provide both fiscal and non-fiscal regulatory

support, which, in turn, promotes niche innovations aimed at increasing the use of low-emission fuels. These environmentally friendly fuels include biofuels, CNG, and other NRE sources in the final energy consumption. Our findings highlight that the advancements in low-emission fuels benefit the transportation sector and contribute to the decarbonisation of other sectors, particularly electricity generation, industrial, and commercial. Therefore, the energy transition within the transportation sector can become a crucial component of sustainable development across Indonesia, assisting to achieve the NZE target. Our findings also reinforce recent literature that underscores the importance of government consistency, especially in emerging countries, in promoting sustainable policies across the entire life cycle of providing affordable and clean vehicle fuel (Xia and Li, 2022; Gulcimen et al., 2021).

4.7 Conclusion

This research stage utilises a historical institutionalist approach to address sub-research question 1, which investigates how multi-level interactions create critical junctures that influence the institutional dynamics of the socio-technical transition toward sustainability in Indonesia's transportation sector. The adoption of historical institutional approaches supports the analysis of the development of stability and institutional change. By utilising the MLP framework to analyse critical junctures, path dependencies, and incremental changes over various periods, this research stage argues that the historical development of the socio-technical landscape has shaped the evolution of national environmental policy institutions, particularly within the transport energy regime. Additionally, this stage focuses on examining the role of the State in formulating key policies that facilitate socio-technical energy transitions. It analyses how changes in institutional regimes formulate regulatory supports for industries to promote niche innovations in affordable and clean fuels for sustainable development.

The evidence presented in this study indicates that the formulation and implementation of institutional arrangements occur over time and involve a combination of exogenous and endogenous influences. Firstly, this study categorises the evolution of the energy transition, shifting from a reliance on fossil fuels (first and second phases) to utilising more environmentally friendly fuels (third phase), based on the dynamic periodisation of the socio-technical landscape. Secondly, several global agendas, trade issues, advancements in environmentally friendly technologies and mass public transportation—such as the Brundtland Report, Kyoto Protocol, oil crises, NGO reports, trade disputes, Curitiba's BRT, biofuels advancement, and global EV trends,—serve as external factors that encourage the energy regime to develop new pathways. These pathways manifest

as national environmental regulations aimed at promoting the use of cleaner fuels. Lastly, endogenous institutional change occurs domestically, driven by the implementation of environmental regulations. These regulatory supports were prompting industries to pursue niche innovations in alternative vehicle fuels, particularly biodiesel, especially in response to current account deficits and to achieve NZE targets.

The research also indicates that emerging economies, such as Brazil, Argentina, and several Southeast Asian countries, have pursued different pathways to advance low-emission fuels, especially biofuels. Brazil has successfully developed ethanol from sugar cane as its primary fuel source since 1978 through the *Pró-Álcool* initiative. In contrast, Argentina relies more on biodiesel, supported by its soybean industry, as an alternative to CNG dominance. Meanwhile, in Southeast Asia, Thailand is leading the way in adopting ethanol derived from sugarcane and cassava and utilising palm oil-based biodiesel for heavy-duty vehicles. The Philippines has chosen a sugarcane-based ethanol pathway and is beginning to optimise its coconut production capacity for biodiesel. Although Indonesia has made advancements with biodiesel, its sugarcane-based ethanol development is still in the limited trial phase (ERIA, 2021b; OECD, 2024).

This chapter concludes that both exogenous landscape factors and endogenous niche innovation factors influence the evolution of socio-technical regime institutional stability. These influences create a duality that affects how energy transition evolves over time (Thelen and Conran, 2016). The application of the MLP framework enhances our understanding of critical junctures and path dependencies, as well as how institutions reformulate policies to create new pathways. This understanding is crucial for dealing with emerging technologies and projecting the trajectory of technology in the future. The chapter demonstrates the mechanisms of institutional development in response to various changes that impact stability and the achievement of stakeholders' objectives.

Conducting comparative studies across different countries will provide further insights into the development of historical institutional theory and the MLP framework, particularly as they relate to emerging technologies and the future implementation of technology trajectories. The next chapter will focus on stakeholder analysis, exploring power dynamics and mapping stakeholders' influence on the institutional development of sustainable energy transport in Indonesia.

Chapter 5 Power Relations in the Socio-technical Transition to Sustainable Transport in Indonesia¹⁸

5.1 Introduction

The socio-technical transition towards sustainable transport in Indonesia involves more than just a technological shift with the introduction of biofuels and electric vehicles; it is fundamentally shaped by various power dynamics, competing narratives, and institutional politics. Allen (2004) conceptualises power not as a static possession but as a relational force, enacted through authority, coercion, inducement, persuasion, and negotiation across different spatial and social contexts. This perspective helps illustrate how various actors—such as multilevel governments, state-owned enterprises (SOEs), biofuel companies, electric firms, automotive manufacturers, infrastructure providers, and civil society organisations—exert influence over sustainability policies and the adoption of green technologies.

In parallel, Newell (2008) examines the concept of power within transnational political economies, highlighting how global institutions, multinational corporations, and other international entities use financial resources and normative frameworks to influence policy in emerging economies. Foucault's theories of power/knowledge, governmentality, and biopolitics (1977, 2008) further emphasise how discursive regimes—such as sustainable transport—become normalised and institutionalised, leading to both inclusion and exclusion in the energy transition.

Djarmika et al. (2024) present a multi-actor perspective on Indonesia's biodiesel development, revealing the power dynamics at play among government agencies, petroleum companies, large biofuel producers, and smallholder farmers. This interplay shapes a just transition by addressing issues related to biofuel mandates, local equity, and climate rhetoric.

Meanwhile, Indonesia's electric vehicle (EV) diffusion has become a widely discussed topic, highlighting the influence of alliances among the state, domestic elites, and global investors, particularly in the nickel and cobalt supply chain, which are essential materials for electric vehicle batteries. This situation has significant implications for the country's national electric vehicle strategy and policies aimed at localising the industry.

¹⁸ This empirical chapter will be submitted to the *International Journal of Sustainable Energy Planning and Management*.

In Indonesia, mandatory regulations and incentive schemes for biodiesel are designed to reduce reliance on fossil fuels while simultaneously supporting the palm oil industry (Farobie and Hartulistiwa, 2022). Moreover, the adoption of EVs has been encouraged through tax incentives, exemptions from luxury taxes, and limited local-content-based subsidies. These initiatives are often linked to strategies for nickel mining and battery processing, which involve collaborations between government entities and investors from China or Korea (IEA, 2024a).

Thus, the diffusion of biodiesel and EV innovations in Indonesia highlights the complex interactions between various stakeholders, including global actors, domestic elites, state agencies, smallholder farmers, technology firms, and civil society. The way these groups access policy-making processes, define sustainability, and shape incentives demonstrates how power is distributed, benefits are allocated, and certain groups may be marginalised.

This research phase examines the dynamics of Indonesia's ongoing transition to sustainable transportation in, with a focus on biofuels and EVs. Understanding the socio-technical transition requires a nuanced analysis of the power relations among various stakeholders. This study employs an integrated analytical framework that combines John Allen's (2003) relational concept of power, Michel Foucault's (1991) discursive and governmentality-focused approach, and Peter Newell's (2021) political economy critique. By using these frameworks together, the study reveals not only how power is exercised but also how it is legitimised, distributed, and contested within the context of energy policy and the diffusion of innovation.

This study utilises a qualitative approach to address the primary research question for this study stage on how does power contestation between global and local actors influences the development of sustainable transport policies in Indonesia? To facilitate addressing the main research question, this study is structured around the following sub-questions: (1) How does contestation of power between global and local actors manifest in the formulation of sustainable transport energy policies in Indonesia? (2) How are coalitions or alliances formed among these actors in the diffusion of biodiesel and EVs? (3) Which actors benefit the most from Indonesia's national policies on biodiesel and EVs? (4) Are there groups or communities that are marginalised or adversely affected by these transitions?

Primary data was gathered through semi-structured interviews with twenty-nine respondents, purposively selected to represent various stakeholders in the transportation sector. These stakeholders included government agencies, SOEs, the biofuel corporates, IPPs, automotive manufacturers, energy associations, NGOs,

smallholder farmers, research institutions, and media representatives. The interviews examined the interactions among these actors within collaborative innovation networks. Additionally, the interviews explored how power contests influence the development of eco-innovation policies, particularly in relation to biofuels and EVs. Additionally, secondary data were analysed from policy documents, company reports, academic studies, and NGO publications. This secondary data was viewed not only as factual information but also as discursive artefacts that reflect power, ideology, and institutional practices. The triangulation of interview results and documentary analysis enhanced the validity and reliability of the findings, providing a comprehensive understanding of how alliances, narratives, and competing interests affect the diffusion of eco-innovation in the Indonesian transportation sector.

5.2 Development of Low-Carbon Transportation in Indonesia

5.2.1 Diffusion of Alternative Vehicle Fuels in Indonesia

The diffusion of alternative vehicle fuels in Indonesia began with the introduction of biofuels in 2006, which has since focused predominantly on palm oil-based biodiesel. The government has prioritised palm oil as the primary raw material for biofuel due to its availability and abundance. The government prioritises palm oil as the primary biofuel feedstock due to its vital role in the economic contribution and its ability to adapt to various markets—food, oleochemical, and biofuel—depending on price and subsidies (Farobie and Hartulistiyoso, 2022; APROBI, 2022). This decision aimed to reduce dependence on fossil fuel imports and strengthen the influence of agribusiness elites connected to policymakers (Choiruzzad, 2019; Ichsan et al., 2025; Obidzinski et al., 2012). The flexible crop of palm oil allows for shifts between export markets and food production, enabling the government to use it as a tool for stabilising domestic politics and international trade during fluctuations in global oil prices and subsidy changes in the 2000s and beyond (Borras Jr et al., 2016; Dharmawan et al., 2021).

Prior to 2006, however, the discussion surrounding biodiesel in Indonesia was closely linked to the goal of empowering smallholder farmers and local communities, particularly in rural areas (Astari et al., 2025; Farobie and Hartulistiyoso, 2022; Dharmawan et al., 2021). The narrative of local empowerment, driven by the expansion of palm oil plantations, has fostered a society-centred power dynamic that originated during the Soeharto administration (1967-1998). The nucleus estate-smallholders program successfully integrated large-corporation-owned plantations with smallholder farmers, thereby supporting Indonesia's non-oil and gas exports. During this period, power was

diffused in a bottom-up method, emphasising the participation of local communities (Astari et al., 2025).

This form of power is characterised by the involvement of local communities in the development of small-scale biofuels. Non-governmental organisations (NGOs), research institutions, and international donor agencies collaborate to promote village bioenergy initiatives. During this time, biofuels are presented as a solution to energy decentralisation, particularly in rural areas or remote regions not connected to the state-owned electricity company network. Various initiatives to develop biofuel sources are conducted within a framework of local knowledge, which is recognised as a source of socio-technical authority. This framework positions local governments and rural communities as key players in the energy transition (Rumah Energi, 2020).

The current account deficit, driven by the gap between crude oil consumption and domestic production capacity, along with the spread of E1 biodiesel initiated by Argentina, has transformed the socio-technical landscape. These changes have paved the way for the emergence of a biofuels diffusion program. Biofuel initiatives in Indonesia have primarily emerged from community and NGO levels, often with support from international donors in the early 2000s. These community-centred initiatives aimed for village energy independence through small-scale biodiesel production utilising local vegetable oils (Caroko et al., 2011; Astari et al., 2025). In 2006, Presidential Instruction number 1 of 2006 marked a paradigm shift towards state-centred power. This shift involved the implementation of top-down policies that centralised power within the government (Ichsan et al., 2025; Astari et al., 2025).

The legitimacy of authority has increasingly shifted to technocrats and state institutions, framed by narratives emphasising energy efficiency, reducing oil imports, and decarbonisation. This technocratic approach has led to the marginalisation of local knowledge, particularly that of smallholder farmers, thereby depoliticising them. Key characteristics of this state-centred power include centralised authority, technocratic governance, and a focus on macroeconomic logic and energy geopolitics. Consequently, the allocation of resources has shifted away from smallholder farmers and local communities, consolidating power in the hands of large corporations, which in turn influences the direction of biofuels development policies (Ichsan et al., 2025; Kapriadi, 2019).

5.2.2 Power Shifts in the Socio-Technical Transition toward Sustainability

The evolution of power in the transportation sector, involving multiple actors across borders, is significantly influenced by globalisation. Globalisation has interconnected

various actors and networks, facilitating the flow of knowledge, finances, social interactions, and policy development. The interaction between the global sustainability agenda and the energy regime has led to both vertical and horizontal shifts. Several global agendas have shaped the formulation of national environmental policies, triggering vertical shifts. For example, the restriction of biofuels with a high risk of indirect land use change (ILUC), as emphasised by the European Union's Renewable Energy Directive II (RED II) (Doumax-Tagliavini and Sarasa, 2018; Kupzok, 2020). This EU policy has affected Indonesia's palm oil-based biodiesel exports, prompting the Indonesian government to adjust its policy to protect palm oil production by implementing a mandatory domestic biofuel use policy (Hasan et al., 2022; Astari et al., 2025). This policy aims not only to safeguard palm oil production but also to reduce petroleum imports (Farobie and Hartulistiyoso, 2022).

Additionally, the changing landscape has influenced local actors. Horizontal shifts have occurred through coordination between relevant ministries, and the palm oil funds management (BPDPKS) regarding incentive schemes designed to enhance the competitiveness of biofuels compared to fossil fuels. Furthermore, there has been ongoing debate over the distribution of palm oil subsidies, specifically whether the primary benefits should go to smallholder farmers or large corporations (Ichsan et al., 2025; Kapriadi, 2019). Additionally, the power dynamics underlying in the horizontal shifts of biofuel diffusion are evident in the ongoing debate over the choice between food and fuel, which involves horizontal negotiations among domestic stakeholders (Ichsan et al., 2025; Kapriadi, 2019).

A significant power shift had occurred due to disruptions from electrification and the rise of EVs. This trend was evident not only in the growing global adoption of EVs but also in the increasing pressure to achieve carbon neutrality by 2050 and the rising standards for Environmental, Social, and Governance (ESG) investments. These factors have prompted vertical shifts in the domestic landscape, encouraging the transportation sector—previously reluctant to embrace EVs—to facilitate their adoption.

In response to these global sustainability norms that influence national policy, the regime has issued Presidential Regulation No. 55/2019 concerning battery-powered electric vehicles. This regulation reflects a commitment to supporting the electrification of road mobility. The regime's support was further reinforced through horizontal coordination among various government entities, including the Ministry of Energy and Mineral Resources, the Ministry of Transportation, the Ministry of Industry, and the State-Owned Electricity Company (PLN). These collaborative efforts aim to develop integrated policies that promote the introduction and testing of EVs in government and public transportation,

establish charging networks, and attract investment. However, these horizontal shifts have also sparked debates regarding the primary energy sources used for electricity generation in Indonesia.

5.3 Relational Power in the Development of Transportation Sustainability

The development of the sustainable transportation sector in Indonesia involves the interaction of various actors at both local and global levels. Formal actors represent state interests, while other participants engage with the social, economic, and technological aspects of the transportation sector. Additionally, several informal institutions play a crucial role in advocating for a decarbonisation policy trajectory within this field. The analysis of the concept of power as relational and capital-based, focusing on three modes of power: power over, power to, power with, and power through (Allen, 2004) in the context of enhancing EI within the transportation sector.

Power Over

In the development of sustainable transportation in Indonesia, 'power over' is reflected in the state's dominance in shaping transportation policy. This power relation creates a vertical power geometry, with the central government at the top making strategic decisions that are then directed down to local governments for implementation. Although this top-down approach is extended nationwide, it remains geographically concentrated.

Key local actors representing state interests include government agencies, particularly the Ministry of Energy and Mineral Resources (MEMR). MEMR is responsible for formulating and implementing policies to develop environmentally friendly fuels. Furthermore, this ministry oversees and enforces regulations of fuel standardisation policies, which encompass fossil fuels, biofuels, and electricity (MEMR, 2025b). Furthermore, this ministry collaborates with the Ministry of Finance (MoF) to formulate and oversee the implementation of fiscal policies, particularly those related to incentives and subsidies to promote the adoption of biofuels and EVs. These ministries work together with BPDPKS to manage palm oil funds, which are essential to support the mandatory biodiesel policy (Farobie and Hartulistiyoso, 2022). This collaboration stimulates growth in national production, supporting the expansion of the B40 policy (MEMR, 2025a).

The introduction and adoption of EVs have been accelerated through collaboration among the MEMR, the MoF, and the Ministry of Industry (MoI). This collaboration focuses on regulating fiscal incentive policies for end-users, automotive manufacturers,

and infrastructure providers. Additionally, they have implemented a limited subsidy scheme for end-users that requires local content and considers consumer income status (Saputra et al., 2023).

MEMR manages the development of biofuels and electric vehicles (EVs) through separate technical directorates. The Directorate General of New, Renewable Energy, and Energy Conservation (DG EBTKE) is responsible for overseeing biofuels and renewable energy infrastructure. Within DG EBTKE, there are two key directorates: the Bioenergy Directorate and the Directorate of Various New and Renewable Energy (Directorate AEBET). The Bioenergy Directorate primarily focuses on developing biofuels. Its responsibilities include formulating technical policies, implementing standardisation and certification processes, and promoting and supervising bioenergy activities. On the other hand, DG AEBET addresses cross-sectoral issues related to renewable energy, including support for the necessary infrastructure for both biofuels and electric vehicles.

To encourage the adoption of EVs, the Directorate General of Electricity (DG Gatrik) oversees the infrastructure required for these vehicles. Various directorates, including the Directorate of Electricity Engineering and Environment and the Directorate of Electricity Business Development, implement technical policies at DG Gatrik. The Directorate of Electricity Engineering and Environment is responsible for licensing and regulating electrical installations, which include charging stations and battery swap stations. On the other hand, the Directorate of Electricity Business Development monitors and supports activities related to electricity supply, ensuring the provision of power for electric vehicles. Figure 5.1 provides relational power networks between key institutions on the diffusion of biofuels and EVs in Indonesia.

The implementation of decarbonisation regulations has involved local governments, which organises general government affairs at both provincial and city/district levels. These local governments formulate regional development plans that are an integrated part of the national development planning system. In particular, local governments in the Greater Jakarta area have implemented sustainability policies focused on mass public transportation based on Transit-Oriented Development (TOD). This concept integrates several modes of public transportation, including Bus Rapid Transit (BRT), commuter line trains, Mass Rapid Transit (MRT), and Light Rapid Transit (LRT). Feeder microbuses provide last-mile services that connect residential areas to the TOD system (Hasibuan and Mulyani, 2022). Additionally, local governments have enacted both fiscal and non-fiscal policies to support the decarbonisation of transportation. Notably, the Greater Jakarta government has implemented an odd-even vehicle restriction policy in the city

centre. However, exemptions are granted to EV users to encourage EV adoption (Sasongko et al., 2024).

The socio-technical transition also includes State-Owned Enterprises (SOEs), which play a crucial role in implementing the diffusion of biofuels and EVs. Pertamina, in collaboration with the MEMR, the BPDPKS, and the Ministry of Environment (MoE), has become the leading implementer of the mandatory biofuel program in Indonesia. As a SOE and a market enabler in national energy policy, Pertamina is central to the development of biofuels in the country (Pertamina, 2025).

According to BPH Migas Regulation Number 3 of 2023, the assignment of business entities responsible for the provision and distribution of biodiesel is managed by Pertamina through its subsidiaries, Pertamina Patra Niaga, along with their distribution agencies (BPH Migas, 2024). Pertamina serves as the primary off-taker for the production of FAME (Fatty Acid Methyl Ester), which is blended with fossil diesel. Through its subsidiary, PT Kilang Pertamina Internasional, Pertamina has developed co-processing techniques and green refineries at its Cilacap and Dumai facilities to produce green diesel, green gasoline, and sustainable aviation fuel (SAF). Additionally, Pertamina plays a vital role in controlling the national supply of these products to maintain market stability amidst fluctuations in global oil and CPO prices (Pertamina, 2025).

Presidential Regulation No. 55 of 2019 designates PLN as the primary driver in accelerating the adoption of electric vehicles (Fathoni et al., 2025). As a state-owned enterprise that provides electricity services, PLN serves as an infrastructure provider and market facilitator, playing a crucial role in supporting the low-carbon transition. The electrification of the road transportation sector has created new opportunities for PLN to diversify its energy services. Previously, PLN has focused on powering rail-based transportation, including commuter line trains, the MRT, and the BRT. Recently, PLN has collaborated with TransJakarta to electrify the BRT system, which promotes the diffusion of EVs into public spaces (PLN, 2025).

Power To

Meanwhile, the 'power to' is applied to the industrial sector involving collaboration between SOEs and private actors. Large palm oil companies, Pertamina and AKR, utilise technical and financial resources to diffuse innovations, focusing on the production and distribution processes of biodiesel. BPH Migas Regulation Number 3 of 2023 also opens opportunities for the private sector to participate in the provision and distribution of

biodiesel. AKR and its distribution agents are involved in purchasing and blending FAME (Fatty Acid Methyl Ester) with fossil diesel to produce biodiesel. In addition, this multinational company is permitted to distribute biodiesel (BPH Migas, 2024).

Large palm oil companies play a crucial role in the diffusion of biodiesel in Indonesia, as they control the primary supply chain for FAME feedstock, the key ingredient for blending biodiesel with fossil fuels (Ichsan et al., 2025; Choiruzzad, 2019). Their involvement extends beyond raw material production to include manufacturing, and even advocacy for energy policy (Sundaraja et al., 2021). Large palm oil companies dominate the biodiesel value chain, which includes palm oil plantations, CPO mills, refining plants, and FAME factories (Papilo et al., 2022; Sundaraja et al., 2021). These companies also control domestic distribution and have access to export markets (Ichsan et al., 2025; Choiruzzad, 2019). This integration from upstream to downstream has provided them with market control and production cost efficiency, allowing significant involvement in the mandatory biodiesel program (Papilo et al., 2022; Pye, 2019). This advocacy for the interests of large companies was presented to policymakers by the Indonesian Palm Oil Entrepreneurs Association (GAPKI), also known as the Indonesian Palm Oil Association (IPOA), which was founded on February 27, 1981. (Astari et al., 2025; Djatmika et al., 2024).

The leading producers of FAME in Indonesia are Wilmar Group, Musim Mas, Apical (part of the RGE Group), First Resources, and Sinar Mas Agro (SMART). These companies supply FAME to Pertamina and AKR for biodiesel blending. Notably, Wilmar and Musim Mas are the two largest FAME producers in Indonesia and have been among the largest biodiesel exporters to the European Union, prior to the imposition of anti-dumping sanctions (Astari et al., 2025). Large palm oil companies are important members of the Indonesian Biofuel Producers Association (APROBI). This organisation has significant influence over the development of mandatory biodiesel policies, including the establishment of production quotas and the allocation of price incentives. APROBI also advocates for biodiesel export policies and has supported the government's lawsuit against the European Union at the WTO, which alleges discrimination against Indonesian biodiesel (Astari et al., 2025).

A significant transition is underway in the Indonesian transportation sector, with industry and the private sector playing crucial roles in both contributing to and being impacted by decarbonisation programs. Automotive manufacturers have adapted to more stringent environmental regulations by innovating low-cost green cars (LCGCs) that promote fuel efficiency (BPPT, 2018). The diffusion of biofuels has put pressure on these manufacturers to improve engine compatibility with biofuel content. Optimisation of

knowledge spillovers has enabled technological innovations to address the issue of biodiesel compatibility due to the presence of glycerides that reduce the performance of existing diesel vehicle engines (Chandran, 2020).

The electricity generation system in Indonesia operates through a combination of PLN and Independent Power Producers (IPPs), which include SOEs, local private companies, and multinational corporations. PLN and its subsidiaries, such as Indonesia Power and Pembangkit Jawa Bali (PJB), operate their own power plants (PLN, 2021a). Additionally, PLN serves as an off-taker within the IPP framework. This system is governed by the General Plan for Electricity Supply (RUPTL), which outlines relevant government policies (PLN, 2021a; Apriliyanti et al., 2024).

IPP sells electricity power to PLN under a long-term Power Purchase Agreement (PPA), typically lasting between 15 and 30 years (PLN, 2025; Budi and Hadi, 2022). Currently, electricity generation is predominantly derived from fossil fuels, particularly coal. Renewable energy sources only make up 13% of generation, primarily from geothermal and hydropower, with solar PV also contributing (PLN, 2025). Although biomass and wind energy are beginning to gain traction, their overall contribution remains limited (PLN, 2021a; Apriliyanti et al., 2024). Additionally, the electrification of the road transport segment has created new opportunities for electric vehicle manufacturers to enter the domestic market (Zarazua de Rubens et al., 2020).

Several startups developed local EV brands to meet the requirements of domestic users. Gesits, along with Viar, was recognised as a pioneer among these brands, having successfully launched their products in the market (Waluyo et al., 2022; Yuniarto et al., 2022). The efforts of these innovators have attracted attention from multinational EV manufacturers, primarily from China and South Korea. Their expertise in essential technologies has allowed these multinational companies to promote and diffuse innovations within the industry (Yuniarto et al., 2022).

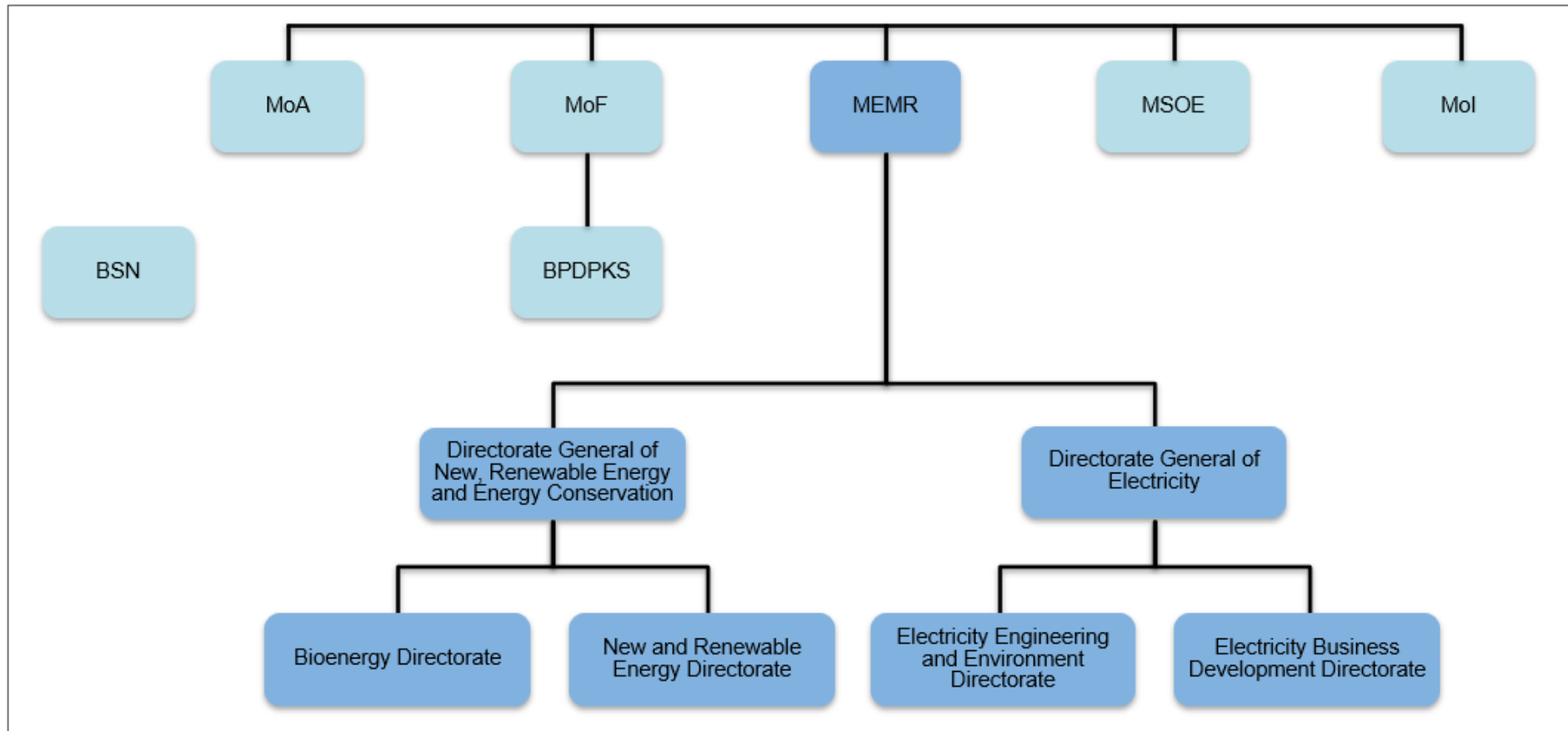


Figure 5.1 The network of power relations among key institutions in the diffusion of biofuels and electric vehicles.

Source: Author

Organisations like GAIKINDO and AISI, representing the automotive industry, have a strong interest in maintaining their market share despite the mandatory biodiesel regulations and the disruptions caused by EVs. This interest is evident in the lengthy process taken to implement alternative-friendly fuel policies. The mandatory biofuel policy only took effect in 2015, despite government discussions beginning in 2006 (Suhara et al., 2024; Farobie and Hartulistiyoso, 2022). Similarly, the policy framework for EVs only started to take shape in 2019 (Afraah et al., 2021).

Power With

The "power with" mode emphasises the collective strength that arises from collaboration among various actors. Indonesia's energy transition has led to the formation of several cross-sector coalitions. This collaboration helps maximise their combined capacity to address individual resource limitations. Power with is present in the state-private coalition, where each participant complements the others. The government has formed strategic partnerships with large biodiesel companies and Pertamina (Ichsan et al., 2025). While the government brings regulatory and fiscal authority, the companies contribute their production and distribution infrastructure. This state-private coalition is essential for implementing the mandatory B35 and B40 biofuels policy, which aims to enhance national energy resilience by reducing dependence on imported fossil diesel (Candra, 2025). Meanwhile, in the electrification sector, a coalition of state and private partners, including infrastructure providers and automotive manufacturers, has established charging points and BSS in public spaces. This coalition aims to tackle the challenges posed by limited and unevenly distributed support for EV infrastructure (Abdurrahman, 2025).

A coalition has been established among financial institutions in the industry, including BPDPKS, domestic banks, and global green financing organisations such as the ADB and United Nations Development Programme (UNDP). BPDPKS, which oversees the palm oil export levy fund, has emerged as a crucial financial hub for funding the biodiesel program. This coalition is actively involved in supporting the expansion of the biodiesel industry and the development of its infrastructure (Astari et al., 2025; Suhara et al., 2024). Additionally, in the electrification sector, state-private coalitions, including infrastructure enablers and automotive manufacturers, have established charging points and BSS in public spaces. This coalition aims to tackle the challenges of limited and unevenly distributed support for EV infrastructure (Sasongko et al., 2024; Balijepalli et al., 2023). The interdependence between financing institutions and production actors demonstrates a power with relationship in this effort.

McCormick (1999) emphasised that the rise of biofuels has led to the formation of a coalition consisting of research institutions, NGOs, and government entities. This coalition focuses on testing how different blends of biodiesel affect diesel engine performance. Additionally, it evaluates second-generation biofuels technology to prevent conflicts between food and fuel, land use changes, and deforestation. NGOs play a vital role in this coalition by advocating for sustainability standards and social equity, especially for small farmers and rural communities near palm oil plantations. This collaboration has created a forum where technical knowledge, environmental concerns, and policy directions can be discussed and negotiated (McCormick, 1999).

Meanwhile, EI, primarily developed abroad, has been introduced through a global-local coalition. This collaborative effort transcends national borders, forming a transnational collective power. The flow of technology, facilitated by partnerships with multinational companies, has promoted the adoption of biofuels and EV technologies (Djarmika et al., 2024). The United Nations Framework Convention on Climate Change (UNFCCC), in collaboration with local stakeholders, has played a vital role in creating a decarbonization framework aimed at accelerating the implementation of national policies related to alternative fuels (Ministry of Environment, 2024). Additionally, the coalition enhances the legitimacy of policies by including multiple actors, which fosters a perception of inclusivity. However, not all interests may be adequately represented within this coalition, potentially leaving vulnerable groups, such as smallholder farmers who are not associated with large companies or plasma partners, overlooked (Astari and Lovett, 2019).

A global-local coalition is forming to industrialise the battery supply chain through collaboration between CATL (China), LG Energy Solution (South Korea), and PT Industri Baterai Indonesia (IBC). The goal of this coalition is to establish a comprehensive national battery industry that encompasses every stage of production, including mineral mining, battery cell manufacturing, second-life applications, and recycling. This EV battery downstream project also involves SOEs, including Aneka Tambang, Pertamina, and PLN. By fostering transnational partnerships, this power with aims to enhance local technological and financial capabilities with the support of global networks and capital (Sasongko et al., 2024).

Foreign investors play a strategic and multifaceted role in enhancing the sustainability of Indonesia's transportation sector. Their investments not only bring in financial capital but also facilitate knowledge spillovers and provide access to global markets. Moreover, the participation of foreign investors has assisted in implementing global sustainability standards in the socio-technical transition occurring in Indonesia (Djarmika et al., 2024).

The process of adopting EVs is more complex than transitioning to biofuels. Consumer acceptance is a crucial factor in the social shift towards new modes of transportation (Balijepalli et al., 2023; Setiawan, A.D. et al., 2022). To address this, an industry-consumer coalition has been formed to assess market acceptance. Automotive manufacturing associations, including GAIKINDO, AISI, and the electric vehicle industry association (PERIKLINDO), are collaborating with the government and media to organise exhibitions, public campaigns, and price subsidies for electric vehicles (Tiwari et al., 2020). This coalition aims to expand the green market and increase public awareness of sustainability. The implementation of this collaborative approach has demonstrated how a partnership between producers, government, and media can effectively influence consumer behaviour.

Power Through

The power relation framework described by Allen (2011) is not solely coercive or collective; it can also manifest in everyday practices. This dynamic is shaped by norms, regulations, and social expectations that influence individual choices. In the context of this socio-technical transition, the concept of 'power through' is applied through government policies that mandate biodiesel use. These policies include limited subsidies for biofuel users, tax exemptions for EVs, purchase subsidies for EV buyers, and efforts to raise awareness about decarbonisation.

The Indonesian government has mandated the utilisation of biodiesel blends (B20 to B40) for diesel-engine vehicles (Ichsan et al., 2025; Suhara et al., 2024). This policy is not enforced through coercive power; rather, it is a system of technical regulations designed to facilitate the socio-technical transition and encourage habit formation among industries and end users. The biofuels distribution network, which includes gas stations, fuel distributors, and automotive manufacturers, has systematically adapted to this change, as it has become an integral part of the legal and operational framework. In this context, compliance has been achieved because all parties involved have been "trained" by the system to follow the regulations without the need for direct supervision (Suhara et al., 2024).

The biodiesel funding and incentive system managed by BPD PKS has created a framework that influences industry players to operate within government guidelines. This implementation of power through illustrates that it does not originate from direct orders, but rather from the flow of funds and incentive mechanisms that shape market behaviour. Moreover, the form of power through the ISPO certification has effectively regulated industry actors using technical standards and procedural audits, without resorting to violence or direct sanctions. This standardisation has ensured that palm oil and biodiesel

producers in Indonesia comply with environmental regulations, workers' rights, and land governance. Although it may seem like a mere administrative detail, this certification plays a crucial role in determining access to incentives, export markets, and partnerships. Thus, this form of governance disciplines actors by enforcing technical norms and procedural audits (Astari et al., 2025; Suhara et al., 2024).

5.4 Political Economy and Energy Justice in the Socio-technical Transition

This study stage refers to the political economist Peter Newell's conceptualisation of power concerning the diffusion of Indonesian biofuels in the energy industry, focusing on structural, institutional, and discursive dimensions. It has identified power asymmetries that affect policy formulation and implementation, which in turn reinforce the dominance of elite groups. However, these policies often marginalise alternative voices and trajectories for achieving sustainable transitions (Newell, 2008; Newell & Pattberg, 2010).

5.4.1 Political Economy and Energy Justice in the Diffusion of Biofuels

Structural Power

The supply chain for biofuel distribution in Indonesia is primarily dominated by large companies that possess the technology, financial resources, and market access needed for success. Borras Jr. et al. (2011) examined how the interests of these corporations have influenced the determination of export quotas and the allocation of biodiesel subsidies. By leveraging their structural power, these large companies integrate their operations across the entire biodiesel supply chain, from plantations to downstream production and marketing. This integration has significantly reduced smallholder farmers' access to the processing and marketing stages of biodiesel (Borras Jr. et al., 2011).

The increasing interest in maintaining export markets that require adherence to international sustainability standards has influenced policymakers' approaches to biofuels. Additionally, landscape dynamics are affected by fluctuating commodity prices, particularly those of crude oil and CPO. This change in the socio-technical landscape has put the government in a challenging position, forcing it to prioritise carbon reduction in response to global market demands. As a result, there has been a reduced focus on social justice, especially concerning smallholder farmers and rural communities (Pye, 2019).

Institutional Power

The shifts in biofuel management that occurred in 2006 has positioned government agencies as key players in the sector. State-centred power is primarily concentrated among executive technocrats from MEMR, the MoF, and BPDPKS. This centralisation of power aims to enhance coordination between institutions and expedite decision-making, particularly regarding mandatory biofuel policies and subsidy schemes. However, this centralised power structure has limited democratic governance and reduced opportunities for stakeholder contestation. As a result, there is a lack of participatory oversight from other stakeholders, such as smallholder farmers and rural communities, who have restricted access to decision-making processes (Ichsan et al., 2025; Kapriadi, 2019).

This absence of participatory oversight leads to minimal transparency in policy implementation, especially concerning the distribution of subsidies, which vertically integrated biodiesel processing corporations predominantly receive. A study by the Commission for Eradication of Corruption (KPK) in Ichsan et al. (2025) indicates that in 2015, 89% of the BPDPKS fund allocation was directed to biodiesel subsidies. Notably, 81.8% of this subsidy was dominated by just three large corporations. Meanwhile, smallholder farmers are facing volatile palm oil prices and limited support for sustainable practices (Ichsan et al., 2025).

The political economist, Newell (2021), has indicated that during the energy transition, various types of incentives—especially fiscal policies, subsidies, and project financing—are frequently co-opted by large energy corporations and established incumbent actors. Instead of replacing existing energy systems, energy transitions often reinforce existing power structures. Ongoing institutional lock-ins have bolstered the position of incumbent actors while marginalising the role of emerging energy innovators and local participants (Newell, 2021).

5.4.2 Political Economy and Energy Justice in the Diffusion of Electric Vehicles

Structural Power

The growth of EV adoption in Indonesia highlights the strong connections between government priorities, oligarchic control over resources, and global green investment. According to the political economist Newell (2021), structural power in the energy transition encompasses sustainable economic arrangements and institutions that shape the chosen trajectories of the transition and determine who benefits from them. In Indonesia, the diffusion of EVs has been primarily driven by top-down, state-centred policies. This prevailing structural power has focused on industrial development and the

dominance of the mineral extraction value chain, especially regarding nickel. Consequently, the prioritisation of mining conglomerates has overshadowed broader goals of comprehensive decarbonisation and energy justice (Newell, 2008).

The widespread adoption of electric vehicles (EVs), highlighted by Presidential Regulation No. 55/2019, has become a key driver in mobilising the government's structural power. The state has taken on the role of a development agent, coordinating various state agencies to formulate policies that encourage private investment. Private investment, especially from multinational corporations, is vital due to the lack of expertise in key technologies for EV industrialisation, particularly in lithium-ion batteries. Notable examples include companies like Hyundai and CATL (Padhilah et al., 2023).

Institutional Power

This research examines the institutional powers influencing the diffusion of EVs. These powers operate not only through formal regulations but also by enabling dominant actors to shape policies that serve their interests, a phenomenon referred to as "regulatory capture" by the political economist Newell (2021). Government agencies, represented by MEMR, Mol, the Ministry of Investment/Investment Coordinating Board (BKPM), and SOEs, have acted as gatekeepers of the EV industrial policy framework. PLN focuses on providing electricity through its power plants and IPPs. In collaboration with Pertamina and other infrastructure enablers, this collaboration expands the network of charging stations and BSS (PLN, 2025).

These government agencies also advocate for upstream integration, particularly in the materials extraction and production of EV batteries. This focus on upstream integration significantly dominates the current discourse. These dominant actors prioritise upstream integration over downstream democratisation to ensure the provision of affordable EVs and public charging infrastructure. The influence of elite actors has been evident in the drafting of the National Industrial Development Plan for 2020–2035 (RIPIN 2025) and the establishment of the Indonesian Battery Corporation (IBC) (DJP MoF, 2023).

The strategic IBC project has involved collaboration between SOEs (Mind ID, ANTAM, Pertamina, and PLN) and multinational corporations. Initially, this SOE consortium collaborated with LG, but then shifted to CATL. The trajectory of EV battery downstream policies increasingly places major players in dominance over the EV supply chain, from nickel mining to battery production and vehicle manufacturing. This practice of institutional power has limited the space for local cooperatives, technology startups, or small producers to participate, thereby only reinforcing the position of established players (Setiawan, V.N., 2022; IEA, 2024a).

Several parties have reviewed that both policy frameworks were developed primarily by dominant actors, with little substantive involvement from civil society or local governments. Local governments, especially those outside of Java, often lack the

authority or resources to adapt EV plans to their specific contexts. This deficiency in local governance has led to spatially uneven socio-technical transitions. The ongoing energy transition in several emerging economies is not only technical and economic but also deeply intertwined with institutional and political interests. As a result, these socio-technical transitions empower some actors while marginalising others who have limited access to power (Newell, 2021).

The economic architecture promoting the increased adoption of EVs through fiscal and non-fiscal policies primarily benefits conglomerates and multinational corporations, which are the dominant players in the market. This system has granted significant land concessions and fiscal incentives to multinational corporations to enhance their penetration into the green market. In contrast, local startup companies focused on EMC face challenges such as high homologation costs and limited access to capital, making it difficult for them to scale up production to meet market demand (Maulana, 2025). Additionally, the monopoly on electricity pricing controlled by SOEs complicates efforts for private infrastructure developers to expand their charging infrastructure and BSS networks (IEA, 2023c).

Consumer Exclusion and the Lack of Just Mobility

Affordability and accessibility continue to pose significant challenges to the adoption of EV in Indonesia. Sasongko et al. (2022) identified the high upfront purchase price as a primary factor discouraging consumers from choosing EVs over comparable ICEVs. However, EV adoption in urban areas has experienced notable growth since 2023, contributing to an increase in the overall EV population. Lukmanul Arsyad, PwC Indonesia's Industry and Services Leader and Partner, mentioned in a report by Sakina (2025) that

"The share of EVs in total passenger vehicle sales in Indonesia rose from 9 per cent in 2023 to 15 per cent in 2024 and is projected to reach 29 per cent by 2030."
(Sakina, 2025)

Despite this surge in sales, consumers in both urban and rural regions still grapple with high upfront costs for EVs. Additionally, public scepticism regarding the ability of EVs to replace petroleum-based vehicles persists, primarily due to the limited and uneven distribution of charging infrastructure and BSS (Setiawan, A.D. et al., 2022). Residents of rural and peri-urban areas remain uncertain about whether EVs can effectively replace ICEVs for their mobility requirements. This scepticism is mainly due to limited infrastructure, unreliable electricity supply, and a lack of awareness about sustainability. Additionally, the emphasis that policymakers place on electrifying private vehicles, rather than decarbonising mass public transportation has hindered inclusivity and transitional justice.

Power is exerted through the diffusion of sustainability discourse, which encourages society to view EVs and biofuels as integral to a modern, environmentally friendly lifestyle. However, it is important to note that not all segments of society have equal access to these technologies or the ability to participate in this green lifestyle. Table 5.1 summarises how market structures and institutions have strengthened the dominance of key actors in Indonesia's transportation transition. In contrast, Table 5.2 highlights other stakeholders who have been marginalised within the power dynamics.

Table 5.1 Dominant Actors in the Transition of Biofuels and EVs

Sector	Dominant Actors
Biofuel	- Government Agencies (MEMR, MSOE, MoA, MoF, MoE) - State-Owned Enterprises (Pertamina and its subsidiaries) - Palm Oil Industry Association (APROBI) - Large Palm Oil Corporations (Wilmar, Musim Mas, Sinar Mas) - Association of Automotive Industries (GAIKINDO and AISI)
EV	- Government (Ministry of Industry, Energy and Mineral Resources, Ministry of Finance) - Multinational Automotive Manufacturers (such as Hyundai, Wuling, Cherry, BYD, KIA, Nissan) - State-Owned Enterprises (PLN and its subsidiaries) - Association of EV Industries (PERIKLINDO)

Table 5.2 Marginalised Groups or Communities in the Transition of Biofuels and EVs

Groups	How Marginalised
Smallholder Palm Oil Farmers	Lack access to the biodiesel industry supply chain, despite the narrative used to justify the policy.
Rural Communities	Lack access to EV Charging, BSS, or gas stations. Lack of socialization of sustainability discourses.
Local Small-Medium Industries	Difficult to penetrate the EV market due to limited access to technology and finance.
Middle-to-lower Income Urban Consumers	Limited state budget allocation for EV subsidies. Home charging installation costs are still high.

5.5 Disciplinary and Discursive Power in the Socio-technical Regime

5.5.1 Disciplinary and Discursive Power in the Diffusion of Biofuels

Knowledge/Power Nexus and Disciplinary Techniques

The governance of EI diffusion in Indonesian biofuels is intricately linked to the formation of power and knowledge, as conceptualised by Michel Foucault. He emphasised that power is not only repressive but also productive and dispersed (Foucault, 1980). The development of national biofuels policies is a collaborative effort that includes not only state agencies but also relies on knowledge inputs from research institutions, certification bodies, and NGOs (Naimah and Morgunova, 2017). The process of defining sustainable or legitimate biofuels has established a normative framework that prioritises specific stakeholders while sometimes minimising the interests of others (Choiruzzad, 2019).

The diffusion of palm oil-based biodiesel technology in Indonesia since the early 2000s have increased the influence of scientific and technical experts. Naimah and Morgunova (2017) has examined that the formulation of national biofuels policies is not solely carried out by state agencies but also involves contributions of knowledge from research institutions, certification bodies, and NGOs. The process of defining sustainable biofuels has created a normative framework that prioritises certain actors while sometimes downplaying the interests of others. Establishing sustainability metrics and validating life cycle assessments (LCAs) for biofuels has required collaborative knowledge exchange among experts from the National Research and Innovation Agency (BRIN), Research and Development Centre for Oil and Gas Technology (Lemigas), several universities (such as Institut Teknologi Bandung and Universitas Gajah Mada), the national certification body (BSN), international certification bodies, BPDPKS, APROBI, Pertamina, and GAIKINDO (Naimah and Morgunova, 2017). This coalition of power/knowledge has developed technical categories that serve as the foundation for identifying sustainable biofuels assessment, including carbon intensity and indirect land-use change (ILUC). The governance of biofuels, supported by technical knowledge, reflects Foucault's concept of governmentality (Foucault, 2007).

The government's efforts towards biofuels sustainability through a series of regulatory mechanisms, primarily centred around a certification regime. Large companies seeking access to global markets must comply with standards set by the Roundtable on Sustainable Palm Oil (RSPO) and the International Sustainability and Carbon Certification (ISCC). This certification scheme extends beyond mere voluntary guidelines; it actively regulates and monitors participants through surveillance, audits, and regular data reporting. The certification system has evolved into a "knowledge/power

regime" that mandates compliance with regulations. Under this system, palm oil producers and biodiesel refiners are required to align their practices with established procedures, traceability systems, and environmental standards (Schouten and Glasbergen, 2011). These standards include protecting biodiversity, minimising carbon emissions, and ensuring compliance with human rights. This system creates a new "regime of truth," which, in the bioeconomy, is adhered to only by parties that meet measurable sustainability metrics.

Sustainability certification regimes are embedded into transnational networks that function through both soft and hard power. This technology of power system has positioned global consumers, particularly in the US and EU, to require certification from organisations such as RSPO or ISCC from exporting countries to access their markets. The two systems are commonly referred to as "knowledge/power regimes." In this context, certification acts as a tool that regulates, classifies, and normalises agricultural practices based on the logic of the international market. However, these certification regimes are often criticised for favouring the interests of large corporations. According to Foucault's framework, these systems represent a form of "governmentality," in which smallholders are encouraged to conform to practices of audit and documentation rather than rely on local traditions or experiences (de Vos et al., 2023).

The influence of knowledge and power from these two international certification bodies often overshadows local practices, such as ISPO, which become subordinate to these global standards. Various local stakeholders prompted the government to advocate for the ISPO certification, as it serves as a national response while aligning with international sustainability standards. ISPO aims to support the interests of all stakeholders, particularly smallholder farmers. This domestic certification system has shown that internal governance, through local institutions, has embraced global disciplinary mechanism (Astari et al., 2025; Choiruzzad et al., 2021).

Even with the emphasis on sustainability, global certification systems often fail to consider local social and ecological diversity. At the same time, many smallholder farmers struggle to access the administrative, financial, and technical resources needed to meet these global certification standards. Consequently, their local knowledge and practices are often overlooked in the certification processes or documents. As a result, they tend to become mere "rule-takers" rather than active participants in shaping what sustainability means (Astari et al., 2025; Choiruzzad et al., 2021).

Discursive Formations

The diffusion of alternative fuels in Indonesia is closely linked to debates over energy independence, climate change mitigation, and inclusivity. Coordinating Minister for Economic Affairs, Airlangga Hartarto, when opening the Energy Corner Special

Talkshow - "B35 Implementation for Energy Resilience and Independence Towards an Equitable and Just Energy Transition," as outlined in MEMR (2023), stated:

"The implementation of B35 reflects the government's commitment to significantly reducing greenhouse gas emissions, accelerating the transition to inclusive, clean, and sustainable energy, and attracting investment to achieve Net Zero Emissions." (Coordinating Minister for Economic Affairs as published by MEMR, January 31, 2023)

The government has also raised the issue of inclusivity, stating that the mandatory biofuel policy benefits not only large corporations but also supports farmers. As reported by Justiari (2021), Dadan Kusdiana, the Director General of New, Renewable Energy, and Energy Conservation at the Ministry of Energy and Mineral Resources, mentioned, "The government will establish criteria for CPO supply that biodiesel producers must meet. These criteria will also address aspects of farmer welfare" (Justiari, 2021).

Meanwhile, Ichsan (2025) has examined the presence of three key policy framings, including national energy sovereignty, climate change mitigation, and rural development, particularly in remote areas. The government has also emphasised the importance of inclusivity, highlighting that the mandatory biofuel policy benefits not only large palm oil companies but also farmers (Justiari, 2021).

The diffusion of second-generation fuels, such as green diesel (HVO) and green gasoline, is fostering discourses on avoiding competition with food sources, as noted by Sugiyono et al. (2020, p.1).

"The development of the green diesel and green gasoline industry requires a clear and gradual grand strategy from the government so that feedstock needs will not interfere with food needs." (Sugiyono et al., 2020, p.1)

The government is also actively promoting second-generation (2G) biofuels as sustainable alternatives. However, the substantial investment requirements and the need for access to advanced processing technologies primarily advantage large corporations. As demonstrated by the 2G project in Alagoas, Brazil, smallholder farmers and rural communities are not directly benefiting from this environmentally friendly initiative (Kirshner et al., 2022). Furthermore, recent research has highlighted that, behind the intense policy framing, submerged discourses have emerged regarding the negative impacts of biofuel plantation expansion, particularly threats to biodiversity [Astari, 2019].

Meanwhile, the dominant policy framing of biofuels industries has led to increased revenue at the subnational level and created jobs for residents around plantations. These

narrations highlight the contributions of these industries to the overall alleviation of poverty in rural areas. However, Choiruzzad (2019) points out a significant issue of inequality among individuals. Despite the profits generated by large companies, little attention was often given to employees' working conditions in the context of rural development (Choiruzzad, 2019). Additionally, in some instances, the expansion of plantations has resulted in social conflicts due to land tenure disputes (Astari and Lovett, 2019; Ichsan et al., 2025).

5.5.2 Disciplinary and Discursive Power in the Diffusion of Electric Vehicles

Knowledge/Power Nexus and Disciplinary Techniques

The institutionalisation of EV diffusion in Indonesia began with a collaboration among universities, BRIN, automotive manufacturers, energy companies, green suppliers, and government agencies. This collaboration formed an epistemic community that developed shared definitions of vehicle performance, environmental benefits, and safety. Their alliance assisted in establishing technical validity criteria, which were then integrated into public policy, notably through the enactment of Presidential Regulation No. 55 of 2019 (Sasongko et al., 2024).

In the diffusion of EVs, particularly the development of local brands, all entities in the automotive industry—from manufacturers to service workshops—must adhere to a system of discipline defined by mandatory technical standards. These entities are required to comply with various regulations concerning drivetrain and electrical systems, batteries and charging infrastructure, vehicle safety audits, and vehicle performance. Failure to meet these standards can lead to administrative penalties. For instance, if a vehicle fails a type test, it may be banned from mass production and necessitate repairs or redesign. Additionally, if manufacturers cannot comply with these regulations, their vehicles may be prohibited from operating on public roads. Non-compliance not only leads to financial losses for manufacturers but also results in a loss of market momentum. The process of implementing EV standardisation reflects Foucault's concept of discipline and punishment, as it internalises norms through systematic surveillance (Foucault, 2007).

The standardisation system acts as a compulsory disciplinary mechanism for manufacturers, importers, and authorised after-sales services. This standardisation regime requires strict adherence to technical standards, which are regularly tested and can lead to administrative sanctions for non-compliance. As a result, technical norms are internalised and become integral disciplines within production and service practices.

Through regular technical inspections and audits, this standardisation system establishes a network of technical oversight within the electric vehicle value chain. This oversight is made "visible" through protocols developed by experts, reflecting the concepts of discipline and punishment (Abera, 2012).

The impact of power/knowledge through standardisation significantly affected the development of local brands during the introduction of EVs, particularly between 2013 and 2015. According to Dahlan Iskan, who served as Minister of State-Owned Enterprises from 2011 to 2014, the unclear regulations and complex bureaucracy have impeded the certification of local EV type tests. This information was reported by Detik (2017).

"The bureaucracy surrounding permits and government regulations is the primary obstacle. For instance, when the electric cars Selo and Gendhis, created by Ricky Elson, were set for testing, many permits had to be processed, and the process was complicated. Additionally, the regulations governing these vehicles are unclear. This situation significantly hinders the development of national electric vehicles and their readiness for mass production." (Detik, 2017)

The dynamics of the global landscape and the rise of a growing group of brand enthusiasts have led the Joko Widodo administration to support the development of local electric motorcycles. Collaborative innovations among universities, automotive manufacturers, and energy companies have improved technological capabilities, leveraging knowledge shared by multinational strategic partners, green suppliers, and internal R&D (Fathoni et al., 2025). In 2020, Gesits and Viar obtained type test certificates, and several other brands received test certificates and began mass production in the same year. This milestone marked the start of the electrification era in the road transportation sector (Maskur, 2020).

The government's commitment to developing the electric vehicle industry and its supporting infrastructure is clear. The growth of EVs has been aided by the standardisation efforts managed by the BSN. In a June 2021 interview, one respondent noted that "around 34 Indonesian National Standards (SNI) have been formulated to support the development of the battery-based electric vehicle industry in Indonesia" (Interviewee 11). The Coordinator of Substance Development for Transportation and Information Technology Standards at the BSN, Mayastria Yektingtyas, reported that the development of EV standards began in 2017. Most of these standards have been adopted from the International Organisation for Standardisation (ISO), the International Electrotechnical Commission (IEC), and the European Norm (EN), prepared by four Technical Committees. According to Mayastria Yektingtyas in BSN (2023),

"There are currently 38 Indonesian National Standards (SNIs) related to electric vehicles. These include 12 standards focused on safety and performance for vehicle systems, 11 standards for safety and performance regarding batteries and propulsion components, and 15 standards addressing electric vehicle infrastructure, including charging systems, cables, and connectors." (BSN, 2023)

Genealogical analysis indicates that prior to the establishment of the certification regime, electric vehicles were viewed as experimental and marginalised within the automotive market. However, following the introduction of the official regime through the SNI and homologation, electric vehicles began to undergo a normalisation process and became an integral part of the national transportation system. The standardisation regime produces a new category of technological subjects: electric vehicles. These vehicles are recognised, controlled, and regulated by the state, leading to the perception that these vehicles are safe, efficient, and environmentally friendly, provided they have successfully undergone the epistemic certification process.

Discursive Formations, Part 2

The initial legitimacy of EVs in Indonesia was established through a government-led discourse that linked their adoption to energy security, environmental conservation, and advanced technology. This narrative began with the implementation of Presidential Regulation No. 55/2019 and was framed around concepts such as "environmentally friendly," "energy transition," and "green economy". These key terms not only outlined policy goals but also portrayed electric vehicles as significant socio-technical commodities deserving of government support (Kemenangan, 2022).

A similar narrative has been stated by one of the respondents, who highlighted the importance of EVs as a clean transportation option that helps decrease fossil fuel imports. The respondent mentioned that:

"We can initiate [the energy transition] by emphasising that electric vehicles play a significant role in reducing greenhouse gas emissions, which subsequently lowers air pollution. Shifting from fossil fuels to electricity is a much cleaner option. A key reason for this transition is that ministries in the economic sector, such as finance and the economy, will understand that this change can lead to a decrease in fuel imports." (Interviewee 6)

The transportation sector electrification policy has been highlighted by discussions that emphasise the importance of using domestic components. Additionally, there has been significant media coverage about "Indonesia's potential to leverage its position as the

holder of the world's largest nickel reserves to create an integrated supply chain for electric vehicles" (Sakina, 2025).

The dominant discourse framed the transition to EVs as a rational, science-based initiative that aligned national interests with the global climate agenda. However, this perspective highlighted that Indonesia's EV policy development was primarily reactive, influenced by environmental challenges such as dependence on fossil fuel imports, the ratification of the Paris Agreement, and the diffusion of global EV trends (Fathoni et al., 2025). This process was prompted by intense lobbying from influential domestic players, especially mining conglomerates, as well as disruptions caused by multinational EV manufacturers. Using Foucault's perspective, this study can view the policy discourse as a "regime of truth" that favours specific narratives while marginalising others (Foucault, 1980).

The key policy framings surrounding the environmental benefits of EVs and the state's role in the green industry, as conveyed by dominant actors, have overshadowed other perspectives. One respondent pointed out that the interests of mining conglomerates drive the push for accelerated EV adoption, as stated below:

"Presidential Regulation 55 of 2019 seems to promote environmental conservation; however, in reality, it does not. While biofuels create a market for crude palm oil, electric vehicles increase demand for coal." (Interviewee 18)

This discourse aligns with the reality of excess electricity generation capacity in Java and Bali, which are key centres for socioeconomic activities. The electricity generation in these regions, primarily reliant on coal, has encountered a situation of under absorption. Electricity consumption in the transportation sector remains below 1% of the total national production capacity. It was projected to grow by approximately 23% to 37% annually, driven by a significant increase in the electric vehicle population (DEN, 2024). Therefore, the push for accelerated EV adoption was closely tied to utilising this surplus electricity production capacity. This connection was emphasised by a high-level PLN management representative, as reported by Justiari (2021).

"Currently, there is a reserve of 14,000 megawatts due to excess capacity. We estimate that the power requirement for one million four-wheeled electric vehicles will reach 2,600 megawatts." (Justiari, 2021)

Table 5.3 Power Analysis on the Diffusion of Biofuels and EVs in Indonesia

No	Actor	Relational Power	Structural Power	Discursive/Disciplinary Power
1	MEMR	Power-through policy coordination	Embedded in fossil-biofuel regime	Constructs national energy narrative
2	Mol	Power-with industrial coalitions	Industrial growth control	Normalizes industrial policy discourses
3	MoF	Power-over subsidy flow	Subsidy and incentives alignment	Disciplines budgetary behaviour
4	MSOE	Power-with SOEs	Managing the SOE market	Technologies of state control
5	MoA	Power-over cultivation and land control	Land-based political economy	Governs access via land titling
6	MoT	Power-through regulation	Transport planning exclusion	Disciplines mobility standards
7	Bappenas	Power-through planning instruments	Structural planner influence	Performs techno-governance
8	BPDPKS	Power-through fiscal channelling	Institutional capture by industry	Surveillance over blending compliance
9	BSN	Power-through standard setting	Technocratic lock-in	Standards and certifications as discipline
10	Pertamina	Power-through market coordination	Structural incumbent in production and distribution	Manage energy security and affordability
11	PLN	Power-with EV infrastructure actors	Grid-based centralism	Infrastructure metrics govern behaviours
12	ANTAM	Power-with battery chain partners	Resource control elite	Knowledge regimes on critical minerals extraction
13	Large Palm Oil and Biofuel Corporation	Power-over smallholders, power-with APROBI	Elite consolidation via subsidies	Exclusion through certification regimes
14	Private IPP	Power-through generation contracts	Private-public partnership control	Audit compliance regimes
15	Multinational Automotive Corporations	Power-with national regulators	Foreign direct investment driven value chains	Discursive clean-technology legitimization

No	Actor	Relational Power	Structural Power	Discursive/Disciplinary Power
16	EV local OEMs	Power-with state innovation system	Medium bargaining position	Controlled by national standards
17	APROBI and GAPKI	Power-with regulators	Policy capture	Shapes legitimacy of palm policies
18	GAIKINDO and ISMOLI	Power-with EV industry	Policy influence	Mobilizes national EV discourse
19	Multinational Investor	Power-through capital flow	Capital dependency	Narrative alignment with growth
20	International Donor	Power-with national plans	Donor conditionalities	Knowledge-for-donor audit
21	Charging & Battery Swap Providers	Power-through physical infra	Market structure domination	Govern user behaviour via technology
22	Transport Providers	Power-through mobility service	Disciplinary route design and fleet choice	Structural partner in last-mile public transport
23	Green Supplier	Power-to disrupt fossil chain	Discursive marketing of green input	Structural niche actors
24	RSPO	Power-over certification inclusion	Market filtering	Enforces sustainability discourse
25	ISPO	Power-through compliance	State-centric sustainability	Compliance with state narrative
26	Local and International NGOs	Power-to critique, power-with communities	Unequal access to policymaking	Surveillance over sustainability claims
27	Research Institutions	Power-with knowledge regimes	Epistemic community shaping policy	Scientific authority over biofuel/EV policy
28	International Biofuel Consumers	Power-through demand market	External influence on domestic supply	Subject to sustainability expectations
29	Smallholder Farmers	Power-to resist/excluded	Marginalized by value chain	Disciplined by yield/sustainability logic
30	Urban EV Consumers	Power-to choose green mobility	Class-based access	Disciplines consumer expectations
31	EV Consumers in Rural Areas	Powerless/infrastructural marginalisation	Infrastructure exclusion	Marginalised from EV discourse
32	Media	Power-through discourse	Agenda setting through legitimacy	Frames what counts as sustainability

Decarbonisation through the electrification of the road sector in Indonesia has sparked debate among various stakeholders, particularly concerning the role of coal in the primary energy mix for power generation. One of the respondents has emphasised the importance of a comprehensive energy transition that prioritises renewable energy sources. Table 5.3 summarises the power analysis on multilevel stakeholders in the diffusion of biofuels and EVs in Indonesia.

“If we genuinely want to be clean, we need to be honest: EV batteries are currently charged with electricity from coal-fired power plants, which means we are still burning carbon. Therefore, the transition to electric vehicles must be comprehensive. We should not take a half-hearted approach; instead, let us ensure that charging stations are environmentally friendly and utilise solar photovoltaic power.” (Interviewee 19)

5.6 Stakeholders' Influence Map and Network Analysis

This section describes the relationship between actors and their domestic and global interaction networks related to sustainability in Indonesia's transportation energy development. This study analyses the actors and their interaction networks and presents the results as a map of stakeholders' influence. This mapping process is based on a qualitative analysis of the direct involvement of actors in formulating and implementing the transportation sustainability policies.

Figure 5.2 maps stakeholders' influence through a sequence of concentric ellipses. The ellipses are organised from the centre to the perimeter according to the stakeholders' impact on policymaking. The centre of the map is reserved for stakeholders with leadership with high power and the most significant influence. Then, at the periphery, locations where stakeholder influence gradually decreases. At the periphery is the group with the lowest influence on policymaking. The lines on this map represent the network of actors influencing decision-making. The MEMR is authorised to formulate and implement the energy security policy, including the transportation sector. This research makes MEMR one of the most influential actors, so it is located in the centre of the map. In the provision of fossil fuels, MEMR has the authority to produce and distribute oil and gas. In the e-mobility sector, MEMR has the authority to manage and provide electricity.

The fuel supply chain, especially biofuel, requires coordination with several relevant ministries. In the biofuel sector, the MoA regulates plantations of oil palm, sugarcane, and other biofuel raw materials. Likewise, providing land for biofuel raw material plantation is the responsibility of the MEF and the MoA. The ISPO Commission has the authority to issue certifications to biofuel companies and to oversee the compliance of

palm oil companies. Fuel product regulation also interacts with regulations in the transportation and automotive sectors. The MEMR Ministry also coordinates with the MoT and the Mol. The MoT also has the authority to set emission standards for fuel and vehicle type test certification. The Mol oversees the implementation of policies governing the manufacturing of low-emission vehicles by automotive manufacturers.

In the electricity sector, most Indonesian government regimes relied on coal power plants to increase generating capacity and electrification ratio. In the first presidential period, Jokowi announced 35 GW of power plant construction, dominated by coal. Most construction was still concentrated in Java and Bali which led to electricity oversupply in these areas. The Government then responded by enacting a policy to create a new market to absorb electricity. This policy encouraged a shift in energy sources in the household sector by replacing gas stoves with electric stoves. Another policy encouraged a shift in fuel oil for transportation with e-mobility through Presidential Regulation no. 55/2019. In the second term President, Jokowi plans to limit new fossil fuel power plants until 2025. After 2025, the construction of new power plants must use new and renewable sources.

In the EV market, foreign investors have emerged as key players, with companies such as CATL, LG Energy Solution, and Hyundai leading the way (IEA, 2024a). While these multinational companies have contributed advanced battery technology, drivetrains, and innovative charging solutions, the mastery of essential EV components like battery cells, chips, and system controls remains mainly in the hands of foreign actors. Furthermore, several infrastructure developments have introduced battery swap station solutions through partnerships with local firms. For instance, Gogoro from Taiwan has collaborated with Electrum, while NIU has partnered with Moove Motors Asia (BCG and AEML, 2022).

International and national NGOs are also in the second layer of the ellipse. International and national NGOs oppose the government coalition. NGOs can affect shifts in producer and customer behaviour through their publications and campaigns, which give them great power and influence. McCormick (1999) emphasised that the socialisation and education of sustainability in Indonesia are closely connected to the role of non-governmental organisations (NGOs), especially in the transition toward an inclusive and low-emission transportation system. International and local NGOs work together effectively, complementing each other's efforts. International NGOs provide a framework that aligns with the global environmental agenda, facilitating technology transfer and resource empowerment. Meanwhile, local NGOs serve as custodians of the local context, ensuring accountability within the community. Additionally, local NGOs promote public participation in the transportation transition by advocating for mass public transport and utilisation of environmentally-friendly mobility such as biofuels and EVs. Additionally,

these institutions promoted decarbonization programs by encouraging various urban areas to become more pedestrian and bicycle-friendly. NGOs have the ability to mobilise public opinion, create global narratives, build cross-border coalitions, and apply political and social pressure on stagnant policymakers. However, they lack the formal power that states or corporations possess, and their legitimacy and representation can often be called into question. Additionally, while some NGOs operate on a global scale, others focus exclusively on local or regional issues (McCormick, 1999).

The indirect role of NGO campaigns and publications related to environmental degradation issues; land tenure disputes and human rights issues provide indirect pressure on the Government to initiate the ISPO system. NGOs also build coalitions together with the RSPO and various other stakeholders to become members of the RSPO. RSPO has a strong position thanks to its access to global markets as a marketing destination for Indonesian palm oil export commodities. RSPO with certification recognition at the international level can influence the Government's sustainability policy in the biofuel sector. Although the RSPO and ISPO cooperate in implementing joint certification, there are some differences between the two. UNDP then played its role in mediating these two certification systems. On the side, the Government prioritises the ISPO certification, which is considered in line with maintaining domestic business stability. NGOs are also in coalition with the UNFCCC in the second elliptical layer campaigning for carbon emission reduction programs. This emission reduction program campaign encourages GAIKINDO and AISI to innovate producing low-emission vehicles, including biodiesel and EV.

The sustainable development of Indonesia's transportation sector also involves support from global institutions such as the UNFCCC and United Nations Development Programme (UNDP). These organisations play a crucial role in fostering sustainability within Indonesia's transportation, particularly regarding decarbonisation, energy transition, and low-carbon development. Their contributions are normative, technical, and financial, encouraging Indonesia to strengthen its climate commitments and develop a clean and inclusive transportation system.

The UNFCCC has established a framework and created global pressure for Indonesia to prioritise sustainable transportation as part of its climate change mitigation efforts. Through the Paris Agreement framework, the UNFCCC encourages Indonesia to set Nationally Determined Contributions (NDC) targets that encompass the transportation sector. The government has updated its 2022 NDC, aiming for a 31.89% reduction in emissions independently and a 43.20% reduction with international assistance across all sectors. Transportation is identified as a key sector for emission reductions, primarily through the use of biofuels and electrification (Ministry of Environment, 2024).

On the other hand, the UNDP provides technical support, financing, and institutional strengthening to ensure that the transformation to low-carbon transportation can be effectively implemented. The UNDP has initiated several low-emission transportation projects, such as the Low Emission Vehicle Development (LEVD) program in various cities across Indonesia. Additionally, in collaboration with the MEMR and ride-hailing providers, the agency has promoted electrification in urban transportation through the EV Smart Mobility Project (2021–2023) (UNDP Indonesia, 2024).

In the third ellipse, there are actors with medium influence and power. Local governments have the authority to issue permits for biofuel and automotive manufacturing companies operating in their areas. The Central Government has close cooperation with local governments in coordinating the formulation and implementation of transportation sustainability policies such as ISPO certification, mandatory biofuel programs, and other carbon emission reductions. Energy companies, automotive manufacturers, and transportation providers are together in this layer as parties that must comply with the Government's policy on energy sustainability in the transportation sector. International consumers in this layer have considerable power to impose their demands on the sustainability of the supply chain of biofuels.

Biofuels export market has generated significant financial gains, which can serve as incentives to help manage fluctuations in crude oil and biofuel prices. Consumer countries, such as those in the European Union, have established sustainability restrictions for the supply chain, which place normative pressure on Indonesian biofuels. Additionally, global consumers have encouraged producing countries to accelerate their energy transition (Astari and Lovett, 2019). International consumers generally convey their demands through mediation by international NGOs, media, or RSPO institutions. The media, as an important actor, places a relatively neutral position on government policies and authorities. The media also has high power by publishing news that can change the opinion of international and national consumers.

The actors in the peripheral ellipse are those who have little influence on policymakers in the biofuel, electrification, and other alternative fuel sectors. In this ellipse, there are also BSN and research and consultancy institutions which put their self in a neutral position towards government policies. The power of BSN and research and consultancy institutions are limited in influencing the process of policy formulation and decision making related to the determination of energy sustainability policies. Green suppliers are also in this layer because they have relatively little knowledge of the certification obligations of biofuel companies.

Smallholder oil palm farmers play a vital role in contributing approximately 35% of the country's total CPO production (Hasan et al., 2022). Their work not only provides a livelihood for their families but also significantly supports community empowerment and

enhances family well-being. As a result, this group of farmers plays an important role in maintaining social stability in rural areas. However, most small farmers do not have direct access to the biodiesel market or processing plants. Instead, they sell their fresh fruit bunches to collectors or cooperatives, which then sell the produce to factories owned by large corporations. As a result, the price farmers receive is lower and tends to fluctuate, depending on their bargaining power and logistical access (Farobie and Hartulistiyoso, 2022).

Limited access to training, land legality, and capital are significant barriers to achieving global sustainability standards. Several initiatives have been implemented to improve the situation for smallholders. These include a replanting program by the BPDPKS, plasma partnerships to enhance market access, and the provision of technical guidance. Additionally, ISPO training is being carried out to promote compliance with sustainability certification. However, the effectiveness of these measures remains limited and varies across different palm oil production regions (Hasan et al., 2022). These smallholder farmers face a high risk from sustainability regulations imposed by markets in the EU and the US. While many have achieved ISPO certification to demonstrate their commitment to sustainable practices, structural inequalities mean that many smallholders may still be at risk of losing access to global markets (Hasan et al., 2022). Rural communities often face marginalisation in the context of the ongoing socio-technical transition due to a lack of social equality. The limited access to gas stations, electric vehicle charging stations, and BSS makes it challenging for these communities to participate in and benefit from the diffusion of eco-innovations. Additionally, promotional campaigns are frequently uneven across the country, leading to a lack of awareness about sustainability issues among rural communities.

Despite the increasing availability of charging points and BSS infrastructure in urban public areas, many urban consumers, especially those with lower-middle incomes, still face obstacles in participating in the transition to EVs. Limited budget allocations for electric vehicle subsidies mean that many urban consumers do not qualify for financial assistance. Although interest in EVs has grown significantly among the urban population, the high purchase prices of electric vehicles remain a barrier when compared to used ICEVs in the same category. Additionally, electric passenger car owners often struggle with the costly installation of charging stations at home.

The outermost ellipse also encompasses small- and medium-sized local startups. While these companies actively contribute to the diffusion of innovation, especially in the development of EVs tailored to the needs of local users, they still encounter challenges in entering the electric vehicle market. These barriers are mainly due to their limited access to advanced technologies and the financing necessary for mass production.

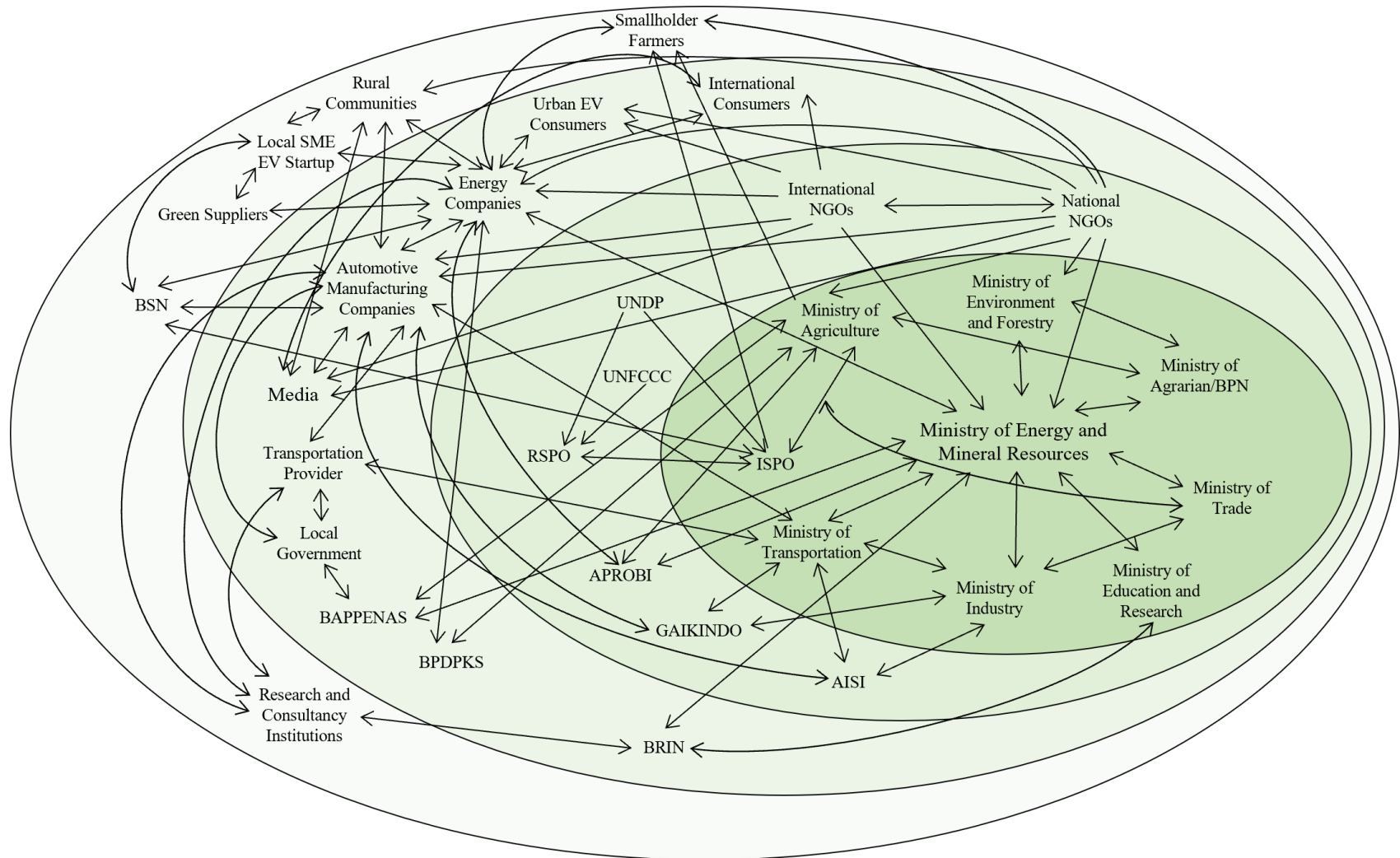


Figure 5.2 Map of stakeholders influence and their interaction network.

Source: Author

5.7 Discussion

The ongoing diffusion of eco-innovation in Indonesia, particularly through biofuels and electric vehicles, represents a key trajectory toward sustainable transportation. This EI diffusion was influenced not only by technological and economic factors but also by complex power dynamics that have generated significant debate among various stakeholders. This study stage has utilised the frameworks of John Allen's relational geography of power, Michel Foucault's theories of disciplinary and discursive power, and Peter Newell's political economy of sustainability transitions to analyse how power operates among different actors and institutions. This study also examines the public discourses that emerge and compares them with the power relations that shape the distribution of social justice among the stakeholders involved.

Allen's framework offers a perspective for understanding how agencies in Indonesia's energy transition deploy power-at-a-distance and form "power with" coalitions. Key state agencies, including the MEMR, MoF, MoI, MoA, and BDPKS, have employed budgetary and regulatory tools to influence distant actors. Meanwhile, smallholder farmers and rural communities were often used to legitimise prevailing narratives. This situation highlights the uneven spatial distribution of power.

The state exerts instrumental power through mandated regulations supported by both fiscal and non-fiscal policies during the socio-technical transition. This instrumental power includes setting biofuel blending targets and formulating subsidies for biodiesel producers (Djarmika et al., 2024; Kapriadi, 2019). This instrumental power also has the authority to construct policies, including limited subsidy programs for EV end-users and various incentives for consumers, manufacturers, and infrastructure providers (Putera et al., 2025; Sasongko et al., 2024). Technical ministries, such as the MoF and MEMR, use budgetary and regulatory tools to influence distant actors, particularly multinational automotive manufacturers and vertically integrated large palm oil corporations. Strategic alliances between the state, Pertamina, and large agro-industries (Choiruzzad, 2019; Ichsan et al., 2025), along with partnerships involving PLN, independent power producers (IPPs), multinational electric vehicle manufacturers, and infrastructure enablers (Sasongko et al., 2024; Setiawan, A.D. et al., 2022), exemplify "shared power." These state-capital alliances shape the narratives surrounding national interests.

However, local resistance or compliance with the diffusion of EI was influenced by relational proximity. In the case of biofuels, small farmers and rural communities, despite being marginalised in certification governance (de Vos et al., 2023), are often used to legitimise the narrative of inclusive development promoted by state agencies (Astari and Lovett, 2019). Similarly, rural communities are marginalised due to the lack of green mobility infrastructure,

as are lower-middle urban groups who do not qualify for subsidies (Detiknews, 2023; Abdurrahman, 2025). Our findings align with Allen's framework, which examines fragmented inclusion in socio-technical transitions and highlights areas where the ongoing integration of power remains uneven (Allen, 2004).

Foucault's concept of discursive power explores how state agencies govern through the language of sustainability. National slogans such as "Save Palm Oil, Save the Nation" (Choiruzzad, 2019) have bolstered the legitimacy of dominant actors seeking to expand palm oil plantations and increase biodiesel production. This advancement of biofuels was framed not only as an energy solution but also as a patriotic responsibility, achieved by shaping public discourse and policy space. However, this discursive power has marginalised environmental narratives on issues such as deforestation and the threat to biodiversity (Astari et al., 2025). Moreover, the narrative that biofuels have improved the welfare of smallholder farmers and stimulated rural economies has obscured the growing social inequality between large multinational palm oil corporations and local communities (Ichsan et al., 2025; Pye, 2019).

The portrayal of EVs as a symbol of national modernity highlights the influence of state agency discourse (Detik, 2017). It indirectly reinforces the increasing dominance of key players in the decarbonization process through electrification. By framing mobility as cutting-edge, cost-effective, and environmentally friendly (Setiawan, A.D. et al., 2022), the narrative has overlooked the continued reliance of the electricity generation sector on coal and the slow progress toward meeting renewable energy development targets (IEA, 2023d). This situation was exacerbated by the surplus electricity supply in Java and Bali, which has been directed toward road transportation. The discursive power regime has been utilised by conglomerates supplying coal to IPPs and multinational EV companies to challenge the dominance of conventional ICEVs in the Indonesian market. Additionally, the widespread adoption of EVs, which requires extensive infrastructure, has resulted in unequal access to public charging facilities. High-income urban residents have much better access than other groups, particularly those in rural communities (Dwi, 2024). Our findings contribute to knowledge about how dominant actors utilise inclusive sustainability discourses. These narratives align with Foucault's concept of normalising discourse, which involves establishing a form of "truth" that gains institutional acceptance. However, these practices often reinforce state legitimacy, thereby further entrenching existing actors (Foucault, 1980; Foucault, 2007).

Since 2006, the governance of palm oil plantations has undergone a significant shift from society-centred to state-centred. This transition has led to a political economy characterised by rent-seeking behaviour (De LT Oliveira et al., 2017; Kapriadi, 2019). Evidence of this system is evident in the biofuel subsidy mechanism, which has been exploited by large palm oil conglomerates through the BDPKS. This subsidy mechanism, backed by mandatory

policies, reinforces the dominance of these businesses while overlooking the advancement of other biofuels, such as ethanol and second-generation fuels (Rahayu, 2023).

Additionally, the policy promoting electric vehicle industrialisation favours state-owned enterprises, multinational EV manufacturers, and urban consumers, thereby perpetuating socio-economic inequalities and marginalising the transportation needs of rural communities (Abdurrahman, 2025). The collaboration between the state and the automotive industry, along with infrastructure monopolies, illustrates regulatory capture, in which policies are designed to maintain the existing structure of extractive capitalism while presenting it as environmentally friendly. These findings align with Newell's perspective that economic incentives often reinforce established players rather than unsustainable practices (Newell and Bray, 2025).

5.8 Conclusion

This study examines the development of sustainable transportation in Indonesia, focusing on the adoption of biofuels and EVs as key pillars of socio-technical transition. This stage utilises a multidimensional perspective on power to analyse the dynamics of policy formulation, actor coalitions, benefit distribution, and processes of marginalisation in Indonesia. The findings reveal a highly stratified and contentious pathway for transition, where power is exerted not only through direct control and resources but also through subtle discursive and institutional mechanisms.

In response to the first research question, this study found that power contestation between global and local actors at various levels manifests in different ways. These contestations occur discursively, through competing narratives about energy security, environmental friendliness, and inclusivity in the diffusion of eco-innovation. This spread concerns the adoption of biofuels and electric vehicles explicitly as pathways toward sustainability. Institutionally, these ongoing power contests have led to overlapping standards between the global RSPO certification regime and the national ISPO certification systems. Additionally, power is structurally displaced through embedded financial flows and subsidies that are co-opted to benefit the interests of entrenched old actors in the socio-technical system.

Global certification bodies, vertically integrated multinational biofuels producers, multinational vehicle manufacturers, and foreign investors have established both cooperative and competitive relationships with government agencies, including ministries and technical management organisations, as well as state-owned energy companies like Pertamina and PLN. Additionally, they engage with private sector associations, collectively shaping the policy framework through a combination of influence, alliance-building, and regulatory manoeuvring.

The study's findings indicate that actor coalitions in the diffusion of biodiesel and EVs were not fixed; instead, they were fluid and often influenced by incentives, institutional proximity, and policy narratives. These results address the second research question: how these coalitions or alliances are formed among the various actors involved in the adoption of biodiesel and EVs. Strategic alliances involving MEMR, MoF, MoA, BPDPKS, large multinational palm oil corporations, and Pertamina have driven the establishment of biodiesel mandate regulations. In contrast, the adoption of EVs has been characterised by fragmented coalitions that include MEMR, MoF, MoI, PLN, global EV manufacturers, and infrastructure producers. These coalitions were primarily based on shared economic interests and national industrial policy objectives. However, they tend to exclude other actors who lack direct access to formal decision-making spaces, such as smallholder farmers, rural communities, low- to mid-income level urban EV consumers, and local SME startups.

The third research question examines which parties benefit from this socio-technical transition. The analysis reveals that national policies related to biodiesel and electric vehicles primarily favour established agencies. These dominant actors include state agencies, state-owned enterprises, particularly Pertamina and PLN, large multinational palm oil companies, and multinational automotive manufacturers associated with GAIKINDO, AISI, and PERIKLINDO. According to Newell, these entities exercise instrumental power by gaining direct access to subsidies and participating in policymaking processes. They also possess structural power due to their central role within the existing energy and industrial infrastructure. Allen's spatial analysis emphasises that their proximity to state agencies and financial networks further solidifies their dominance, often to the detriment of marginalised stakeholders.

This socio-technical transition aimed at inclusivity does have its victims. Smallholder farmers, rural communities, lower-middle-income urban consumer groups, local small-scale electric vehicle startups, and independent bioenergy innovators remain marginalised due to inadequate infrastructure support, lack of access to certification, and limited access to mainstream funding programs. Our findings align with Foucault's framework of disciplinary power, illustrating how technocratic norms—such as standardisation, certification, and type testing—regulate and exclude certain actors from the transition. Additionally, discourses of "national interest," "energy security," and "environmental conservation" have been repurposed to justify the continuance of elite-driven development models.

In conclusion, the case study of Indonesia's transport sector, as a developing country, demonstrates that the transition to sustainable transport is neither straightforward nor equitable. Instead, it is significantly influenced by overlapping and contested power dynamics. This situation calls for a more inclusive and reflective governance model that actively recognises and addresses power imbalances. It is crucial to ensure that the sustainability

transition does not perpetuate existing inequalities while presenting itself as environmentally friendly, which could undermine the involvement and interests of various stakeholder groups.

Thus, the successful and effective implementation of the Indonesian transportation energy policy requires the commitment and active participation of all stakeholders. The next chapter discusses the analysis of the eco-innovation diffusion process related to alternative fuels (AFs) in developing countries. The adoption of environmentally friendly fuels in these regions lags behind that in developed countries, primarily due to high initial costs, limited infrastructure, and inconsistent policies. By examining case studies of biofuels and EVs in Indonesia, this study investigates the factors that promote and hinder their adoption, particularly among users in remote areas.

Chapter 6 Navigating the Energy Transition: Key Determinants of Technology Diffusion and Eco-Innovation Adoption for Alternative Vehicle Fuels in Indonesia²⁰

6.1 Introduction

This chapter examines the diffusion process of eco-innovation in alternative fuels (AFs) within emerging economies. The adoption rate of eco-friendly fuels in these regions lags behind that of developed countries, primarily due to high initial costs, limited infrastructure, and inconsistent policies. By analysing the case study of biofuels and EVs in Indonesia, this research stage investigates the factors that both promote and hinder their adoption, particularly among users in remote areas.

Utilising a combination of multi-level interviews and triangulation with secondary data, this stage of the study addresses the following research questions: First, why is the diffusion of AFs slow in developing countries despite a high vehicle population? Second, how does collaborative innovation support the local adoption process of AFs, especially in remote areas? Third, how do stakeholders overcome the main obstacles in the diffusion of AFs, particularly the high initial costs, regulatory uncertainties, and lack of infrastructure?

The following section presents the diffusion process of AF technology and its adoption by users in Indonesia. Following that, Section 6.3 discusses the diffusion of technology and the adoption of EI related to biofuels. Section 6.4 examines the diffusion of EVs and the user innovation process in their adoption, with consideration of individual mobility needs. Section 6.5 will provide a comprehensive discussion of the findings from this phase of the study, highlighting its contributions to the body of knowledge on technology diffusion in developing countries. Finally, Section 6.6 will conclude this study stage and describe the policy implications for promoting the sustainable development of affordable and clean energy, particularly in the transportation sector.

²⁰ This chapter has been published in the Journal of Environmental Management with the following reference:

Fathoni, F., Kesidou, E., Rifansha, M.M. and Tiftazani, A., 2025. Drivers and barriers of eco-innovation in electric vehicle diffusion: Evidence from Indonesia. *Journal of Environmental Management*, 389, p.126021. <https://doi.org/10.1016/j.jenvman.2025.126021>

6.2 The Diffusion of Alternative Vehicle Fuels Technology in Indonesia

Indonesia has experienced a current account deficit since 2004, primarily due to its dependence on petroleum products and the uncontrolled growth of private vehicles (Huntington, 2015; Sefriyadi et al., 2023). The rapid increase in private vehicles has outpaced the development of road infrastructure and public transportation systems, leading to severe traffic congestion and worsening air pollution (Sefriyadi et al., 2023; Janssen et al., 2022). In contrast, advancements in alternative fuel technologies, particularly the diffusion of ethanol since the 1970s and biodiesel since the 2000s, have spread globally (Nikas et al., 2022; Manuel, 2021).

Efforts to promote the diffusion of AFs in Indonesia were driven by "government policies aimed at reducing emissions, cutting fuel subsidies, and decreasing imports" (Interviewee 12, Section Head). In the fuel oil sector, the Indonesian government has assigned Pertamina to carry out crude oil distillation, biofuel blending, distribution, and marketing to consumers. Pertamina receives biofuel supplies from several biodiesel and bioethanol companies, including Wilmar Nabati Indonesia, Sinarmas Bio Energy, Apical Group, KPN Group, Wings Group, Molindo Raya Industrial, and Energi Agro Nusantara. These companies produce and process biodiesel and bioethanol, and are commonly private companies with integrated businesses spanning plantations and crude palm oil production to biofuel processing. The diffusion of biofuel technologies has involved innovative collaboration between energy companies and automotive manufacturers, particularly Toyota Astra Motor, Mitsubishi, Hino, and Isuzu, in adapting biofuels for compatibility with existing internal combustion engine vehicles.

Its dependence on fossil fuels hinders Indonesia's adoption of alternative fuels (AFs), as well as changes in political leadership and consumer resistance to change. Despite lagging behind other Southeast Asian nations, the government has promoted EV adoption since 2019. Figure 6.1 shows the relationships among stakeholders involved in the diffusion of biofuels and electric vehicles in Indonesia. The Indonesian government has assigned PLN the responsibility of managing distribution and marketing within the electrification sector. PLN sources electricity from various power plants, including its subsidiaries and private companies. To foster the diffusion of EVs in Indonesia, PLN has established partnerships with infrastructure enablers and EV manufacturers. Several oil companies, retailers, and battery swapping services have partnered with PLN to enhance the EV infrastructure network.

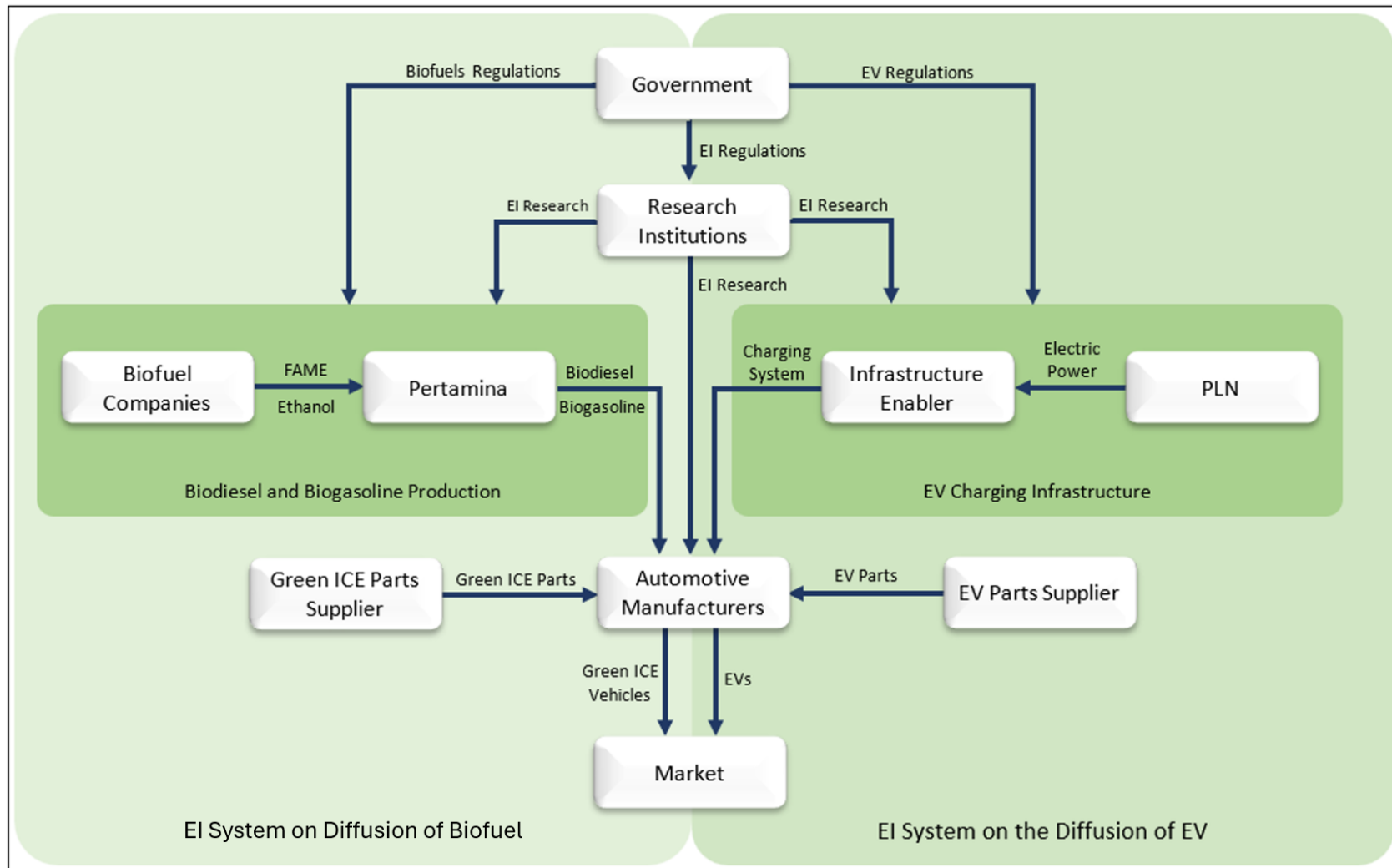


Figure 6.1 Stakeholders in the EI system of Biofuel and EV Diffusion.

Source: Author

Key automotive manufacturers involved in this collaboration include Hyundai, Nissan, Wuling, Wika Industri Manufacture, Selis, Swap Energy, United Motor, ECGo, Strum, Neta, and Polytron. This collaboration has spurred user innovation and accelerated the diffusion of EVs in the country.

6.3 The Diffusion of Biofuels Technology in Indonesia

6.3.1 The Diffusion of Biofuels

Proposition

Biofuels have become a prominent alternative to fossil fuels in Indonesia. While stakeholders have increasingly focused on the biofuels' proposition as a low-emission energy option, driven by "government policies aimed at reducing emissions, along with fuel subsidies and the need to decrease imports" (Interviewee 12, Section Head). On the other hand, consumers desire affordable and clean energy, along with the certainty of its availability to support public activities, as expressed by Interviewee 3.

"Customers desire several key factors related to energy supply. The first is affordable and clean energy. The second factor is the assurance of availability. Currently, subsidised fuel can be challenging to obtain. At times, the public is even willing to pay a higher fuel price, as long as it is in stock." (Interviewee 3, Researcher)

Global energy concerns are growing due to the depletion of global oil reserves, highlighting the urgent need for alternative fuels. "President Susilo Bambang Yudhoyono has decided to develop various types of alternative fuels, including castor oil, biodiesel, and alcohol-based biofuels" (Interviewee 58, Engineer). In response to the 2004 current account deficit, Indonesia began implementing policies to encourage the diffusion of biofuels in 2006. As the global biodiesel movement gained traction, which started in Argentina, both the government and the private sector recognised the potential of utilising "there are many oil palm plantations [as raw materials for biodiesel]" (Interviewee 42, Team Leader). Secondary data emphasise that one of the primary considerations in selecting a biofuel type is the availability of the feedstock. Therefore, palm oil was chosen as the basis for biodiesel diffusion in Indonesia. In response, the government began formulating policies to support the biodiesel initiative (Suhara et al., 2024; Farobie and Hartulistiyoso, 2022).

In conjunction with the implementation of mandatory biodiesel policies in the transportation sector, the government collaborates with biodiesel industry associations, oil companies, automotive manufacturers, and research institutions. This collaborative network aims to

develop biodiesel specifications and ensure compatibility with existing diesel ICEVs. Most biodiesel companies benefit from knowledge spillovers from foreign licensors to develop their manufacturing processes. Following this, several EI activities were conducted to minimise the process cost and optimise the energy efficiency, as explained by one of the respondents below:

"For technology, we definitely have vendors. Because the vendor has the [biofuel processing] technology, they have a rough process outline. However, because we are users here, we always seek improvement. There will be improvements, whether in terms of steam usage [energy] or terms of the process. ...Because we need data and trials in order to get the quality that consumers want. ...Of course, we will do it on a lab scale first and then continue to trial [stage]....So, [coordination] between users is between heads of departments, for example, production, refinery, and other related [departments]. We discuss how to reduce one budget and another. Then [innovations] ideas like that emerge." (Interviewee 42, Team Leader)

The growth of the biofuel industries, especially biodiesel, has brought financial advantages to various stakeholders, particularly farmers and large corporations. The use of palm oil harvests as a feedstock for biofuel has enhanced farmers' welfare and created job opportunities for the local community. Additionally, the social impact of the increasing adoption of palm oil-based biodiesel has fostered financial stability within the community, contributing to future development for the next generation. This sentiment is reflected in the words of one respondent:

"My family's welfare has improved, and it has positively impacted the surrounding residents as well. The plantation has created job opportunities, primarily for local families, helping them with employment, financial stability, and securing a better future for their children." (Interviewee 62, Rural Farmer)

The mandatory biodiesel policy has a significant impact on the finances of large companies. Previously, the palm oil industry concentrated more on the food and oleochemical markets. Currently, the manufacturing plants' production capacity is dominated by biodiesel products due to high market demand. Interviewee 42 shared insights on the financial impact of biodiesel industrialisation, stating:

"Yes, it is evident that profits [have increased] since the establishment of this biodiesel plant. Previously, our focus was primarily on processing CPO into cooking oil. However, since the launch of the biodiesel plant, we have shifted our focus to biodiesel production. As a result, the majority of our shipments are now biodiesel." (Interviewee 42, Team Leader)

A secondary source also highlights the impacts of biodiesel industrialisation, which not only increases profits for large companies but also enhances farmers' welfare, especially in rural areas. Justiari (2021) reported that the government mandated the use of biodiesel to enhance the welfare of oil palm farmers by ensuring fair prices for their harvests.

"The government is relying on biodiesel produced from CPO as a biofuel to facilitate the energy transition in the transportation sector. The welfare of oil palm farmers is one of the criteria for selecting CPO suppliers as a biodiesel feedstock." (Justiari, 2021)

Encounter

Since the late 1970s and early 1980s, the government has encouraged the development of oil palm plantations by involving farmers in community-based core plantations. Initially, however, large companies led the way in producing palm oil-based biodiesel, focusing primarily on "exports that yield higher profits compared to the local market" (Interviewee 42, Team Leader). Large-scale palm oil companies benefit from access to feedstock, investment capital for FAME²⁰ mills, and adequate technological support for commercial biodiesel production.

Biodiesel began to diffuse in the domestic market after the implementation of the B2.5²¹ mandatory policy for subsidised transportation in five provinces in 2008. Additionally, biodiesel companies have begun using biodiesel to power generators in their factories. The compatibility of biodiesel with existing diesel power generators has led some stakeholders to urge the government to mandate a wider adoption of biodiesel in the transportation sector and beyond. Interviewee 28 emphasised this point by stating:

"Biodiesel has already proven its reliability as a fuel source for power generation in factories, with no operational issues reported. This success paved the way for the rollout of B10²² biodiesel, followed by B15²³. Yet, astonishingly, only the transportation sector has fully embraced these advancements. Industries such as mining, heavy equipment, defence, and fishing were still resistant to adopting biodiesel. Moreover, the use of biodiesel in the industrial sector remains merely optional." (Interviewee 28, Senior Manager)

²⁰ FAME refers to fatty acid methyl esters, which are organic compounds produced from the transesterification reaction between vegetable oils or animal fats with methanol, usually using a catalyst (base such as NaOH/KOH) (Figueroa-Torres et al., 2020).

²¹ B2.5 refers to diesel oil containing 2.5% biodiesel in volume.

²² B10 refers to diesel oil containing 10% biodiesel in volume.

²³ B15 refers to diesel oil containing 15% biodiesel in volume.

Following several years of increasing biodiesel production, global crude oil prices rose significantly in 2014. At the same time, trade disputes and sustainability concerns suspended exports to the EU and US, resulting in a collapse in CPO prices and causing farmers to abandon their harvests. This led to social impacts, particularly among farmers who now require government support to domestically absorb biodiesel. In response, the mandatory B20 regulation has facilitated the broader diffusion of biodiesel, as noted by the following respondent:

"In 2014, there was a spike in the price of crude oil, touching nearly USD 100 per barrel. On the other hand, the price of fresh palm fruit bunches for the biodiesel industry has fallen. So that farmers want to avoid harvesting it and causing rot in the garden. Recognising the urgency of this issue, the government began to scrutinise the growing disparity between diesel and CPO prices. Fortunately, the biodiesel sector has been thriving, offering a viable solution to this dilemma. So why not make biodiesel usage mandatory? Embracing biodiesel presents a tremendous opportunity to bolster the industry while addressing critical economic and social challenges. Finally, the government saw the potential use of biodiesel by establishing a mandatory use policy for transportation." (Interviewee 28, Senior Manager)

To maximise domestic absorption, "the government encouraged [domestic absorption] by mandating biodiesel" (Interviewee 2, Researcher) use in transportation, industrial, and power sectors. "Over time, 2018 has seen a significant increase in Indonesia's biodiesel production" (Interviewee 28, Senior Manager). According to secondary sources, as biodiesel becomes more compatible with existing diesel engines, the government is gradually increasing the proportion of biodiesel blended with fossil fuels. Since 2016, the effective implementation of mandatory biodiesel usage policies has led to significant growth in biodiesel production (Farobie and Hartulistiyoso, 2022; Candra, 2025).

This research stage indicated that most participants noted that EI in biofuel diffusion is influenced not only by regulations but also "there are many factors, especially the main driver is the subsidy [or the incentives scheme]" (Interviewee 12, Section Head). The Palm Oil Fund Management Bureau (BPDPKS) manages the incentive schemes for the Indonesian biodiesel industry. "FAME [industries] are robust due to the support of BPDPKS, which manages the palm oil funds" (Interviewee 2, Researcher). These funds are generated from the exports of Indonesian biodiesel companies and are utilised to bridge the price gap between CPO and crude oil. This incentive scheme has played a crucial role in promoting the sustainability of biodiesel development in Indonesia.

Secondary sources also emphasised the critical role of palm oil fund management in maintaining the stability of the domestic mandatory biodiesel program. In addition to bridging the price gap between FAME and fossil diesel to ensure market competitiveness, BPDPKS actively promoted sustainability through research and development. Moreover, this institution collaborates with smallholder palm oil farmers on replanting initiatives and outreach efforts to reduce deforestation during plantation expansion (Farobie and Hartulistiyoso, 2022; Astari and Lovett, 2019).

The diffusion of biofuels was primarily influenced by their compatibility with existing diesel engines and their ease of use in current distribution facilities. As a result, the policies that determine the required biodiesel blending content significantly impact automotive manufacturers' development efforts. One respondent highlighted this concern:

“Talking about biofuels will be the core of the vehicle's working mechanism. So, before the regulations were implemented, we quickly communicated with the principal regarding developing vehicles to be compatible with biofuels... then there will be no issues in the market.” (Interviewee 47, General Manager)

Disposition

The diffusion of biofuels, especially biodiesel, as alternative fuels is heavily influenced by consumer evaluation. This analysis focused on the disposition aspect that affects consumer attitudes towards biofuel adoption, which are primarily shaped by their diverse backgrounds, particularly previous experiences with fossil fuels. Furthermore, consumer evaluations and social analyses of biofuel usage are influenced by socioeconomic status, social factors, and individual risk assessments. One respondent expressed caution towards new fuel products, avoiding non-standardised fuel that could potentially affect their vehicle's reliability.

“Even when we visit palm oil plantations [in North Sumatra], we ask [the consumers] where they buy [their fuel]. They typically respond, 'I bought it at the gas station; it is not far?' There is no issue with this, but we are cautious because it is new technology. Therefore, we prefer not to take risks with non-standardised fuel.” (Interviewee 26, Business and Marketing Analyst)

In the initial stages of palm oil-based biodiesel emergence, some individuals exploited the opportunity by selling non-standardised fuel. As a result, the composition of the raw materials, especially the water content, did not comply with the specifications set by the regulators. Interviewee 26 shared insights into consumer experiences regarding the effects of this non-standardised fuel on diesel vehicles, noting the following:

"In our experience, a common issue arises when the product starts to malfunction, emitting white smoke, typically due to a high-water content and low power output. If the situation worsens, the engine may not start at all, and if it does start, it won't operate continuously." (Interviewee 26, Business and Marketing Analyst)

This study findings indicate that during the early stages of biodiesel implementation, consumers expressed concerns about the composition of the biofuel. These concerns stemmed from the presence of glycerides, which can negatively impact the performance of diesel vehicles, as detailed below:

"Vehicle manufacturers encounter challenges with clogged injectors caused by the glyceride content in biodiesel. Furthermore, if a vehicle is not used for an extended period, sediment may form due to the presence of biofuel content." (Interviewee 26, Business and Marketing Analyst)

The diffusion of EI biodiesel depends significantly on diesel vehicle users who, as consumers, provide valuable feedback to automotive manufacturers regarding technical issues. This study stage highlights the necessity of maintaining effective communication channels between vehicle sales and consumers to facilitate the adoption of biodiesel in Indonesia. This point was emphasised by Interviewee 47, who said, "To address these concerns proactively, we have been utilising effective communication and collecting feedback from our consumers, which has been running smoothly so far". (Interviewee 47, General Manager)

Automotive manufacturers have continuously improved their vehicles to enhance compatibility with the increasing levels of biodiesel blending.

"The purchase price of the vehicle has increased due to changes in the fuel tank and the filter converter. If these changes are made, the material costs will rise. However, the most essential aspect is how we educate customers through sales news and discussions. We need to inform them about the additional costs while assuring them that the new parts are compatible and will not cause any operational issues."

Interviewee 47 shared his experience regarding parts that were initially designed as optional but became highly desirable for consumers because they support biodiesel use in their vehicles. Additionally, a social evaluation revealed that consumers were increasingly recognising the importance of preventive maintenance to avoid financial losses from potential damage.

"We successfully developed a component that is available for optional installation. However, we are currently struggling to meet the high demand. As a result, we are experiencing a supply shortage because consumers believe our device can minimise

the effects of biodiesel. Consequently, customers are willing to accept higher costs for preventive maintenance to avoid operational breakdowns." (Interviewee 47, General Manager)

Secondary data emphasise that the diffusion of biofuels as an alternative fuel was aimed at achieving similar characteristics to those of fossil fuels. The effectiveness of the energy transition through biofuels was significantly impacted by consumers' analyses and social evaluations of diesel vehicle performance. This important feedback was crucial for automotive manufacturers to enhance their vehicle products. Therefore, collaboration between energy companies, automotive manufacturers, and customers was essential to ensure that biofuels are compatible with existing vehicles (Chandran, 2020; Kahn Ribeiro et al., 2007).

Responses

This study found that in the early stages of biofuel diffusion, some consumers were indifferent toward biodiesel. According to Interviewee 30, consumers were increasingly focusing on operational costs, which were primarily influenced by fuel prices. In the private vehicle sector, there has been a noticeable shift towards gasoline. This change was attributed to restrictions on the distribution of subsidised biodiesel. As a result, the cost of non-subsidised biodiesel has risen above that of subsidised gasoline, increasing overall operational costs for diesel vehicles.

"Consumer decision-making primarily revolves around running costs, which are closely related to fuel prices... Currently, with [biodiesel] subsidies limited to specific consumer groups and various policies, it has become challenging to obtain subsidised diesel... Consequently, [non-subsidised] biodiesel fuel prices may be twenty to thirty per cent higher compared to non-subsidised gasoline, which affects the running costs from the consumer's perspective. In the passenger vehicle segment, many have already switched to gasoline vehicles." (Interviewee 30, Team Leader)

This study findings also highlight that the increase in biodiesel blending has led to consumer uncertainty and a delay in replacing their passenger cars with new ones. This slowdown in sales was attributed to consumers waiting to see if the new biodiesel variants were compatible with conventional ICEVs. One respondent expressed this concern as follows:

"Our sales have been stagnating [since the increase in biodiesel blending]... Consumers there are adopting a wait-and-see approach, leading to a hold on updates for new unit purchases." (Interviewee 26, Business and Marketing Analyst)

Conversely, a different situation exists in "the commercial [vehicle segment], which remains a viable option because these vehicles are still permitted to use subsidised fuel" (Interviewee 30, Team Leader). Additionally, commercial vehicles have no alternative but to rely on diesel engines. Consequently, there is significant pressure on automotive manufacturers to address the issue of biofuel compatibility with these vehicles. Interviewee 47 also highlighted that commercial vehicle consumers are willing to switch to other brands if manufacturers fail to resolve this compatibility issue.

"In contrast, the commercial vehicle segment operates differently. Customers generally expect manufacturers to address compatibility issues, believing that warranties should remain valid regardless. If a manufacturer fails to resolve these issues, potential buyers are likely to reconsider their purchase of the vehicle." (interview 47, General Manager)

However, the necessity for availability of affordable fuel encouraged consumers to adapt to the effects of biodiesel on engine performance. As a result, consumers began to replace fuel filters more frequently to ensure the reliability of their vehicles. The additional cost of these filters remains beneficial when compared to the full use of fossil diesel fuel. Interviewee 62 expressed this sentiment as follows:

"I believe it is fairly suitable, although there are complaints regarding its cleanliness... However, what users of biodiesel want is a low price, a stable supply—despite frequent complaints about this—and good quality, specifically the clarity of the biodiesel. Many users recommend changing the oil filter more often when using biodiesel fuel." (Interviewee 62, Rural Farmer)

This study findings indicate that feedback responses from automotive manufacturers and diesel vehicle users regarding the use of biodiesel have prompted energy companies to enhance their technological capabilities. These EI activities aim to develop new products that are more compatible with fossil diesel fuel. The first generation²⁴ of hydrotreated vegetable oil (HVO) technology, referred to as green diesel or renewable diesel, has been manufactured and has traits that are very comparable to those of fossil diesel, according to interviewee 2.

²⁴ Carriquiry et al. (2011) classify three generations of biofuels. First-generation biofuels derived from sugar, grains or seeds are converted into fuel through a relatively simple process. Second-generation biofuels are sourced from edible lignocellulosic biomass (such as corn taxi, rice husk, forest logging and sawdust), plant biomass (including switchgrass and poplar) and vegetable oils from plants that can grow on degraded lands (such as jatropha). The production of second-generation biofuels using by-products has increased product value and enhanced energy independence (IEA Bioenergy, 2024). The third generation of biofuels comes from the process of extracting oil from algae which are currently still on a laboratory scale. Based on environmentally friendly use and economic benefits, second-generation biodiesel is better than first-generation biofuel (Köhler et al., 2014).

"HVO is similar to fossil diesel. In terms of calorific value, HVO also has a higher energy content compared to FAME. Furthermore, HVO boasts a higher cetane number, which indicates better combustion quality. From a cleanliness perspective, HVO is relatively cleaner because it does not contain monoglycerides, which means it has a lower likelihood of clogging fuel filters. As a result, its filter-blocking tendency is low, making it comparable to fossil diesel in this regard... As for the first generation HVO, my company has been able to [produce it] successfully. My company is currently researching the development of second generation HVO." (Interviewee 2, Researcher)

Green market demand is growing, which requires HVO, especially from the EU. Several EU countries have developed standardisation regarding green diesel imports. "Meanwhile in Europe, they want second generation [biodiesel] which does not compete with food." (Interviewee 2, Researcher). Similarly, the mining sector demands the green diesel due to the identical characteristics to those of fossil diesel. Concerns over land usage, deforestation, and food security are driving the transition from first-generation to second-generation biofuels, according to secondary data (IEA Bioenergy, 2024).

Meanwhile, the diffusion of molasses-based ethanol biogasoline is also very slow compared to other countries in the Southeast Asian region. Similar to green diesel, the lack of appropriate regulatory support, particularly the absence of a subsidy scheme, has made it difficult for this ethanol to compete with existing fuels in the market. Additionally, the availability of feedstock, which competes with the food sector, has become a significant barrier to the diffusion of ethanol-based fuel. Meanwhile, producing green diesel requires substantial investment to upgrade existing oil refinery configurations (Interviewee 3, Researcher).

6.3.2 The Adoption of Biofuels

The transportation sector in Indonesia has been reliant on fossil fuels for several decades. Although the global trend of using biofuels began with Brazil's ProAlcool program in the 1970s and has spread to various regions, Indonesia only started adopting biofuels in the mid-2000s. This transition towards energy in the Indonesian transportation sector was driven by the growing pressure to adopt alternatives to fossil fuels as part of various decarbonization initiatives, while also aiming to reduce imports and subsidies.

Unlike Brazil and the United States, which focus primarily on ethanol development, Indonesia has explored various feedstocks for biofuel production, including both ethanol and biodiesel. However, the government prioritised feedstock availability, price stability, and policy support when determining the direction of biofuel technology adoption. The country's vast palm oil

plantations, initially intended for the food sector, have emerged as a promising source for biofuel feedstock (Interviewee 42, Team Leader).

Argentina's success in developing biodiesel and the potential for export markets to the EU have caught the attention of stakeholders in Indonesia, highlighting the potential of palm oil-based biodiesel. The adoption of biodiesel EI was initially pioneered by large companies that prioritised "exports with higher profits than the local market" (Interviewee 42, Team Leader). According to OECD-FAO (2024), Indonesia's biodiesel production was recorded at 9.09 million litres in 2005, with 75% of that production dedicated to the export market, as shown in Figure 6.2. The domestic market absorbed only 25% of the production capacity. The diffusion of biodiesel continued to expand, with production sharply increasing to 630 million litres in 2008 and then reaching 2.2 billion litres in 2012. By 2012, the proportion of biodiesel absorbed by the domestic market had increased slightly, reaching 30.45% (OECD-FAO, 2024).

The utilisation of palm oil as a feedstock for biodiesel, both in export and domestic markets, has encouraged community participation, particularly in rural areas, to engage in oil palm plantations. Interviewee 62 noted that the motivation for rural farmers to participate in the biodiesel program, in addition to enhancing their welfare, also fosters independence in resource management.

"Yes, it could have an effect, particularly in terms of domestic palm oil usage. A portion of palm oil can be utilised domestically, which may benefit the farmers, palm oil industry, and foster our independence in managing our resources." (Interviewee 62, Rural Farmer)

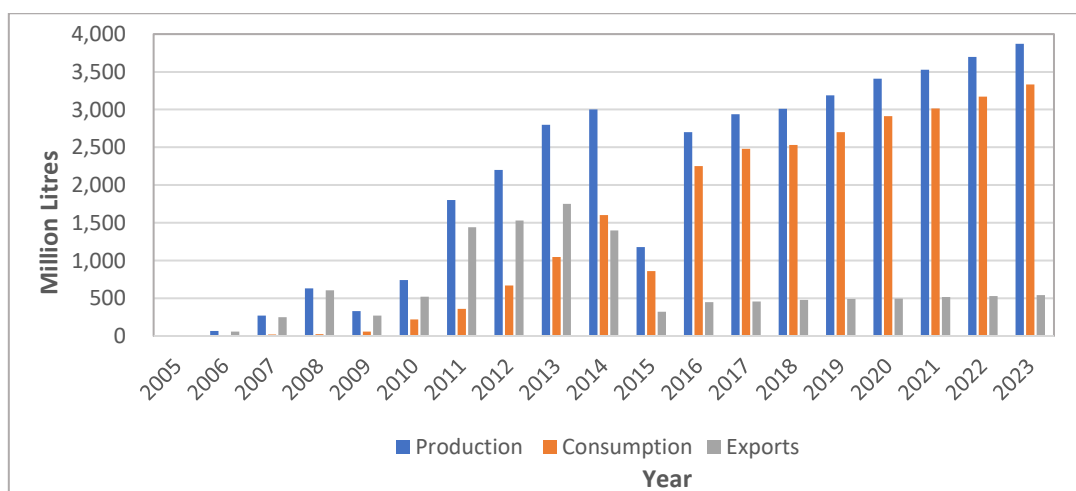


Figure 6.2 Indonesian biodiesel production, consumption, and export capacity (2005-2023)

Source: (OECD-FAO, 2024)

The broader socio-technical adoption of biodiesel in the domestic market began to crystallise after the ratification of the Paris Agreement and in response to social unrest, particularly among rural farmers. This social unrest was primarily triggered by the suspension of exports to the European Union and U.S. markets due to concerns over sustainability and trade disputes. The Indonesian government has implemented mandatory biofuel utilisation regulations in various sectors, including transport, commercial, industry, and electricity generation, through MEMR Ministerial Regulation No. 12/2015 to absorb biofuel production marked a critical juncture, which was followed by the introduction of the B20 program in 2016 (Interviewee 28, Manager).

Secondary sources also emphasise that the Indonesian government's commitment to ratifying the Paris Agreement at COP 21 in 2015, aimed at reducing greenhouse gas emissions, is also emphasised by secondary sources. This commitment has been outlined in Presidential Regulation Number 22 of 2017, which pertains to the National Energy General Plan (RUEN). The RUEN targets biofuel production of 15.6 million kilolitres in 2025 and 54.2 million kilolitres in 2050, as well as a blending target of 30% biodiesel and 20% bioethanol (BPPT, 2018).

The advancement in the adoption of "FAME [-based biodiesel] is well supported by BPDPKS, which manages palm oil funds [effectively]" (Source 2, Researcher). This institution managing funds from palm oil export levies to develop human resources, research and development, plantation promotion, plantation rejuvenation, infrastructure development and biodiesel supply (BPPT, 2018). As a result of the regulatory drivers, the proportion of the domestic biodiesel market absorption increased from 72.88% in 2015 to 83.33% in 2016. The introduction of the B30 policy further boosted the absorption rate, reaching 84.62%, and climbing to 86.03% in 2023 due to the B35 program (OECD-FAO, 2024).

Despite rapid growth, the broader adoption of EI biofuels still faces several barriers, particularly in terms of regulation, finance, technology, market, and environmental concerns.

Lack of Adequate Regulatory Support

Data analysis reveals that apart from acting as one of the main drivers, inappropriate regulations have become a barrier to EI biofuel development. In line with EI's success in developing biodiesel, one of the participants was concerned about the rapid increase in biodiesel blend levels. The implementation of short-term policies created socio-technical impact on difficulties in developing biofuel compatibility with diesel engines, as stated by one participant:

"We hope the government will issue a biofuel mid-term roadmap or policies, not a short-term one because it is relatively complex to calculate parts. If mid-term or long-

term, we know whether our product is compatible with the long-term government plan. As for the long-term government plan, we can calculate the impact and see compatibility. Not only from a local perspective but also because one vehicle model is sold in many countries from a regional and global perspective." (Interviewee 30, Team Leader)

One respondent highlighted the necessity for thorough policies addressing the complexities of the distribution network due to the increased blending of biofuel in biodiesel fuel.

"Our main challenge, aside from the technical issues in biodiesel development, is to provide input to the government, which establishes policies for increasing biofuel content. Additionally, the biodiesel distribution network is quite complex. Not all plantation companies have their fuel storage tanks, which can complicate distribution. In contrast, mining companies typically have their storage tanks, allowing them to purchase fuel under separate contract agreements specifically tailored to their supply needs." (Interviewee 26, Business and Marketing Analyst)

Unlike the full regulatory support for first-generation biodiesel. Despite the EU market's openness to green diesel products for their sustainability, there were limited regulatory concerns regarding green diesel, as noted by one participant.

"In Indonesia, there is no government policy regarding the mandatory use of green diesel, but the existing policy is biodiesel. ... Because there are no specifications, there is no policy, ... [so] biodiesel is still enforced" (Interviewee 3, Researcher).

This study stage also highlights the lack of regulatory support for the broader adoption of ethanol. Ethanol, which has been produced for many years as a potential source of biogasoline, does not currently receive sufficient regulatory support for its use as an alternative biofuel to fossil fuel. As several interviewees have pointed out:

"Indonesia still lacks regulatory support regarding ethanol as biofuel, in contrast to palm oil, which is supported by a [well-implemented] mandatory use policy" (Interviewee 46, Vice President).

"But then finally there was Presidential Decree number 40 of 2023... well, finally it requires Pertamina to take [ethanol as raw material for fuel]... (Büthe) it is still in the trial [stage] in Surabaya and Jakarta" (Interviewee 57, Director).

The lack of regulatory support for biofuel variants other than first-generation biodiesel has created market barriers to the adoption of more environmentally friendly biofuels in Indonesia. Several interviewees noted that slow market growth was a significant obstacle, particularly in the development of biogasoline and green diesel. One interviewee commented on the limited

local market for biogasoline, which has led companies to export ethanol to countries that mandate its use. Interviewee 46 remarked:

"If there is no demand for [ethanol-based biofuel in the local market], we have to export it abroad. We export to several countries, including the Philippines, Thailand, Japan, South Korea, Vietnam, Australia, and New Zealand" (Interviewee 46, Vice President).

Secondary data have examined the lack of regulatory support, and the absence of incentive schemes present significant barriers to the development of biofuels in some countries (Breetz, 2020; De LT Oliveira et al., 2017). Furthermore, Panoutsou et al. (2021) emphasised that the policy mechanisms of the EU have set targets and monitoring frameworks aimed at promoting low-carbon fuels and improving vehicle engine performance. However, these measures remain insufficient to support the market adoption of advanced biofuels.

Price Vulnerability, High Investment Risk, and Social Welfare Concern

The growing adoption of biodiesel has raised concerns among stakeholders regarding the price disparity between crude oil and CPO. Both products are vulnerable to price fluctuations, mainly due to various trade and geopolitical issues. The government has implemented an incentive scheme to help reduce the impact of price disparities for these two important energy commodities on the public. This price vulnerability not only affects large companies but also significantly impacts the welfare of small rural farmers. As a result, farmers hope that the mandatory biodiesel policy can improve selling prices for their agricultural produce. One respondent noted that these price changes not only impact the market but also have social implications for farmers. In particular, farmers hope to see an increase in the prices of fresh fruit bunches (FFB) that corresponds with improvements in biodiesel prices.

"However, palm oil farmers indeed seek fair prices for fresh fruit bunches and aim to keep up with the price fluctuations of essential supplies for palm oil plantations, such as fertilisers. I believe that the implementation of biodiesel, which is only designated for subsidised use, will unlikely directly contribute to an increase in the price of fresh fruit bunches." (Interviewee 62, Rural Farmer)

Meanwhile, in the logistics of CPO as a raw material for biodiesel, a "challenge in West Kalimantan is also [from] the transportation factor... the road infrastructure is also inadequate... So, yesterday, we had a CPO shortage. Then again, if the weather is bad, we cannot dock the ship. That might be one of the weather factors." (Interviewee 42, Team Leader).

While the Indonesian biodiesel industry is growing rapidly, there are significant differences between biogasoline and green diesel. Indonesian biogasoline producers face challenges due to the high cost of ethanol as a raw material, which is more expensive than gasoline. Likewise, with “palm oil biomass, the logistics costs are a challenge for us” (Interviewee 35, Business Development). One producer stated, “We do not yet have [incentives] for ethanol, so we rely solely on the market index prices issued by the MEMR” (Interviewee 57, Director). The lack of an incentive scheme creates difficulties, as highlighted by another interviewee who noted, “The problem is that, at our [ethanol] price, achieving the economies of scale needed to replace gasoline at a price below USD 0.67 per litre is quite difficult” (Interviewee 46, Vice President).

This study stage also revealed financial barriers associated with developing “second generation [biodiesel], ... there needs to be additional treatment up front and an investment process ahead ... you must build a new refinery” (Interviewee 3, Researcher). In the green diesel industry, another interviewee mentioned, “Actually, in the upstream, we already have some materials ready. In the downstream too, if they are ready, we must wait for the economic scale” (Interviewee 35, Business Development).

The emergence of second-generation biodiesel and the adoption of ethanol require significant investment, which affects not only the economic landscape but also social equity. The high costs associated with these investments mean that established companies, which dominate the energy sector, primarily benefit from the newly accessible green market. Consequently, this situation exacerbates the gap in social justice between large corporations and small rural farmers, as emphasised by Kirshner et al. (2022).

Compatibility Concerns and Technology Capability Barriers

The adoption of biofuels, particularly biodiesel, has experienced several socio-technical transitions. This study stage highlights the emphasis placed on technical aspects related to adjustments made by automotive manufacturers and consumers regarding the characteristics of biodiesel. Although first-generation biodiesel closely resembles fossil fuel, its glyceride and water content can degrade the performance of vehicles that were initially designed for fossil fuel. In addition to user innovations by automotive manufacturers, which include enhanced specifications for fuel tanks, combustion systems, and other related components. This study findings describe how automotive manufacturers adapt to regulatory changes: “We understood the direction of biofuel policy, and the appropriate technical specifications were already established to ensure compatibility” (Interviewee 30, Team Leader).

One of the respondents expressed that diesel ICEV customers show behavioural adaptation to the presence of biodiesel and an increase in its blending ratio, as suggested by the manufacturer:

“In our recent meetings, we discussed several short-term solutions, including the addition of filters, cleaning the combustion chamber, and cleaning the injectors. One of the proposed actions is to change the filters more frequently.” (Interviewee 26, Business and Marketing Analyst)

Consumers facing these technical challenges tend to perform preventive maintenance more frequently than those with ICEVs. These adaptations underscore the importance of preventive maintenance by customers to minimise costs associated with operational disruptions caused by injector blockages.

“Transport providers are not overly concerned about the frequency of parts purchases. However, when it comes to injector replacement, the entire set must be replaced, leading to considerable downtime and increased costs. This is the reason why it is essential to conduct regular preventive maintenance to address minor issues, such as clogged filters, before they develop into larger problems.” (Interviewee 26, Business and Marketing Analyst)

Furthermore, the extra costs of preventive maintenance and the more frequent use of filters, a technical consequence of subsidised biodiesel, remain lower than the operational costs of vehicles using non-subsidised fossil diesel, such as PertaDex and Shell V-Power Diesel.

“We have calculated two costs that customers need to consider. When compared to using PertaDex, the operational costs are not significantly different. Therefore, our sales team must be thorough in their communication, especially when we demonstrate that installing this component at this price is safe. While we can estimate the costs, it is crucial for customers to feel reassured.” (Interviewee 47, General Manager)

The data analysis highlights several technological barriers to the development of biofuels in Indonesia. First, it emphasises the need for continuous improvement in meeting standards. For example, in the development of HVO, “there are still shortcomings regarding the pour point and cloud point. These requirements are critical considering that Europe, with its four seasons, requires fuel quality that can perform at low temperatures” (Interviewee 2, Researcher). Second, developing advanced biofuels that closely resemble fossil fuels and utilise environmentally friendly raw materials necessitates intensive research and development. In the case of second-generation biodiesel, “there is an ongoing need to accelerate technological [advancements]” (Interviewee 35, Business Development).

6.4 Understanding the Diffusion of Eco-Innovation: Perceived Attributes of EVs in the Indonesian Market

The presence of EVs in Indonesia has expanded the spectrum of eco-friendly driving options available to consumers. This study found that the global socio-technical trend towards EVs is a major driver of their adoption in Indonesia. As a result, "EVs are increasingly evolving into a lifestyle choice for the people of Indonesia. EVs represent a significant trend globally" (Interviewee 34, Director).

EV mobility mode has only diffused in Indonesia in recent years. This research reveals regulatory support through the government's net zero emission (NZE) program emphasise the utilisation of clean energy. The target of achieving the renewable energy mix has encouraged "development of EV may be more widely implemented because there is a focus on decarbonisation or countering CO₂ emissions, that is why electric [vehicles]" (Interviewee 4, Vice President).

Technology transfer flows abundantly in the EV diffusion in Indonesia. This research explores the findings of knowledge spillovers through two mechanisms. First, EV manufacturers are building collaborations with several parties in e-mobility innovation. Interviewee 10 explained that research collaboration with universities was the initial momentum for his company to enter the EMC industry, as stated below:

"The EMC was initially formed in partnership with universities. In 2017, we either partnered with or collaborated with the university. At that time, the university team needed industrial collaborators... From 2017 to 2019, we conducted joint research with these university partners, leading to the development of a prototype. Subsequently, we enhanced it in accordance with the standards or guidelines that we implemented within these industries by the end of 2019." (Interviewee 10, Engineer)

In line with that, to advance the diffusion and manufacturing of EVs, "we cooperate with various brands or suppliers that are capable of low-carbon conversion" (Interviewee 40, Training Instructor). On the other hand, several brands have collaborated business-to-business with transport providers "especially dominated by online ride-hailing" (Interviewee 5, Assistant Manager).

Furthermore, the government was also encouraging the development of battery technology together with global EV producers to grow the EV adoption in Indonesia, as stated by Interviewee 4 below:

"This company is set to evolve into an investment holding entity that collaborates with its partners across the entire EV ecosystem, from upstream to downstream. These

partners may include nations that are prominent producers of EVs, including Korea and China." (Interviewee 4, Vice President).

The second mechanism of knowledge spillovers is developing the firm's technological capabilities. These companies are committed to the vision that " we will certainly continue to innovate... [Thus], given the numerous swap stations, range anxiety ought to be the primary concern regarding this EMC; hopefully that will decrease over time" (Interviewee 34, Director). Technological updates were enhanced through "training for our employees, that is the first thing from the technical side" (Interviewee 40, Training Instructor).

This analysis stage also reveals the flow of knowledge through recruiting experienced personnel from other companies as well as indirect technology transfer from suppliers, as stated by Interviewee 61 as follows:

"Technology development is carried out in combination. Internally, we also innovate, and recruit experienced staff from other companies. We also use local suppliers because many are open [information]. They tend to be open and transfer their knowledge. Yes, it is quite good [technology transfer], but it depends on how we explore it." (Interviewee 61, Engineer)

The increasing public interest in EVs has prompted automotive manufacturers to leverage knowledge spillovers and enhance their technological capabilities. This growing interest has also put pressure on the government. Furthermore, the socio-technical regime political alignment with China, a leading producer of EVs, has encouraged the government to formulate regulatory support for the widespread adoption of EVs. In its implementation, "the government enacted Presidential Regulation" (Interviewee 10, Engineer) number 55 of 2019 to accelerate the battery EV initiative. This regulation has encouraged EMC's local manufacturing. Regulatory support has been crucial for the local production of electric motorcycles (EMCs). One respondent stated, "Our company began retail commercialisation of the product in 2020" (Interviewee 10, Engineer). Furthermore, several global brands are also marketing their EV products in Indonesia.

The government has also intensified promotional campaigns for EVs through "Presidential Instruction number 7 of 2022, which supports the transition to EVs for operational fleets of SOEs and local governments" (Interviewee 4, Vice President). In addition, to stimulate the interest of private vehicle owners "then, there are also some places where EVs are free to drive, meaning that other motorcycles are subject to the odd-even rule" (Interviewee 10, Engineer). Special treatment on the highway, which can reduce travel time, is one of the policies for the EV user's convenience.

Since its introduction in 2017, the Indonesian EV market has been gradually growing, reflecting the increasing public interest in EVs. Automotive manufacturers have responded to this demand by increasing production capacity and launching new products tailored to meet the needs of local consumers. Secondary sources record that the EV population in Indonesia in 2017 consisted of only 32 units of EMC. By 2019, this number had increased significantly to 1,248 units of EMC, 85 units of electric four-wheelers (E4Ws), and 787 hybrid electric vehicles (HEVs). Institutional regulatory support has played a critical role in the transition to EVs, leading to a total of 1,947 units of EMC, 229 units of E4Ws, and 1,978 units of HEVs in 2020 (Deloitte and Foundry, 2023; Agustiar, 2024; Abdurrahman, 2025). The growth of EV adoption in Indonesia is summarised in Figure 6.3.

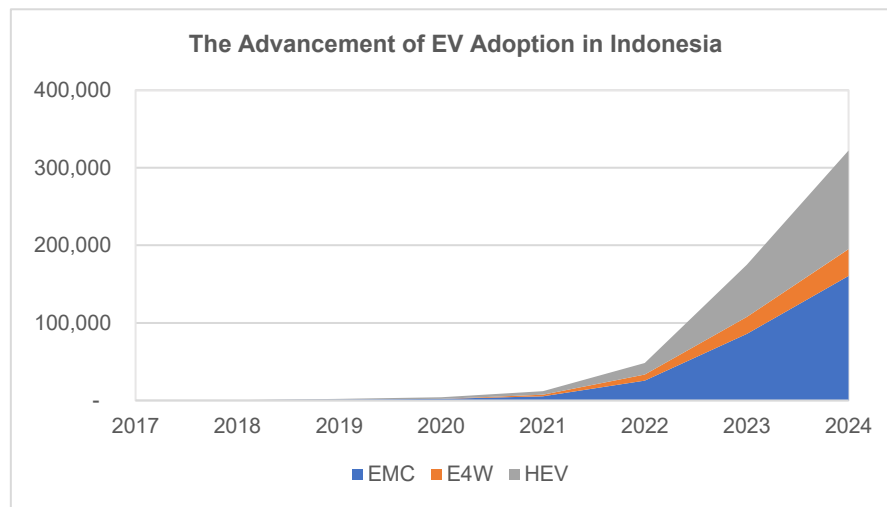


Figure 6.3 The growth of EV adoption in Indonesia

Adopted from: (Deloitte and Foundry, 2023; Agustiar, 2024; Abdurrahman, 2025)

6.4.1 The Diffusion of Electric Vehicles Technology

Proposition

The socio-technical transition in Indonesia is shaped by the value proposition of EV diffusion. The diffusion of EVs involves more than just switching to greener alternative fuel technology; the public is primarily interested in the benefits that EVs offer. This study stage research emphasises that the diffusion of EVs is primarily influenced by "the government program focused on green energy and the efficient use of fossil fuels" (Interviewee 10, Engineer). The decarbonisation program through EVs aims "to make transportation more environmentally friendly" (Interviewee 1, Researcher). However, most participants observed that consumers are pragmatic and often prioritise the advantages of reduced transportation costs by utilising

EVs. The consideration of reducing transportation costs is the main consideration of Indonesian consumers, as stated by Interviewee 34 below:

"Indeed, after utilising an EV, it appears that the operational expenses are considerably reduced from the consumer's perspective ... Well, I think society is more [considering] cost first, comfort second. In terms of cost, it is cheaper to use. Those two [factors] I think you must have." (Interviewee 34, Director)

The financial advantages for the EV include "cheaper operational costs" (Interviewee 60, Manager), "low maintenance costs" (Interviewee 41, Marketing and Business Analyst), and "the total cost of ownership ... will also decrease. Because the costs [the ride-hailing driver] usually costs for swapping batteries are cheaper than having to buy fuel" (Interviewee 1, Researcher). Interviewee 41 explained the low maintenance costs, especially for batteries as the most expensive component, as follows:

"Oh yes, in terms of batteries, particularly lithium ones, the components can be serviced individually, allowing for damaged cells to be checked and replaced as needed. For example, if five cells are damaged, only those five can be removed and replaced with new ones. This approach helps keep costs low when the battery starts to decline over time, as maintenance expenses will be reduced." (Interviewee 41, Marketing and Business Analyst)

This study findings align with recent research, indicating that electricity prices in Indonesia are low due to the generation of electricity from fossil fuels, primarily coal. This results in reduced costs for charging at home, at public charging points, and at battery swapping stations, making these options more affordable compared to petroleum fuels (Sasongko et al., 2024). Furthermore, EVs consist of fewer components than conventional ICEVs, leading to lower maintenance costs (Ji and Gan, 2022; Afraah et al., 2021).

To encourage the adoption of EVs, the government has introduced various policies aimed at providing convenience for EV users. For instance, "there are specific areas where EVs can drive freely while conventional motorcycles must adhere to the odd-even driving rule" (Interviewee 10, Engineer).

While the public is still weighing the cost of switching to EVs, the potential for population growth could align with the government's focus on decarbonisation programs. Interviewee 4 emphasized the government's assistance in the electrification by stating:

"The diffusion of EVs may be more widespread due to a focus on decarbonisation and reducing CO₂ emissions, which is why [the government supports] electric [vehicles]." (Interviewee 4, Vice President)

Encounter

The emergence of EVs highlights how the Indonesian public interacts with new mobility technology, which differs from their previous habits with conventional ICEVs. This research indicates that the initial phase of EV introduction was driven by the early adopters group. Some early adopter groups "have read much literature about EVs, and perhaps looked at other countries that use EVs" (Interviewee 10, Engineer). As stated by one of the sources, "EMCs users primarily use them within the city or among those who are already familiar with the technology" (Interviewee 41, Marketing and Business Analyst).

This study findings show that the early adopter group established brand enthusiast clubs. These clubs played a crucial role in modifying the EMC to meet their mobility needs better and testing its performance. In addition to user innovation, this group significantly contributes in promoting EVs through social media. This observation is supported by insights from Interviewee 61, as detailed below:

"Firstly, electric motorcycles have specific user groups. For instance, fans of particular brands often form their own communities. Over time, some members modify their bikes to test the travelling distance [and performance]... Indirectly, these groups help promote electric motorcycles to the public through social media, and eventually, they contribute to direct outreach." (Interviewee 61, Engineer)

Since 2020, enhanced promotional support from the government, automotive manufacturers, energy companies, and NGOs has contributed to the growth of green markets. Additionally, Interviewee 4 pointed out the significant influence of regulatory drivers, particularly Presidential Instruction No. 7 of 2022, which encourages the transition to EVs through an official fleet conversion program.

"This was originally the 2019 Presidential Decree aimed at accelerating EVs for road transportation. Presidential Instruction No. 7 of 2022 also addresses the implementation of EVs in SOEs and local government fleets. Several subsidiaries continue to operate, and information about their vehicles will be converted to reflect the use of EVs, including operational cars and those assigned to directors." (Interviewee 4, Vice President)

Public interactions with EVs were also encouraged by low-carbon transportation initiatives undertaken by ride-hailing companies, as mentioned by one of the respondents below:

"The development of the ride-hailing project is promising. We hope that it will not only make transportation more environmentally friendly but also reduce the overall cost of ownership for ride-hailing drivers. This reduction is because the expenses related to battery swapping are lower than the costs associated with purchasing fuel."
(Interviewee 1, Researcher)

This study's findings align with recent research, which highlights that government policies have facilitated the socio-technical transition to EVs for the public in developing countries, such as Indonesia (Hakam and Jumayla, 2024; Apriliyanti et al., 2024). Additionally, regulatory support has accelerated the growth of the EV population (Shamsuddoha and Nasir, 2025; Waluyo et al., 2022).

This study stage analysis also explored the presence of these green EV markets in remote rural areas, which have more reliable electricity distribution networks compared to gas stations. The increased use of EVs in remote rural markets has led automotive manufacturers to expand their sales networks to better support user mobility needs. Interviewee 23 describes this finding as follows:

"Our most significant sales come from outside Java. In some areas, the electricity network is better than the gas stations. Because of this, people choose to buy EMCs instead of ICEVs, especially when gas stations are far away... We have already expanded to Borneo and Sumatra, and we have sub-dealers there." (Interviewee 23, Manager)

Disposition

This stage of the research also analyses the aspect of disposition, which pertains to users' initial perceptions of EVs as a new form of green mobility technology. This study stage found that consumer evaluations are shaped by various individual backgrounds, particularly socioeconomic level, social considerations, past experiences with mobility technology, and personal risk assessments. One of the respondents stated that "the [EV upfront purchase] price is still high" (Interviewee 1, Researcher), especially for low-income communities. This study findings confirm recent literature that outlines the high upfront purchase cost as the main obstacle to EV diffusion in emerging markets (Abdul Qadir et al., 2024; Pandita et al., 2024; Abbasi et al., 2021).

These findings emphasised that "some customers may seek a quicker EMC than the current maximum speed. In contrast, others favour more extended mileage" (Interviewee 34, Director). One respondent noted that consumer usage remains limited to short-distance travel, particularly among "...those with electric motorcycles; there are many still [riding around] in the city" (Interviewee 41, Marketing and Business Analyst). Additionally, secondary sources indicate that the public expects EV performance to be comparable to their experiences with existing ICEVs in meeting their mobility needs. Given that motorcycles represent the predominant vehicle in Indonesia, the public requires EV specifications that offer top speeds and travelling ranges similar to those of conventional motorcycles (Yang et al., 2023; Singh, V. et al., 2021).

Another technological obstacle hindering the widespread adoption of EVs is the extended duration required for charging: "charging is time-consuming. For long-distance travel, one must charge for approximately 4 to 5 hours prior to use" (Interviewee 5, Mid-level Management). The extended charging duration of EVs, in contrast to the rapid refuelling process of petrol-powered vehicles, necessitates a cultural adaptation. Additionally, it demands investment in infrastructure development, including charging stations and battery swap systems. These facilities should not only be concentrated in urban areas but also be accessible in rural regions.

Responses

The presence of EVs in Indonesia has been examined from both consumer perspectives and social impacts. One respondent expressed the benefits of using EVs, stating, "If housewives go to the market or take their children to school, it remains reliable" (Interviewee 5, Assistant Manager). Consumers have responded positively to the various features offered by EVs. As expressed by Interviewee 34 below:

"There is awareness that electric motorcycles, first of all, do not pollute and do not disturb us... Additionally, most consumers report feeling less fatigue and experiencing no vibrations throughout their rides." (Interviewee 34, Director).

This study findings support recent studies that highlight consumer satisfaction with the environmental benefits of EVs, particularly in reducing GHG emissions (Abdul Qadir et al., 2024; IEA, 2024a). Additionally, consumers in various developing countries have relied on EVs to fulfil their daily short-distance travel needs (IEA, 2024a).

Unlike biofuel, which works in existing diesel vehicles, companies must better educate consumers about EVs. So, companies must develop green market sensing capabilities as a

vital market-driving aspect. Interviewee 34 revealed his marketing strategy by paying attention to the transition in local consumer habits in paying energy charging costs through battery swapping as follows:

"Yes, we developed our system in-house to meet the needs of the Indonesian people. Our approach differs from that of companies that developed many of their systems abroad. It was implemented in Indonesia, where market behaviour may vary significantly, operating in a very different manner. For example, the first time we register a user, we only pay per kilometre of road." (Interviewee 34, Director)

This study stage indicated that low public interest in switching to EVs mainly stems from the high initial acquisition cost. Interviewee 41 emphasised that the high initial cost of EVs is mainly due to "three key components: the battery, the controller, and the BLDC²⁵ [motor dynamo]... There has been no reduction in local prices" (Interviewee 41, Business Analyst and Marketing), which together make up 30% of the vehicle's price. The analysis of Indonesian consumers, particularly those from lower-middle-income groups, revealed that the high initial cost of purchasing EVs is a key barrier to wider adoption and the decarbonization of the transportation sector. This study findings confirm that financial challenges are also present in many developing countries (Abdul Qadir et al., 2024; Pandita et al., 2024; Abbasi et al., 2021).

In terms of infrastructure, the internal evaluation by the Indonesian public still raises doubts about the support for EVs in meeting their daily transportation needs, particularly for using E4Ws on long-distance trips out of town, especially to rural areas. Doubts on energy access are mainly caused by "[the challenge] apart from [lack of] the charging station, perhaps it is more about battery interchangeability" (Interviewee 61, Engineer). Secondary sources have indicated that limited access to charging points, especially for long-distance travel, poses barriers for EV users in various emerging economies. This infrastructure issue has also been experienced in emerging economies (Shamsuddoha and Nasir, 2025; Zarazua de Rubens et al., 2020).

²⁵ Yedamale (2003) explained that Brushless Direct Current (BLDC) motors are synchronous motors powered by direct current (DC). Electronic controllers direct DC power to motor coils, creating an efficient spinning magnetic field paired with a permanent magnetic rotor (Yedamale, 2003).

This social evaluation results indicate that the Indonesian public is largely indifferent to transportation sustainability issues, especially regarding decarbonisation. In the field, EVs still face competition from other sustainable modes of transportation, as outlined below:

"Apart from that, most of society is not concerned with sustainable issues. The majority of Indonesian people. If we look at the discourse, people concerned about sustainability also have options other than electricity... such as cycling or using public transportation." (Interviewee 1, Researcher)

The lack of widespread public attention to the importance of sustainability is highlighted by previous studies. The low concern for EVs stems from insufficient socialisation regarding their benefits (Abbasi et al., 2021; Pandita et al., 2024).

6.4.2 Obstacles and Motivations for Indonesian Consumers Adopting Electric Vehicles

High Upfront Purchase Price

EVs are a main initiative of the government to achieve the Net Zero Emissions (NZE) target, but their adoption in Indonesia has been limited. According to the IEA (2025), fewer than 0.2 per cent of the nation's vehicles are EVs as of 2024 (IEA, 2025). PwC Indonesia, as reported by Sakina (2025), indicates that the share of EVs in passenger vehicle sales grew from 9% in 2023 to 15% in 2024, with projections of reaching 29% by 2030 in Indonesia (Sakina, 2025). While EV technology provides numerous advantages, particularly for the environment, one respondent noted that the primary barrier to widespread EV adoption in Indonesia is the high cost of EVs, especially batteries. This respondent suggested that establishing local battery manufacturing facilities could help overcome this challenge as below:

"OK, in Indonesia itself, EV adoption is still relatively slow, right? First is because the price is still high. And we hope that it will be even cheaper when Indonesia produces its battery cells domestically around 2026." (Interviewee 1, Researcher)

Secondary sources also indicate that the battery is the component with the highest cost proportion in an EV, making it more expensive compared to ICEVs in the same class. Additionally, localising EV battery production is crucial to reducing the overall cost of EVs. Increased affordability is essential for EVs to compete effectively with conventional ICEVs in the automotive market (Singh, V. et al., 2021; Dutt, 2023).

This study stage also analyses another mechanism to address this financial barrier: developing new variants with specification changes that make EV prices more affordable. Interviewee 10 stated the following:

"So, for this new variant, we have set the motor at 1.5 kW with the hope that the price will also be more affordable, and many people will be able to enjoy it." (Interviewee 10, Engineer)

Meanwhile, the government also was actively involved in addressing the financial barrier posed by high initial cost of purchasing EVs. The regulatory drivers were implemented through tax reductions, the provision of incentives, and limited subsidies. One of the respondents highlighted this regulatory support in their comments:

"Then there are also indications that incentives will be given for IDR 7 million [USD 467] subsidized motorcycles. For cars there will be a VAT [exemption] from 11% to 1%. Indeed, the government has implemented a push and pull policy." (Interviewee 4, Vice President)

This research assumes the exchange rate of 1 USD = IDR 15,000. Therefore, implementing Ministry of Finance Regulation No. 38/2023 provides an upfront purchase price subsidy of USD 467 for EMC. Meanwhile, E4W users receive a subsidy of USD 2,000 to USD 4,300. This subsidy is still limited due to restrictions on consumers from lower economic groups eligible for EV subsidies. Apart from that, there are requirements for manufacturers, especially a 40% local content requirement. Various tax incentives and subsidy schemes aim to encourage the growth of EV adoption.

Interviewee 5 revealed that although the subsidy scheme initially caused controversy, it has made the purchase price of EVs equivalent to that of ICEVs, thereby meeting the needs of public mobility.

"That's the new thing at the moment, which is quite controversial, yes, subsidies. If, for example, it is later passed, I think it could catalyse the sales or growth of electric vehicles. Because, of course, people think that a subsidised (Dwi) motorcycle costs IDR 7 million [USD 467], which is equivalent to 1 battery. So now consumers can buy [electric motorcycles] at the price of the old ICE. [You] can get a range of maybe a hundred kilos. Which is in the form of a daily mobility or commuting system in Jakarta." (Interviewee 5, Assistant Manager)

Various initiatives by automotive manufacturers, "supported by the government through a [limited] subsidies [scheme]" (Interviewee 61, Engineer), have significantly accelerated the adoption rate of EVs. According to secondary sources, the population of EMCs more than

tripled in 2023, reaching 85,838 units compared to just 25,782 units in the previous year. Additionally, the number of E4Ws rose from 7,679 units in 2022 to 22,003 units in 2023 (Deloitte and Foundry, 2023; Agustiar, 2024; Abdurrahman, 2025).

Insufficient Regulatory Support

The introduction of the subsidy scheme has significantly boosted public interest in purchasing EVs. However, initial coordination issues among government agencies in distributing the subsidies have delayed some potential buyers' plans, as noted by one respondent:

"Yes, there are currently strong interests [in buying EVs]. Although government subsidies and incentives may stimulate further purchases, we are still awaiting clear guidelines from the government. Unfortunately, we are currently unable to implement these measures due to various regulatory requirements. As a result, not everyone may be able to take advantage of these subsidies or incentives." (Interviewee 37, Manager)

These study findings support recent research indicating that the gradual adoption of EVs in emerging markets is primarily due to inadequate coordination among government institutions and ineffective policy implementation (Shamsuddoha and Nasir, 2025; Wu, J. et al., 2018).

While the adoption rate of EVs has made notable progress, it remains significantly below the decarbonisation roadmap's goal of achieving 2 million E4Ws and 13 million EMCs by 2030 (Abdurrahman, 2025). This research stage indicates that some stakeholders advocate for the expansion of the subsidy scheme beyond just the lower-middle class, as highlighted by one of the respondents below:

"The current [subsidy scheme] limits household electrical power to 900 watts. Removing these restrictions could boost demand for EVs." (Interviewee 61, Engineer)

The analysis results align with secondary sources, which state that "this subsidy has numerous interested applicants, with thousands already registered, yet only over 20% meet the criteria" (Detiknews, 2023). Additionally, Detiknews (2023) indicated that public demand to eliminate restrictions on the subsidy scheme. The proposed expansion of this subsidy program is driven by growing interest in EVs, especially among middle- and upper-income groups who currently do not qualify for the subsidy (Detiknews, 2023).

Meanwhile, HEVs saw a substantial rise, increasing from 14,777 units in 2022 to 67,340 units in 2023—an increase of more than fourfold (Deloitte and Foundry, 2023; Agustiar, 2024; Abdurrahman, 2025). However, secondary source noted that the government has not given enough attention to the role of HEVs in reducing GHG emissions (Putra, D.L.E., 2024).

“Hybrid cars have gained popularity over the past two years as part of a strategy to adopt EVs. They could sell better with government subsidies, given their ability to lower GHG emissions. However, the government has not prioritised hybrids in the [socio-technical] transition to electrification program.” (Putra, D.L.E., 2024)

This study reveals that some respondents emphasised the need for "more aggressive policies to achieve significant growth. In the EV sector, we are not alone; other countries, including Thailand, are implementing special policies and are competing to attract investors" (Interviewee 4, Vice President). Additionally, this analysis identified that "The regulations governing the processing of battery waste may need to be emphasised again" (Interviewee 60, Manager). These study findings align with recent literature emphasising the significance of regulatory factors in promoting EVs adoption among consumers, particularly in rural areas (Schulz and Rode, 2022; Sovacool et al., 2022).

Inadequate Charging and Battery Swap Infrastructures

Indonesian consumers face significant challenges in adopting EVs, particularly due to the limited availability of charging stations (Interviewee 61, Engineer). This issue undermines public confidence, particularly regarding EV's ability to meet long-distance travel needs during special events, such as tourism and holiday visits, as well as daily urban use. The limited availability of charging points and battery swap stations in Indonesia is primarily due to high investment costs. Those responsible for developing the infrastructure face a dilemma. There are still relatively few EVs in the country, yet establishing the necessary high-voltage systems requires a significant financial investment. This challenge was highlighted by a respondent who expressed these concerns.

"In terms of revenue, not yet. Because if you look at it yourself, the number of EVs is still not large, the kwh tends not to be too much. Not too much, but EVs require a high voltage and significant investments in charging infrastructure... Because it's quite difficult for us to have mostly electric vehicles, according to the survey, there are more home charging." (Interviewee 5, Assistant Manager)

Secondary sources have highlighted the significant effect of inadequate charging point infrastructure, which limits EV adoption, particularly in emerging markets (Pandita et al., 2024). To tackle the barrier posed by insufficient infrastructure, the government has enacted several regulations to attract investment in EV infrastructure development. The MEMR Regulation No. 13 of 2020 provides regulatory support to simplify the licensing process and improve access to electricity for infrastructure providers. Furthermore, the government has waived import

duties, value-added taxes, and land access fees for the establishment of charging points and BSS, as outlined in the Minister of Finance Regulation No. 74/PMK.03/2021.

With the support of regulations, PLN has collaborated with various energy companies and infrastructure providers to develop charging points. This collaboration presents opportunities for companies to establish new businesses in the energy supply for EVs. As one respondent stated, "Our subsidiary also built charging stations in its new building" (Interviewee 4, Vice President). Alongside the expansion of infrastructure with EV charging points, several companies have developed EV business models that incorporate battery swapping stations (BSS). The purpose of the electric vehicle BSS was to facilitate a cultural transition that helps consumers shift their energy purchasing habits from ICEVs. This cultural transition of energy purchasing habits is reflected in the insight shared by Interviewee 34 below:

"We [developed] the business model; we conducted a survey looking at the behaviour of Indonesian people who have been driving petrol vehicles for decades, namely buying and then using petrol. So, what he bought is what he paid for. It suits what he wears. It is just that we are digital; they are just petrol." (Interviewee 34, Director)

This study reveals that a rapid transition to a new cultural approach cannot be accomplished simply by implementing foreign BSS technology. Unlike biofuels, which can be directly integrated into existing fossil diesel vehicles, this shift requires a more nuanced strategy. Stakeholders must intensify their efforts in consumer education, particularly in the marketing of EVs. Consequently, the company must enhance the capabilities of green market sensing to understand better local consumer behaviours related to the battery swap system, as mentioned by Interviewee 34 below:

"Yes, we developed our system ourselves, focusing on the specific necessities of the Indonesian users. Unlike other companies that build their systems abroad, our approach is tailored specifically for Indonesia, where market behaviours and operations can differ significantly. For instance, when we first register a user, we only charge for the kilometres travelled." (Interviewee 34, Director)

Secondary sources indicate that regulatory support is essential for developing EV infrastructure. According to the MEMR (2025c), there were 3,202 charging stations and 1,902 BSS installed in 2024. This population represents a significant increase in EV infrastructure compared to 2021, when only 267 charging points and 266 BSS were installed (MEMR, 2022). Despite progress, the development of EV infrastructure continues to concentrate on major urban areas of Java, which account for 58% of charging points and 72% of battery swapping stations, leaving many other regions without adequate service (MEMR, 2025c).

"The government should standardise battery connectors for plug-and-play compatibility" (Interviewee 61, Engineer). Standardising battery connectors could help facilitate the expansion of charging points and the BSS network. This standardisation would allow for the interchangeability of batteries, potentially reducing infrastructure investment costs.

Requirement for Enhancing Performance and After-Sales Services

The process of adopting EVs underscores the public's interest in how new technology can meet mobility needs that have traditionally relied on ICEVs. Consequently, several respondents emphasised the consumer demand for longer travel distances and increased top speed (Interviewee 41, Marketing and Business Analyst). EV manufacturers continuously innovate to overcome range anxiety and charging time limitations. One approach was to optimise knowledge spillovers to expand the BSS network, thereby increasing consumer mobility, as highlighted by a respondent below:

"We will never stop innovating. We cannot stop, so we want to expand this year with the hope that people will trust EVs more. Many people still have doubts. With the establishment of numerous swap stations, [we aim to alleviate] range anxiety, which has been a significant concern for electric motorcycles. We hope that [this issue] will become less common as time goes on." (Interviewee 34, Director)

The optimisation of charging time through the implementation of BSS has been initiated by infrastructure enablers in collaboration with ride-hailing providers, who are corporate consumers. This initiative was stated by Interviewee 1 as follows:

"Meanwhile in Jakarta, my company is collaborating with ride hailing providers ... to try out the battery swapping business. And why do they have to swap? Because [the ride hailing driver] they don't have time to charge. Because they are chasing targets. So that's our first step in electrification" (Interviewee 1, Researcher)

Public demand for enhanced EV performance requires mastery of technological capabilities. As a new green technology, the process of absorbing knowledge spillovers involves "collaborating with various manufacturers or suppliers that are adequately equipped for green energy conversion" (Interviewee 40, Training Instructor). Additionally, "we also [focus on] innovation and [actively] recruit experienced staff from other companies" (Interviewee 61, Engineer). Despite advancements, EI on key technologies face challenges due to a shortage of local experts. One respondent linked this issue to the limited industrialisation of EVs in Indonesia. "There are many experts available abroad. However, in Indonesia, [skilled workers]

remain limited because [the country] is not yet fully industrialised for EVs" (Interviewee 4, Vice President).

Meanwhile, the public still doubts the after-sales service to maintain vehicle reliability throughout its lifespan. This study reveals the understanding of the importance of building a vast after-sales service network to assure the public of the reliability of EVs. Some companies even "just dared to market this second model throughout Indonesia because this company is confident [in] having a service centre. Like [home appliances] have spread. We take the benefits from there" (Interviewee 61, Engineer). Even Interview 41 emphasised the role of a vast after-sales service network in supporting the sustainability of EV adoption as expressed below:

"On the after-sales side, consumers easily access spare parts and maintenance services... If we are dealing with specialists, that is a positive aspect, as we are long-term players in the market. It is not just about the current boom in subsidies for electric motorcycles." (Interviewee 41, Marketing and Business Analyst)

Low Public Awareness of Sustainability

This study found that the slow adoption of EVs by the Indonesian public is primarily due to a lack of public attention to sustainability issues. Although EVs provide various benefits, especially in terms of cost savings and environmental protection, they still face competition from other sustainable transportation options, as outlined below:

"Aside from that, most of society does not seem to be concerned with sustainability issues, [particularly among] the majority of the Indonesian population. If we examine the discourse, [it becomes clear that] those who are concerned about sustainability have alternatives to electricity. They can choose options like cycling or using public transportation." (Interviewee 1, Researcher)

Meanwhile, some parties remain apathetic about the role of EVs in reducing GHG emissions. An interviewee pointed out, "In Indonesia, coal accounts for nearly sixty per cent of power generation... [The target for achieving renewable energy sources] by 2023 is only halfway met." (Interviewee 5, Assistant Manager). Furthermore, Interviewee 5 emphasised the significance of emissions in lithium-ion battery manufacturing. While EVs produce low emissions during operation, thorough life cycle assessments of carbon emissions are crucial:

"However, at first glance, EVs appear more efficient, with lower [emissions]. [However, it is critical to realise that] the manufacture of lithium batteries also emits pollutants.

Therefore, a comprehensive study of the entire life cycle is necessary." (Interviewee 5, Assistant Manager)

The government and other stakeholders should "educate [the public] about the environmental advantages of using EVs" (Interviewee 10, Engineer). This education and advocacy can be enhanced by utilising both mass media and social media to overcome the environmental barriers that hinder broader EV adoption. Additionally, campaigns and promotions can be expanded by electrifying public transportation, government service fleets, taxis, and ride-hailing services.

To address public concerns regarding emissions from the entire life cycle of EVs, several companies have developed business models focused on repurposing retired EV batteries. These retired EV batteries still possess significant energy capacity and can be utilised as energy storage systems for various applications, as explained by Interviewee 10 below:

"Battery materials can be used at different stages. Initially, they are utilised in EVs. After approximately five to seven years, their performance may decline, but they do not immediately become waste. Instead, they can be recycled or repurposed into products like stationary energy storage systems for streetlights... In some countries, EV batteries are also used for power banks and laptop batteries." (Interviewee 10, Engineer)

Secondary sources emphasise the need for a comprehensive approach that involves various stakeholders to promote broader EV adoption in emerging economies. Educating the public about the vital role of EVs in transitioning to sustainable energy is essential (Abbasi et al., 2021; Pandita et al., 2024). Additionally, encouraging eco-innovation, such as repurposing retired EV batteries and increasing the use of renewable sources, can significantly lower emissions throughout the EV life cycle (Altuntas Vural et al., 2025; Rufino Júnior et al., 2023).

6.5 Discussion

In 2024, despite growth, EVs accounted for only 0.2% of the total vehicle population in Indonesia, which exceeded 163 million units. This phenomenon illustrates the slow adoption of EVs in the country, despite their presence since 2017. A crucial factor contributing to this slow diffusion is the strong biofuels advocacy network, which has become deeply rooted in Indonesia's socio-technical transition. In contrast, the decarbonisation of the transportation sector in Indonesia differs significantly from trends in major producers like the US, EU, and China, where the shift towards EVs has taken priority over biofuels.

The availability of raw materials, technology mastery, and government support have influenced the varying approaches to biofuels and energy independence taken by policymakers in several countries. Brazil has concentrated on developing sugarcane-based ethanol and utilises ICEV technology to support flex-fuel vehicles (FFVs) by mandating E27. Additionally, Brazil's biodiesel policy, which relies on soybean oil, used cooking oil (UCO), and animal fats, depends on these sources. In contrast, the US has prioritised corn as the main feedstock to support its ethanol program under the Renewable Fuel Standard (RFS). This policy has facilitated the implementation of fuel blends such as E10, E15, and E85 for FFVs. In the European Union, the implementation of RED II aims for 14% renewable energy in transportation by 2030, with each member state having different obligations regarding biofuel blend mandates. Generally, biofuels in the EU were utilised at a concentration of B7 to B10, primarily based on rapeseed oil, waste fats, and used cooking oil. Ethanol, derived from wheat, corn, and beet sugar, was utilised at levels ranging from E5 to E10.

Indonesian policymakers were prioritising the adoption of biodiesel as an AF. This regulatory choice was driven by abundant feedstock availability from domestic palm oil production and its compatibility with existing oil infrastructure. Furthermore, the socio-technical transition to biofuels requires less adjustment for consumers already accustomed to using ICEVs. These findings align with recent studies that emphasise the vital role of regulation in expanding access to affordable and clean energy. Recent studies emphasise the importance of feedstock availability, technological capabilities, incentive mechanisms, and robust regulatory support in shaping the priorities of decarbonisation programs (Ichsan et al., 2025; Astari et al., 2025; Choiruzzad et al., 2021).

The socio-technical transition in the industrialisation of biodiesel has involved many stakeholders, particularly rural residents who are often marginalised. The equitable distribution of social justice resulting from the adoption of first-generation biodiesel has had a positive impact on small farmers. Additionally, the increased adoption of biodiesel has been spurred by social shocks, such as the abandonment of farmers' harvests due to stagnation in export markets in the EU and the US. Policymakers have responded to these social shocks by mandating biodiesel use across the transportation, industrial, and commercial sectors. These findings reinforce previous studies that emphasise the importance of social justice for all stakeholders, particularly rural farmers who are often overlooked in the transition to clean energy (Kirshner et al., 2022).

This study found that the effectiveness of regulations promoting the diffusion of biodiesel can only be realised through a policy that mandates its use, supported by incentive mechanisms and the effective palm oil fund management (Djarmika et al., 2024; Farobie and Hartulistiyoso, 2022). The timeline indicates that significant advancements in biodiesel were not realised until

after the launch of the biofuel policy in 2006, and not until 2016. This progress aligns with policies and supports incentive schemes, allowing new alternative fuels to compete effectively with fossil fuels in the market. In contrast, the lack of policy support, particularly in terms of mandatory usage and incentive schemes (Ebadian et al., 2020), has hindered the development of other biofuels, such as biogasoline and second-generation biodiesel in Indonesia.

This study analysed how users evaluated and adapted to the early stages of biodiesel adoption. The early adoption of first-generation biodiesel presents several challenges. While biodiesel offers the value proposition of low emissions, reduced dependence on fossil fuel imports, and lower subsidies, financial factors are affecting consumer choices. Rising fuel costs have made it difficult for some passenger vehicle owners to access subsidised biodiesel, leading them to switch to gasoline ICEVs instead of opting for unsubsidised fossil diesel. In contrast, the commercial sector continues to utilise diesel ICEVs, as they benefit from the availability of subsidised biodiesel.

We found that collaborative innovation networks have been established among biodiesel companies, automotive manufacturers, and research institutions to address user concerns regarding the decline in ICEV performance resulting from the use of biodiesel. These findings contribute to the understanding of knowledge spillover through these collaborative networks, which have improved the compatibility of biodiesel with existing ICEVs (Chandran, 2020; Kahn Ribeiro et al., 2007). Furthermore, users have developed a socio-technical adaptation that emphasises the importance of purchasing standardised fuel and the necessity of preventive maintenance.

The global market is increasingly shifting towards second-generation biofuels to prevent competition with the food sector, land use, and deforestation. However, this study findings indicate that the adoption of second-generation biofuels not only requires substantial investment but also a strong grasp of the necessary technology. These two challenges must be addressed to successfully enter the export market, especially since the domestic market has not yet developed significantly. This situation creates opportunities for established players who currently dominate the development of advanced biofuels. This observation aligns with existing literature on the energy transition to second-generation biofuels, which emphasises the strengthening of dominant actors in the industry. However, the dominance of old-entrenched actors has widened the socio-technical gap between large companies and rural farmers (Kirshner et al., 2022).

These findings indicate that promotional campaigns, both in mainstream news broadcasts and on emerging social media platforms, significantly influenced global trends in the transition to

EVs. This information flow motivated a group of innovators to explore electric vehicles, inspiring early adopters from 2017 to 2019. Some of these early users formed enthusiastic brand communities to share their experiences and the value proposition of using EVs. Furthermore, the information circulating about the performance and challenges of EVs during their introduction phase has facilitated a socio-technical transition into the broader public domain. Recent literature on the diffusion of innovation (DOI) emphasises the significance of influencing the public to adopt emerging technologies through various media (Lestaluhu et al., 2023). This word-of-mouth and media socialisation has particularly influenced the diffusion of EVs in emerging markets (Lestaluhu et al., 2023; Struben and Sterman, 2008).

The public, particularly in major urban areas, has begun to recognise the key value proposition of EVs, which includes low long-term operational and maintenance (O&M) costs as well as environmental benefits. Additionally, this study has identified a niche market in rural areas, where residents far from gas stations were experiencing the advantages of EVs for their daily mobility demands. These findings align with recent research on the application of the DOI theory at the micro level, specifically focusing on individual consumers' adoption behaviours regarding new energy vehicles. Key factors influencing these behaviours include regulatory support, initial price, O&M costs, infrastructure accessibility, service quality, psychological characteristics, and additional related factors (Shamsuddoha and Nasir, 2025; Pandita et al., 2024; Lazuardy et al., 2024).

The emergence of green markets has attracted the interest of PLN, the state-owned electricity company, to collaborate with EV manufacturers, infrastructure enablers, and research institutions in providing vehicles and expanding charging station networks. This innovation collaboration network has facilitated the acquisition of knowledge spillovers from leading producing countries, enabling the development of local brands and their charging infrastructure, which aims to meet local consumer needs. The technological challenges identified in this study of Indonesian consumer preferences include the demand for increased range, increased maximum speeds, enhanced access to charging infrastructure, and shorter charging duration. Additionally, this collaboration network advocates for the government to formulate regulations that foster the socio-technical transition to EVs in Indonesia. This study contributes to the literature by emphasising the importance of collaborative networks in enhancing knowledge spillovers, improving green market sensing, and facilitating the broader adoption of emerging low-carbon technologies (Hakam and Jumayla, 2024; Shamsuddoha and Nasir, 2025; Gupta and Barua, 2018b).

At the macro level, the socio-technical transition in the adoption of EVs largely depends on the government's ability to develop policies that promote EV diffusion, particularly by encouraging interest and willingness among lower- and middle-class consumers to purchase

EVs through incentive programs and subsidies. The government's effectiveness also influences investment in EV manufacturing and the development of charging infrastructures. The adoption of EVs in emerging economies gains momentum only when they can compete effectively with existing conventional ICEVs (IEA, 2025; Nair et al., 2024). The collaboration network for EV diffusion not only facilitates the technology transfer from leading producers but also advocates for regulatory support from the government, especially regarding incentives and subsidies. These findings indicate that policy support in Indonesia only began in 2019, which is significantly later than the widespread adoption of EVs observed in the developed countries.

Since 2023, Indonesia has implemented some limited subsidy policies for new EV users. This study has revealed coordination challenges among institutions during the initial stages of implementing limited subsidies based on local vehicle content and users' social levels. This lack of institutional coordination temporarily delayed potential consumers' interest in purchasing EVs. However, as the coordination among institutions improved, the subsidy scheme became more effective, successfully increasing buyer interest in adopting EVs. As a result, the number of EVs has increased significantly since 2023. However, these policies are still lagging behind the EV subsidy initiatives in China, which began in 2009. China initially provided subsidies for EV buyers in ten major cities, and by 2010, the program had expanded to include five additional cities. In September 2013, subsidies for electric vehicles (EVs) were expanded nationwide, with a tiered system based on vehicle range per charge. Although there is no official national ban on ICEVs, strict regulations and the introduction of the new energy vehicle credit (NEV Credit) have driven a shift towards EVs and HEVs. As a result, the IEA reported that in 2023, China accounted for approximately 65% of all passenger car EVs worldwide (IEA, 2024a).

Meanwhile, policymakers in India introduced the FAME-I program, which ran from April 2015 to March 2019, to provide incentives for hybrid and electric passenger vehicles, commercial vehicles, and buses (IEA, 2024a; Dutt, 2023). This regulatory support continued with the FAME-II program, which began in April 2019 and will run until March 2024. FAME-II places a greater emphasis on public transportation, particularly electric buses, as well as on developing charging infrastructure and promoting high local content. The Production-Linked Incentive (PLI) scheme has been enacted to support domestic manufacturing. A series of regulations has boosted EV adoption, resulting in a 2% market share for EVs in 2023 (IEA, 2024a; Dutt, 2023).

Norway has been recognised as the European country with the highest sales of EVs, reaching nearly 95% of all new vehicle sales in 2023 IEA (2024a). The government imposes a purchase tax that considers a vehicle's weight, CO₂ emissions, and nitrogen oxides (NO_x). However,

electric cars are exempt from the weight-based tax until 2023. Additionally, any imported car that weighs more than 500 kg incurs an import fee for each additional kilogram. Due to the EV sales tax exemption, electric cars were more affordable than ICEVs across all segments. IEA (2024a) estimated the electricity premium to be approximately -5% in 2018. With effective incentive policies, this premium is projected to improve, reaching around -15% and even -30% for medium-sized cars by 2022. A combination of fiscal and non-fiscal policies, along with advancements in charging infrastructure, has established Norway as a role model in the socio-technical transition towards widespread electric vehicle adoption (Yang et al., 2023; Schulz and Rode, 2022; Singh, V. et al., 2021).

This study indicates that while the sales share of EVs was increasing rapidly, several significant barriers hinder their wider adoption, particularly in rural areas. The primary obstacle is the high initial purchasing cost, primarily due to the ongoing import of three key components: batteries, BLDC motors, and controllers. Efforts to localise the supporting EV industry have begun, with several manufacturers now producing LIB batteries, BLDC motors, and controllers. However, increasing local production levels of these essential components requires further regulatory support through incentives and subsidies. Additionally, automotive manufacturers were innovating to lower upfront purchase prices by differentiating motor capacities in their new models. This product differentiation enables the division of vehicle segments based on upfront purchase prices, aligning them more closely with consumer purchasing power.

On the other hand, various stakeholders have suggested expanding the criteria for public eligibility for subsidies, as interest in EVs tends to be concentrated among upper-middle-class consumers. Furthermore, the government's attempts to bridge this gap through the implementation of limited subsidies are still constrained by the country's budget limitations. These findings also contribute to the recent debate highlighting the significant impact of inadequate regulatory support on the diffusion of low-carbon EI in emerging markets (Abdul Qadir et al., 2024; Singh, V. et al., 2021; Costa et al., 2021).

The insufficient charging infrastructure and lack of battery swapping options hinder the growth of EV adoption, especially in regions outside major urban centres. This study examines the development of an EI business model for battery swapping stations (BSS) that addresses the socio-technical shift in public habits regarding energy purchasing. While incentive policies have been introduced, the high investment costs associated with installing the various charging plugs remain a challenge. Some stakeholders were advocating for the standardisation of charging plugs to help reduce these infrastructure investment costs. Additionally, enhancing the role of HEVs in overcoming infrastructure challenges, particularly in rural areas and during long-distance travel, remains a priority for the government. The rapid

development of HEVs, which were nearly equivalent to E2Ws, has not yet attracted attention from policymakers. The reduction of emissions and improvement of fuel efficiency have not received sufficient regulatory support. Countries with high EV adoption rates have effective regulatory support for HEVs as a socio-technical transition toward the broader adoption of fully battery electric vehicles (IEA, 2024a).

Lastly, the broader adoption of new green energy technologies was significantly influenced by public awareness of sustainability. Similar to other emerging economies, the public tends to prioritise the affordability of AFs over the essential need for emission reduction. This study stage reinforces recent research emphasising the importance of education and socialisation on the collective responsibility of all stakeholders in promoting sustainability (Bardhi and Gashi, 2025).

6.6 Conclusion

Previous literature has emphasised the significance of the socio-technical transition in the diffusion of eco-innovations related to alternative fuels in developing countries. By examining the experiences of first-generation biofuels and EVs in Indonesia, the findings reveal several factors that influence the trajectory of innovations aimed at decarbonising the transportation sector. This research phase utilises a qualitative methodology, analysing primary data from 62 multi-level actors and triangulating it with secondary sources. The goal is to fill the research gap in understanding the socio-technical dynamics that affect the diffusion of low-carbon EIs in contexts outside of developed countries. Emerging economies possess different socio-technical landscapes and regime dynamics that influence the diffusion of green EI technologies.

This study stage reveals that policymakers have prioritised biofuels, especially biodiesel, as the primary alternative to fossil fuels in Indonesia. This emphasis on biodiesel has hindered the adoption of EVs in Indonesia compared to other emerging economies and Southeast Asian countries. Additionally, the effectiveness of mandatory policies, paired with robust incentive management, has driven the advancement of biodiesel adoption. The mandatory biodiesel utilisation policy in transportation, industry, and commerce has engaged small farmers, resulting in social impacts that have improved the welfare of rural residents around palm oil plantations.

These findings emphasise the necessity for a long-term strategy to elevate biodiesel blending while ensuring compatibility with conventional ICEV engines through technological advancements. Furthermore, small farmers were urging policymakers to raise the prices of

fresh fruit bunches to reflect the rising demand for biodiesel. This adjustment is crucial for promoting social justice and equitable distribution. The clarity of the biodiesel policy roadmap has positively influenced public preferences for fuel types, particularly in the domestic passenger car market, and in meeting the requirements of the automotive export market.

The lack of regulatory support, both fiscal and non-fiscal, has hampered the widespread adoption of ethanol and second-generation biodiesel. Despite not competing with food and having greater compatibility than first-generation biodiesel, the high investment risks necessitate incentives or subsidies to make these alternative fuels competitive in the market. In addition, the development of second-generation biofuels relies on advanced technologies that was primarily accessible to large companies. The case study in Alagoas, Brazil, illustrates that the dominance of these old-entrenched companies will further widen the social welfare gap with small farmers in rural areas.

The adoption of biodiesel offers a value proposition that includes low emissions, compatibility with existing infrastructure, decreased reliance on fossil fuel imports, and reduced subsidies. However, in the initial stages of its introduction, consumers face technical challenges due to the FAME content, which can negatively impact engine performance. In response to consumer evaluation and feedback, the innovation collaboration network has optimised knowledge spillovers, leading to the development of spare parts and combustion systems compatible with biodiesel. Additionally, the advancement of biofuels has shifted consumers' socio-technical perspectives, highlighting the necessity for standardised fuels and underscoring the importance of preventive maintenance.

This study stage highlights the role of innovators and early adopters within brand enthusiast groups in encountering the global EV trends and engaging the Indonesian public. These brand enthusiast groups, utilising word-of-mouth and social media networks, have encouraged innovation collaboration networks aimed at developing local EVs. Besides focusing on technical advancements to ensure EV performance meets the standards of ICEVs, this collaboration network has also advocated that policymaker formulate regulations to support the widespread adoption of EVs. Support from both fiscal and non-fiscal regulations, particularly subsidies, has significantly increased EV purchases, although their overall market share remains low.

The public has faced a significant barrier to adopting EVs due to their high initial purchase price. The government face the ongoing challenge of attracting investments for the localised production of many expensive key components that are currently imported. Although various incentive policies and subsidy programs have been introduced, their effectiveness has been

initially hampered by a lack of coordination among institutions. Nevertheless, these fiscal measures have contributed to increasing EV adoption, even though their overall market share remains low due to national budget constraints.

This research contributes to the current debate on the necessity for green market sensing capabilities to promote EV adoption. This stage has also identified the financial challenges faced by developing countries in financing the expansion of charging infrastructure. This study stage explores how innovation collaboration networks can optimise knowledge spillovers to diffuse EI outcomes, services, and business models tailored to the local energy purchasing practices of the Indonesian customers, thereby facilitating the socio-technical transition to EVs. Additionally, this study examines infrastructure enabler strategies that have enhanced distribution networks and after-sales services to reach niche markets in rural areas, especially where access to gas stations is limited. This study has observed a significant increase in the population of HEVs as a temporary solution to the lack of charging infrastructure. However, these vehicles have not yet received sufficient regulatory support.

In conclusion, ensuring the availability of feedstock, providing adequate regulatory support, implementing incentive schemes—particularly subsidies, fostering collaborative networks for innovation, and promoting social welfare equality have been key factors driving the socio-technical transition in the adoption of alternative vehicle fuels. Besides, widespread adoption of EVs and second-generation biofuels in emerging economies must tackle several barriers, including regulatory uncertainty, high upfront purchase prices, significant investment risks, and insufficient supporting infrastructures. Moreover, the socio-technical transition will be effective by encouraging public awareness of sustainability and involving the active participation of all stakeholders, particularly small farmers and rural residents, in the EI lifecycle.

This research emphasises environmental conservation issues linked to increasing the use of renewable resources in the final energy mix, as well as the strategy for utilising and recycling retired electric vehicle batteries. The next chapter will explore the factors that promote technology adoption, with a focus on the social acceptance of electric vehicles as an emerging technology in Indonesia.

Chapter 7 Social Acceptance of Electric Vehicle Technology in Indonesia ²⁶

7.1 Introduction

The energy transition is one of the main agendas in providing affordable and clean energy as defined in the 7th SDG (Scoones et al., 2020; Panoutsou et al., 2021). The shift from previously being dependent on fossil energy sources to clean and renewable energy sources mark the energy transition. In the transportation sector, the use of alternative vehicle fuels such as biofuels, electricity, and hydrogen is important for reducing carbon emissions. Government support for the development of massive charging infrastructure and the implementation of various fiscal policies, including incentives and subsidies, has encouraged the growth of transportation electrification in some developed countries and growing economies such as the US, EU, China, and Japan (IEA, 2025; Yang et al., 2023; Schulz and Rode, 2022; Zhuge et al., 2021).

The Indonesian government has promoted energy diversification in the transport sector by using low-carbon fuels, such as biodiesel and gas, as well as low carbon electricity. The diffusion of biofuels has progressed rapidly, supported by a well-established socio-technical institution established in 2006. Since 2016, the diffusion of biofuels has accelerated, largely due to aligned policies and incentive schemes (Astari and Lovett, 2019; Farobie and Hartulistiyoso, 2022). These aligned regulations have fostered increased collaboration among stakeholders, encouraging the eco-innovation (EI) in the adoption of biofuel technologies. In contrast, the adoption rate of electric vehicles in Indonesia is lower than in developed countries and some fast-growing economies. Although the government has enacted regulations to accelerate the electric motor vehicle program and has introduced incentive schemes and limited subsidies, public interest in purchasing electric vehicles still remains low (Putera et al., 2025; Fathoni et al., 2025; Setiawan, A.D. et al., 2022).

The literature has examined the socio-technical transition aspects of EV adoption. The Multi-Level Perspective (MLP) technique has been utilised to analyse the dynamics of change in the transportation energy sector. This approach emphasises that major changes occur when pressures from the landscape, such as global electrification trends, destabilise the fossil fuel

²⁶ This empirical chapter will be submitted to Sustainability

regime, allowing niche EV innovations to mature and challenge it in the market (Geels, 2024). Additionally, the transition management (TM) concept, developed by Grin et al. (2010), emphasises that transitions do not occur organically but can be managed through a long-term vision, learning, experimentation, and the formation of coalitions among stakeholders. This approach emphasises the importance of reflexivity and multi-actor governance to accelerate the adoption of low-carbon technologies, including electric vehicles and second-generation biofuels (Grin et al., 2010). Recent literature has identified challenges in advancing EV adoption in emerging countries, including consumer social acceptance (Sasongko et al., 2022), manufacturing capabilities (ERIA, 2021a), infrastructure development (IEA, 2022), and fiscal and non-fiscal incentive policies, particularly subsidy schemes (Afraah et al., 2021; Singh, V. et al., 2021).

In the study presented in this chapter, a hybrid approach was utilised to address the research question regarding how the interaction between regimes and niches affects the socio-technical transition process of EV adoption. An online survey was first conducted, collecting data from 600 respondents in two regions with distinct geographical and demographic characteristics: the Greater Jakarta and the Greater Bandung areas. The survey aimed to identify the factors influencing the social adoption of EVs. Additionally, an analysis was conducted to assess the economic disparity between EV adoption in Indonesia and the global market. To enhance the validity of the findings, secondary sources were also explored for triangulation.

The study presented in this chapter aimed to answer several research questions: (1) How significant are socio-technical considerations for the public in emerging economies when deciding to adopt EVs? (2) What are the major factors contributing to the public's reluctance to engage in the social transition toward EVs? (3) What is the size of the economic gap between EV products diffusing in Indonesia and those in the global market?

The following section examines Indonesian consumers' social acceptance of adopting EVs. Section 7.3 discusses the interaction between the regime and niche in the socio-technical transition towards EV adoption. It also analyses the economic gaps in EV diffusion within both the Indonesian and global markets. Furthermore, it scrutinises the challenges related to infrastructure development. Section 7.4 explores improvements in EV life-cycle management. Section 7.5 will provide a comprehensive discussion of the findings from this phase of the study, highlighting their contributions to understanding green technology adoption in Indonesia. Finally, Section 7.6 will conclude this phase of the study and outline the policy implications for promoting sustainable development of affordable and clean energy, particularly in the transportation sector.

7.2 Consumers' Social Acceptance of Adopting Electric Vehicles

This research examined the preferences of Indonesian consumers, as an emerging country, regarding their willingness to buy an electric motorcycle (EMC), which has lower barriers than EV passenger cars. This section describes the results of collecting consumer preference data on their willingness to buy EMC in 2 urban areas in Indonesia: The Greater Jakarta and the Greater Bandung areas. Figure 7.1 illustrates the topology of the Greater Jakarta area and the Greater Bandung area. Figure 7.2 presents the demography of these urban areas.

The first location, the Greater Jakarta area, is the largest metropolitan region in Indonesia, encompassing the special province of Jakarta and the surrounding cities of Bogor, Depok, Tangerang, and Bekasi. The greater Jakarta area serves as the centre of government offices and national economic activities, featuring industries and residential areas. Covering approximately 6,638 square kilometres, the Jakarta Metro area is predominantly low-lying, with an average elevation of about 7 metres above sea level. In contrast, the outlying areas, such as Bogor and Tangerang, have hilly terrains. The region is home to approximately 32.20 million people in 2024 (BPS Banten Province, 2025; BPS DKI Jakarta Province, 2025; BPS Jawa Barat Province, 2025).

The second location is the Greater Bandung area; a metropolitan area situated approximately 140 km southeast of Jakarta. It is situated in the Bandung Basin, surrounded by mountains, and at an altitude of approximately 768 meters above sea level. Metro Bandung itself is on a plateau characterised by hilly topography, with surrounding mountains reaching up to 1,050 meters. The Greater Bandung covers around 3,500 square kilometres, comprising the city of Bandung, Bandung Regency, West Bandung Regency, and Cimahi. In 2024, the total population in Metro Bandung was approximately 9.95 million. Socioeconomic activities in Metro Bandung are primarily focused on education, industrial centres, tourism, and residential development (BPS Jawa Barat Province, 2025).

This study surveyed 600 respondents selected to reflect the demographic profile of Indonesian. Key control variables included age, household size, monthly family income, motorcycle ownership, and education level. Table 7.1 summarises the respondent socio-economic characteristics. This study recruited respondents from the community who were eligible to obtain a driver's license for a motorised vehicle. Based on the socio-economic characteristics of respondents from the two urban areas, the majority are aged 40 years and under, accounting for 63.17% of the total. Respondents from Jakarta (13.67%) have slightly more family members than those from Bandung (8%).

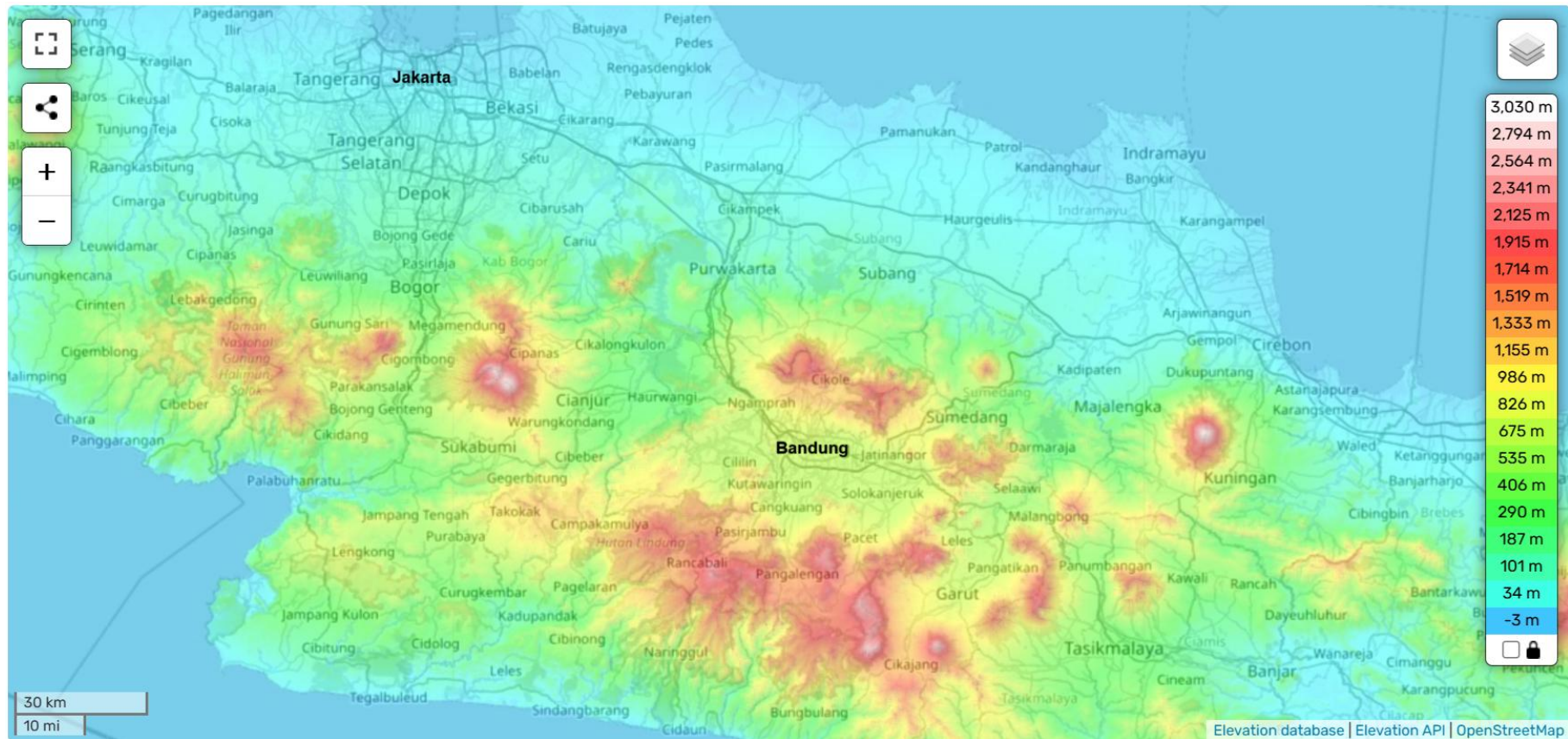


Figure 7.1 Topology of the Greater Jakarta area and the Greater Bandung area.
Source: (World Topographic Map, 2020)

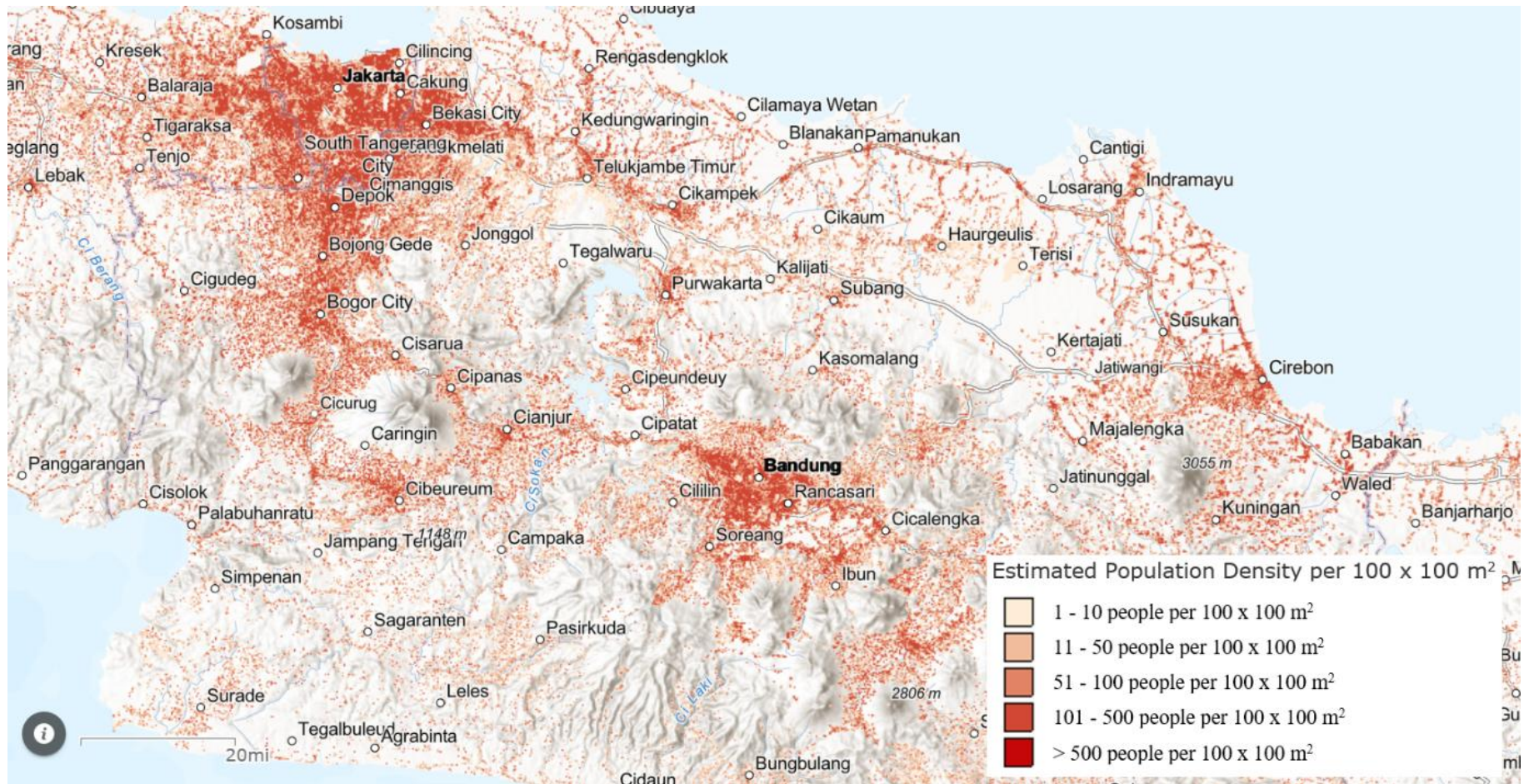


Figure 7.2 Topology of the Greater Jakarta area and the Greater Bandung area.
Source: (Geoportal BPS, 2023)

Financially, respondents from Jakarta tend to have a higher monthly family income, with 51.33% earning above USD 533, compared to 84.33% of respondents from Bandung who earn below USD 533. Additionally, the educational level of Jakarta participants is predominantly at the bachelor's degree level or higher, with 67.33% in this category. In contrast, a significant portion of respondents from Bandung are low educated, accounting for 61.33%. This study also included a segment of the population that did not own a motorcycle, which comprised 14.17% of the participants.

The prevalence of motorcycle ownership among respondents from both areas shows that this type of vehicle has become the primary choice for the Indonesian public, regardless of their residence, level of education, or income. This study stage aimed to assess interest in EMC among individuals who do not possess conventional motorcycles. Our findings indicated that 80.33% of the participants expressed interest in purchasing EMC in the future, while 19.67% stated they had no plans to adopt it. Respondents from Jakarta (79.33%) and Bandung (81.33%) showed similar interest in adopting EMCs.

Through further questioning of several respondents, this study found that the public has begun to show some interest in adopting EMC. However, perceptions regarding EMC's support for users' daily mobility differ. For example, Respondent A stated that "I am interested [in purchasing an EMC], because it is pollution-free... I believe it is suitable to use an EMC for daily needs" (Respondent A). Furthermore, some users mentioned that "EMCs are suitable for trips where the destination is already known, such as going shopping or taking a short trip near home" (Respondent D). Meanwhile, other respondent interested in adopting the EMC do not plan to use it for their daily transportation needs. Instead, they intend to use the EMC as a secondary or backup vehicle for occasional trips, such as on weekends. One respondent also noted that the EMC is more frequently used for daily use in the ride-hailing sector, as mentioned below:

"I might be interested in having an EMC as a second or spare vehicle for weekend use, rather than as a daily ride. Currently, I have noticed some ride-hailing services using electric motorcycles, which may be suitable for daily use." (Respondent B)

Table 7.1 Respondent socio-economic characteristics (N=600)

Socio-Economic Characteristics	Jakarta		Bandung	Total
	Freq.	Pct.	Freq.	Pct.
Age				
18 – 30	84	28.00%	78	26.00%
31 – 40	125	41.67%	92	30.67%
41 – 50	55	18.33%	77	25.67%
51 – 60	35	11.67%	44	14.67%
More than 60	1	0.33%	9	3.00%

Socio-Economic Characteristics	Jakarta		Freq.	Bandung		Total	
	Freq.	Pct.		Pct.	Freq.	Pct.	
Household size							
Equal to 2 or less	41	13.67%	24	8.00%	65	10.84%	
3 or more	259	86.33%	276	92.00%	363	89.16%	
Monthly family income (USD)							
Less than 267	100	33.33%	192	64.00%	292	48.67%	
267 up to 533	45	15.00%	61	20.33%	106	17.67%	
533 up to 800	31	10.33%	25	8.33%	56	9.33%	
800 up to 1,333	33	11.00%	14	4.67%	47	7.83%	
More than 1,333	91	30.33%	8	2.67%	99	16.50%	
Education level							
Elementary school	7	2.33%	58	19.33%	65	10.83%	
Secondary school	72	24.00%	126	42.00%	198	33.00%	
Diploma	19	6.33%	22	7.33%	41	6.83%	
Bachelor	128	42.67%	82	27.33%	210	35.00%	
Master or doctor	74	24.67%	12	4.00%	86	14.33%	
Motorcycle ownership							
Yes	253	84.33%	262	87.33%	515	85.83%	
No	47	15.67%	38	12.67%	85	14.17%	

Table 7.2 shows the correlations between motorcycle ownership, household size, and monthly family income. Among respondents from households of three or more members, the majority still own motorcycles (76.83%), compared to those who do not (12.33%). Additionally, the group of respondents with the highest family monthly income (more than USD 1,333) has a higher motorcycle ownership rate (12.50%) than those without a motorcycle (2.67%). This data indicates that motorcycles have become widely adopted for personal transportation in urban areas such as Jakarta and Bandung.

Table 7.2 Crosstabulation between respondent's members of family and monthly family income with motorcycle ownership

		Household Size		Monthly Family Income (USD)				
		2 or less	3 or more	Less than 267	267 up to <533	533 up to <800	800 up to <1,333	more than 1,333
Motorcycle Ownership	No	1.83%	12.33%	1.50%	1.17%	0.50%	0.50%	2.67%
	Yes	9.00%	76.83%	15.17%	15.17%	4.67%	5.00%	12.50%
Total		100%		100%				

This study has also examined consumers' daily travel preferences regarding distance, energy consumption, and operational and maintenance (O&M) costs. Table 7.3 summarises the respondents' travelling preferences. The effective range for low-cost (budget-type) and medium-cost (mass-adopted type) EMCs, which range from 50 km to 80 km on a single charge, is adequate for most respondents. Specifically, 55.33% of participants reported a daily travel distance of less than 10 km, while 25% reported a distance of 10 - 20 km. The survey results indicate that respondents in Jakarta who travel daily distances of 20 kilometres or more comprise 22.67% of the total, compared to 19.67% in Bandung. This reveals that respondents in Jakarta have longer daily travel distances.

The socio-technical transition from ICE motorcycles to EMCs requires the development of sufficient charging points and battery-swapping infrastructure. Among the respondents, 222 (72.17%) prefer charging their EMCs at home, 21.83% favour public charging stations, and 6% choose battery swapping systems. While respondents from both locations generally prefer home charging, there is a slight difference in their preferred locations for EMC charging stations. The selection of charging locations is primarily dominated by home charging. However, a notable 30.16% of respondents in Jakarta reported using public EV charging points and BSS. In contrast, only 26% of respondents in Bandung opted for locations other than their homes for charging. Additionally, in Jakarta, 8.33% of respondents preferred BSS, compared to only 3.67% in Bandung. This preference for BSS in Jakarta can be attributed to the unequal distribution of BSS infrastructure across Indonesia, with most socioeconomic activities concentrated in Jakarta.

Respondent E mentioned that the socio-technical transition regarding EV charging methods favours home charging for private vehicle users over public charging stations. Additionally, BSS has addressed the need for quick power charging, particularly among EMC ride-hailing drivers.

“Charging at home has been very convenient for us, especially since we mainly use our electric car for commuting to the office. However, the availability of public EV charging stations is uneven, and I often have to wait in line. I have not yet tried the battery swap feature, but I believe it could be a potential solution for [EMC] ride-hailing drivers who require quick charging times.” (Respondent E)

According to secondary data, most EV users in Indonesia charge their vehicles at home, particularly those with EMCs (Abdurrahman, 2025). The small battery capacity of EMCs allows users to charge slowly overnight at home when vehicles are not in use. Additionally, PLN offers a 30% discount on EV charging rates during off-peak hours, from 10:00 PM to 5:00 AM (PLN, 2021b).

Table 7.3 Respondent travel preferences (N=600)

Travel Preferences	Jakarta		Bandung		Total	
	Freq.	Pct.	Freq.	Pct.	Freq.	Pct.
Daily travel distance (km)						
Less than 10	161	53.67%	171	57.00%	332	55.33%
10 – 20	71	23.67%	79	26.33%	150	25.00%
20 – 40	50	16.67%	31	10.33%	81	13.50%
40 – 60	13	4.33%	12	4.00%	25	4.17%
More than 60	5	1.67%	7	2.33%	12	2.00%
EMC charging location						
Home charging	211	70.33%	222	74.00%	433	72.17%
Public electric charging station	64	21.83%	67	22.33%	131	21.83%
Battery swap	25	8.33%	11	3.67%	36	6.00%
Desired EMC purchase price (USD)						
Less than 1,000	192	64.00%	260	86.67%	452	75.33%
1,000 up to 1,333	80	26.67%	26	8.67%	106	17.67%
1,333 up to 1,667	18	6.00%	9	3.00%	27	4.50%
1,667 up to 2,000	8	2.67%	4	1.33%	12	2.00%
More than 2,000	2	0.67%	1	0.33%	3	0.50%
Desired monthly O&M cost (USD)						
Less than 13.33	186	62.00%	245	81.67%	431	71.83%
13.33 up to 26.67	89	29.67%	51	17.00%	140	23.33%
26.67 up to 40.00	10	3.33%	2	0.67%	12	2.00%
40.00 up to 53.33	11	3.67%	1	0.33%	12	2.00%
More than 53.33	4	1.33%	1	0.33%	5	1.00%
Willingness to buy EMC in the future						
Yes	238	79.33%	244	81.33%	482	80.33%
No	62	20.67%	56	18.67%	118	19.67%

Meanwhile, respondents with daily commutes longer than 40 km (6.17%) typically work in logistics or ride-hailing. This group of EMC users' needs quick charging times to facilitate their activities. As a result, ride-hailing companies collaborated with infrastructure enablers to enhance their BSS networks. Secondary data indicates that the implementation of EMC by ride-hailing operators using battery swapping for charging has facilitated daily EV use. The rapid charging time offered by battery swapping has supported ride-hailing drivers' operations, alleviating the range anxiety commonly experienced by many EV users (BCG and AEML, 2022).

Secondary sources indicate that motorcycles have become the dominant mode of transportation in cities across Indonesia, a trend similar to those observed in many other Asian countries. High population density has influenced the choice of public transport options. Rising property prices have compelled low- and middle-income residents to relocate further away from city centres. As a result, many people prefer motorcycles, especially those residing in areas moderately to far from the city centre. Motorcycles offer a convenient and cost-effective

solution for fast trips, enabling riders to avoid traffic congestion and making them a competitive option compared to public transportation (Fevriera et al., 2021; Janssen et al., 2022). In contrast, higher-income groups residing in city centres tend to favour passenger cars for their mobility. However, they also occasionally use motorcycles for shorter trips (Janssen et al., 2022).

This study examined consumers' willingness to purchase EMCs by analysing various travel characteristics, such as daily travel distance, preferred charging locations, purchase price, and monthly operating and maintenance (O&M) costs, along with other priority factors. The online questionnaire also asked respondents about the price ranges they find appealing for purchasing an EMC. The results show that 75.33% of participants prefer a purchase price below USD 1,000, which is competitive with the prices of entry-level ICE motorcycles. Additionally, an analysis of O&M costs reveals that 71.83% of respondents sought the lowest possible monthly O&M cost, ideally under USD 13. This monthly O&M cost was significantly lower than the fuel costs of ICE motorcycles.

In Jakarta, 36% of respondents consider a price of USD 1000 or more to be reasonable for an EMC to support their mobility. This price range is nearly on par with that of a conventional motorcycle. Respondents in Jakarta were willing to pay a higher upfront purchase price and monthly operating and maintenance (O&M) costs, which is probably due to their higher income levels. In contrast, only 13.33% of respondents in Bandung chose the EMC within the same price range. As a result, most respondents in Bandung prefer a lower price for the EMC, largely because of affordable second-hand conventional motorcycles are readily available. Additionally, respondents in Jakarta were willing to pay higher initial purchase prices and monthly operating and maintenance costs due to their higher income levels. Figure 7.3 illustrates the distribution of desired EMC purchase prices and the range of O&M costs.

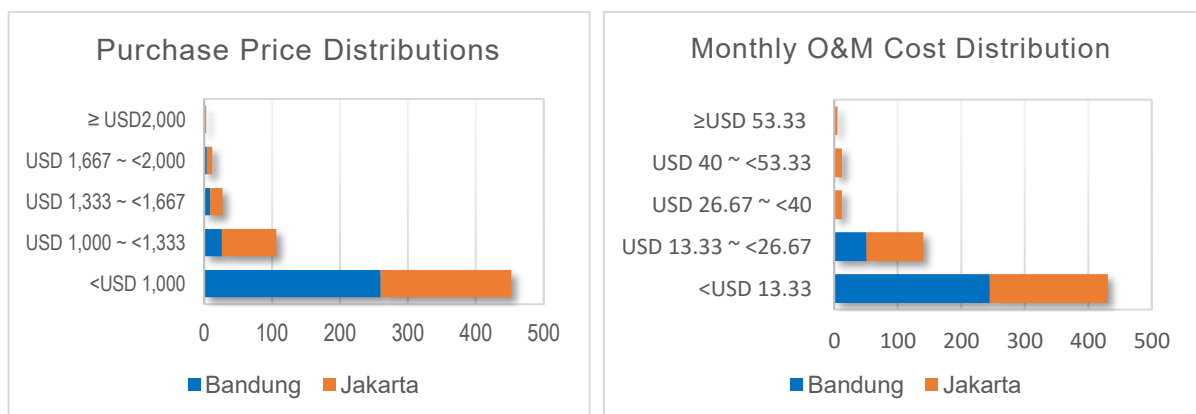


Figure 7.3 Desired EMC purchase price and range of O&M costs.

This study also explored the underlying considerations in customers' acceptance of purchasing EMC in the future. Two hundred ninety-five consumers (49.17%) in these two regions considered the purchase price the top factor in deciding whether to buy EMC. Consideration of range ranks the second with 20.33% of respondents, followed by monthly O&M cost (13.67%), charging location (12.17%) and charging time (4.67%). Even though consumer purchasing interest is high in EMC, Indonesian consumers face obstacles, especially the high purchase price (40.33%). Then followed by inadequate infrastructure (25.83%), insufficient public knowledge (17.17%), less reliable EMC (10.17%), and difficulty with spare parts (6.50%). Based on the mean importance ranking for the very high and high group of factors, the purchase price ranks first (31.5%), followed by the monthly cost (23.6%), and the range (17.3%). Meanwhile, among barriers, the high purchase price is ranked first (32.3%), followed by inadequate infrastructure (25.8%) and difficulty with spare parts (14.7%). Table 7.4 shows the priority considerations for consumer acceptance and the obstacles they face in adopting EMC.

Table 7.4 Aggregation of consumer considerations and obstacles to buy EMC in the future.

	Consumer Considerations Ranking						Consumer Obstacles Ranking			
	Range	Charging Location	Charging Time	Purchase Price	Monthly O&M Cost	Inadequate Infrastructure	High Purchase Price	Difficult to Find Spare Part	Less Reliability	Lack of Public Knowledge
1 = Very High	20.3%	12.2%	4.7%	49.2%	13.7%	25.8%	40.33%	6.5%	10.2%	17.2%
2 = High	14.2%	21.2%	17.3%	13.8%	33.5%	25.8%	24.2%	22.8%	17.0%	10.2%
3 = Moderate	29.5%	20.8%	29.2%	8.0%	12.5%	19.8%	16.5%	37.3%	18.8%	7.5%
4 = Low	13.3%	25.7%	27.3%	18.8%	14.8%	16.0%	13.0%	23.5%	37.3%	10.2%
5 = Very Low	22.7%	20.2%	21.5%	10.2%	25.5%	12.5%	6.0%	9.8%	16.7%	55.0%
Very High + High	17.3%	16.7%	11.0%	31.5%	23.6%	25.8%	32.3%	14.7%	13.6%	13.7%
Mean Moderate + Low + Very Low	21.8%	22.2%	26.0%	12.3%	17.6%	16.1%	11.8%	23.5%	24.3%	24.2%
N Valid	600	600	600	600	600	600	600	600	600	600
Missing	0	0	0	0	0	0	0	0	0	0
Mean	3.04	3.21	3.44	2.27	3.05	2.64	2.20	3.07	3.33	3.76
Median	3.00	3.00	3.00	2.00	3.00	2.00	2.00	3.00	4.00	5.00
Mode	3	4	3	1	2	1a	1	3	4	5
Std. Deviation	1.413	1.312	1.142	1.473	1.432	1.350	1.261	1.055	1.228	1.588
Variance	1.997	1.723	1.305	2.171	2.051	1.821	1.590	1.113	1.508	2.522
Range	4	4	4	4	4	4	4	4	4	4
Minimum	1	1	1	1	1	1	1	1	1	1
Maximum	5	5	5	5	5	5	5	5	5	5

Respondents from the two urban areas exhibited different perspectives, as illustrated in Figure 7.4. The accumulation profile of respondents' priority choices in Bandung was steeper than in Jakarta. Among the obstacles respondents in the Bandung region faced, a significant issue was the lack of public awareness of EMC. Conversely, respondents from the Greater Jakarta

area cite insufficient infrastructure—particularly the charging system—as their primary concern, followed closely by the high purchase price of EMC. In Greater Jakarta, higher levels of education and monthly family income have contributed to a better understanding of EMC among residents. Table 7.5 presents a crosstabulation of the high upfront purchase price and inadequate infrastructure by respondents' locations.

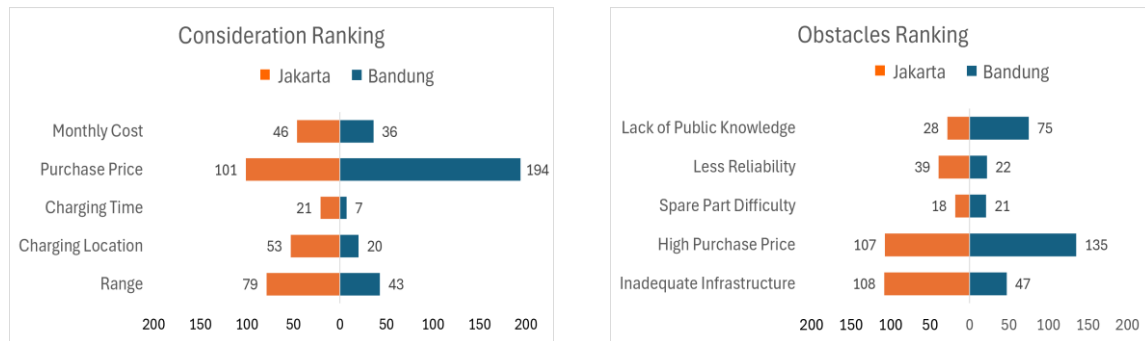


Figure 7.4 Customers consideration and obstacles ranking on willingness to buy EMC.

Table 7.5 Distribution of customers consideration and obstacles ranking on willingness to buy EMC based on location

Respondent Location * High Upfront Purchase Price Crosstabulation							
		Count					
		High Upfront Purchase Price					
		Very High	High	Moderate	Low	Very Low	Total
Respondent	Jakarta	107	83	45	48	17	300
Location	Bandung	135	62	54	30	19	300
Total		242	145	99	78	36	600

Respondent Location * Inadequate Infrastructure Crosstabulation							
		Count					
		Inadequate Infrastructure					
		Very High	High	Moderate	Low	Very Low	Total
Respondent	Jakarta	108	62	55	42	33	300
Location	Bandung	47	93	64	54	42	300
Total		155	155	119	96	75	600

In addition to the drivers and obstacles identified from the online survey data, this stage of the study highlighted a growing public awareness of the benefits of EMCs. The public recognised not only the low emissions but also the comfort of a vibration-free ride and the superior acceleration of EVs. However, a significant concern among the public was the limited availability of after-sales service outside major cities, particularly in rural areas.

“The advantages of electric motorcycles include their quiet operation, which makes for a comfortable ride free from vibrations, and their quick acceleration. On the downside, there are few well-known motorcycle brands available in Indonesia, which means after-sales service is limited to a few major cities.” (Respondent B)

Secondary data indicate that public interest in adopting EVs outside major cities remains limited, mainly due to concerns about the charging infrastructure availability. Abdurrahman

(2025) reported that the EV charging network remains unevenly distributed, making it difficult for users to access charging stations. Additionally, there are challenges in expanding this network beyond Java, the main island for socioeconomic activities. Wikanto and Mardiansyah (2024) highlighted that the uneven distribution of sales dealerships across Indonesia contributes to the low uptake of subsidised EMCs.

The Dynamics of Regime-Niche Interactions in the EV Transition

EVs have become a crucial component of decarbonising Indonesia's transportation sector and are a key element of the automotive industry's roadmap. The government acknowledges the significant potential of the domestic automotive market, especially in the EMC segment. This socio-technical transition from a fossil-fuel-dominated regime requires effective handling and the promotion of green niche innovations. The regulator has outlined specific measures across policies to accelerate EV adoption, aiming to encourage consumer acceptance and achieve substantial market share (Sasongko et al., 2022).

As discussed in the previous empirical chapters, the global trend toward electrification has significantly influenced the Indonesia's socio-technical landscape . This shift, driven by innovators and brand enthusiast groups, has encouraged various stakeholders to capitalise on the opportunity for EV diffusion in the country. Since 2017, collaborative networks involving research institutions, EV manufacturers, PLN, and green suppliers have initiated niche innovations that successfully advocated for government support for EV growth alongside biofuels.

Presidential Regulation Number 55 of 2019 marks a critical juncture for the industrialisation of EVs in Indonesia. Additionally, the National Master Plan, developed in collaboration with the government, research institutions, industry associations, and environmental organisations, has established ambitious goals. The targets include achieving a fleet of 2.5 million EMCs and 600,000 electric four-wheeled vehicles (E4Ws) by 2030 (Deloitte and Foundry, 2023). The lower entry barriers for EMCs compared to E4Ws have led the government to prioritise strategies for adopting EMCs. The low incomes of Indonesian households have driven this focus on the EMC approach. Additionally, the domestic electricity infrastructure, with an average capacity of 1,300 watts, was adequate for slow EMC charging (BCG and AEML, 2022).

Existing automotive manufacturing capabilities and supply chain collaboration between global manufacturers and local partners support the goal of EV adoption. Furthermore, Indonesia has significant potential for EV battery manufacturing due to its abundant reserves of nickel, copper, tin, and bauxite (MSAEBR, 2023). To stimulate growth in production capacity and

meet demand for EVs, the government has enacted both fiscal and non-fiscal manufacturing incentives. However, challenges such as budget constraints for the limited-subsidy scheme and infrastructure investments, as well as a lack of public awareness of sustainability, have emerged as barriers to accelerating the EV adoption (Sasongko et al., 2022).

7.2.1 The Economic Gaps in EV Diffusion within the Indonesian and Global Markets

Most consumers in emerging countries face many financial obstacles, especially the high upfront purchase price and the unattractive total cost of ownership. The government provides several incentives and subsidy schemes to overcome adopter barriers related to willingness to pay (Balijepalli et al., 2023). One of the respondents identified the high upfront purchase price of EVs in the Indonesian market as a constraint.

“However, EMCs have some disadvantages including limited range and still relatively high upfront purchase prices... The affordability of EMC varies depending on the brand and model.” (Respondent D)

The government has implemented various regulatory supports, particularly fiscal and non-fiscal policies, to address the main EI barriers, including the high upfront purchase price of EVs. The MoF Regulation 138/PMK.02/2021 on the reduction of costs for vehicle type testing and certification fees. This policy also provides fiscal support for fostering niche innovations. Similarly, Government Regulation No. 74/2021 exempts luxury goods from purchase tax. While the Ministry of Home Affairs Regulation No. 1/2021 provides reductions in annual taxes and transfer fees, it makes consumers more comfortable purchasing EVs (DEN, 2023). Furthermore, the Minister of Industry Regulation No. 6 of 2023 addresses EMC purchase subsidies that meet the economic qualification criteria (DEN, 2024). This limited subsidy policy has resulted in a significant price reduction of USD 466.67, lowering the initial purchase price and enabling EMC vehicles to compete directly with ICEVs in the same class (Putera et al., 2025).

The implementation of various limited incentive policies and subsidy schemes has improved the affordability of EMCs, so "in terms of [upfront purchase] pricing, EMCs can vary widely and can be directly compared to conventional motorcycles" (Respondent B). Other respondents also agree that fiscal policy affects the affordability of budget-type EMCs with small battery capacities. However, premium-class EMCs were still considered too expensive compared to conventional ICEVs in the same class.

“The price of EMCs is relatively affordable; small EMCs are generally considered cheap. However, larger EMCs with higher cc ratings tend to be overpriced compared to gasoline motorcycles with similar engine capacity.” (Respondent C)

The government has promoted electrification through policies aimed at transitioning government fleets and public transportation to electric vehicles. This green transition has also been adopted by several private sectors, particularly in the taxi, ride-hailing, and logistics industries. The socio-technical transition process has fostered the growth of the EV population, thereby accelerating the adoption of electric passenger cars (E4Ws). Since 2023, there has been significant momentum in the increase of E4Ws on the road. One of the respondents shared their experience with EVs, emphasising how these environmentally friendly technologies enhance their daily mobility. Additionally, the exemption from the odd-even rule has made it more convenient for EV users to perform activities in Jakarta, including on weekdays.

“The primary reason I chose to drive an EV is to have a car for my daily round-trip commute to the office that is environmentally friendly. This choice also alleviates my concerns about the odd-even traffic regulations that are enforced in some areas of Jakarta. Additionally, the lower operational and maintenance costs compared to traditional vehicles were significant factors in my decision. My family and I want to contribute to reducing carbon emissions and air pollution, especially in large cities. Furthermore, I am interested in new technologies and see electric vehicles as a vital part of the future of cleaner and brighter transportation.” (Respondent E)

Secondary data has highlighted that, in addition to offering fiscal policy support and subsidies that directly benefit consumers, the government has introduced various regulatory measures to encourage infrastructure investment and aid the transition from conventional ICEVs to EVs. The Jakarta local government promotes electric vehicle adoption by exempting EV users from even-odd license plate regulations in central areas, as stated in the Governor of DKI Jakarta Regulation Number 88 of 2019 (Sasongko et al., 2024). Table 7.6 summarises the fiscal and non-fiscal policies to support the EV diffusion in Indonesia.

This section presents the results of an analysis of the comparisons between the economic and technical aspects of EVs, especially EMCs, marketed in Indonesia and those in the global market. This economic and performance comparison closely align with the online survey on consumer preferences, which indicates that high upfront purchase prices are the main barrier to buying an EV. For this reason, this research stage examined the techno-economic aspects of locally manufactured EMC and the impact of implementing fiscal incentives, tax relaxations, and subsidy schemes on the rate of EV adoption in Indonesia. This comparison of upfront purchase prices from EMC uses technical specifications as a reference, which include battery capacity, maximum driving range, charging time, top speed, and motor capacity. EMC

samples that mainly use lithium-ion batteries (LIB) have also been taken from several countries, with prices published on websites of official brands, reseller agents, or newspapers.

Several EMC samples use sealed lead-acid (SLA) batteries, especially in the Indonesian Market. Appendix E summarises the comparison of price and performance aspects of several EMCs in the Indonesian market. Comparative countries and regions observed in this stage are major EMC producers or have significant EMC markets, including China, Taiwan, India, Vietnam, Thailand, Nepal, the UK, Italy, Sweden, and the US. Appendix F compares price and performance aspects of several EMCs in the global market. This study has conducted several economic and performance comparisons between EMCs sold in Indonesia and other countries. The first stage compared the impact of the subsidy scheme on reducing upfront purchase prices in Indonesia and the global market. In the Indonesian market, the EMC price ranged from USD 820 to USD 3,327 before the subsidy was given. However, after the USD 467 subsidy, the EMC price range widened to USD 353 - USD 2,860 (Wikanto and Mardiansyah, 2024). Based on the EMC average price of USD 1,400, eligible Indonesian consumers receive 33% subsidy. BCG and AEML (2022) examined that subsidised pricing for EMC in other countries and regions, including Thailand (24%), India (22%), mainland China (40%), South Korea (35%) and Taiwan (15%). Figure 7.5 shows the benchmarks for the consumer subsidies scheme.

Table 7.6 Fiscal and non-fiscal policies related to foster EV adoption in Indonesia

Fiscal Policies	Non-fiscal Policies
- Ministry of Finance (MoF) Regulation No. 38/2023: VAT reduction - Ministry of Industry Regulation No. 6/2023: EMC purchase subsidies with economic qualification fulfilment. - Law No. 1/2022: exemption from automobile taxes and title transfer fees. Circulation Financial Services Authority: EV financing (producing and buying) reduction. - Government Regulation No. 74/2021: luxury goods sales tax exemption. - Ministry of Home Affair (MoHA) Regulation No. 1/2021: annual tax and title transfer charge decrease. - MoF Regulation 138/PMK.02/2021: reduction of costs for vehicle type testing and certification.	- Ministry of Energy and Mineral Resources (MEMR) Regulation No. 1/2023: charging. infrastructures integration and business schemes offering. - Ministry of Transportation (MoT) Regulation No. 15/2022: conversion of vehicles other than two-wheelers. - Presidential Instruction No. 7/2022: Adoption of EVs for government officials' fleets. - MoT Regulation 44/2020: EV testing and certification procedure. - MoT Regulation No. 45/2020: special type EV safety. - MoT Regulation No. 65/2020: conversion of conventional 2W to EMC. - DKI Jakarta Regulation No. 88/2019: exempting EV users from even-odd license plate regulations in central areas.

Source: (BCG and AEML, 2022; Padhilah et al., 2023; Sasongko et al., 2024)

BCG and AEML (2022) have examined the implementation of the USD 185/kWh EMC subsidy scheme in India. The Hero Optima CX type has a battery capacity of 1.54 kWh from an initial price of USD 1,325, which, with subsidies, decreases to USD 783. Meanwhile, the Ola S1 type with 3 kWh battery, initial priced at USD 1,747, with subsidies decreases to USD 1,205. The Ola S1, with greater battery capacity, saw a larger price reduction of USD 663 compared to the Hero Optima CX, which experienced a reduction of USD 482. The subsidised EMC price was comparable to the same level ICE, such as the Hero Splender Plus at USD 843 and the TVS Raider at USD 1,084 (BCG and AEML, 2022).

This study found that the subsidy scheme in Indonesia, with a fixed value of USD 467, has significantly reduced the budget-type EMC upfront purchase price more than the premium type (Wikanto and Mardiansyah, 2024). In contrast, India's policy under the FAME II program of providing a subsidy scheme of ₹15,000/kWh of battery capacity (USD 173/kWh), capped at 40% of the ex-showroom price, has significantly lowered the upfront purchase cost of EMC with larger battery capacity compared to the smaller ones (ICCT, 2024). Despite this, the subsidy offered to the Indian market was still higher than that obtained by Indonesian consumers.

Governments in developed countries, such as the EU and the US, have implemented various financial incentives and subsidy schemes for consumers who adopt EVs (BCG and AEML, 2022). For instance, the UK government launched the plug-in motorcycle grant (PiMG) in 2016 to help bridge the price gap between zero-emission motorcycles and petrol motorcycles (Department for Transport, 2025). The PiMG implementation has resulted in significant price reductions on EMCs with large battery capacities, such as the Niu MQi-GT, which comes with a 3.74 kWh battery and saw a reduction of USD 1,655 (Niu International, 2024). In comparison, the Yadea G5S, with a 2.88 kWh battery, experienced a price reduction of USD 637 (Yadea, 2024).

The third comparison analysed the price of battery packs with similar specifications sold in Indonesia and globally. According to recent research, batteries are the most expensive component of an EMC (BCG and AEML, 2022). Rokadiya et al. (2021) examined EMC costs in India; the battery costs for a 75-km range EMC budget type comprise 25.61% of the total costs. Meanwhile, for the 75-km range EMC premium type, the battery cost was 38.23%. Figure 7.6 presents the cost breakdown of the 75-km range EMC budget type and the 100-km EMC premium type in India.

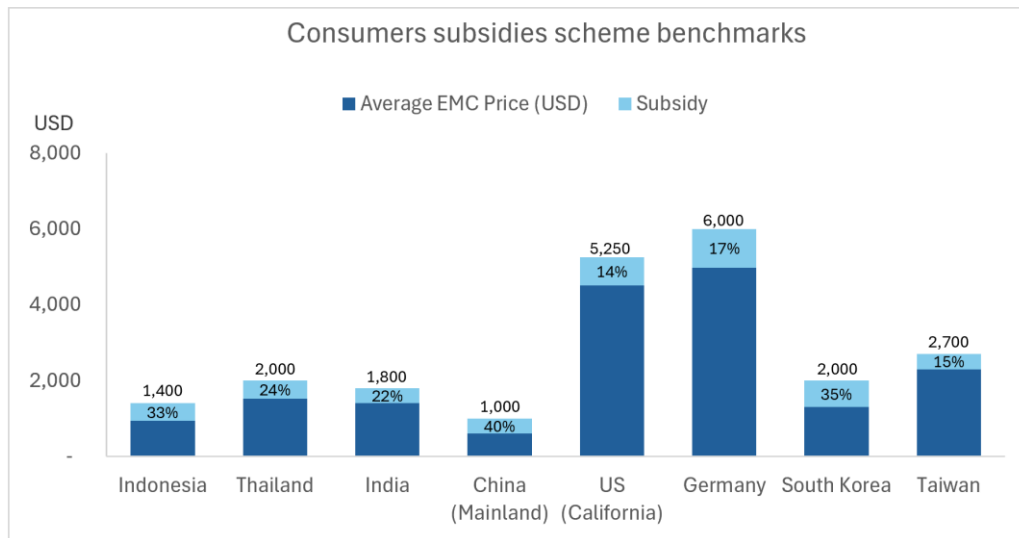


Figure 7.5 Consumers subsidies scheme benchmarks.

Source: BCG and AEML (2022)

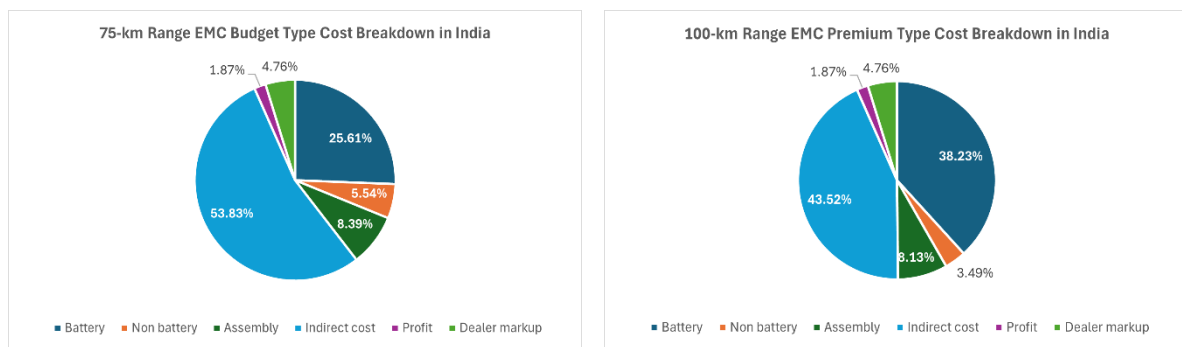


Figure 7.6 Cost breakdown of the 75-km range EMC budget type and the 100-km EMC premium type in India.

Source: Rokadiya et al. (2021)

Batteries significantly contribute to the rising prices of EVs in Indonesia. Most EV users were still unfamiliar with battery-related issues, particularly because the relatively short lifespan of EVs has become a noticeable concern since 2021. One respondent expressed:

"The main drawback [of EVs] is the battery, as its cost is quite high, and there are no case studies from manufacturers in Indonesia that can guarantee its durability or specify how long it will last. Considering that electric vehicles in Indonesia have only been around for about 3-4 years since their initial release." (Respondent F)

In Indonesia, the Gesits G1, the most popular EMC, has a battery cost of USD 567, equivalent to 29.34% of the total cost, including import tax. This battery pack has a capacity of 1.44 kWh, which costs USD 394 per kWh. Meanwhile, the ECGO 2 battery costs USD 400, which is

equivalent to 43.17% of the total cost. With a capacity of 1.25 kWh, this battery pack costs USD 321 per kWh. Refer to the global average EV battery cost of USD 139 per kWh, where the lowest region is China at USD 126/kWh. In comparison, the packs in the US and Europe were 11% and 20% higher, respectively (BloombergNEF, 2023).

This stage of the study has also examined the price structure of electric passenger cars that have begun to enter the domestic market. This techno-economic analysis focuses on various car segments, including entry-level segments (such as the BYD Atto 1 and Wuling Air EV), mid-range options (like the BYD Atto 3 and MG ZS EV), and premium vehicles (including the Hyundai Ioniq 5 and BYD Sealion 7). In the entry-level segment, the Wuling Air EV has been available in the domestic market since mid-2022, with an on-the-road (OTR) price in Jakarta ranging from approximately USD 11,500 to USD 15,600. The battery for this model is estimated to cost around USD 6,250 (USD 202 per kWh). On the other hand, the BYD Atto 1 was introduced in mid-2025, priced at USD 12,000 to USD 14,700. Similar to the Wuling Air EV, the battery for the Atto 1 is also estimated to cost USD 6,250 (USD 251 per kWh) (Dianawuri, 2025b).

In the mid-level segment, the MG ZS EV is priced between USD 23,500 and USD 26,000, and it is powered by a battery valued at around USD 12,500, equivalent to approximately USD 248 per kWh. Similarly, the BYD Atto 3 starts at USD 29,400 and goes up to USD 33,100 and features a battery estimated at USD 12,500, which equates to approximately USD 250 per kWh. In the premium class segment, the BYD Sealion series is emerging as a contender to the Hyundai Ioniq series. The BYD Seal is priced between USD 40,000 and USD 46,900, with an estimated battery cost of USD 18,130 (USD 220 per kWh). In comparison, the Hyundai Ioniq 5 has a price range supported by a battery estimated at USD 18,750 (USD 323 per kWh) (Dianawuri, 2025b; Dianawuri, 2025a). Table 7.7 presents a comparison of the upfront purchase price of electric passenger cars and the estimated battery cost in the domestic market.

At the entry level, the upfront purchase price of Electric 4-Wheelers (E4Ws) remains higher than that of conventional Internal Combustion Engine Vehicles (ICEVs). For instance, the highest variant of the Daihatsu Ayla is priced between USD 8,900 and 12,300, which corresponds to the lowest variant of the BYD Atto 1. In the medium segment, the lowest variant of the MG ZS EV, priced at USD 23,500, is still more expensive than the highest variant of the Mitsubishi Expander, which is priced at USD 21,100. However, in the premium segment, the BYD Seal, priced at USD 40,000 to 46,900, is comparable to the Honda Civic RS, priced at USD 43,700 (Dianawuri, 2025b; Dianawuri, 2025a).

Table 7.7 The Upfront Purchase Price and the Estimated Battery Cost of Electric and Conventional Passenger Cars in Domestic Market

Segment	Model	Upfront Purchase Price, OTR in Jakarta (USD)	Battery Capacity (kWh)	Estimated Battery Price (USD)	Estimated Battery Price (USD per kWh)	Maximum Range (km)	Powertrain Capacity (kW)	Engine Capacity (cc)	Charging Time
Entry-level	Wuling Air EV	11,500 up to 15,700	18 up to 26.7	6,250	234	200 up to 200	30	N/A	AC 8 to 11 hours DC 30-90 minutes
	BYD Atto 1	12,200 up to 14,700	30.88 up to 38.88	6,250	202	300 up to 380	55	N/A	AC 6 up to 8 hours DC 30 up to 40 kW (30-80%) in 30 minutes
	Daihatsu Ayla	8,900 up to 12,300	N/A	N/A	N/A	up to 486	N/A	998 up to 1198	N/A
Medium-level	BYD Atto 3	29,400 up to 33,100	49.9 up to 60.4	12,500	251	410 up to 480	150	N/A	AC 8 up to 10 hours DC 80 kW (0–80%) in 40 minutes
	MG ZS EV	23,500 up to 26,100	50.30	12,500	249	280 up to 403	130	N/A	AC 8 hours DC 30–80% in 30 minutes
	Mitsubishi Expander	16,900 up to 21,100	N/A	N/A	N/A	up to 540	N/A	1,499	N/A
Premium-level	Hyundai Ioniq 5	46,100 up to 57,900	58 up to 72.6	18,750	323 up to 344	384 up to 451	125 up to 230	N/A	AC 8 up to 10 hours DC 350 kW (10%-80%) in 18 minutes
	BYD Seal	40,000 up to 46,900	61.4 up to 82.5	18,130	220	460 up to 580	150	N/A	AC 12 hours DC 150 kW (10%-80%) in 25 minutes
	Honda Civic RS	43,700	N/A	N/A	N/A	up to 700	N/A	1,498	N/A

Source: (Dianawuri, 2025b; Dianawuri, 2025a)

This study found that the cost of batteries in most Indonesian EMCs remains significantly higher than the global average. Previous research indicates that increasing EV production volume and utilisation can help reduce the cost of battery packs (König et al., 2021). The disparity in battery pack costs poses a major challenge for the Indonesian government, requiring the introduction and implementation of measures to accelerate the expansion of the EV industry. Additionally, the government can promote the development of the local manufacturing industry to produce EV components, particularly batteries (IEA, 2024a).

Despite implementing various financial incentives and subsidy schemes, EV adoption in Indonesia has not seen significant growth. Low-income consumers still find the upfront purchase price of subsidised EMCs high and prefer buying used ICE motorcycles, which offer better performance at the same price. The lack of consumer interest has led several stakeholders to request that the government provide EMC subsidies to the entire community, without economic-level criteria (Fathoni et al., 2025).

7.2.2 Infrastructure Development Challenges

The analysis of the online survey data revealed that inadequate infrastructure for charging points and BSS is a significant barrier that decreases consumer enthusiasm in transitioning to EVs. Although "there are now many private charging stations in several places, such as restaurants, malls, offices, and so on. That is usually for electric car vehicles." (Respondent F). "But I have rarely encountered battery swap locations" (Respondent B). Additionally, Respondent E mentioned, "The availability of public EV charging stations is uneven, and I often have to wait in line." Furthermore, Respondent D highlighted the disparity in EV-supporting infrastructure between urban and rural areas, stating, "In large cities, charging points and battery swapping stations are quite common. However, in rural areas, charging points and BSS are scarce" (Respondent D).

Secondary data has highlighted the significant impact of charging network development on the adoption of EVs, particularly in emerging economies (Costa et al., 2021; Singh, V. et al., 2021). According to Dwi (2024), by June 2024, there were 3,457 public EV infrastructures, including 1,575 EV charging points and 1,882 BSS. However, this infrastructure was primarily concentrated in Java, Bali, and East Nusa Tenggara, which account for 73.40% of EV charging points and 84.06% of BSS. The uneven distribution of EV support infrastructure has raised public concerns about the socio-technical transition towards EVs. Consequently, many EV users have opted to install home charging systems (Dwi, 2024).

In Indonesia, the growth of charging infrastructure was primarily driven by slow-home charging, primarily through household installations. PLN (2025) reported that in 2024, the quantity of home charging customers totalled 28,356. This figure represents a 302% increase compared to 2023, when 9,393 customers were recorded. As a result, total electricity consumption by EV users reached 9,100 MWh, representing a 370% increase from 2023's 2,400 MWh (PLN, 2025). Despite the growing number of home EV charging stations, high installation costs have raised concerns among many consumers. Consequently, the public has demanded that the government enact a policy that "provides subsidies for home charging installations, as these costs remain relatively high" (Respondent E).

This research stage found that the proliferation of BSS providers has offered prepositional value for changing consumer behaviour through faster battery replacement times and energy subscription schemes. BSS integrators offer a 10-second exchange to replace a discharged battery with a full one. This value proposition has answered consumer anxiety regarding the long EMC charging time, namely around 3-4 hours (normal) and 1-2 hours (fast charging), total charging time (Deloitte and Foundry, 2023), because consumers are used to refuelling at gas stations, which takes 2 to 5 minutes. Through collaboration with the network of gas station operators and convenience markets, as well as ride-hailing providers, it was recorded that 1,772 battery swap stations were operating by the end of 2023. The BSS network is not only present in Java, the main island, but has also spread to Sumatra, Bali, Borneo, and Sulawesi, although it remains limited to big cities (Padhilah et al., 2023). The end-user convenience provided by BSS also boosts the growth of EV adoption, as stated below:

"Battery swapping has proven its compatibility in the market. Of the 25,782 e-motorcycles on the road, the battery swapping model accounts for 54.87%" (Deloitte and Foundry, 2023, p.13)

BSS integrators offer two different business models to Indonesian consumers. The first model, developed by Swap Energi, uses a subscription system based on per-kilometre charges. With this system, users can swap batteries at any time with an unlimited swapping quota. This variable-based pricing approach resembles the familiar experience of paying for gasoline. For a monthly mileage of 700 km to 800 km, consumers pay an average of USD 0.01 per km, resulting in a total monthly cost of around USD 8.3 to USD 10. In contrast, other integrators, such as Gogoro, SGB, Oyika, and Volta, are developing EIs based on monthly subscriptions and fixed fees. The second integrator type offers features: quota-based swapping, users swapping when the battery range is low, and a fixed fee per swap. SGB used a fee of USD 23 per 50 swaps per month. Meanwhile, Oyika charges USD 10 per month. Therefore, the second subscription system sets a cost per swap at USD 0.46, with an estimated monthly cost of USD

10 - 14 (Deloitte and Foundry, 2023). In the BSS industry, brand owners and BSS integrators have a significant presence, especially in the business-to-business model that involves ride-hailing operators and logistics companies.

However, “not all electric motorcycles use a battery swap system” (Respondent F). The reliance on battery packs from specific BSS brands has restricted battery interchangeability, hindering the broader adoption of BSS networks (Padhilah et al., 2023). To overcome this challenge, stakeholders can collaborate to standardise battery packs, thereby increasing the flexibility of battery swapping.

The growth of E4W adoption faces critical challenges, including limited public charging infrastructure. Apart from inadequate numbers, the charging points were also not evenly distributed. Likewise, the distribution of fast-charging and slow-charging still needs to be optimally placed. Most E4W fast charging stations are located in state-owned company buildings, limiting access for most consumers (Padhilah et al., 2023). Placing fast charging in public facilities will help EV users reduce waiting time. Furthermore, connecting charging points on the highway will extend the EV's range to convince consumers to travel long distances (Pagany et al., 2018).

High investment costs also hamper the expansion of E4W charging infrastructure due to MEMR Regulation No. 13/2020, which requires three charging port types: CHAdeMO, CCS, and GB/T. The investment cost for one charging point to comply with these regulations was estimated to be USD 50,000 to USD 100,000. Meanwhile, several locations were suitable for slow or medium charging (less than 22 kW AC), ranging from USD 1,700 to USD 33,000. PLN, as the state-owned electricity producer and distributor, has carried out EI through the Investor-Owned Investor-Operated (IO2) business scheme, which offers three investment schemes for medium, fast, and ultra-fast chargers. This scheme requires investment costs of USD 24,000 to USD 73,000 with an estimated monthly gross income of USD 500 to USD 1,400. However, this scheme still needs to be more attractive to investors due to operational costs, including electricity tariffs, salaries, land rent and interest (Padhilah et al., 2023). The government must collaborate with EV manufacturers and infrastructure enablers to develop a standard for charger ports to reduce investment costs. In addition, the government is encouraged to provide incentives for infrastructure enablers to expand the charging point and BSS network by collaborating with public facilities and highway managers (Sasongko et al., 2022; IEA, 2022).

In response to the increasing demand for EV charging infrastructure, several manufacturers are introducing hybrid vehicles. In Indonesia, the number of hybrid electric vehicles (HEVs) experienced a remarkable increase, rising from 14,777 units in 2022 to 67,340 units in 2023

and further to 127,243 units in 2024 (Deloitte and Foundry, 2023; Agustiar, 2024; Abdurrahman, 2025). Despite this significant growth, the government has not yet taken substantial steps to enhance convenience for end users. The government has introduced a fiscal policy through MoF Regulation Number 12 of 2025, reducing the luxury goods sales tax on HEVs from 6% to 3% starting in early 2025. However, the government could implement more fiscal and non-fiscal incentives to benefit HEV users. Many countries have adopted policies such as interest-free loans and exemptions from road taxes in low-emission zones to make HEVs more appealing (Putra, D.L.E., 2024). Government support can increase the interest of potential consumers in adopting HEVs. The increasing number of HEVs not only supports the shift to fully battery electric vehicles (BEVs) but also has the potential to positively influence consumer behaviour. Ultimately, a rise in HEVs will contribute to the socio-technical transition toward electric vehicles, especially in emerging economies (IEA, 2024a; Christidis and Focas, 2019).

7.2.3 The Impact of Life Cycle Management Enhancements on the Total Cost of Ownership for Electric Vehicles

Public opinion has considered the upfront purchase price as the first contributing factor when considering the purchase of EVs, followed by the O&M costs compared with similar expenses for existing ICEVs. Additionally, the accessibility of charging points and BSS infrastructure is also essential for facilitating the socio-technical transition to EVs. A common concern among potential consumers is the perception that replacing EV batteries is very expensive, which often leads them to reconsider their decision to switch to EVs (Dianawuri, 2025b). This concern also contributes to a decline in the resale value of used EVs (Sandi, 2025).

Concerns have been raised by one respondent regarding the significant decline in used EV prices. This decline is notably sharper than that of conventional ICEVs, which has emerged as a significant drawback that decreases public interest in switching to EVs. Below are the barriers affecting public perception of used EV prices:

“In my opinion, one significant drawback of EVs is their resale value. Many vehicle buyers in Indonesia consider the selling price of a used vehicle as a key factor when purchasing a vehicle. However, it has been observed that electric vehicles depreciate largely within just a year of use, which is a concern for potential buyers.” (Respondent B)

Secondary data has highlighted the significant decline in used EV prices, ranging from 20% to 30% within a year, which has raised public concerns and decreased interest in purchasing

EVs (Kompas, 2025). In contrast, used ICEVs in the Indonesian market still maintain a higher resale value. Conventional vehicles typically depreciate by 15% to 20% in the first year and by 5% to 10% in subsequent years, depending on various factors (Bank OCBC NISP, 2023).

Secondary data indicate that the public in emerging markets generally has a limited understanding of EVs' total cost of ownership (TCO). TCO is affected not only by the initial purchase price, fuel costs, and O&M costs, but also by depreciation in resale value and battery replacement expenses (Ji and Gan, 2022; Hagman et al., 2016). Additionally, several customers assume that retired EV batteries still have some resale value. However, the processes for second-life cycle technologies and the recycling of these batteries have not yet been established as financially viable options for automotive manufacturers, battery producers, or recycling companies in emerging economies, particularly in Indonesia.

This research collected secondary data on upfront purchase prices, battery costs, battery life cycles, and maintenance costs from official automotive manufacturer websites, sales agents, and newspapers. Additionally, supporting data such as petrol costs, electricity rates, and taxes, along with assumptions such as insurance, depreciation, discount rates, increased energy consumption, and travelling range, were obtained from government websites, energy companies, and newspapers. In addition, this study collected secondary data from previous related studies (Afraah et al., 2021; Kumar and Chakrabarty, 2020; Saputra et al., 2023). The assumptions used in calculating TCO are presented in Table 7.8.

The TCO is obtained through calculations using the model formulation in equation 2.1 for the length of vehicle ownership for ten years, which is shown in Table 7.9. This study took samples of motorcycles in three classes from brands and types widely known by the public in Indonesia. TCO calculation results consistently show that EMC ownership costs are proven to be more efficient than ICE. When comparing a used entry-level ICEV, which costs USD 573, this study found that the UPP of the unsubsidised budget EMC is USD 955, whereas the subsidised budget EMC is only USD 488. However, the energy costs associated with owning these vehicles differ significantly. The energy cost for the entry-level ICEV is USD 792, whereas the budget EMC has an energy cost of just USD 146. As a result, the TCO for the unsubsidised budget EMC at USD 1,408 remains more competitive than that of the used ICEV at USD 1,723.

There is a significant difference in TCO in the budget and premium classes. In the budget class, several EMC brands sell product variants without subsidies at prices competitive with EMC. However, there are differences in performance, especially at top speed, where the EMC budget is 50 kmph compared to the ICE budget of 95 kmph. Apart from that, the maximum

range of the budget EMC, once refuelled, can cover 230 km compared to 60 km on a budget EMC electric charge. Even though the upfront purchase price of EMC without subsidies is close to ICE, there will be a significant difference in TCO after ten years of use.

Table 7.8 Assumptions for TCO Calculation from ICE and EMC in Indonesia

Assumption	Value	Unit	Assumption	Value	Unit
Battery life	1,000	Charge cycle	Gasoline cost	0.67	USD/litres
Vehicle lifecycle	10	years	Electricity tariff	0.11	USD/kWh
Discount rate	12.78%	Sum of inflation and consumption rate (%)	Increase in fuel consumption (ICE)	5% per year	
Vehicle depreciation	7.08% per year		Increase in electricity consumption (EV)	5% per year	
Battery depreciation	14% per year		Charging efficiency	90%	
Insurance	1.5% per year		Operational Days in a year	260	Days
Daily travelling distance	54.55	kms	Annual travelling distance	14,183	kms

Source: Saputra et al. (2023) and Afraah et al. (2021)

Meanwhile, EMC has a higher upfront purchase price in the mass and premium classes than ICE. The EMC medium sample without subsidies provides a TCO cost of USD 2,417, close to the ICE medium, which costs USD 2,568. The high UPP of the mass EMC sample of USD 1,932 and the battery replacement cost of USD 340, compared to a travelling distance of only 50 km per charge, has increased the TCO for ten years of use. In contrast, the premium EMC sample without subsidies has a TCO of USD 3,246, significantly different from the premium ICE sample (TCO of USD 3,685). The sample EMC premium cost structure with a base purchase price of USD 2,850 provides a mileage of 125 km per charge.

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Table 7.9 TCO Calculation for ICE and EMC in Indonesia without Lifecycle Management

	Subsidised Budget EMC	Budget EMC	Used Budget ICE	Budget ICE	Subsidised Mass EMC	Mass EMC	Mass ICE	Subsidised Premium EMC	Premium EMC	Premium ICE
Performance										
Brand and type	Viar NX	Viar NX	TVS Dazz	TVS Dazz	Gesits G1	Gesits G1	Honda PCX160	Alva Cervo	Alva Cervo	Honda Vario 150
Upfront purchase price	488	955	573	963	1,465	1,932	1,710	2,383	2,850	2,627
Cylinder capacity (cc)	n/a	n/a	110	110	n/a	n/a	150	n/a	n/a	160
Top speed (km/h)	50	50	95	95	70	70	120	103	103	120
Maximum range (km)	60	60	230	230	50	50	265	125	125	342
Fuel consumption (km/l)	n/a	n/a	45	45	n/a	n/a	52.9	n/a	n/a	42.2
Battery capacity (kWh)	1.34	1.34	n/a	n/a	1.44	1.44	n/a	3.6	3.6	n/a
Range/charge (km/charge)	60	60	n/a	n/a	50	50	n/a	125	125	n/a
Electricity consumption (km/kWh)	44.78	44.78	n/a	n/a	34.72	34.72	n/a	34.72	34.72	n/a
First Year Cost of OPEX (USD)										
Cost of Energy	38.71	38.71	210.12	210.12	49.92	49.92	178.74	49.92	49.92	224.06
Cost of Maintenance	34.95	34.95	76.35	59.82	34.95	34.95	59.82	38.95	38.95	75.82
Cost of Insurance	6.80	13.31	7.99	13.43	20.42	26.92	23.83	33.21	39.72	36.61
Tax	13.00	13.00	23.27	23.27	13.00	13.00	27.53	16.79	16.79	52.11
Annual Cost of OPEX	93.47	99.97	317.72	306.63	118.29	124.80	289.92	138.87	145.38	388.60
Monthly Cost of OPEX	7.79	8.33	26.48	25.55	9.86	10.40	24.16	11.57	12.11	32.38
Ten Years Period TCO (USD)										
Upfront Purchase Price	488	955	573	963	1,465	1,932	1,710	2,383	2,850	2,627
Resale Value	70	138	83	139	211	278	246	343	411	379
Cost of Battery Replacement	240	240	0	0	340	340	0	324	324	0
Cost of Energy	146	146	792	792	188	188	674	188	188	845
Cost of Maintenance	132	132	287	226	132	132	226	147	147	286
Cost of Insurance	15	29	17.6	30	45	59	53	73	88	81
Tax	39	44	134	105	39	44	152	61	61	226
Total Cost of Ownership	989	1,408	1,723	2,013	1,998	2,417	2,568	2,833	3,246	3,685

Providing subsidies further widens the difference in ownership costs for all EMC classes compared to ICE (Abdul Qadir et al., 2024). After subsidies, the EMC budget sample experienced the largest TCO difference (USD 953) from the ICE budget sample. Apart from that, through subsidies, mass EMC has an almost equal TCO (USD 16) to the ICE budget. So, through TCO analysis, subsidies play a role in reducing EMC's upfront purchase price and giving consumers the option to obtain EMC in the mass class at the price of a budget ICE. Figure 7.7 displays the cost comparison of the TCO calculation results for 10 years in EMC and ICE of Indonesia.

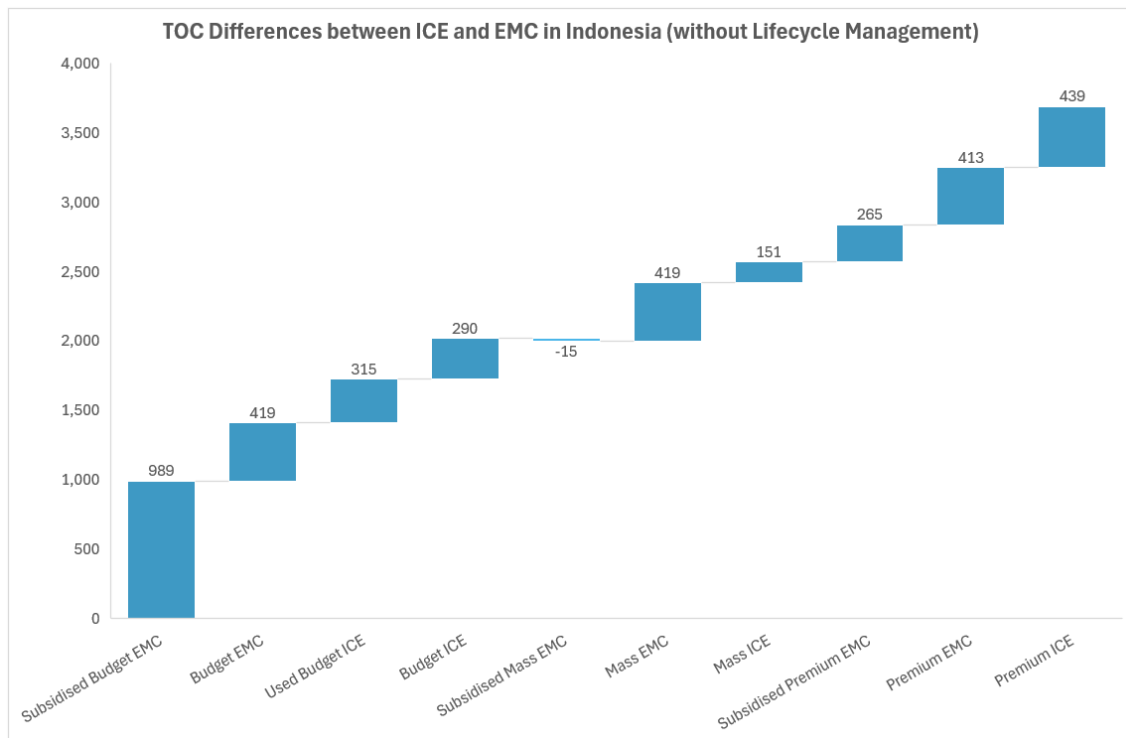


Figure 7.7 TCO differences between ICE and EMC classes without lifecycle management in Indonesia

Apart from the upfront purchase price, the survey results show that participants consider monthly O&M costs. This study examined the first-year operational expenditure costs, including energy, maintenance, repairs, insurance, and taxes. Calculations were carried out using secondary data on annual travelling distance, fuel/electricity consumption, battery/tank capacity, and energy costs. Table 8 shows the monthly O&M costs of EMC and ICE in Indonesia. Our calculation results consistently show that EMC requires lower O&M costs than ICE. Even subsidised premium EMC requires a monthly O&M cost of USD 12.11, which is lower than the ICE budget of USD 25.55. Electricity costs for each EMC class range from 18.43% to 27.93% of ICE fuel costs.

EMC maintenance costs in the budget and mass classes are 58.43% lower than ICE in the same class. Likewise, the EMC premium reduces consumers by 51.37% compared to the ICE premium. The lower number of EMC components has significantly reduced the maintenance and reparation costs (Costa et al., 2021; Ji and Gan, 2022; Tarei et al., 2021). The same thing happens to tax costs; the annual and five-year tax relaxation policies have reduced costs for EMC consumers compared to ICE, with premium types at 32.21%, mass types at 47.22%, and premium types at 55.87%.

However, when calculating insurance costs, the results show that the EMC mass and premium without subsidies are higher, ranging from 8.49% to 12.98%, than those of the ICE of a similar class. The high insurance cost is due to the insurance calculation, a percentage of the upfront purchase price. So, non-subsidised EMCs with higher purchase prices will experience higher insurance costs than ICEs. However, the insurance value of EMCs decreased after the subsidy was provided, so it was below than of ICEs in the same class.

Through the results of TCO modelling, this study calculates operational expenditure costs for using EMC compared to ICE. Overall, COPEX for EMCs is cheaper than ICEs. Among the budget class, the budget EMC COPEX (USD 351) is lower than ICE, decreasing to USD 332 with subsidies. On the other hand, the premium EMC without subsidies incurs a COPEX of USD 484, which is still much lower than the budget ICE, which requires USD 1,153. The significant reduction in TCO was greatly influenced by the low electricity tariff of 11 cents per kWh, tax incentives and maintenance costs. The operational expenditure expenses in both the non-subsidised and subsidised EMC budgets range from 24.14% to 32.29% of the total cost of ownership. This cost decreases in the mass EMC category, varying from 17.53% to 20.26%, and is the lowest in premium EMCs, ranging from 14.37% to 15.88%. In contrast, ICE users face higher expenses, ranging from 39.02% to 58.29% of the total cost of ownership. These results are consistent with the first-year expense calculations. Figure 7.8 shows the TCO composition of ICE and EMC in Indonesia. Upfront purchase prices still provide the most significant portion of projected EMC costs across all classes. ICEs in the mass and premium classes experience similar conditions. In contrast, for budget models, energy costs are the most significant contributor.

Public concern for environmental conservation during the socio-technical transition was reflected in the views of one respondent who believes that EVs can help reduce pollution. While the prevalence of fossil fuel use in power generation and the continued high reliance on personal vehicles, particularly motorcycles, the adoption of EVs may only serve as a temporary solution. Traffic congestion also remains a significant contributor to energy inefficiency. Therefore, it is essential to develop policies that promote comprehensive

solutions, such as increasing the use of mass public transportation powered by renewable energy sources, as expressed below:

“Since Indonesia ranks third in the world for motorcycle usage, I believe EMCs can help reduce air pollution. However, their use should not be viewed as a comprehensive solution, but rather as a temporary alternative.” (Respondent B)

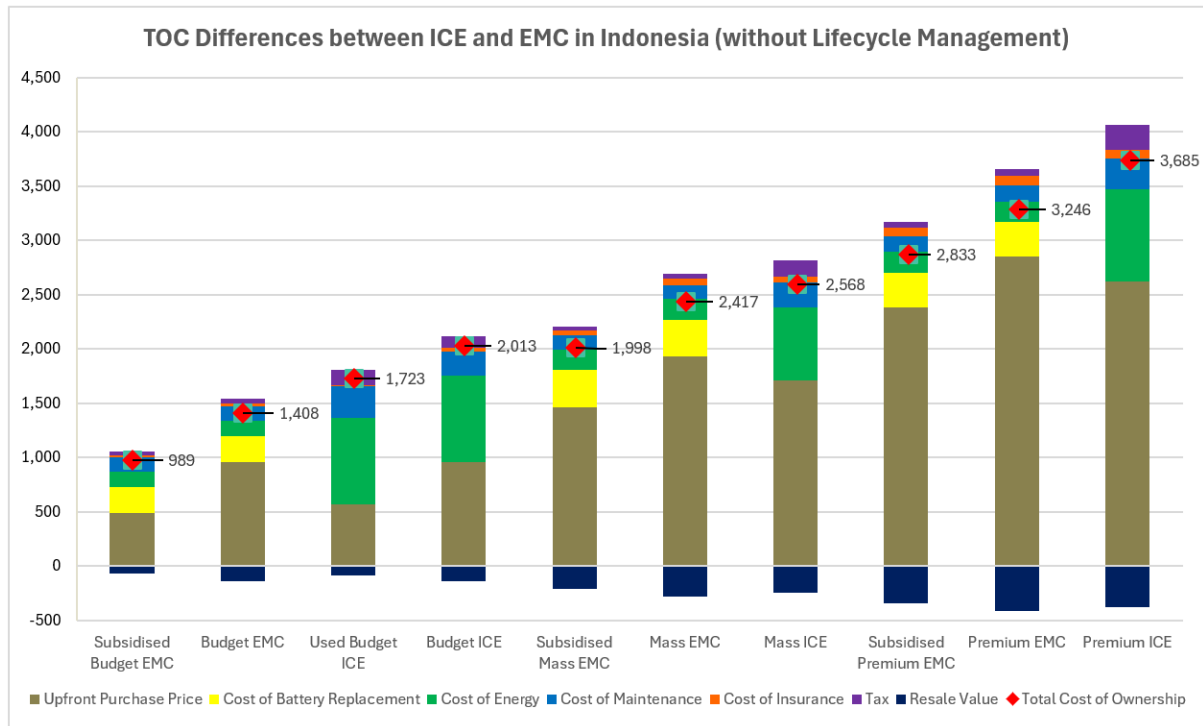


Figure 7.8 TCO Composition of ICE and EMC without Lifecycle Management in Indonesia.

The public's growing interest in adopting EVs must be balanced with improvements in life cycle management. This study analysed several secondary sources that explored these innovations and conducted quantitative assessments to evaluate their impacts. The life cycle of EV batteries represents a layered process that illustrates the decline in functionality and the transition of the battery's economic value—from production and initial use in an EV to the final recycling stage, as illustrated in Figure 7.9. The EV life cycle encompasses the manufacturing phase, utilisation phase, extending utilisation phase, second-life phase, and end-of-life phase. The production phase is heavily influenced by determining technical specifications that meet consumer needs. Literature elaborated that the EV life cycle management bridges the fulfilment of technical specifications through a production process that involves supply chain

of materials, mastery of technology, manufacturing capabilities, and energy availability (Verma et al., 2021; Glöser-Chahoud et al., 2021; Harper et al., 2019; Safarzadeh and Di Maria, 2025).

In the first stage of its lifecycle, the battery serves as the primary power source in EVs when its State of Health (SoH) is between 100% and approximately 80%. Within this range, the battery performs optimally, providing good vehicle performance in terms of both range and energy efficiency. However, when the capacity degrades below 80%, it results in reduced mileage and increased internal resistance, which makes the battery economically unsuitable for automotive applications (Song et al., 2024; Glöser-Chahoud et al., 2021). In the use phase, attention is prioritised on transportation demand and energy conversion in a green market. In addition, recent research attention is focused on efforts to maintain and extend the lifespan of EV use by end-users. The lifespan of an EV largely depends on the user profile and driving behaviour (Verma et al., 2021; Rufino Júnior et al., 2023). Unlike conventional ICEs, maintaining battery usage is crucial to the lifespan of an EV. Research shows that several factors can affect the condition and lifespan of an EV battery. Multiple factors influence the EV battery's degradation rates, such as temperature, charge, and discharge voltage, current, and the level at which the battery is charged or discharged (Han, X. et al., 2019; Martinez-Laserna et al., 2018). Recognising these factors can significantly reduce battery failure rates and enhance their performance and lifespan. The after-sales network ensures spare parts supply availability and improves EV reliability (Zarazua de Rubens et al., 2020). Furthermore, qualified maintenance specialists are required to improve EV reliability and overcome technical problems during the use phase (Fleet News, 2014).

The second stage focuses on extending battery lifespan. When a battery's SoH falls within the range of approximately 70% to 80%, it undergoes refurbishment or remanufacturing. The refurbishment process begins with industrial disassembly, which involves systematically dismantling the battery system down to the module or cell level to identify usable components. Next, diagnostics and grading are performed to assess each module's capacity, internal resistance, and thermal stability. Battery modules or cells that have undergone significant degradation will be replaced through a cell replacement process. In contrast, modules that remain in good condition will be recalibrated and reconditioned by reassembling and balancing the electrical system and the Battery Management System (BMS). If the results are satisfactory, the battery can be reused in EVs. However, if the SoH is below 70%, it is transferred to a second-life application (Glöser-Chahoud et al., 2021; Xia and Li, 2022).

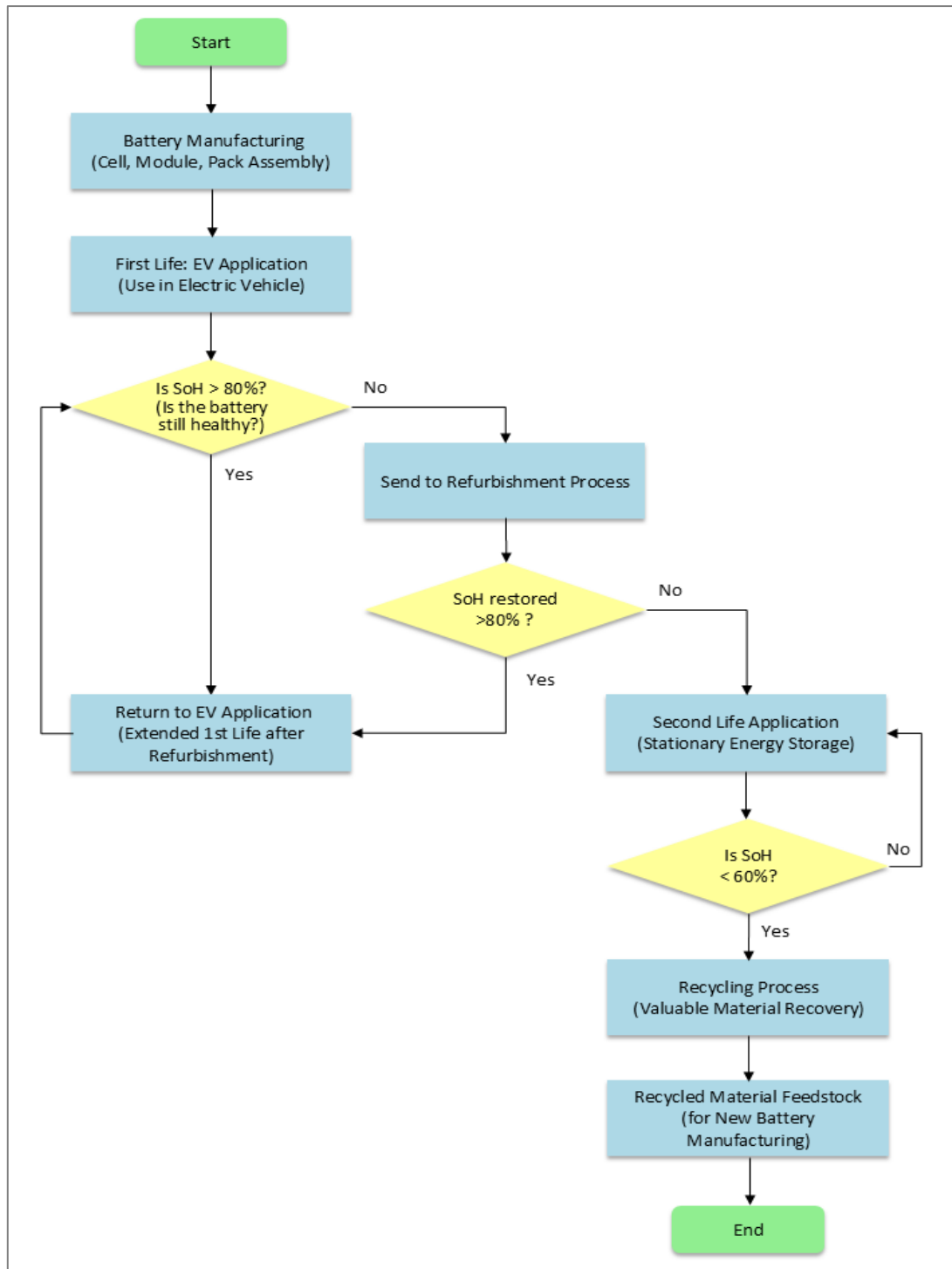


Figure 7.9 EV Battery Life Cycle Management

Source: Adopted from Song et al. (2024) and Glöser-Chahoud et al. (2021)

In the next stage, when the SoH is approximately 70–60% (or even down to 50%), retired EV batteries enter their second life cycle (Song et al., 2024; Glöser-Chahoud et al., 2021). Rufino et al. (2023) examined several automotive companies that have initiated or developed second-life business models using retired EV batteries. The Chinese EV manufacturer Yinlong has

established a second-life battery scheme for electric buses, focusing on energy storage systems (ESS) applications. Nissan has partnered with Sumitomo Corporation to reuse batteries from its Leaf series through the 4R Energy Corporation project, which emphasises four key concepts: Reuse, Refabricate, Resell, and Recycle. The Nissan's second-life batteries have been utilised for both home and commercial energy storage. In Germany, a collaboration among Bosch, Vattenfall, and BMW has allowed for the implementation of used EV batteries in applications such as peak shaving and on-grid energy storage. Additionally, Renault, in partnership with Umicore and Connected Energy, has repurposed used EV batteries for off-grid solar storage and household systems (Rufino Júnior et al., 2023; Kampker et al., 2023).

The rising adoption of EVs in Indonesia is driving up the demand for batteries. When EV batteries lose their efficiency and capacity, they need to be replaced. However, retired EV batteries can pose environmental challenges. To address this, several EV manufacturers have implemented battery utilisation schemes. After their use in EVs, these batteries can enter a second-life phase, serving as a stationary ESS for applications like solar-powered street lighting (Ghozali, 2023; Nurdawati and Agrawal, 2022).

Finally, once the retired battery reaches an SoH below 60%, it is considered unsuitable for energy storage and enters its end-of-life stage (Song et al., 2024; Glöser-Chahoud et al., 2021). Several local EV manufacturers have implemented waste management practices during the end-of-life phase, focusing on recycling parts that can no longer be used as valuable materials. Some companies were even researching ways to repurpose waste material from E4W batteries into bricks (CNN Indonesia, 2022). On a global scale, recycling technology development is centred on extracting valuable active materials from lithium batteries due to their high economic worth (Harper et al., 2019; Safarzadeh and Di Maria, 2025). The recycling phase is a strategic factor for companies, as they require time to internally develop their recycling processes and find effective solutions for separating the black mass, which mainly consists of lithium, manganese, cobalt, and nickel (Rufino Júnior et al., 2023; Perdana et al., 2025).

Table 7.10 and Figure 7.10 present a comparison of TCO calculations for various potential lifecycle management development scenarios for retired EMC batteries in Indonesia, evaluated against both new and used conventional ICEs. Implementing a lifecycle management scenario by extending the first lifecycle can reduce the TCO across various EMC categories. Specifically, it could lower TCO by USD 130 for premium EMC, USD 68 for mass EMC, and USD 43 for the smallest non-subsidised EMC budget. Furthermore, in scenarios that involve extending the first cycle, adding a second cycle, and incorporating recycling, there

is a greater opportunity to reduce TCO across segments further. The most significant potential for TCO reduction lies in the subsidised EMC budget, with a decrease of USD 188, followed by mass EMC at USD 170 and premium EMC at USD 130. There is no difference in the impact of life-cycle management between the first and second scenarios on the premium EMC segment, as the long battery life eliminates the need for replacement after 10 years of use.

Table 7.10 TCO Calculation for ICE and EMC in Indonesia with Lifecycle Management

Vehicle Type	Brand	10 Year TCO		
		Without Life Cycle Management	Extended First Life Cycle	Extended First Cycle, Second Cycle, and Recycling
Subsidised Budget EMC	Viar NX	989	941	801
Budget EMC	Viar NX	1,408	1,365	1,278
Used Budget ICE	TVS Dazz	1,723	n/a	n/a
Budget ICE	TVS Dazz	2,013	n/a	n/a
Subsidised Mass EMC	Gesits G1	1,998	1,930	1,828
Mass EMC	Gesits G1	2,417	2,349	2,247
Mass ICE	Honda PCX160	2,568	n/a	n/a
Subsidised Premium EMC	Alva Cervo	2,833	2,703	2,703
Premium EMC	Alva Cervo	3,246	3,117	3,117
Premium ICE	Honda Vario 150	3,685	n/a	n/a

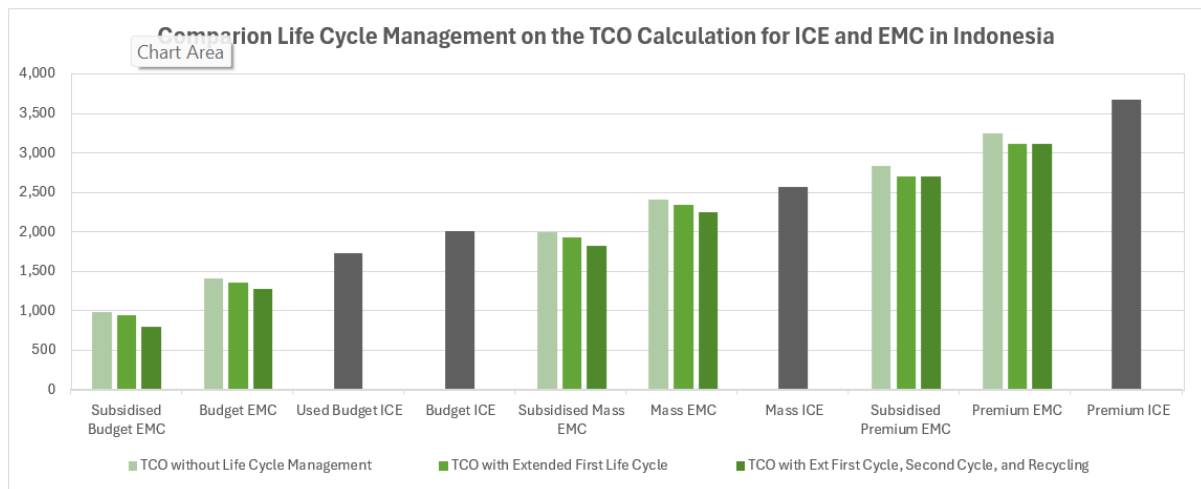


Figure 7.10 Comparison of TCO potential between EMC and ICE through the implementation of lifecycle management scenarios.

7.3 Discussion

Research on the provision of affordable and clean fuels has analysed socio-technical transitions in the diffusion of EVs. This study explicitly examines the Indonesian public's social acceptance of low-carbon technologies, particularly in the transportation sector. Multilayered interactions have influenced the diffusion of EVs within the socio-technical landscape, which includes global trends in EV adoption and local demand for alternative vehicle fuels. These dynamics have facilitated the knowledge spillovers that promote niche innovations, thereby creating pressure on the government regime to implement regulations that encourage the adoption of EVs.

This study stage underscores the critical role of customer acceptance in the socio-technical transition to EVs in Indonesia, a developing economy. This analysis focuses on the EMCs, which face lower adoption barriers than four-wheel electric vehicles (E4Ws) in Indonesia. Research shows that even affluent, multi-income families often own motorcycles. This trend is driven by urban sprawl that has pushed the middle class away from city centres, coupled with inadequate public transit. As a result, motorcycles have become the essential mode of transport due to their unmatched cost-effectiveness and ability to navigate traffic, a preference common across Indonesia, India, and Vietnam.

The survey results indicate that respondents typically engage in short-distance daily travel, which can be effectively supported by EMC. Additionally, EMC batteries have lower power requirements than E4Ws, enabling more convenient home charging, as noted by most respondents. This finding reinforces existing data showing a higher adoption rate of EMC than E4W (Agustiar, 2024; Balijepalli et al., 2023). Furthermore, the majority of EV users prefer charging at home rather than in public locations or BSS (Abdurrahman, 2025). Meanwhile, respondents travelling long distances of 40 kilometres or more were predominantly found in Jakarta, a central urban area that is larger than Bandung. This long-distance daily mobility requires support for short-term charging infrastructure, which is provided by BSS providers. BSS has been established to offer solutions for fast-moving consumer segments, including two-wheeled ride-hailing drivers and logistics fleets (BCG and AEML, 2022).

Respondents from both locations expressed a desire for lower upfront purchase prices and O&M costs for EVs compared to conventional ICE vehicles. However, respondents in Jakarta indicated a slightly higher budget due to their greater monthly family income compared to those in Bandung. This survey finding aligns with previous research, which has shown that most consumers prefer lower upfront purchase prices for EVs (Balijepalli

et al., 2023; Novizayanti et al., 2021; Tarei et al., 2021). Although EVs' performance may not yet match that of ICE vehicles in the same class, Indonesian consumers tend to compare the purchase price of EVs with that of used ICE motorcycles. Additionally, respondents expressed a desire for lower monthly O&M costs compared to existing ICE vehicles (Abdul Qadir et al., 2024; Afraah et al., 2021; Singh, V. et al., 2021).

Meanwhile, respondents from the two urban areas expressed differing views on the primary considerations and barriers to the adoption of EVs. The cumulative profile of respondents' priority choices in Bandung was steeper than that in Jakarta. In Bandung, a significant barrier identified was a lack of public awareness about EMC. In contrast, respondents from the Greater Jakarta area cited inadequate infrastructure—particularly regarding charging stations—as their primary concern, followed closely by the high EVs' upfront purchase price. Additionally, higher levels of education and monthly family income in Greater Jakarta have contributed to a better understanding of electric mobility among residents.

The results of this survey indicate that public awareness, particularly in large cities, is growing regarding the benefits of EVs as low-emission alternatives that contribute to environmental conservation. Most respondents recognise the lower O&M costs of EVs compared to traditional ICEVs. Additionally, some respondents appreciate the comfort that EVs provide, such as reduced vibration and faster acceleration. Urban consumers are increasingly interacting with EV users and becoming more informed about the significance of equitable charging infrastructure availability, despite recognising the high upfront purchase price. The findings of this study phase align with previous research on the significance of sustainability promotion campaigns to enhance public awareness, facilitating the socio-technical transition towards EVs (Abbasi et al., 2021; Pandita et al., 2024).

The high upfront purchase prices of EVs in Indonesia are influenced by the battery cost, which remains higher than those in the global market. While the price of electric car batteries has decreased compared to those of EMCs in the local market, making them competitive with conventional ICEVs, the cost of EV batteries still poses a significant concern when it comes to replacement at the end of their lifetime. To address this issue, the government is working on building the EV battery factories to help bridge the price gap. In February 2023, the MSAEBR reported President Jokowi's statement:

"We want to integrate all these natural resources into one item that will be needed, namely EV lithium batteries. There are components from nickel, copper, tin, and bauxite... In the future, there will be EV batteries... which in the future,

like it or not, all countries will be looking for this item" ("Ekosistem Kendaraan Listrik Strategi, Besar Indonesia jadi Negara Maju", 2023)

The government has implemented various fiscal and non-fiscal policies to lower the upfront purchase price of EVs. Incentive programs, supported by limited subsidies, have proven effective in increasing EV adoption, especially since 2023. However, the current EV population is still significantly below the targets set in the National Energy General Plan. This shortfall has led several stakeholders to advocate for the government to broaden the scope of subsidies. Expanding these subsidies is expected to promote further EV adoption nationwide, including in remote rural areas. These findings are consistent with existing literature highlighting the necessity for regulators to develop more appealing incentive policies for end-users, EV manufacturers, battery producers, and infrastructure enablers to achieve established decarbonisation roadmap targets (Abdul Qadir et al., 2024; Setiawan, A.D. et al., 2022).

In the E4Ws segment, promising growth has emerged following the entry of global brands like Wuling and Hyundai. The arrival of companies such as BYD, MG, and KIA has significantly boosted EV adoption. However, the growing popularity of EVs faces challenges, including high upfront purchase prices and insufficient public charging infrastructure, particularly in strategic locations. Public EV charging points are essential for supporting long-distance travel, especially for those visiting relatives in rural areas during holidays. Although PLN has partnered with infrastructure enablers to improve the situation, the distribution of charging stations remains uneven, primarily concentrated in large cities in Java, Bali, and West Nusa Tenggara. The requirement to provide three types of plugs has made high investment costs a significant challenge for the broader EV infrastructure networks. To address this issue, the government could offer incentives through a carbon tax, similar to those implemented in leading EV-adopting countries. This approach could generate funds for the diffusion of EVs and the expansion of the charging infrastructure network (Schulz and Rode, 2022; Yu et al., 2018).

The government is promoting the adoption of hybrid electric vehicles (HEV) to meet the demand for EV charging infrastructure. The population of HEVs in Indonesia has seen a significant increase, comparable to that of electric motorcycles. However, this rise in HEV numbers has not yet garnered sufficient attention from the government to enhance convenience for end-users. In January 2024, Jawa Pos reported the statement of an automotive expert as follows:

"The shift from ICE to EV will take place smoothly during 2024. The biggest sales will actually occur in hybrid vehicles. The problem of batteries which are still

expensive remains a challenge. It is believed that cars with hybrid technology will sell better if the government provides subsidies, apart from that it is also can reduce emissions. However, unfortunately the government in its transition program to the electrification era has not yet looked at hybrid as a goal" (Mobil Hybrid di Indonesia Tumbuh Subur, Pemerintah Masih Enggan Beri Subsidi", 2024)

To facilitate the transition to full battery electric vehicle (BEV) adoption, the government is advised to strengthen collaborative networks among automotive manufacturers, infrastructure enablers, and research institutions, and to introduce both fiscal and non-fiscal incentive policies for HEVs. Our findings support recent literature that emphasises the importance of collaboration among stakeholders to attract investment in the development of EV infrastructure (IEA, 2024a; Abdurrahman, 2025).

This study analysed three scenarios to calculate the TCO and described the cost structure throughout the vehicle's lifetime. In the baseline scenario, users of EMCs replace the battery at the end of its useful life. In both the budget and mass-market segments, a complete battery replacement is required every 4 years, while in the premium segment, it is required every 8 years. Over 10 years, the TCO for both budget and premium EMCs shows a significant advantage over conventional ICEVs. Even for budget EMCs, which do not receive subsidies and have a higher upfront price than used budget ICEVs, they still have a lower TCO because electricity is cheaper than fossil fuels. In contrast, the TCO for EMC in the unsubsidized mass-market segment is USD 2,417, only slightly lower (5.88%) than that of conventional ICEVs, at USD 2,568. The higher UPP of mass EMC, at USD 1,932, compared to mass ICE, at USD 1,710, along with the cost of two battery replacements, significantly affects the TCO.

Public understanding of the economic benefits of EVs in Indonesia remains limited, as reflected in the country's low EV adoption rate. This study indicates that the depreciation of used EVs in Indonesia is faster than that of used ICEVs. The high cost of battery replacement has led the public to hesitate before purchasing used EVs. Additionally, the low prices of used EVs have significantly decreased interest in purchasing new EVs (Nanda and Kurniawan, 2025). A lack of user knowledge of proper EV use has prevented extending of battery life. Moreover, the lack of viable second-life and battery recycling businesses in Indonesia means that consumers must be responsible for covering the full cost of battery replacement (Rufino Júnior et al., 2023; Tarei et al., 2021; Martinez-Laserna et al., 2018).

In the second scenario, the battery is not replaced entirely but remanufactured. This refurbishment aims to extend the battery's lifespan. When considering non-subsidised

mass EMCs, this refurbishment can lower TCO, resulting in an 8.52% difference compared to ICEVs. In the third scenario, the implementation of lifecycle management—by extending the first cycle, utilising the second cycle for energy storage in stationary applications, and recycling the retired EV batteries—results in a significant TCO difference of 12.50% when compared to mass ICE vehicles.

Our findings contribute to the recent literature by highlighting the importance of enhancing the lifecycle of EV to promote adoption in developing countries, such as Indonesia. Effective lifecycle management ensures that technical specifications are met during the production phase, and align with consumer needs. In the usage phase, the extension of an EV's lifespan is significantly influenced by consumer knowledge, especially regarding driving behaviours that affect battery health (Verma et al., 2021). Additionally, a comprehensive after-sales network has contributed to maintaining EV reliability (Zarazua de Rubens et al., 2020).

At the end of life for EVs, effective waste management is essential for dismantling and repurposing components as refurbished goods. Retired EV batteries can also be repurposed for stationary applications, such as street lighting, off-grid solar PV power plants, and grid-connected power distribution (Rufino Júnior et al., 2023; Nurdiawati and Agrawal, 2022; Martinez-Laserna et al., 2018). Waste management efforts focus on recycling these end-of-life materials to recover resources and extract valuable active materials from lithium batteries (Rufino Júnior et al., 2023; Harper et al., 2019). By localising the manufacturing, second-life, and recycling of EV batteries, the government could reduce battery replacement costs, thereby significantly impacting the broader adoption of EVs.

One key finding is the need to align EV adoption with environmental sustainability. The continuing reliance on fossil fuels, particularly coal, for electricity generation raises concerns among stakeholders. The government must accelerate the decarbonisation of the power sector by increasing the use of renewable energy to minimise emissions throughout the EV life cycle. These findings reinforce previous studies highlighting the importance of optimising NRE sources for powering EVs (Deng et al., 2024; Maghfiroh et al., 2021; Shahid et al., 2022). Additionally, the research underscores the significance of integrating the transition to electrified transportation with efforts to conserve the environment (Martinez-Laserna et al., 2018; Nurdiawati and Agrawal, 2022).

7.4 Conclusion

EVs have emerged as a viable alternative for achieving the seventh SDG, which focuses on providing affordable and clean energy. However, adopting EVs requires a comprehensive socio-technical transition to effectively address mobility needs, driven by rapid population growth and uncontrolled urbanisation in Indonesia. This socio-technical transition is significantly shaped by multilayered interactions that examine the impacts of the global EV trend and various domestic factors that foster niche innovations. The pressure from the decarbonisation movement, increasing demand for alternative fuels, and the emergence of local niche innovations in electric vehicles, have prompted the government to implement both fiscal and non-fiscal policies to accelerate the adoption of EVs.

This stage of the study, focusing on the socio-technical transition to transportation electrification, has highlighted the significant role of motorcycles, which have become the primary mode of transportation for the Indonesians. Increasing urbanisation has driven many middle- and lower-income residents to move away from city centres. Traffic congestion and the lack of reliable and comfortable mass public transportation have prompted the public to turn to motorcycles. In addition to their ability to navigate traffic jams, motorcycles consume less fuel than passenger cars. The promotion of EMC offers opportunities to adopt low-emission technology, with lower entry barriers than electric passenger cars.

This study emphasises the importance of consumer acceptance in driving the social adoption of EVs in emerging markets such as Indonesia. Most respondents recognise the benefits of EMCs in supporting their daily travel needs, which typically involve short distances within urban areas. Additionally, the demand for low operational and maintenance costs has been met by lower electricity prices than those for petroleum-based fuels. The limited battery capacity of EMCs allows users to conveniently charge their vehicles at home, which the majority of respondents prefer. As a new driving technology, the public is starting to understand that EMCs produce low emissions while offering a smooth, vibration-free ride and better acceleration than conventional ICEVs.

Meanwhile, the public's desire to adopt EVs is still hindered by the high upfront purchase price. Although the government has implemented various fiscal and non-fiscal policies, including incentives, the crucial role of subsidies in reducing the upfront purchase price to make it competitive with ICEVs is limited by the country's budgetary constraints, limiting the number of the public eligible for subsidies. Additionally, localising EV battery manufacturing could help reduce the gap with global electric vehicle prices.

The findings of this study highlight the essential role of stakeholder collaboration in expanding the network of charging points and BSS infrastructure. A significant challenge identified by respondents in the Jakarta metropolitan area is the limited and uneven distribution of infrastructure. This issue dampens public interest in adopting EVs, particularly for long-distance travel beyond major cities and into rural areas. Although the government has introduced incentives to encourage the development of EV charging infrastructure, the need for various plug types has raised investment costs. Consequently, this high investment risk is inversely related to the currently low number of EV users utilising public charging stations. In contrast, user innovation through the socio-technical transitions offered by BSS providers has successfully addressed niche markets such as two-wheeler ride-hailing and logistics. However, similar to charging points, the distribution of BSS remains concentrated in major urban centres.

This study has revealed that some stakeholders are advocating for the government to expand subsidies to promote EV adoption. These expanded subsidies are intended not only for end-users, but also as more attractive incentives for automotive manufacturers and infrastructure enablers. These incentive policies have enhanced the collaboration network for innovation, optimising knowledge spillovers to tackle the socio-technical challenges faced by consumers. The public is seeking incentives to lower the installation costs of home charging. Additionally, the push for standardising charging plugs could help reduce investment risks during the transition to this green mobility technology.

The innovation collaboration network must intensify the initiatives to utilise the second life of retired EV batteries. Industrialising the use of second-life EV batteries can significantly reduce replacement costs, a major concern for the public. This reduction in battery replacement costs will enhance the resale value of used EVs, addressing worries about their high depreciation. Thus, the TCO of EVs will increasingly be able to compete with conventional vehicles.

Moreover, advancements in recycling technology for retired EV batteries will substantially reduce EV waste and lessen the need for mineral extraction needed to produce lithium-ion battery components. To build on this, it is crucial to align measures that facilitate EV adoption with environmental conservation. This alignment can be achieved by increasing the use of renewable energy in EV power generation and in the manufacturing of their components. Ultimately, this study emphasises the importance of engaging all stakeholders to promote a circular economy throughout the lifecycle of EVs.

Chapter 8 Development of a Sustainable Socio-technical Transition in the Emerging Economies Transportation Energy Sector

8.1 Introduction

This chapter endeavours to synthesise conclusions based on the theoretical and empirical analysis reported in Chapters 4, 5, 6, and 7. A sequence of queries and responses provides a summary of the research questions and explains how they come together to address the overarching research question: How does the diffusion of low-carbon eco-innovations (EI) shape the socio-technical transition towards sustainable transportation in Indonesia? This chapter begins by reviewing the findings from the earlier chapters and presents a series of research sub-questions along with their answers, providing an explicit summary of the research outcomes. This chapter also includes a reflection on these findings in the context of current theoretical debates and practical applications in the field. Additionally, the chapter discusses the study's limitations. Finally, this chapter ends with suggestions for further investigation into the relationship between EI diffusion and socio-technical transitions towards sustainability, specifically within the transportation sector of emerging economies.

8.2 Overview of the Previous Chapters

The empirical chapters of this study collectively illustrate how the interplay of institutional legacies, power dynamics, inter-actor coalitions, and consumer cultural practices shapes the diffusion of EI in Indonesia's transportation sector practices. By integrating the multilevel perspective (MLP), historical institutionalism (HI), and power theory, this research does not depict technology diffusion as a linear process. Instead, it emphasises the contested nature of socio-technical transitions, path dependence, and relational power dynamics. These empirical chapters are not isolated studies; instead, they offer a cumulative contribution that builds a comprehensive understanding of how EI trajectories develop in emerging economies. Furthermore, these dynamics resonate with and enhance broader discussions regarding socio-technical transitions toward sustainability in the transportation sector.

Chapter 4 highlighted the significance of the institutional arrangement in shaping the socio-technical pathways of transition. This study utilises MLP in conjunction with HI to

analyse how the interplay between commitment to the global climate agenda, oil price volatility, and domestic political dynamics has created pressures at the landscape level that influence Indonesia's national transportation policy agenda. In 2004, the current account deficit impacted domestic political dynamics, as the focus on road infrastructure development and uncontrolled urbanisation led to increased reliance on private vehicles and a significant rise in fuel subsidies. These landscape pressures have resulted in both incremental adjustments and critical junctures within the regime's institutional dynamics. At the same time, the diffusion of low-carbon transport innovations, such as the BRT system developed in Curitiba, Brazil, was occurring in Asia during the early 2000s. Landscape pressures on the socio-technical regime created a window of opportunity for implementing BRT systems at the micro-niche level within a TOD framework, indicating a partial shift towards low-carbon mass mobility solutions. However, policy formulation and implementation remained heavily influenced by the private-vehicle-oriented regime and entrenched dependence on fossil fuels (Skovgaard and van Asselt, 2019; Sefriyadi et al., 2023). Similarly, palm oil-based biodiesel has emerged as the primary EI path-dependent trajectory because it aligns with the country's comparative advantage in palm oil production and political-economic interests in the plantation sector. This biodiesel advancement did not solely respond to external pressures such as oil price shocks or commitments to the global climate agenda (Astari et al., 2025; Suhara et al., 2024; Pye, 2019).

The concept of critical junctures (Lockwood et al., 2017; Fioretos et al., 2016; Pierson and Skocpol, 2002) has proven highly useful for explaining how exogenous shocks have been transformed into opportunities to institutionalise the diffusion of EI. The global push for decarbonisation, driven by the Paris Agreement, and Indonesia's domestic need to stabilise its palm oil sector amid trade disputes have created a window of opportunity to pursue EIs as a strategy that addresses both environmental and economic objectives. However, as noted by scholars such as North (1990), Mahoney and Thelen (2010), and Gidley and Palmer (2021), institutions are not mere passive channels for external pressures. Instead, they actively mediate these influences, filtering, reinterpreting, and sometimes rejecting change. This study provided evidence on how Indonesian policymakers promote the narrative of biodiesel blending as a nationalistic measure for energy resilience, thereby integrating EI into the broader discourse of energy security and economic growth (Ichsan et al., 2025; Choiruzzad, 2019; Astari and Lovett, 2019).

While the MLP and HI frameworks are essential for understanding the structural conditions of EI diffusion, they do not adequately capture the agency of contested actors. Chapter 5 introduces theories of power relations to explore how discourse, alliances, and asymmetries influence the trajectory of EI diffusion. At this research phase, concepts

such as relational power (Allen, 2004; Allen, 2011a), discourse power and disciplinary mechanisms (Foucault, 1980; Aberra, 2012), and the political economy of sustainability transitions (Newell, 2021; Newell and Bray, 2025) create a more comprehensive analytical framework. The findings reveal how a coalition of dominant actors—including Pertamina, palm oil conglomerates, multinational automotive manufacturers, and bureaucratic agencies—utilise discursive strategies centred around energy resilient, industrial growth, and rural development to legitimise biofuels as the primary path for EI. Meanwhile, international certification regimes and climate finance institutions implement disciplinary mechanisms by establishing sustainability benchmarks. These benchmarks often marginalise smallholder farmers who struggle to meet these standards (Ichsan et al., 2025; Djatmika et al., 2024; Choiruzzad et al., 2021). Similarly, the electrification of the road sector was marked by the dominance of the PLN alliance, with infrastructure enablers leveraging their control over infrastructure and regulatory instruments to shape EV adoption. Meanwhile, multinational EV manufacturers have promoted narratives of electrification that align with their global strategies. Additionally, the certification process has established strict requirements that can make it challenging for local MSME startups to meet the testing standards required for homologation of their innovative outcomes. This discursive power has marginalised alternative narratives that highlight concerns about food-fuel conflicts, the exclusion of smallholder farmers and rural communities, and environmental externalities.

These findings underscore that the diffusion of EI is not a neutral or technocratic process, but rather one shaped by elite alliances, practices of exclusivity, and the contestation of knowledge power (Newell and Bray, 2025; Geels, 2018; Adomako et al., 2023). The key concern is that the concentration of power among dominant agencies has led to uneven inclusiveness, where specific EI pathways—such as biodiesel—were prioritised over others, raising questions about the inclusiveness of the transportation transition in Indonesia (Ichsan et al., 2025; Djatmika et al., 2024; Choiruzzad et al., 2021). Moreover, the case of Indonesia aligns with studies from other developing countries where the political capture of EI diffusion has been documented, such as Brazil's ethanol policy (Mosquéra et al., 2024; Grandis et al., 2024; Machado et al., 2015) and Argentina's biodiesel program (Nikas et al., 2022; US Department of Commerce, 2017; Tomei and Upham, 2009).

The political economy perspective on the socio-technical transition highlights both the inclusive and exclusive outcomes of EI diffusion in biofuels. While multinational corporations and domestic elites gain economic benefits and discursive legitimacy from biofuel development, smallholder farmers and rural communities are often marginalised. These groups disproportionately face risks such as land tenure disputes, energy price

volatility, and limited access to decision-making processes. These findings align with the body of literature that views energy transitions as fundamentally political projects, in which power asymmetries influence not only "how" the socio-technical transition occurs but also "who" benefits from it (Geels et al., 2020; Newell, 2021).

The next stage of analysis, detailed in Chapter 6, examines how niche-level actors attempt to address the entrenched asymmetry by forming collaborative networks. Referring to the concept of low-carbon innovation diffusion (Glover et al., 2019; Douthwaite et al., 2001), this chapter has analysed the role of brand enthusiast groups as innovators who socialise global EV trends through social media to the Indonesian public. Additionally, this phase of research has identified how local startups, PLN, infrastructure enablers, research institutions, and non-governmental organisations (NGOs) collaborate to leverage knowledge spillovers in the diffusion of EVs. Together, these collaborative networks advocate for policymakers to establish institutional arrangements that support low-carbon EI. These collaborative networks have emerged as key drivers of EI, facilitating learning-by-interaction, forming global partnerships, and engaging in policy advocacy, as highlighted in the literature (Tomai et al., 2024; Ozusaglam et al., 2018; Melander, 2018).

In the Indonesian context, the alliance among PLN, EV manufacturers, and infrastructure developers not only promotes technological experimentation but also strategically lobbies policymakers to implement regulatory reforms, provide incentives, allocate limited subsidies, and attract infrastructure investment. Moreover, this study has identified the development of an EI business model to enhance user adoption through battery swap technology, which helps adapt the local consumer purchasing culture to existing fuel. However, this study is also consistent with recent research identifying key barriers to the diffusion of ethanol, advanced biofuels, and EVs, including a lack of policy clarity, price volatility, limited access to investment capital, and resistance from entrenched interests in the fossil fuel sector. These findings suggest that while niche markets can mobilise agency and knowledge, their ability to scale up significantly depends on whether dominant actors are open to their influence—a tension central to transition studies (Geels, 2024; Köhler et al., 2019).

Chapter 7 emphasises the significance of social legitimacy and consumer acceptance in the adoption of low-carbon technologies. Drawing on the adoption of technology framework (Smith et al., 2010) and recent empirical studies on consumer acceptance of EVs (Pandita et al., 2024; Waluyo et al., 2022; Abbasi et al., 2021), this chapter illustrates that the low adoption of electric vehicles, particularly electric motorcycles, in Indonesia

is influenced by a complex interplay of factors. These factors include regulatory clarity, economic affordability, infrastructure accessibility, and sustainability awareness.

The survey results indicate that while some consumer segments were motivated by long-term operational and maintenance cost savings, widespread adoption was still constrained by high upfront purchase prices, inadequate charging networks, and limited of public awareness of sustainability. This finding echoes patterns documented in other developing countries such as India, China, and Malaysia (Pandita et al., 2024; Zhuge et al., 2021; Abbasi et al., 2021), while also highlighting Indonesia's specific challenges, such as the deeply entrenched political economy of fuel subsidies, which artificially suppresses fossil fuel prices and thus weakens the economic rationale for low-carbon technologies, particularly electric vehicles. Furthermore, by examining life cycle sustainability concerns—including optimising the use of renewable energy sources and managing retired EV batteries—this analysis contributes to the ongoing international debate regarding circular economy approaches in electrification within the transportation sector (Verma et al., 2021; Altuntas Vural et al., 2025; Rufino Júnior et al., 2023; Kampker et al., 2023).

The empirical chapters in this study have revealed that the diffusion of EI in the Indonesian transportation sector is simultaneously an institutional, political, economic, and cultural process. Institutional analysis clarifies the structural conditions that make EI viable; power relations analysis explains whose interests shape the trajectory of EI; EI diffusion analysis explains how market niches build collaborative networks by optimising knowledge spillovers and resources to overcome barriers to EI diffusion; and consumer analysis indicates how social legitimacy, end-user preferences, and social adoption of low-carbon technologies in the transportation sector in Indonesia, as a developing country, influence the socio-technical transition toward sustainability. Therefore, this multidimensional explanation underscores that the diffusion of EI is not solely a technological process or an initiative driven solely by regulation. However, this study underscores the inherently socio-technical nature of this transition, where institutions, actors, and practices are closely interconnected.

This cumulative perspective enhances this study's contribution to the global literature on sustainability transition. The case of the Indonesian transportation sector illustrates that different factors often drive socio-technical transitions in emerging economies than those in developed countries. While examples from the US and the EU emphasise climate action agendas, institutional coherence, and technological frontrunners (Geels et al., 2020; Kern and Rogge, 2016), socio-technical transitions in Indonesia are characterised by development imperatives, a focus on addressing the energy trilemma, and

contestation between global and domestic interests (Wibisono et al., 2023; Setyowati, 2020; Gunningham, 2013). These findings contribute to the growing body of knowledge advocating for the decolonisation and contextualisation of socio-technical transition studies, recognising the diverse socio-political realities present in emerging economies (Xu, S., 2021; Arora, S. and Stirling, 2023). By analysing the diffusion of EI in Indonesia, this study enhances the understanding of how the transition to sustainable transportation occurs amidst institutional complexity, political contestation, and social diversity.

8.3 Discussion

8.3.1 Integration of MLP and Historical Institutionalism

Integrating MLP and HI provides an analytical framework for a deeper understanding of how EI diffusion occurs in the Indonesian transportation sector. The MLP framework emphasises the interaction between niches, regimes, and landscape pressures, highlighting how socio-technical transitions are driven by cross-level tensions (Cameron and Geels, 2019; Geels, 2019). HI, on the other hand, emphasises how institutional arrangements evolve through processes of path dependence, critical junctures, and incremental change (Lockwood et al., 2017; Pierson, 2000a; Thelen and Conran, 2016). This study has shown that technological learning at the niche level or by landscape dynamics cannot solely explain the diffusion of EI in Indonesia. Instead, it is significantly influenced by institutional legacies and the timing of political and economic changes (Geels et al., 2020; Cameron and Geels, 2019; Lockwood et al., 2017).

The emergence of the TransJakarta BRT system, which has continued to evolve within the TOD framework, highlights how critical junctures—such as the current account deficit, soaring fuel subsidies, and urban congestion triggered by reliance on private vehicles—create windows of opportunity for regime adaptation (Nikitas and Karlsson, 2015; Hasibuan and Mulyani, 2022). Similarly, the diffusion of palm oil biodiesel illustrates the concept of path dependence. By aligning its transportation energy policy with its comparative advantage in palm oil production, the government mitigated social unrest stemming from global trade disputes. This alignment led to the development of subsequent policy frameworks that reinforced reliance on palm oil, specifically prioritising FAME-based biodiesel over other alternative fuels such as ethanol or second-generation biofuels (Choiruzzad et al., 2021; Astari et al., 2025; Pye, 2019). Despite increased awareness of environmental quality threats and concerns about the injustices caused by the rapid expansion of palm oil cultivation, this trajectory continued within institutions (Choiruzzad, 2019; Ichsan et al., 2025).

Meanwhile, the ongoing diffusion of electric vehicles has reflected hybrid dynamics. While external pressures from global climate commitments, global EV trends, and multinational EV manufacturers have encouraged the diffusion of EI niches. However, the lack of supporting institutional reforms has slowed the pace of socio-technical transition, particularly before 2019. The findings of this study align with broader comparative insights that socio-technical transitions in developing countries are not purely path-dependent or completely disruptive. Instead, these transitions evolve through negotiated interactions between institutional inertia and landscape-induced change (Hakam and Jumayla, 2024; Sembiring, 2025).

The synthesis of the MLP and HI combination thus highlights the significance of temporality and sequence in the diffusion of EI. Socio-technical transitions do not result solely from isolated technological breakthroughs; instead, they emerge through historically rooted institutional choices that influence which innovations gain traction. These findings contribute to the study of socio-technical transitions by expanding the application of MLP beyond its Eurocentric origins, demonstrating its relevance when integrated with institutional approaches in contexts where colonial legacies, resource dependence, and development-oriented states shape sustainability pathways (Arora, S. and Stirling, 2023; Fernandes de Freitas and Jehling, 2023; Eitan and Hekkert, 2023; Nikas et al., 2022). For Indonesia, this implies that the trajectory of EI has reflected a layered interaction between domestic institutional structures and exogenous global pressures, resulting in a transition that is both resilient and sensitive to disruption.

8.3.2 Power Dynamics and Actor Contestation

Although MLP and HI provide valuable structural insights, further investigation is needed to examine the role of agencies, power relations, and contestation in shaping EI trajectories. The findings from this study, particularly those presented in Chapter 5, highlight that power relations significantly influence why certain EI pathways, such as biodiesel, are prioritised over others. Moreover, these power dynamics help frame sustainability discourses that legitimise elite interests. Drawing on the concepts of Allen (2011b) and Foucault (1980), it is clear that power is not merely possessed by certain actors; rather, it is exercised relationally through networks, discourse, and disciplinary mechanisms that define the limits of possible action. In Indonesia, structural power is predominantly exerted by state-owned enterprises such as Pertamina and large palm oil corporations. Their control over distribution networks and financial resources allows them to exert significant influence over the country's biofuel trajectory. At the same time, discursive power was mobilised by government agencies that framed biodiesel as a national energy sovereignty project, aligning it with nationalist narratives and

marginalising other narratives, particularly those concerning environmental degradation and social injustice (Choiruzzad, 2019; Ichsan et al., 2025; Pye, 2019).

The contestation between global and local actors is increasingly revealing how the diffusion of EI is embedded in cross-border power relations. Multinational automakers have been promoting electrification strategies aligned with their global supply chains, often sidelining local manufacturers, particularly small- and medium-sized startups, that do not yet possess comparable technological capabilities. International certification regimes and green finance mechanisms impose benchmarks that, while aiming to ensure sustainability, can marginalise smallholder farmers and local innovators who are unable to comply (de Vos et al., 2023; Hasan et al., 2022; Choiruzzad et al., 2021; Astari and Lovett, 2019). This uneven power geometry reflects what Newell (2021) calls the politics of transition, where the governance of EI diffusion becomes a contested terrain over who is served and whose narratives are excluded. In practice, this results in an uneven power distribution: biodiesel pathways receive strong institutional support because they align with the interests of the state and large corporations. At the same time, EV diffusion remains fragmented and reliant on foreign investment and technology transfer.

At the same time, a countervailing power emerged through the resistance and advocacy of civil society organisations, local innovators, and consumer groups. These actors have sought to challenge the dominant discourse by highlighting the environmental costs of palm oil expansion (Astari et al., 2025; Suhara et al., 2024; Farobie and Hartulistiyoso, 2022), advocating for wider EV affordability (Shamsuddoha and Nasir, 2025; Hakam and Jumayla, 2024; Afraah et al., 2021), and urging more inclusive policy design (Djarmika et al., 2024; Pye, 2019). However, their influence remains constrained by resource asymmetry and institutional access. These findings align with the socio-technical transition literature that transitions are not only technical or economic, but also highly political, with dominant and marginalised actors shaped by uneven power distribution (Ichsan et al., 2025; Astari et al., 2025; de Vos et al., 2023). For Indonesia, this shows that sustainable transportation policies cannot be understood without examining how elite alliances consolidate power and how marginalised groups struggle to resist the dominant trajectory.

8.3.3 Diffusion of Eco-Innovation in Indonesian Transportation Sector

This study phase has adopted the theory of diffusion of innovation (Douthwaite et al., 2001; Glover et al., 2019), EI management (Paipa-Sanabria et al., 2025; Mavi et al., 2019; Beltrán-Estevé and Picazo-Tadeo, 2015), and socio-technical transition studies applied in the context of developing country economies (Djarmika et al., 2024; Kirshner et al., 2022). Empirical analysis conducted has shown that the diffusion of EI in

Indonesia's transportation sector is both facilitated and constrained by the quality of multilevel interactions among the various actors involved. On the one hand, the collaborative network involving state agencies, research institutions, automotive manufacturers, green suppliers, infrastructure enablers, NGOs, and international donors has optimised the absorption of knowledge spillovers and the advancement of technological capabilities (Wang et al., 2023; Melander, 2018; Hojnik, 2017).

In the case of local electric motorcycle development, collaborations among local startups, energy companies, green suppliers from both domestic and international markets, and government pilot programs have facilitated development. These actors' interactions align with Glover et al. (2019) and Geels and Turnheim (2022), who noted that diffusion pathways often rely on how niche actors forming cross-sector alliances to secure regulatory support and resources (Geels and Turnheim, 2022; Glover et al., 2019). On the other hand, the diffusion of EI continues to face significant barriers. The high initial purchasing costs of EVs, a fragmented regulatory framework, weak institutional capacity to enforce emission standards, and a lack of coordinated infrastructure investment have all contributed to the slow adoption of low-carbon technologies. Indonesia's situation illustrates the challenges of aligning environmental externalities with fiscal policies. While biofuels have gained political support through mandates and established subsidy schemes, concerns such as indirect land use change, deforestation, and the marginalisation of smallholder farmers and rural communities remain inadequately addressed (Astari and Lovett, 2019; Ichsan et al., 2025; Djatmika et al., 2024). Likewise, although the electric vehicle roadmap sets ambitious targets, it suffers from insufficient financial support and a lack of investment in charging infrastructure, which is slowing widespread adoption (Shamsuddoha and Nasir, 2025; Zarazua de Rubens et al., 2020).

One important finding is that barriers to technology adoption are not static; rather, they are dynamic outcomes of political and institutional interactions. For instance, financial barriers to electric vehicle adoption are worsened by a lack of long-term policy certainty, which delays private-sector investment in charging point and battery swap station infrastructure. Similarly, social barriers—such as consumer perceptions that EVs are expensive, take a long time to charge, or are harder to find charging stations for than conventional vehicles—have been influenced by marketing strategies and practices. This observation aligns with the concept advanced by Douthwaite et al. (2001), who stated that promising technologies often fail not because of their inherent limitations, but because of insufficient end-user involvement in the technology-adoption process.

From a comparative perspective, Indonesia's transportation sector offers valuable insights into how EI diffuses in developing countries, underscoring the need for a broader

conceptualisation of optimising drivers and overcoming barriers. Unlike developed countries, which typically prioritise technological readiness and environmental awareness, Indonesia's approach to tackling the energy trilemma focuses primarily on economic resilience, energy sovereignty, and job creation as the main drivers. In contrast, significant obstacles such as weak governance, profit-seeking practices, and inconsistent policies play a greater role compared to the context of developed countries. These findings indicate that the theory of EI diffusion needs to be adapted to account for the unique social, economic, and political context in various developing countries (Sovacool et al., 2022; Lee et al., 2020).

8.3.4 Regime–Niche Interactions in EV Adoption

Based on the concept of MLP (Geels, 2002; Schot and Geels, 2008; Smith and Raven, 2012) and the literature on consumer acceptance of EVs (Abbasi et al., 2021; Pandita et al., 2024), this study phase has explored the institutional and social dimensions of EV adoption emerging as a low-carbon mobility technology in Indonesia. Empirical findings indicate that the adoption of electric vehicles is influenced not only by technological readiness but also by the interaction between the regime and the niche, which affects consumer acceptance, affordability relative to public purchasing power, and the development of adequate infrastructure. On the regime's side, entrenched dependence has created a path dependency on fossil fuel-powered private vehicles, particularly motorcycles. Subsidies, industrial policies, and cultural preferences further reinforce this reliance on fossil fuels. Conversely, on the niche side, EVs, especially EMCs, are gaining popularity due to various incentive schemes, including limited subsidies and the entry of both domestic and foreign manufacturers into the market.

Survey data from Jakarta and Bandung indicate that consumer perceptions significantly influence the adoption trajectory of EMCs. Respondents in both cities appreciated the savings in operational and maintenance costs associated with EMCs. However, they expressed concerns about the high upfront purchase price, limited charging availability, and a general lack of awareness regarding sustainability. These concerns align with findings from other developing countries, where issues of affordability and infrastructure accessibility are significant barriers to expanding EV adoption (Abdul Qadir et al., 2024; Pandita et al., 2024; Abbasi et al., 2021). A key finding is that the differences between Jakarta and Bandung reveal how geography and demographics shape adoption patterns. In Jakarta, factors such as higher education levels, higher monthly household incomes, denser street networks, and the enforcement of odd-even traffic regulations contribute to greater public exposure to EMC adoption. In contrast, Bandung faces challenges such as topographical variations, cultural preferences regarding mobility, and

less stringent enforcement of emission regulations, all of which are less conducive to EV adoption. Lower exposure to the emergence of EVs has resulted in limited concerns among Bandung residents about the benefits and role of EVs as one of the pathways towards sustainability.

At the institutional level, interactions between regimes and niches manifest in ways that both facilitate and hinder the adoption of EVs. For instance, policies aimed at replacing government service vehicles and TransJakarta buses with EVs (Difa and Sulistiyandari, 2021), along with partnerships between the ride-hailing and logistics sectors and automotive manufacturers for electric mobility fleet trials, demonstrate how niche innovations can collaborate with established regime actors to promote low-carbon mobility technologies (Nikitas and Karlsson, 2015; Prestes et al., 2022). However, these partnerships may also reinforce the dominance of large corporations, potentially excluding small-scale operators and underinvesting in charging infrastructure in rural areas, thus raising concerns about inclusivity (Sovacool et al., 2022; Newell and Bray, 2025). Additionally, lifecycle sustainability analysis highlights gaps in policy planning. While EVs help reduce local emissions, insufficient attention often given to the reliance on coal as a primary fuel for electricity generation. Moreover, there is potential for developing second-life applications for used batteries and creating recycling infrastructure, which raises the risk of merely shifting environmental burdens instead of effectively addressing them (Altuntas Vural et al., 2025; Rufino Júnior et al., 2023; Kampker et al., 2023; Safarzadeh and Di Maria, 2025).

8.3.5 Comparative Insights with Other Emerging Economies

The four empirical chapters demonstrate the close interconnection of EI diffusion within the Indonesian transportation sector. This analysis reveals that institutional dynamics, power relations, stakeholder interactions, and regime-niche linkages are not isolated processes. Instead, they are overlapping dimensions that collectively influence the trajectory of socio-technical transitions towards sustainability.

At the institutional level, the critical junctures discussed in Chapter 4 highlight how pressures in the macro landscape—such as rising oil prices, global climate change commitments, and trade disputes—have created opportunities for transformation. However, whether these critical junctures result in significant change depends on how power dynamics are contested and reshaped, as explained in Chapter 5. Power asymmetry influences which EI pathways are prioritised, often with state-owned enterprises and elite alliances steering policies toward incremental adjustments rather

than radical restructuring. These findings support the argument made by Meadowcroft (2011) and Newell (2021) that sustainability transitions are fundamentally political projects, shaped by discussions about existing power structures and control.

Chapters 6 and 7 extend this analysis by representing how the interactions among multilevel actors and consumer practices influence the diffusion of EIs. Collaborative networks between niche innovators, government institutions, research institutions, and international partners create pathways to optimise knowledge spillovers and advocate for policies that address barriers to technological and infrastructure investments. However, this collaboration is often uneven, favouring large corporate actors while sidelining local SME innovators, smallholder farmers, rural communities, and low-to middle-income urban consumers. Furthermore, consumer surveys indicate that adoption of low-carbon technologies relies not only on structural incentives but also on consumers' cultural experiences regarding affordability, ease of access to infrastructure, and trust in new technologies. These insights have strengthened the push within sustainability transition studies to incorporate sociocultural perspectives into analyses that have traditionally focused on structural and technological changes (Geels, 2024; Schot and Steinmueller, 2018; Hansmeier et al., 2021).

This synthesis also highlights that the Indonesian case illustrates a hybrid form of transition, where the diffusion of EI simultaneously strengthens and destabilises the existing regime. For instance, the mandatory biodiesel use policy has supported the domestic palm oil industry, reinforced a resource-dependent political economy, while also contributed to incremental decarbonisation (Ichsan et al., 2025; Choiruzzad, 2019). Similarly, the electric motorcycle pilot project aligns with BRT TransJakarta operator, ride-hailing providers, and logistics companies, strengthening platform capitalism, but also presents disruptive potential by changing consumer perceptions of mobility (Difa and Sulistiyandari, 2021; BCG and AEML, 2022; Deloitte and Foundry, 2023). These hybrid dynamics suggest that socio-technical transitions in emerging economies often develop through the layering of EIs onto existing regimes, rather than through abrupt shifts (Sembiring, 2025; Astari et al., 2025). This analysis aligns with comparative studies of socio-technical transitions in other resource-dependent contexts such as Brazil, Argentina, and India (Mosquera et al., 2024; Kirshner et al., 2022; Nikas et al., 2022; Dutt, 2023).

8.4 The Answers to the Research Questions

8.4.1 The Empirical Sub-Questions

Sub-question 1: How have multi-level interactions influenced critical junctures in the institutional dynamics of socio-technical transitions toward sustainability in the Indonesian transport sector?

Analysis of this research revealed that multi-level interactions—between global landscape pressures, national regimes, and local niches—have significantly shaped the timing and nature of critical junctures in the socio-technical transition towards sustainable transportation in Indonesia. At the landscape level, commitments to the global climate agenda, fluctuating oil prices, and trade disputes have created unstable pressure on the entrenched fossil fuel regime. These pressures have opened a window of opportunity for EIs developed abroad that have diffused to micro-niche levels, particularly in the form of mandates for the use of palm oil-based biofuels (B20, gradually increased to B40), TOD-based public transportation systems, and policies aimed at accelerating the introduction of EVs. However, the regime's response is influenced by a longstanding institutional legacy that relies on fuel subsidies and was dominated by large oil corporations and multinational automotive manufacturers. HI helps explain these patterns, as critical junctures often occur when external shocks intersect with domestic institutional weaknesses, prompting policy reforms (North, 1990; Pierson, 2004; Cameron and Geels, 2019). Nevertheless, these reforms often reinforce rather than dismantle pre-existing trajectories, exposing deeply entrenched path dependencies.

The implementation of a biodiesel mandate in Indonesia has been influenced by international climate discussions, domestic energy security concerns, and social unrest stemming from trade disputes. However, it remains closely linked to the country's historical reliance on palm oil as the backbone of the biofuel industry. This trajectory mirrors Brazil's ethanol program, where the global oil crisis intersects with domestic agricultural capabilities to establish a biofuel framework, ultimately leading to a state of dependence as the country transitions toward sustainability (Sembiring, 2025; Astari et al., 2025; Mosquera et al., 2024). This situation demonstrates that critical moments in the economy do not emerge as clear-cut critical junctures; instead, they often reinforce existing institutional arrangements, even as they open the windows of opportunity for the diffusion of EI. Therefore, the multi-level interactions formed by exogenous shocks and endogenous legacies have become central to Indonesia's transportation sustainability trajectory (Geels, 2024; Sembiring, 2025; Lockwood et al., 2017).

Sub-question 2: How does the power contestation between global and local actors influence the development of sustainable transport policies in Indonesia?

The power relation between global and domestic actors plays a crucial role in shaping the outcomes of EI policies. Global actors—including multinational corporations, development banks, and international donors—have introduced the discourse of decarbonisation and funded pilot projects in transportation sectors, including public transportation, biofuels, and electric vehicles. However, this global pressure is mediated by domestic elite agencies that align international narratives with local priorities, which include energy security, resource nationalism, and industrial advancement. In practice, this selective adaptation often further reinforces the dominance of state-owned enterprises such as Pertamina and PLN, strengthening their positions as key gatekeepers in the transition pathway of the transportation sector.

The Indonesian case, as observed by Newell (2008) and Newell and Bray (2025), shows that structural and instrumental power often align to ensure that socio-technical transitions favour dominant coalitions. Foucault (1980) concept of discursive power and disciplinary mechanisms further explains how the global narrative of sustainability has been reinterpreted domestically to legitimise specific policy choices, particularly the continued reliance on palm oil-based biofuels, despite alternative narratives that highlight environmental degradation and social conflicts arising from the expansion of plantation lands. As a result, a hybrid governance landscape emerges, in which the discourse of sustainability coexists with entrenched interests. Similar power dynamics have been observed in Brazil, where global climate commitment initiatives are influenced by domestic power structures, resulting in uneven and contested outcomes in second-generation ethanol-based biofuels (Kirshner et al., 2022; Nikas et al., 2022). In Indonesia, civil society organisations and marginalised stakeholders often lack institutional access and influence to shape policy actively. This asymmetric power leads to outcomes that prioritise dominant actors while sidelining alternative narratives of sustainable mobility.

Sub-question 3: How can multilevel interactions between stakeholders enhance drivers and address key barriers in the diffusion of eco-innovation within the transportation sector of emerging economies?

The findings of this study indicate that a collaborative network of cross-scale actors, referred to as an innovation coalition, plays a crucial role in overcoming barriers and enhancing the drivers of EI diffusion. Key niche actors, including startups, state-owned

energy companies, research institutions, green suppliers, government agencies, and non-governmental organisations, have mobilised resources and knowledge to promote EI, particularly in biofuels and electric vehicles. This collaborative network fosters knowledge spillover, builds legitimacy, and advocates for regulatory support for innovation, even in the face of fragmented or resistant central institutions. For instance, the partnership between local governments, especially in the Jakarta metropolitan area, and electric vehicle manufacturers has facilitated the launch of TransJakarta electric buses and the expansion of charging infrastructure in urban centres. Additionally, this partnership continues to thrive through the implementation of local policies that exempt electric vehicle users from odd-even driving restrictions. Meanwhile, the alliance between palm oil producers, government agencies, and Pertamina has strengthened the biofuel supply chain. The biodiesel mandate policy has positively impacted some small farmers and generated job opportunities for local residents. However, this study has revealed a lack of inclusiveness in social equity, highlighting a significant welfare gap between large corporations and the majority of rural communities in the narrative of rural development.

The collaborative network involving infrastructure enablers, EV manufacturers, and PLN in developing the EI battery swapping system business model has bridged local culture in fuel purchasing, demonstrating the adaptation of local culture to the diffusion of similar innovations in Taiwan and China. The dynamics of this collaborative network align with the existing literature on EI and user adaptation, which highlights the significance of collective action in the diffusion of EI (Paipa-Sanabria et al., 2025; Tomai et al., 2024; Hojnik, 2017). Similarly, in Indonesia, innovation coalitions play a crucial role in mitigating for the weaknesses of strong top-down governance, though their effectiveness is often constrained by resource constraints and regulatory uncertainty. Nonetheless, these findings indicate that multi-level interactions can significantly enhance the drivers of, and reduce barriers to, the diffusion of EI, particularly in developing countries that face considerable institutional challenges (Shamsuddoha and Nasir, 2025; Wu, J. et al., 2018).

Sub-question 4: How does the interaction between regimes and niches affect the socio-technical transition process of EV adoption in emerging economies?

The interaction between the regime and market niches is most evident in the adoption of electric vehicles. The diffusion of niche EIs—such as local EMCs, charging stations, and battery-swapping stations—aims to challenge the fossil-fuel-based mobility regime. However, the widespread EV adoption depends on factors at the regime level, including

subsidy policies, industrial strategies, and infrastructure development. In Indonesia, the existing regime plays an ambivalent role. On the one hand, they introduce supportive regulations, such as tax exemptions on the import of EV and limited subsidies for electric vehicles. On the other hand, they hinder broader adoption by prioritising their own industrial interests, such as maintaining fossil fuel subsidies, prioritising biodiesel, and protecting multinational automotive manufacturers.

This dual role illustrates the complex interactions between niches and regimes, as observed in transition studies (Geels, 2024; Geels, 2002; Smith and Raven, 2012). Niche technologies often rely on support from existing regimes to enhance their adoption, while regimes may adopt niche technologies to strengthen their own stability. For instance, government support for EVs was part of an industrial strategy to utilise excess electricity generated by coal-fired power plants (Apriliyanti et al., 2024; Hamdi and Adhiguna, 2021). This strategy helps build a narrative around decarbonisation and reducing dependence on imported fuels (Gulagi et al., 2025; Gunningham, 2013; IEA, 2023a). Focusing on capturing this upstream value sometimes obscures consumer affordability and the need for infrastructure deployment, limiting the inclusivity of the electrification transition. A comparison with India reveals similar challenges, where the adoption of electric vehicles is constrained by affordability and infrastructure challenges, despite ambitious national targets (Pandita et al., 2024; Singh, V. et al., 2021). This finding shows that in developing countries, niche-regime interactions are not a linear substitution process. Instead, these interactions are complex negotiations that often result in hybrid outcomes—where EI diffuses, but on terms that reinforce incumbent power structures.

8.4.2 The Overarching Question

The overarching research question—*How does the diffusion of eco-innovation influence socio-technical transitions toward sustainability in the Indonesian transport sector?*

By synthesising the findings from the sub-questions, this dissertation argues that the diffusion of EI in Indonesia is a contested, path-dependent process driven by coalitions that simultaneously enable and hinder the socio-technical transition towards sustainability in the Indonesian transportation sector. The diffusion of EI in the form of mass public transport, biofuels, and EVs has undeniably opened new pathways for transport decarbonisation. However, historical institutional legacies, power asymmetries, and social acceptance heavily influence its diffusion. Rather than merely being a technological substitution, the diffusion of EI in Indonesia is embedded in a complex

interplay between global pressures, domestic political dynamics, and local practices (Astari et al., 2025; Djatmika et al., 2024; Sadiq et al., 2023).

On the one hand, the diffusion of EI has challenged several entrenched aspects of the fossil fuel regime, introducing new actors into the policy-making process and generating iterative learning effects that contribute to sustainability. For instance, the implementation of mandatory biodiesel policies has shown that the diffusion of EI can alter the national energy portfolio while also creating new economic opportunities (Farobie and Hartulistiyoso, 2022; Astari et al., 2025). Similarly, the policy to accelerate the introduction of EVs, along with the growing consumer interest in adopting EVs—particularly EMCs—highlighted the potential for expanding market niches, mainly if supported by a robust innovation coalition (Tomai et al., 2024; Abdul Qadir et al., 2024; Thananusak et al., 2020).

On the other hand, the diffusion of EI has also widened existing inequalities and reinforced path dependencies. Policies promoting biofuels have strengthened dependence on palm oil, raising concerns about environmental degradation related to deforestation and indirect land-use change (Ichsan et al., 2025; Astari et al., 2025; Choiruzzad, 2019). Likewise, the growing adoption of EVs and the centralisation of supporting infrastructure development tend to benefit affluent urban consumers, exacerbating socio-economic disparities, particularly for rural communities (Shamsuddoha and Nasir, 2025; Sovacool et al., 2022). The asymmetry of power has ensured that the dominant coalition reaps most of the benefits, while marginalised groups and alternative civil society narratives remain overlooked. As a result, the diffusion of EI has not automatically led to a just or inclusive transition.

The broader implication is that EI serves as both an enabler and a mirror of existing regime structure. The diffusion of EI has enabled new socio-technical opportunities while also reflecting the institutional and political structures in which it is embedded. For Indonesia and other developing countries, this means that the diffusion of EI alone cannot ensure sustainability. Without deliberate efforts to reform institutions, democratise decision-making, and ensure equal access to resources and benefits, EI risks perpetuating unsustainable practices, merely under a different appearance. In this regard, the Indonesian case contributes to the global debate on sustainable mobility by demonstrating that socio-technical transitions are not a universal path, but rather a highly contextual process. This framework indicates that studies on the diffusion of EI must give equal attention to technological capabilities, institutional legacies, power dynamics, and social acceptance (Pineda et al., 2023; Billanes and Enevoldsen, 2021). The broader relevance of these findings is evident: for a socio-technical transition to be genuinely

sustainable, the diffusion of EI must be integrated in governance structures that are not only technologically effective but also socially inclusive and politically accountable.

8.5 Theoretical Contributions

The findings of this dissertation provide a series of theoretical contributions to the literature on socio-technical transitions towards sustainability and the diffusion of EI. Although this study focuses on the Indonesian transportation sector, its conceptual insights extend to broader debates about how socio-technical transitions occur in developing countries characterised by institutional fragility, uneven development, and contested governance. By systematically integrating the Multi-Level Perspective (MLP), HI, and power theories with the literature on the diffusion of EI and social acceptance of technology, this research offers a more nuanced and diverse understanding of the transition process.

8.5.1 Extending the Multi-Level Perspective (MLP) in Emerging Economies

This study extends the MLP theory in two keyways. First, this study highlights that multi-level interactions in developing countries often produce hybrid outcomes, rather than the linear substitution processes commonly emphasised in cases from the Global North. For example, Indonesia's biodiesel program demonstrates how niche-level EI diffusion can be scaled up. However, it does so in a way that reinforces the established palm oil-based regime instead of replacing it. These findings challenge the Eurocentric assumption that regime destabilisation naturally leads to sustainable alternatives (Arora, S. and Stirling, 2023; Fernandes de Freitas and Jehling, 2023; Eitan and Hekkert, 2023; Smith and Raven, 2012). Second, the Indonesian case emphasises the impact of fragmented governance and uneven institutional capacity on the timing and effectiveness of transition pathways. While MLP has been widely praised for its ability to capture interactions among landscapes, regimes, and niche levels (Geels, 2024; Geels, 2002; Geels and Schot, 2007), its application in Global South countries requires a closer examination of institutional volatility, informal networks, and regional disparities. This finding aligns with calls for the Southernization of transition studies by moving beyond the assumption of stable institutions and instead addressing the complex realities of emerging economies (Fernandes de Freitas and Jehling, 2023; Schot and Steinmueller, 2018; Segers, 2016).

8.5.2 Contribution to Historical Institutionalism (HI)

This dissertation also advances HI by demonstrating that critical junctures in developing countries often reproduce path dependence rather than initiate radical change. For instance, the policy mandating the use of biodiesel, which requires a gradual increase from B20 to B40, was adopted during a period of global oil price volatility and a commitment to the climate agenda (Farobie and Hartulistiyoso, 2022; MEMR, 2025a). However, this policy was significantly shaped by long-standing institutional relationships among energy policies, oil companies, large palm oil corporations, and rural development. Instead of eliminating fossil fuel subsidies, the reforms were layered on top of existing structures, resulting in a hybrid institution that combines elements of change and continuity. This framework supports Lockwood et al. (2017) statement that HI can be effectively applied to sustainability transitions, but also goes further by showing that in developing countries, institutional change tends to be incremental and highly path-dependent, constrained by development priorities and the bargaining power of elites. Thus, this study contributes to the expansion of HI by showing that critical junctures in developing countries often lead to limited diffusion of EI—policies that create market niches while still maintaining the underlying logic of the existing regime.

8.5.3 Foregrounding Power Relations in Transition Studies

The main theoretical contribution of this research is the integration of power relations as a fundamental element in socio-technical transitions. Although MLP and HI recognise the existence of actors, there is a need for a more in-depth examination of how power explicitly shapes outcomes. By referring to Allen (2011b) spatial conceptualisation, Foucault (1980) ideas about discursive and disciplinary power, and Newell (2008) analysis of structural and instrumental power, this study demonstrates that the diffusion of EI in Indonesia has been intensely mediated by cross-border contestation between global and local actors. The ability of domestic elites to selectively appropriate the global sustainability narrative demonstrates that power not only shapes the distribution of material benefits but also influences the framing of sustainable discourses. This contribution aligns with recent literature that critiques the apolitical tendencies in transition theory (Köhler et al., 2019; Sovacool et al., 2022) and emphasises the importance of power in the analysis of low-carbon transitions.

8.5.4 Contribution to the Diffusion of Eco-innovation

This dissertation contributes to the literature on EI by reframing the concept of diffusion as a coalition-driven, politically contested process rather than a linear spread of technology through market mechanisms. The case of Indonesia's transportation sector

has revealed that networks of interaction among various actors, along with institutional negotiations, have shaped the diffusion of EI. Niche actors—such as research institutions, startups, energy companies, automotive manufacturers, and government agencies—play a crucial role in building legitimacy, mobilising resources, and advocating for policy change. These findings align with the work of Hojnik (2017), Glover et al. (2019), and Douthwaite et al. (2001) regarding the diffusion of EI and user adoption; however, this study extends their research by illustrating how diffusion in developing economies relies on multi-level coalitions that address fragmented governance. Therefore, this study bridges EI research with socio-technical transition theory, demonstrating that the diffusion of EI is not merely a function of firm-level initiatives; rather, it is a systemic phenomenon embedded in a socio-technical context characterised by power relations.

8.5.5 Contribution to Social Acceptance of Technology

Finally, this research contributes to the discussion on social acceptance by emphasising the importance of equity in technology adoption in developing countries. Although Egbue and Long (2012) and Billanes and Enevoldsen (2021) focused on consumer perceptions, beliefs, and attitudes, this study demonstrates that in Indonesia, adoption is significantly affected by affordability gaps, limited infrastructure investment, and socioeconomic inequality. Survey findings in Jakarta and Bandung indicate that while EVs are viewed as a desirable low-carbon technology, many consumers face challenges, including regulatory uncertainty, high initial purchase costs, and a limited and uneven charging network, especially outside major urban areas. These findings highlight that the social acceptance of environmentally friendly technologies in developing countries should be considered not only through the lens of culture or attitudes, but also in terms of distributive justice and structural inequality (Singh, J. and Clough, 2024; Arora, S. and Stirling, 2023). Consequently, this dissertation expands reception theory to better explain the differing adoption patterns among socioeconomic groups in developing countries.

8.5.6 Synthesis: Toward a Multi-theoretical Approach

By integrating the literature on MLP, HI, power, EI diffusion, and social acceptance, this dissertation develops a more holistic and context-sensitive theoretical framework for understanding sustainability transitions. This dissertation argues that socio-technical transitions in developing countries are best understood as contested, path-dependent processes shaped by coalitions operating within uneven institutional and socio-economic landscapes. The case of Indonesia provides a foundation for expanding existing theories and developing a more suitable conceptual framework to capture the complexities of low-

carbon transitions outside the Global North (Fernandes de Freitas and Jehling, 2023; Schot and Steinmueller, 2018).

8.6 Policy Implications

The empirical and theoretical insights from this study have important implications for policy design and governance in Indonesia and other developing countries seeking to accelerate the socio-technical transition of the transportation sector towards sustainability. The findings reveal that the diffusion of EI in Indonesia is not only driven by technological advancement but also significantly influenced by institutional legacies, power asymmetries, and social acceptance patterns (Astari et al., 2025; Ichsan et al., 2025; Choiruzzad, 2019; Shamsuddoha and Nasir, 2025). Translating these insights into actionable policies requires a multi-level, multi-actor approach that aligns industrial development goals with sustainability objectives. The policy implications outlined here are intended not only for policymakers and SOEs in Indonesia, but also for private-sector actors, civil society organisations, and international stakeholders. Furthermore, these insights are relevant to other developing countries facing a similar energy trilemma involving energy security, growth equity, and decarbonisation.

One of the most pressing implications is the need to address the institutional legacy that perpetuates path dependency. Indonesia's ongoing reliance on fossil fuel subsidies primarily benefits private vehicle users. This dependence has also undermined EI's competitiveness, particularly in low-carbon mass public transport options such as electrification and second-generation biofuels. Policymakers should prioritise phased subsidy reform, reallocating fiscal resources towards targeted incentives for low-carbon mobility. These fiscal resource reallocations can include the development of TOD infrastructure based on BRT, commuter rail, LRT, and MRT systems. Additionally, fossil fuel subsidies could be redirected to support entry-level EMC subsidies, provide tax breaks for EV imports, and fund grants for the development of charging points and BSS infrastructure, especially in rural areas. These policies have the potential to address investment needs for essential infrastructure development, including mass public transport, EV charging stations, and BSS, as well as for the construction of second-generation biofuel processing plants. Moreover, reallocating fossil fuel subsidies can expand support for rural communities, urban middle- and lower-income consumers, and MSMEs. Lessons from developing countries such as India and Brazil indicate that while subsidy reform can be politically controversial, it can also be effectively combined with compensatory measures for vulnerable groups. This approach helps minimise social

backlash and promotes the diffusion of EI (Kirshner et al., 2022; Singh, V. et al., 2021; Johnson and Silveira, 2014).

It is equally important to ensure regulatory coherence across different ministries and levels of government. The fragmentation between MEMR, MoI, MoT, MSOE, and local governments often result in contradictory or overlapping regulations. This confusion can deter investors and impede the growth of niche markets. Enhancing the function of the national coordination body for sustainable transportation—tasked with integrating energy, industry, and transportation policies—will improve incentive allocation and ensure that EI initiatives are incorporated within a unified regulatory framework. This regulatory coherence highlights lessons learned from China's EV strategy. In China, centralised coordination between the industry and energy ministries has enabled rapid production and the scaling of infrastructure (Wu, Z. et al., 2021; Wu, J. et al., 2018). However, in a democratic country like Indonesia, achieving similar coordination would necessitate more inclusive mechanisms to prevent the risks of authoritarianism.

SOEs, particularly Pertamina and PLN, play a crucial role in Indonesia's transportation transition. To ensure that these enterprises effectively drive the transition, it is essential to provide them with the right incentives. This initiative will enable them to mobilise capital, infrastructure, and technical expertise on a large scale. If their focus remains solely on short-term profitability and industrial protectionism, it could hinder the diffusion of EI and undermine sustainability efforts. Therefore, prioritising long-term sustainability over immediate financial gains is vital for these SOEs. Policymakers should incorporate sustainability criteria into SOE mandates. This mandate would require Pertamina to adopt biofuel sustainability standards. Similarly, PLN should prioritise the development of electric vehicle charging networks as part of its expansion strategy and increase the proportion of renewable energy sources to reduce reliance on polluting sources, particularly coal. Drawing inspiration from European practices, where utility companies are increasingly aligning their investment strategies with decarbonisation targets (Kern and Rogge, 2016; Alotaiq, 2025), Indonesian SOEs can be guided to balance financial performance with public sustainability goals. International partnerships and green financial instruments can enhance these efforts by providing SOEs with the capital and expertise necessary to accelerate the diffusion of EI.

This finding indicates that the effective diffusion of EI relies on a coalition of niche actors, such as research institutions, startups, green suppliers, local governments, and NGOs. However, in Indonesia, these coalitions often face constraints due to resource shortages and a lack of legitimacy. Therefore, the policy framework should institutionalise support for the grassroots diffusion of EI. The effective diffusion of EI could be achieved through

dedicated funding for pilot projects, the establishment of innovation hubs, and the implementation of demonstration programs at the city level. Brazil's ethanol program showcases the importance of integrating research institutions within industrial clusters to promote sustainable innovation and technology transfer (Nikas et al., 2022; Grandis et al., 2024). Similarly, Indonesia can utilise universities, the National Research and Innovation Agency (BRIN), and local governments as vital components for absorbing green knowledge spillovers and fostering stronger relationships between local initiatives and national policies. Additionally, expanding opportunities for the participation by often marginalised groups—particularly smallholder farmers, rural communities, local MSME startups, and low- to-middle-income urban consumers—in policy advocacy will enhance inclusivity and accountability while reducing the risk of elite capture.

The main barrier to EV adoption in Indonesia is affordability; the upfront purchase price remains high for low- and middle-income consumers. Additionally, EV adoption faces competition from the used ICEV market, which is highly popular among the public. Therefore, policy design must explicitly incorporate equity considerations into support mechanisms. For instance, subsidies and tax incentives could be targeted at entry-level EMCs, which offer a more accessible pathway to mass adoption than the passenger car segment. Additionally, EMCs' grant and soft loan programs could be targeted at logistics and ride-hailing operators. Furthermore, implementing decarbonization zoning policies—especially in urban areas—could help accelerate the adoption of electric vehicles (IEA, 2025; Kester et al., 2018).

Policymakers can enhance both fiscal and non-fiscal policies for hybrid electric vehicles (HEVs) during the socio-technical transition process. Currently, the government has not prioritised convenience for HEVs. However, HEVs, particularly in the passenger car segment, have the potential to address long-distance travel challenges, given the uneven distribution of charging infrastructure outside major urban areas. The Indonesian government can adopt the policy roadmaps of several key regions, such as the US, EU, China, and India, that have supported the widespread adoption of HEVs as a transition path to full battery EVs (Pandita et al., 2024; Shamsuddoha and Nasir, 2025; Yang et al., 2023).

The government must consistently work towards its goal of increasing the share of renewable energy sources in electricity generation. This measure includes phasing out coal-fired power plants to ensure that decarbonisation is not just a sustainability narrative from dominant agencies, but is actively implemented according to the roadmap for achieving net-zero emission (NZE) targets in the transportation sector (Sembiring, 2025; Apriliyanti et al., 2024; Skovgaard and van Asselt, 2019). Equally important is the

development of robust life-cycle policies for retired EV batteries, including standards for reuse, second-life applications, and recycling. Establishing a framework for the industrialisation of retired EV batteries aims to reduce hazardous waste and has the potential to lower the cost of battery replacement (Kampker et al., 2023; Nurdiawati and Agrawal, 2022; Rufino Júnior et al., 2023). The high cost of replacing EV batteries has diminished interest among potential buyers, not just in developing countries but also in some developed nations (Afraah et al., 2021; Neubauer et al., 2012). By promoting the industrialisation of used EV batteries, it aims to instil public confidence that electric vehicles can meet their mobility needs without concerns about a sharp decline in resale value (Karim and Ferdian, 2025). By presenting EV adoption as both an environmental necessity and a pathway to economic inclusion and job creation, policymakers can enhance public support for this socio-technical transition.

Ultimately, the Indonesian case highlights that the diffusion of EI in developing countries brings both opportunities and challenges. The diffusion of EI requires significant changes to institutions, politics, and social structures (Cameron and Geels, 2019; Schot and Steinmueller, 2018). Other developing countries should be prepared for similar dynamics: established interests may resist disruptive changes, existing institutional frameworks may limit policy choices, and social acceptance may vary widely across different socioeconomic groups. Therefore, socio-technical transition policies must be designed to balance developmental goals with the necessity of sustainability. It is essential to avoid the temptation to pursue low-carbon pathways that reproduce existing inequalities. The government and other relevant stakeholders should enhance public awareness campaigns focused on sustainability. It is essential to educate consumers about the benefits of mass public transportation, biofuels, and electric vehicles. Promoting education and awareness of sustainability can encourage greater adoption of these practices and support the building of public trust (Al-Dalain et al., 2025; Tomai et al., 2024; Hakam and Jumayla, 2024). By incorporating inclusivity, equity, and accountability into the governance of these transitions, developing countries can ensure that the diffusion of EIs not only supports in decarbonisation but also contributes to broader sustainable development goals.

8.7 Future Research

The findings of this dissertation provide valuable insights into the dynamics of EI diffusion in the Indonesian transportation sector. However, they also highlight significant gaps and opportunities for further research. The complexity of socio-technical transitions,

especially in developing countries, indicates that no single study can capture the entire spectrum of existing dynamics. Therefore, future research is essential to refine the theoretical framework, broaden the empirical scope, and develop innovative methodologies. This framework will help deepen our understanding and provide more effective guidance for policy and practice.

First, future research on the socio-technical transition of sustainable transportation in Indonesia should focus on the interaction between rapid technological advancements and the necessary institutional and human capacity for effective implementation. While the diffusion of biofuel EIs has progressed relatively smoothly due to their utilisation of existing infrastructure—particularly within the fossil fuel distribution network (Köhler et al., 2014; Geels and Turnheim, 2022)—the adoption of EVs presents different challenges. Despite rapid reductions in battery costs and improvements in performance (Link et al., 2024; Nykvist and Nilsson, 2015), there is a notable lag in charging infrastructure and support systems. This challenge is exacerbated by a shortage of trained technicians and maintenance professionals, particularly when compared to major EV regions (Fechtner et al., 2015; Kosmanis et al., 2023). This discrepancy between the pace of EV diffusion and the preparation of a skilled workforce highlights a critical research gap. Future research should examine the extent to which government initiatives in Indonesia—such as vocational training, certification programs, and university-industry partnerships—are concurrent in their support for the broader adoption of EVs (Fechtner et al., 2015; Kosmanis et al., 2023).

Second, a promising direction for future research is to adopt longitudinal designs and mixed-methods to capture the evolving nature of transitions over time. While this study has utilised a cross-sectional analysis of institutional dynamics, power relations, actor coalitions, the diffusion of EI, and consumer acceptance of technology, future research could benefit from longitudinal case studies and process tracing to examine specific EI pathways over several decades. This approach would provide a broader understanding of how critical junctures, institutional layering, and power dynamics develop over time. Additionally, using quantitative modelling alongside a systems dynamics approach can enhance qualitative findings by simulating policy scenarios for EV adoption, the sustainability of second- and subsequent-generation biofuels, hydrogen fuel cell vehicles, and shifts in public transportation modes. Comparative studies that utilise big data analytics on mobility patterns, energy consumption, and emissions can further strengthen empirical robustness, especially as real-time data becomes more accessible through intelligent mobility initiatives (Ojadi et al., 2024).

One methodological limitation is the increased focus on participatory research and the co-production of knowledge with local stakeholders. In contexts like Indonesia, where marginalised groups are often underrepresented in policy debates and advocacy, participatory action research can serve not only as a data-collection method but also as a means of empowerment. This methodology ensures that future research contributes to more inclusive governance in socio-technical transitions. Such an approach aligns with the growing calls in sustainability science for transdisciplinary research that connects academia, policy, and society (Scoones et al., 2020).

Third, from a theoretical perspective, future research should aim to refine and further integrate existing frameworks. MLP requires ongoing adaptation to effectively address the fragmented governance, informality, and hybrid transition pathways common in developing countries. By incorporating insights from political economy, development studies, and critical social theory, MLP analysis can be enriched and better contextualised within the realities of developing nations. Likewise, HI could benefit from closer alignment with political economy approaches. This integration would allow for an exploration of how elite bargaining, resource nationalism, and the logic of the developmental state influence institutional change. Such an approach would help mitigate HI's tendency to overemphasise stability, thereby providing a clearer understanding of sudden disruptions and hybrid institutional innovations. Moreover, the power-centred framework needs to be expanded to not only investigate the strategies of dominant elites but also to examine the forms of resistance and counter-power mobilised by civil society, social movements, and grassroots innovators. This theoretical perspective would offer a more balanced understanding of contestation during transitions, moving beyond elite-centric viewpoints (Apostolopoulou et al., 2022).

Additionally, there is significant potential to enhance the diffusion of EI theories by incorporating justice, equity, and inclusion as central factors. Much of the existing EI literature views diffusion primarily as a competitiveness issue at the micro-niche level of corporations or focuses on market incentives. However, research from Indonesia has highlighted that political bargaining, institutional legacies, and social equality are equally important considerations. Similarly, theories of social acceptance of low-carbon technologies could be expanded to address structural inequalities, affordability, and varying adoption rates across demographic groups. Future research in this area could bridge the gap between the socio-psychological approach to technology acceptance and the political-economic perspective on structural inequality. This integration can lead to a deeper understanding of adoption dynamics in developing countries (Arora, S. and Stirling, 2023; Eitan and Hekkert, 2023).

Fourth, several research areas require further exploration. While this dissertation has concentrated on the diffusion of biofuels and electric vehicles, the transition to sustainable transportation in Indonesia encompasses other environmentally friendly innovations, particularly TOD. Moreover, various EIs are emerging, although they are still in the early research phase and are primarily studied outside Indonesia. These include hydrogen fuel cell vehicles, second-life applications and recycling of retired EV batteries, and smart mobility platforms. Future studies could investigate how these EIs interact with existing socio-technical systems in emerging economies. Additionally, more observation is needed to assess whether these EIs strengthen or disrupt existing path dependencies. For instance, research on the retired EV battery market and recycling processes could provide critical insights into how Indonesia can address end-of-life challenges and the high costs of replacing EV batteries. Conversely, this research also presents new economic opportunities. Similarly, the expansion of TOD projects in metropolitan Jakarta and their early adoption in other urban areas offer a valuable opportunity to explore how urban planning, public transportation, and EI intersect in shaping the future of efficient mobility. Comparative studies across emerging economies in Asia, Africa, and Latin America will provide valuable insights into how EI diffuses in different contexts. Although Brazil's ethanol program, Argentina's biodiesel initiatives, and India's electric vehicle projects have been widely researched, conducting a comparative analysis with Indonesia can illuminate both similarities and differences, thus enhancing theoretical generalisations. Additionally, Global South comparative studies can clarify the conditions under which the diffusion of EI contributes to inclusive development rather than exacerbating inequality (OECD, 2024; Yip et al., 2024).

Fifth, future research should focus on the influence of governance, finance, and international trade policies on national sustainability transitions. The case of Indonesia illustrates how the commitment to the global climate agenda and equitable development discourses are often appropriated domestically to reinforce the interests of the existing regime. Additional empirical studies could explore how international mechanisms—such as green finance, trade agreements, and transnational certification systems—affect the diffusion of EI in developing countries. This research will help contextualise national sustainability transitions within the broader political economy of globalisation, ensuring that sustainability studies are aligned with the dynamics of local and global power relationships (Geels, 2024; Newell and Bray, 2025).

Finally, beyond technology advancements, future research is essential for guiding policy decisions. By providing evidence on the successes and failures of various regulatory frameworks and the conditions under which they operate, research can enable policymakers to design interventions that avoid past mistakes and capitalise on

opportunities for inclusive transitions. On a global scale, promoting a more diverse and context-aware approach to socio-technical transition science can enhance learning among developing countries and ensure that international sustainability frameworks better reflect their realities. Therefore, future research can help bridge the gap between theoretical concepts of socio-technical transition and the practical challenges of managing the diffusion of EI amid issues of inequality, institutional fragility, and conflicting development priorities (Tomai et al., 2024).

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Appendices

Appendix A List of Interview Topics on Institutional Arrangements in the Indonesian Transportation Energy Sustainability

Interview Questions for Government Officer

Section 1 (General)

1. Please explain the duties and functions of your institution.
2. Does your institution relate to energy sector development?
3. If yes, please describe the role of your institution in the formulation of policies for the energy sector sustainable development?
4. How are alternative fuel policies established in the context of energy sustainability in the transportation sector?
5. In your opinion, do the global agenda related to sustainable development influence policy development in the Indonesian energy sector?
6. What is the role of your institution to encourage eco-innovation in the development of environmentally friendly fuels?

Section 2 (Biofuel Development)

1. Do the biofuel policies initiative in line with the vision and mission of your institution?
2. Please explain the main triggers for the government to initiate biofuel policies.
3. What is the impact of the implementation of biofuel policies on national energy security?
4. In your opinion, how is the consistency of the actors in developing biofuels towards environmental conservation?
5. Regarding several environmental issues such as deforestation or the threat of biodiversity, do you think that there is pressure from the international community on actors in Indonesia?
6. How do Indonesian actors address these environmental issues?

Section 3 (EV Development)

1. Does your institution play an active role in formulating policies for the acceleration of electric vehicles?
2. In your opinion, do energy companies, automotive manufacture and transportation service providers play an active role in supporting electric vehicle policies?
3. Does the policy get a wide response from the consumers in Indonesia?
4. If electric vehicles are not yet widespread in Indonesia, please explain what the challenges faced are?

Section 4 (Future institutional arrangements)

1. What is your suggestion for the transportation energy sustainability policies so that it can be implemented effectively?
2. Does your institution always assess the trajectories of emerging and future green fuel technologies?

3. In your opinion, how should the government formulate institutional arrangements to utilise advanced environmentally-friendly technology in the future?

Interview Questions for Energy Companies

Section 1 (General)

1. In what year did your company's business start operating?
2. What are your company's vision and mission?
3. How does your company view government policies regarding sustainable development in the energy sector?

Section 2 (Affordable and clean energy development)

1. Does your company develop environmentally friendly energy?
2. If yes, how long has your company developed this environmentally friendly energy?
3. What are the sales opportunities for clean energy products after the government has implemented a policy of sustainable development? Does your company expect an increase in sales after this policy?
4. Does the company get a premium price for clean energy products (such as biofuel or electric vehicle charging)?
5. What are the challenges in developing environmentally friendly energy?
6. Referring to several negative campaigns related to the provision of green energy in Indonesia and its sustainability (such as clearing land for oil palm plantations and coal-fired power plants), what do you think about that?
7. Did the campaign negatively affect your company's clean energy sales?
8. If yes, how did your company overcome this problem?

Section 3 (Future sustainable development)

1. Do you think that the policies can encourage eco-innovation in providing affordable and clean energy in the transportation sector?
2. Do you have any suggestions on the sustainable transportation energy policy so that it can be implemented effectively?
3. What are your recommendations regarding government policy plans in utilizing advanced green technology in the future?

Interview Questions for Automotive Manufacturer

Section 1 (General)

1. In what year did your company's business start operating?
2. What are your company's vision and mission?
3. How does your company view government policies regarding sustainable development in the energy sector?

Section 2 (Affordable and clean energy development)

1. Does your company develop low-carbon vehicles compatible with biofuels and electrification?
2. If so, how long has your company been developing these low-carbon vehicles?

3. What are the opportunities for selling green vehicle products after the government has implemented a policy of sustainable development? Does your company expect an increase in sales after this policy?
4. Does your company get a premium price for low-carbon vehicle products?
5. What are the challenges in developing low-carbon vehicles?
6. Referring to several negative campaigns related to the provision of environmentally friendly energy in Indonesia and its sustainability (such as clearing land for oil palm plantations and coal-fired power plants), what do you think about that?
7. Did the campaign negatively affect your company's sales of low-carbon vehicles?
8. If yes, how did your company overcome this problem?

Section 3 (Future sustainable development)

1. Do you think that the policies can encourage eco-innovation in developing of low-carbon vehicles?
2. How do you recommend a low carbon vehicle sustainability policy so that it can be implemented effectively?
3. What are your suggestions regarding the government's policy plan to utilise advanced green technology in the future?

Interview Questions for Transportation Provider

Section 1 (General)

1. In what year did your company's business start operating?
2. What are your company's vision and mission?
3. How does your company view government policies regarding sustainable development in the energy sector?

Section 2 (Affordable and clean energy development)

1. Does your company develop transportation services with vehicles that use biofuels or electric?
2. If yes, how long has your company been using these low-carbon vehicles?
3. What are the opportunities for low-carbon vehicle services after the government has implemented a policy of sustainable development? Does your company expect an increase in revenue after this policy?
4. Does the company get a premium price for services using low-carbon vehicles?
5. What are the challenges in developing low-carbon vehicle services?
6. Referring to several negative campaigns related to the provision of environmentally friendly energy in Indonesia and its sustainability (such as clearing land for oil palm plantations and coal-fired power plants), what do you think about that?
7. Did the campaign negatively affect your company's sales of low-carbon vehicle services?
8. If yes, how did your company overcome this problem?

Section 3 (Future sustainable development)

1. In your opinion, can government policies encourage eco-innovation in the development of low-carbon vehicle services?

2. How do you suggest a policy on sustainability for low carbon vehicle services so that it can be implemented effectively?
3. What are your suggestions regarding the government's policy plan to utilise advanced green technology in the future?

Interview Questions for Energy Associations

Section 1 (General)

1. In what year was your institution established?
2. What is the vision and mission of your institution?
3. Please explain the role of your institution in the development of policies for the energy sector sustainability.
4. In your opinion, do the global agenda related to sustainable development influence policy formulation in the Indonesian energy sector?
5. What is the role of government policies to encourage eco-innovation in developing affordable and clean energy?

Section 2 (Biofuel Development)

1. Do the biofuel policies in line with the vision and mission of your institution?
2. Please explain the main triggering factors for the government to initiate biofuel policies.
3. What is the impact of the implementation of biofuel policies on national energy security?
4. In your opinion, how is the consistency of the actors in developing biofuels towards environmental conservation?
5. Regarding several environmental issues such as deforestation or the threat of biodiversity, do you think that there is pressure from the international community on actors in Indonesia?
6. How do Indonesian actors address these environmental issues?

Section 3 (EV Development)

1. Does your institution play an active role in the development of an electric vehicle acceleration policy?
2. In your opinion, do energy companies, automotive manufacture and transportation service providers play an active role in supporting electric vehicle policies?
3. Does the EV acceleration policy get a wide response from the consumers in Indonesia?
4. If electric vehicles are not yet widespread in Indonesia, please explain what the challenges faced are?

Section 4 (General)

1. What is your suggestion for the transportation energy sustainability policy so that it can be implemented effectively?
2. Does your institution always assess the trajectories of emerging and future green fuel technologies?
3. In your opinion, how should the government formulate institutional arrangements to utilise advanced environmentally-friendly technology in the future?

Interview Questions for International Institutions and NGOs

Section 1 (General)

1. In what year was your institution established?
2. What is the vision and mission of your institution?
3. Please explain the role of your institution in the development of policies for the energy sector sustainability.
4. In your opinion, do the global agenda related to sustainable development influence policy formulation in the Indonesian energy sector?
5. What is the role of government policies to encourage eco-innovation in developing affordable and clean energy?

Section 2 (Biofuel Development)

1. Do the biofuel policies in line with the vision and mission of your institution?
2. Please explain the main triggering factors for the government to initiate biofuel policies.
3. What is the impact of the implementation of biofuel policies on national energy security?
4. In your opinion, how is the consistency of the actors in developing biofuels towards environmental conservation?
5. Regarding several environmental issues such as deforestation or the threat of biodiversity, do you think that there is pressure from the international community on actors in Indonesia?
6. How do Indonesian actors address these environmental issues?

Section 3 (EV Development)

1. Does your institution play an active role in the development of an electric vehicle acceleration policy?
2. In your opinion, do energy companies, automotive manufacture and transportation service providers play an active role in supporting electric vehicle policies?
3. Does the EV acceleration policy get a wide response from the consumers in Indonesia?
4. If electric vehicles are not yet widespread in Indonesia, please explain what the challenges faced are?

Section 4 (General)

1. What is your suggestion for the transportation energy sustainability policy so that it can be implemented effectively?
2. Does your institution always assess the trajectories of emerging and future green fuel technologies?
3. In your opinion, how should the government formulate institutional arrangements to utilise advanced environmentally-friendly technology in the future?

Interview Questions for Academics

Section 1 (General)

1. How long have you contributed to the energy sector?
2. Have you ever been invited by the government to discuss policies in the energy sector?

3. In your opinion, what is the direction of the Indonesian government policy regarding sustainable development in the energy sector?
4. In your opinion, do the global agenda related to sustainable development influence policy formulation in the Indonesian energy sector?
5. What is the role of government policies to encourage eco-innovation in developing affordable and clean energy?

Section 2 (Biofuel Development)

1. Do the biofuel policies in line with the provision of affordable and clean energy?
2. Please explain the main triggering factors for the government to initiate biofuel policies.
3. What is the impact of the implementation of biofuel policies on national energy security?
4. In your opinion, how is the consistency of the actors in developing biofuels towards environmental conservation?
5. Regarding several environmental issues such as deforestation or the threat of biodiversity, do you think that there is pressure from the international community on actors in Indonesia?
6. How do Indonesian actors address these environmental issues?

Section 3 (EV Development)

1. What is your view regarding the policy for electric vehicle acceleration?
2. In your opinion, do energy companies, automotive manufacture and transportation service providers play an active role in supporting electric vehicle policies?
3. Does the EV acceleration policy get a wide response from the consumers in Indonesia?
4. If electric vehicles are not yet widespread in Indonesia, please explain what the challenges faced are?

Section 4 (General)

1. What is your suggestion for the transportation energy sustainability policy so that it can be implemented effectively?
2. Does your institution always assess the trajectories of emerging and future green fuel technologies?
3. In your opinion, how should the government formulate institutional arrangements to utilise advanced environmentally-friendly technology in the future?

Interview Questions for Media

Section 1 (General)

1. Since what year did your media start operating?
2. What is the vision and mission of your institution?
3. Please explain the role of your institution in the development of policies in the energy sector.
4. In your opinion, what is the direction of the Indonesian government policy regarding sustainable development in the energy sector?

5. In your opinion, do the global agenda related to sustainable development influence policy formulation in the Indonesian energy sector?
6. What is the role of government policies to encourage eco-innovation in developing affordable and clean energy?

Section 2 (Biofuel Development)

1. Do the biofuel policies in line with the providing affordable and clean energy?
2. Please explain the main triggering factors for the government to initiate biofuel policies.
3. What is the impact of the implementation of biofuel policies on national energy security?
4. In your opinion, how is the consistency of the actors in developing biofuels towards environmental conservation?
5. Regarding several environmental issues such as deforestation or the threat of biodiversity, do you think that there is pressure from the international community on actors in Indonesia?
6. How do Indonesian actors address these environmental issues?

Section 3 (EV Development)

1. Does your institution play an active role in the development of an electric vehicle acceleration policy?
2. In your opinion, do energy companies, automotive manufacture and transportation service providers play an active role in supporting electric vehicle policies?
3. Does the EV acceleration policy get a wide response from the consumers in Indonesia?
4. If electric vehicles are not yet widespread in Indonesia, please explain what the challenges faced are?

Section 4 (General)

1. What is your suggestion for the transportation energy sustainability policy so that it can be implemented effectively?
2. Does your institution always assess the trajectories of emerging and future green fuel technologies?
3. In your opinion, how should the government formulate institutional arrangements to utilise advanced environmentally-friendly technology in the future?

Appendix B List of Interview Topics on the Diffusion of Eco-innovation and Social Acceptance of Low-Carbon Transportation Technologies

Section 1 (EI in the Development of Biofuels and/or Diffusion of EVs):

1. Could you tell me about EVs and/or biofuels?
2. When did your company start developing/distributing them?
3. Have you changed them? What characteristics have changed? Why did you make that change?
4. Did your company's sales increase after developing/distributing them?

Part 2 (Drivers of EI in the Development of Biofuels and/or Diffusion of EVs)

1. What are the main drivers of the development of biofuels and/or diffusion of EVs? Please explain in more detail.
2. Are government policies spurring the development of biofuels and/or the diffusion of EVs?
3. How effective are the financial incentives and supporting policies?
4. What is the role of technology capability, knowledge, or skills for your company? How did your company acquire it?
5. What is the consumer's perception of reducing carbon emissions through biofuels and/or EVs?
6. Is the market responding to the presence of energy-efficient products?
7. How significant are oil price fluctuations to sales of biofuels and/or EVs?
8. Are there other drivers of eco-innovation development and diffusion? Please explain in more detail.

Part 3 (Barriers of EI in the Development of Biofuels and/or Diffusion of EVs)

1. What are the main barriers to developing biofuels and/or EV diffusion? Please explain in more detail.
2. Are the costs and risks of investment holding back your company?
3. How will infrastructure requirements and/or availability affect biofuels and/or EVs?
4. How significant is the influence of barriers to availability and mastery of technology?
5. How will the high price of biofuels and/or EVs impact your EI?
6. Are there any socio-economic barriers that affect biofuels and/or EVs?
7. Are there any unclear or conflicting government policies that hinder biofuels and/or EVs?
8. Have environmental issues prevented the development of biofuels and/or the diffusion of EVs? How does your company address these issues?
9. Are there other barriers to eco-innovation development and diffusion? Please explain in more detail.

Appendix C The Online Survey Design on Customer Preferences on Their Willingness to Buy an Electric Motorcycle

Electric Motorcycle Customer Preference

Section 1 Questionnaire (General Information)

1. What is your age group? * *Required*

- ☐ 18-30 years old
- ☐ 31-40 years old
- ☐ 41-50 years old
- ☐ 51-60 years old
- ☐ 61 years old or above

2. How many members of your family? * *Required*

3. How much is the monthly family income? * *Required*

- ☐ < Rp. 4.000.000
- ☐ Rp. 4.000.000 up to < Rp. 8.000.000
- ☐ Rp. 8.000.000 up to < Rp. 12.000.000
- ☐ Rp. 12.000.000 up to < Rp. 20.000.000
- ☐ ≥ Rp. 20.000.000

4. Do you have a motorcycle? * *Required*

- ☐ Yes
- ☐ No

5. What was your last level of education? * *Required*

- ☐ Elementary school
- ☐ Secondary school
- ☐ Diploma
- ☐ Bachelor
- ☐ Master/magister or Doctoral

Section 2 Questionnaire (Costumers' preferences on willingness to buy electric motorcycle)

1. How much distance do you usually travel by motorcycle every day? * *Required*

- ☐ <10 km
- ☐ 10 km up to <20 km
- ☐ 20 km up to <40 km
- ☐ 40 km up to <60 km
- ☐ ≥60 km

2. Where will you most often charge an electric motorcycle and what is the acceptable maximum charge time for an electric motorcycle? * *Required*

- ☐ Home (6 hours to 8 hours)
- ☐ Parking areas in workplaces such as offices and campuses (4 hours to 6 hours)
- ☐ Commercial parking areas such as shopping centres, restaurants and cinemas (1 hour to 2 hours)
- ☐ Public electric charging station (0.5 hours or less)
- ☐ Battery swap (10 minutes or less)

3. What is the desired price range for buying an electric motorcycle if you buy it? * *Required*

- ☐ <Rp. 15,000,000
- ☐ Rp. 15,000,000 up to <Rp. 20,000,000
- ☐ Rp. 20,000,000 up to <Rp. 25,000,000
- ☐ Rp. 25,000,000 up to <Rp. 30,000,000
- ☐ ≥Rp. 30,000,000

4. What is the desired monthly electrical charge if you buy an electric motorcycle? * *Required*

- ☐ <Rp. 200,000
- ☐ Rp. 200,000 up to <Rp. 400,000
- ☐ Rp. 400,000 up to <Rp. 600,000
- ☐ Rp. 600,000 up to <Rp. 800,000
- ☐ ≥Rp. 800,000

This part of the survey uses a table of questions. [view as separate questions instead?](#)

5. Please determine priority considerations if one day you buy an electric motorcycle by filling in numbers 1 to 5 in the right column of the following statement: (Note: 1 = the most important factor; 5 = the least important factor. You can only select one number for each priority factor) * *Required*

Please don't select more than 1 answer(s) per row.

Please select exactly 5 answer(s).

Please don't select more than 1 answer(s) in any single column.

	1	2	3	4	5
Range	☐	☐	☐	☐	☐
Charging location and time	☐	☐	☐	☐	☐
Charging time	☐	☐	☐	☐	☐
Purchase price	☐	☐	☐	☐	☐
Monthly operational and maintenance costs	☐	☐	☐	☐	☐

6. Please determine the priority of the obstacles you face in buying an electric motorcycle by filling in numbers 1 to 5 in the right column of the following statement: (Note: 1 = the most important factor; 5 = the least important factor. You can only select one number for each priority factor) * Required

Please don't select more than 1 answer(s) per row.

Please select exactly 5 answer(s).

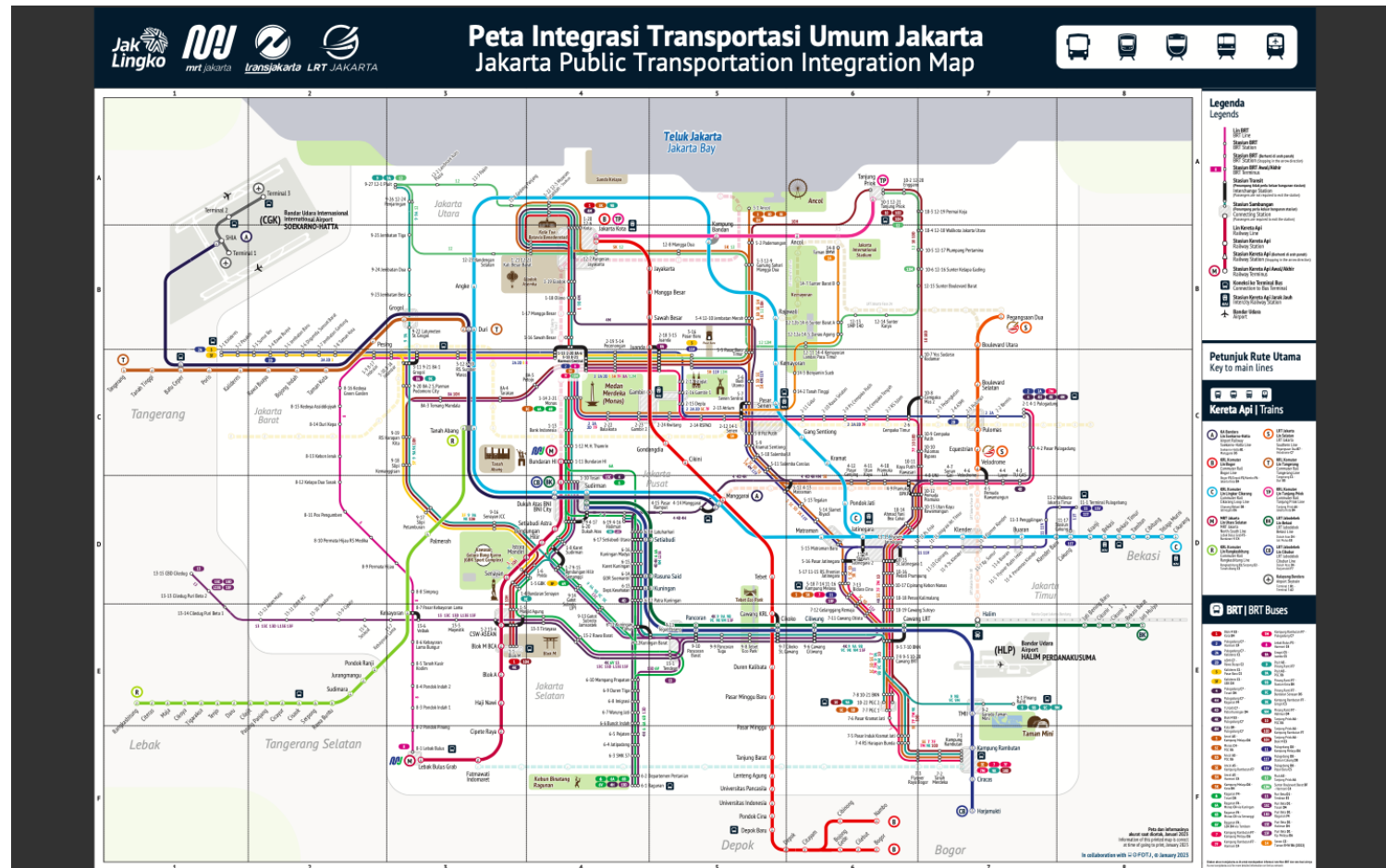
Please don't select more than 1 answer(s) in any single column.

	1	2	3	4	5
Inadequate charging infrastructure	☐	☐	☐	☐	☐
The purchase price of a vehicle is too expensive	☐	☐	☐	☐	☐
Spare part service is difficult	☐	☐	☐	☐	☐
Reliability (less flexible; limited mileage, top speed and power)	☐	☐	☐	☐	☐
Public knowledge is still lacking	☐	☐	☐	☐	☐

7. Do you have the interest to buy an electric motorcycle? * Required

- ☐ Yes
☐ No

Appendix D Map of the Integration of MRT, LRT, and BRT in the Greater Jakarta Area



Source: MRT Jakarta (2025)

Appendix E EMC Price and Performance in Indonesian Market

Brand	Model	Base Price (USD)	Price After Subsidies (USD)	Battery Capacity (kWh)	Battery Type	Rated Power (kW)	Peak Power (kW)	Range (km)	Charging Time (hours)	Top Speed (kmph)	Observed Countries	Remark
Greentech	Unity	820	353	1.92	SLA	0.8	1	100	4	65	Indonesia	
Exotic	Sterrato	839	372	1.21	SLA	0.8	N/A	55	4	50	Indonesia	
Uwinfly	GN Smart	866	399	1.44	SLA	1.2	N/A	80	4	55	Indonesia	
Viar	NX	955	488	1.34	LIB	1	2	60	5	50	Indonesia	
United e-Motor	MX1200	1,053	587	1.44	LIB	1.2	2.2	80	5	65	Indonesia	
Volta	401	1,130	663	1.38	LIB	N/A	1.5	60	5	60	Indonesia	Battery swap
Polytron	Fox-S	1,213	747	1.94	LIB	3	N/A	70	5	80	Indonesia	
Smoot	Tempur	1,233	767	1.34	LIB	1.5	3	60	8	60	Indonesia	Battery swap
Smoot	Zuzu	1,327	860	1.38	LIB	1.5	3	60	8	60	Indonesia	Battery swap
Polytron	Fox-R	1,367	900	3.7	LIB	3	N/A	130	5	95	Indonesia	
Selis	E-max	1,367	900	1.5	LIB	1.2	N/A	60	5	55	Indonesia	
Yadea	T9	1,433	966	2.74	LIB	2	3	100	8	60	Indonesia	
Viar	New Q1	1,435	968	1.4	LIB	0.8	2	60	5	60	Indonesia	
ECGo	ECGo 3	1,527	1,060	2	LIB	1.7	2.1	80	3	75	Indonesia	
Yadea	E8S Pro	1,593	1,127	2.74	LIB	2	2.8	100	8	60	Indonesia	
Gesits	Raya G	1,860	1,393	1.44	LIB	1.5	3	60	3	70	Indonesia	
Gesits	G1	1,931	1,465	1.44	LIB	2	5	50	3	70	Indonesia	
Selis	Go Plus	1,967	1,500	1.62	LIB	2	N/A	70	5	80	Indonesia	
United e-Motor	T1800	2,260	1,793	1.68	LIB	1.8	N/A	65	4	70	Indonesia	
Honda	EM1	2,667	2,200	1.48	LIB	0.58	1.7	41.1	6	45	Indonesia	
Alva	Cervo	2,850	2,383	3.6	LIB	N/A	9.8	125	4	103	Indonesia	
United e-Motor	TX3000	3,327	2,860	3.36	LIB	3	4.2	120	4	90	Indonesia	

Appendix F EMC Price and Performance in Global Market

Brand	Model	Base Price (USD)	Battery Capacity (kWh)	Battery Type	Rated Power (kW)	Peak Power (kW)	Range (km)	Charging Time (hours)	Top Speed (kmph)	Observed Countries	Remark
Autotec	Xiaolegui	400	1.2	SLA	1	N/A	70	6.5	45	China	
Ampere	V48	450	1.15	SLA	0.25	N/A	60	6	60	India	
Honda	U-Be	475	0.72	LIB	0.35	N/A	55	2	55	China	
Ninebot	Q80C	551	N/A	LIB	0.35	0.8	115	6	45	China	
Yadea	Rayman	610	2.3	SLA	1	2	60	10	55	China	
VinFast	EVO200	731	3.5	LIB	1.5	2.5	203	4	70	Vietnam	
VinFast	EVO200 Lite	731	3.5	LIB	1.5	2.45	205	4	49	Vietnam	
Luyuan	MB5 Basic	850-1,000	1.2	LIB	1.2	2	50	5	45	China	
Yadea	T9	906	2.74	LIB	2	3	100	8	60	China	
Luyuan	Super S70	1,000	3.24	LIB	2.5	N/A	80	8	80	China	
Luyuan	S30 Plus	918-1,200	2.16	LIB	1.5	3	80	8	60	China	
OLA	S1 X+	1,083	3	LIB	N/A	6	151	7.4	90	India	
VinFast	Feliz S	1,097	3.5	LIB	1.8	3	198	6	78	Vietnam	
Kymco	Like 125 EV	1,195	3.25	LIB	3.2	N/A	200	1	45	Taiwan	
Honda	U-Go	1,233	1.44	LIB	1.2	1.8	63	2	53	China	
Simple	One	1,323	5	LIB	4.8	8.5	212	5.5	105	India	
Hero	Optima CX	1,325	1.54	LIB	1.2	1.9	135	4.5	55	India	Subsidised Price USD 783
Deco	Sofia/Luciano	1,349	1.26	LIB	1	N/A	60	4	65	Thailand	Subsidised Price USD 806.58
H SEM	Ciao	1,400	1.2	LIB	2	N/A	60	4	60	Thailand	
TVS	iQube	1,489	3.04	LIB	3	4.4	100	4.5	78	India	
Ather	450 Plus	1,510	2.23	LIB	N/A	N/A	70	4.5	80	India	
Kymco	Cozy	1,565	1.2	LIB	0.8	N/A	100	6	45	Taiwan	
VinFast	Klara S	1,621	3.5	LIB	N/A	3	120	4.8	48	Vietnam	
Ather	450X	1,660	2.9	LIB	6.4	7	90	6.5	90	India	
Yadea	E8S Pro	1,731	2.74	LIB	2	2.8	100	8	60	Nepal	
Bajaj	Chetak	1,738	3.2	LIB	4	4.2	126	4.5	73	India	
Gogoro	2 Premium	1,742	3.4	LIB	7	N/A	170	2.5	110	Taiwan	6s battery swap
OLA	S1 Pro	1,747	3.97	LIB	N/A	11	195	6.5	120	India	Subsidised Price USD 1,205
Yadea	T9	1,772	2.74	LIB	2	3	100	8	60	Nepal	

Brand	Model	Base Price (USD)	Battery Capacity (kWh)	Battery Type	Rated Power (kW)	Peak Power (kW)	Range (km)	Charging Time (hours)	Top Speed (kmph)	Observed Countries	Remark
Deco	MaxOne	1856	2.21	LIB	2	N/A	50	4	70	Thailand	
Gogoro	Viva Mix	1,917	3.4	LIB	6	N/A	150	2.5	90	Taiwan	6s battery swap
Gogoro	Delight	2,003	3.4	LIB	7	N/A	150	2.5	80	Taiwan	6s battery swap
VinFast	Vento S	2,031	3.5	LIB	N/A	5.2	160	6	89	Vietnam	
Deco	DoubleAce/G-Five	2250	3.09	LIB	2	N/A	120	6	80	Thailand	Subsidised Price USD 1,707.78
Yadea	Keeness	2,353	4.6	LIB	5.5	11	129	6	100	China	
Askoll	eS1	2,490	2.1	LIB	1.5	N/A	100	6	45	Italy	
Niu	MQi-GT	2,545	2.98	LIB	3	3.1	110	4.5	70	UK	
VinFast	Theon S	2,560	3.5	LIB	N/A	7.1	150	6	99	Vietnam	
Yadea	G5	2,634	1.92	LIB	1.2	2.3	80	6	60	Nepal	
Yadea	C1S	2,785	1.92	LIB	1.8	2.2	80	6	60	Nepal	
Yadea	E-Lex	2,789	2.88	LIB	1.5	1.8	80	8	45	UK	Price after Grant USD 2,597
Piaggio	1	3,151	1.4	LIB	1.2	1.34	55	6	45	Italy	
H SEM	Mobila G	3,344	4.32	LIB	3	N/A	90	4	90	Thailand	
Piaggio	1	3,438	1.4	LIB	1.2	1.34	55	6	45	UK	
Super Soco	TC	3,449	3.6	LIB	1.5	3	126	4	45	US	Price after Grant USD 3,299
Askoll	NGS3	3,647	2.82	LIB	2.7	N/A	87	6	66	Italy	
Pega	Surron Light Bee X	3,868	2.4	LIB	3	6	100	3.5	75	China	
Piaggio	1 Active	4,033	2.3	LIB	2	3	85	6	60	Sweden	Price after Grant USD 3,550
Piaggio	1	4,225	1.4	LIB	1.2	1.34	55	6	45	Sweden	Price after Grant USD 2,877
Yadea	G5S	4,431	2.88	LIB	3	4.1	116	8	80	UK	Price after Grant USD 3,794
Pega	79 Bike Falcon-M	4,499	2.52	LIB	4	8	120	3.5	80	China	
Piaggio	1+	4,706	2.3	LIB	1.2	1.34	100	6	45	Sweden	Price after Grant USD 3,358
Piaggio	1	4,799	1.4	LIB	1.2	1.34	55	6	45	US	
Niu	MQi-GT-EVO	6,110	3.74	LIB	5	6.5	75	5	95	UK	Price after Grant USD 4,455
Sondors	Metacycle	6,500	4	LIB	8	14.5	130	4	130	US	

Appendix G Research Ethics Review

This study used semi-structured interviews, telephone surveys and online questionnaires to the respondents. Respondents were divided into three groups. The first group consists of stakeholders in institutions who are decision makers in the energy transportation sector. In contrast, the second group is the general public as transportation users. Meanwhile, the third group came from various levels of energy and automotive manufacturing company employees. Requirements for data collection have been submitted to the Research Ethics Committee and received an email about Conditional Ethical Approval, as shown in the figure below.

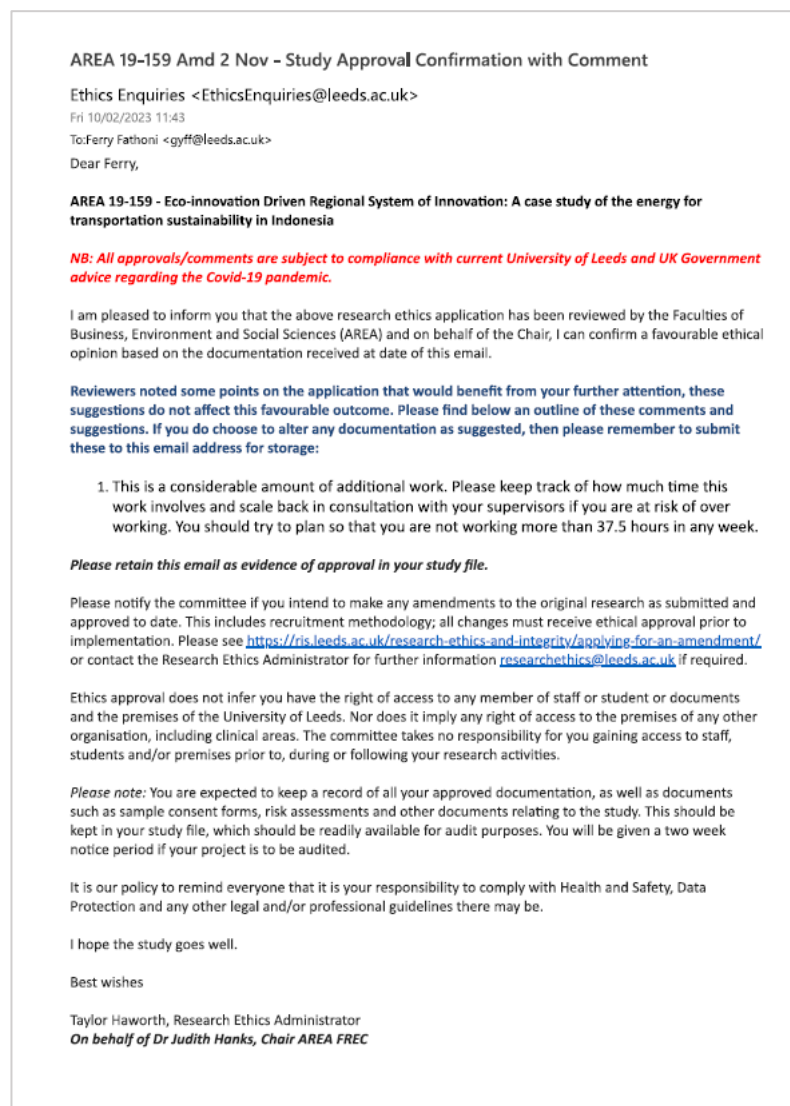


Figure A1. Research Ethics Committee email about Conditional Ethical Approval