

ERIA Research Project Report FY2026, No. 6

Towards an Effective Road Transport Fleet Renewal Strategy for Indonesia

by

Economic Research Institute for ASEAN and East Asia (ERIA)

Pusat Studi Energi Universitas Gadjah Mada



Towards an Effective Road Transport Fleet Renewal Strategy for Indonesia

Economic Research Institute for ASEAN and East Asia (ERIA)

Sentral Senayan II 6th Floor

Jalan Asia Afrika No. 8, Gelora Bung Karno

Senayan, Jakarta Pusat 12710

Indonesia

© Economic Research Institute for ASEAN and East Asia, 2026.

ERIA Research Project Report FY2026, No. 6

Published in May 2026

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted in any form by any means electronic or mechanical without prior written notice to and permission from ERIA.

The findings, interpretations, and conclusions expressed herein do not necessarily reflect the views and policies of the Economic Research Institute for ASEAN and East Asia, its Governing Board, Academic Advisory Council, or the institutions and governments they represent.

Any error in content or citation in the respective chapters is the sole responsibility of the author/s.

Material in this publication may be freely quoted or reprinted with proper acknowledgement.

Please cite this publication as:

ERIA (2026), 'Towards an Effective Road Transport Fleet Renewal Strategy for Indonesia'. *ERIA Research Project Report FY2026, No. 6*. Jakarta: ERIA.

Acknowledgements

We thank the Pusat Studi Energi (PSE) or Centre for Energy Studies, Universitas Gadjah Mada (UGM), for its invaluable support in providing resources, expertise, and guidance throughout the research process. Its commitment to advancing energy studies and sustainable transport has greatly contributed to the success of this work. We also appreciate the collaborative environment and encouragement from the PSE UGM team, which have inspired and facilitated our efforts.

List of Project Members

Members from Pusat Studi Energi (Center for Energy Studies), Universitas Gadjah Mada

Adhika Widyaparaga	Team leader, engineering expert
Bertha Maya Sopha	Industrial engineering expert
I Made Miasa	Engineering expert
Ardyanto Fitradny	Economist
Irine Handika	Legal expert
Ardi Wiranata	Engineering assistant
Sucipto	Engineering assistant
Dawi Karomati Baroroh	Engineering assistant
Annisa Cahyaningsih	Assistant economist
Stephanie Kristina Susanto	Legal assistant
Kenley Wijaya	Legal assistant

Members from the Economic Research Institute for ASEAN and East Asia

Alloysius Joko Purwanto	Energy economist
Ryan Wiratama Bhaskara	Research associate
Laksmi Dwi Hersaputri	Research associate
Shafa Nabilla Haya	Research associate

Contents

	Acknowledgements	iii
	List of Project Members	iii
	List of Figures	v
	List of Tables	vii
	List of Abbreviations and Acronyms	ix
	Executive Summary	xi
Chapter 1	Introduction	1
Chapter 2	Circular Economy Analysis	4
Chapter 3	Regulatory Analysis	27
Chapter 4	Cost–Benefit Analysis	85
Chapter 5	Conclusions and Recommendations	124
	References	126

List of Figures

Figure 2.1	Forecast of Total Passenger Vehicle Population	5
Figure 2.2	Composition of Vehicle Sales (Historical Data Incorporated from BPS Indonesia and GAIKINDO)	6
Figure 2.3	Active Vehicle Population (Business-As-Usual Scenario)	7
Figure 2.4	Schematic Diagram of Model Algorithm for Calculating Total Vehicle Kilometre, Fuel Consumption, and Emissions	8
Figure 2.5	Projection of Fuel Economy and Energy Consumption for Clean Vehicle Alternatives based on Production Year	9
Figure 2.6	Specific Emissions (kgCO ₂ eq/litre gasoline equivalent) for Passenger Vehicle Fuels	10
Figure 2.7	Vehicle Kilometres Travelled (in billion kilometres) Business-As-Usual Scenario	11
Figure 2.8	Energy Consumption for BAU and Simulation A Scenarios	12
Figure 2.9	Carbon Emissions for BAU and Simulation A Scenarios	13
Figure 2.10	Energy Consumption for BAU and Simulation B Scenarios	14
Figure 2.11	Carbon Emissions for BAU and Simulation B Scenarios	14
Figure 2.12	Energy Consumption under the BAU, Simulation A, and Simulation B Scenarios	15
Figure 2.13	Carbon Emissions for the BAU, Simulation A, and Simulation B Scenarios	15
Figure 2.14	Sankey Diagram for Internal Combustion Engine Passenger Car	18
Figure 2.15	Sankey Diagram for Battery Electric Passenger Car	19
Figure 2.16	Sankey Diagram for Hybrid Electric Passenger Car	20
Figure 2.17	Sankey Diagram for Plug-In Hybrid Electric Passenger Car	20
Figure 2.18	Sankey Diagram for Fuel Cell Electric Passenger Car	21
Figure 2.19	Heat Map of Passenger Car (Values in Rp)	24
Figure 2.20	Statistical Analysis of Potential Value Amongst Vehicle Types	25
Figure 3.1	Regulatory Landscape of Indonesia	28

Figure 3.2	LEZ in Kota Tua, Jakarta	68
Figure 3.3	Proposed Regulatory Improvements for Fleet Renewal in Indonesia	70
Figure 4.1	Projection of Fuel Economy and Energy Consumption for Clean Vehicle Alternatives Based on Production Year	101
Figure 4.2	Framework of Cost–Benefit Analysis	102
Figure 4.3	Framework of Cost of Ownership	110
Figure 4.4	Framework of Fuel Import Calculations	110
Figure 4.5	Framework of Deadweight Loss Calculations	111
Figure 4.6	Framework of Marginal Abatement Costs	113
Figure 4.7	Total Cost of Ownership in 2025 and 2035 (Baseline)	119
Figure 4.8	Total Cost of Ownership in 2035 (Baseline and After Intervention)	121

List of Tables

Table 2.1	Material Composition, Recyclability Rate, and Economic Value of Retired Passenger Vehicles by Type	16
Table 2.2	Estimated Economic Value of Recycled Materials Amongst Five Passenger Vehicle Types	22
Table 2.3	Kruskal–Wallis Test	25
Table 3.1	Summary of Relevant Laws	29
Table 3.2	Types of LCEVs	32
Table 3.3	Emission Quality Standards for Motor Vehicles in Categories M, N, and O	35
Table 3.4	Emission Quality Standards for Motor Vehicles in Category L	35
Table 3.5	Taxes and Other Levies for Motor Vehicles and EVs	37
Table 3.6	Import Duties According to the Harmonization System Code	38
Table 3.7	Luxury Goods Sales Tax for ICE Vehicles	39
Table 3.8	Special Tax Base for EVs	41
Table 3.9	Annual Taxes and Levies for Motor Vehicles and EVs	44
Table 3.10	Identified Regulatory Gaps	45
Table 3.11	General Incentives According to Presidential Regulation No. 55/2019	49
Table 3.12	Specific Incentives According to Presidential Regulation No. 55/2019	50
Table 3.13	Legal Structure to Support BEV Adoption According to Presidential Instruction No. 7/2022	53
Table 3.14	Policies to Accelerate LCEV Adoption	61
Table 3.15	Recommendations Regarding Carbon-Intensive Vehicle Retirement Policies	64
Table 3.16	Presidential Mandate to Establish a National Vehicle Scrappage Programme	72
Table 4.1	China’s Regional Subsidy for Charging Infrastructure	92

Table 4.2	Matrix of Fleet Renewal Strategies	104
Table 4.3	CBA Scenarios	105
Table 4.4	Assumptions of Scenarios	106
Table 4.5	Assumptions in Total Cost of Ownership	114
Table 4.6	Fuel Import Calculation Assumptions	116
Table 4.7	Emission Calculation Assumptions	117
Table 4.8	Assumptions for Calculating Avoided Economic Inefficiency	118
Table 4.9	Results of the Cost–Benefit Analysis (with a One-Time Scrappage Programme)	122
Table 4.10	CBA Results (with Gradual Scrappage Programme)	123

List of Abbreviations and Acronyms

BAU	business-as-usual
BEV	battery electric vehicle
BBnKB	transfer fee for motor vehicle/vehicle ownership transfer fee
BPKB	vehicle ownership book
CBA	cost–benefit analysis
CBU	completely built up
CKD	completely knocked down
CO ₂	carbon dioxide
EU	European Union
EV	electric vehicle
FCEV	fuel cell electric vehicle
GDP	gross domestic product
GHG	greenhouse gas
HEV	hybrid electric vehicle
ICE_D	internal combustion diesel engine
ICE	internal combustion engine
ICE_G	internal combustion gasoline engine
ICEV	internal combustion engine vehicle
IDR	Indonesian rupiah
IUPTL	electric power supply business licence
KTP	National Identity/Identification Card
LCEV	low-carbon emission vehicle
LCGC	low-cost green car
LDV	light-duty vehicle
LEZ	low-emission zone
PPnBM	luxury goods tax
LUC	land use change
MCDA	multi-criteria decision analysis

MoEMR	Minister/Ministry of Energy and Mineral Resources
MoEF	Ministry of Environment and Forestry
MoF	Ministry of Finance
MoHA	Ministry of Home Affairs
NDC	nationally determined contribution
PHEV	plug-in hybrid electric vehicle
PLN Negara)	Indonesia's State Electricity Company (Perusahaan Listrik
PMK	Minister of Finance Regulation
PPh	income tax
PPnBM	luxury goods sales tax/luxury goods tax (<i>Pajak Penjualan-Barang Mewah</i>)
PKB	annual vehicle tax (<i>Pajak Kendaraan Bermotor</i>)
REE	rare earth element
SOE	state-owned enterprise
SPBKLU	public electric vehicle battery exchange station
SPKLU	public electric vehicle charging station
STNK	Vehicle Registration Certificate
SWDKLLJ	Mandatory Road Traffic Accident Insurance Contribution
TCO	total cost of ownership
TKDN	domestic component level
TNKB	vehicle number plate
UK	United Kingdom
VKT	vehicle kilometre travelled
xEV	electrified vehicle

Executive Summary

Indonesia's enhanced commitment to reducing carbon emissions – raising its nationally determined contribution (NDC) target to 31.89% by 2030 – places the transport sector at the centre of decarbonisation efforts. Road transport accounts for approximately 24% of national emissions, driven by rapid growth in vehicle ownership and continued reliance on fossil fuels. With motorcycles and passenger cars dominating the fleet, and demand projected to rise, energy consumption and emissions will continue to increase in the absence of significant policy intervention.

A central challenge is the prevalence of old, inefficient vehicles, reflecting the absence of a structured fleet renewal and vehicle retirement policy. This study applies a population-based model to estimate vehicle ownership, fleet composition, travel activity, and fuel consumption, enabling a comprehensive assessment of emissions trajectories. The findings underscore the urgency of accelerating the transition to cleaner technologies – including electric vehicles (EVs), biofuels, and hydrogen – supported by targeted incentives and strengthened regulatory frameworks.

Business-as-Usual Scenario and Vehicle Population Projection

To inform policy planning, the study develops a population- and gross domestic product (GDP)-based model to project vehicle ownership, fuel distribution, and energy use. Vehicle ownership rates are estimated and translated into fleet composition across internal combustion engine vehicles (ICEVs), hybrids, plug-in hybrids, battery electric vehicles (BEVs), and low-cost green cars (LCGCs). Combined with average annual mileage, this yields estimates of vehicle kilometres travelled (VKT), fuel consumption, infrastructure needs, and subsidy requirements.

The model incorporates a 20-year vehicle lifespan and accounts for improvements in fuel economy across newer cohorts, thereby capturing the continued impact of older, less efficient vehicles on emissions. Vehicle growth is projected using a modified Gompertz curve, reflecting the relationship between GDP per capita and vehicle ownership over time. While the share of electrified vehicles (xEVs) is projected to increase steadily, ICEV sales decline more gradually, with LCGCs maintaining a stable share due to their affordability and efficiency.

Under the business-as-usual (BAU) scenario, both energy consumption and emissions decline modestly despite rising VKT, driven by improvements in average vehicle efficiency. However, these gains remain insufficient to meet long-term decarbonisation objectives.

To assess policy options, two simulation series are developed: (A) a one-time scrappage programme covering 2 million vehicles in 2030, and (B) a gradual scrappage programme implemented annually from 2030 to 2035 for the same total number of vehicles. These

are combined with tax reforms to increase annual vehicle taxes (Pajak Kendaraan Bermotor, PKB) for high-emission vehicles.

The results show that a one-time scrappage programme generates an immediate reduction of approximately 8.4% in both energy consumption and emissions in 2030. While emissions remain lower than BAU through 2035, the gap narrows over time, suggesting that periodic interventions are required to sustain reductions. Comparatively, a gradual scrappage programme yields lower annual emissions by 2035, but the one-time intervention delivers greater cumulative benefits over the longer term due to earlier gains.

1.1. Circular Economy Analysis

To complement fleet renewal strategies, the study adopts a circular economy perspective by assessing the material composition and recycling value of vehicles. Key recyclable materials – including steel, aluminium, copper, and battery components – are evaluated across ICEVs, BEVs, hybrids, plug-in hybrids, and fuel cell vehicles. Electrified vehicles contain higher shares of valuable materials such as nickel, rare earth elements, and lithium compounds, increasing their recycling potential despite lower mass shares.

Material recovery values are estimated at approximately Rp18.5 million for fuel cell vehicles, compared to Rp7.6 million for ICEVs. These findings highlight the importance of aligning fleet renewal policies with material recovery strategies to enhance resource efficiency, reduce dependence on imported critical materials, and offset part of the costs associated with fleet transition.

Cost–Benefit Analysis

The study evaluates policy options using cost–benefit analysis (CBA), supported by multi-criteria decision analysis (MCDA). Three scenarios are assessed: (1) a scrappage programme, (2) tax reform targeting high-emission vehicles, and (3) a combined approach. All scenarios include baseline measures such as emissions standards, fuel economy standards, and tax incentives for low-carbon vehicles.

The analysis considers four key components: vehicle ownership costs, fuel imports, economic inefficiencies (including fossil fuel subsidies), and emissions reductions. Results indicate that all scenarios generate positive net social benefits. The combined scenario delivers the highest net benefit at Rp64.57 trillion, followed by the scrappage-only scenario at Rp59.93 trillion. Tax reform alone yields more limited gains (Rp4.64 trillion).

The design of the scrappage programme also affects outcomes. A one-time programme produces higher net benefits than a gradual six-year approach (Rp35.72 trillion), reflecting the advantage of early emissions reductions and compounding benefits over time. Notably, both approaches generate net benefits exceeding the total subsidy cost of Rp25.5 trillion.

Legal and Regulatory Analysis

The study undertakes a comprehensive review of Indonesia's legal and regulatory framework, including mapping, international benchmarking, and gap analysis. The current framework is characterised by a range of laws, presidential regulations, and ministerial decrees that collectively support the transition to low-carbon emission vehicles (LCEVs), particularly BEVs. A key instrument is Presidential Regulation No. 55/2019, as amended by Regulation No. 79/2023.

To strengthen fleet renewal and accelerate decarbonisation, the study recommends several regulatory actions. These include expanding incentives beyond BEVs to encompass hybrid and plug-in hybrid vehicles; introducing disincentives for high-emission vehicles; establishing a formal scrappage programme under the Ministry of Transportation; and developing national standards for emissions and fuel economy applicable to private vehicles. These measures should be supported by implementing regulations at the ministerial level, including a dedicated regulation on vehicle scrappage aligned with Presidential Regulation No. 1/2022 on road transport safety.

Chapter 1

Introduction

Indonesia's commitment to global sustainability and its pledge to mitigate carbon emissions have been central to its policy direction following its ratification of the Paris Agreement in 2016 (Indonesia, 2016). With an initial nationally determined contribution (NDC) targeting a 29% unconditional reduction in carbon emissions by 2030, the nation has since increased its ambition with an enhanced NDC in 2022, raising the target to a 31.89% reduction (Indonesia, 2022). To achieve this, aggressive and strategic measures must be undertaken across all economic sectors, particularly in transportation, which is amongst the most significant contributors to national emissions.

The transport sector plays a crucial role in Indonesia's energy consumption and carbon emissions. In 2023, the sector accounted for approximately 22% of Indonesia's total greenhouse gas (GHG) emissions, making it a key area of focus for achieving national decarbonisation goals (Asian Transport Outlook, 2024). Within this sector, road transportation is the predominant source of emissions, driven by increasing vehicle ownership and continued reliance on fossil fuels.

Indonesia's energy demand in transportation is expected to grow significantly in the coming years due to rising population, urbanisation, and economic development. The road transport sector alone is projected to account for 87% of total transport energy demand by 2030. Fuel consumption in the sector is overwhelmingly dominated by petroleum-based fuels, such as gasoline and diesel, with biofuels contributing only a small fraction of the total energy mix (Widyaparaga et al., 2017). This heavy reliance on fossil fuels contributes to elevated CO₂ emissions, deteriorating air quality in urban centers, and increased health risks associated with pollution exposure.

Motorised transport in Indonesia consists of various vehicle types, including motorcycles, passenger cars, buses, and freight transport. Amongst these, motorcycles account for the majority of the vehicle population. Between 2015 and 2022, the number of passenger cars in Indonesia surged from 12 million to 17 million, while the number of motorcycles increased from 89 million to 125 million (Badan Pusat Statistik, 2024). Given that nearly all these vehicles are powered by internal combustion engines (ICEs), the sector's emissions are set to rise further without strong intervention. Despite advances in technology leading to improvements in fuel efficiency and emissions reduction for new ICEVs, the overall impact is offset by the sheer increase in vehicle numbers.

One of the primary challenges exacerbating emissions in Indonesia's road transport sector is the significant presence of old, inefficient vehicles. Unlike many developed economies, Indonesia lacks a structured fleet renewal and vehicle retirement policy, leading to a persistent accumulation of outdated, high-emission vehicles within the

national vehicle stock. Many of these legacy vehicles continue to operate beyond their intended lifespan, resulting in:

- Higher fuel consumption and emissions per kilometre (km) travelled compared to newer vehicles
- Increased air pollution, particularly in densely populated urban areas
- Greater maintenance costs for vehicle owners yet continued economic incentives to keep these vehicles in operation due to their high resale value in the secondary market.

The absence of a scrapping policy or stringent vehicle retirement regulations further exacerbates the problem. Many older vehicles, rather than being removed from circulation, continue to operate due to weak enforcement of emissions standards and lenient vehicle inspection policies. In contrast, countries with successful fleet renewal strategies, such as Japan and Germany, implement strict emission-based taxation, buyback programs, and incentives to encourage vehicle replacement.

The transition towards cleaner transport alternatives, particularly the adoption of EVs and alternative fuel vehicles, presents a viable pathway to reducing emissions. The global shift towards xEVs, which include battery electric vehicles (BEVs), hybrid electric vehicles (HEVs), and plug-in hybrid electric vehicles (PHEVs), has positioned electrification as a promising solution for reducing emissions from road transport. However, widespread EV adoption in Indonesia faces several challenges, including:

- High upfront costs: EVs remain significantly more expensive than ICEVs, making them less accessible to the average consumer.
- Limited charging infrastructure: The availability of EV charging stations remains low, especially outside major urban centres.
- Lack of local manufacturing and supply chain development: Indonesia is still in the early stages of developing a domestic EV production industry, limiting supply and increasing costs.

Despite these challenges, xEV adoption is gradually gaining momentum in the Indonesian market, particularly with government support in the form of tax incentives, subsidies, and charging infrastructure development initiatives. Additionally, alternative fuel solutions, such as biofuels and hydrogen fuel cell vehicles, present potential opportunities for reducing road transport emissions. The integration of these technologies into fleet renewal strategies will be a key aspect of long-term decarbonisation efforts.

This report is organised into five chapters, each building on the previous one to create a logical flow of analysis, evidence, and policy recommendation on fleet renewal strategies for Indonesia's road transport sector. Chapter I outlines the background, objectives, and scope of the study. It highlights Indonesia's climate commitments, the role of the transport sector in national emissions, and the urgency of developing a fleet renewal strategy. Chapter II provides a quantitative foundation for the study by examining structure of

Indonesia's road vehicle fleet and projecting its growth under a business-as-usual (BAU) scenario. Also, it includes an analysis of VKTs, energy demand, and emissions, followed by scenario development for vehicle retirement. The simulation exercises illustrate the effect of different retirement strategies on energy and emissions reduction. Further, the circular economy, material composition of retired vehicles mapping, recycling rates, and potential economic value of recovered materials are also addressed. Chapter III explores the regulatory environment that underpins fleet renewal and electrification efforts. It begins with a mapping of Indonesia's current transport and electrification policy framework including tax incentives, scrappage schemes, roadworthiness tests, and emission standards, which are reviewed to identify best practices. The chapter concludes with proposed regulatory improvements, including revisions to existing regulations and the design of fiscal instruments to support the establishment of a structured national scrappage programme. After the technical and regulatory assessments, Chapter IV evaluates the economic implications of different fleet renewal strategies. It elaborates a set of policy instruments (standards, subsidies, regulations, taxes, scrappage, and government purchases) and defines clean vehicle alternatives that are suitable for Indonesia, such as LCGCs, HEVs, PHEVs, and BEVs. Vehicle fuel economy projections are incorporated into the modelling. Using cost-benefit analysis (CBA), the chapter assesses various scenarios to compare the financial outcomes of fleet renewal, providing quantitative evidence for decision-making. The final chapter summarises the insights from the preceding analysis, drawing on the impacts of fleet renewal strategies, regulatory measures, and cost-benefit outcomes. It culminates into a set of policy recommendations to guide Indonesia in designing an effective and sustainable road transport fleet renewal strategy that balances economic feasibility, emissions reduction, and long-term energy security.

Chapter 2

Circular Economy Analysis

A sustainable approach to vehicle fleet renewal necessitates a thorough examination of material recovery and waste management from decommissioned vehicles. This chapter focuses on analysing Indonesia's current vehicle stock and exploring strategies for responsible vehicle retirement. A key component of Chapter II will be the identification of recyclable materials and reusable vehicle components, facilitating a circular economy model that minimises waste and maximises resource efficiency. By studying global best practices in vehicle dismantling and recycling, this work package will lay the foundation for a structured, environmentally responsible vehicle retirement process.

1. Analysis of Road Vehicle Fleet Structure and Projection of Vehicle Population (Business-As-Usual Scenario)

1.2. Projection of Vehicle Population

Vehicle population serves as a key indicator of transport demand and urban development, reflecting both economic growth and societal progress. The size of the vehicle population directly influences infrastructure planning, environmental policy, and traffic management strategies. To project future vehicle population, we employed a modified Gompertz diffusion model (Lu et al., 2017), which enhances forecasting accuracy by accounting for market saturation and fluctuations in vehicle ownership trends. The equation of modified Gompertz diffusion model is presented in Eq1. Where X_{g_t} is the quantity of vehicle ownership per 1,000 people in year t , and g_t is GDP per capita in year t while a , b , c are parameters of the function to be calculated (in our simulation, we get each value of a , b , and c as follows: 354, -2,378 and -0,00007965, respectively). The calculation from the Gompertz diffusion model was also further incorporated into the recent vehicle population by the Central Bureau of Statistics (BPS) Indonesia and the sales data from the Indonesian Automobile Industry Data (GAIKINDO) to better reflect the actual vehicle population. Vehicle data up to 2013 were sourced from BPS, after which annual GAIKINDO vehicle sales figures were incorporated to extend the dataset through 2024.

$$X_{g_t} = a \cdot \exp(-b \cdot \exp(-c \cdot g_t)) \quad (1)$$

We first simulated the growth of the entire vehicle population, including older vehicles that may have limited functionality due to age. The forecast was carried out until 2035 to first establish a solid data foundation for predicting the effects of the vehicle retirement scenario, enabling its use for long-term forecasting.

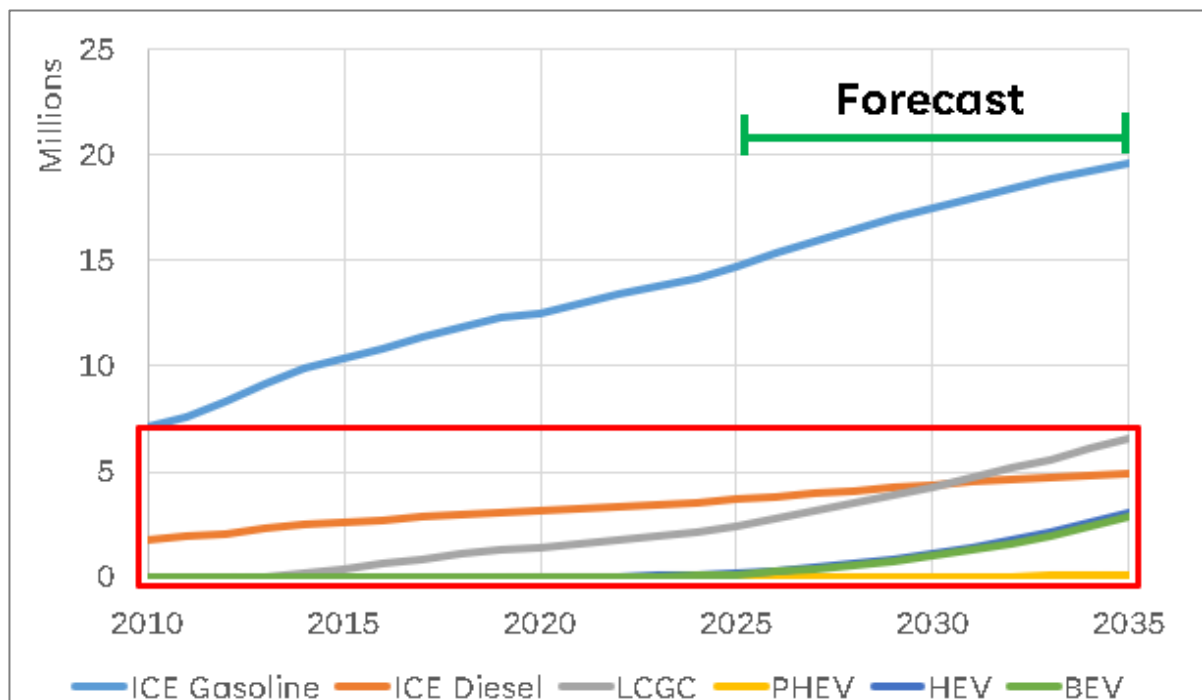
Figure 2.1 illustrates this projected passenger vehicle population from 2010 to 2035, segmented by vehicle type: internal combustion gasoline engine (ICE_G) vehicles, internal combustion diesel engine (ICE_D) vehicles, low-cost green cars (LCGCs), plug-in hybrid

electric vehicles (PHEVs), hybrid electric vehicles (HEVs), and battery electric vehicles (BEVs). ICE_G vehicles dominate the forecast, showing a steady increase from approximately 7 million in 2010 to nearly 20 million by 2035. This trend reflects a continued strong reliance on gasoline-powered ICEVs.

ICE_D vehicles exhibit modest growth, rising gradually from around 1.5 million to 5 million over the same period. The other vehicle types – highlighted in the red box in Figure 2.1 – represent emerging and alternative fuel technologies, all of which begin with near-zero adoption in 2010. Amongst these, LCGCs show a significant upward trend starting from 2010, gaining popularity steadily over time. By 2035, our forecast suggests that LCGCs may surpass ICE_D vehicles, PHEVs, HEVs, and BEVs in total population due to the changes in sales composition (Figure 2.2).

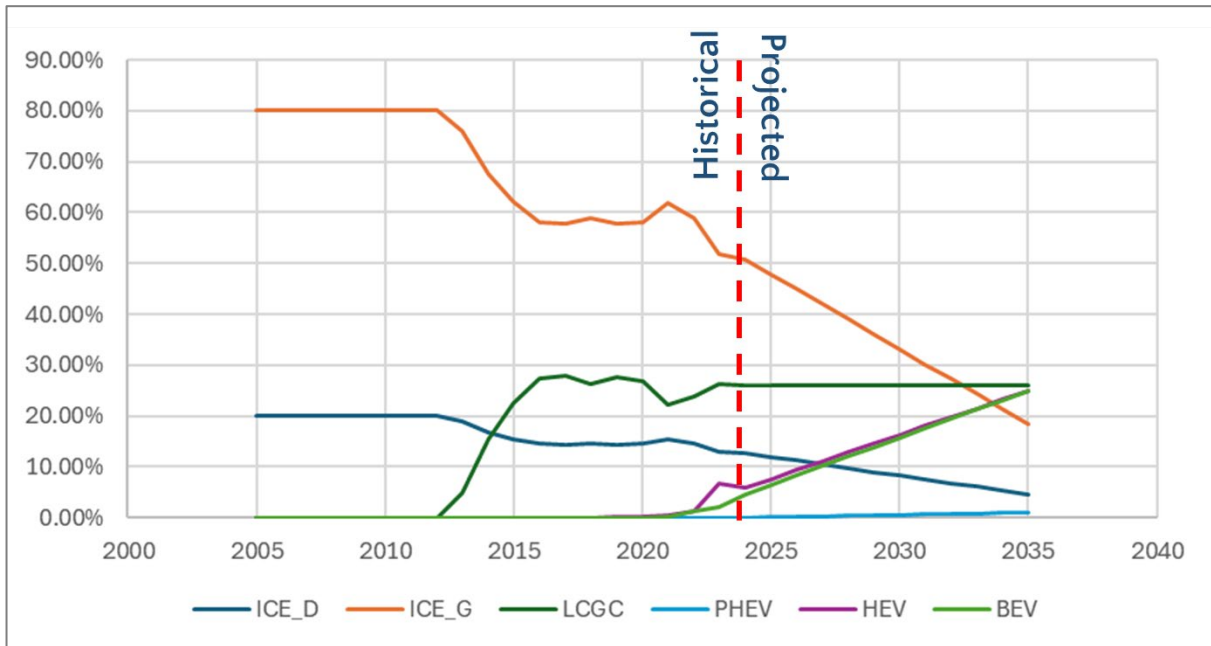
In summary, while conventional ICE_G vehicles remain dominant throughout the projection period, the graph indicates a clear and growing shift towards more environmentally friendly vehicle technologies, particularly LCGCs, HEVs, and BEVs.

Figure 2.1. Forecast of Total Passenger Vehicle Population



Source: Created by author by using data from BPS and GAIKINDO.

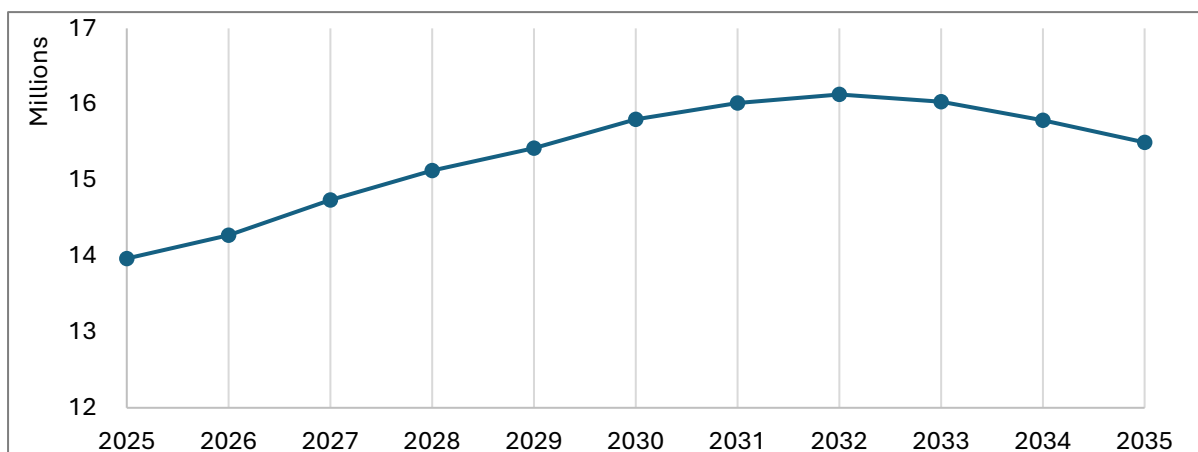
Figure 2.2. Composition of Vehicle Sales
(Historical Data Incorporated from BPS Indonesia and GAIKINDO)



Source: Historical data incorporated from BPS Indonesia and GAIKINDO.

However, as vehicles age, their functionality tends to decline and eventually cease, thus being naturally retired. We have therefore also calculated and modelled the size of the active vehicle population. This model assumes that by 20 years of usage, vehicles will be rendered unusable due to wear and prohibitive cost of maintaining function. The model assumes that 20% of these naturally retired vehicles will be replaced by newer vehicles. Figure 2.3 illustrates the trend of active vehicle population from 2025 to 2035, measured in millions of vehicles. It shows a gradual increase in the active vehicle population from approximately 14 million in 2025, peaking at around 16.1 million in 2032. After reaching this peak, the number slightly declines to about 15.5 million by 2035. This pattern indicates that the number of vehicles reaching obsolescence are more than vehicles purchased.

Figure 2.3. Active Vehicle Population (Business-As-Usual Scenario)



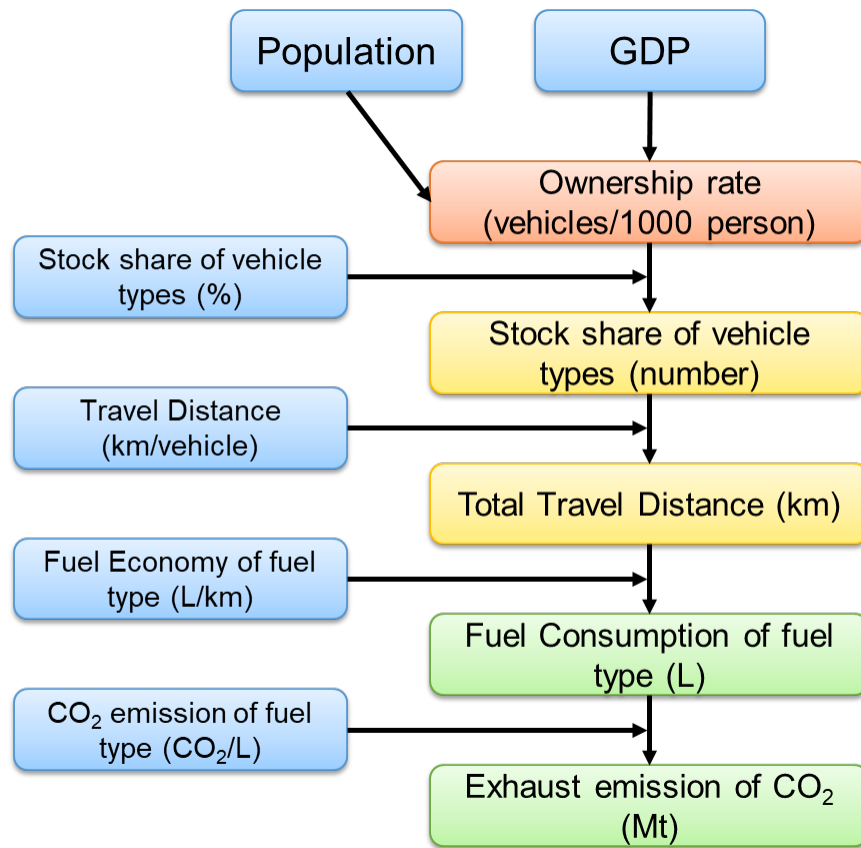
Source: Created by the author using data from BPS and GAIKINDO.

1.3. Analysis of Vehicle Kilometre Travelled, Energy Consumption, and Emissions

To support a comprehensive understanding of emissions from Indonesia's road transport sector and to explore potential fleet renewal strategies, a systematic calculation framework was developed using population and economic indicators Figure 2.4. The model begins by estimating the vehicle ownership rate, defined as the number of vehicles per 1,000 people. This rate is calculated using population and GDP data, which reflect both economic capacity and mobility demand.

As discussed in Section 1.1, a modified Gompertz diffusion model was employed to project future vehicle populations based on current vehicle data. From the ownership rate, the model estimates the stock share of vehicles by fuel type – both as percentages and absolute numbers – segmented into ICEVs, HEVs, PHEVs, BEVs, and LCGCs. This step provides insights into the current fleet composition and how it may change under various policy scenarios.

Figure 2.4. Schematic Diagram of Model Algorithm for Calculating Total Vehicle Kilometre, Fuel Consumption, and Emissions



Source: Widyaparaga et al. (2017).

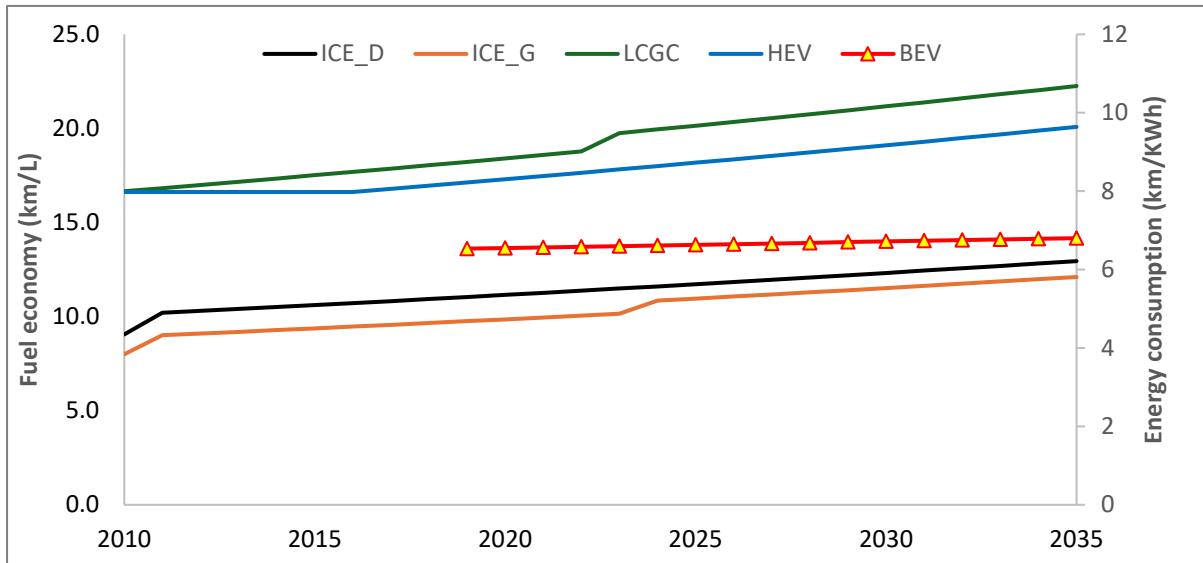
Furthermore, we incorporate the average travel distance per vehicle, which, when combined with the vehicle stock, enables the calculation of the total travel distance (in kilometres) for each vehicle type. This measure of total travel activity is essential for estimating fuel consumption. By applying fuel economy values (litres per kilometre) specific to each vehicle and fuel type, we calculate the overall fuel consumption. This calculation forms the basis not only for estimating energy demand but also for assessing the government's fuel subsidy burden and the infrastructure investments required – particularly in the context of EV adoption.

The resulting equation for total energy consumption is thus:

$$E = \sum_{i=1}^6 N_i \cdot SFC_i \cdot D$$

Where N_i is the number of vehicles and SFC_i is the specific energy consumption for the corresponding vehicle type (i). The subscript i represents each of the six vehicle types in this study. D is the annual travel distance which is 18,000 km/year.

Figure 2.5. Projection of Fuel Economy and Energy Consumption for Clean Vehicle Alternatives based on Production Year



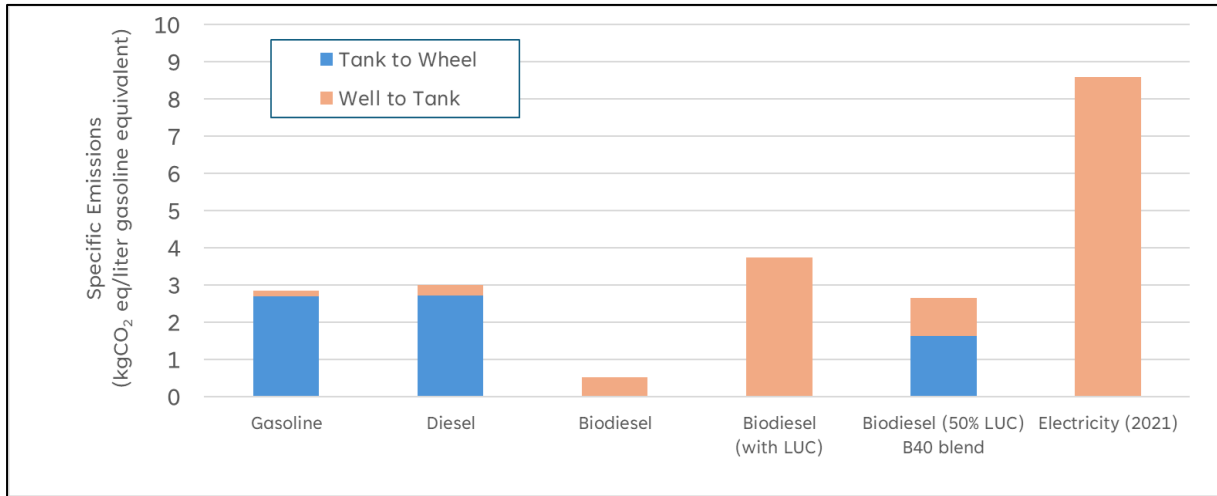
Sources: Topgear (2023); Gridoto (2023); Autodeal (2024); Electric Vehicle Database (n.d.-a); Otosia (2012); Electric Vehicle Database (n.d.-b).

The model assumes natural retirement of vehicles once they reach 20 years of age from the year of production. Fleet renewal scenarios involve the voluntary retirement of vehicles at 15 years. As such, fuel efficiency must be tracked for each production batch. The average specific energy consumption for yearly production batches of cars is shown in Figure 2.5. An annual 1% improvement in fuel efficiency is assumed.

Next, from an environmental perspective, we use CO₂ emission factors (in CO₂ per litre of gasoline equivalent) for each fuel type to quantify exhaust CO₂ emissions in metric tonnes (Mt). This emissions output is critical for assessing the sector's contribution to national carbon inventories and for identifying the potential impact of fleet renewal strategies. Figure 2.6 displays the specific emissions for fuels modelled in this study. Well-to-tank emissions refer to emissions produced during the production and distribution of fuel, while tank-to-wheel (TTW) emissions are emitted during the operation of the vehicle. Biodiesel is assumed to be carbon neutral; thus, its TTW emissions are set to zero. In addition, specific emissions were calculated for biodiesel sourced from land-use-change (LUC) plantations. The final emissions for B40 blend biodiesel reflect a 1:1 blend of LUC and non-LUC biodiesel.

The model thus integrates population growth, vehicle adoption trends, fuel economy improvements, and resulting energy and emission outcomes. This allows policymakers to simulate various scenarios and evaluate the benefits of introducing cleaner vehicle technologies and retiring older, inefficient vehicles.

Figure 2.6. Specific Emissions (kgCO₂eq/litre gasoline equivalent) for Passenger Vehicle Fuels



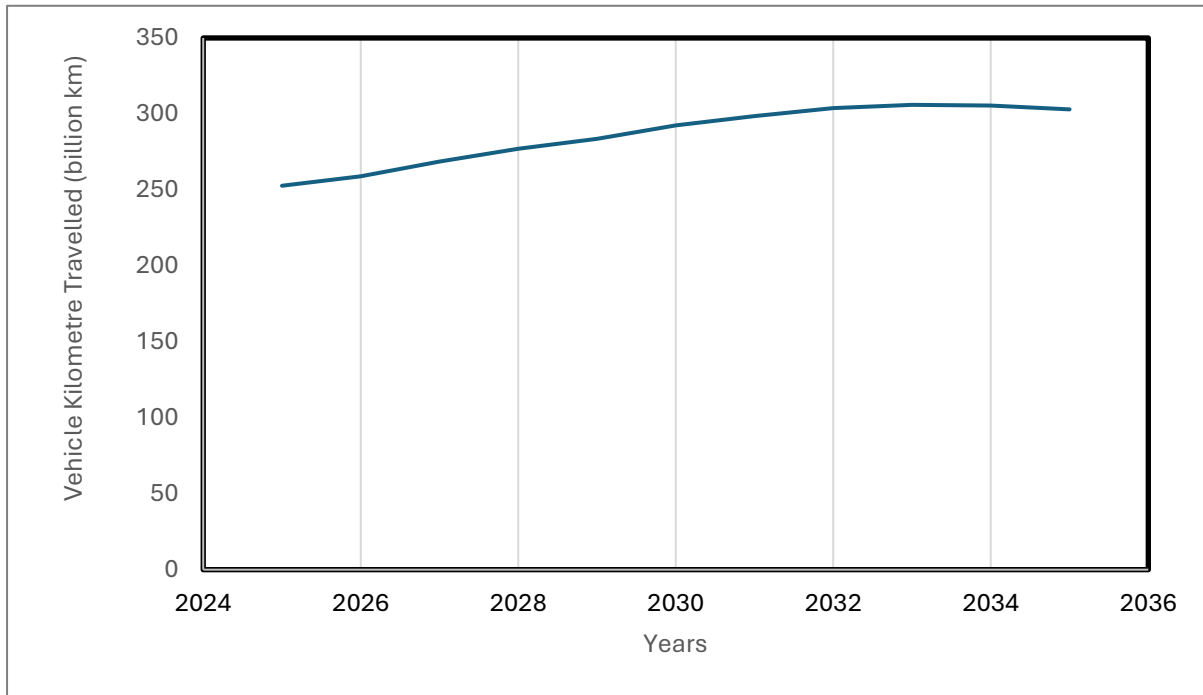
Source: Restianti and Gheewala (2012); Wirawan (2009).

The total VKT for each type is projected from 2024 to 2035 and expressed in billions of kilometres, using the following equation:

$$VKT = \sum_{i=1}^6 N_i \cdot D$$

The number of vehicles is projected for each internal combustion gasoline engine (ICE_G), ICE_D, LCGC, HEV, PHEV, BEV type and the yearly average mileage per vehicle is assumed to be 18,000 km. Figure 2.7 illustrates a steady upward trend in VKT starting at around 250 billion km in 2024, gradually increasing to approximately 305 billion km by 2032. After this peak, the graph shows a slight plateau, levelling off just below 305 billion km towards 2035. This pattern suggests a growing demand for vehicle travel over the period, reflecting increasing mobility needs or economic growth, followed by a stabilisation phase potentially due to saturation, improvements in transportation efficiency, or policy interventions aimed at controlling travel demand.

Figure 2.7. Vehicle Kilometres Travelled (in billion kilometres) Business-As-Usual Scenario



Source: Authors.

2. Scenario Development and Modelling of Vehicle Retirement (by Scenario)

To assess the potential impact of policy interventions on reducing emissions from Indonesia's road transport sector, a scenario-based modelling approach was developed. Three policy packages were constructed to simulate strategies for accelerating vehicle fleet renewal and promoting the transition to cleaner vehicles.

The first policy package is a voluntary scrappage programme offering financial incentives to encourage the retirement of older vehicles. We have prepared two variations of this package: (A), a scrappage programme for 2 million vehicles held once in 2030; and (B), a gradual annual scrappage programme implemented from 2030 to 2035 also for 2 million vehicles.

The second policy package is a tax on new ICEV purchases. This policy aims to discourage continued adoption of ICE vehicles.

The third policy package combines both approaches – scrappage incentives and ICEV taxation – to explore the potential for stronger and more integrated policy outcomes.

2.1. Simulation A Series

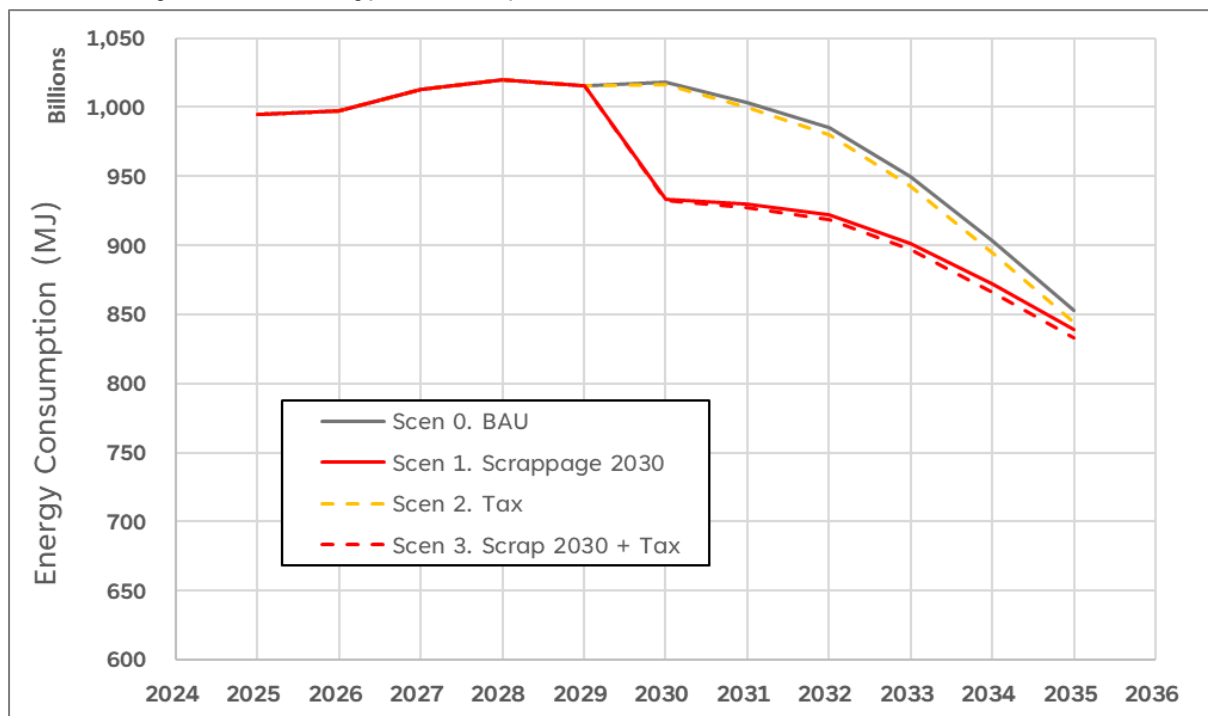
This simulation presents a series of scenarios in which a voluntary scrappage programme is introduced in 2030 for vehicles aged 15 years and above. Approximately 2 million vehicles are expected to be scrapped, and a tax increment on the purchase of ICEVs is

applied. The scenarios are formulated according to the policy packages outlined earlier and consist of the following:

- Scenario 1 (Scrappage 2030)
A scrappage programme is introduced in 2030 where vehicle owners can voluntarily submit their vehicles for retirement and scrappage. Vehicle owners will receive Rp10 million.
- Scenario 2 (Tax)
The tax reform simulates an increase in the annual vehicle tax (PKB) coefficient from 1.05 to 1.5 (increase by 42.86%).
- Scenario 3 (Scrappage 2030 + Tax)
Combines Scenarios 1 and 2

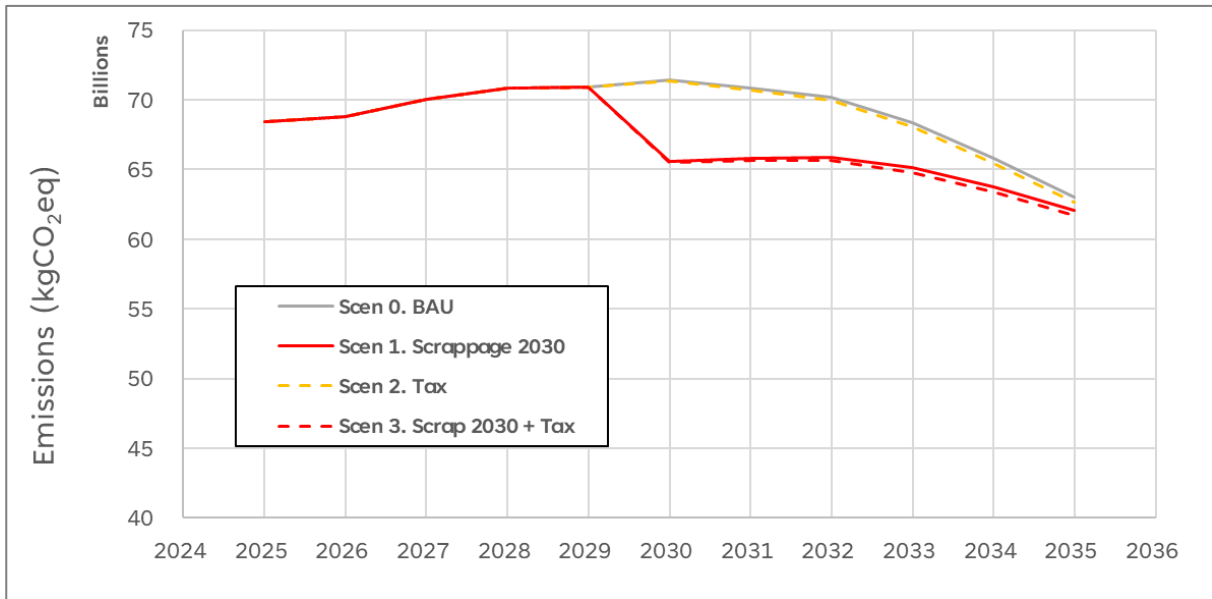
Figure 2.8 and Figure 2.9 show the fuel consumption and emissions for Scenarios 1 to 3, respectively. Each scrapped vehicle is retired and replaced by a new one. Because the replacement ratio is 1:1, the scrappage programme does not reduce the total number of vehicles in the fleet. In 2030, for both Scenario 1 and 3, the programme results in a steep drop in energy consumption of 8.4%. A similar reduction of 8.4% is observed for carbon emissions in the same year. Both scenarios maintain lower emissions than the BAU case through to 2035. However, the differences in energy consumption and emissions between Scenarios 1 and 3 and the BAU case diminish gradually over time. Therefore, to sustain lower levels of energy use and emissions, periodic scrappage may be required.

Figure 2.8. Energy Consumption for BAU and Simulation A Scenarios



Source: Authors.

Figure 2.9. Carbon Emissions for BAU and Simulation A Scenarios



Source: Authors.

The figures also show that the effect of tax, which discourages ICEV purchase, contributes very little to both emission and energy consumption reduction. This occurs in both scenarios with and without scrappage. By 2035, without scrappage, the introduction of tax reduces annual energy consumption by 1.1%. Meanwhile with scrappage, in 2030, the reduction due to tax is even less at 0.9%. Regarding emissions, in 2035, without scrappage and with scrappage the reduction due to tax is 1.5% and 1.6%, respectively.

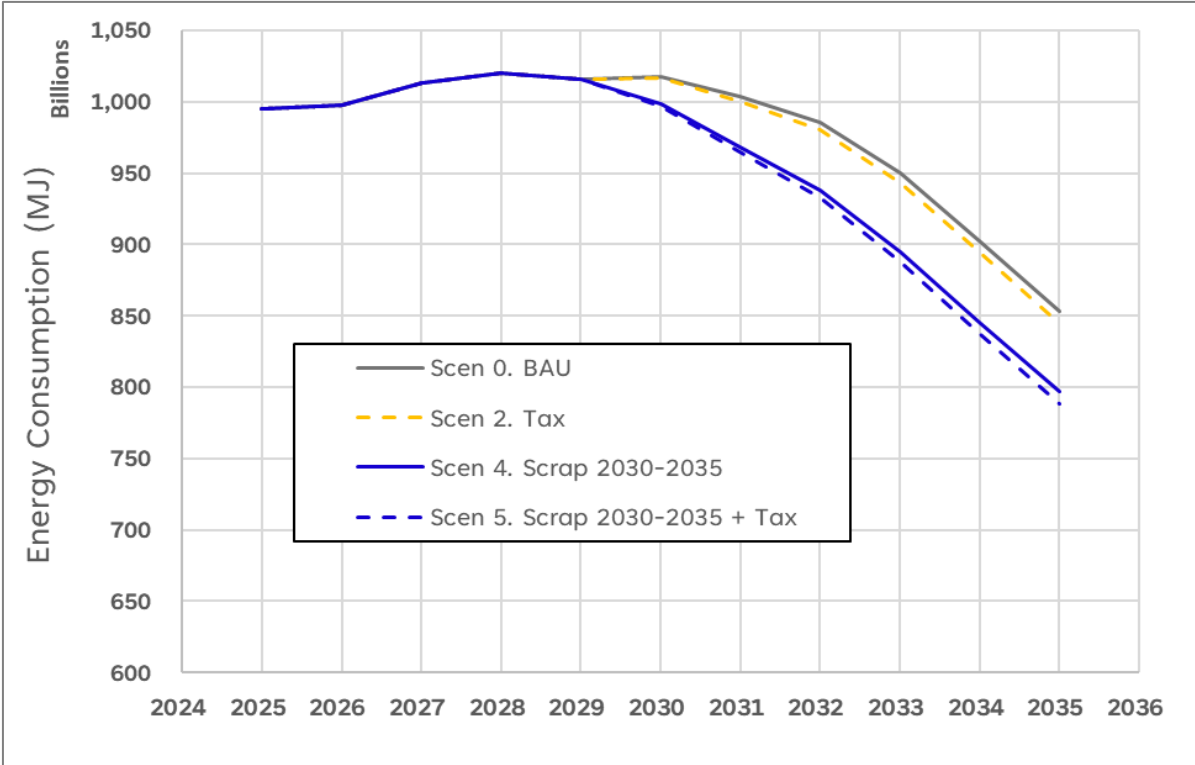
2.2. Simulation B Series

The Simulation B series simulates conditions in which the scrappage programme is introduced and implemented annually from 2030 to 2035, with the total number of voluntarily retired vehicles kept the same as in the Simulation A series.

The series consists of the following scenarios formulated according to previously specified policy packages:

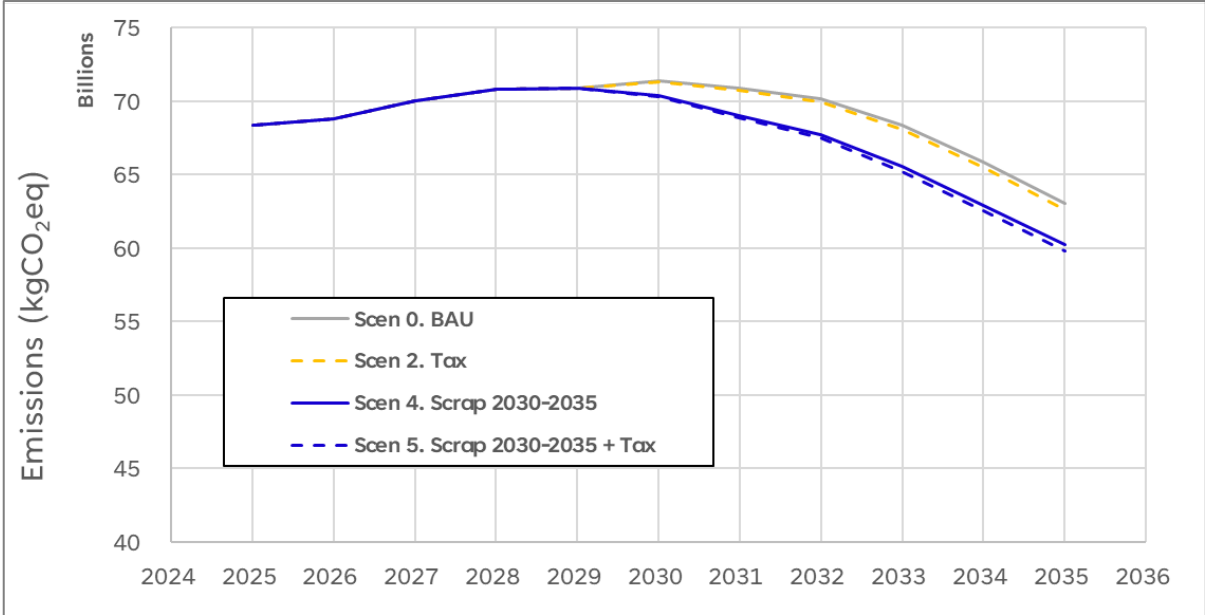
- Scenario 4 (Scrappage 2030–2035)
A scrappage programme is introduced in 2030, allowing vehicle owners to voluntarily submit their vehicles for retirement. However, this scenario differs from Scenario 1 in that the programme is implemented annually from 2030–2035, while keeping the total number of scrapped vehicles equal to that in Scenario 1. Vehicle owners again receive Rp10 million as compensation for each scrapped vehicle.
- Scenario 5 (Scrappage 2030–2035 + Tax)
Combined Scenario 4 and Scenario 2 therefore incorporates a tax disincentive for ICEV purchases alongside an annual scrappage programme implemented from 2030 to 2035.

Figure 2.10. Energy Consumption for BAU and Simulation B Scenarios



Source: Authors.

Figure 2.11. Carbon Emissions for BAU and Simulation B Scenarios

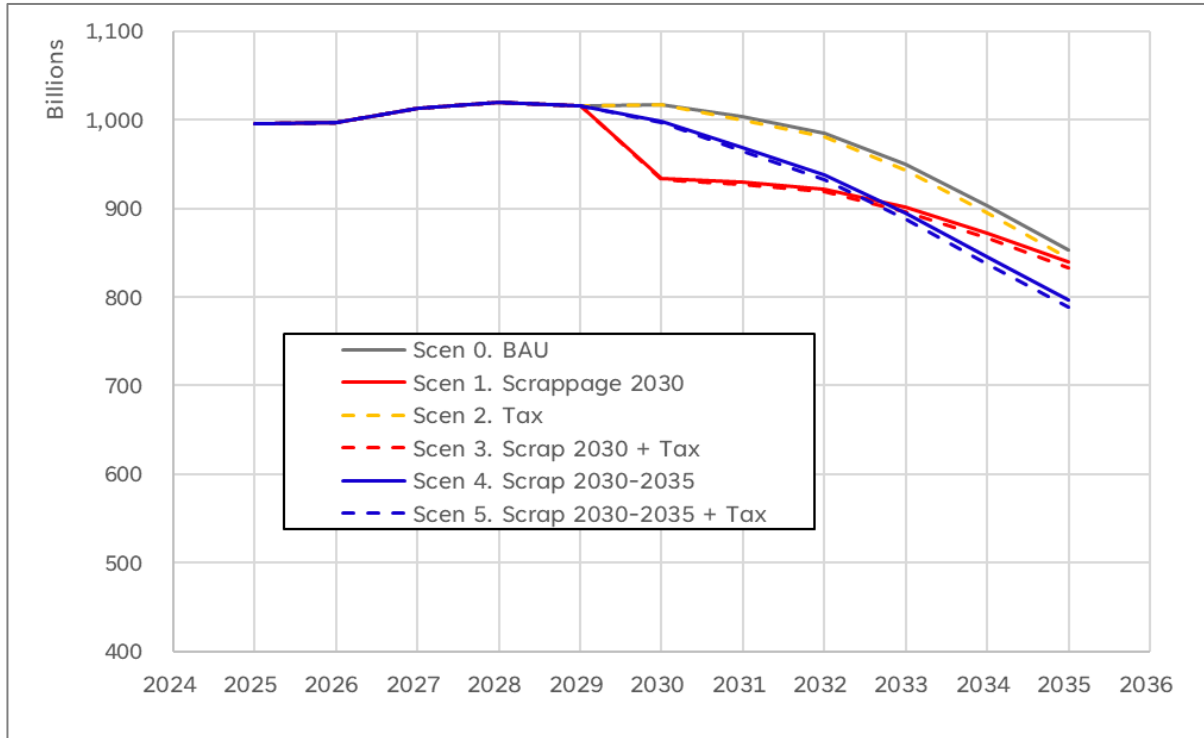


Source: Authors.

Figure 2.10 and Figure 2.11 present the fuel consumption and emissions for the BAU scenario and Simulation B scenario, respectively. As in the Simulation A series, each scrapped vehicle is retired and replaced by a new one. However, in Simulation B, vehicle

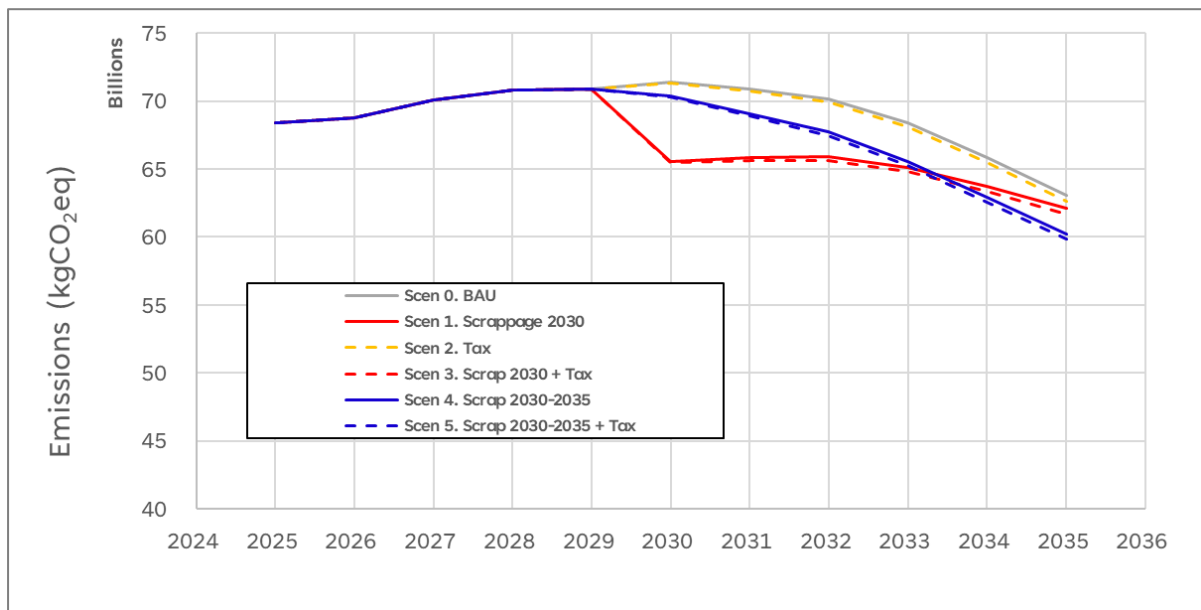
scrapping takes place annually from 2030 to 2035, with the total number of scrapped vehicles matching that of Simulation A.

Figure 2.12. Energy Consumption under the BAU, Simulation A, and Simulation B Scenarios



Source: Authors.

Figure 2.13. Carbon Emissions for the BAU, Simulation A, and Simulation B Scenarios



Source: Authors.

Figure 2.12 and Figure 2.13 show the energy consumption and emissions for all scenarios. A comparison of Simulations A and B reveals that annual scrappage from 2030 to 2035 (Scenario 4) results in lower annual energy consumption and emissions in 2035 compared with a one-off scrappage event in 2030 (Scenario 1). However, over the long term, an earlier one-off scrappage programme delivers greater overall benefits than a gradual, annual scrappage programme with regard to total emissions and energy consumption.

3. Circularity Mapping of Retired Vehicle and Composing Materials

To strengthen Indonesia's fleet renewal strategy in achieving emission reduction and energy efficiency targets, this analysis adopts a circular economy perspective by mapping the material composition and recycling potential value of two- and four-wheeled vehicles. This part presents a comparative analysis of the weight composition of various vehicle types, including ICEVs, BEVs, HEVs, PHEVs, and FCEVs for passenger cars, as well as ICEVs and BEVs for motorcycles. The analysis focuses on evaluating the recyclability of constituent materials and estimating the corresponding economic value derived from material recovery. The circularity mapping process consists of four sequential stages:

- 1) Identification and classification of key materials for each vehicle type
- 2) Quantification of the weight percentage of each material
- 3) Assessment of material recyclability based on current recycling technologies
- 4) Estimation of the economic value of recycled materials.

All data are obtained from industry reports, peer-reviewed material composition studies, and market price references for recycled materials, as detailed in Table 2.1.

3.1. Passenger Car Material Composition and Recycling Rate

The recyclability and economic value of passenger car components across different types are summarised in Table 2.1.

Table 2.1 Material Composition, Recyclability Rate, and Economic Value of Retired Passenger Vehicles by Type

Material	ICEV (~1402 kg)	BEV (~1716 kg)	HEV (~1491 kg)	PHEV (~1539 kg)	FCEV (~1627 kg)	Recycle Rate	Value of Money/kg (Rp)
Steel	59.24%	44.90%	60.40%	52.48%	52.14%	96–100%	3.226
Stainless steel	N/A	N/A	N/A	N/A	3.18%	95%	21.225
Plastic	15.20%	11.19%	10.12%	8.93%	14.28%	91%	6.792
Aluminium, cast	8.15%	8.21%	4.53%	9.71%	7.42%	91%	6.792

Material	ICEV (~1402 kg)	BEV (~1716 kg)	HEV (~1491 kg)	PHEV (~1539 kg)	FCEV (~1627 kg)	Recycle Rate	Value of Money/kg (Rp)
Aluminium, wrought	4.59%	6.26%	N/A	9.71%	3.68%	91%	6.792
Aluminium, forged	N/A	N/A	2.45%	9.71%	N/A	91%	6.792
Rubber	3.87%	2.55%	1.57%	1.65%	3.56%	3–15%	3.396
Copper/Brass	2.35%	6.50%	4.27%	4.65%	3.39%	95%	67.920
Glass	2.32%	1.72%	2.40%	N/A	2.09%	100%	1.189
Cast iron	1.87%	N/A	5.18%	10.05%	0.36%	100%	3.226
Fibreglass	0.02%	0.01%	0.02%	2.75%	0.01%	13%	4.585
Lead	0.81%	0.40%	0.78%	0.75%	0.42%	100%	32.941
Graphite/Carbon	N/A	4.60%	0.32%	1.43%	N/A	1%	23.093
Active materials	N/A	8.71%	0.72%	1.47%	N/A	LAB (99%)* LIB (1–5%)* NiMH (50–60%)*	after being multiplied by recycle rate LFP: 1,297 NCM: 3,669
Nickel	N/A	N/A	N/A	0.73%	0.83%	58–62%	255.379
Rare earth element (REE)	N/A	N/A	N/A	N/A	0.18%	1%	348.090
Glass fibre-reinforced plastic	0.86%	0.36%	N/A	N/A	1.02%	13%	4.584
Carbon fibre-reinforced plastic	N/A	N/A	N/A	N/A	5.49%	20%	348.090
Electrolyte	N/A	2.08%	0.30%	1.07%	N/A	90%	2.547
Other battery-related materials**	0.26%	1.60%	1.83%	0.51%	0.23%	N/A	N/A
Others**	0.45%	0.91%	5.10%	3.83%	1.72%	N/A	N/A

LAB = lead-acid battery, LFP = lithium-iron phosphate, LIB = lithium-ion battery, NiMH = Nickel-metal hydride battery.

Note:

**Components weighing no more than 1 kilogram and have low recyclability and low economic value are typically classified as others.

Sources: Composition: Ahmed et al., (2022); Rashid and Pagone (2023); Zhang et al. (2024).

Recycle Rate: Merkisz-Guranowska (2018); Chen et al. (2019); Bai et al. (2020); Gopalraj and Karki (2020); Etude et al. (2024)].

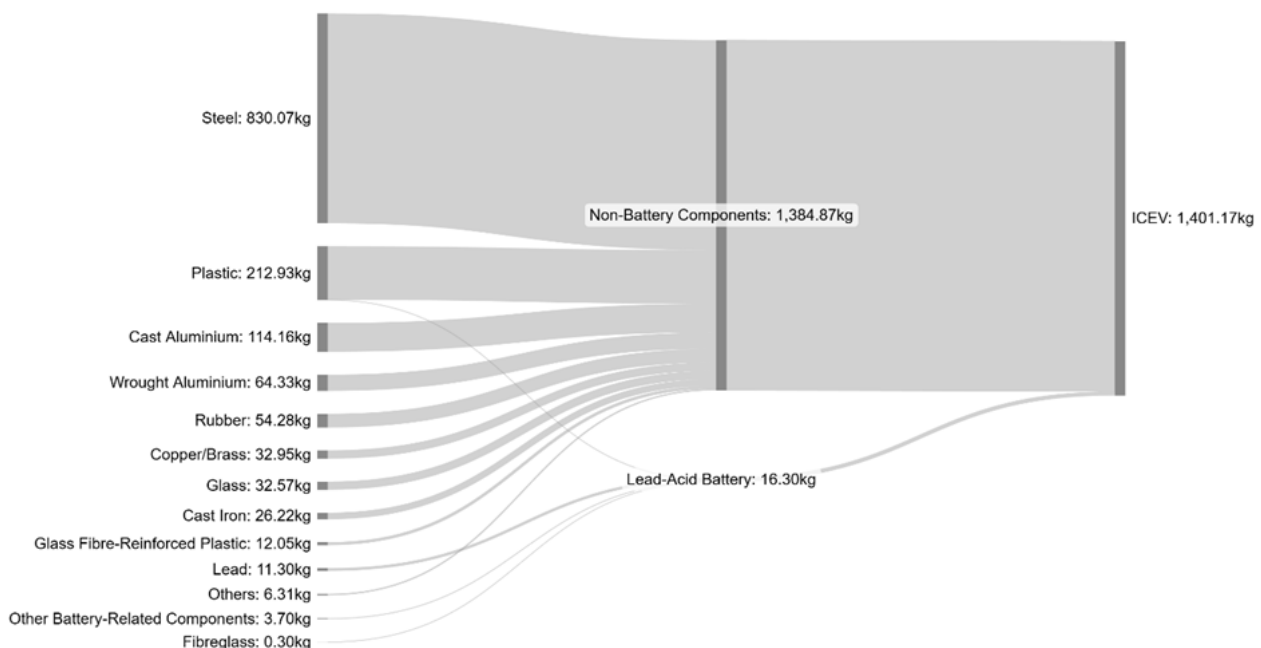
Economic Value: Cousins et al. (2019); Shehab et al. (2021); Arnold et al. (2021); Shafique et al. (2022); Chinwego et al. (2025).

Table 2.1 presents a comparative circularity mapping of key materials found in retired passenger vehicles across five vehicle types: ICEVs, BEVs, HEVs, PHEVs, and FCEVs. It summarises the material composition (in kilogram), recyclability rates, and economic value per kilogram (in Rp) for each material. Conventional vehicles (ICEVs) primarily consist of steel, aluminium, and plastic, while electrified vehicles – particularly BEVs, PHEVs, and FCEVs – contain additional high-value materials such as copper, nickel, cobalt, lithium, and REEs, mainly associated with battery and fuel cell systems. The recyclability rates for metals are generally high (up to 95%), offering substantial economic recovery potential, especially for copper and cobalt. However, some advanced materials, despite their high market value, pose recycling challenges due to technological and infrastructure limitations. This comparison highlights the shifting material profile of modern vehicles and underscores the importance of tailored recycling strategies for future sustainable mobility.

To further illustrate the material flow in retired vehicles, a Sankey diagram is generated. These diagrams (Figures 2.14–2.18) visualise the distribution of total component weight in descending order, highlight the proportional allocation of materials across various components, and distinguish between battery-related and non-battery material compositions.

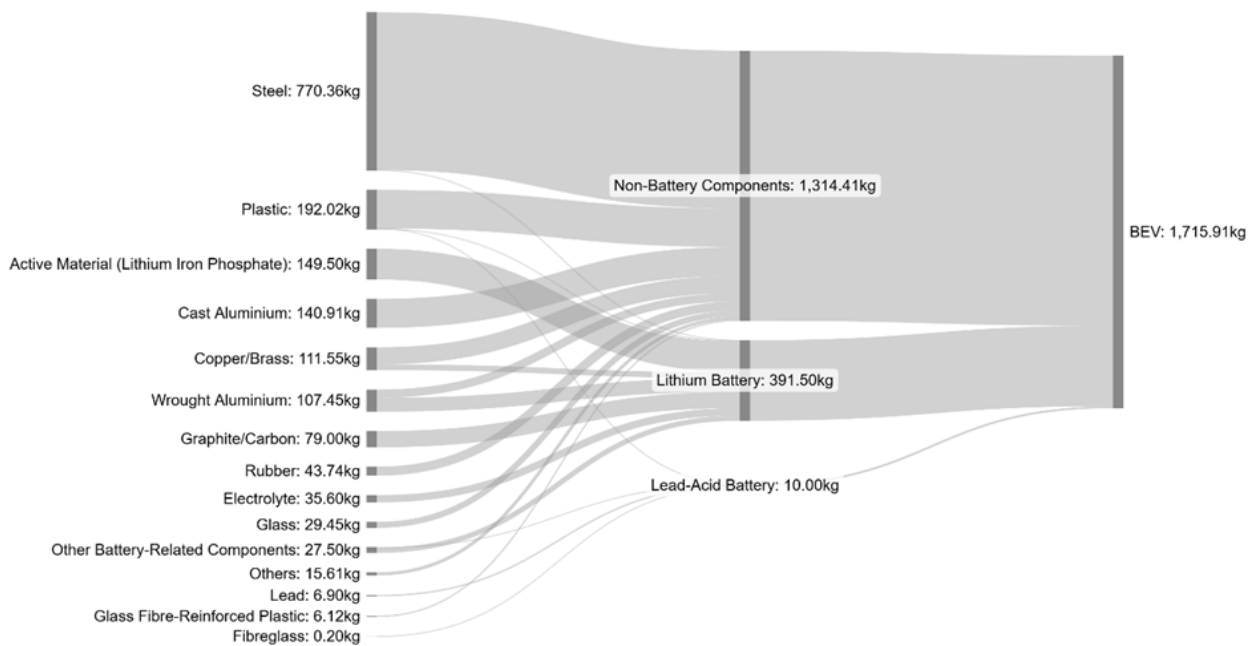
Figure 2.14 shows that a typical ICEV (1,401.17 kg) is largely made of steel, with significant portions of plastics and aluminium, while rubber, copper, glass, and other materials contribute smaller shares. Nearly all the weight comes from non-battery components, with the lead-acid battery adding only about 1.2%, emphasising the vehicle’s steel-centric design and the minor role of batteries in ICEVs.

Figure 2.14. Sankey Diagram for Internal Combustion Engine Passenger Car



Source: Authors.

Figure 2.15. Sankey Diagram for Battery Electric Passenger Car

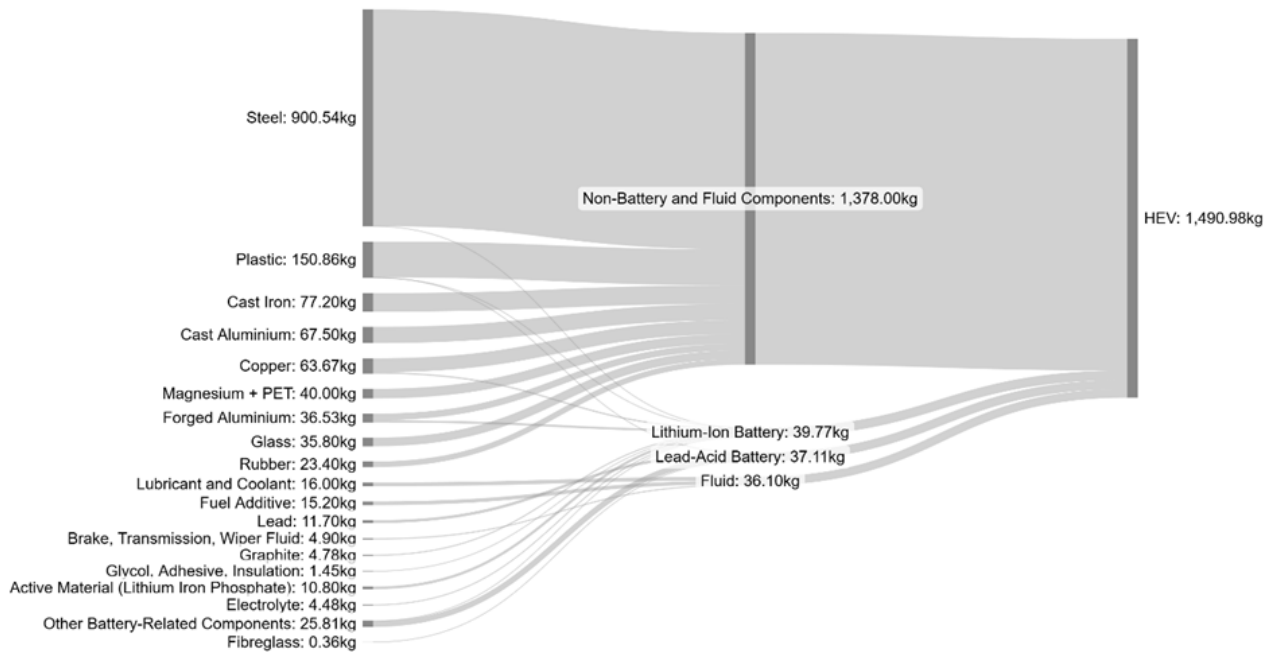


Source: Authors.

Figure 2.15 shows the material composition of a BEV (1,715.91 kg), where steel (770.36 kg) is still dominant, but a large share comes from the lithium battery (391.50 kg, ~23% of total mass), containing lithium iron phosphate, graphite, copper, aluminium, and electrolyte. Non-battery components weigh 1,314.41 kg, while a small lead-acid battery adds 10 kg. Compared to ICEVs, BEVs are heavier overall and more battery-centric, with specialised materials playing a key role alongside steel, aluminium, and plastics.

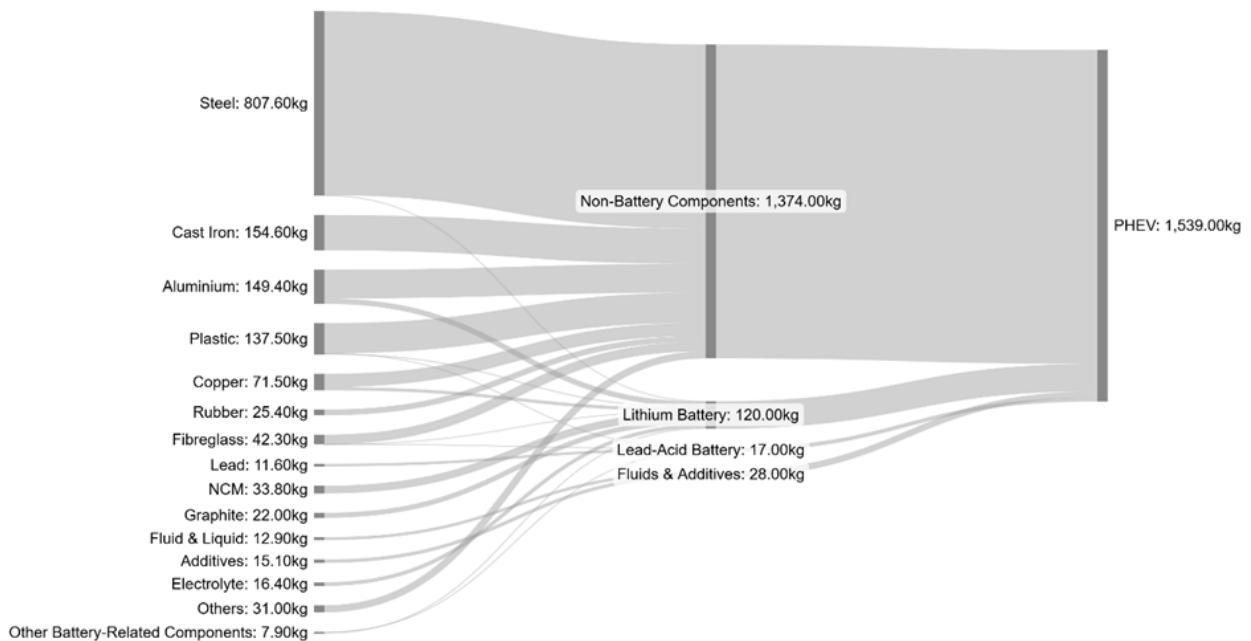
Figure 2.16 shows the material composition of an HEV weighing 1,490.97 kg, dominated by steel (900.54 kg) along with plastics, cast iron, aluminium, copper, and other materials. Most of the weight (1,378.00 kg) comes from non-battery and fluid components, while the lithium-ion battery (39.76 kg), lead-acid battery (37.11 kg), and fluids (36.10 kg) make up only a small fraction. Compared to an ICEV, HEV is slightly heavier due to the additional lithium-ion battery, but still strongly steel-centric. In contrast to a BEV, which dedicates nearly a quarter of its mass to a large traction battery, the HEV's battery share is minimal, highlighting its intermediate position between the steel-heavy ICEV and the battery-centric BEV.

Figure 2.16. Sankey Diagram for Hybrid Electric Passenger Car



Source: Authors.

Figure 2.17. Sankey Diagram for Plug-In Hybrid Electric Passenger Car

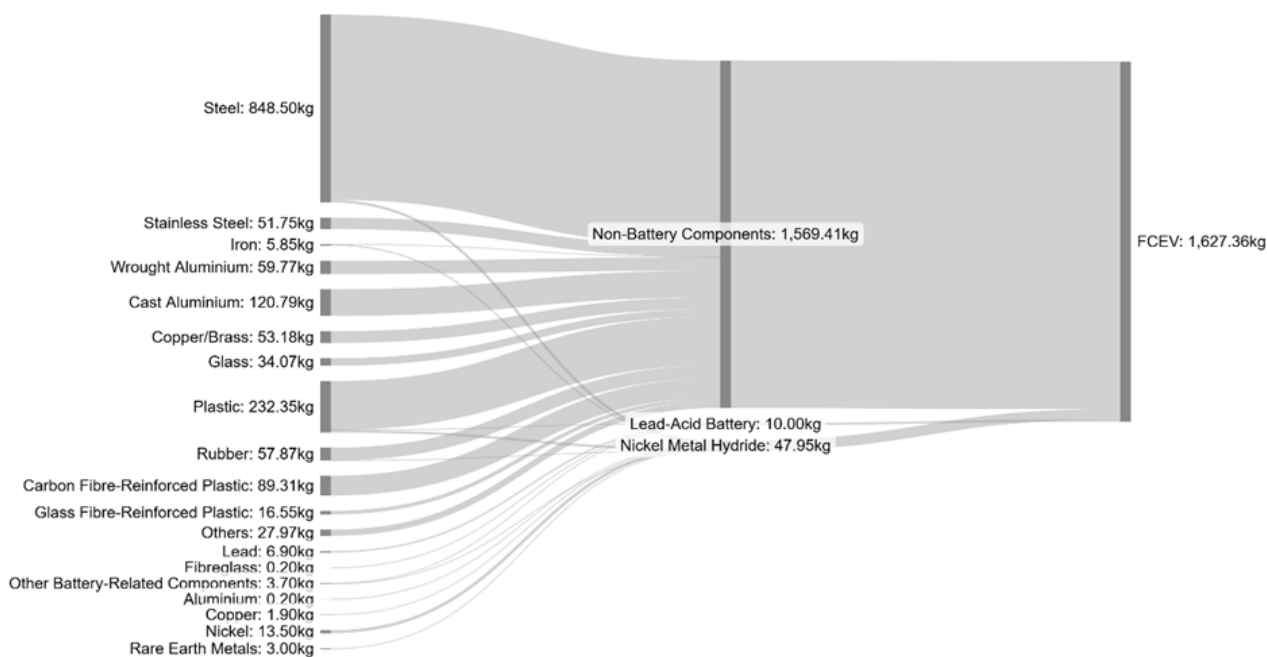


Source: Authors.

Figure 2.17 illustrates the material composition of a PHEV weighing 1,539.0 kg, with the bulk of the mass in non-battery components (1,374.0 kg). These are dominated by steel (807.6 kg), followed by cast iron, aluminium, plastics, copper, fibreglass, and other materials. The vehicle includes a lithium battery (120 kg), a lead-acid battery (17 kg), and fluids and additives (28 kg), making the battery share much larger than in conventional

HEVs but smaller than in BEVs. Compared to ICEVs, PHEVs are heavier due to their sizeable lithium battery, while compared to BEVs, they rely less on batteries and remain more steel-heavy, reflecting their hybrid nature that balances combustion and electric power.

Figure 2.18. Sankey Diagram for Fuel Cell Electric Passenger Car



Source: Authors.

Figure 2.18 shows an FCEV weighing 1,627.36 kg, mainly steel (848.50 kg), plastics, and aluminium, with smaller shares from carbon fibre, copper, and rubber. It uses only small batteries (47.95 kg Ni-MH and 10.00 kg lead-acid) but requires specialised materials like REEs and carbon paper for the fuel cell. Compared with an ICEV, it is slightly heavier but replaces the engine with a fuel cell. Unlike a BEV or PHEV, it avoids large lithium batteries; and compared with an HEV, it carries more hydrogen-related components but less battery mass, highlighting its hydrogen-based design.

Overall, Figures 2.14–2.18 show that structural components dominate the material mass distribution, with steel accounting for about 44% to 60% and plastics for about 10% to 15% of total vehicle weight. Notably, ICEVs contain the highest share of plastics (15%), while HEVs have the highest share of steel (60%).

3.2. Passenger Car Material Economic Value

Table 2.2 summarises the total potential economic value of recycled materials. It is calculated by (i) determining the recycled material weight by multiplying the material weight (kg) by the midpoint recycling rate (%), and (ii) calculating the potential economic value (in Rp) using the formula:

Potential Economic Value (Rp) = Recycled Material Weight (kg) × Economic Value per kg (Rp)

Table 2.2. Estimated Economic Value of Recycled Materials Amongst Five Passenger Vehicle Types

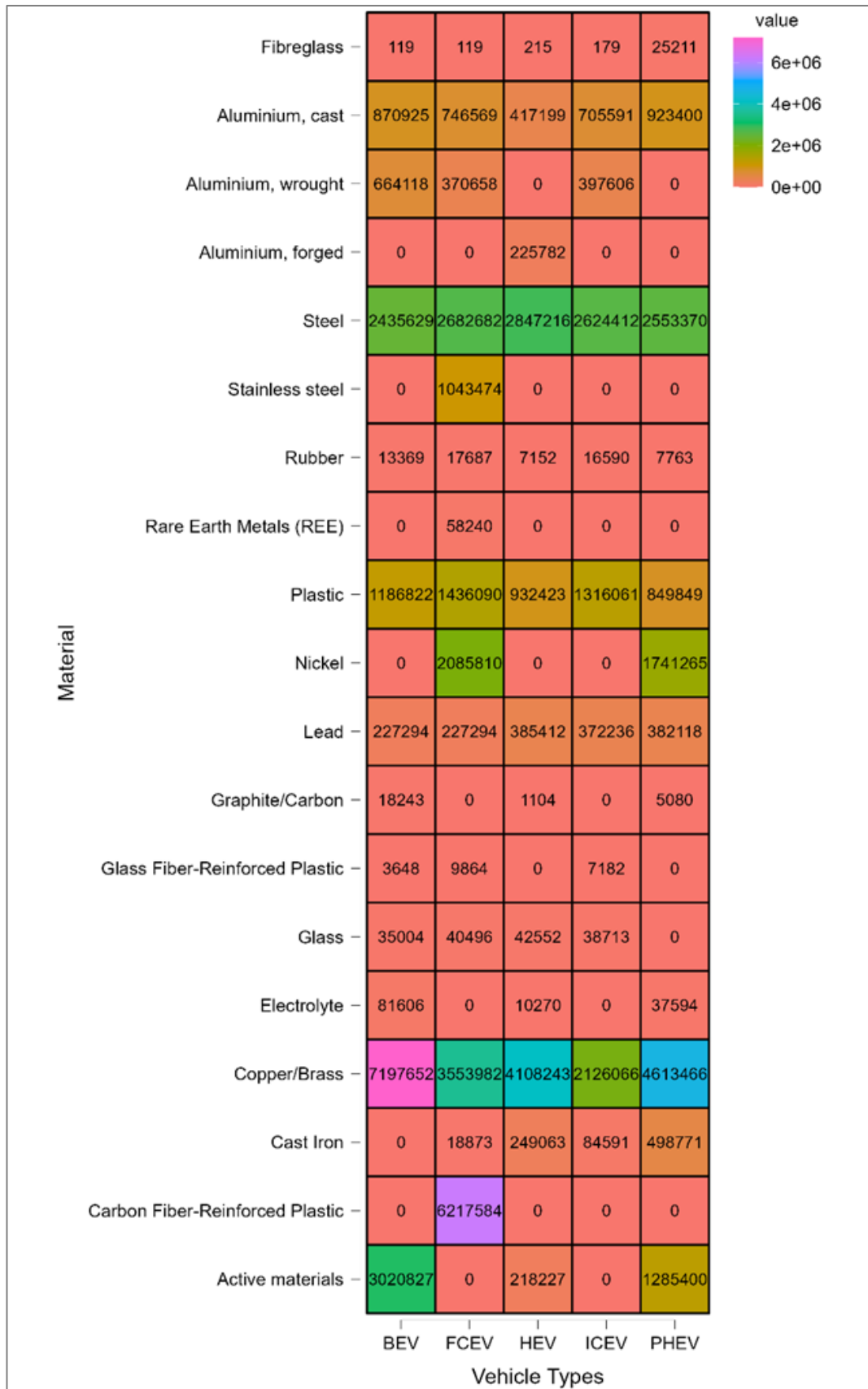
Materials	Potential Economic Values of Recycled Materials (Rp)				
	ICEV (~1402 kg)	BEV (~1716 kg)	HEV (~1491 kg)	PHEV (~1539 kg)	FCEV (~1627 kg)
Steel	2,624,412	2,435,629	2,847,216	2,553,370	2,682,682
Stainless steel	0	0	0	0	1,043,474
Plastic	1,316,061	1,186,822	932,423	849,849	1,436,090
Aluminium, cast	705,591	870,925	417,199	923,400	746,569
Aluminium, wrought	397,606	664,118	0	0	370,658
Aluminium, forged	0	0	225,782	0	0
Rubber	16,590	13,369	7,152	7,763	17,687
Copper/Brass	2,126,066	7,197,652	4,108,243	4,613,466	3,553,982
Glass	38,713	35,004	42,552	0	40,496
Cast Iron	84,591	0	249,063	498,771	18,873
Fibreglass	179	119	215	25,211	119
Lead	372,236	227,294	385,412	382,118	227,294
Graphite/Carbon	0	18,243	1,104	5,080	0
Active materials	0	3,020,827	218,227	1,285,400	0
Nickel	0	0	0	1,741,265	2,085,810
Rare earth metals (REEs)	0	0	0	0	58,240
Glass fibre-reinforced plastic	7,182	3,648	0	0	9,864
Carbon fibre-reinforced plastic	0	0	0	0	6,217,584
Electrolyte	0	81,606	10,270	37,594	0
Total	7,689,226	15,755,256	9,444,856	12,923,285	18,509,422

Source: Authors.

Table 2.2 highlights a clear shift in material value and complexity between conventional and electrified vehicles. ICEVs rely heavily on recyclable metals like steel and aluminium, offering high-volume but relatively low-value recovery. In contrast, electrified vehicles such as BEVs, PHEVs, and FCEVs contain high-value materials – including nickel, cobalt, graphite, and REEs – primarily from battery and motor systems, resulting in greater economic recovery potential. Emerging lightweight materials like carbon fibre-reinforced plastic and glass fibre-reinforced plastic also appear in newer vehicle designs but pose recycling challenges due to immature separation technologies. Additionally, critical materials such as electrolytes and REEs face recovery barriers due to the lack of standardised processes and recycling infrastructure, particularly in developing regions. These insights emphasise the need for targeted recycling strategies, investment in advanced recovery technologies, and integration of material value considerations into life cycle and end-of-life vehicle policies to support a circular economy in the evolving automotive landscape.

The total potential economic value of each material across different vehicle types is presented in a heat map (Figure 2.19). This visualisation compares the recyclable material values for BEVs, FCEVs, HEVs, ICEVs, and PHEVs. The values (in Rp) indicate the estimated market worth of each material, with colour gradients representing relative contributions – ranging from red (low or zero value) to green/yellow (medium) and blue/purple (very high). From Figure 2.19, copper/brass shows the highest potential economic value across all vehicle types, driven by its relatively high price per kilogram and strong recyclability. Steel and plastics also make substantial contributions due to their large share of vehicle weight and high recycling rates, resulting in medium to high economic value. In BEVs, active materials provide the highest potential value, largely because of their considerable weight (~149 kg). In PHEVs and FCEVs, nickel contributes moderately by weight but offers high economic potential owing to its high unit value. REEs exhibit exceptionally high value (~Rp350,000/kg); however, their impact appears limited in the heat map because of the very low recycling rate (1%) currently achievable in FCEVs. Overall, the heat map shows that vehicle electrification shifts recycling value away from steel and towards battery-related and electrical materials, with BEVs and PHEVs offering the highest recycling potential due to their large copper and active material content, while FCEVs are distinct for the reliance on carbon fibre and nickel.

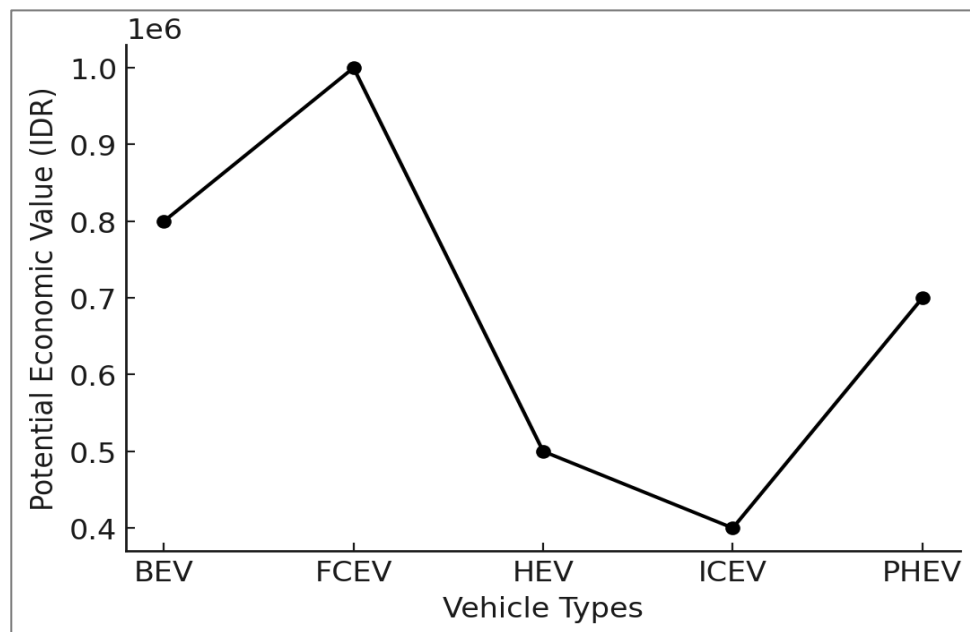
Figure 2.19. Heat Map of Passenger Car (Values in Rp)



Source: Authors.

Building on the heat map analysis of material contributions, a statistical test was performed to examine whether the potential economic values differ significantly across vehicle types. Figure 2.20 plots potential economic value (Rp) by vehicle type. Values (in millions; '1e6' = 1,000,000) peak at FCEVs (~1.0 million), followed by BEVs (~0.8 million) and PHEVs (~0.7 million), with HEVs (~0.5 million), and ICEVs (~0.4 million) the lowest.

Figure 2.20. Statistical Analysis of Potential Value Amongst Vehicle Types



Source: Authors.

At a 95% confidence level $\alpha = 0.05$, the normality assumption was violated ($p < 0.001$). Therefore, the Kruskal–Wallis test, a non-parametric method, was applied to compare potential economic values across vehicle types. The Kruskal–Wallis test ($p = 0.692$, $p > 0.05$) (Table 2.3) shows no statistically significant difference in potential economic value across vehicle types. The largest numerical difference is seen between FCEVs and ICEVs.

Table 2.3. Kruskal–Wallis Test

Factor	Statistic	df	p
Vehicle Types	2.237	4	0.692

Source: Authors.

This finding suggests that although the descriptive analysis and heat map highlighted numerical differences – such as higher values in FCEVs and BEVs compared to ICEVs – these differences are not statistically significant within the given dataset and assumptions. In practice, this implies that although specific materials (e.g. copper, nickel, and active battery materials) may drive higher economic potential in electrified vehicles, the overall

recycling value distribution across vehicle types remains broadly comparable when tested statistically.

Based on the analysis of material composition, recycling potential, and economic value across different vehicle types, several key insights can be drawn:

- Electrified vehicles offer higher recycling potential than ICEVs, with FCEVs valued at ~Rp18.5 million compared to ~Rp7.6 million for ICEVs, due to the presence of high-value materials (as shown in Table 2.2).
- Nickel and REEs should be prioritised in recycling strategies because of their high economic value per kilogram, even when present in small amounts.
- Copper/brass is critical for bulk recovery, combining substantial weight with moderate per-kilogram value.
- Steel and plastics contribute high total economic value due to their large volumes but are less strategic for targeted high-value recovery given their low unit value.
- Balanced recycling strategies should integrate both high-volume and high-value recoverable to maximise profitability and sustainability.

Chapter 3

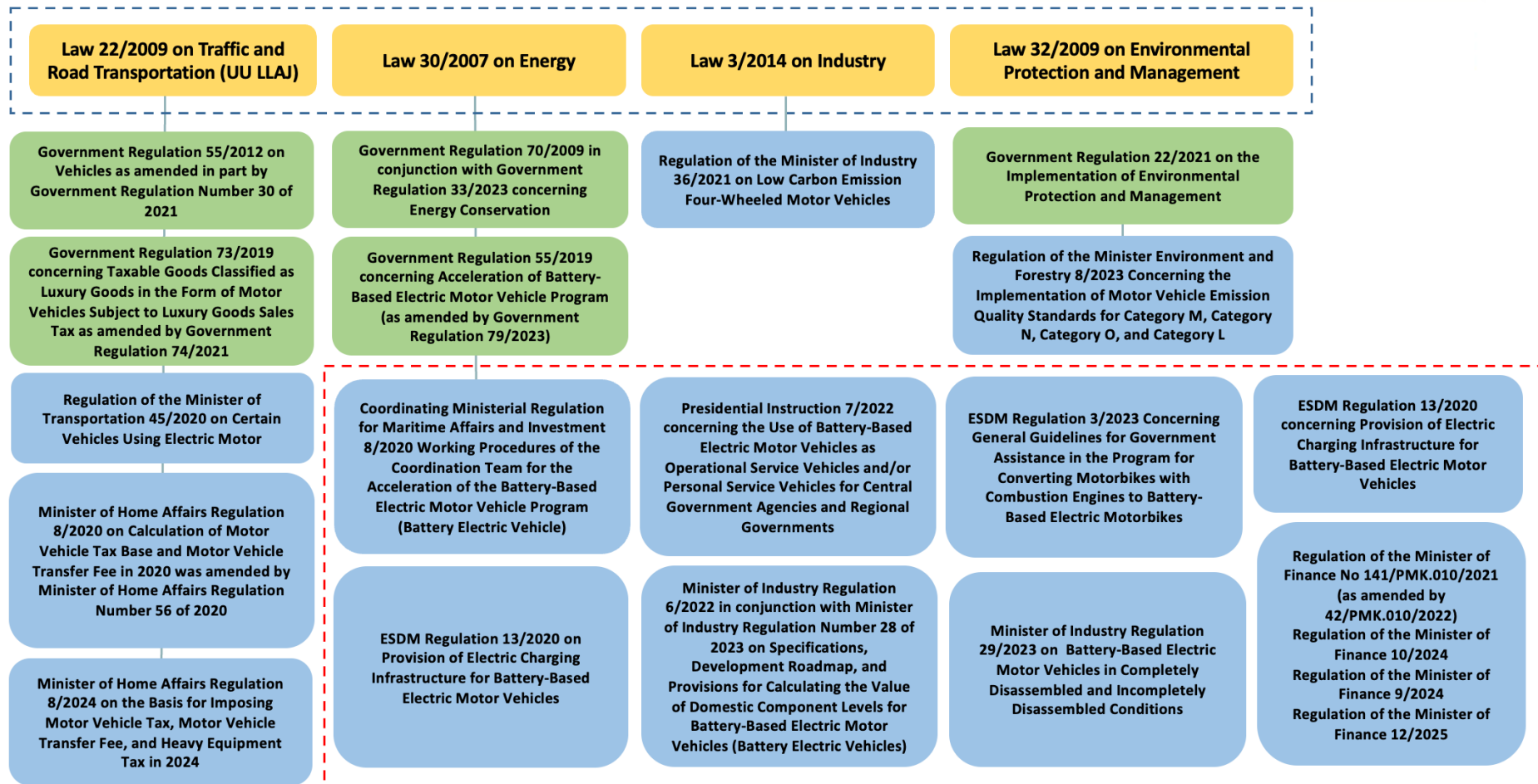
Regulatory Analysis

1. Mapping the Existing Regulatory Landscape for Road Transport and Electrification in Indonesia

The acceleration of LCEV adoption in Indonesia requires more than market forces alone; It demands a comprehensive understanding of the regulatory landscape that enables or constrains this transition. This regulatory analysis provides the foundational framework for policy recommendations in this report by examining existing legal infrastructure and identifying strategic gaps that must be addressed to achieve Indonesia's vehicle electrification goals. The findings directly inform the policy recommendations that follow, ensuring interventions are legally feasible and address the key regulatory bottlenecks currently impeding large-scale LCEV adoption in Indonesia

The first part of this regulatory analysis examines the current framework governing road transport and the electrification agenda in Indonesia. This includes identifying key laws, presidential and ministerial regulations, as well as implementing regulations issued by relevant government agencies and institutions. This mapping exercise seeks to present a comprehensive overview of institutional responsibilities, policy objectives, and regulatory gaps that may impact the acceleration of EV adoption and infrastructure development.

Figure 3.1. Regulatory Landscape of Indonesia



Source: Authors (2024).

Table 3.1. Summary of Relevant Laws

Category	Law/Regulation	Summary
1. Incentives for LCEVs	Presidential Regulation No. 55/2019 on the Acceleration of the Battery-Electric Vehicle Programme for Road Transportation (amended by No. 79/ 2023)	Establishes fiscal and non-fiscal incentives (import duty exemptions, luxury goods tax (PPnBM) relief, regional tax breaks, charging infrastructure support) for battery electric vehicles.
	Minister of Finance (MoF) Regulation No. 42/ 2022 on Luxury Goods Sales Tax for Motor Vehicles (amending No. 141/2021)	Sets tiered PPnBM rates tied to fuel economy and emissions; establishes a 15% taxable base for battery electric vehicles
	Government Regulation No. 22/2021 on the Implementation of Environmental Protection and Management	Regulating that compliance with emission standards is one of the factors determining the amount of vehicle tax
	MoF Regulation No. 12/2025 on Government-Borne Value-Added Tax for Battery-Electric Vehicles in Domestic Transactions	Government bears up to 10% of VAT on domestic BEV sales, reducing consumer VAT liability to 2%.
	MoF Regulation No. 135 of 2024 on Government-Borne Luxury-Goods Sales Tax for Completely Knocked-Down (CKD) Battery-Electric Vehicles	Government covers 100% of PPnBM for CKD battery electric vehicles (0% PPnBM)
	MoF Regulation No. 10/2024 (amending No. 26/2022) on Import Duties for Motor Vehicles	Exempts certain BEV categories from import duties (0%)
	Regulation of the Head of the Investment Coordinating Board No. 6/2023 on Investment Incentives for Battery-Electric Vehicles	Grants 0% import duty and luxury-goods tax for CBU/CKD BEVs with 20–40% local content
	Minister of Industry Regulation No. 21/2023 on Government Assistance in the Form of Price Discounts for the Purchase of Two-Wheeled Battery-Electric Vehicles	Provides an Rp7 million purchase subsidy per new battery-electric motorcycle for Indonesian citizens
	Minister of Environment and Forestry (MoEF) Regulation	Defines maximum allowable concentrations of CO, hydrocarbons,

Category	Law/Regulation	Summary
2. Emission standards and roadworthiness	No. 8/2023 on Motor Vehicle Emission Quality Standards for Categories M, N, O, and L	and opacity by vehicle category and year of manufacture
	MoEF Regulation No. 5/ 2006 on Exhaust Emission Thresholds for Older Motor Vehicles	Establishes exhaust gas emission thresholds for older vehicles, forming the basis for compliance testing
	Law No. 22/2009 on Road Traffic and Transportation	Requires periodic roadworthiness inspections, including emissions and noise tests, as a condition for vehicle operation
	Minister of Transportation Regulation 19/2021 on Periodic Testing of Motor Vehicles	established roadworthiness standards that vehicles must meet to be legally operated
3. Taxes and levies	MoF Regulation No. 26/2022 on Import Duties for Motor Vehicles (amended by No. 10/2024)	Specifies import-duty rates: 0% for qualifying BEVs; 10%/50% for CKD/CBU ICEVs
	MoF Regulation No. 41/2022 on Income Tax Article 22 for Imports	Imposes a uniform 10% withholding tax on the import value of motor vehicles
	MoF Regulation No. 131/2024 on the Treatment of Value-Added Tax for the Import and Supply of Taxable Goods and Services	Clarifies the 12% VAT calculation for vehicle imports and domestic deliveries under the Tax Harmonisation Law
	Government Regulation No. 73/2019 on Taxable Luxury Goods in the Form of Motor Vehicles (amended by No. 74/2021)	Sets luxury goods tax (PPnBM) rates: 15% for passenger BEVs (<10 or 10–15 persons) and 10% for double-cab BEVs
	Minister of Home Affairs (MoHA) Regulation No. 8/2024 on Regional Taxes and Levies	Exempts BEVs from motor vehicle tax (PKB) and transfer fee (BBnKB) for first ownership in Jakarta.
	Law No. 1 of 2022 on Financial Relations between the Central Government and Regional Governments	Governs revenue-sharing arrangements and enables regional tax exemptions for low emission vehicles
4. Definitions and Types of LCEVs	Minister of Industry Regulation No. 36/2021 on Low Carbon Emission Four-Wheeled Motor Vehicles	Defines six categories: LCGCs, mild/full HEVs, PHEVs, BEVs, FCEVs, and flex-fuel engine vehicles, along with technical criteria

Category	Law/Regulation	Summary
5. Infrastructure for LCEVs	Minister of Energy and Mineral Resources [MoEMR] Regulation No. 13 of 2020 on Electric Vehicle Charging Infrastructure	Mandates public charging and battery swap stations at fuel stations, government offices, malls, and major highways. Sets tariff multiplier rules.
	Presidential Regulation No. 55/2019 (Article 3)	Requires development of charging infrastructure, electricity tariff regulations, and assignment to Perusahaan Listrik Negara (PLN) for initial rollout
6. Vehicle Scrappage and Safety	Government Regulation No. 22/2021 on Environmental Permits and Standards	Links emissions compliance to motor vehicle tax rates via an environmental damage coefficient
	Presidential Regulation No. 1/2022 on the National Road Transport Safety Master Plan	Mandates the Ministry of Transportation to design a road safety-focused vehicle scrappage programme.
7. Institutional Structure and Coordination	Presidential Instruction No. 7/2022 on the Use of Battery Electric Vehicles as Official Vehicles	Directs all ministries and agencies to adopt BEVs for official fleets, with coordination, reporting, and budget support duties
	Coordinating Minister for Maritime Affairs and Investment Regulation No. 8/2020 on the Working Procedures of the Coordination Team for the Battery Electric Vehicle Program	Establishes a multi-ministerial coordination team to accelerate BEV deployment, meeting at least twice a year
	Minister of Industry Regulation No. 6/2022 on the National Roadmap for the Battery Electric Vehicle Industry	Establishes production targets, local-content requirements, and infrastructure goals for the BEV industry.

PPnBM = *Pajak Penjualan-Barang Mewah* (luxury goods sales tax).

Source: Authors (2024).

Article 1 (3) of Law No. 22 of 2009 defines road transportation as the movement of people and/or goods from one place to another using vehicles on road traffic areas. With the increasing presence of low-carbon vehicles in Indonesia, the government has taken steps to address this emerging trend by enacting Minister of Industry Regulation No. 36/2021 on Low Carbon Emission Four-Wheeled Motor Vehicles. This regulation not only outlines specific standards for these vehicles but also establishes a clear definition for LCEVs as

domestically produced four-wheeled motor vehicles designed for passenger transportation which meet several environmental and technical criteria. LCEVs are four-wheeled motor vehicles for transporting people, produced domestically, and meeting certain requirements.

As of the current date, Indonesia categorizes LCEVs into six types: LCGCs, HEVs (further classified as full hybrids and mild hybrids), PHEVs, BEVs, FCEVs, and flex-fuel engine each with their own set of technical requirements (Table 3.2).

Table 3.2. Types of LCEVs

LCEV Type	Definition and Key Characteristics
KBH2/LCGC (Fuel-efficient and affordable four-wheeled motor vehicle)	<p>LCGC is an LCEV for transporting fewer than 10 people, including the driver. To qualify as an LCGC, a vehicle must meet the following requirements:</p> <ol style="list-style-type: none"> 1) Have a spark-ignition engine with a maximum engine capacity of 1,200 cc or a compression-ignition engine (diesel) with a maximum engine capacity of 1,500 cc 2) Achieve a minimum fuel consumption of 20 km/litre for gasoline or 21.8 km/litre for diesel, or have a CO₂ emission level of no more than 120 grams/km 3) Have a maximum turning radius of 4,600 millimeters (mm) and a minimum ground clearance of 150 mm 4) Feature an additional Indonesian brand, model, and logo that reflect Indonesia 5) Have a maximum retail price of Rp135 million based on the location of the brand holder's head office 6) Display fuel usage information with an octane rating of at least 92 for a spark-ignition engine or a cetane rating of at least 51 for a compression-ignition engine on the fuel tank cap and the lower corner of the rear window.
Hybrid Electric Vehicle (HEV)	<p>HEVs consist of mild hybrids and full hybrids.</p> <p>To qualify as a mild hybrid, a vehicle must meet the following requirements:</p> <ol style="list-style-type: none"> 1) Have an engine capacity up to 4000 cc using a spark-ignition engine with gasoline consumption or a compression ignition engine (diesel or semi-diesel) with diesel fuel consumption

LCEV Type	Definition and Key Characteristics
	<ol style="list-style-type: none"> 2) Achieve fuel consumption of more than 15.5 km/litre for gasoline or more than 17.5 km/litre for diesel, or have CO₂ emissions no higher than 150 grams/km 3) Have a battery with a maximum voltage of 60 volts 4) Display the mild hybrid technology logo. <p>To qualify as a full hybrid, a vehicle must meet the following requirements:</p> <ol style="list-style-type: none"> 1) Have an engine capacity up to 4000 cc using a spark ignition engine with gasoline consumption or a compression ignition engine (diesel or semi-diesel) with diesel fuel consumption 2) Achieve fuel consumption of more than 15.5 km/litre for gasoline or more than 17.5 km/litre for diesel, or have CO₂ emissions no higher than 150 grams/km 3) Have a battery with a voltage greater than 60 volts 4) Display the full hybrid technology logo.
Plug-in Hybrid Electric Vehicle (PHEV)	<p>A PHEV is an LCEV consisting of at least one electric motor or generator and at least one combustion engine, equipped with an external charging system. A vehicle qualifies as a PHEV if it meets the following requirements:</p> <ol style="list-style-type: none"> 1) Achieve fuel consumption of more than 28 km/litre for gasoline or diesel, or has CO₂ emissions no higher than 100 grams/km 2) Can operate in electric-only mode for at least 40 km 3) Have an external charging system (external plug) 4) Display the PHEV technology logo.
Battery Electric Vehicle (BEV)	<p>A BEV is an LCEV that only uses an electric motor powered by a rechargeable battery system. To qualify as a BEV, the vehicle must meet the following requirements:</p> <ol style="list-style-type: none"> 1) Use only an electric motor for propulsion 2) Have a rechargeable battery system 3) Include at least the electric motor, battery, and power control unit or inverter 4) Have an external charging system (external plug) 5) Display the BEV technology logo.
Fuel Cell Electric Vehicle (FCEV)	<p>An FCEV is an LCEV equipped with a fuel cell as an energy source and an electric motor as the propulsion system. To qualify as an FCEV, the vehicle must meet the following requirements:</p>

LCEV Type	Definition and Key Characteristics
	<ol style="list-style-type: none"> 1) Use only an electric motor for propulsion 2) Use a fuel cell as an energy source 3) Include at least the electric motor, battery, power control unit or inverter, and hydrogen tank 4) Display the FCEV technology logo.
Flex-fuel Engine	<p>A flex-fuel engine is an LCEV with a combustion engine capable of running on 100% biofuels and automatically adjusting its combustion process without driver intervention. To qualify as a flex-fuel engine, the vehicle must meet the following requirements:</p> <ol style="list-style-type: none"> 1) Can operate on 100% biofuel or be adaptable to it 2) Have an automation system, either mechanical or electrical, capable of adjusting the combustion process without driver intervention 3) Display the flex-fuel engine technology logo.

Source: Authors.

1.1.1. Indonesia's regulatory landscape on energy

Indonesia's energy sector is governed by a multifaceted regulatory framework designed to balance economic development with sustainable energy practices. Since the signing of the Paris Agreement in 2016, Indonesia has been striving to reduce its GHG emissions, enhance energy security, and diversify its energy mix through increased adoption of renewable energy sources. In the energy sector, this proactive approach has led to a series of regulatory initiatives aimed at accelerating the transition to cleaner energy, driving investments in renewable infrastructure, and incentivising sustainable practices across various industries.

In the energy sector, regulations have been designed to encourage technological development in renewable energy and conservation, while gradually 'phasing out older, more carbon-intensive technologies as part of its transition strategy. The cornerstone of Indonesia's energy regulatory regime is Law No. 30/2007 on Energy, which provides the statutory basis for subsequent regulatory measures.

In furtherance of these objectives, the government issued MoEF Regulation No. 8/2023, establishing Motor Vehicle Emission Quality Standards for Categories M, N, O, and L. Article 1(1) defines 'emission quality standards' as the maximum allowable concentration of pollutants that may be introduced into ambient air. The annex of MoEF Regulation No. 8/2023 sets out the specific provisions and technical details governing these standards.

Table 3.3. Emission Quality Standards for Motor Vehicles in Categories M, N, and O

Category	Year of Manufacture	Parameters			Test Method
		Carbon Monoxide	Hydrocarbon	Opacity	
Gasoline-powered motor vehicles					
Category M	< 2007	4%	1000 ppm		Idle Condition
	2007–2018	1%	150 ppm		
	> 2018	0.5%	100 ppm		
Category N and O	< 2007	4%	1100 ppm		
	2007–2018	1%	200 ppm		
	> 2018	0.5%	150 ppm		
Diesel-powered motor vehicles					
Categories M, N, and O					
JBB less than or equal to 3.5 tonnes	< 2010			65% HSU	Free Acceleration
	2010–2021			40% HSU	
	> 2021			30% HSU	
JBB more than 3.5 tonnes	< 2010			65% HSU	
	2010–2021			40% HSU	
	> 2021			30% HSU	

Source: MoEF Regulation No. 8/2023.

Table 3.4. Emission Quality Standards for Motor Vehicles in Category L

Category	Year of Manufacture	Parameters		Test Method
		Carbon Monoxide	Hydrocarbon Opacity	
Gasoline-powered motor vehicles				
2-stroke engine motorcycle	< 2010	4.5%	6000 ppm	Idle Condition
4-stroke engine motorcycle		5.5%	2200 ppm	
Motorcycle	2010–2016	4%	1800 ppm	
	>2016	3%	1000 ppm	

Source: MoEF Regulation No. 8/2023.

Article 2(1) of this regulation requires that every motor vehicle owner comply with the emission quality standards specified above. In simpler terms, vehicle owners must ensure that their vehicles do not exceed the pollutant limits defined in the annex. To confirm

compliance, Article 3(1) mandates that an emission test be conducted. Essentially, this means that each vehicle must undergo testing to verify that it meets the required emission standards. Additionally, Article 4(1) stipulates that, when paying the motor vehicle tax, operators must submit the results of this emission test as an integral part of the administrative process. As the international community places increasing emphasis on promoting BEVs, Indonesia has similarly made significant progress in strengthening its policies and initiatives in this area.

1.1.2. Indonesia's regulatory landscape on road vehicles

Law No. 22/2009 defines road transportation as moving people and/or goods by vehicle on public roads and their supporting facilities. Vehicles include those powered by engines, such as motorcycles, cars, buses, trucks, and special purpose vehicles, as well as non-motorised vehicles propelled by human or animal energy. Rail-based systems are not covered by this definition.

The law requires every motorised vehicle to pass technical and roadworthiness inspections that include emission and noise tests. Vehicle owners and operators must prevent air pollution and excessive noise. These provisions set clear standards to ensure that only vehicles meeting environmental criteria are allowed on the road.

The government is tasked with creating and overseeing environmentally friendly transport policies, infrastructure, and programmes. Public transport companies must implement these green programmes, provide sustainable services, and meet environmental quality standards. The community also has an obligation to support and maintain environmental sustainability in all road transport activities.

1.1.3. Indonesia's regulatory landscape on the EV industry

A significant policy shift has been directed towards the promotion of BEVs. In 2019, the President issued Presidential Regulation No. 55/2019 on the acceleration of BEVs for road transportation, as amended by No. 79/2023. This regulation outlines the government's measures to promote and expedite BEV initiatives in Indonesia, to enhance energy efficiency, ensure energy security, and conserve energy within the transport sector. It also supports the transition to clean energy, improves air quality, and reinforces Indonesia's commitment to reducing GHG emissions. The presidential regulation emphasises several key areas to accelerate BEV adoption: (i) development of a domestic BEV industry; implementation of incentives; establishment of charging infrastructure and appropriate electricity tariffs for BEVs; definition of technical standards for BEVs; and implementation of environmental protection.

1.1.4. Indonesia's regulatory landscape on taxes and other levies for motor vehicles and EVs

Indonesia's vehicle taxation regime is structured to include both imported and domestically produced vehicles. The framework is designed not only to generate revenue but also to ensure equitable fiscal relations between the central and local governments. At its core, the system is built upon a series of ministerial regulations and laws, including key instruments such as Law No. 1/2022, which governs financial relationships between the central and local governments, and ministerial regulations that establish tax bases and calculation methods. Table 3.5 shows the types of taxes and other levies for motor vehicles and EVs.

Table 3.5. Taxes and Other Levies for Motor Vehicles and EVs

Import Duties and Taxes	Domestic Transaction Taxes	Annual Taxes and Levies
<ol style="list-style-type: none"> 1. Import duty 2. PDRI (tax in the context of importation): <ol style="list-style-type: none"> a. Luxury goods sales tax on imports (PPnBM) b. VAT on imports c. Income tax (PPh) on imports (Article 22) 	<ol style="list-style-type: none"> 1. Luxury goods sales tax on domestic transaction (PPnBM) 2. Value Added Tax (VAT) on Domestic Transaction 3. PPh on domestic transaction 	<ul style="list-style-type: none"> • Motor vehicle tax (PKB) • Vehicle ownership transfer fee (BBnKB) • Mandatory road traffic accident insurance contribution (SWDKLLJ) • Vehicle registration certificate Fee (STNK) • Indonesian Motor Vehicle Number Plate Fee (TNKB) • Motor Vehicle Ownership Book Fee (BPKB)

Source: Authors.

1.1.4.1. Import duties (*Bea Masuk Impor*)

Import duties on motor vehicles are governed by Minister of Finance Regulation (PMK) No. 26/PMK.010 of 2022, partially amended by PMK No. 10 of 2024. These regulations specify import duty rates according to the Harmonised System Code and vehicle type, distinguishing between ICEVs and LCEVs, including electric vehicles (Indonesia National Single Window, 2025).

Table 3.6. Import Duties According to the Harmonization System Code

Type	ICE	LCEV						
		LCGC	HEV (Full)	HEV (Mild)	PHEV	BEV	FCEV	Flex-Fuel
HS Code	8703.10 (golf carts, snowmobiles) 8703.21 (<1000 cc gasoline) 8703.22 (1000–1500 cc gasoline) 8703.23 (1500–3000 cc gasoline) 8703.24 (>3000 cc gasoline) 8703.31 (<1500 cc diesel) 8703.32 (1500–2500 cc diesel) 8703.33 (<2500 cc diesel)		8703.40 (gasoline) 8703.50 (diesel)		8703.60 (gasoline) 8703.70 (diesel)	8703.80	-	-
Import Duty Rate	Sedan: CKD 10% Sedan: CBU 50% <i>will be different for caravans, ambulances, ATVs.</i>		CKD 10% CBU 50%		CKD 10% CBU 50%	0% import duty, in accordance with Article 4A of PMK No. 10 of 2024	-	-

Source: Minister of Finance Regulation (PMK) No. 26/PMK.010 of 2022.

This policy structure reflects Indonesia’s fiscal incentives to promote clean energy vehicles, particularly EVs, by significantly reducing import barriers through 0% import duties for eligible models. The differentiation between ICE and LCEV classifications ensures targeted support for sustainable transport while maintaining revenue considerations for conventional vehicles.

1.1.4.2. Luxury goods sales tax (PPnBM)

The imposition of the luxury goods sales tax (PPnBM) on motor vehicles is governed under Minister of Finance Regulation (PMK) No. 42/PMK.010/2022, which serves as an amendment to PMK No. 141/PMK.010/2021. The new PPnBM framework reflects a more progressive, performance-based approach aligned with environmental policy objectives. By tying tax obligations to a vehicle’s environmental footprint, the regulation

seeks to incentivise the production, import, and consumption of low-emission, fuel-efficient vehicles, while gradually disincentivising more polluting and fuel-intensive vehicle types. This not only supports national emission reduction commitments but also aligns fiscal tools with Indonesia's broader energy transition and decarbonisation goals.

For ICEVs, including both gasoline and diesel-powered cars, PPnBM is structured across a tiered scale. Vehicles with smaller engines (<3,000 cc) and higher efficiency (e.g. >15.5 km/litre and <150 g/km CO₂) are subject to a lower PPnBM rate of 15%. As fuel economy worsens and emissions rise, the rate increases up to 40%. For larger engines (3,000–4,000 cc), the highest PPnBM rates reach 70%, particularly for the least efficient, high-emission models. This approach aims to create a clear disincentive for larger, less-efficient cars, which are more common in luxury and high-performance segments.

BEVs are given a standardised PPnBM rate of 15%, with a 0% taxable base, effectively eliminating their luxury tax burden. This serves as a major incentive to promote EV adoption, although stakeholders have suggested that additional fiscal leeway may be required to make BEVs more competitive in the mainstream market.

Table 3.7. Luxury Goods Sales Tax for ICE Vehicles

Type	CC	Fuel Economy	Emission Level	PPnBM Tariff, %
Motor vehicles with spark-ignition reciprocating internal combustion piston engines, with cylinder capacity not exceeding 3,000 cc, including hybrid vehicles	<3000 cc	> 15.5 km/litre	< 150 g/km	15
		> 11.5 s.d. 15.5 km/litre	150 s.d. 200 g/km	20
		> 9.3 s.d. 11.5 km/litre	> 200 s.d. 250 g/km	25
		< 9.3 km/litre	> 250 g/km	40
Motor vehicles with compression ignition internal combustion piston engines (diesel or semi-diesel), with cylinder capacity not exceeding 3,000 cc, including hybrid vehicles	<3000 cc	> 17.5 km/litre	< 150 g/km	15
		> 13.0 s.d. 17.5 km/litre	150 s.d. 200 g/km	20
		> 10.5 s.d. 13.0 km/litre	> 200 s.d. 250 g/km	25
		> 10.5 km/litre	> 250 g/km	40
Motor vehicles with spark-ignition reciprocating internal combustion piston	3000–4000 cc	> 15.5 km/litre	< 150 g/km	40
		> 11.5 s.d. 15.5 km/litre	150 s.d. 200 g/km	50

Type	CC	Fuel Economy	Emission Level	PPnBM Tariff, %
engines, with cylinder capacity more than 3,000 cc but not exceeding 4,000 cc, including hybrid vehicles		> 9.3 s.d. 11.5 km/litre	> 200 s.d. 250 g/km	60
		< 9.3 km/litre	> 250 g/km	70
Motor vehicles with compression-ignition internal combustion piston engines (diesel or semi-diesel), with cylinder capacity more than 3,000 cc but not exceeding 4,000 cc, including hybrid vehicles	3000–4000 cc	> 17.5 km/litre	< 150 g/km	40
		> 13.0 s.d. 17.5 km/litre	150 s.d. 200 g/km	50
		> 10.5 s.d. 13.0 km/litre	> 200 s.d. 250 g/km	60
		> 10.5 km/litre	> 250 g/km	70
Motor vehicles powered solely by electric motors	-	-	-	15

Source: Minister of Finance Regulation (PMK) No. 42/PMK.010/2022.

Beyond ICEVs, LCEVs, including HEVs, PHEVs, and flex-fuel vehicles, are subject to a differentiated tax structure under the same regulatory framework. The key innovation here lies in the variable taxable base. Rather than applying a flat rate to the full vehicle price, the regulation sets the taxable base as a percentage of the selling price, which varies according to each vehicle's fuel efficiency and tailpipe emission levels.

Table 3.8. Special Tax Base for EVs

LCEV Type	CC	Tax Base (DPP)	PPnBM Tariff
KBH2 (LCGC)	<1200 cc	KBH2 Gasoline with FE >20 km/l and TE <120 g/km = 20% of Selling Price	15%
	<1500 cc	KBH2 Diesel with FE >21.8 km/l and TE <120 g/km = 20% of Selling Price	15%
Hybrid Gasoline	<3000 cc	Full Hybrid with FE >23 km/l and TE <100 g/km = 40% of Selling Price	15%
		Full Hybrid with FE 18.4–23 km/l and TE 100–125 g/km = 46⅔% of Selling Price	
		Full Hybrid with FE 15.5–18.4 km/l and TE 125–150 g/km = 53⅓% of Selling Price	
		Mild Hybrid with FE >23 km/l and TE <100 g/km = 53⅓% of Selling Price	
		Mild Hybrid with FE 18.4–23 km/l and TE 100–125 g/km = 66⅔% of Selling Price	
		Mild Hybrid with FE 15.5–18.4 km/l and TE 125–150 g/km = 80% of Selling Price	
	3000–4000 cc	Full/Mild Hybrid with FE >23 km/l and TE <100 g/km	20%
		Full/Mild Hybrid with FE 18.4–23 km/l and TE 100–125 g/km	25%
		Full/Mild Hybrid with FE 15.5–18.4 km/l and TE 125–150 g/km	30%
Hybrid Diesel	<3000 cc	Full Hybrid with FE >26 km/l and TE <100 g/km = 40% of Selling Price	15%
		Full Hybrid with FE 20–26 km/l and TE 100–125 g/km = 46⅔% of Selling Price	
		Full Hybrid with FE 17.5–20 km/l and TE 125–150 g/km = 53⅓% of Selling Price	
		Mild Hybrid with FE >26 km/l and TE <100 g/km = 53⅓% of Selling Price	
		Mild Hybrid with FE 20–26 km/l and TE 100–125 g/km = 66⅔% of Selling Price	
		Mild Hybrid with FE 17.5–20 km/l and TE 125–150 g/km = 80% of Selling Price	
	3000–4000 cc	Full/Mild Hybrid with FE >26 km/l and TE <100 g/km = 20% PPnBM	20%
		Full/Mild Hybrid with FE 20–26 km/l and TE 100–125 g/km = 25% PPnBM	25%
		Full/Mild Hybrid with FE 17.5–20 km/l and TE 125–150 g/km = 30% PPnBM	30%
PHEV	<3000 cc	FE >28 km/l and TE <100 g/km = 33⅓% of Selling Price	15%
BEV	-	0%	15%
Flex-Fuel Engine	-	Flex-Fuel Engine = 53⅓% of Selling Price	15%

Source: Minister of Finance Regulation (PMK) No. 42/PMK.010/2022.

In addition to the differentiated PPnBM structure outlined in earlier regulations, Minister of Finance Regulation No. 12/2025, particularly Article 15, introduces further fiscal support mechanisms in the form of government-borne PPnBM (PPnBM DTP) for specific categories of LCEVs. According to Article 15, the delivery of certain LCEVs as referred to in Article 14(2) is subject to PPnBM in accordance with the classification of four-wheeled low-carbon emission motor vehicles as regulated in Government Regulation No. 73/2019 on taxable luxury goods in the form of motor vehicles, as amended by No. 74/2021. This provision stipulates that for LCEVs meeting the criteria in Articles 14(2) and (3), the PPnBM payable is borne by the government at a rate of 3% of the vehicle's selling price (*Harga Jual*). This means that instead of being paid by manufacturers or consumers, the 3% PPnBM is effectively waived and covered by the state budget.

This tiered and performance-based PPnBM structure represents a major policy innovation that leverages taxation as a tool for sustainable mobility. While the headline PPnBM rates may appear uniform (e.g. 15% for most LCEVs), the variation in the tax base or DPP introduces a de facto progressive tax scheme. Cleaner, more efficient vehicles benefit from significantly lower effective tax burdens, thereby supporting a shift in consumer behaviour towards greener vehicle choices.

1.1.4.3. Value-added tax (PPN)

Pursuant to MoF Regulation No. 131/2024 on the Treatment of Value Added Tax (VAT) for the Import and Delivery of Taxable Goods and Services, the applicable VAT rate for the importation of motor vehicles is set at 12%, calculated based on the taxable base, which refers to the selling price or import value. This provision aligns with the Law on the Harmonization of Tax Regulations, which amends Law No. 8 of 1983 (as last amended by Law No. 42 of 2009), and reaffirms the VAT rate of 12% effective on 1 January 2025.

To support the adoption of EVs, a specific fiscal incentive is introduced through MoF Regulation No. 12/2025, which provides government-borne VAT (PPN DTP) for BEVs in domestic (non-import) transactions. Under Article 5 of the regulation, the VAT obligation is covered by the government under the following conditions:

- 1) The vehicle qualifies as a four-wheeled BEV.
- 2) It meets a minimum local or domestic content requirement (TKDN) of 40%.
- 3) The VAT borne by the government is up to 10% of the vehicle's selling price.
- 4) The incentive is only applicable to local transactions, not to imported BEVs.

This policy aims to reduce the upfront cost of BEVs for consumers, boost domestic EV demand, and accelerate the growth of a locally integrated EV industry, in line with Indonesia's broader energy transition and industrial development objectives.

1.1.4.4. Income tax (PPh)

In accordance with MoF Regulation No. 41/PMK.010/2022, which serves as the second amendment to PMK No. 34/PMK.010/2017 on the collection of Income Tax Article 22 for payments relating to the delivery of goods and activities in the import or other business sectors, a uniform Income Tax (PPh Pasal 22) rate of 10% is imposed on the importation of designated goods. This uniform rate applies regardless of whether the importer uses an Importer Identification Number (*Angka Pengenal Impor/API*) or not. Specifically, motor vehicles categorised under HS Code 87.03, which includes cars and other motor vehicles primarily designed for passenger transport (excluding those under HS 87.02), such as station wagons and racing cars, are subject to this 10% income tax rate, calculated based on the import value. The imposition of this tax is outlined in Annex I of PMK 41/2022 and represents a policy measure to control imports of luxury and high-value goods, while also contributing to government revenue from high-demand sectors such as automotive.

1.1.4.5. Annual taxes and levies

Motor vehicle ownership in Indonesia is subject to a series of annual taxes and administrative levies, governed by both national and regional regulations. These charges include the motor vehicle tax (PKB), the vehicle ownership transfer fee (BBnKB), the mandatory road traffic accident insurance contribution (SWDKLLJ), and fees associated with vehicle documentation, such as the vehicle registration certificate (STNK), the number plate fee (TNKB), and the vehicle ownership book (BPKB).

Here, we take the example of DKI Jakarta. In DKI Jakarta, the PKB is set at 2% of the vehicle's sales value (NJKB) for first-time ownership, while the BBnKB is levied at 12.5% of NJKB. However, as part of the government's broader effort to promote low-emission mobility, BEVs are granted full exemption from both PKB and BBnKB, effectively reducing annual ownership costs. These exemptions are provided for under a combination of national and regional legal instruments, including Law No. 1/2022 on Financial Relations between the Central Government and Regional Governments, Regional Regulation of DKI Jakarta No. 1/2024 on Regional Taxes and Levies, and supporting implementation through Ministry of Home Affairs Regulation No. 8/2024.

Table 3.9. Annual Taxes and Levies for Motor Vehicles and EVs

Type of Taxes or Levies	Tariff/Rate	BEV Exemption	Regulation
Motor vehicle tax (PKB)	DKI Jakarta, First Ownership: 2% of NJKB (vehicle's sales value)	0% of NJKB for BEVs	<ul style="list-style-type: none"> • Law No. 1/2022 on Financial Relations between the Central Government and Regional Governments • Regional Regulation of the Special Capital Region of Jakarta Province 1/2024 on Regional Taxes and Levies • MoHA Regulation No. 8/2024
Vehicle ownership transfer fee (BBnKB)	DKI Jakarta, First Ownership: 12.5% of NJKB	0% of NJKB for BEVs	<ul style="list-style-type: none"> • Law 1/2022 on Financial Relations between the Central Government and Regional Governments • Regional Regulation of the Special Capital Region (DKI) Jakarta Province Number 1 of 2024 on Regional Taxes and Levies
Mandatory road traffic accident insurance contribution (SWDKLLJ)	Rp143,000	-	MoF Regulation No. 16/PMK.010/2017 on The Amount of Compensation and Mandatory Contributions to the Road Traffic Accident Fund
Vehicle registration certificate (STNK)	New: Rp200,000 Renewal: Rp200,000	-	Government Regulation (PP) No. 76/2020 on Types and Tariffs of Non-Tax State Revenue Applicable to the Indonesian National Police
Indonesian motor vehicle number plate Fee (TNKB)	Rp100,000	-	
Vehicle ownership certificate (BPKB)	Rp375,000	-	

Source: Ministry of Home Affairs Regulation No. 8/2024.

This multi-tiered fiscal framework highlights the importance of local tax autonomy while also demonstrating how central and regional governments are increasingly coordinating

to provide incentives for clean energy vehicles, thereby reducing the long-term financial burden on EV owners and supporting the shift towards sustainable transportation.

2. Evaluation and Analysis of Existing Indonesian Regulations

Despite a growing commitment to support the development and adoption of BEVs, Indonesia's current regulatory landscape remains limited in its ability to address the broader spectrum of LCEVs or to implement a holistic fleet renewal strategy. Several foundational policies, ranging from vehicle retirement schemes to infrastructure planning and tax incentives, are either underdeveloped or narrowly focused on BEVs. Table 3.10 outlines key regulatory gaps identified in the existing framework, as discussed in this paper, and highlights areas that require urgent attention to enable a more inclusive and effective transition to cleaner road transport.

Table 3.10. Identified Regulatory Gaps

Policy Area	Current Focus (as described in the report)	Identified Regulatory Gap (based on report)
Vehicle retirement/Scrappage Policy	There is currently no national regulation, programme, or financial incentive to mandate or encourage the retirement of old and inefficient ICEVs.	Indonesia lacks a scrappage or vehicle retirement scheme, in contrast to countries like Japan, the Republic of Korea, and the European Union. This results in a prolonged lifespan of old, high-emission vehicles.
Luxury goods sales tax (PPnBM)	BEVs benefit from a 0% PPnBM rate, especially for CKD units, under MoF Regulation 135/2023. This has improved BEV affordability compared to other vehicle types.	Other LCEVs, including HEVs, PHEVs, and FCEVs, remain subject to higher PPnBM rates under the original PP No. 73/2019, reducing their market competitiveness.
Provincial taxes (PKB & BBnKB)	Under Minister of Home Affairs Regulation No. 8/2024, BEVs are fully exempted from annual vehicle tax (PKB) and vehicle transfer fee (BBnKB), incentivising adoption at the regional level.	There is no provision to extend this tax exemption to other LCEVs, resulting in uneven fiscal incentives across vehicle technologies.
Infrastructure support	Government initiatives, especially through PLN and MEMR Regulation No. 13/2020, have focused on	No regulatory framework exists for refuelling or infrastructure support for other LCEV types, such as hydrogen stations for

	deploying public charging stations (SPKLUs) and special electricity tariffs for BEVs.	FCEVs or ethanol infrastructure for flex-fuel vehicles.
National Roadmap or Transition Strategy	Presidential Regulation No. 55/2019 and Ministry of Industry Regulation 6/2022 establish a roadmap for BEV industrialisation and adoption, with clear production targets and domestic component level requirements.	The roadmap is BEV-centric and lacks coverage of other LCEV technologies, resulting in a fragmented transition strategy and limited technological flexibility in the transport sector.

Source: Authors (2024).

2.1. Government Acceleration Programme for Electrification in Indonesia

Indonesia has provided regulatory framework to support the adoption of LCEVs, primarily BEVs, through many fiscal incentives, non-fiscal incentives, and structural support. The main regulation for acceleration of the BEV programme in Indonesia is Presidential Regulation No. 55/2019 concerning the Acceleration of the Battery-Based Electric Motor Vehicle Programme (as amended by No. 79/2023). The first key point of Presidential Regulation No. 55/2019 (as amended by No. 79/2023) is its emphasis on the development of BEVs, both in their new form and as converted vehicles. Article 2 of Presidential Regulation No. 55/2019 states that BEVs, as referred to in paragraph (1), may include newly manufactured BEVs, and/or BEVs resulting from conversion carried out by conversion workshops.

Furthermore, according to Article 1.14, conversion is defined as the process of changing the propulsion system of a motor vehicle from an ICE to an electric motor. Converted BEVs are also granted certain special support. For example, Article 8(2) stipulates that converted BEVs are not required to meet the TKDN requirements that apply to standard BEVs. This means that the government's electrification strategy for vehicles focuses on two key aspects: not only increasing the production of new EVs but also converting existing fossil fuel-powered vehicles into battery-powered vehicles.

The second key point of Presidential Regulation No. 55/2019 is the enumeration of activities aimed at implementing the development of BEVs in Indonesia, which are subsequently followed by derivative regulations and government programs. These activities are outlined in Article 3, which states that the acceleration of the BEV programme for road transportation shall be carried out by (i) accelerating the development of the domestic BEV industry; (ii) providing incentives; (iii) providing charging infrastructure and regulating electricity tariffs for BEVs; (iv) ensuring compliance with technical standards for BEVs; and (v) protecting the environment.

The third key point of Presidential Regulation No. 55/2019 is the establishment of the Coordination Team for the Acceleration of the BEV Programme, as mentioned in Article 4(1). This mandate is further elaborated in the Coordinating Minister for Maritime Affairs and Investment Regulation No. 8/2020 concerning the Working Procedures of the Coordination Team for the Acceleration of the Battery Electric Vehicle Programme for Road Transportation and Working Groups. According to this regulation, the structure of the Coordination Team comprises:

Chairperson : Coordinating Minister for Maritime Affairs and Investment

Vice Chairperson: Coordinating Minister for Economic Affairs

Members :

- 1) Minister of Finance
- 2) Minister of Research and Technology/Head of the National Research and Innovation Agency
- 3) Minister of Industry
- 4) Minister of Trade
- 5) Minister of Energy and Mineral Resources
- 6) Minister of Transportation
- 7) Minister of Environment and Forestry
- 8) Minister of Home Affairs
- 9) Chief of the National Police of the Republic of Indonesia

To ensure the sustainability of the Coordination Team's performance, Article 6 of Law No. 8/2020 mandates that the team hold regular meetings at least once every 6 months to evaluate the implementation of the BEV acceleration programme for road transport. In addition, Article 9(1) establishes working groups to support the smooth execution of the Coordination Team's duties. These working groups include (i) a working group to accelerate the implementation of presidential regulation legislation and (ii) other working groups formed as needed (Article 10 in conjunction with Article 12).

The fourth key provision of Presidential Regulation No. 55/2019 focuses on encouraging domestic BEV development so that the resulting economic benefits support local manufacturers and suppliers rather than primarily foreign entities. Article 6(1) of the regulation states that BEV industry companies and/or BEV component industry companies are required to establish manufacturing facilities for BEVs within Indonesia to carry out BEV industry activities as outlined in Article 5. Moreover, paragraph 3 emphasises that, to accelerate the development of the domestic BEV industry, BEV component manufacturers and/or domestic BEV component industry companies must support and collaborate with domestic BEV producers. Article 8 specifies that the production of BEV components must be conducted by BEV component industry companies that meet the following criteria:

- 1) They are established under Indonesian law and operate within the territory of the Republic of Indonesia.
- 2) They hold an industrial business license for assembling or producing main and/or supporting components for BEVs in accordance with applicable laws and regulations.

The regulation also provides specific requirements regarding local content requirements (*Tingkat Komponen Dalam Negeri* or TKDN). Article 8 requires BEV and component manufacturers to prioritise the use of local components according to the following criteria:

For two-wheeled and/or three-wheeled BEVs:

- 2019–2026: Minimum TKDN of 40%
- 2027–2029: Minimum TKDN of 60%
- 2030 onwards: Minimum TKDN of 80%

For four-wheeled or larger BEVs:

- 2019–2021: Minimum TKDN of 35%
- 2022–2026: Minimum TKDN of 40%
- 2027–2029: Minimum TKDN of 60%
- 2030 onwards: Minimum TKDN of 80%.

The fifth key point of Presidential Regulation No. 55/2019 concerns the authority of the government to implement policies to control the use of fossil fuel-powered vehicles. Article 16 of the regulation stipulates that, to accelerate the adoption of BEVs, the central government may gradually regulate the use of fossil fuel-powered vehicles. This gradual regulation of fossil fuel vehicle usage is to be implemented based on the national motor vehicle industry development roadmap. With this provision, the government has strong legitimacy to introduce disincentive policies for fossil fuel-powered vehicles. Such policies aim to encourage the retirement of these vehicles, paving the way for their replacement with electric-powered vehicles.

The sixth key point of Presidential Regulation No. 55/2019 is the provision of incentives for BEVs. Article 17(1) states that the central government and regional governments shall provide incentives to accelerate the BEV programme for road transportation. Paragraph 2 explains that these incentives consist of fiscal and non-fiscal incentives. Table 3.11 presents the forms of fiscal and non-fiscal incentives that can be provided.

Table 3.11. General Incentives According to Presidential Regulation No. 55/2019

Fiscal Incentives	Non-fiscal Incentives
<ul style="list-style-type: none"> • Article 19(1): 1) Customs duty incentives on the importation of BEVs in completely knocked down (CKD) form, incompletely knocked down form, or main components for a specified quantity and period 2) Incentives for luxury goods tax (PPnBM) 3) Incentives for the exemption or reduction of central taxes 4) Incentives for the exemption or reduction of regional taxes 5) Customs duty incentives on the importation of machinery, goods, and materials for investment purposes 6) Customs duty exemptions covered by the government for the importation of raw materials and/or auxiliary materials used in the production process 7) Incentives for the creation of public charging stations (SPKLU) and battery swap stations (SPBKLU) 8) Export financing incentives 9) Fiscal incentives for research, development, and technological innovation activities, as well as vocational training in the BEV component industry 10) Parking fee incentives at locations designated by local governments 11) Reduction in electricity charging costs at SPKLU 12) Financial support for the development of SPKLU infrastructure 13) Professional competency certification for human resources in the BEV industry n. Product certification and/or technical standards for BEV and BEV component industries. • Paragraph 2: 	<ul style="list-style-type: none"> • Article 20, paragraph 1: 1) Exemption from restrictions on the use of certain roads 2) Transfer of production rights for technology related to BEVs whose patents are held by the central government and/or regional government 3) Guidance on security and/or protection of industrial sector operations to ensure the continuity and smooth functioning of logistics and production activities in industrial enterprises designated as national vital objects.

Fiscal Incentives	Non-fiscal Incentives
For two-wheeled BEVs, the government may provide purchase assistance and conversion assistance programmes for a specified period.	

Source: Presidential Regulation No. 55/2019.

In addition to the general incentives mentioned above, Article 18 also provides specific incentives for BEV manufacturing companies that procure BEVs imported in a CBU state; and BEV manufacturing companies that can accelerate the assembly process domestically within the importation period for CBU vehicles.

Table 3.12. Specific Incentives According to Presidential Regulation No. 55/2019

Special Incentives for Battery Electric Vehicle (BEV) Manufacturing Companies Procuring BEVs Imported in a Completely Built-Up (CBU) State	Special Incentives for BEV Manufacturing Companies Able to Accelerate Domestic Assembly within the Importation Period of CBU Units
<p>Article 19A(1):</p> <ol style="list-style-type: none"> 1) Import duty incentives for BEVs imported in CBU conditions or import duties borne by the government for such imports 2) Luxury goods tax (PPnBM) incentives for BEVs imported in CBU condition, or PPnBM incentives borne by the government for such imports 3) Exemption or reduction of regional taxes for BEVs in CBU condition. 	<p>Article 19A(2):</p> <ol style="list-style-type: none"> A1) Import duty incentives BEVs produced domestically, or import duties borne by the government for the importation of domestically produced BEVs b. PPnBM incentives for BEVs produced domestically or PPnBM incentives borne by the government for domestically produced BEVs c. Exemption or reduction of regional taxes for domestically produced BEVs in CKD condition 4) Import duty incentives for machinery, goods, and materials for investment purposes 5) Import duty incentives for raw materials and/or auxiliary materials used in the production process.

Source: Presidential Regulation No. 55/2019.

The seventh key point of Presidential Regulation No. 55/2019 concerns the provision of SPKLU) and SPBKLU) and SPBKLU) and SPBKLU) should be

provided at public fuel stations, public gas filling stations, offices of the central and regional governments, shopping centres, and public parking along highways.

The provision of SPKLUs and SPBKLUs can be carried out by state-owned enterprises in the energy sector or other business entities (Article 23[1]). However, for the first time, the provision of EV charging infrastructure for the battery-based electric vehicle will be executed through an assignment to PT PLN (Persero) (Article 23[2]). The provisions and policies contained in the presidential regulation above are further elaborated through a series of implementing regulations. Below are the existing implementing regulations in Indonesia to support the adoption of LCEVs.

2.1.1. Luxury goods sales tax rates for electric vehicles

Government Regulation No. 73/2019, in conjunction with Government Regulation No. 74/2021, stipulates the luxury goods sales tax rates for EVs as follows:

- 15% for passenger vehicles transporting fewer than 10 persons (including the driver), with electric motors powered entirely by batteries or other energy storage media, or other power generators either directly on the vehicle or externally.
- 15% for passenger vehicles transporting 10–15 persons (including the driver), with electric motors powered entirely by batteries or other energy storage media, or other power generators either directly on the vehicle or externally.
- 10% for double-cabin motor vehicles with electric motors powered entirely by batteries or other energy storage media, or other power generators either directly on the vehicle or externally.

EVs exempted from the luxury goods sales tax include passenger vehicles designed to transport 10–15 persons (including the driver) and used as official vehicles by the Indonesian National Armed Forces or the National Police of the Republic of Indonesia. These vehicles must be powered entirely by electric motors using batteries or other energy storage media, or other power generators either directly on the vehicle or externally.

However, Minister of Finance Regulation No. 135/2024 stipulates that the luxury goods sales tax payable on the delivery and import of CKD BEVs by business actors shall be borne by the government. The implication of this regulation is that CKD BEVs are subject to a 0% luxury goods sales tax.

2.1.2. Motor vehicle tax and transfer fee for motor vehicles

Based on MoHA Regulation No. 8/2024, motor vehicle tax (PKB) and transfer fee for motor vehicle title (BBnKB) for BEVs are regulated under Article 10, which states that:

- 1) The imposition of the PKB) for BEVs is set at 0% of the PKB and BBnKB tax base for

- a) Passenger vehicles,
 - b) Goods vehicles,
 - c) Public passenger transport, and/or
 - d) Public goods transport.
- 2) The 0% rate also applies to motor vehicles converted from fossil fuel to battery-based systems.
 - 3) Further provisions regarding the tax imposed on converted vehicles will be regulated by a governor's regulation.

2.1.3. Value-added tax

MoF Regulation No. 12/2025 provides incentives in the form of a VAT discount for the purchase of BEVs. Article 2 of the regulation stipulates that the VAT payable on the delivery of certain four-wheeled BEVs shall be borne by the government. Article 5 further specifies that the VAT borne by the government amounts to 10% of the sales price. Considering that the current VAT rate is 12%, this means that BEV buyers are required to pay only 2% VAT.

2.1.4. Official mandate to adopt BEVs

Presidential Instruction No. 7/2022 on the Use of Battery Electric Vehicles for Official Vehicles (INPRES 7/2022) is a strategic step in the effort to decarbonise Indonesia's transport sector. INPRES 7/2022 is the instruction for central and regional government agencies to adopt EVs as official vehicles. This initiative aims not only to reduce GHG emissions and air pollution but also to support innovation and the use of environmentally friendly technology. The implementation of this regulation is supported by incentives and facilitation from the government, including purchasing ease, tax incentives, and the development of supporting infrastructure, such as EV charging stations.

2.1.5. Legal structure to support BEV adoption

Presidential Instruction No. 7/2022 regulates the delegation of tasks to various ministries and government agencies to accelerate BEV adoption. These tasks include coordination, synchronisation, monitoring, evaluation, and problem-solving related to the implementation of the programme. Additionally, various ministries are responsible for formulating and revising regulations, as well as allocating budgets to support the acceleration of BEV adoption. This includes encouraging the development of infrastructure such as EV charging stations, speeding up EV production and research, and integrating relevant information systems. Periodic reports must be submitted to the central government regarding the progress and implementation of this programme. Stakeholders at the regional level are also expected to support this initiative by formulating local regulations, budget allocations, and relevant incentives to accelerate BEV adoption.⁶

Table 3.13. Legal Structure to Support BEV Adoption According to Presidential Instruction No. 7/2022

<p>Coordinating Minister for Maritime Affairs and Investment</p>	<ul style="list-style-type: none"> • Coordinating, synchronising, monitoring, evaluating, and controlling the implementation of this presidential instruction • Resolving any issues that hinder the acceleration of the programme to use BEVs as official operational vehicles and/or individual vehicles for central and regional government agencies • Reporting the implementation of this presidential instruction to the President on a regular basis every 6 months, or as required
<p>Minister of Home Affairs</p>	<ul style="list-style-type: none"> • Synchronising regulations related to the norms, standards, procedures, and criteria for public services provided by local governments to support the acceleration of the BEV programme for use as official operational vehicles and/or personal vehicles for local government agencies • Encouraging governors and regents/mayors to draft and enact regional regulations to support the acceleration of the BEV programme, promoting their use as official operational vehicles and/or personal vehicles for local government agencies and regional state-owned enterprises • Regularly conducting socialisation activities on this presidential instruction to ensure that governors and regents/mayors, along with their staff, begin transitioning to the use of BEVs as official operational vehicles and/or personal vehicles for local government agencies • Encouraging local governments to allocate funds in their regional revenue and expenditure budget for the transition to BEVs as official operational vehicles and/or personal vehicles for local government agencies, and to provide justifications to the Ministry of Home Affairs if the procurement of non-BEV vehicles remains necessary • Supervising and providing guidance to governors and regents/mayors regarding the increased use of BEVs as official operational vehicles and/or personal vehicles for local government agencies and regional state-owned enterprises • Submitting periodic reports on the progress of BEV adoption as official operational vehicles and/or personal vehicles for local

	<p>government agencies every 3 months, or as required, to the Coordinating Minister for Maritime Affairs and Investment, with copies to the Head of the Presidential Staff.</p>
<p>Minister of Defence and Commander of the Indonesian National Armed Forces</p>	<ul style="list-style-type: none"> • Drafting and enacting regulations and allocating budgets to support the acceleration of the implementation of the BEV programme for use as official operational vehicles and/or personal vehicles within the Ministry of Defence and the Indonesian National Armed Forces • Prioritising the gradual procurement of BEVs as official operational vehicles and/or personal vehicles for the Ministry of Defence and the Indonesian National Armed Forces • Encouraging the Strategic Studies, Research, and Development Centre of the Indonesian National Armed Forces, together with the Army, Navy, and Air Force Research and Development Agencies, to implement the programme for converting official operational vehicles and/or personal vehicles of the Indonesian National Armed Forces from ICEVs to BEVs.
<p>Minister of Finance</p>	<ul style="list-style-type: none"> • Improving regulations related to the cost standards for central and regional governments to support the acceleration of the implementation of the BEV programme for use as official operational vehicles and/or personal vehicles within central government agencies and regional administrations • Reviewing budget proposals for the procurement of operational vehicles for ministries and government agencies, prioritising proposals for BEV procurement, and assessing justifications if the proposed procurement of operational vehicles and/or personal vehicles for central government agencies does not involve BEVs • Formulating policies to accelerate the procurement of BEVs through a moratorium on the procurement of conventional vehicles – both new and replacement – while considering the condition of state-owned assets and the principles of budget efficiency and effectiveness • Providing facilitation and technical support for budget preparation required to accelerate the procurement of BEVs in accordance with applicable regulations.

Minister of Education, Culture, Research and Technology and Head of the National Research and Innovation Agency	Coordinating and synchronising the implementation of initiatives to strengthen and develop the research ecosystem for BEVs.
Minister of Industry	<ul style="list-style-type: none"> • Accelerating the production of various types of BEVs, including motorcycles and four-wheeled or larger vehicles, to support the transition from ICEVs into BEVs • Providing technical support for the deepening of the domestic BEV industry structure to meet the domestic component level (TKDN) target • Accelerating the development of key components and supporting components for the BEV industry • Speeding up the production of charging station equipment and supporting components for the BEV industry.
Minister of Energy and Mineral Resources	<ul style="list-style-type: none"> • Synchronising regulations related to norms, standards, procedures, and criteria to support the acceleration of the BEV programme for government operational vehicles and/or personal vehicles for central and regional government agencies • Encouraging the acceleration of the development of SPKLUs and SPBKLUs to enhance connectivity for BEV transportation within cities and districts, as well as between cities, districts, and provinces • Facilitating and expediting business licensing for SPKLUs and SPBKLUs through the optimisation of the Online Single Submission system, the provision of facilities for testing and inspection of SPKLUs, and the provision of electricity tariff incentives for SPKLU and SPBKLU operators • Coordinating the designation of locations and supporting electrical infrastructure for the placement of SPKLUs and SPBKLUs

	<ul style="list-style-type: none"> • Accelerating the vehicle conversion programme from ICEVs to BEVs as part of energy transformation.
Minister of Transportation	<ul style="list-style-type: none"> • Encouraging the implementation of the roadmap for the transformation of operational government vehicles from ICEVs to BEVs • Providing periodic reports on the progress of the use of BEVs as operational and/or personal vehicles for central and regional government agencies every 3 months, or as required, to the Coordinating Minister for Maritime Affairs and Investment, with a copy to the Head of the Presidential Staff • Promoting the implementation of physical inspection and testing of BEVs, particularly operational and/or personal vehicles used by central and regional government agencies across all provinces and cities/districts.
Minister of National Development Planning/Head of National Development Planning Agency	<ul style="list-style-type: none"> • Developing integrated planning for the acceleration of BEV adoption, the development of the BEV industry, and the expansion of the BEV ecosystem as part of national development planning • Preparing a scheme or transition for subsidies that were previously given to users of gasoline-powered vehicles to users of BEVs to accelerate energy transformation.
Minister of State-Owned Enterprises	<ul style="list-style-type: none"> • Formulating and enacting regulations to support the acceleration of the implementation of the programme for using BEVs as operational vehicles for state-owned enterprises (SOEs) • Encouraging SOEs to increase the use of various types of BEVs • Encouraging SOEs to allocate budgets to support the acceleration of the implementation of the programme for using BEVs as operational vehicles within SOEs • Encouraging PT PLN (an SOE or <i>Persero</i>) and PT Pertamina (<i>Persero</i>) to collaborate with other SOEs in preparing supporting infrastructure – such as SPKLU and SPBKLU – particularly in sectors managed by SOEs, including rest areas on toll roads, airports, seaports, train stations, tourist destinations, and public fueling stations • Encouraging SOEs in the banking sector to provide financing facilities for BEVs in accordance with applicable regulations.

Minister of Tourism and Creative Economy/Head of Tourism and Creative Economy Agency	<ul style="list-style-type: none"> • Encouraging the use of BEVs by local tourism programme administrators to support green tourism in tourism destinations across Indonesia • Encouraging the use of BEVs in tourism destinations throughout Indonesia • Encouraging the provision of charging station facilities at tourism destinations across Indonesia to support the operation of BEVs • Facilitating the development of green tourism route schemes using BEVs at various tourism destinations across Indonesia, while regularly providing education and promotional activities.
Minister of Investment/Head of Investment Coordinating Board	<ul style="list-style-type: none"> • Developing a plan aimed at accelerating investment strategies through a business facilitation mechanism to support the production and use of BEVs from upstream to downstream • Optimising the use of the Integrated Electronic Business Licensing System (Online Single Submission) in issuing business licences for investment related to BEVs by coordinating with relevant ministries/agencies.
Minister of Transportation, Minister of Energy and Mineral Resources, and Chief of the Indonesian National Police	Preparing and implementing an integrated information system based on information technology to support the acceleration of the programme for converting ICEVs into BEVs as operational vehicles and/or personal vehicles for central and local government agencies.
Chief of Presidential Staff	<ul style="list-style-type: none"> • Supporting the implementation of monitoring, evaluation, and control over the execution of this presidential instruction • Resolving issues that hinder the implementation of the accelerated programme for using BEVs as operational vehicles and/or personal vehicles for central and local government agencies
Minister of Industry, Minister of Transportation,	<ul style="list-style-type: none"> • Providing socialisation and/or technical guidance to business actors in the EV sector and supporting facilities to facilitate and accelerate the entry of EVs into the electronic catalog

<p>and Head of Government Goods/Services Procurement Policy Agency</p>	<ul style="list-style-type: none"> • Providing socialisation and/or technical guidance to ministries/agencies and local governments regarding various types of BEVs listed in the electronic catalog to facilitate and accelerate the procurement of operational vehicles and/or personal vehicles for central government agencies and local governments.
<p>Chief of the Indonesian National Police</p>	<ul style="list-style-type: none"> • Prioritising the gradual use of BEVs as operational vehicles and/or personal vehicles for the Indonesian National Police • Developing and establishing regulations and budget allocations to support the acceleration of the programme for the use of BEVs for operational vehicles and/or personal vehicles for the Indonesian National Police • Encouraging the Indonesian National Police Research and Development Centre to implement a programme for converting operational vehicles and/or personal vehicles of the Indonesian National Police from ICEVs to BEVs through the development of standards and specifications • Providing priority services for the registration, identification, and modification processes of the Vehicle Registration Certificate (STNK), Vehicle Number Plate (TNKB), and Vehicle Ownership Book (BPKB) for vehicles converted from ICEVs to BEVs.
<p>Governors, Regents, and Mayors</p>	<ul style="list-style-type: none"> • Preparing and establishing regional head regulations and budget allocations to support the acceleration of the programme for the use of BEVs as operational vehicles and/or personal vehicles of regional government agencies • Encouraging regional SOEs to increase the use of various types of BEVs • Creating synergy and supervision for each regional working unit to monitor the development of the use of BEVs as operational vehicles and/or personal vehicles for regional government agencies in their respective regions • Providing periodic reports on the progress of BEV use as operational vehicles and/or personal vehicles for regional government agencies to the Ministry of Home Affairs every 3 months, or as required; and

	<ul style="list-style-type: none"> • Providing fiscal and non-fiscal incentives in the form of facilities and priorities for BEV users in accordance with applicable regulations.
--	--

2.1.6. National roadmap for developing the BEV industry

Minister of Industry Regulation No. 6/2022 established a national roadmap for developing the BEV industry. Article 4 of the regulation stipulates that the development of the BEV industry must align with this national roadmap. The details of the roadmap are presented in Attachment I of the regulation. It encompasses various aspects, including production targets for EVs, with ambitious goals for both four-wheeled and two-/three-wheeled vehicles. The roadmap also emphasises the importance of increasing the TKDN for EVs, with targets ranging from 35% to 80% by 2030 for different vehicle categories. Furthermore, it outlines a comprehensive set of policies and strategies to stimulate demand for EVs, including pilot projects, fiscal and non-fiscal incentives, the expansion of charging infrastructure, and, ultimately, mandatory EV usage in certain areas.

2.1.7. Electric motorcycle purchase subsidy

Minister of Industry Regulation No. 6/2023 stipulates government assistance in the form of a price discount for the purchase of two-wheeled BEVs. Article 1(1) states that 'Government Assistance for the Purchase of Two-Wheeled Battery Electric Vehicles, hereinafter referred to as the Assistance Program, is assistance provided in the form of a price discount for the purchase of a new two-wheeled battery electric vehicle for the public'. Article 3(6) provides that the price discount is set at Rp7 million for the purchase of one unit of a two-wheeled BEV. The requirements for individuals to receive this discount are outlined in Article 3, as follows: (i) be an Indonesian citizen, (ii) be at least 17 years of age, and (iii) possess an electronic identification card (e-KTP).

Based on this regulation, every Indonesian citizen purchasing an electric motorcycle for the first time in Indonesia is eligible to receive a price discount of Rp7 million.

2.1.8. Vehicle conversion programme

MoEMR Regulation No. 3/2023 (as amended by Regulation No. 13/2023) provides for the form of government assistance for the motorcycle conversion programme and its technical provisions. Article 3(1) of this regulation explains that government assistance is provided in the form of a conversion cost discount. The discount applies only to the conversion costs for the battery pack, brushless DC motor, and controller, adjusted according to the energy capacity of the battery and the power of the electric motor (Article 3[2]). The assistance provided is valued at Rp7 million for each converted motorcycle (Article 3[4]). According to Article 3(3), the maximum conversion cost is Rp17 million for motorcycles with an engine capacity of 110 cc up to 150 cc. Thus, the maximum amount

of assistance for an individual converting to an electric motorcycle is set at Rp10 million. In addition, a quota is established for the number of assistance units provided by the government. According to Article 3(6), the total assistance provided for fiscal year (FY) 2023 is up to 50,000 units of electric motorcycles, and for FY 2024 is up to 150,000 units of electric motorcycles.

However, it is still uncertain whether this programme will be extended to 2025 and beyond.

2.1.9. Charging infrastructure for BEVs

MoEMR Regulation No. 13/2020 regulates Electric Charging Infrastructure for Battery-Based Electric Motor Vehicles. The first key point of this regulation concerns the provision of charging infrastructure for battery electric motor vehicles, particularly outlining the locations and parties responsible for its development. Article 12(2) stipulates that SPKLU be provided at public fuel filling stations, gas fuel filling stations, central and regional government offices, shopping centres, and public parking lots on the side of roads.

The subjects responsible for providing SPKLUs are business entities holding an integrated electric power supply business licence (IUPTL) or an IUPTL for electricity sales with an operational area for electricity sales at SPKLUs (Article 9). However, business entities that do not hold an integrated IUPTL or electricity sales licence may also participate in providing SPKLUs through various partnership schemes with IUPTL holders, in accordance with the provisions of Article 11 of the regulation. Article 19 also assigns PT PLN (*Persero*) with the task of initially providing electricity charging infrastructure for BEVs. To carry out this task, PT PLN is mandated to create a roadmap for providing SPKLU and SPBKLU infrastructure (Article 20).

The second key point of this regulation is the establishment of specific tariffs for electricity used in charging battery electric motor vehicles. This is addressed in a separate chapter, Chapter III, which covers the electricity tariff for charging EVs. The calculation provisions are highly technical, detailed in Articles 22 and 23, which establish the minimum and maximum multiplier factors.

The third key point is the provision of relief for those involved in providing charging infrastructure for BEVs. Article 24(1) states that owners of private electricity installations, holders of IUPTL for electricity sales, and SPBKLU business entities applying for new connections or changes in electricity capacity from integrated IUPTL holders will receive relief. This relief includes connection fees and/or electricity subscription guarantees (Article 24[2]). Additionally, owners of private electricity installations used for charging public transport, SPKLU business entities, and SPBKLU business entities will also be exempted from the obligation to pay minimum billing to integrated IUPTL holders for the first 2 years (Article 24[3]).

2.1.10. Supply-side incentives

BKPM Regulation No. 6/2023 provides for incentives for businesses that supply EVs, aimed at supporting the supply side of EV production. Article 2 of the regulation states that businesses can be granted incentives for the importation of CBU four-wheeled BEVs and CKD four-wheeled BEVs, with a minimum TKDN of 20% and a maximum of less than 40%. The incentives include a 0% import duty and luxury goods sales tax (PPnBM) covered by the government.

Furthermore, Article 4 specifies that to receive these incentives, businesses must commit to producing four-wheeled BEVs in Indonesia that meet the technical specifications outlined in the regulations set by the Ministry of Industry.

This regulation is designed to support the short-term availability of EVs in Indonesia through imports while promoting the development of domestic EV manufacturing in the long term. Ensuring an adequate supply of EVs is crucial for encouraging widespread adoption by the public. Without sufficient availability, the transition to EVs could be slowed, undermining national efforts to reduce emissions and achieve sustainability goals. The combination of immediate import incentives and the requirement for local production fosters both the growth of the EV market and the strengthening of Indonesia's industrial capacity in the EV sector.

Table 3.14. Policies to Accelerate LCEV Adoption

Aspect	Incentives for Battery Electric Vehicles (BEVs)	Incentives for Low-Carbon Vehicles (LCEVs, excluding BEVs)
Luxury goods sales tax (PPnBM)	0% luxury goods sales tax on the delivery of completely knocked down (CKD) BEVs by business actors (Minister of Finance [MoF] Regulation No. 135/2024)	Lower luxury goods sales tax rate compared to high-carbon vehicles (depending on the type of LCEV) (Chapter 3 of PP 73/2019 in conjunction with PP 74/2021)
Motor vehicle tax (PKB)	0% PKB on BEVs for <ul style="list-style-type: none"> • passenger vehicles • goods vehicles • public transportation for passengers • public transportation for goods (Minister of Home Affairs [MoHA] Regulation No. 8/2024) 	No special provisions for other LCEVs

Aspect	Incentives for Battery Electric Vehicles (BEVs)	Incentives for Low-Carbon Vehicles (LCEVs, excluding BEVs)
Vehicle ownership transfer tax (BBnKB)	0% BBnKB on BEVs for <ul style="list-style-type: none"> • passenger vehicles • goods vehicles • public transportation for passengers • public transportation for goods (MoHA Regulation No. 8/2024) 	No special provisions for other LCEVs
Luxury goods sales tax (PPnBM) payable on the import of BEVs	0% luxury goods sales tax rate on the import of CKD BEVs by business actors (MoF Regulation No. 135/ 2024)	No special provisions for other LCEVs
Value-added tax (VAT)	10% reduction of VAT payable on the delivery of BEVs in the form of cars designed for the transportation of passengers and/or certain battery-based electric buses to buyers (MoF Regulation No. 12/2025)	10% reduction of VAT for HEVs (MoF Regulation No. 12/2025)
Electric motorcycle purchase subsidy	Rp7 million subsidy for every purchase of one unit of electric motorcycle by one National Identity Card (KTP) holder. (Ministry of Industry Regulation Number 21 of 2023)	No special provisions for other LCEVs
Legal structure	<ul style="list-style-type: none"> • Coordination Team Forum for accelerating the BEV programme, involving various ministries (Presidential Regulation No. 55/2019 in conjunction with Presidential Regulation No. 79/2023 and Coordinating Minister for Maritime Affairs and Investment Regulation 9/2020) • Clear instructions to ministries to support the BEV programme through budget allocation, programme development, periodic reporting, and task division (Presidential Instruction No. 7/2022) 	No coordination forum or clear cross-ministerial instructions
Supply-side Incentives	0% Import duty and 0% PPnBM on the importation of completely built-up (CBU)	No special provisions for other LCEVs

Aspect	Incentives for Battery Electric Vehicles (BEVs)	Incentives for Low-Carbon Vehicles (LCEVs, excluding BEVs)
	BEVs and CKD BEVs, with a minimum domestic content (TKDN) of 20% and a maximum of less than 40%. (BKPM Regulation No. 6/2023)	
Supporting infrastructure	<ul style="list-style-type: none"> • Assignment to PT PLN to provide electricity charging infrastructure for BEVs (Presidential Regulation No. 55/2019 in conjunction with Presidential Regulation No. 79/2023) • Legal basis for businesses in providing charging infrastructure (Minister of Energy and Mineral Resources [MoEMR] Regulation No. 13/2020) • Special electricity tariffs for charging infrastructure (MoEMR Regulation No. 13/2020) • Discounts on electricity capacity upgrades and minimum account charges for public charging station owners (MoEMR Regulation 13/2020) 	No special provisions to support LCEVs infrastructure
Mandate to regional governments	Mandate for regional governments to adopt EVs as official vehicles, with central government support for purchases, charging infrastructure, etc. (Presidential Instruction No. 7/2022)	No special mandate for regional governments to adopt LCEVs
Planning documents	A national roadmap for developing the BEV industry has been prepared. (Minister of Industry Regulation No. 6/2022)	No specific roadmap for developing the LCEV industry
Vehicle conversion	Rp7 million for converting motorcycles to battery-powered motorcycles (MoEMR Regulation No. 3/2023)	No provisions for converting vehicles to LCEVs

Source: Authors.

2.2. Evaluation of the Existing Policies

2.2.1. Retirement of carbon-intensive vehicles

Indonesia currently lacks comprehensive policies specifically aimed at retiring carbon-intensive vehicles. The existing regulatory framework focuses more on promoting the adoption of cleaner vehicles rather than directly addressing the phase-out of older, high-emission vehicles. Without clear mandates, vehicle owners are under no legal obligation to phase out their high-emission vehicles. This regulatory vacuum allows older vehicles, which typically have higher emissions and lower fuel efficiency, to remain in operation. These vehicles disproportionately contribute to urban air pollution and GHG emissions, exacerbating environmental and public health issues.

To address these challenges, the following measures are recommended (Table 3.15).

Table 3.15. Recommendations Regarding Carbon-Intensive Vehicle Retirement Policies

<p>The absence of specific regulations addressing the retirement of older, carbon-intensive vehicles poses a significant challenge. Without clear mandates, vehicle owners have no legal obligation to phase out their high-emission vehicles. This regulatory gap allows older vehicles – typically characterised by higher emissions and lower fuel efficiency – to remain in operation. Consequently, these vehicles contribute disproportionately to urban air pollution and GHG emissions, exacerbating environmental and public health concerns.</p>	<ul style="list-style-type: none">• Develop and implement policies that mandate the retirement of vehicles beyond a certain age or those that fail to meet emission standards. These policies should be phased in gradually to allow vehicle owners time to comply.• Establish a clear timeline for the retirement of carbon-intensive vehicles, with specific milestones to track progress.
<p>The financial burden of replacing older vehicles remains a major barrier for many owners. Newer, cleaner vehicles – particularly electric and hybrid models – are often significantly more expensive upfront than their older counterparts. In the absence of adequate financial incentives or subsidies, many owners cannot afford such upgrades. This economic constraint slows the transition towards a cleaner vehicle fleet and impedes efforts to reduce emissions.</p>	<ul style="list-style-type: none">• Provide financial incentives, such as subsidies or tax breaks, to encourage the retirement of older, high-emission vehicles. This could include trade-in programmes where owners of older vehicles receive discounts on new, cleaner models.• Offer low-interest loans or grants to assist vehicle owners in purchasing new, low-emission vehicles.

Source: Authors (2024).

2.2.2. Roadworthiness

Indonesia has established roadworthiness standards that vehicles must satisfy to be legally operated. These standards, outlined in Minister of Transportation Regulation No. 19/2021 on Periodic Testing of Motor Vehicles, include checks on mechanical condition, safety features, and emission levels. According to the regulation, motorised vehicles, trailers, and attached trains that are operated on public roads must undergo periodic testing. Periodic tests are carried out on public transportation and large transport vehicles, such as general passenger cars, buses, freight cars, trailers, and stick cars. Vehicles must undergo a periodic test by the owner before being operated on the road. Periodic tests consist of the following:

- 1) Periodic test of vehicle registration (mandatory periodic test)
- 2) Initial periodic test
- 3) Periodic test for the extension of validity.

The test consists of a physical examination and testing, comprising (i) examination of technical requirements and (ii) testing of roadworthiness requirements.

In terms of emissions, the roadworthiness test takes into account exhaust emissions, including exhaust gas smoke thickness. This aligns with Minister of Environment Regulation No. 5/2006, which sets exhaust gas emission thresholds for older motor vehicles. Failure to pass the roadworthiness test may result in fines. Under Articles 285 and 286 of Law No. 22/2009 on Road Traffic and Transportation, non-compliance can lead to penalties of up to Rp250,000 for motorbikes and Rp500,000 for cars.

However, Indonesia faces several challenges in enforcing roadworthiness standards effectively. One of the primary issues is inconsistent enforcement across different regions. This inconsistency leads to a significant number of unfit vehicles continuing to operate on roads, which compromises safety and increases environmental pollution. Another major challenge is the lack of regular and mandatory inspections. While regulations may call for periodic checks, these are not systematically implemented. As a result, many vehicles that have deteriorated over time remain in operation without meeting the necessary standards.

Resource limitations also pose a significant barrier. Regulatory agencies often lack the necessary resources and capacity to conduct thorough and frequent inspections. This shortfall hinders their ability to enforce standards effectively and ensures compliance across the board. Corruption and regulatory evasion further undermine the effectiveness of roadworthiness standards. The presence of corruption allows some vehicle owners to bypass inspections or receive favourable results without meeting the required criteria. This ability to evade regulations perpetuates the presence of unsafe and polluting vehicles on the roads.

Japan, for instance, has one of the most rigorous vehicle inspection systems in the world, known as *Shaken*. Vehicles undergo comprehensive inspections every 2 years, with new cars inspected 3 years after purchase and subsequently every 2 years. The *Shaken*

inspection covers emissions, safety features, and overall mechanical condition. This detailed and often costly process encourages vehicle owners to maintain their cars in good condition or replace them with newer, more compliant models, including EVs.

Incorporating similar rigorous inspection standards in Indonesia would not only improve roadworthiness but also create an environment that supports the adoption of EVs. As EVs typically have lower emissions and require less maintenance compared to traditional ICEVs, a robust inspection system can highlight these benefits, further incentivising the switch to cleaner transport options. Additionally, as part of this transition, Indonesia should consider implementing specific inspection protocols for EVs, ensuring that their unique components, such as batteries and electric drivetrains, are also thoroughly checked and maintained. This holistic approach will ensure that all vehicles on Indonesian roads are safe, reliable, and environmentally compliant, thereby contributing to reduced air pollution and improved public health.

2.2.3. Tax incentives

Indonesia already has a fairly comprehensive regulatory framework on tax incentives for EVs. A range of tax incentives is available for BEVs, including the following:

- 0% luxury goods sales tax (PPnBM)
- 0% motor vehicle tax (PKB)
- 0% vehicle ownership transfer fee (BBnKB)
- 10% value-added tax (VAT) reduction
- 0% PPnBM rate and 0% import tariffs on imported BEVs in CBU and CKD conditions, with a domestic component level 20–40%.

Although many incentives are already provided for the purchase of BEVs, there are still some aspects of the tax regulatory framework in Indonesia that can be evaluated, which is why the adoption rate of low-emission vehicles nationally has not yet reached its potential. First, there is a lack of attention to tax incentives for LCEVs other than BEVs. The various tax incentives mentioned above only apply to BEVs, while other LCEVs have not received equivalent tax incentives. Based on Government Regulation No. 79/2019 (as amended by Government Regulation No. 74/2021), LCEVs other than BEVs are still subject to a significant amount of PPnBM, although at a reduced rate, depending on the emission level. Additionally, LCEVs other than BEVs do not receive any incentives related to PKB, BBnKB, VAT, or the PPnBM rate on imported goods. Since LCEVs other than BEVs can also contribute to reducing emissions in the transport sector, the lack of tax incentives may result in a slower adoption rate for these vehicles.

Tax incentives for the supply side are also insufficient. The two key incentives for the supply side are a 0% PPnBM rate and 0% import tariffs on imported BEVs in CBU and CKD conditions with a domestic component level of 20–40%. To qualify for those incentives, business operators must commit to producing four-wheeled BEVs in Indonesia. However,

these incentives are inadequate for three reasons: (i) current regulations only provide incentives for BEVs, disregarding other LCEVs; (ii) even the incentives for BEVs are temporary, expiring on 31 December 2025 (Article 2, Regulation of the Minister of Investment/Head of the Investment Coordinating Board No. 6/2023); and (iii) the incentives apply solely to BEV imports, offering no advantage when businesses transition to domestic production. Since the government's long-term goal is to boost BEV production in Indonesia, additional tax incentives for domestic manufacturers are necessary to encourage investment in local production. This would attract more manufacturers to commit to producing BEVs in Indonesia and enhance their competitive edge over ICEV producers.

2.2.4. Purchase subsidy

The Government of Indonesia provides subsidies for both the conversion of ICE motorcycles to electric motorcycles and the purchase of new electric motorcycles, with a subsidy of Rp7 million in each case. These subsidies are substantial and represent a significant step by the government to boost the adoption of two-wheeled EVs in Indonesia, as they cover a significant portion of the cost for motorcycle conversions or new EV purchases. The typical market price for converting a motorcycle is around Rp15 million, meaning, the conversion cost would drop to under Rp10 million after the subsidy (detikOto, 2023). For new electric motorcycles, there are several affordable options, with the least expensive model costing less than Rp6 million after the subsidy (Kompas.com, 2024).

There are two key weaknesses in the current government subsidies: (i) the lack of subsidies for LCEVs other than EVs, and (ii) the absence of subsidies for the supply side. The same issue observed with tax incentives also applies to subsidies, but the situation is even more pronounced in this case. No subsidies are specifically allocated to LCEVs beyond EVs, meaning, hybrid and other low-emission alternatives are completely overlooked. This creates a narrow focus on full EVs, potentially limiting the broader adoption of diverse clean technologies that could also contribute to reducing emissions.

Additionally, there are no subsidies for businesses involved in the production or provision of EVs, such as manufacturers, battery suppliers, or infrastructure developers. Supporting the supply side through targeted incentives could help reduce production costs, strengthen domestic manufacturing capacity, and enhance the availability of EV-related technologies. Without such support, businesses may find it more difficult to scale up production or offer competitive pricing, which could slow the overall growth of the EV market in Indonesia.

2.2.5. Environmental zones

Presidential Regulation No. 55/2019 (as amended by Presidential Regulation No. 79/2023) provides the Government of Indonesia with a legal framework to establish environmental zones for vehicles. Article 20(1)(a) of the regulation states that one of the non-fiscal

incentives to accelerate EV adoption is the exemption from certain road usage restrictions. Based on this provision, the government has the authority to create low-emission zones (LEZs), which would restrict access to normal ICEVs. For instance, Jakarta has already implemented two LEZs that are accessible only to pedestrians, cyclists, public transport, and vehicles with special low-emission stickers (Jakarta Portal, 2024). Therefore, from a legal standpoint, there is sufficient justification to establish LEZs across Indonesia.

However, significant problems arise in the implementation phase. So far, Jakarta is the only city that has established LEZs; and even within Jakarta, their coverage is extremely limited, confined to small areas. The lack of expansion of LEZs both within Jakarta and across other cities means the policy has minimal impact on promoting EV adoption. Without a broader rollout, EV users see little practical advantage over ICEV users, as the areas where LEZs apply are few and far between. Moreover, the small scope of the existing zones limits their effectiveness in reducing overall emissions and improving air quality, undermining the intended environmental benefits. These issues create barriers to the success of LEZs as a meaningful incentive for EV adoption.

Figure 3.2. LEZ in Kota Tua, Jakarta



Source: AtmaGo (n.d.).

Emission standards as a basis for vehicle taxation

Article 206 of Government Regulation No. 22/2021 stipulates that compliance with emission standards is one of the factors determining the amount of vehicle tax. This provision applies to road-based land transportation that has been in service for more than 3 years. Paragraph 4 of the article delegates the responsibility for setting specific guidelines on the imposition of motor vehicle tax rates to the minister responsible for domestic government affairs. In response, the Minister of Home Affairs issued Regulation No. 8/2024, which, under Article 7, establishes that the level of environmental damage caused by a vehicle will be one of two coefficients used to calculate vehicle tax. Furthermore, the regulation mandates that adjustments to this environmental damage coefficient for vehicles in service for more than 3 years must be specified in a governor's regulation.

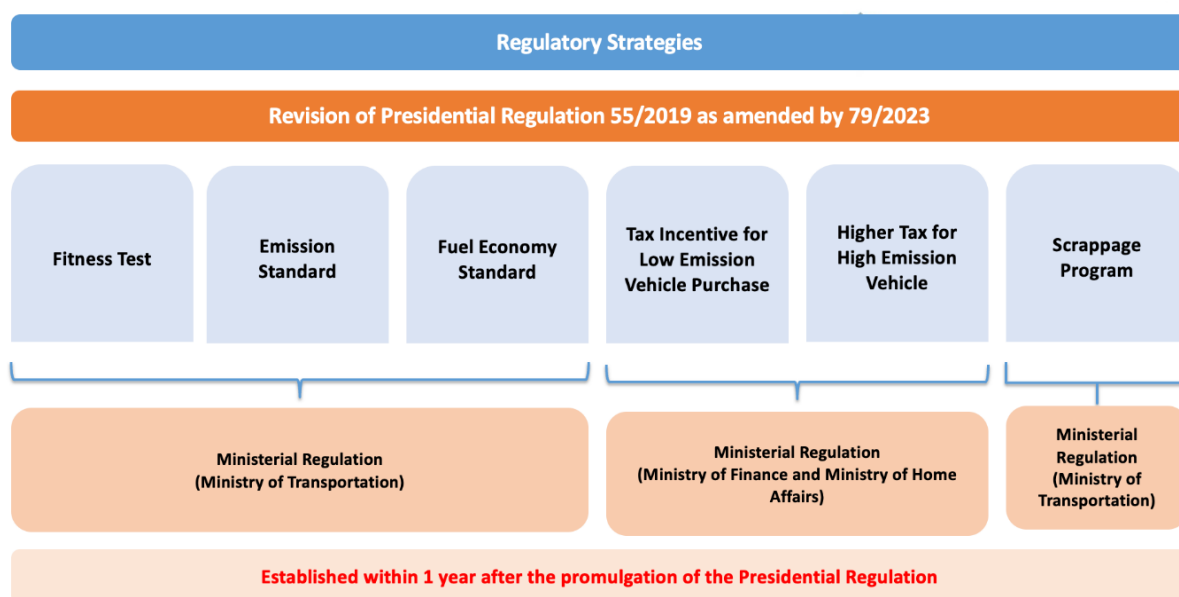
However, no governor has yet enacted the regulations mandated by Article 7 of Minister of Home Affairs Regulation No. 8/2024. As a result, the provision that ties emission standards to vehicle tax calculations for road-based vehicles in service for over 3 years cannot be implemented. This delay creates a significant gap in enforcing vehicle taxation based on environmental impact, preventing the intended incentive to encourage compliance with emission standards. Without these governor regulations, the broader goal of using tax policy to promote cleaner vehicles and reduce emissions remains stalled at the implementation stage.

3. Proposing Regulatory Improvements to Incentivise the Adoption of Clean Vehicles and the Retirement of High-Carbon Vehicles

In pursuit of a cleaner and more sustainable transport sector, Indonesia's regulatory strategy must evolve to meet its climate and public health objectives. Central to this strategy is the proposed revision of Presidential Regulation No. 55/2019, as amended by No. 79/2023, which currently serves as the legal backbone for promoting BEVs (Figure 3.3). The revision aims to broaden the scope of the regulation beyond BEVs, encompassing a more inclusive range of LCEVs, while simultaneously introducing a suite of mechanisms to phase out high-emission ICEVs.

This regulatory shift is structured around six key pillars: (i) the implementation of periodic fitness tests; (ii) the adoption of national emission standards; (iii) the establishment of fuel economy benchmarks; (iv) the provision of tax incentives for low-emission vehicle purchases; (v) the imposition of higher taxes on high-emission vehicles; and (vi) the launch of a national vehicle scrappage programme. Together, these pillars form a comprehensive approach to both incentivise clean vehicle adoption and disincentivise continued reliance on outdated, polluting technologies.

Figure 3.3. Proposed Regulatory Improvements for Fleet Renewal in Indonesia



Source: Authors.

To operationalise these strategies, a revision of the presidential regulation must be adopted, revising and expanding upon the current scope of Presidential Regulation No. 55/2019. This will serve as the legal umbrella under which ministerial regulations, to be issued by the Ministry of Transportation, Ministry of Finance (MoF, Ministry of Industry, Ministry of Environment and Forestry (MoEF), and Ministry of Home Affairs (MoHA), will be enacted. These implementing regulations will address specific mandates, including technical standards, fiscal mechanisms, vehicle classification, and compliance procedures.

Importantly, all derivative regulations should be drafted and enacted within 1 year of the promulgation of the revised presidential regulation to ensure coordinated and timely implementation. This timeline is consistent with prevailing practices under Law No. 12/2011 on law-making and is critical to maintaining policy momentum.

This chapter sets forth the legal rationale, policy objectives, and implementation roadmap for each of these six pillars. It begins with an in-depth proposal for the revision of Presidential Regulation No. 55/2019, followed by the articulation of regulatory instruments necessary to implement emissions testing, fiscal incentives, vehicle scrappage mechanisms, and tax adjustments. The aim is to deliver a future-ready regulatory framework that enables Indonesia to transition towards a sustainable, low-emission, and equitable road transport system.

3.1. Revision of Presidential Regulation 55/2019 (as amended by No. 79/2023)

Presidential Regulation No. 55/2019, as amended by No. 79/2023, has played a pivotal role in promoting BEVs in Indonesia. However, considering regulatory gaps and evolving policy objectives, a further revision of this regulation is necessary to better support a comprehensive clean vehicle transition strategy. The objective of revising the presidential regulation is to broaden its scope beyond BEVs, strengthen its environmental ambition, and ensure its alignment with the current regulatory, fiscal, and infrastructural ecosystem. Four key areas for improvement have been identified, each addressing critical gaps that currently limit the regulation's effectiveness in enabling a comprehensive LCEV transition.

1) Expansion of incentives to non-BEV LCEVs

One of the most pressing limitations of the current regulation is its narrow focus on BEVs. While BEVs represent the goal of electrification, other vehicle types, such as HEVs, PHEVs, and flex-fuel engines capable of running on 100% biofuels, also contribute significantly to the reduction of GHG emissions. Expanding the regulation to provide incentives for these LCEV categories would encourage a more inclusive and phased transition across Indonesia's diverse vehicle market.

2) Introduction of disincentives for high-emission vehicles

To balance the promotion of clean vehicles, the revised regulation must introduce disincentive mechanisms targeting high-emission ICEVs. This could take the form of a differentiated taxation scheme, where the PKB and BBnKB are calculated based on a vehicle's carbon emission profile. Such a strategy would not only discourage the continued use of high-emission vehicles but also provide a clear economic signal to consumers in favour of cleaner alternatives.

3) Establishment of a national vehicle scrappage programme

Indonesia currently lacks a formal framework to retire ageing, inefficient, and high-polluting vehicles from the road. The revised regulation should mandate the Ministry of Transportation to design and implement a national vehicle scrappage programme. Such programme would provide structured incentives, such as financial rebates or tax credits, to encourage the replacement of older ICEVs with newer, cleaner technologies. By doing so, Indonesia can avoid the long-term environmental and health costs associated with legacy vehicle fleets. This mandate is already outlined in Presidential Regulation No. 1/2022 on National General Plan for Traffic and Road Transport Safety.

Table 3.16. Presidential Mandate to Establish a National Vehicle Scrappage Programme

PROGRAM DAN KEGIATAN	INDIKATOR	TARGET 5 TAHUN KE-				INSTANSI PENANGGUNG JAWAB	INSTANSI/PIHAK PENDUKUNG
		1	2	3	4		
3.2.2	Pelaksanaan uji tipe kendaraan bermotor dan penelitian rancang bangun dan rekayasa kendaraan bermotor (berbahan bakar, listrik, hibrida)	Terseleenggaranya kegiatan	✓	✓	✓	✓	Kemenhub Kemenperin
3.2.3	Pengembangan fasilitas uji <i>Proving Ground</i> dan lab uji tabrak	Tersedianya fasilitas uji	✓	✓	✓	✓	Kemenhub Kemenperin
3.2.4	Pembinaan teknis terhadap bengkel modifikasi kendaraan bermotor	Persentase bengkel yang terbina	30%	60%	100%	100%	Kemenhub Kemenperin
3.2.5	Pemberian sertifikasi uji tipe kendaraan bermotor dengan mengadopsi NCAP	Terseleenggaranya kegiatan	✓	✓			Kemenhub BNSP
3.2.6	Penyusunan regulasi dan pelaksanaan <i>Scraping</i> kendaraan bermotor	Tersedianya regulasi dan terlaksananya kegiatan	✓	✓	✓	✓	Kemenhub Polri, Kemenperin, Pemda Kabupaten/Kota
3.3	Penyelenggaraan dan Perbaikan Prosedur Uji Berkala						
3.3.1	Penyempurnaan NSPK uji berkala kendaraan bermotor	Tersedianya NSPK	✓	✓	✓	✓	Kemenhub Kemendagri, Pemda Kabupaten/Kota

3.3.2 Akreditasi . . .

Source: Presidential Regulation No. 1 /2022 on National General Plan for Traffic and Road Transport Safety.

4) Mandate for emissions and fuel economy standards for privately owned vehicles

While technical and emissions standards exist for new LCEVs, no binding national standards applied to the broader fleet of privately owned vehicles. The revised regulation should require the development and enforcement of fuel economy and emission standards applicable to all road vehicles, regardless of ownership or technology type. These standards would be overseen jointly by the Ministry of Industry and the Ministry of Environment and Forestry (MoEF), supported by regular testing and certification mechanisms.

3.2. Implementing ministerial regulations on fitness testing, emission standards, and fuel economy requirements

Considering Indonesia's escalating air pollution and its commitment to reduce transport-related emissions under its enhanced nationally determined contribution (NDC), the current framework for periodic vehicle fitness testing, previously limited to public transport and commercial vehicles, must be expanded to cover all private vehicles. This strategic shift is not only justified by environmental urgency but is also legally and institutionally feasible, provided it is formalised through a new presidential regulation. Under Minister of Transportation Regulation No. 19/2021, Indonesia already possesses a technically robust framework for periodic motor vehicle testing (*uji berkala*). This regulation mandates semi-annual inspections of public vehicles, focusing on both technical specifications and roadworthiness, including emissions, braking systems, and safety equipment. However, the scope of this regulation is limited, excluding the vast majority of privately owned vehicles – many of which are ageing and contribute disproportionately to urban air pollution

The current legal basis for expanding this testing regime exists in Law No. 22/2009 on Road Traffic and Transportation, particularly Article 74, which allows the government to regulate periodic testing for all motor vehicles. Moreover, Articles 210 and 213 of the same law place a legal obligation on the government to control vehicle emissions and ensure that road transport activities support environmental sustainability. This expansion aligns with broader regulatory recommendations already proposed in this study, which calls for harmonising vehicle fitness testing with national emission and fuel economy standards. The current emissions regulation, MoEF Regulation No. 8/2023, sets emission thresholds, but it is yet to be fully enforced, and no systematic testing scheme has been applied to private vehicles.

By adopting a phased regional rollout, the government can begin implementation in urban areas with the highest pollution levels, such as Jakarta, Surabaya, and Bandung, before scaling the programme nationally. This will allow time for infrastructure development, human resource training, and stakeholder engagement.

To ensure high compliance and institutionalise environmental accountability amongst vehicle owners, the proposed expansion of the periodic vehicle fitness test to privately owned vehicles must be closely tied to existing administrative and fiscal processes. In particular, two widely implemented mechanisms, PKB and STNK renewal, can serve as effective leverage points to enforce compliance. This framework not only provides regulatory efficiency but also public legitimacy. Both PKB and STNK are familiar obligations for vehicle owners across Indonesia. Linking them with fitness testing does not introduce an additional layer of bureaucracy but rather integrates environmental compliance into an existing and well-understood administrative system. This approach creates a natural incentive for compliance, eliminating the need for separate punitive enforcement mechanisms while improving the reliability of national fleet data.

Legally, this approach finds its foundation in Law No. 22/ 2009 on Road Traffic and Transportation, particularly Articles 48, 74, and 210, which establish the government's authority to enforce roadworthiness and emissions standards. Further, Law No. 28/2009 on Regional Taxes and Levies provides legal space for local governments to condition tax collection on compliance with national transport regulations. Together, these laws create a strong enabling environment for the implementation of environmentally grounded compliance measures through fiscal channels.

Importantly, such a policy must also account for social and regional disparities. In areas where access to testing facilities is limited, the government should prioritise the deployment of mobile inspection units and establish public service partnerships to deliver inspections at the sub-provincial level. Additionally, to prevent the policy from disproportionately burdening low-income households, incentives such as free or subsidised tests could be offered based on income classification or vehicle type.

3.3. Implementing Ministerial Regulations on Fiscal Instruments: Incentives for LCEVs and Disincentives for High-Emission Vehicles

As discussed in the previous chapter, there is a notable lack of attention to tax incentives for LCEVs other than BEVs. Unlike BEVs, other types of LCEVs, such as HEVs and PHEVs, do not benefit from incentives related to PKB, BBnKB, PPN, or the PPnBM on imported goods. Consequently, the potential emission reductions from adopting these LCEVs remain underutilised. For instance, hybrid vehicles can reduce CO₂ emissions by up to 49%, while PHEVs can achieve reductions of up to 58% (Maulana, 2024). Despite this potential, as of August 2024, hybrid vehicles constitute only 6.3% of total car sales in Indonesia (CNN Indonesia, 2024) whereas ICEVs still dominate the market, accounting for more than 90% of sales (Arifin, 2024). These figures highlight the competitive disadvantage faced by LCEVs other than BEVs when compared with conventional ICEVs.

The limited government support for LCEVs other than BEVs, such as hybrid vehicles, undermines their ability to contribute significantly to emission reduction. Without optimised incentives, the potential for HEVs and PHEVs to reduce more than half of the CO₂ emissions produced by cars cannot be fully realised. Therefore, to maximise the contribution of LCEVs other than BEVs to emission reduction, the government must introduce targeted incentives to promote their adoption.

3.3.1. PPnBM

To optimise the adoption of other types of LCEVs, comparable tax incentives should be extended to them as those provided for BEVs. Since all LCEVs are already subject to a special PPnBM rate based on their type and emission levels, as regulated in Government Regulation No. 73/2019 (as amended by No. 74/2021), the government does not need to enact new policies or regulations to introduce PPnBM reductions for LCEVs.

3.3.2. PPnBM on imported goods

Regarding the PPnBM on imported goods, the incentive for BEVs is designed as a temporary measure set to expire on 31 December 2025. This incentive is contingent upon the commitment of business operators to produce four-wheeled BEVs domestically, with the aim of fostering local BEV manufacturing in Indonesia. A similar approach should be adopted when granting PPnBM reductions for imported LCEVs. First, such tax incentives should not apply to types of LCEVs already being produced domestically, such as HEVs. For LCEVs that are not yet manufactured on a significant scale in Indonesia, PPnBM reductions may be applied under the same condition: a commitment from business operators to produce those vehicles domestically. This ensures alignment with Indonesia's broader goal of fostering local production while supporting LCEV adoption.

3.3.3. PKB, BBnKB, and PPN

To extend the tax incentives currently provided to BEVs, including PKB, BBnKB, and PPN, the government needs to enact new regulations to apply these tax cuts to LCEVs other than BEVs. In implementing such incentives, the government must adhere to the principles of proportionality and cost-effectiveness. The ultimate objective is to reduce national emissions and achieve net-zero emissions. Therefore, the cost incurred by the government in providing these incentives should correspond to the benefits gained in terms of emission reductions.

3.3.3.1. Amount of incentives

According to Article 10 of Law 1/2022 (page 17), the maximum PKB rate for first-time vehicle ownership is 1.2%, or 2% for areas at the provinces that are not divided into autonomous districts or cities. As the law does not specify a minimum rate, the government may set the PKB rate as low as 0% for LCEVs.

For BBnKB, Article 15 of Law 1/2022 (page 19) states that the maximum rate is 12%, or 20% for areas at the same administrative level as a province without autonomous districts or cities. Similar to PKB, the law does not prescribe a minimum rate, allowing the government to impose a 0% BBnKB rate for LCEVs.

For VAT (PPN), Article 7 of Law 42/2009 sets the maximum rate at 15% and the minimum at 5%. This means the government cannot directly impose a 0% VAT rate for LCEVs under current regulations.

However, alternative mechanisms exist to effectively establish a tax rate of 0% or below the minimum allowed for LCEV buyers. Firstly, LCEVs could be exempted from PKB and BBnKB. According to Articles 7 (3)(d)(e) and 12 (3)(d)(e) (pages 14 and 18, respectively), the government can exempt renewable energy-based or other specific vehicle types from PKB and BBnKB. To implement this measure, the central government would need to issue a MoHA regulation mandating a nationwide exemption, which would then be further elaborated through regional regulations. However, this approach cannot be applied to exempt LCEVs from VAT, as no comparable provision exists for VAT as it does for PKB and BBnKB. To implement a VAT exemption, the government would need to amend Government Regulation No. 49/2022, which currently governs the exemption of certain goods from VAT.

Secondly, the government could introduce a government tax payment scheme to cover a portion of the VAT, PKB, and BBnKB for LCEVs, similar to the current subsidy for BEVs. For instance, Article 4 of MoF Regulation No. 8/2024 states that the government covers 10% of the 12% VAT payable on BEVs, effectively reducing the VAT burden on buyers to 2%. Using this approach, the government could reduce the VAT paid by LCEV buyers to below the minimum 5% legal rate by subsidising the difference. Under this scheme, tax

authorities would still receive the full amount of tax due, but the government would need to allocate budgetary funds to cover the difference.

3.3.3.2. Proportionality

Given that different types of LCEVs have varying capacities to reduce emissions, the value of tax incentives should reflect each type's contribution to emission reduction. This means that vehicles with greater emission reduction potential should receive higher incentives. A similar approach has already been applied to the PPnBM tax cuts, where BEVs, PHEVs, and FCEVs are eligible for a 100% tax cut due to their significant emission reductions, whereas other LCEVs, such as flex-fuel engine vehicles, still face an 8% PPnBM rate.

3.3.3.3. Local content requirement

The new tax incentives should also include local content requirements (TKDN) as a condition for eligibility. Making TKDN a prerequisite will encourage businesses to strengthen Indonesia's domestic supply chain for LCEVs, thereby creating greater economic benefits for the Indonesian people. A similar approach has already been implemented for BEVs under Article 17(3)(c) of Presidential Regulation No. 79/2023, which mandates that incentives are provided to industrial companies meeting TKDN requirements and manufacturing BEVs domestically. To operationalise this policy, the government has issued Regulation of the Minister of Finance No. 8/2024, stipulating that only BEVs meeting the TKDN requirements are eligible for VAT reduction incentives. Additionally, the Decree of the Minister of Industry No. 885/2024 lists BEVs that fulfill the TKDN criteria and qualify for the VAT incentives. This framework should be extended to LCEVs other than BEVs, ensuring that only those meeting the TKDN requirements are eligible for similar tax incentives.

3.3.3.4. Subjective eligibility

In addition to regulating the eligibility criteria for the objects of the incentives, the subject eligibility (i.e. who can receive the incentives) must also be addressed. To maximise adoption, the ideal approach is to make the incentives accessible to all Indonesian citizens, as verified by their KTP. Previously, the government implemented a restrictive eligibility criterion for EV subsidies under Minister of Industry Regulation No. 6/2023, limiting access only to certain low-income individuals. This approach resulted in an adoption rate of less than 1% of the allocated subsidy quota, as the stringent criteria discouraged widespread participation. Recognising this issue, the government later revised the eligibility criteria, allowing all Indonesian citizens aged 17 or older with an electronic KTP to qualify for the subsidies. Following this adjustment, the entire subsidy quota was successfully distributed within the subsequent year. This experience demonstrates that overly restrictive subjective eligibility criteria are counterproductive to increasing LCEV

adoption. Therefore, the new subjective eligibility criteria for these incentives should be broad and inclusive, ensuring access to as many individuals as possible.

3.3.3.5. Protecting local government revenue

PKB and BBnKB are sources of income for local governments. If the central government reduces PKB and BBnKB rates, local government revenue may be at risk. Therefore, when expanding incentives for LCEVs nationwide, the central government must ensure that local governments' fiscal capacity remains intact. One way to mitigate this risk is through the Government Tax Payment Scheme, where the central government covers the PKB and BBnKB costs. This ensures that local governments continue to receive the same tax revenue as they normally would, without any financial shortfall. Alternatively, if the incentive expansion is implemented by directly reducing PKB and BBnKB rates, the central government can compensate for the loss by increasing the general allocation fund (DAU) for local governments. DAU is a state budget allocation distributed to regional governments to equalise financial capacity amongst regions. Increasing DAU would require amendments to the State Budget Law, a presidential regulation on budget details, and an MoF regulation governing the policy's technical implementation. By adopting either of these mechanisms, the government can expand LCEV incentives without undermining the fiscal sustainability of local governments.

3.3.3.6. Legal framework

To implement the expanded tax incentives for all LCEVs, the government must draft and enact a series of legal frameworks. The primary regulation serving as umbrella law should take the form of a presidential regulation, mirroring the successful precedent set by Presidential Regulation No. 55/2019, which became the cornerstone for implementing various tax incentives for BEVs.¹ Following the enactment of the presidential regulation, sectoral regulations must be developed as implementing frameworks. At a minimum, the government would need to issue the following regulations:

- 1) An MoF regulation specifying the details of VAT incentives for LCEVs
- 2) A MoHA regulation defining the specifics of PKB and BBnKB, considering that these taxes fall under the authority of regional governments
- 3) Regulations related to the state budget, including the annual State Budget Law and a presidential regulation detailing state revenue and expenditure allocations. Alternatively, PKB and BBnKB incentives could be implemented through local

¹ There is a legal ambiguity regarding the correct legal product to regulate the VAT incentives for LCEVs. According to Law No. 42/2009, the modification of VAT should be regulated by government regulations. However, in practice, VAT incentives for BEVs are regulated by Presidential and MoF regulations. More than 5 years after the presidential regulation entered into effect, this practice has not caused any problem. Thus, it is safe to regulate VAT incentives through presidential regulations following the successful precedent of Presidential Regulation No. 55/2019.

regulations, as these taxes are collected by local governments. This approach may be preferred if enacting a new presidential regulation proves to be too challenging. However, a drawback of implementing these incentives through local regulations is the potential lack of uniformity and synchronized implementation across the country. In any case, the government must ensure the establishment of a solid legal framework to effectively implement the expanded tax incentives and facilitate the widespread adoption of all LCEVs.

This paper recognises that extending tax incentives to other LCEVs may require reallocating limited fiscal resources currently focused on BEVs. However, this reallocation is unlikely to hinder the overarching goal of maximising emission reductions. Tax incentives can be distributed proportionally based on each type of LCEV's ability to reduce emissions. As a result, whether fiscal resources are directed towards BEVs or other LCEVs, every rupiah spent by the government is expected to yield a comparable rate of reduction of emissions. Furthermore, given that Indonesia's current public and private infrastructure for supporting BEVs remains underdeveloped, adopting HEVs or PHEVs may be a more practical choice for consumers in certain areas. Consequently, BEVs and other LCEVs can coexist and develop synergistically, as they cater to different market segments and address diverse mobility needs across the population.

3.4. Implementing Ministerial Regulation on the Establishment of a National Vehicle Scrappage Programme

With over 20 million cars on Indonesia's roads, most of which are ICEVs, implementing policies to encourage their transition to LCEVs is crucial. Beyond increasing PKB rates based on emissions, a highly effective approach is introducing a vehicle scrappage programme. This programme offers financial incentives to retire old, polluting ICEVs and replace them with greener alternatives. By accelerating fleet renewal, such initiatives can substantially reduce the emissions from the transport sector, a critical step towards achieving Indonesia's enhanced NDC target of a 32% emission reduction by 2030, equivalent to 915 million tonnes of CO₂ (UNFCCC, 2022).

3.4.1. Vehicle scrappage programme in other countries and Indonesia

The mechanism of a scrappage programme involves vehicle owners exchanging their old, polluting vehicles for a rebate, which can be used to purchase a greener replacement. As mentioned previously, this approach has been adopted by many countries to encourage the transition to environmentally friendly vehicles. A notable example is the Car Allowance Rebate System, commonly known as the 'Cash for Clunkers' programme, implemented by the US federal government in 2009. This programme provided subsidies for the purchase of high-fuel economy vehicles, contingent upon scrapping low-fuel economy ones, resulting in 677,842 vehicles being retired during their 1-month implementation (Ankney and Leard, 2022). Similarly, the scrappage programme of the United Kingdom (UK)

(2009–2010) led to 400,000 new car registrations (Penmetsa et al., 2023). These examples demonstrate that a well-executed scrappage programme can effectively remove polluting vehicles from circulation and replace them with greener alternatives.

The creation and implementation of a vehicle scrappage programme is not just a policy option but a legal mandate, as outlined in Presidential Regulation No. 1/2022 concerning the National General Plan for Traffic and Road Transportation Safety. Specifically, Table 5.1, point 3.2.6, assigns the Ministry of Transportation, supported by the Police, the Ministry of Industry, and regency/city governments, the responsibility of drafting and enacting regulations on vehicle scrapping, with a deadline of 2027 for finalisation and implementation. However, the regulation primarily emphasises safety aspects rather than the environmental impacts of old, high-polluting vehicles. As such, additional modifications are necessary. When designing the regulation for Indonesia's scrappage programme, the government must address several critical considerations.

3.4.2. Determining subjective eligibility

One key consideration is determining who qualifies for the rebates. In some jurisdictions, such as California, only individuals from lower-income backgrounds are eligible for such incentives (Fortuna, 2023). Restricting access to fleet renewal programmes exclusively to low-income individuals can lead to low participation rates, rendering the policy ineffective. Indonesia could learn from London's Ultra Low Emission Zone (ULEZ) policy. Initially, ULEZ limited eligibility of its scrappage programme to individuals who met strict criteria, such as those receiving disability benefits, child benefits, or earning below a certain income threshold. However, in August 2022, the policy was expanded to allow anyone owning a vehicle that met the scrappage requirements to participate, significantly increasing both accessibility and effectiveness (Greater London Authority, n.d.). To maximise the programme's impact and accelerate the transition to cleaner vehicles, Indonesia's scrappage programme should aim to include as many participants as possible, rather than imposing overly restrictive eligibility requirements.

3.4.3. Defining objective eligibility criteria

The second key consideration for the government is determining the criteria for vehicles eligible for rebates under the scrappage programme. Given that the primary objective is to reduce emissions, only older vehicles that emit significant amounts of pollution should qualify. A critical aspect of this is the vehicle age criterion. Implementing a flat subsidy amount, for example, Rp15 million for all cars older than 15 years, would undermine the programme's cost-effectiveness. Older vehicles – such as those around 23 years old – typically have lower future emissions than slightly newer ones, such as those 15 years old, because they are driven less frequently and are nearing the end of their operational lifespan. In contrast, younger, high-emission vehicles are more likely to remain in use for longer periods and contribute more significantly to future emissions if not scrapped.

Moreover, subsidising vehicles that are already close to retirement due to age or mechanical deterioration could result in inefficiencies, as these vehicles are likely to be retired naturally without government intervention. As a result, providing rebates for such vehicles would mean the government is paying for actions that would have occurred regardless of the programme, thus wasting valuable resources.

3.4.4. Enhancing cost-effectiveness through differentiated subsidies

To optimise cost-effectiveness, the government should adopt a tiered or differentiated subsidy structure. Under this model, the amount of the subsidy would be linked to the vehicle's estimated potential for future emissions. Vehicles with higher emissions potential would qualify for larger rebates, ensuring that public funds are directed towards vehicles posing the greatest obstacle to emission reduction goals. Studies have shown that linking subsidies to future emissions can improve the cost-effectiveness of scrappage programmes by up to 50%. Additionally, offering larger rebates for high-emission vehicles creates a stronger behavioural incentive, encouraging owners to retire relatively newer yet highly polluting vehicles earlier than they otherwise would (Linn, 2020a). By implementing a differentiated subsidy structure, the scrappage program can maximise its impact while being cost-effective.

3.4.5. Types of benefits: From rebates to public transport vouchers

Regarding the incentives provided to car owners who scrap their vehicles, the most common benefit offered is a rebate for purchasing a replacement vehicle. Naturally, the replacement vehicle must meet certain criteria, particularly concerning its environmental impact. For Indonesia, the rebate should be claimable only if the replacement vehicle qualifies as an LCEV, as defined in the Regulation of the Minister of Industry No. 36/2021 on Low-Carbon Emission Four-Wheeled Motor Vehicles. The rebate value should follow a tiered structure that reflects the varying levels of emission reduction achieved by different types of LCEVs. The most environmentally friendly LCEVs – such as BEVs – should receive the highest rebate amounts, while those with lower but still significant emission reductions, such as HEVs, should receive smaller rebates. This tiered approach ensures that incentives are aligned with the environmental benefits provided by each type of vehicle. Moreover, eligibility standards already established in existing tax incentive schemes, such as the local content requirement, should also apply to the scrappage programme. These standards would ensure that the programme not only promotes cleaner vehicles but also supports domestic manufacturing and economic growth. By implementing a tiered rebate system and maintaining consistent eligibility criteria, the scrappage programme can effectively encourage the adoption of LCEVs while maximising its environmental and economic impact.

Besides offering rebates when eligible individuals purchase replacement vehicles, another form of incentive the government could provide for those who scrap their vehicles

is points for using public transport. Public transport, which can carry many passengers simultaneously, emits less pollution per individual compared to private vehicles. Moreover, in Indonesia, more public transportation options are adopting environmentally friendly vehicles, such as the Transjakarta electric buses (Sihombing, 2025). A similar policy is implemented under California's Clean Cars 4 All scrappage programme, whereby participants can choose up to US\$7,500 in credit for public transport and other mobility alternatives in exchange for scrapping their old vehicle. Offering the option to redeem points for public transport or other mobility alternatives, in addition to rebates for replacement vehicles, could encourage a more sustainable transportation system in Indonesia (California Air Resources Board, n.d.).

3.4.6. Program duration and budget allocation

The fifth key consideration for the government is determining when and how long the scrappage programme will last. A vehicle scrappage programme that offers rebates or points to individuals who scrap their vehicles is not intended to be a permanent initiative. In most countries, vehicle scrappage programmes last for less than a year. For example, the UK's scrappage programme ran for 1 year (2009–2010), and the US Car Allowance Rebate System (Cash for Clunkers) lasted only a month due to exhausted appropriated resources (Penmetsa et al., 2023). The temporary nature of such programmes is essential because offering rebates and points incurs significant costs for the government. Similar to Indonesia's current policy on electric motorcycle purchase subsidies, the government must decide on a quota and set a clear time frame for the programme.

3.4.7. Managing the end-of-life process

The sixth key consideration for the government is determining what to do with the vehicles turned in for scrapping. Since the goal of the scrappage programme is to protect the environment, the government must ensure that the scrapped vehicles are disposed of or recycled in an environmentally responsible manner. If vehicles that are turned in for scrapping are simply resold and put back on the road, the benefits of the programme would be undermined. Lessons from Germany's scrappage programme show that many vehicles intended for scrapping were exported to other countries, such as those in Africa and Eastern Europe, where they continued to pollute. Therefore, the Indonesian government must implement a clear plan for handling scrapped vehicles to ensure they do not continue to harm the environment.

3.4.8. Resetting to first vehicle ownership for PKB

The PKB tariff increases based on the number of vehicles owned. For first-time vehicle ownership, the maximum tariff is 1.2% or 2% for regions at the same administrative level as a province but not divided into autonomous districts or cities. For second and subsequent vehicle ownership, the maximum PKB tariff rises to 6% and 10% in those same regions.

Under normal circumstances, when a vehicle is sold, a legal name transfer process records the change in ownership. This ensures that if the original owner purchases another vehicle, it is considered first ownership. However, a formal vehicle scrappage system has yet to be established. Without such a system, there is a risk that scrapping a vehicle instead of selling it could result in the next vehicle being classified as second ownership, leading to a higher PKB rate. To make vehicle scrappage a viable and attractive option for owners, the government must implement a registry system that resets the ownership count for individuals who scrap their vehicles.

3.4.9. Legal framework

To effectively implement the vehicle scrappage programme, the government must enact legislation that specifically addresses the programme. The first step is to establish a presidential regulation as the primary legal framework for regulating the scrappage initiative. While Presidential Regulation No. 1/2022 mandates the Ministry of Transportation to create regulations on vehicle scrapping, it is focused on vehicle safety rather than environmental concerns. As such, relying solely on this regulation to create a comprehensive scrappage programme aimed at fleet renewal and emission reduction would not provide a solid legal foundation. Once a presidential regulation addressing the environmental aspects of the scrappage programme is established, the government will need to create additional technical regulations for implementation, mainly through a regulation from the Minister of Transportation.

3.5. Creating a New Minister of Home Affairs Regulation to Impose Higher Taxes on High- Emission Vehicles

Currently, the implementation of additional taxes for high-emission vehicles is ineffective. The only related regulation is a weight factor coefficient used as a multiplier in calculating the PKB rate. According to Article 4(2) of MoHA Regulation No. 8/ 2024, the taxable base for PKB is determined by multiplying the NJKB with the weight factor, which reflects a vehicle's impact on road damage and environmental pollution.

The weight factor is calculated based on several criteria:

- 1) Axle pressure: Differentiated by the number of axles, wheels, and the weight of the motor vehicle
- 2) Type of fuel: Categorized as gasoline, diesel, or other fuels, excluding renewable energy-based fuels
- 3) Vehicle specifications: Including type, usage, year of manufacture, and engine characteristics, differentiated by cylinder capacity

Using these criteria, the regulation provides the following coefficients for vehicle categories:

- 1) Coefficient 1.0: Three-wheeled passenger cars, three-wheeled goods cars, two-wheeled motorcycles, three-wheeled passenger motorcycles, and three-wheeled goods motorcycles
- 2) Coefficient 1.025: Sedans
- 3) Coefficient 1.050: Jeeps and minivans
- 4) Coefficient 1.085: Blind vans, pickup trucks, pickup boxes, and minibuses
- 5) Coefficient 1.1: Buses
- 6) Coefficient 1.3: Light trucks and similar vehicles
- 7) Coefficient 1.4: Trucks and similar vehicles

However, emission rates are not explicitly considered as a factor in determining the weight factor coefficient, and the categories are overly broad. This approach treats all vehicles within the same category equally, despite significant differences in emissions. For example, the Bentley Continental GT V8 S and the Genesis G80 Electrified both fall under the sedan category with a coefficient of 1.025, even though the Bentley emits 246 g/km of CO₂, while the Genesis G80, as an EV, produces no emissions (Priyadi, 2016). This disparity highlights the current regulation's failure to accurately tax vehicles based on their actual environmental impact, making it an inadequate tool for addressing emissions.

An accurate and effective higher tax for high-emission vehicles is crucial to encouraging the transition to LCEVs. Conventional ICEVs still hold a competitive advantage over LCEVs, as evidenced by their market dominance, accounting for over 90% of total car sales nationally in 2024 (Arifin, 2024). Implementing a higher tax on high-emission vehicles would serve as a disincentive for continued use of such vehicles while also generating additional government revenue. This revenue could then be earmarked to fund incentives for LCEVs, accelerating their adoption and supporting the shift towards cleaner transportation.

A critical reform lies in revising the weight factor formula set forth in the MoHA regulation, which currently determines PKB based primarily on vehicle type and ownership count. To strengthen its environmental utility, the formula must be modified to include emission levels as a core determinant of the coefficient value. For example, the regulation could introduce a 0.01 increase in the coefficient value for every additional 10 grams of CO₂/km emitted by a vehicle. This means that higher-emitting vehicles would automatically fall into higher tax brackets, thereby internalising the environmental cost of their continued use. To operationalise this system, MoHA would need to compile a comprehensive emission database listing the emission rates of all vehicle models registered in Indonesia. This list should be made publicly available as an appendix to the revised regulation to ensure transparency and ease of implementation.

In addition, the revised weight factor formula should account for vehicle age, recognising that older vehicles tend to emit more pollutants due to mechanical degradation and

outdated technologies. A simple and efficient approach would be to increase the coefficient by 0.5 for vehicles older than 15 years. While actual emissions testing would be more precise, such procedures are costlier and require technical infrastructure. Using age as a proxy for emissions aligns with the principle of tax efficiency embedded in Indonesia's taxation system, minimising administrative and compliance burdens while still achieving regulatory outcomes. Age-based adjustments can be readily implemented through existing vehicle registration data, making this a low-cost, high-impact policy change.

The PKB is uniquely positioned to function as a behavioural lever in the country's transition to cleaner vehicles. Unlike the BBnKB, which is paid only once upon purchase, PKB is levied annually. This provides the government with a recurring opportunity to influence vehicle owner behaviour, not only discouraging the prolonged use of high-emission vehicles but also encouraging the shift towards LCEVs. As of 2024, Indonesia has more than 20 million registered cars, most of which are powered by ICE technology. This reality underscores the need to target existing vehicle stock, not only new purchases. By revising the PKB formula to reflect environmental performance, the government sends a clear policy signal: maintaining high-emission vehicles will become progressively more expensive, while transitioning to cleaner alternatives will yield long-term financial benefits.

The legal basis for this reform is firmly established in current regulations. MoHA Regulation No. 8/2024 already recognises the principle that vehicles contribute to environmental degradation and can be taxed accordingly. Specifically, Articles 7(4) and 7(5) allow for adjustments to the coefficient value based on a vehicle's compliance with emission quality standards, albeit only after the vehicle has been in operation for 3 years.

However, this delay in applying emission-based adjustments limits the effectiveness of the regulation. To fully align PKB with Indonesia's climate goals, emission criteria must be integrated into the tax calculation from the first year of a vehicle's operation. Doing so ensures that environmental accountability is embedded throughout the life cycle of vehicle ownership. Moreover, incorporating emission factors into the PKB formula would not introduce a new tax, but rather improve the accuracy and fairness of the existing tax structure. The reform would align the taxes paid by vehicle owners more closely with the external environmental costs imposed by their vehicles – a principle well established in both environmental and fiscal policy.

Chapter 4 of this report presents a simulation of the cost-benefit analysis (CBA) under a scenario where the coefficient changes from 1.05 to 1.5.

Chapter 4

Cost–Benefit Analysis

1. Elaboration of Fleet Renewal Strategies

The transport sector is one of the primary contributors to GHG emissions on both global and national scales. In 2023, Indonesia's transport sector ranked second in final energy demand, accounting for 36.74% or a consumption equivalent to 448.54 million BOE of fuel oil (MoEMR–Indonesia, 2024). Despite the continuous rise in energy demand within the transport sector, averaging 2.77% annually since 2013, its proportion of overall energy demand has diminished due to significant growth in other sectors, particularly the industrial sector. Given the anticipated expansion of the vehicle fleet in the forthcoming years as a result of economic development, decarbonisation in the sector is necessary to achieve net-zero emissions by 2060. The government's existing initiatives have successfully reduced GHG emissions in the transport sector by 27.52 million tonnes between 2017 to 2023 (Kemenhub, 2024). In 2023, the transport sector achieved a reduction of 4.68 million tonnes of CO₂, accounting for approximately 23.28% of the total GHG emissions reduction in the energy sector, which amounted to 127.67 million tonnes of CO₂. The most significant decrease in emissions was observed in the railway sector at 54%, followed by the air transport sector at 25.03%, and the land transport sector at 18.01%. The transport sector's low contribution to emission reduction emphasises the need to accelerate decarbonisation efforts, particularly in the land transport subsector.

A commonly adopted approach to achieving sustainable transportation is the Avoid–Shift–Improve (ASI) framework. The primary objective of ASI as a traffic management framework is to influence individual mobility decisions to reduce the number of trips, shorten the distance, and ensure that the remaining motorised journeys are as sustainable as possible (Bräuninger et al., 2012). Such initiatives will reduce the demand for high-emission transportation and enhance the demand for more sustainable alternatives (Goulden, Ryley, and Dingwall, 2014). The ASI framework outlines three primary pillars to enhance the efficiency of transport utilization. 'Avoid' strategies emphasise system efficiency by minimising vehicle activity and trip duration through compact urban development, advancing digitalisation to reduce the need for physical travel, implementing travel reduction policies, and encouraging behavioural changes such as shorter workweeks and ridesharing. Shift strategies emphasise trip efficiency by encouraging populations to transition from less efficient transportation modes to low- or zero-carbon alternatives, such as non-motorised transport or public transit, through enhancements in pedestrian and bicycle infrastructure, land use planning, parking management, and transit-oriented development. 'Improve' strategies focus on improving the efficiency of vehicles, infrastructure and operations through technological

advancements and optimisation (Zamora, 2014; Creutzig et al., 2018; Peters et al., 2017). Road fleet renewal can be accelerated through the implementation of all pillars of the ASI approach.

Road fleet renewal involving the substitution of old or ineffective vehicles with new alternatives plays a vital role in the decarbonisation of the transport sector. A slow pace of product replacement results in a continued prevalence of older, less energy-efficient products within society, thereby increasing CO₂ emissions associated with their use. The economic conditions significantly influence the pace of fleet renewal from the viewpoint of consumers (ACEA, 2018). In higher-income regions, the typical duration of vehicle usage appears to be shorter than that in lower-income regions. As the market welcomes a new wave of fuel-efficient vehicles, there is a noticeable trend of older cars being passed on to those in less affluent circumstances (Vanherle and Vergeer, 2016). At the international level, a similar trend is evident: between 2015 and 2022, about 80% of the total 23 million used light-duty vehicles (LDVs) exported globally were destined for low- and middle-income countries (UNEP, 2024). While Indonesia has established regulations concerning the ban on importing used cars for personal use, it presently lacks any rules pertaining to the age limit of used cars available for domestic trade. The safety and energy consumption of used vehicles are also a concern because of the substantial number of old vehicles that are still in operation, in addition to the increased CO₂ emissions.

Many nations across the world have implemented accelerated vehicle replacement programmes, including tax incentives and subsidies. Initially, such incentives were introduced during periods of economic recession to stimulate new car purchases and mitigate adverse shock to the automotive industry during challenging times (Laborda and Moral, 2019). The policy was enacted in 2009 across several nations, including Japan (Alhulail and Takeuchi, 2014), the US (Li, Linn, and Spiller (2013), and various European countries (Grigolon, Leheyda, and Verboven, 2016). On the other hand, this initiative can enhance road safety and mitigate emissions. The decrease in emissions is the result of the transition to low-carbon energy sources (fuel switching) or the improvement in efficiency of new vehicles. Alongside financial incentives, a range of complementary measures – such as emission standards, vehicle fitness tests, and feebate schemes – can play a significant role in promoting fleet renewal (Rimpas et al., 2025).

Despite the potential for positive environmental impacts, the implementation of these policies requires certain expenditures. Considering the opportunity costs of the limited government's budget, this study will analyse the costs and benefits of various policies that accelerate fleet renewal to identify which policy yields the most favourable net benefit. The following section addresses the fleet renewal strategies that have been implemented in many nations.

2. Standards

2.1. Emission standards

Emission standards, a set of legal rules, regulate the amount of air pollutants that can enter the atmosphere. Emission standards set numerical limits on the amount of specific air pollutants that may be released over a defined period. Their primary objectives are to improve air quality and protect human health. Los Angeles' smog issue prompted the US to enact vehicle emission rules for the first time in 1963. Japan came next in 1966, and then Canada, Australia, and several European nations from 1970 to 1972. While early rules primarily addressed the control of hydrocarbons and carbon monoxide, controls for nitrogen oxides were first implemented in the US, Japan, and Canada between 1973 and 1974.

The European Union (EU) has adopted environmentally friendly transport technologies to reduce emissions. In the early 1990s, the EU published regulations mandating that gasoline-powered vehicles be fitted with catalytic converters – commonly referred to as the Euro 1 standard. This standard aims to decrease the amount of pollution that cars emit. Consequently, the EU progressively raised standards under Euro 2 (1996), Euro 3 (2000), Euro 4 (2005), Euro 5 (2009), and Euro 6 (2014). Both light- and heavy-duty commercial vehicles and diesel cars are required to meet the same standards.

Many nations throughout the world have also embraced the European rules for motor vehicle emissions. Fuel quality improves after these emission standards are put into effect. For instance, engines must be built using technology that exclusively uses unleaded gasoline to comply with Euro 1. Diesel with a sulphur concentration of less than 500 parts per million is required for Euro 2 vehicles. Euro 3 and Euro 4 control further reductions in sulphur levels in gasoline and diesel engines, while Euro 5 regulates diesel trucks.

2.2. Fuel economy standards

Fuel economy standards are regulations aimed at improving energy efficiency in motor vehicles by restricting the sale of vehicles that do not meet minimum fuel efficiency requirements. These standards typically set fuel consumption limits (maximum fuel use or minimum efficiency levels). Some countries have set specific efficiency targets for the medium to long term. For example:

- 1) In 2019, Japan's Ministry of Land, Infrastructure, Transport and Tourism and Ministry of Economy, Trade and Industry issued new fuel economy standards for passenger vehicles starting in model year 2030. The standards require an average fleet gasoline-equivalent fuel economy of 25.4 km/litre by 2030, which is a 32.4% improvement over the fleet average for fiscal year 2016.

- 2) Saudi Arabia, through its Corporate Average Fuel Economy policy, targets LDV efficiency to increase from 15.7 to 21.0 km/litre in 2024 to 18.5–24.8 km/litre in 2028.
- 3) Chile targets an increase in LDV efficiency from 14.9 km/litre gasoline equivalent (lge) in 2020 to 18.8 km/lge (2024–2026), then 22.8 km/lge (2027–2029), and finally reaching 28.9 km/lge in 2030.

2.3. EV energy consumption rate limit

Understanding the energy consumption of EVs is also an important factor for owners or prospective buyers of EVs. Energy consumption, measured in kWh per mile or kWh per kilometre, determines the range of a vehicle and its running costs. Vehicles with lower kWh per mile consumption are more efficient, meaning, they are more energy and cost-efficient.

According to research by Transport and Environment, EVs in the UK consume around 17.6–23.5 kWh per 100 km in a mixed driving cycle. This equates to around 2.8–3.7 kWh per mile. However, this figure can vary depending on the make and model of the vehicle, its weight and aerodynamics, driving speed, and external conditions such as weather.

Implementing better fuel economy standards and energy efficiency technologies will help reduce reliance on fossil fuels and reduce GHG emissions, supporting the transition to more sustainable transport. In Indonesia, MoEF Regulation No. 8/2023 for emission testing focuses on ensuring compliance with emission quality standards, but the testing scheme itself has not been implemented yet. In addition, there are no established energy consumption rates specifically for EVs.

3. Subsidy Programmes

To promote the transition to cleaner and more energy-efficient transport systems, many countries have implemented extensive subsidy programmes targeting both users and manufacturers of EVs. These initiatives aim to lower the cost barrier of EV adoption and support the development of EV-related industries, contributing to national decarbonisation goals.

On the user side, France has introduced several incentives, including financial support for the purchase of electric, hydrogen-powered, and energy-efficient vehicles. In 2023, the French government launched the *Bonus Écologique* programme, offering bonuses ranging from €2,000 to €7,000 depending on the vehicle's emission level, price, and buyer income (European Alternative Fuels Observatory, n.d.). Additionally, a 'social leasing' scheme was introduced in early 2024, allowing eligible individuals to lease an EV for as low as €100 per month. Similarly, Italy allocated €1 billion in 2024 through its Ecobonus programme, which not only encourages EV purchases but also incentivises the scrapping of older, more polluting vehicles (Ministry of Business and Made in Italy, 2024).

The Republic of Korea continues its structured subsidy approach by setting an annual budget for EV purchases. In 2024, the government allocated KRW1.7 trillion (approximately US\$1.3 billion) for various EV categories, including KRW932 billion for light-duty passenger vehicles (IEA, 2024). These subsidies are tailored based on multiple factors such as battery performance, recycling potential, and vehicle maintenance. While the official objectives emphasise safety, innovation, and equitable access, media outlets have speculated that part of the policy shift is intended to protect domestic manufacturers from foreign competition.

In Estonia, the Environmental Investment Centre launched a support programme in February 2023, funded through carbon credit trading proceeds. The programme offers subsidies of €5,000 for individuals and €4,000 for companies purchasing electric or hydrogen vehicles, and up to €1,250 for electric cargo bikes, strengthening the nation's commitment to zero-emission transport (Environmental Investment Centre, 2023).

On the manufacturing side, several governments are also channelling funds to develop domestic EV production capabilities. In Hungary, the government allocated €14.3 million to support Boysen Group's investment in a new EV parts manufacturing facility, projected to generate 400 new jobs (Hungarian Investment Promotion Agency, 2023). Likewise, the UK invested GBP73.5 million in 2020 into 10 projects aimed at advancing EV technology, including electric taxis, recyclable batteries, and lightweight components (Department for Business, Energy & Industrial Strategy, 2020).

Meanwhile, Canada made a historic investment in October 2020 by committing CAD295 million, matched by Ontario, to transform the Ford Oakville Assembly Complex into a global hub for BEV production. This CAD1.8 billion project is set to create a high-volume BEV manufacturing facility, with operations expected to begin in 2025 and over 3,000 direct jobs supported (Ontario Newsroom, 2020).

4. Regulations

4.1. Fitness test

A fitness test is a process of inspecting a motor vehicle to ensure that it meets the safety, emission, and technical feasibility standards set by the competent authority (May, 2023).

This fitness test aims to ensure that vehicles operating on the highway are safe, environmentally friendly, and do not endanger drivers or other road users. This inspection generally covers various important vehicle components, such as the braking system, suspension, exhaust emissions, and other safety components, such as seat belts, lights, and tyres.

Various countries in the world implement vehicle fitness tests with slightly different rules. In Austria, vehicle fitness tests are regulated under Article 57a of the Motor Vehicle Act. The results of these tests are classified into several categories, ranging from minor defects that must be repaired immediately to very dangerous defects requiring repair

before the vehicle can be used again. After passing the fitness test, the vehicle will be given a sticker indicating the month and year of the next test (European Commission, 2020). Meanwhile in the UK, a roadworthiness test known as the Ministry of Transport test is carried out every year after the vehicle is 3 years old, with checks focusing on safety and emissions aspects (Only Do MOTs, 2024). In California, US, roadworthiness tests focus on exhaust emissions with checks conducted every 2 years for registered vehicles. If the vehicle fails to meet emission standards, the vehicle owner cannot renew the vehicle registration without first making repairs (California Air Resources Board, 2024).

In addition to its benefits for safety and the environment, vehicle roadworthiness tests also have a significant economic impact. Directly, roadworthiness tests can reduce traffic accidents caused by vehicle damage, thereby reducing accident maintenance costs, insurance claims, and medical costs that must be borne by the government and the community (Sekadakis et al., 2025). In addition, roadworthiness tests encourage vehicle owners to carry out routine maintenance, which increases demand for vehicle maintenance services and spare parts, providing benefits to the automotive industry and vehicle repair shops (Simply Fleet, n.d.). Roadworthiness tests that include emission checks also play a role in reducing air pollution, reducing GHG emissions and other pollutants, which in turn improves air quality and reduces health costs related to air pollution (Jakarta Rendah Emisi, 2024).

The implementation of roadworthiness tests also requires administrative and supervision costs that must be borne by the government. However, the long-term benefits gained – such as reduced accidents, reduced emissions, and increased traffic safety – often outweigh the costs incurred for conducting a roadworthiness test. In addition, a valid roadworthiness certificate can enhance the resale value of a used vehicle, as prospective buyers tend to prefer vehicles that have passed roadworthiness tests, considering them safer and more environmentally friendly.

4.2. Charging infrastructure

The transition from traditional ICEVs to EVs is one of the most significant transformations in the global transport sector. Governments, businesses, and consumers are increasingly recognising the importance of reducing carbon emissions, improving air quality, and moving towards more sustainable forms of mobility. To accelerate this transition, countries are implementing policies and incentives designed to encourage EV adoption. A critical component of this transition is the development of a robust charging infrastructure, as widespread access to reliable and convenient charging stations is critical to driving EV adoption. Without an extensive charging network, the fear of running out of power without a nearby charging station remains a major barrier to widespread EV adoption (Abdullah, 2024).

To address this issue, many countries are launching initiatives to increase the number of public charging stations, particularly in urban areas, along highways, and at commercial

locations. The EU, for example, has set a target of installing 1 million public charging stations by 2025 as part of its Green Deal, which aims to make the continent carbon neutral by 2050 (Ormazabal, 2019). The expansion of public charging stations is critical to ensuring that EV owners have access to reliable charging options on the go. By placing these stations in strategic locations – such as cities, shopping malls, and motorway rest areas – governments are making it easier for drivers to adopt EVs without worrying about the availability of charging points.

In Norway, charging stations are mostly operated under a free market system. However, in the early stages, some cities became the first provider of public charging infrastructure. For example, the city of Oslo initially built several public charging stations and allowed EV users to charge for free, before introducing user fees once EVs became more common in the city (Manthey, 2019). On the commercial side, a few companies specialised in providing public charging stations for EVs like Fortum, Grønn Kontakt, Ionity, and more (Futurehome, n.d.). Companies that provide public fast-charging stations often collaborate with other businesses – such as McDonald's and retail outlets – to establish joint facilities. These partnerships may follow various arrangements: 50–50 split of profits and construction costs; full funding by the fast-charging company, with the partner providing only the land; or, in some cases, ownership of the charging stations by the land providers themselves, such as McDonald's and other retailers (Kempower, 2022).

In the People's Republic of China, state actors and private entities have developed an extensive charging network across the country. According to the China Electric Vehicle Charging Infrastructure Promotion Alliance, by the end of August 2023, there were 7,208,000 charging infrastructure units in China, compared to only 175,575 charging outlets in the US during the same year. Moreover, China has standardised its charging infrastructure, allowing EVs from any brand to use any charging station, unlike the current situation in Norway. China's charging service providers can be categorised into three groups: (i) state actors, such as the government itself; (ii) companies specialising in charging services; and (iii) EV manufacturers offering their own charging networks. Leading public charging providers, including TELD, StarCharge, YKC, State Grid, and Orange Charging, control about 70% of the market and collaborate with numerous automakers. Additionally, manufacturers like SAIC, NIO, and Tesla are expanding their public charging infrastructure (MarkLines, 2023).

Some provinces and cities in China also provide targeted incentives to support charging stations. These incentives generally fall into four main categories, as shown in Table 4.1.

Table 4.1. China's Regional Subsidy for Charging Infrastructure

Types	Examples of Relevant Regions and Policies
Investment subsidy	Beijing: Subsidies for EV charging infrastructure are less than 30% of the total investment Wuhan: Public charging stations are subsidised at 20% of the actual investment amount
Construction subsidy	Shanghai: Subsidies at 50% of investment in charging equipment Shandong: Construction subsidies based on 40% of the total investment minus the purchase cost of charging facilities
Operation subsidy	Beijing: Daily operation subsidy standard is US\$0.016 /kWh Jiangxi: Municipal subsidy standard is US\$0.047 /kWh
Charging subsidy	Shanghai: US\$784 charging subsidy for EV consumers Anhui: US\$313 charging subsidy for new EV purchasers.

Source: Chen et al (2023).

In addition to the growth of public charging stations, governments are also investing in fast-charging infrastructure to make EVs more convenient for long-distance travel. Fast-charging stations can charge an EV battery to 80% in 30 minutes or less, reducing the time it takes to charge and increasing the overall convenience of EV ownership (Jason, 2023). These stations are typically located along major highways and transport hubs, making long-distance travel more accessible for EV owners. The installation of fast-charging infrastructure is critical to addressing one of the main challenges to EV adoption: charging time. Therefore, consumers can confidently use EVs for daily commutes, long trips, and business trips.

In addition to public charging stations and fast charging, governments also offer incentives to encourage the installation of home charging stations. In the US, for example, federal and state programmes provide tax credits or rebates to encourage consumers to install EV chargers at home (US Department of Energy, 2022). Home-charging stations offer a convenient solution for EV owners, allowing them to charge their vehicles overnight and start each day with a full battery. These incentives help reduce the initial cost of installing a home charger, making it more affordable for consumers to adopt EVs. By encouraging home charging, governments ensure that EV owners have the flexibility to charge their vehicles without having to rely entirely on public charging stations.

4.3. Environmental zone

Low emission zones (LEZs) are areas where vehicles with elevated levels of pollution, especially older ones, are restricted or prohibited from operating. The main purpose of implementing LEZs is to reduce air pollution in large cities and densely populated areas, and to meet the air quality standards set by the EU. LEZs are often considered the most effective measure to improve air quality in large cities by reducing emissions of fine

particulate matter, nitrogen dioxide, and ozone. In Europe, air pollution, especially from motor vehicles, has become a major public health problem, and LEZs are one of the efforts designed to address this.

The concept of LEZs was first introduced in Sweden in 1996, followed by other countries such as Germany, the Netherlands, Italy, and the UK in the 2000s. In Germany, for example, several large cities such as Berlin and Stuttgart have implemented LEZs that restrict vehicles with lower emission standards from entering the city centre (Federal Ministry for the Environment, Climate Action, Nature Conservation and Nuclear Safety, 2020). In addition, London is also a prominent example of the strict implementation of LEZs, which require motor vehicles to meet higher emission standards or pay a fee to enter the zone (Transport for London, 2019).

Each LEZ has different regulations regarding which vehicles are allowed to enter the zone. In many LEZs, only vehicles with lower emissions, in accordance with certain Euro standards, are allowed to enter. For example, vehicles with Euro 4 standards or newer may be allowed, while vehicles with Euro 3 standards or older cannot enter the zone. Some LEZs in Europe also provide retrofit options for vehicles that do not meet emission standards, where the vehicle can be fitted with emission control devices, such as diesel particulate filters, to meet existing requirements.

In Europe, the presence of LEZs has increased significantly. For example, in the UK, London has implemented an LEZ that includes heavy vehicles such as trucks and buses that must meet Euro 6 standards for diesel and Euro 4 for petrol (FBHVC, 2025). This aims to reduce emissions of nitrogen dioxide which are harmful to health, especially in areas with high traffic density. In addition, cities, such as Berlin in Germany and Rome in Italy, have also implemented LEZs that affect both private and commercial vehicles. In some Italian cities, even scooters and motorbikes are included in the restrictions on vehicles allowed to enter the LEZ.

However, while LEZs can reduce air pollution, they also present challenges for users of vehicles that do not meet emission standards. Some countries allow the retrofitting of older vehicles with emission control devices, although not all provide incentives or financial support for doing so. In Germany, for example, Euro 3 vehicles fitted with diesel particulate filters may be classified as equivalent to Euro 4 vehicles, enabling them to enter the LEZs without paying additional fees (Emission Standards, n.d.). In addition, some LEZs charge higher-polluting vehicles if they wish to enter the zone. These fees, such as those in London, are designed to incentivise vehicle owners to switch to vehicles with lower emissions.

LEZs are not uniform across the EU; each country or city enforces its own regulations, tailored to local conditions. In the Netherlands, for example, major cities such as Amsterdam and Rotterdam have implemented strict LEZ systems, whereas in countries such as Norway and Portugal, LEZs remain in the planning stage. These systems apply not only to domestic vehicles but also to foreign ones, which must obtain special

registration or display a designated sticker to enter the zone. Therefore, the implementation of LEZs plays a key role in reducing GHG emissions and improving air quality in urban areas across Europe.

As the number of LEZs in Europe increases, many countries are developing retrofit schemes to help owners of older vehicles comply with the new emission standards. These countries are also adopting technology to monitor vehicles entering the LEZ, such as camera systems and sensors that can identify vehicles that do not meet emission standards. Some countries also provide verified emission control devices that must be installed on older vehicles to enter the LEZs. Since 2014, the United Nations Economic Commission for Europe (UNECE) has developed a certification scheme for emission retrofit devices, which serves as basis for European countries to develop their own retrofit schemes (EUR-Lex, 2015).

4.3.1. Other incentives by regulation

In addition to providing fiscal incentives such as tax breaks, non-fiscal incentives mandated by regulation can also be implemented to promote the adoption of LCEVs. Between 1997 and 2017, EVs in Norway were exempted from toll charges, allowing EV users to travel freely on toll roads across the country. A similar exemption was applied to ferry services from 2009 to 2017.

Starting in 2018, while full exemptions were phased out, EVs continued to benefit from significant discounts, with ferry fares capped at 50% of the equivalent charge for fossil-fuelled cars. Toll road discounts followed a similar pattern, whereby from 2018 to 2022, EV users paid no more than half the rate imposed on conventional vehicles, increasing modestly to a 70% threshold in 2023. Operational advantages were further reinforced through free municipal parking, offered between 1999 to 2017, which helped reduce day-to-day costs for EV users. Another practical measure was granting EVs access to bus lanes, a policy introduced in 2005 and still in force today. Since 2016, however, municipalities have had the discretion to limit this access to EVs carrying passengers to balance traffic flow.

Recognising the unique challenges faced by urban residents, Norway also enacted a 'charging right' in 2017, requiring apartment buildings to provide access to EV charging infrastructure for their residents, thereby removing a major barrier to adoption amongst city dwellers. Beyond individual user benefits, Norway has integrated LCEVs into public sector operations through green procurement policies. Since 2022, all new vehicles purchased by public institutions must be zero-emission vehicles, and this mandate will extend to city buses by 2025 (Norwegian Electric Vehicle Association, n.d.).

Similarly, China also offers a range of non-fiscal incentives for EV buyers and users. For example, China grants free special licence plates for EVs, whereas buyers of ICEVs must obtain plates through lotteries or auctions (Helveston, 2022). In 2016, the odds of winning the Beijing lottery were one in 667; in Shanghai, plates often sold for \$10,000 or more. A

2016 survey by China Automotive Technology and Research Center revealed that 52% of Beijing respondents purchased EVs due to the free special licence plates. Moreover, these plates permit EVs to be driven any day of the week, even during rush hours, unlike regular plates, which are restricted to specific days, roads, and times (PolyMatter, 2023).

Beyond consumer incentives, the Chinese government employs a carrot-and-stick approach to regulate EV production. The dual credit system, resembling the carbon trading market, mandates automakers to produce a certain number of EVs for every conventional car sold. Automakers falling short must purchase credits from competitors. For example, Tesla earned US\$1.58 billion from credit sales in 2020 (Helveston, 2022). This policy has pressured traditional automakers to increase EV production while enabling EV manufacturers to profit significantly from selling their credits.

4.4. Taxes

Governments worldwide have implemented a range of tax incentives to accelerate the adoption of EVs and support the growth of local EV-related industries. These policies include VAT deductions, income tax exemptions, and corporate tax incentives aimed at both consumers and manufacturers.

On the consumer side, Austria offers a VAT deduction and tax exemption scheme for BEVs and FCEVs used for business purposes (ACEA, 2025). The VAT deduction is tiered based on the gross purchase value: full deduction for vehicles priced up to €40,000, partial deduction for those between €40,000 and €80,000, and no deduction beyond €80,000.

Meanwhile, Belgium and Spain provide various tax exemptions for vehicles emitting less than 120g CO₂/km. In Spain, beginning in 2025, individuals purchasing BEVs, PHEVs, extended range EVs, or FCEVs may claim a personal income tax deduction of 15% (up to €3,000) on the vehicle's acquisition cost, plus up to €4,000 for home EV infrastructure installation. Additionally, the Canary Islands exempt VAT for alternatively powered vehicles emitting less than 110g CO₂/km (ACEA, 2025). Norway has also demonstrated the impact of sustained fiscal policy on EV adoption. In 2023, 82% of all new car sales in the country were electric, a result of incentives progressively introduced since 1990 (Kelley, 2024). These included the removal of purchase and import taxes until 2022, followed by the introduction of a weight-based purchase tax in 2023. The exemption from the 25% VAT on purchase applied from 2001 to 2022, with VAT imposed only on purchase values above 500,000 Norwegian krone starting in 2023. Annual road tax was waived from 1996 to 2021 and later phased in again. In addition, the company car tax saw various reductions, 25% (2000–2008), 50% (2009–2017), 40% (2018–2021), and 20% from 2022 onwards. Norway also continues to exempt EV leasing from VAT since 2015 (Norwegian Electric Vehicle Association, n.d.).

Other countries focus on registration charge exemptions. For instance, the Czech Republic and the UK waive registration charges for BEVs, FCEVs, and PHEVs emitting 50g CO₂/km or less. In Germany, BEVs and FCEVs registered from January 2016 to December 2025 are

exempt from the annual circulation tax for up to 10 years, with eligibility extended until 2030 for those emitting less than 95g CO₂/km.

On the manufacturing side, Malaysia provides generous tax incentives for companies producing EV charging equipment. From 2023 to 2032, manufacturers are eligible for a 100% income tax exemption and a full Investment Tax Allowance (ITA) on qualifying capital expenditures for 5 years. This ITA can offset 100% of statutory income annually, with unused allowances carried forward (MGTC, 2024). Similarly, Brazil is offering tax benefits to promote local EV manufacturing, including exemptions and a phased increase in import tariffs on foreign EVs, aiming to protect domestic producers and reduce reliance on imported vehicles (Duchiade, 2025).

The Netherlands presents a comprehensive model for disincentivising high-emission vehicle use. It is amongst the EU member states with the lowest average CO₂ emissions from new passenger cars, approximately 10 g CO₂/km below the EU average. The annual motor vehicle tax in the Netherlands is determined based on CO₂ emissions, vehicle weight (including the battery), fuel type, and a provincial-level surcharge. The one-time registration tax on new vehicles is also based on emission, consisting of a basic fee of €356 plus a CO₂ charge per gram that increases progressively across five emission bands. For instance, cars emitting between 1 g and 73 g CO₂/km are charged €2/g, whereas those emitting over 162 g CO₂/km are taxed at €458/g. Diesel vehicles are subject to an additional surcharge of €87.38/g starting from 63 g CO₂/km. Furthermore, the Netherlands imposes a fuel consumption tax, with car owners paying €0.780 per litre for gasoline and €0.495 per litre for diesel. Taxes constitute about 64% of the pump price for gasoline and 53% for diesel, based on 2018 figures (Wappelhorst, Mock, and Yang, 2018).

4.5. Scrappage Programme

A scrappage programme is a policy that provides financial incentives to encourage vehicle owners to replace their old vehicles with new ones that are more efficient and environmentally friendly (Svoboda, Fanta, and Mošovský, 2023). The main purpose of this programme is to stimulate new vehicle sales, support economic growth, and reduce the negative impact of old vehicles on the environment. This programme has been implemented in several countries, such as the US, European countries, and Japan.

The 'Cash for Clunkers' programme in the US began in July–August 2009. Under this programme, the government provided incentives from US\$3,500 to US\$4,500 to consumers who exchanged their old vehicles for new, more environmentally friendly vehicles (Linn, 2020b). The total number of old vehicles destroyed in this programme is almost 680,000 units. Although the purpose of this programme is to reduce emissions and support the automotive industry, the cost incurred by the government reached US\$3 billion. However, research shows that the emission reductions generated by this programme are very limited. One of the main problems was the phenomenon of 'adverse selection', wherein many recipients of the incentives had already planned to buy new

vehicles even without the programme, resulting in no significant change in consumer behaviour.

Scrappage programmes were also launched in other countries in response to the 2007–2008 global economic crisis. In Germany, the *Abwrackprämie* (or *Umweltprämie*) programme was launched in January–September 2009 with an incentive of US\$3,400 per vehicle at a total cost of US\$6.8 billion (Kaul, Pfeifer, and Witte, 2012). A total of 2,000,000 vehicles were scrapped. In Japan, the Eco-Car programme, which ran from 2009 to 2012, offered subsidies to consumers who replaced their old cars with environmentally friendly vehicles under two series of programmes. The government spent 589.9 billion yen (JPY) (US\$4.92 billion) on the first eco-friendly car programme from April 2009 to September 2010, and JPY300 billion (US\$2.5 billion) on the second, from April 2012 to September 2012. In total, more than 700,000 vehicles were scrapped. Next, one of the latest scrappage programmes is the Clean Cars 4 All in California, which aims to reduce air pollution and promote more environmentally friendly vehicles. This programme provides incentives for low-income people to replace old, high-polluting vehicles with new, cleaner vehicles, such as EVs, PHEVs, and hybrids (California Air Resources Board, n.d.). Started in 2015, the programme has involved more than 10,000 participants, with total incentive funds reaching US\$82.5 million as of September 2020.

The UK's scrappage programme (2009–2010) led to 400,000 new car registrations (Penmetsa et al., 2023). Vehicles first registered in the UK on or before 29 February 2000 and light vans under 3.5 tonnes registered before 28 February 2002 were eligible for the scheme. To qualify, the vehicle had to have been owned for at least 1 year and possess both a valid Ministry of Transport certificate – confirming that the vehicle met the minimum environmental and road safety standards required by law at the time of testing – and a tax discount. This requirement ensured that unroadworthy or unused vehicles could not be scrapped. While households were allowed to scrap more than one vehicle, only one subsidy could be claimed per new vehicle purchased. For example, a GBP4,000 discount could not be applied to a single new car for scrapping two old ones. The new vehicle had to be registered on or after the scheme's start date, 18 May 2009. It could not have been previously registered to another owner and had to be registered to the same individual who owned the scrapped vehicle (Crossley, Leicester, and Level, 2009). In addition, the manufacturer of the new vehicle had to be a registered participant in the scheme. Of the GBP2,000 government-backed discount, GBP1,000 was funded by the government, while the remaining GBP1,000 was contributed by the vehicle manufacturer (Butcher, 2018).

The impact of scrappage programmes varies depending on the country and the scheme implemented. Grigolon, Leheyda, and Verboven (2016), who analysed eight European countries, found that scrappage programmes played a significant role in stabilising total car sales in 2009. Countries with schemes targeting low-emission vehicles experienced a 30.5% decline in car sales, while countries with schemes that did not target emissions decreased by 29% (Grigolon, Leheyda, and Verboven, 2016). Kaul, Pfeifer, Witte (2016) who

evaluated the scrappage programme in Germany found that the average price of vehicles purchased with subsidies decreased compared to those not receiving subsidies, indicating that subsidised consumers benefited more than the amount of the subsidy itself.

There is significant disagreement regarding the contribution of scrappage programmes to reducing emissions. Van Wee, De Jong, and Nijland (2011) concluded that the indirect impacts on the used car market, the impacts of car use and emissions from use, and vehicle life cycle emissions are not sufficiently considered. The impacts on emissions are small and temporary. The cost-effectiveness of scrappage programmes is often inadequate, with the most favourable outcomes observed in densely populated urban areas, particularly when vehicles without emission-control technology are removed. Lelli et al. (2010) also noted that the evolution of CO₂ emissions over the entire vehicle life cycle is largely unaffected by the acceleration replacement of cars prompted by scrappage programmes. Similarly, Brand, Anable, and Tran (2013) found that such programmes save only a small amount of CO₂ and may even increase emissions when assessed on a life cycle basis.

However, scrappage programmes have significant environmental benefits in terms of improved fuel efficiency, as eligible vehicles generally have better fuel efficiency (Grigolon, Leheyda, and Verboten, 2016). Studies on the environmental and safety impacts of scrappage programmes in France, Germany, and the US found that fleet renewal initiatives can reduce CO₂ emissions, lower air pollution, and improve road safety. However, these benefits are insufficient to offset the value of the discarded vehicles, many of which could still be used reliably for some time. In some cases, the net loss is considerable (Fraga, 2011). Therefore, in this context, the environmental benefits resulting from scrappage programmes are relatively small compared to the total costs of the fiscal intervention. The potential CO₂ emission reductions achieved by these schemes could be much higher if the replacement of old vehicles were limited to hybrid vehicles, in particular (Kagawa et al., 2013).

4.6. Government Purchase

Government purchase incentives, particularly in the public sector, play a significant role in accelerating the adoption of EVs. China has been a frontrunner in this area, introducing a major policy in 2009 aimed at promoting EV use in the public sector, specifically in public transport and public services. This initiative included EV purchase subsidies and investment in supporting infrastructure, making it one of the largest-scale EV promotion efforts in the world, particularly focused on public transport rather than on private vehicles. This policy is greatly significant given that the acceptance of EVs by the public can speed up the replacement of existing gasoline vehicles (Zhang et al., 2022). Building on this foundation, the Chinese government has encouraged the use of new energy vehicles (NEVs), including EVs, in government and public fleets. This has included mandates for local governments and public institutions to prioritise NEVs in their official fleets. Some cities, such as Shenzhen and Beijing, have gone further by mandating 100%

electrification for specific public vehicle categories, including buses, taxis, and even delivery services (Jin, 2023).

India has also adopted a similar strategy through the FAME (Faster Adoption and Manufacturing of Hybrid and Electric Vehicles) policy, which provides incentives for states and union territories to transition their government fleets to electric. A prominent example is Delhi which, under the Delhi EV Policy implemented in 2020, mandates that all new government vehicle purchases must be electric. This policy marks a significant step in the city's broader effort to electrify its entire government vehicle fleet (IEA, 2023).

5. Define Clean Vehicle Alternatives for Fleet Renewal (e.g. FCEVs, HEVs, PHEVs, BEVs)

5.1. Clean Vehicle Alternatives

Clean vehicle alternatives for fleet renewal are critical components for achieving a sustainable and low-emission transport future. This study focused on several viable options aligned with Indonesia's current infrastructure, industrial capacity, and market readiness, namely, low-cost green cars (LCGCs), HEVs, PHEVs, and BEVs.

LCGCs represent an entry-level vehicle option that emphasises fuel efficiency and affordability (Komaladewi and Indika, 2017). These vehicles are designed to meet specific fuel consumption and emission standards while remaining accessible to a large portion of Indonesian population as a transitional technology that can help reduce emissions per kilometre.

On the other hand, xEV technologies provide several options with technology shifting from gasoline- or diesel fuel-based to electricity-powered vehicles. HEVs offer another intermediate solution by combining an ICE with an electric motor to improve overall fuel economy and reduce emissions without requiring external charging infrastructure.

The combination of existing fuel systems and relatively lower cost compared to full EVs make HEVs a practical alternative for the short to medium transition. Pushing forward, a breakthrough on a simulation model of an Energy Management System (EMS) for a PHEV was developed, controlling the distribution of power system components such as mechanical braking, regenerative braking, motor-only driving, battery recharging, engine and motor assist, and engine-only mode, depending on the power demand (Hannan, Azidin, and Mohamed, 2014). PHEVs allow significant tail pipe exhaust gas reduction, particularly in urban areas with shorter travel ranges due to EV mode and can bridge the technology until full electrification is more widely feasible. BEVs offer a promising clean alternative for Indonesia due to their high efficiency and zero tailpipe emissions. BEVs operate using an electric drivetrain powered by rechargeable batteries, enabling significant reductions in urban air pollution and fossil fuel dependence. As battery costs continue to decline and charging infrastructure gradually expands, BEVs are expected to become increasingly competitive with ICEVs. However, the environmental benefits of BEVs are limited by

Indonesia's coal-dominated power grid, which undermines emission reduction gains. Accelerating renewable energy development is essential to ensure that BEV adoption delivers genuine climate benefits.

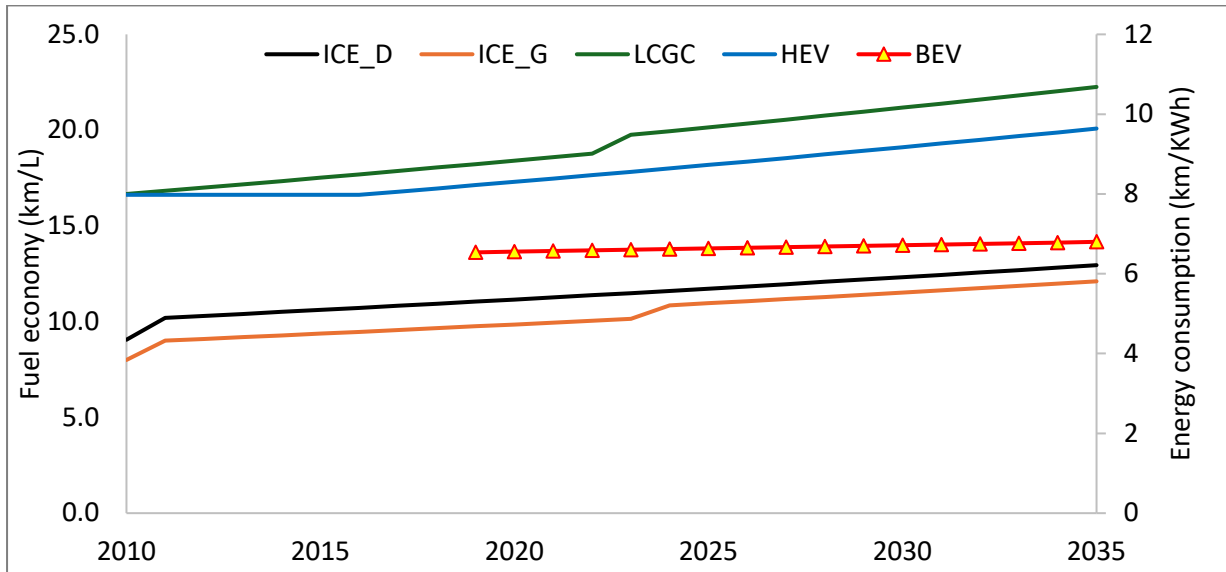
In contrast, despite offering high energy density and long driving ranges, FCEVs face more critical barriers to implementation in Indonesia. These include the complexity and cost of hydrogen production, limited infrastructure for hydrogen storage and refuelling, and significant safety concerns associated with handling compressed hydrogen fuel (Muthukumar et al., 2021). While FCEVs hold promise in countries with advanced hydrogen ecosystems, their deployment in Indonesia remains premature due to the lack of foundational infrastructure and domestic hydrogen supply chains. Therefore, the current strategy prioritises BEVs, HEVs, and PHEVs as cleaner, more practical, and immediately scalable vehicle alternatives for reducing emissions in Indonesia's road transport sector. FCEVs are excluded from consideration at this stage due to limitations in infrastructure preparation and the lack of domestic readiness to supply hydrogen for road transport.

5.2. Vehicle Fuel Economy Projection

As shown in Figure 4.1 ICE gasoline (ICE_G) fuel economy is projected to improve gradually, increasing from approximately 8 km/litre to 12 km/litre by 2035, implying an efficiency gain of roughly 1% per year. Similarly, ICE diesel (ICE_D) vehicles also demonstrate a continuous increase in fuel economy, rising from 10–13 km/litre through to 2035.

LCGCs exhibit a more significant rise in fuel economy, starting around 16.5 km/litre in 2010 and projected to reach approximately 22 km/litre by 2035. This substantial improvement highlights their growing role as efficient and affordable alternatives. HEVs also show a strong and sustained improvement in fuel economy, starting near 16.5 km/litre in 2010 and anticipated to reach around 20 km/litre by 2035, with their consistent upward trajectory underscoring the optimising effect of hybrid technology on overall efficiency.

Figure 4.1. Projection of Fuel Economy and Energy Consumption for Clean Vehicle Alternatives Based on Production Year



Source: Topgear (2023); Gridoto (2023); Miranda (2024); Electric Vehicle Database (n.d.-a); Otosia (2012).

Lastly, BEVs energy consumption, measured in km/kWh, appears relatively stable from its introduction around 2019 at approximately 6.5 km/kWh through 2035. While the visual representation shows little change, projections for BEV efficiency imply a very slight improvement of about 0.25% per year, reflecting subtle gains in BEV technology that are already highly efficient.

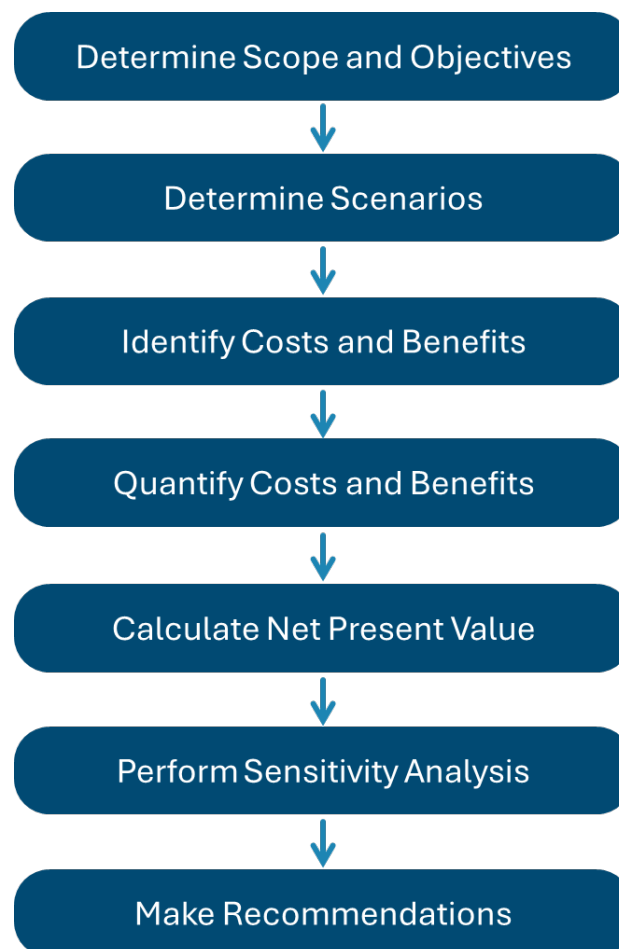
6. Evaluating Costs and Benefits on Fleet Renewal Strategies

Considering the presence of various policy alternatives for accelerating fleet renewal, optimal decision requires the decision maker to identify the most effective allocation of scarce resources amongst competing priorities (Levine et al., 2011). An analytical instrument that decision makers may utilise is cost-benefit analysis (CBA). CBA is a method for evaluating different actions or policies based on the net social benefits they generate for the overall community. The term 'net social benefit' denotes the disparity between social benefits and social costs, encompassing all tangible and intangible consequences (Atkinson, 2015; Commonwealth of Australia, 2006). This holds significant relevance when the decision under consideration entails certain positive or negative externalities that are not fully reflected in the market price or non-market goods. Implementation of the programme or initiative is justifiable if the social benefits exceed the social costs. In this regard, CBA can serve as a decision rule by identifying the most advantageous alternative.

The CBA model offers two primary advantages. First, all costs and benefits are expressed in monetary value. The attachment of monetary values to outcomes makes it possible to compare different policy alternatives and use economic evaluation methods to determine

whether a particular programme or policy offers an overall net gain to society in the sense that its total benefits exceed its total costs. Second, each cost and benefit assessed refers to the costs and benefits that the programme generates for society, rather than for specific individuals or interest groups. The phases involved in conducting a CBA are shown in Figure 4.2.

Figure 4.2. Framework of Cost–Benefit Analysis



Source: Authors.

The first step focuses on establishing the scope and objectives of the analysis to determine whose benefits and costs, as well as whose interests, should be incorporated. The main objective in this study is to determine which fleet renewal strategies generate the highest net social benefits. The chosen strategies, which favour low-carbon vehicles, may influence individual preferences and the demand for such vehicles. Consequently, changes in consumer choices will impact the composition of the vehicle population. The projected vehicle population under the intervention will then serve as the basis for the CBA calculations. The CBA compares the benefits and costs of allocating resources in the fleet renewal strategies against the outcomes that would have occurred without interventions – the baseline scenario.

Given that each strategy has a distinct impact on the vehicle composition within the population, it is essential to identify the strategies that will be incorporated into the analysis. In the second step, this study utilised multi-criteria decision analysis (MCDA) to identify the strategy set employed as scenarios in the CBA. The process of selecting strategies is addressed in the following section. Following the specification of the scenarios, the study must identify the costs and benefits associated with each scenario. This process involves identifying the potential impact of each scenario, selecting the relevant metrics, and specifying the metrics in terms of costs or benefits. The subsequent step is estimating and monetising all benefits and costs throughout the analysis periods.

The study acknowledges that policy intervention encompasses multiple years. Thus, future benefits and costs are discounted to derive their present values. Discounting implies that resources available in the future are worth less than the same amount available at present, or it reflects the opportunity cost of resources (Boardman et al., 2014). In the case of public investment, choosing an appropriate social discount rate is essential for CBA and significantly influences resource allocation decisions. Establishing a high social discount rate may prevent the implementation of numerous socially beneficial public projects, whereas a low rate could lead to numerous economically inefficient investments (Zhuang et al., 2007). This study employed a 9% discount rate, which is the standard social discount rate applied by the Asian Development Bank (2017).

As discussed in the previous section, the estimation of the intervention's aggregate impact is a critical step in comprehending its benefits to society. The net present value of the scenario is determined by accumulating the stream of discounted net benefits, which are the present value of costs subtracted from the total present value of benefits. The formula of the net present value is:

$$NPV = \sum_{t=0}^t \frac{(B_t - C_t)}{(1 + r)^t}$$

where B denotes the benefits received in any future year, C refers to the costs incurred in any future year, r is the social discount rate, and t refers to the year. The fundamental choice criterion for a singular alternative strategy, in comparison to the counterfactual, is to implement the project if its net present value (NPV) is positive ($NPV > 0$). When comparing mutually exclusive alternatives or when budgetary and other constraints require the ranking of alternative options, the criterion is to choose the project with the highest NPV. Sensitivity analysis addresses the substantial uncertainty surrounding the anticipated impacts, owing to the numerous dynamic factors that may ultimately influence the outcomes of interventions. Based on the analysis performed according to the preceding processes and the detailed information produced by the CBA, recommendations regarding the intervention can be formulated.

6.1. CBA Scenarios

Scenarios in the CBA are developed with MCDA. MCDA is a robust approach to systematically evaluating alternatives based on a clearly defined set of criteria that encompass the most relevant variables in a specific decision-making context (Geneletti and Ferretti, 2015). This method is highly advantageous when numerous alternatives and criteria exist, particularly in participatory contexts involving various stakeholders with multiple points of view (Linkov et al., 2006). Consequently, this approach is suitable for developing the scenarios employed in the CBA. This study formulates scenarios as combinations of strategies acknowledging that one strategy might require the implementation of another.

Several steps are involved in carrying out MCDA. The initial stage is to establish the goals and objectives to be attained. MCDA aims to identify the fleet renewal strategy suitable for implementation in Indonesia, with substantial potential societal impact. The next step is to identify alternative strategies for analysis. The strategies outlined in the previous section of this study will serve as alternative strategies. The subsequent phase involves establishing the assessment criteria. The study employs acceptability and feasibility of the strategy as evaluation criteria. Each alternative is evaluated according to technical, economic, and legal criteria, receiving a score ranging from 1 to 5. A value of 1 indicates low acceptability and feasibility of the strategy, whereas a value of 5 signifies high acceptability and a strong likelihood of implementation in Indonesia. At last, strategies for CBA are selected according to the ranking of the overall matrix and the highest potential impact.

Table 4.2. Matrix of Fleet Renewal Strategies

Strategies	Score			Rank
	Technical	Economic	Legal	
Standard				
Emission standard	5	5	5	1
Fuel economy standard	4	4	5	7
EV energy consumption rate limit	3	2	3	16
Subsidy				
Subsidy to purchase new BEV	4	3	3	11
Subsidy to purchase new low-emission vehicle	4	3	3	11
Conversion to EV subsidy	5	4	4	7
Low-emission vehicle producer subsidy	2	3	3	16
Regulation				
Fitness test	5	5	4	3
Space for EV charger	1	2	4	18

Strategies	Score			Rank
	Technical	Economic	Legal	
Environmental zone	3	4	4	10
Support EV infrastructure (mandate)	4	5	5	3
Tax				
Tax incentive for low-emission vehicle	5	5	4	3
Tax incentive for BEV	4	5	5	3
Fossil fuel tax (carbon tax)	2	4	4	11
Higher annual tax for higher CO ₂ emitter vehicle	3	4	5	9
Tax incentive for low-emission vehicle producer	1	3	3	18
Tax incentive for BEV producer	1	3	5	15
Scrappage programme	3	4	3	11
Government purchase	5	5	5	1

Source: Authors.

According to the expert assessment in the MCDA, the strategies that ranked in the top 10 out of 19 total strategies will be incorporated into the CBA scenario. These high-ranking alternative strategies are subsequently re-evaluated based on the potential impacts they may generate. The regulation for establishing EV infrastructure and environmental zones is anticipated to exert minimal influence. Conversely, while the scrappage programme does not occupy the top position in the MCDA matrix, it will have a major impact on fleet renewal. Therefore, this study will examine six strategies: (i) fitness test, (ii) emission standard, (iii) fuel economy, (iv) tax incentives for low-emission vehicle purchases, (v) higher taxes for high-emission vehicles, and (vi) a scrappage programme. Table 4.3 shows the scenarios of the CBA.

Table 4.3. CBA Scenarios

	Fitness Test	Emission Standards	Fuel Economy	Tax Incentives for LCEVs	Higher Tax for High-Emission Vehicles	Scrappage Programme
Baseline						
Scenario 1	ü	ü	ü	ü		ü (one-time)
Scenario 2	ü	ü	ü	ü	ü	
Scenario 3	ü	ü	ü	ü	ü	ü
Scenario 4	ü	ü	ü	ü		ü (gradual)
Scenario 5	ü	ü	ü	ü	ü	ü

Source: Authors.

Table 4.4. Assumptions of Scenarios

	Fitness Test	Emission Standards	Fuel Economy	Tax Incentives for LCEVs	Higher Tax for High-Emission Vehicles	Scrappage Programme
Baseline	Maintenance cost represents the cost to ensure the same levels of fitness test criteria, emission standards, and fuel economy: <ul style="list-style-type: none"> All new cars are assumed to meet fitness test criteria. The maintenance cost in the following years ensure the cars meet the standards. 			BEV incentives (period 2024–2028): <ul style="list-style-type: none"> 0% PPnBM 0% PKB 0% BBnKB 10% VAT reduction 0% PPnBM rate and 0% Import tariffs on imported BEVs in CBU and CKD with domestic component level 20–40% condition 		
Scenario 1						Rp10 million per car with total subsidy of Rp25.5 trillion (in 2030).
Scenario 2					PKB coefficient from 1.05 to 1.50	
Scenario 3					PKB coefficient from 1.05 to 1.50	Rp10 million per car with total subsidy of Rp25.5 trillion (in 2030).
Scenario 4						Rp10 million per car with total subsidy of Rp25.5 trillion (in 2030 – 2035).
Scenario 5					PHEV and HEV incentives: 3% government-borne luxury goods sales tax (PPnBM) is assumed to be implemented for the period 2025–2027	PKB coefficient from 1.05 to 1.50

Source: Authors.

This study presents three scenarios for CBA. The baseline scenario represents a condition without any intervention. Fitness tests, emission standards, fuel economy standards, and tax incentives for LCEVs will be implemented across all scenarios. The cars registered each year are assumed to comply with fitness tests, emission standards, and fuel economy standards. The tax incentives used in the CBA follow current regulations governing BEV, HEV and PHEV incentives, as discussed in the regulatory analysis section.² The distinction amongst scenarios remain in the incorporation of a scrappage programme and tax reform. The first scenario will address the one-time scrappage programme, while the second scenario will examine tax reform (higher taxes for high-emission vehicles). In the third scenario, tax reforms and the one-time scrappage programme will be integrated. The fourth scenario will employ a gradual scrappage programme. The last scenario will combine tax reforms and a gradual scrappage programme.

The next step of scenario formulation is determining the size of the intervention. As discussed in the previous section, this study examined the potential economic value of end-of-life vehicles. To influence consumer choices, the compensation offered under a scrappage programme must be higher than the vehicle's economic value. The premium on top of the economic value is assumed to be the benefit from fleet renewal. This study assumes that the compensation for each scrapped vehicle is Rp10 million. This number is 25% higher than the potential economic value of ICEVs that is Rp8 million. This study utilises a targeted scrappage programme in which consumers receive a subsidy for purchasing a new low-emission vehicle upon scrapping an old ICEV.

Vehicle tax (PKB) is one of the tax components considered in this CBA. The components for PKB calculation are the retail price of motor vehicles and a coefficient representing the extent of road damage and/or environmental pollution resulting from vehicle usage. If a vehicle is deemed to have a greater impact on environmental pollution, the PKB coefficient will correspondingly increase. The vehicles utilised in this study typically conform to a coefficient classification of 1.05 as per Indonesian regulations. The tax reform analysed in the CBA involves an increase in the PKB coefficient from 1.05 to 1.5, representing a 42.86% increase.

6.2. Vehicle Structure Projection

The calculation of CBA requires forecasts of passenger populations as the basis. This section will primarily address the potential impact of strategies on vehicle structure projection, while the forecasting model is elaborated upon in the technical section.

The extensive promotion of low emission vehicles for fleet renewal will depend on consumer assessments of various policy instruments (Li, Wang, and Wang, 2020).

² All tax incentives for BEVs are assumed to be implemented for the period 2024–2028 (according to Government Regulation No. 79 of 2019 (as amended by No. 74 of 2021). Tax incentives for HEVs and BEVs in the form of government-borne PPnBM are assumed to be implemented for the period 2025–2027 (according to Minister of Finance Regulation No. 12 of 2025).

Financial incentives, including subsidies and tax incentives that lower purchase and usage costs, have been shown in previous studies to significantly enhance the demand for low-carbon emission vehicles (Li et al., 2018; Wee, Coffman, and La Croix (2018)). In other cases, non-financial incentives that enhance convenience for consumers, such as access to high-occupancy vehicle lanes and the removal of driving restrictions, serve as the determining factor for certain consumers in their decision to purchase BEVs (Bjerkan, Nørbech, and Nordtømme, 2016; Wang, Li, and Zhao, 2017). Changes in consumer purchasing decisions regarding vehicle types will eventually impact the vehicle structure within the population.

One issue that arises in assessing the projection is evaluating the extent of the policy's impact on changes in vehicle structure. The most frequently used method is the application of elasticity. In this study, the elasticity of new vehicle sales with respect to fiscal incentives provides a framework to assess the impact of the intervention. Sales elasticity quantifies the variation in vehicle sales volumes – including changes in vehicle types – that results from changes in subsidies or tax reforms. Due to data limitations, this study utilises sales elasticity data from other regions as proxies for the analysis.

The scrappage programme, which provides subsidies for the purchase of new low-carbon emissions vehicles following the scrapping of old vehicles, has two primary implications. First, this strategy enhances the rate of vehicle retirement. Second, because the programme's economic compensation has been targeted at vehicle purchases, it will increase LCEV sales. Evidence from Europe indicates that the sales elasticity of targeted scrapping schemes is 2.4 (Grigolon, Leheyda, and Verboven, 2016). This implies that a 1% increase in the subsidy results in a 2.4% increase in LCEV sales. This study utilises targeted scheme estimation, as it aligns with Indonesia's strategic framework, despite the differing estimations presented by non-targeted schemes. In this case, the intervention results in a 1:1 ratio between the number of retired vehicles and the number of new vehicles sold.

The tax reform imposing higher annual taxes on high-emission vehicles will increase their operational costs. In this context, the ownership costs associated with low-emission vehicles seem to be significantly lower. This strategy does not directly impact retirement but may influence the selection of vehicle types for new purchases. Previous study from the UK indicates that the elasticity of new ICE car registrations in response to taxes is -0.296 (Cerruti, Alberini, and Linn, 2019). A 1% increase in the annual tax leads to a 0.296% decrease in the sales of ICEVs. The reduction of ICE sales is then offset by an increase in the sales of low-emission vehicles.

6.3. Component of Costs and Benefits

This section will examine the components of costs and benefits used in this study. The objective of fleet renewal is to enhance efficiency and promote environmental sustainability. As outlined in the preceding section, advancements in technology will enhance fuel efficiency, thereby potentially decreasing a country's reliance on fuel imports.

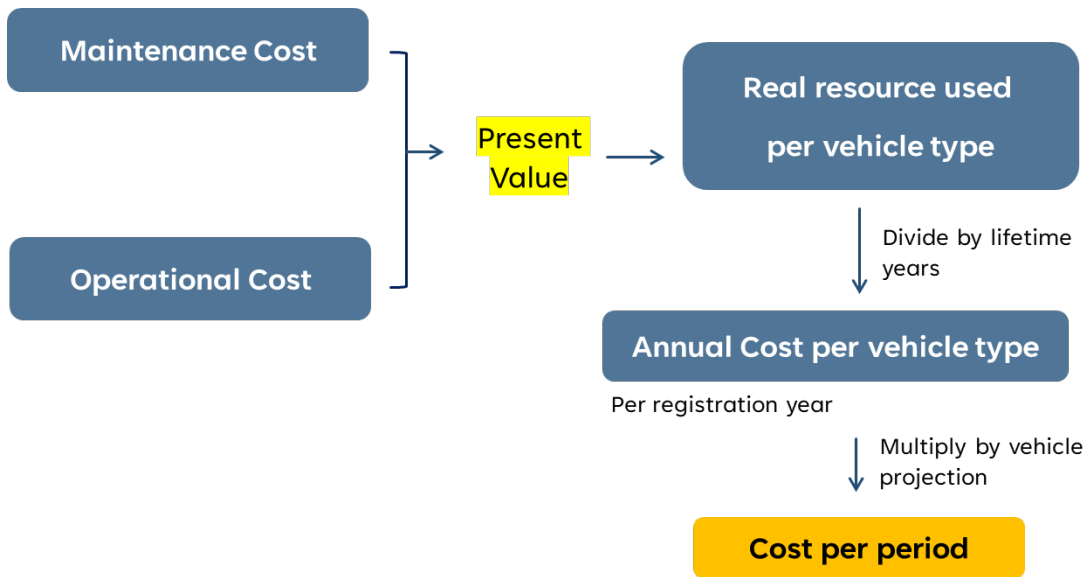
Since the intervention impacts the vehicle structure within the population, total fuel consumption will also change. The costs associated with vehicle ownership and fuel imports serve as direct impacts of interventions.

This study acknowledges certain externalities as indirect effects of interventions in the transport sector. Indonesia implements numerous fuel subsidy programmes to maintain affordable fuel prices, especially for vulnerable groups. Subsidy provisions may lead to economic inefficiencies by distorting market signals and preventing optimal outcomes. While subsidies represent a distributional transfer that does not inherently alter social benefit (transfer from government to society), their associated economic inefficiencies can lead to allocative effects, thereby impacting overall social benefit. On the other hand, the environmental effect is a significant factor that must be considered in CBA. Consequently, both the avoidance of economic inefficiency and the reduction of emissions will serve as indirect effects of fleet renewal strategies.

6.3.1. Total cost of ownership

The total cost of ownership (TCO) outlines all costs associated with vehicle ownership, covering the period from acquisition through operation and maintenance until the vehicle is disposed of by the owner. In this case, calculating TCO is essential to quantify and compare the expenses of different vehicle alternatives. This method is advantageous, especially when vehicle options utilise varying fuel economies and fuel types. TCO includes capital expenditures, operational expenses, and maintenance charges. It is essential to recognise that certain financial cost items are not considered economic costs, as they do not affect the availability of resources for the economy as a whole. Transfer payments between parties – such as taxes, subsidies, and capital costs – are therefore excluded from the CBA. Consequently, only operational costs and maintenance costs are included in the CBA. Figure 4.3 below shows the framework in estimating the cost of real resources used.

Figure 4.3. Framework of Cost of Ownership



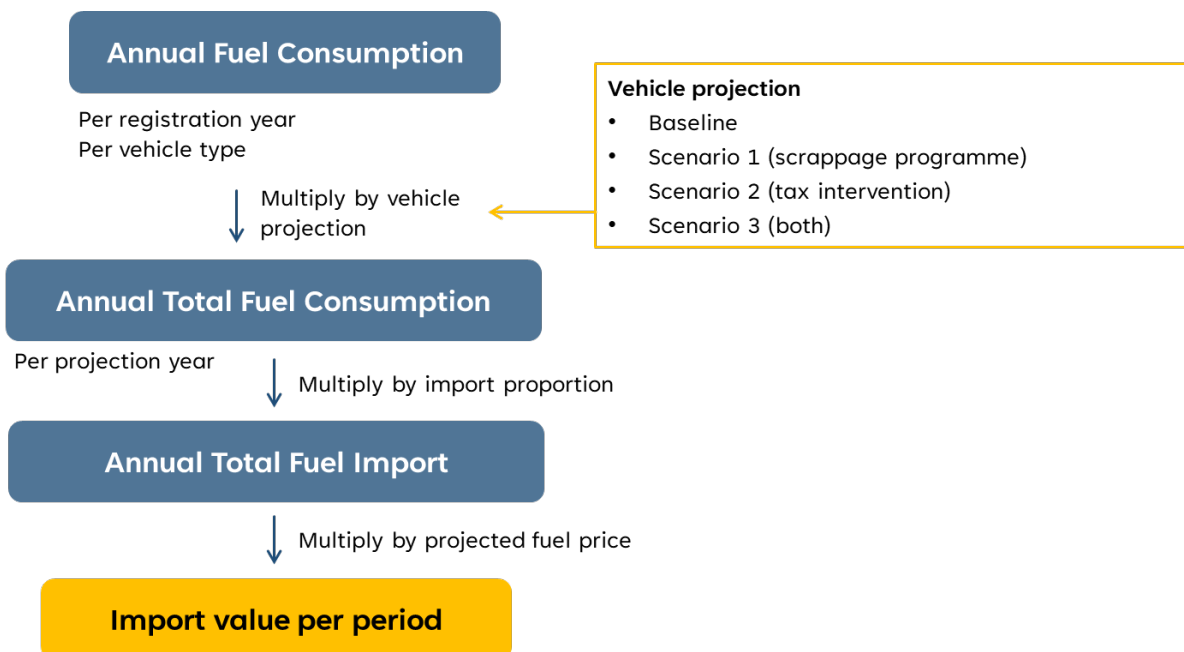
Source: Authors.

Nevertheless, this study estimates the TCO to assess the competitiveness of each vehicle type.

6.3.2. Fuel imports

The decrease in fuel imports is a co-benefit of implementing fleet renewal strategies. The shift to more fuel-efficient or EVs will lead to decreased annual fuel consumption. Assuming a constant import proportion, total fuel imports will decline in line with the reduction in fuel consumption. Figure 4.4 outlines the framework for estimating the fuel imports.

Figure 4.4. Framework of Fuel Import Calculations



Source: Authors.

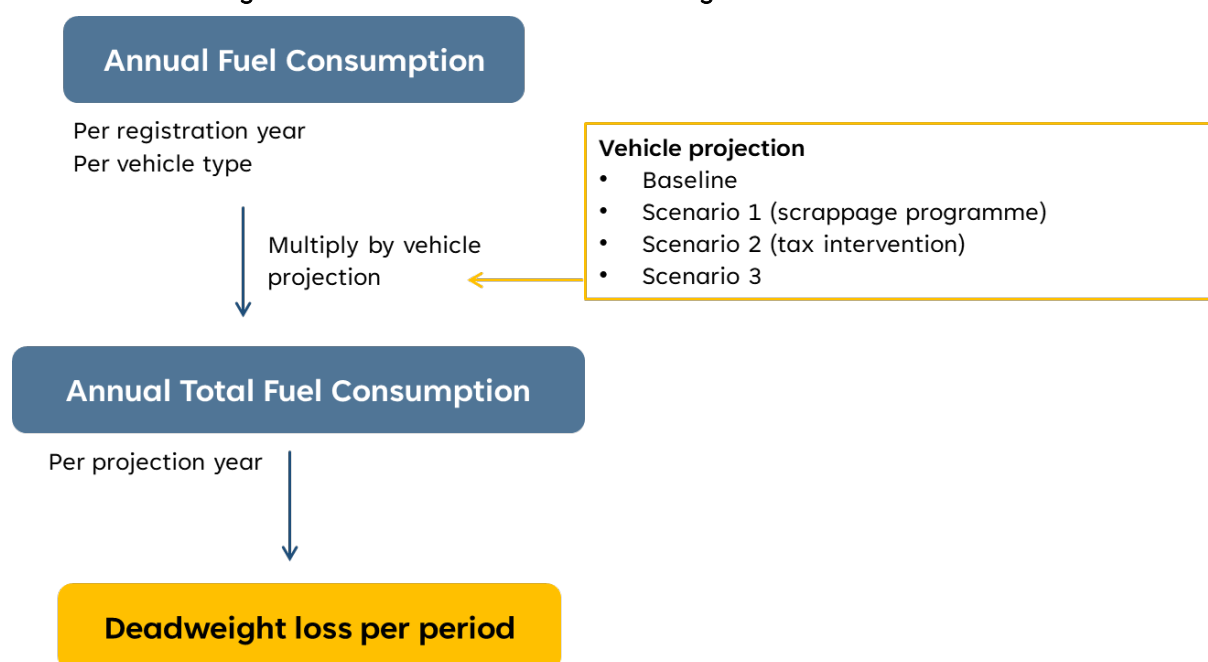
6.3.2.1. Avoidance of economic inefficiency

In Indonesia, fuel subsidies are implemented to maintain affordable fuel prices, particularly for vulnerable groups. However, while subsidies serve as a mechanism for income redistribution, they can distort market signals and create economic inefficiencies by encouraging overconsumption of subsidised fuels and discouraging energy conservation. This misallocation of resources leads to a deadweight loss – a loss of economic welfare that neither benefits consumers nor producers – reducing overall societal welfare compared to a scenario with optimal market pricing.

Fleet renewal strategies, particularly those promoting the adoption of low-emission and fuel-efficient vehicles, can mitigate this inefficiency. By lowering aggregate fuel demand, these interventions reduce the volume of subsidised fuel consumed, thus minimising the distortionary effect of subsidies on fuel prices. The avoided economic inefficiency is quantified by estimating the reduction in deadweight loss, which arises when fuel consumption moves closer to its economically efficient level.

Figure 4.5 illustrates the process for quantifying the deadweight loss avoided because of implementing fleet renewal and tax intervention policies.

Figure 4.5. Framework of Deadweight Loss Calculations



Source: Authors.

First, the annual fuel consumption is determined for each vehicle type and registration year. This consumption figure is then multiplied by the projected vehicle population under different scenarios – including the baseline, a scrappage programme, tax intervention, and a combined policy scenario – to estimate the total annual fuel consumption for each projection year. By comparing the total fuel consumption across these scenarios, the model calculates the deadweight loss per period, reflecting the economic inefficiency

caused by fuel subsidies. A reduction in total fuel consumption leads directly to a lower deadweight loss, demonstrating the economic benefit of policies that promote more fuel-efficient and low-emission vehicles.

In the CBA framework of this study, the benefit of avoided economic inefficiency is incorporated as an indirect effect of the policy intervention. This benefit, along with direct savings in fuel imports and environmental improvements, contributes to the overall net social benefit of accelerated fleet renewal policies.

Deadweight loss is calculated using the following formula (Davis, 2014):

$$DWL = (p_1 - p_0)q_0 - \frac{A}{(1 + e)} [p_1^{(1+e)} - p_0^{(1+e)}]$$

where:

p_1 = market fuel price

p_0 = subsidised fuel price

q_0 = fuel demand (with subsidised price)

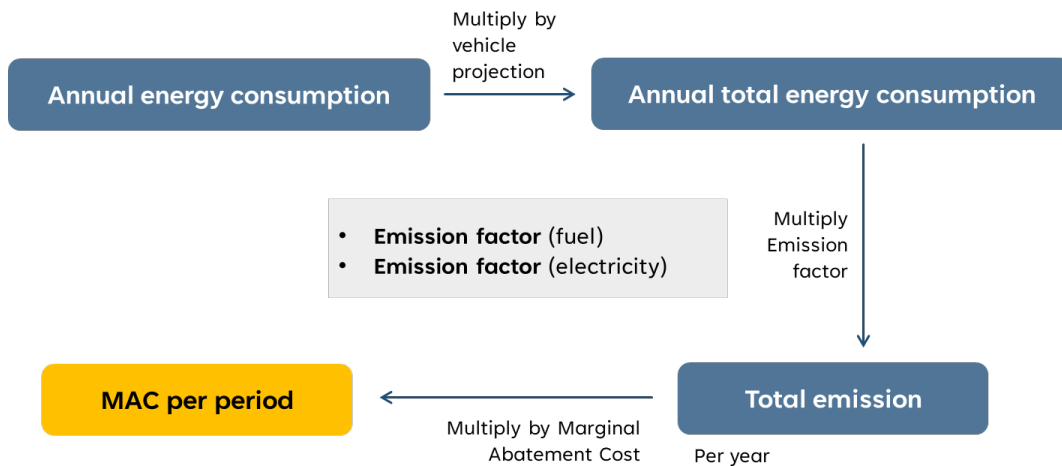
A = a scale parameter that varies across countries and fuels, price p , and elasticity

e = fuel demand elasticity.

6.3.2.2. Emissions

The main goal of the fleet renewal strategy is to reduce emissions in the transport sector. It is therefore important to estimate the effect of intervention on emissions. The monetary value of emissions is best represented by the marginal abatement cost (MAC), as the MAC reflects the cost of reducing one additional unit of pollution, typically measured in terms of dollars per tonne of CO₂. This cost-based perspective provides a direct way to assign a monetary value to emissions based on what it would cost to avoid them.

Figure 4.6. Framework of Marginal Abatement Costs



Source: Authors.

In carbon pricing systems such as carbon taxes or cap-and-trade programmes, the MAC plays a central role by helping determine the appropriate emissions price. Ideally, the carbon price should match the MAC, ensuring that firms reduce emissions when doing so is cheaper than paying the price to pollute. Such alignment ensures cost-effectiveness in achieving environmental goals. In the case of Indonesia, this study employs the MAC estimated by PSE UGM (2020) which is US\$42.75 per tonne CO₂. This value is multiplied by total emissions to estimate the overall MAC.

6.3.3. Assumptions

The following assumptions are employed in this study for each cost–benefit component calculation.

Table 4.5. Assumptions in Total Cost of Ownership

Parameter	ICE Diesel	ICE Gasoline	LCGC	PHEV	HEV	BEV
Vehicle price (NJKB) ^a	Rp144 million	Rp180 million	Rp82 million	Rp527million	Rp438 million	Rp463,000,000
Year of NJKB ^a	2018	2025	2017	2019	2018	2025
Vehicle price changes ^b	0.42%	0.42%	0.42%	-1.23%	-1.03%	-5.16%
Fuel Type ^c	Diesel	RON 92 (15%) RON 90 (85%)	RON 92	RON 92 (18.89%) Electricity (81.11%)	RON 92	Electricity
Fuel price (subsidised price 2024) ^{d, e, f}	Rp6,800	Rp12,100 Rp10,000	Rp12,100	Rp12,100 Rp1,699.53 (R-2/R-3)	Rp12,100	Rp1,699.53 (R-2/R-3)
Fuel price changes ^g	2.34% (Diesel)	4.75% (RON 92) 2.99% (RON 90)	4.75% (RON 92)	4.75% (RON 92) 2.37% (Electricity)	4.75% (RON 92)	2.37% (Electricity)
Fuel Economy (vehicle registered in 2024) ^c	11.61 km/l	10.85 km/l	19.95 km/l	18.00 km/l 6.62 km/kWh	18.00 km/l	6.62 km/kWh
Annual efficiency increment	1%	1%	1%	1% 0.25%	1%	0.25%
Maintenance cost ^h	\$0.0898/miles	\$0.0898/miles	\$0.0839/miles	\$0.0819/miles	\$0.0819/miles	\$0.0746/miles
Inflation	2.5% (APBN 2025)					
Exchange rate	Rp 4,820/\$ (Purchasing Power Parity) ⁱ					
Vehicle lifetime	20 years					
Mileage	18,000 km per year					

Parameter	ICE Diesel	ICE Gasoline	LCGC	PHEV	HEV	BEV
Tax	Follow Indonesia Regulation (including PKB, PPN, PPnBM, BBnKB, BPKB, TNKB, STNK, SWDKLLJ)					

Sources:

^a Provinsi DKI Jakarta (2025).

^b König et al. (2021).

^c Authors' analysis.

^d CEIC (2025a).

^e CEIC (2025b).

^f CEIC (2025c).

^g Authors' estimation according to historical data.

^h AAA (2020).

ⁱ World Bank (2025a).

This study employed the selling value of motorised vehicles, known as NJKB (*Nilai Jual Kendaraan Bermotor*), as the reference for vehicle price. NJKB is a value that has been officially determined by the Regional Revenue Service or Dispenda (*Dinas Pendapatan Daerah*). In this study, we utilised NJKB implemented in Jakarta province. PHEVs, HEVs, and BEVs in this study are imported CBU vehicles while ICEs and LCGCs are locally manufactured.³ Although some HEV models, such as Toyota Kijang Innova Zenix HEV, are manufactured in Indonesia, their prices are comparable to those of imported CBU HEV. Changes in vehicle prices over time are assessed based on the research conducted by König et al. (2021), which outlines the variations in ICE prices and battery costs in 2020 and 2030. ICE_G, ICE_D, and LCGC are assumed to have equal price growth. The price changes of HEVs, PHEVs, and BEVs are determined by variations in battery costs and the proportion of battery costs relative to the total vehicle cost. The battery cost as a proportion of total costs is 8% for HEVs, 9% for PHEVs, and 39% for BEVs. The relevant proportion is subsequently multiplied by the annual decrease in battery cost (–13.10%). The fuel price change refers to the compound annual growth rate of retail fuel costs, including electricity, from 2016 to 2024. Additional assumptions are detailed in the Table 4.6.

Table 4.6. Fuel Import Calculation Assumptions

Parameter	Solar	RON 90	RON 92	Sources
Market price (Rp/litre) (2024) ^f	11,950	11,700	12,100	Subsidised price ^{a b c} plus subsidy, estimated by PSE UGM
Price changes	5%			World Bank (Crude oil price growth) ^d
Import percentage	18%	53.74%	65%	Statistics oil & gas ^e
Fuel economy (km/litre)	Different for each vehicle type and registration year			PSE UGM ^f
Mileage (km)	18,000 km per year			PSE UGM ^f
Fuel Consumption (litre)	Mileage ÷ Fuel economy			PSE UGM ^f

Sources:

^a CEIC (2025a).

^b CEIC (2025b).

^c CEIC (2025c).

^d World Bank (2025b).

^e Directorate General of Oil and Gas – Ministry of Energy and Mineral Resources (2024).

^f Authors.

³ The vehicle types chosen in this study are Suzuki Ertiga AVI413FD (4X2) M/T (ICE_D), Suzuki Ertiga ARK415F GA (4X2) M/T (ICE_G), Toyota Agya AGYA 1.0 E M/T (B100RA-GMRFJ) (LCGC), Toyota Prius 1.8 PHV A/T (ZVW52R-AHXEBW) (PHEV), Toyota Prius 1.8 HYBRID A/T (ZVW50R-AHXEBW) (HEV), and BYD M6 (ME-60 (4X2) AT) (BEV).

The market price of fuel is the combination of subsidised price and the fuel subsidy (Kumparan Bisnis, 2025). The change of market price refers to the compound annual growth rate of average crude oil prices (average spot price of Brent, Dubai, and West Texas Intermediate) (World Bank, 2025b). from 2015 to 2024. This study assumes that the proportion of import remains constant over the years, using the median of historical import percentages (Directorate General of Oil and Gas – Ministry of Energy and Mineral Resources, 2024). This study estimated the median for RON 92 and solar from 2018 to 2023. On the other hand, RON 90 has been utilised since 2022. Therefore, the median for RON 92 corresponds to the period from 2022 to 2023. Both fuel economy and mileage utilize the same assumption as that employed in the cost of ownership calculation.

Table 4.7. Emission Calculation Assumptions

Parameter	Solar	RON 90	RON 92	Electricity
Emission factor (tonne CO ₂ per litre or kWh) ^a	0.003	0.00284	0.00284	Emission intensity (Optimal scenario RUPTL)
Marginal abatement cost ^b	US\$42.75 per tonne CO ₂			
Electricity consumption (kWh) ^a	Estimated from vehicle projection			
Fuel consumption (litre) ^a	Estimated from vehicle projection			

Sources:

^a Authors.

^b PSE UGM (2017).

The emission factor for solar, RON 90, and RON 92 is determined by aggregating total emissions, covering both tank-to-wheel and well-to-tank emissions. The emission factor for electricity utilised the emission intensity based on RUPTL's optimal scenario. The emission intensity for electricity was 0.892 tonne CO₂/ MWh in 2021 and is projected to be 0.815 tonne CO₂/MWh in 2030. The MAC used in this study is US\$42.75 per tonne CO₂ (PSE UGM, 2017).

Table 4.8. Assumptions for Calculating Avoided Economic Inefficiency

Parameter	Solar	RON 90	RON 92	Sources
Market price (Rp/litre) (2024)	11,950	11,700	12,100	Subsidised price plus subsidy, estimated by PSE UGM
Market price changes	5%			World Bank (Crude oil price growth) (2015–2024) ^a
Subsidised price (Rp/litre) (2024)	6,800	10,000	12,100	CEIC ^{b c d}
Subsidised price changes	2.34%	2.99%	4.75%	CEIC (growth from 2016 to 2024) ^{b c d}
Price elasticity of fuel demand	-0.7			Brons et al. (2008)
Fuel Consumption (litre)	Estimated from vehicle projection			PSE UGM

Sources:

^a World Bank (2025b).

^b CEIC (2025a).

^c CEIC (2025b).

^d CEIC (2025c).

In addition to the assumptions explained in the preceding sections, calculating avoided economic inefficiency – or avoided deadweight loss – requires information on the price elasticity of fuel demand. According to the literature, the long-run elasticity of demand for transport fuels tends to range from –0.6 to –0.8 (Brons et al., 2008). Thus, this study employed –0.7 as the price elasticity of fuel demand (median).

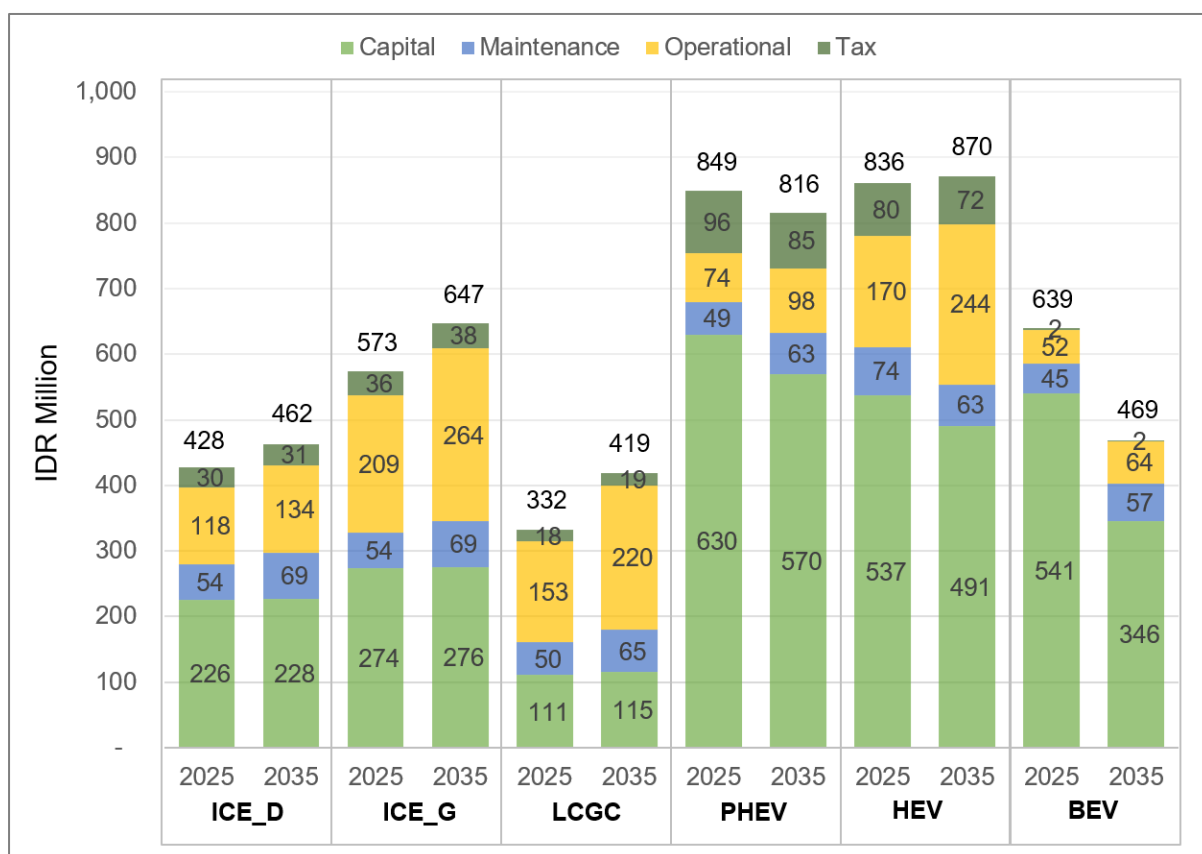
6.3.4. Results

The findings of this study are presented in two parts. First, the study examines the TCO for each vehicle type and the effect of the intervention on TCO. Second, it evaluates the outcomes of the CBA for each of the three scenarios. In addition, the study demonstrates the impact of variations in programme duration on the overall net benefit.

6.3.4.1. Total cost of ownership

Figure 4.7 illustrates the total cost of ownership for each vehicle type that is registered in 2025 and 2035 based on calculations derived from the assumptions outlined in the preceding section.

Figure 4.7. Total Cost of Ownership in 2025 and 2035 (Baseline)



Note: The calculation of operational costs for ICE_G and HEV vehicles depends on the fuel-type prices (RON 92 versus RON 90) and the respective escalation rates applied in each fuel type projection. Readers may refer to Table 4.5 for detailed assumptions.

Source: Authors.

The TCO for ICE_D, ICE_G, LCGC, and HEV increases from 2025 to 2035. Conversely, PHEVs and BEVs experience a reduction in TCO value over the same period. The primary elements driving this divergence are capital expenditure and operational expenditure components. In 2025, the capital costs of PHEVs, HEVs, and BEVs are comparatively higher than those of other vehicle types. However, by 2035, these costs have significantly dropped,

particularly by 9.58%, 8.53%, and 36.05%, respectively. The energy costs per kilometre in 2035 are Rp373.11 for ICE_D, RpR733.15 for ICE_G, Rp611.95 for LCGCs, Rp272.82 for PHEV, Rp678.17 for HEV, and Rp178.24 for BEV.

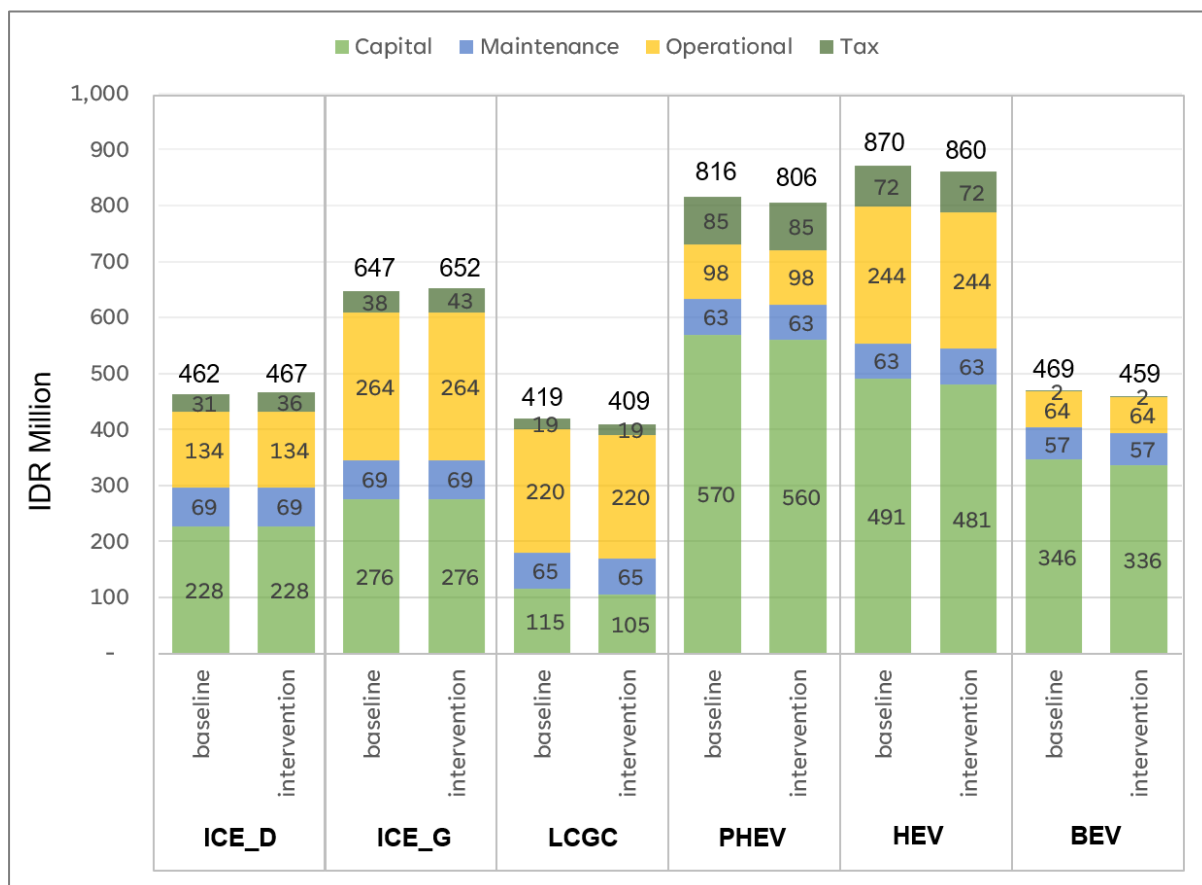
Despite a reduction in capital costs, HEVs – like other petrol-powered vehicles – experience a significant rise in operational expenses, thereby increasing their TCO. Both HEVs and LCGCs face increases in operational expenses of up to 44%, attributable to rising fuel prices. The TCO of BEVs in 2035 is projected to be lower than that of ICE_G vehicles and highly competitive with ICE_D and LCGCs. PHEVs and HEVs have comparatively substantial tax components relative to other vehicle categories due to high capital expenditures associated with imported vehicles. Although BEVs are also imported, numerous subsidies received by the BEV sector greatly minimise the tax burden. This result is in line with regulation analysis where LCEVs other than BEVs do not receive any incentives related to PKB, BBnKB, VAT, or the PPnBM rate on imported goods. The lack of tax incentives may result in a slower adoption rate for these vehicles compared to BEVs as empirical research indicates that subsidies can effectively stimulate demand for alternative fuel vehicles (Gallagher and Muehlegger, 2011; Springel, 2021).

The subsequent section examines the effect of the intervention on TCO. Figure 4.8 illustrates the variation in the TCO for each vehicle type resulting from the tax intervention and the scrappage programme.

In general, tax intervention results in higher tax cost for ICE_D and ICE_G while a scrappage programme facilitates a decrease in capital cost for LCGCs, PHEVs, HEVs, and BEVs. The remaining components stay unchanged. To reduce the TCO of PHEVs and HEVs, additional tax incentive may serve as a temporary solution. In the long term, domestic production of PHEVs and HEVs is crucial for lowering capital costs.

Domestic production of LCEVs helps reduce costs through several interconnected factors. Local manufacturing enables companies to eliminate, or significantly reduce, expenses associated with shipping, import tariffs, and customs duties – charges that are often substantial when vehicles are imported from abroad. In addition, producing vehicles domestically allows manufacturers to develop and rely on local supply chains, which shortens delivery times for parts, reduces inventory and logistics costs, and improves overall production efficiency. Domestic production will both mitigate the potential risks and ensure supply chain stability (White House, 2021). As production volumes increase, manufacturers benefit from economies of scale, meaning the cost per unit decreases as more vehicles are produced. Governments often support domestic manufacturing through subsidies, tax incentives, and grants, further reducing production costs. Taken together, these advantages make domestic LCEV production a key driver in lowering the overall cost of EVs for consumers.

Figure 4.8. Total Cost of Ownership in 2035 (Baseline and After Intervention)



Source: Authors.

Although the TCO of HEVs are relatively higher than that of PHEVs, HEVs remain a more practical and impactful short- and mid-term solution for road decarbonisation compared with BEVs and PHEVs, particularly during the transition phase. HEVs can deliver immediate emission reduction because they significantly improve fuel efficiency over ICEVs while requiring no changes to refuelling infrastructure. Unlike BEVs and PHEVs, HEVs do not depend on a widespread charging network or a clean electricity grid, both of which require time and investment to develop. This makes them especially valuable in regions where the electricity grid is still carbon-intensive or where charging infrastructure is limited. PHEVs, while promising in theory, often underperform in practice because many users do not charge them regularly, leading to fuel consumption patterns that resemble conventional vehicles. HEVs, by contrast, consistently deliver emissions benefits regardless of user habits. Taken together, HEVs provide a scalable, low-barrier option for reducing transport emissions in the short and medium term, serving as a crucial bridge while countries build the necessary infrastructure, supply chains, and clean energy systems to support widespread EV adoption in the longer term.

6.3.4.2. Results of the cost–benefit analysis

This section will address the outcomes of the CBA. Table 4.9 shows the result of CBA under three main scenarios. The scrappage programme in this analysis is a one-time intervention that results in the disposal of 2,549,683 ICEVs (including ICE_D and ICE_G) in 2030. All values highlighted in Table 4.9 represent marginal value, defined as the difference between the scenario outcome and the baseline.

**Table 4.9. Results of the Cost–Benefit Analysis
(with a One-Time Scrappage Programme)**

	Scenario 1	Scenario 2	Scenario 3
Marginal cost (Rp)			
Resource used	-1,102,799,993,306	-1,407,794,544,686	-2,510,616,687,814
Marginal benefit (Rp)			
Fuel import	45,548,185,764,637	2,522,613,230,491	48,070,816,508,224
Emission	11,127,353,254,244	571,981,563,595	11,699,333,375,072
Avoided inefficiency	2,153,553,772,487	133,895,528,081	2,287,446,975,089
Total	59,931,892,784,674	4,636,284,866,854	64,568,213,546,199

Source: Authors.

The CBA indicates that integrating fleet renewal strategies results in a positive net benefit across all scenarios. Implementing all solutions (Scenario 3) yields a net profit of Rp64.57 trillion. A one-time scrappage programme (Scenario 1) delivers a larger net benefit than the tax intervention (Scenario 2), with the estimated gains reaching Rp59.93 trillion and Rp4.64 trillion, respectively. Under all scenarios, the resource used is negative, indicating that all interventions result in resource savings in economy.⁴ The simulation indicates that both the scrappage programme and tax reform result in decreased fuel imports, reduced emissions, and enhanced economic efficiency.

The length of the scrappage programme's implementation will also affect its net benefit. Table 4.10 presents the outcomes of the CBA across three primary scenarios, including a modification to the duration of the programme. This analysis examines a gradual scrappage programme implemented over 6 years, which results in the disposal of 424,947 ICEVs annually (including both ICE_D and ICE_G vehicles) from 2030 to 2035.

⁴ The savings are derived from lower fuel consumptions in scenarios 1, 2, and 3 compared to that of the baseline scenario.

Table 4.10. CBA Results (with Gradual Scrappage Programme)

	Scenario 4	Scenario 5
Marginal cost (Rp)		
Resource used	1,470,587,721,982	62,843,765,277
Marginal benefit (Rp)		
Fuel import	29,516,692,180,137	32,039,323,580,483
Emission	6,467,862,876,561	7,039,843,569,314
Avoided inefficiency	1,202,786,010,526	1,336,679,777,490
Total	35,716,753,345,242	40,353,003,162,009

Source: Authors.

The gradual scrappage programme (a 6-year programme) in Scenario 4 generates a net benefit of Rp35.72 trillion, which is lower than that of the one-time scrappage programme (Scenario 1). The combination of a gradual scrappage programme and tax reform in Scenario 5 also produces a smaller net benefit compared with the combination of a one-time scrappage programme and tax reform (Scenario 3). This outcome may be due to the substantial benefits generated in the initial year, which continue to persist in subsequent years in. This value exceeds the incremental accumulation of advantages in the gradual scrappage programme scenario. However, both scrappage programmes generate net benefits beyond the total subsidy of Rp25.5 trillion.

Chapter 5

Conclusions and Recommendations

Conclusions

1. The BAU scenario indicates that, as older vehicles (aged 20 years and above) are naturally retired, fuel consumption and emissions gradually decline. This trend is further supported by the growing share of more fuel-efficient vehicles, particularly LCGCs.
2. A one-time, large-scale scrappage programme implemented in 2030 results in greater cumulative reductions in fuel consumption and emissions over the 2030–2035 period compared to a gradual annual scrappage programme, even when the total number of vehicles scrapped is the same.
3. Between 2025 and 2035, the total cost of ownership (TCO) for ICEVs – including both gasoline and diesel vehicles – as well as LCGCs and HEVs, is projected to increase steadily. In the case of HEVs, this increase is largely driven by reliance on imports, leading to higher purchase prices and associated costs. By contrast, PHEVs and BEVs are expected to experience a notable decline in TCO, primarily due to rapid advancements and cost reductions in battery technology.
4. The cost–benefit analysis (CBA) demonstrates that all modelled fleet renewal strategies generate positive net benefits. The integrated scenario combining a scrappage programme with targeted tax reform (Scenario 3) yields the highest net benefit, outperforming both standalone scrappage and tax reform scenarios.
5. When assessed independently, the scrappage programme generates substantially greater economic returns than tax reform alone.
6. A one-time, large-scale scrappage programme delivers higher net benefits than a phased, multi-year approach, both as a standalone intervention and when combined with complementary fiscal measures.

Recommendations

1. Policymakers should prioritise the implementation of an accelerated, one-time scrappage programme rather than a gradual phase-out. The analysis shows that an early, large-scale intervention generates higher net economic benefits and more immediate emissions reductions.
2. To maximise cost-effectiveness and overall societal benefits, the scrappage programme should be complemented by well-designed tax reforms. This integrated approach yields significantly higher net benefits than either measure alone. Fiscal incentives should prioritise reducing upfront costs for low- and zero-emission vehicles to accelerate adoption. These measures should be reinforced by

regulatory instruments – such as age limits for high-emission vehicles and stricter emissions standards – to ensure sustained fleet modernisation.

3. Given that the rising TCO of HEVs and PHEVs is largely driven by import dependence, the government should introduce policies to promote local assembly and production. These may include targeted tax incentives, investment support for domestic manufacturers, and partnerships with global automotive firms to localise supply chains. While BEVs currently benefit from lower TCO due to incentives and declining battery costs, long-term policies are needed to strengthen domestic production capacity.
4. Continued investment in battery research and development, alongside support for domestic battery manufacturing, will be critical to sustaining cost reductions for PHEVs and BEVs. This will enhance their long-term competitiveness relative to conventional vehicles.
5. A robust monitoring and evaluation framework should be established to track policy impacts. This should include periodic reviews to refine incentives, address unintended consequences, and ensure responsiveness to market and technological developments.
6. Presidential Regulation No. 55 of 2019, as amended, and its implementing regulations should be revised to establish a comprehensive and time-bound national framework. This framework should both incentivise the adoption of all low-carbon emission vehicles (LCEVs) and disincentivise high-emission ICEVs through coordinated measures, including tax reform, scrappage programmes, emissions and fuel economy standards, and expanded vehicle testing regimes, ensuring environmental effectiveness and fiscal sustainability across national and subnational levels.

References

- AAA (2020), Your Driving Costs. <https://newsroom.aaa.com/wp-content/uploads/2020/12/2020-Your-Driving-Costs-Brochure-Interactive-FINAL-12-9-20.pdf>
- Abdullah (2024), 'The Global Push for Electric Vehicles: Policies and Incentives', *EVMechanica*. <https://www.evmechanica.com/the-global-push-for-electric-vehicles-policies-and-incentives/>
- Ahmed, A.A. et al. (2022), 'A Comprehensive Sustainability Assessment of Battery Electric Vehicles, Fuel Cell Electric Vehicles, and Internal Combustion Engine Vehicles through a Comparative Circular Economy Assessment Approach', *Sustainability*, 15(1), p. 171.
- Alhulail, I. and K. Takeuchi (2014), *Effects of Tax Incentives on Sales of Eco-Friendly Vehicles: Evidence from Japan* (No. 1412). Kobe: Graduate School of Economics, Kobe University.
- Ankney, K. and B. Leard (2022), 'The Social Cost of Carbon: Estimating the Benefits of Reducing CO₂ Emissions', *Resources for the Future Working Paper 22-13*, August. https://media.rff.org/documents/WP_22-13.pdf
- Arifin, R. (2024), *Mobil hybrid banyak dilirik masyarakat Indonesia, ini sebabnya*. *Detikoto*, 9 August. <https://oto.detik.com/mobil/d-7623468/mobil-hybrid-banyak-dilirik-masyarakat-indonesia-ini-sebabnya>
- Arnold, M. et al. (2021), 'Economic Viability of Extracting High Value Metals from End-of-Life Vehicles', *Sustainability*, 13(4), p. 1902.
- Asian Development Bank (2017), *Guidelines for the Economic Analysis of Projects*. Mandaluyong: Metro Manila, Philippines.
- Asian Transport Outlook (2024), *Transport and Climate Profile: Indonesia*. <https://asiantransportoutlook.com/analytical-outputs/countryprofiles/profile-indonesia/>
- Atkinson, G. (2015), 'Cost-Benefit Analysis: A Tool That Is Both Useful and Influential?', in *The Tools of Policy Formulation*. Edward Elgar Publishing, pp.142-60.
- AtmaGo (n.d.), *Low Emission Zone di Jakarta*. https://www.atmago.com/berita-warga/low-emission-zone-di-jakarta_094b1c71-9dc8-437e-a127-7017e883adb2
- Badan Pusat Statistik (2024), *Perkembangan Jumlah Kendaraan Bermotor Menurut Jenis (Unit) 2015-2022*. <https://www.bps.go.id/id/statistics->

<table/2/NTcjMg==/perkembangan-jumlah-kendaraan-bermotor-menurut-jenis.html>

- Bai, Y. et al. (2020), 'Energy and Environmental Aspects in Recycling Lithium-Ion Batteries: Concept of Battery Identity Global Passport', *Materials Today*, 41, pp.304–15.
- Bjerkan, K.Y., T.E. Nørbech, and M.E. Nordtømme (2016), 'Incentives for Promoting Battery Electric Vehicle (BEV) Adoption in Norway', *Transportation Research Part D: Transport and Environment*, 43, pp.169–80.
- Boardman, A. et al. (2014), *Cost-Benefit Analysis*. 4th Edition. The Pearson Series in Economics.
- Bräuninger, M. et al. (2012), *Achieving Sustainability in Urban Transport in Developing and Transition Countries*. Berlin.
- Brand, C., J. Anable, and M. Tran (2013), 'Accelerating the Transformation to a Low Carbon Passenger Transport System: The Role of Car Purchase Taxes, Feebates, Road Taxes and Scrappage Incentives in the UK', *Transportation Research Part A: Policy and Practice*. 49, pp.132–48. doi: 10.1016/j.tra.2013.01.010.
- Brons, M. et al. (2008), 'A Meta-Analysis of the Price Elasticity of Gasoline Demand. A SUR Approach', *Energy Economics*, 30(5), pp.2105–22.
- Butcher, L. (2018), 'Vehicle Scrappage Schemes', *Briefing Paper* Number CBP 8091, 7 March. House of Commons Library. <https://researchbriefings.files.parliament.uk/documents/CBP-8091/CBP-8091.pdf>
- California Air Resources Board (n.d.), 'Clean Cars 4 All: About'. <https://ww2.arb.ca.gov/our-work/programs/clean-cars-4-all/about>
- California Air Resources Board (2024), 'Clean Truck Check – Emissions Compliance Testing Requirements'. <https://ww2.arb.ca.gov/vehicle-owners-emissions-compliance-testing-requirements-clean-truck-check>
- CEIC (2025a), *Indonesia Retail Price: Fuel: Gasoline 90 (Pertalite)*. <https://www.ceicdata.com> (accessed 17 February).
- CEIC (2025b), *Indonesia Retail Price: Fuel: Gasoline 92 (Pertamax)*. <https://www.ceicdata.com> (accessed 17 February).
- CEIC (2025c), *Indonesia Retail Price: Fuel – High Speed Diesel/Gas Oil*. <https://www.ceicdata.com> (accessed 17 February).
- Cerruti, D., A. Alberini, and J. Linn (2019), 'Charging Drivers by the Pound: How Does the UK Vehicle Tax System Affect CO₂ Emissions?', *Environmental and Resource Economics*, 74, pp.99–129.

- Chen, Y. et al. (2019), 'Life Cycle Assessment of End-of-Life Vehicle Recycling in China: A Comparative Study of Environmental Burden and Benefit', *International Journal of Environmental Studies*.
- Chen, R. et al. (2023), 'Effects of Multiple Incentives on Electric Vehicle Charging Infrastructure Deployment in China: An Evolutionary Analysis in Complex Network', *Energy*, 264, 125747. <https://doi.org/10.1016/j.energy.2022.125747>
- Chinwego, C. et al. (2025), 'Sufficiency-Driven Business Models for Rare Earth Recycling: Integrating Stakeholder Collaboration and Customer Discovery for Sustainable Innovation', *Journal of Innovation and Entrepreneurship*, 14(1), p.20.
- CNN Indonesia (2024), Perbandingan penjualan mobil hybrid dan listrik semester I 2024, 9 August. <https://www.cnnindonesia.com/otomotif/20240809162229-603-1131272/perbandingan-penjualan-mobil-hybrid-dan-listrik-semester-i-2024>
- Commonwealth of Australia (2006), *Handbook of Cost-Benefit Analysis*.
- Cousins, D.S. et al. (2019), 'Recycling Glass Fiber Thermoplastic Composites from Wind Turbine Blades', *Journal of Cleaner Production*, 209, pp.1252–63.
- Creutzig, F. et al. (2018), 'Towards Demand-Side Solutions for Mitigating Climate Change', *Nature Climate Change*, 8(4), pp.260–63.
- Crossley, T.F., A. Leicester, and P. Level (2009), 'Chapter 3: Fiscal Stimulus and the Consumer', in *The IFS Green Budget: February 2010*. London: Institute for Fiscal Studies. https://ifs.org.uk/sites/default/files/output_url_files/10chap3.pdf
- Davis, L.W. (2014), 'The Economic Cost of Global Fuel Subsidies', *American Economic Review*, 104(5), pp.581–85.
- Department for Business, Energy & Industrial Strategy (2020), '£73.5 Million to Boost Green Economic Recovery in Automotive Sector'. <https://www.gov.uk/government/news/735-million-to-boost-green-economic-recovery-in-automotive-sector>
- detikOto (2023), Resmi dibuka, ini kisaran biaya konversi motor listrik usai dipotong subsidi Rp 7 juta. <https://oto.detik.com/mohytor/d-6655975/resmi-dibuka-ini-kisaran-biaya-konversi-motor-listrik-usai-dipotong-subsidi-rp-7-juta>
- Directorate General of Oil and Gas – Ministry of Energy and Mineral Resources (2024), *Statistics Oil and Gas 2023*.
- Duchiade, A. (2025), 'Brazil's Unions See Potential and Pressures from Chinese Carmakers', *Dialogue Earth*, 9 January. <https://dialogue.earth/en/business/brazils-unions-see-potential-and-pressures-from-chinese-carmakers/>
- Electric Vehicle Database (n.d.-a), 'BYD Seal'. <https://evdb.nz/v/byd-seal>

- Electric Vehicle Database (n.d.-b), 'Hyundai IONIQ Electric', *EV Database*. <https://ev-database.org/car/1165/Hyundai-IONIQ-Electric>
- Emission Standards (n.d.), 'EU: Low Emission Zones (LEZ)', <https://dieselnet.com/standards/eu/lez.php>
- Environmental Investment Centre (2023), 'Purchase of Zero-Emission Vehicles'. <https://www.kik.ee/en/grants/purchase-zero-emission-vehicles>
- Etude, M.C. et al. (2024), 'Recycling Lithium-Ion Batteries: A Review of Current Status and Future Directions', *Sustainable Chemistry One World*, 4, 100027.
- EUR-Lex (2015), *Uniform Rules Concerning the Approval of Retrofit Emission Control Devices (REC)*. <https://eur-lex.europa.eu/EN/legal-content/summary/uniform-rules-concerning-the-approval-of-retrofit-emission-control-devices-rec.html?fromSummary=20>
- European Commission (2020), 'Austria RWC models', https://road-safety.transport.ec.europa.eu/road-safety-member-states/roadworthiness-certificate-and-proof-test/austria-rwc-models_en.
- FBHVC (2025), *Guide to UK Clean Air and Low Emissions Zones*. <https://www.fbhvc.co.uk/a-guide-to-uk-clean-air-and-low-emissions-zones>
- Federal Ministry for the Environment, Climate Action, Nature Conservation and Nuclear Safety (2020), 'Emissions-control sticker/Low emission zone', <https://www.bundesumweltministerium.de/en/topics/air/emissions-control-sticker-and-low-emission-zone>.
- Federation of British Historic Vehicle Clubs (FBHCV) (2025), *Guide to UK Clean Air and Low Emissions Zones*. <https://www.fbhvc.co.uk/a-guide-to-uk-clean-air-and-low-emissions-zones>
- Fraga, F. (2011), 'Car Fleet Renewal Schemes: Environmental and Safety Impacts', *International Transport Forum*.
- Futurehome (n.d.), 'Charging Stations in Norway – Comparing Providers'. <https://www.futurehome.io/en/charging-stations-in-norway-comparing-providers-2?srsltid=AfmB0ooBINgTdwR7LbPh6rME2j38P2vw00Y7LN7ybZgLF4AHn1bAmxdM>
- Gallagher, K.S. and E. Muehlegger (2011), 'Giving Green to Get Green? Incentives and Consumer Adoption of Hybrid Vehicle Technology', *Journal of Environmental Economics and Management*, 61(1), pp.1–15.
- Geneletti, D. and V. Ferretti (2015), 'Multi-Criteria Analysis for Sustainability Assessment: Concepts and Case Studies, in A. Morrison-Saunders, J. Pope,

- and A. Bond (eds.), *Handbook of Sustainability Assessment*. Cheltenham, UK: Edward Elgar Publishing, pp.235–24.
- Gopalraj, S.K. and T. Kärki (2020), 'A Review on the Recycling of Waste Carbon Fibre/Glass Fibre-Reinforced Composites: Fibre Recovery, Properties and Life-Cycle Analysis', *SN Applied Sciences*, 2(3), p.433.
- Goulden, M., T. Ryley, and R. Dingwall (2014), 'Beyond "Predict and Provide": UK Transport, the Growth Paradigm and Climate Change', *Transport Policy*, 32, pp.139–47.
- Greater London Authority (n.d.), *How Does the Scrappage Scheme Work?* <https://www.london.gov.uk/programmes-strategies/environment-and-climate-change/pollution-and-air-quality/ultra-low-emission-zone-ulez-london/ulez-frequently-asked-questions/how-does-scrappage-scheme-work> (accessed 14 January 2025).
- Gridoto (2023), 'Adu irit konsumsi BBM Honda Brio CVT vs Toyota Agya 1.2 A/T vs Suzuki Ignis AGS', *GridOto.com*. <https://otoseken.gridoto.com/read/343195910/adu-irit-konsumsi-bbm-honda-brio-cvt-vs-toyota-agya-12-at-vs-suzuki-ignis-ags>
- Grigolon, L., N. Leheyda, and F. Verboven (2016), 'Scrapping Subsidies During the Financial Crisis – Evidence from Europe', *International Journal of Industrial Organization*, 44, pp.41–59.
- Hannan, M.A., F.A. Azidin, and A. Mohamed (2014), 'Hybrid Electric Vehicles and Their Challenges: A Review', *Renewable and Sustainable Energy Reviews*, 29, pp.135–50.
- Helveston, J. (2022), *China's EV Policy*. <https://slides.jhelvy.com/2022-ucsd-conf-china-ev-policy/#4> (accessed 14 January 2025).
- Indonesia (2016), *First Nationally Determined Contribution*. UNFCCC. <https://unfccc.int/sites/default/files/NDC/2022-06/First%20NDC%20Indonesia%20submitted%20to%20UNFCCC%20Set%20November%20%202016.pdf>
- Indonesia (2022), *Enhanced Nationally Determined Contribution*. UNFCCC. <https://unfccc.int/sites/default/files/NDC/2022-09/23.09.2022%20Enhanced%20NDC%20Indonesia.pdf>
- Jakarta Portal (2024), *Low Emission Areas*. 1 February. <https://www.jakarta.go.id/kawasan-rendah-emisi#:~:text=Saat%20ini%2C%20Jakarta%20telah%20memiliki,dirasakan%20secara%20maksimal%20oleh%20warga>

- Jakarta Rendah Emisi (2024), 'Uji Emisi Kendaraan, Solusi Tekan Pencemaran Udara', 2 February. <https://rendahemisi.jakarta.go.id/article/199/uji-emisi-kendaraan-solusi-tekan-pencemaran-udara>
- Jin, L. (2023), *Accelerating New Energy Vehicle Uptake in Chinese Cities: A 2023 Policy Update in a Post-Subsidy Era*. International Council on Clean Transportation (ICCT). December. https://theicct.org/wp-content/uploads/2023/12/ID-24-%E2%80%93-NEVs-2023-briefing-A4-70114-v4_final.pdf
- Kelley, L. (2024), 'What the US Can Learn from Norway When It Comes to EV Adoption', CNBC, 17 February. <https://www.cnbc.com/2024/02/17/what-the-us-can-learn-from-norway-when-it-comes-to-ev-adoption.html>
- Kemhub (2024), 'Capaian Penurunan Emisi Gas Rumah Kaca (GRK) Sektor Transportasi', 16 July. <https://hubnet.kemhub.go.id/dataset/content/dataset/489>
- Kempower (2022), 'Fast Food & Fast Charging: The Benefits of Level 3 Charging at Fast Food Restaurants', 21 December. <https://kempower.com/fast-food-fast-ev-charging-benefits/>
- Komaladewi, R. and D. Indika (2017), 'A Review of Consumer Purchase Decision on Low-Cost Green Car in West Java, Indonesia', *Review of Integrative Business and Economics Research*, 6(2), p.172.
- Kompas.com (2024), Daftar motor listrik subsidi Februari 2024, harga mulai Rp 5,3 juta. <https://otomotif.kompas.com/read/2024/02/07/154100615/daftar-motor-listrik-subsidi-februari-2024-harga-mulai-rp-5-3-juta>
- König, A. et al. (2021), 'An Overview of Parameter and Cost for Battery Electric Vehicles', *World Electric Vehicle Journal*, 12(1), p.21.
- Kumparan Bisnis (2025), 'Terungkap Harga Pertalite Seharusnya Rp 11.700/Liter, Solar Subsidi Rp 11.950', *Kumparan Bisnis*, 6 January. <https://kumparan.com/kumparanbisnis/terungkap-harga-pertalite-seharusnya-rp-11-700-liter-solar-subsidi-rp-11-950-24FaUvWzRd4/full>
- Laborda, J. and M.J. Moral (2019), 'Scrappage by Age: Cash for Clunkers Matters!' *Transportation Research Part A: Policy and Practice*, 124, pp.488–504.
- Lelli, M. et al. (2010), 'Car Scrappage Incentives Policies: A Life Cycle Study on GHG Emissions', *WIT Transactions on Ecology and the Environment*, 131, pp.1–10. <https://www.witpress.com/elibrary/wit-transactions-on-ecology-and-the-environment/131/20911>
- Levine, O.S. et al. (2011), 'The Future of Immunisation Policy, Implementation, and Financing', *The Lancet*, 378(9789), pp.439–48.

- Li, L., Z. Wang, and Q. Wang (2020), 'Do Policy Mix Characteristics Matter for Electric Vehicle Adoption? A Survey-Based Exploration', *Transportation Research Part D: Transport and Environment*, 87, 102488.
- Li, S., J. Linn, and E. Spiller (2013), 'Evaluating "Cash-for-Clunkers": Program Effects on Auto Sales and the Environment', *Journal of Environmental Economics and Management*, 65(2), pp.175–93.
- Li, W. et al. (2018), 'Effects of Personal Carbon Trading on the Decision to Adopt Battery Electric Vehicles: Analysis Based on a Choice Experiment in Jiangsu, China', *Applied Energy*, 209, 478–88.
- Linkov, I. et al. (2006), 'From Comparative Risk Assessment to Multi-Criteria Decision Analysis and Adaptive Management: Recent Developments and Applications', *Environment International*. 32, pp.1072–93.
- Lu, H., H. Ma, Z. Sun, and J. Wang (2017), 'Analysis and Prediction on Vehicle Ownership Based on an Improved Stochastic Gompertz Diffusion Process', *Journal of Advanced Transportation*, 4013875, 8 pp.
- Malaysian Green Technology and Climate Change Corporation (MGTC) (2024), 'Malaysia Announces Tax Incentives for Electric Vehicles', 29 November. <https://www.mgtc.gov.my/ms/2024/11/malaysia-announces-tax-incentives-for-electric-vehicles/>
- MarkLines (2023), 'Charging Infrastructure in China (Part 1)', September. https://www.marklines.com/en/report/rep2535_202309
- Maulana, A.D. (2024), 'Seberapa efektif mobil hybrid dapat mengurangi emisi karbon?' Kompas.com, 20 February. <https://otomotif.kompas.com/read/2024/02/20/131200315/seberapa-efektif-mobil-hybrid-dapat-mengurangi-emisi-karbon->
- May, O. (2023), 'A Comprehensive Guide to Vehicle Fitness Certificate (FC) for Cars', *The Real Slice*, 18 November. <https://therealslice.com/a-comprehensive-guide-to-vehicle-fitness-certificate-fc-for-cars/>
- Merkisz-Guranowska, A. (2018), 'Waste Recovery of End-of-Life Vehicles', In *IOP Conference Series: Materials Science and Engineering*, Vol. 421, October, p.032019. IOP Publishing.
- Ministry of Business and Made in Italy (MIMIT) (2024), *Ecobonus 2024: pubblicato in Gazzetta Ufficiale il DPCM con le misure per il nuovo piano incentivi auto* (Ecobonus 2024: The Prime Ministerial Decree with measures for the new car incentive plan has been published in the Official Journal). <https://www.mimit.gov.it/it/notizie-stampa/ecobonus-2024-pubblicato-in-gazzetta-ufficiale-il-dpcm-con-le-misure-per-il-nuovo-piano-incentivi-auto>.

- Ministry of Energy and Mineral Resource Republic of Indonesia (MoEMR–Indonesia) (2024), *Handbook of Energy and Economic Statistics of Indonesia 2023*. Jakarta.
- Ministry of Environment and Forestry (MoEF) (2023), *MoEF Regulation No. 8/2023, Motor Vehicle Emission Quality Standards for Categories M, N, O, and L*.
- Muthukumar, M. et al. (2021), 'The Development of Fuel Cell Electric Vehicles: A Review', *Materials Today: Proceedings*, 45, pp.1181–87.
- Norwegian Electric Vehicle Association (n.d.), *Norwegian EV Policy*. <https://elbil.no/english/norwegian-ev-policy/#:~:text=The%20Norwegian%20EV%20incentives%3A,000%20Norwegian%20Kroner%20and%20over>
- Ontario Newsroom (2020), 'Historic Ford Canada Investment Transforming Ontario into Global Electric Vehicle Manufacturing Hub', *News Release*, 8 October. <https://news.ontario.ca/en/release/58736/historic-ford-canada-investment-transforming-ontario-into-global-electric-vehicle-manufacturing-hub>
- Ormazabal (2019), 'EU Commission Calls for 1 Million Charging Stations', <https://www.ormazabal.com/en-gb/eu-commission-calls-for-1-million-charging-stations/>
- Otosia (2012), '20 Mobil irit BBM di Indonesia untuk tahun 2012', *Otosia.com*, 13 December. <https://www.otosia.com/berita/read/4815064/20-mobil-irit-bbm-di-indonesia-untuk-tahun-2012>
- Penmetsa, P. et al. (2023), 'Incentives to Encourage the Adoption of Connected and Automated Vehicles: Lessons Learned from Hybrid-Electric Vehicle Incentive Programs', *Future Transportation*, 3(3), 2 August, pp.986–95. <https://doi.org/10.3390/futuretransp3030054>
- Peters, G.P. et al. (2017), 'Key Indicators to Track Current Progress and Future Ambition of the Paris Agreement', *Nature Climate Change*, 7(2), pp.118–22.
- PolyMatter (2023), *How China Won the Electric Vehicle Race* [Video]. YouTube, September. <https://www.youtube.com/watch?v=8-NcTawauXA>
- Pribadi, T. (2016), 'Seberapa hebat mobil sedan mewah terbaru Bentley', *VIVA*. <https://www.viva.co.id/otomotif/review/767280-seberapa-hebat-mobil-sedan-mewah-terbaru-bentley>
- Provinsi DKI Jakarta (2025), *Badan Pendapatan Daerah Pemerintah Provinsi DKI Jakarta: Informasi Nilai Jual Kendaraan Bermotor*. https://samsat-pkb.jakarta.go.id/INFO_NJKB, (Accessed 18 March 2025)
- PSE UGM (2017), *CO₂ Tax Scheme Study*. Sleman, Indonesia.
- PSE UGM (2020), *True Cost of Coal and Its Impact on Its (Social) Average Cost of Electricity*. Sleman, Indonesia.

- Rashid, S. and E. Pagone (2023), 'Cradle-to-Grave Lifecycle Environmental Assessment of Hybrid Electric Vehicles', *Sustainability*, 15(14), 11027.
- Restianti, Y.Y. and S.H. Gheewala (2012), 'Life Cycle Assessment of Gasoline in Indonesia], *The International Journal of Life Cycle Assessment*, 17, pp.402–08.
- Rimpas, D. et al. (2025), 'Decarbonizing the Transportation Sector: A Review on the Role of Electric Vehicles Towards the European Green Deal for the New Emission Standards', *Air*, 3(2), p.10.
- Sekadakis, M. et al. (2025), 'Evaluating the Environmental and Safety Impacts of Eco-Driving in Urban and Highway Environments', *Sustainability*, 17(6), 2762. <https://doi.org/10.3390/su17062762>
- Shafique, M. et al. (2022), 'Material Flow Analysis for End-of-Life Lithium-Ion Batteries from Battery Electric Vehicles in the USA and China', *Resources, Conservation and Recycling*, 178, 106061.
- Shehab, E. et al. (2021), 'A Cost Modelling System for Recycling Carbon Fiber-Reinforced Composites', *Polymers*, 13(23), 4208.
- Sihombing, T. (2023), ' *Transjakarta Hadirkan 400 Bus Listrik di Tahun 2025* ', 14 September. <https://moladin.com/news/transjakarta-hadirkan-400-bus-listrik-di-tahun-2025/>
- Springel, K. (2021), 'Network Externality and Subsidy Structure in Two-Sided Markets: Evidence from Electric Vehicle Incentives', *American Economic Journal: Economic Policy*, 13(4), pp.393–432.
- Svoboda, M., M. Fanta, and J. Mošovský (2023), 'Effectiveness of Car Scrappage Schemes: Comparative Analysis of European Countries', *IES Working Paper No. 28/2023*. Prague: Charles University in Prague, Institute of Economic Studies.
- Topgear (2023), 'Review: 2024 Toyota Zenix 2.0V', *TopGear Philippines*. <https://www.topgear.com.ph/drives/car-reviews/toyota-zenix-2-0v-review-pha5100-20231201-lfrm>
- Transport for London (2019), *Low Emission Zone*. <https://tfl.gov.uk/modes/driving/low-emission-zone>
- United Nations Environment Programme (UNEP) (2024), *Used Vehicles and the Environment: A Global Overview of Used Light Duty Vehicles: Flow, Scale, and Regulation: Update and Progress 2024*.
- UNFCCC (2022), Enhanced Nationally Determined Contribution Republic of Indonesia, https://unfccc.int/sites/default/files/NDC/2022-09/23.09.2022_Enhanced%20NDC%20Indonesia.pdf

- Van Wee, B., G. De Jong, and H. Nijland (2011), 'Accelerating Car Scrappage: A Review of Research into the Environmental Impacts', *Transport Reviews*, 31(5), pp.549–69. doi: 10.1080/01441647.2011.564331
- Vanherle, K. and R. Vergeer (2016), *Data Gathering and Analysis to Improve the Understanding of Second-Hand Car and LDV Markets and Implications for the Cost-Effectiveness and Social Equity of LDV CO₂ Regulations: Final Report for DG Climate Action*. Technical Report. Brussels.
- Simply Fleet (n.d.), 'Vehicle Inspections: Why They Matter and Exactly What to Check. <https://www.simplyfleet.app/blog/vehicle-inspections-things-checked>
- Wang, S., J. Li, and D. Zhao (2017), 'The Impact of Policy Measures on Consumer Intention to Adopt Electric Vehicles: Evidence from China', *Transportation Research Part A: Policy and Practice*. 105, pp.14–26.
- Wappelhorst, S., P. Mock, and Z. Yang, Z. (2018), *Using Vehicle Taxation Policy to Lower Transport Emissions: An Overview for Passenger Cars in Europe*. Berlin: International Council on Clean Transportation. https://theicct.org/wp-content/uploads/2021/06/EU_vehicle_taxation_Report_20181214_0.pdf
- Wee, S., M. Coffman, and S. La Croix (2018), 'Do Electric Vehicle Incentives Matter? Evidence from the 50 US States', *Research Policy*, 47(9), pp.1601–10.
- White House (2021), *Building Resilient Supply Chains, Revitalizing American Manufacturing, and Fostering Broad-Based Growth: 100-Day Reviews under Executive Order 14017*. A Report by the White House.
- Widyaparaga, A. et al. (2017), 'Scenarios Analysis of Energy Mix for Road Transportation Sector in Indonesia', *Renewable and Sustainable Energy Reviews*, 70, pp.13–23.
- Wirawan, S.S. (2009), *The Effect of Biodiesel Utilization in Transportation Sector to Pollutant Emission and External Cost: A Case Study of Jakarta* (Doctoral dissertation, Bogor Agricultural University).
- World Bank (2025a), 'PPP Conversion Factor, GDP (LCU per international \$) – Indonesia'. <https://data.worldbank.org/indicator/PA.NUS.PPP?locations=ID>.
- World Bank (2025b), 'World Bank Commodity Price Data (The Pink Sheet)'. <https://thedocs.worldbank.org/en/doc/18675f1d1639c7a34d463f59263ba0a2-0050012025/related/CMO-Historical-Data-Annual.xlsx>.
- Zamora, J.C.P. (2014), 'World Bank Commodity Price Data Avoid–Shift–Improve Model: A Powerful Planning Tool for Transportation Schemes with Low GHG Emissions', *MIPALCON*, p.141.
- Zhang, J. et al. (2022), 'Does Electric Vehicle Promotion in the Public Sector Contribute to Urban Transport Carbon Emissions Reduction?' *Transport Policy*, Vol. 125, pp.151–63. <https://doi.org/10.1016/j.tranpol.2022.06.002>

Zhang, Y. et al. (2024), 'Life Cycle Assessment of Plug-In Hybrid Electric Vehicles Considering Different Vehicle Working Conditions and Battery Degradation Scenarios', *Energies* (19961073), 17(17).

Zhuang, J. et al. (2007), 'Theory and Practice in the Choice of Social Discount Rate for Cost-Benefit Analysis: A Survey', *ERD Working Paper Series* No. 94.