ERIA Research Project Report FY2023 No. 16

Analysis of Future Mobility Fuel Scenarios Considering the Sustainable Use of Biofuels and Other Alternative Vehicle Fuels in East Asia Summit Countries – Phase III

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List of Abbreviations and Acronyms

2W	Two-wheeler
AC	Alternating Current
AIST	National Institute of Advanced Industrial Science and Technology
APAEC	ASEAN Plan of Action for Energy Cooperation
ASEAN	Association of Southeast Asian Nations
B2	2% biodiesel blend
B5	5% biodiesel blend
B10	10% biodiesel blend
B20	20% biodiesel blend
BAU	Business as Usual
BEV	Battery Electric Vehicle
BIT	Bandung Institute of Technology, Indonesia
BPS	Indonesia Central Agency on Statistics
CAGR	Compound Annual Growth Rate
CBU	Completely Built Unit
CES	Clean Energy Scenario
CH_4	Methane
CKD	Completely Knocked Down
CNG	Compressed Natural Gas
Co	Cobalt
CO_2	Carbon Dioxide
COP 26	26^{th} Conference of the Parties, UNFCC
CREVI	Comprehensive Roadmap for the Electric Vehicle Industry
DAKN	National Agricommodity Policy, Malaysia
DC	Direct Current
DISCOM	Distribution Companies, India
DOTr	Department of Transportation, Philippines
E2W	Electric Two-wheeler

E5	5% Ethanol Blend
E10	10% Ethanol Blend
E15	15% Ethanol Blend
E20	20% Ethanol Blend
EAS	East Asia Summit
eMC	Electric Motorcycle
ENTEC	National Energy Technology Centre
ERIA	Economic Research Institute for ASEAN and East Asia
EU	European Union
EV	Electric Vehicle
EVCS	EV and Charging Station
EVIDA	Electric Vehicle Industry Development Act, Philippines
FAME	Faster Adoption and Manufacturing of Electric Vehicles, India
FCVs	Fuel-cell Vehicles
FDI	Foreign Direct Investment
FE	Fuel Economy
FiT	Feed-in Tariff
FY	Fiscal Year
GAIKINDO	Association of Indonesian Automotive Industries, Indonesia
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GJ	Gigajoule
GWP	Global Warming Potential
HUST	Hanoi University of Science and Technology, Viet Nam
ICE	Internal Combustion Engine
IEA	International Energy Agency
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
IVC	India Vision Case
KMUTT	King Mongkut’s University of Technology Thonburi, Thailand
ktoe	Kilotonne of Oil Equivalent
LEAP	Low Emissions Analysis Platform

LEV	Light Electric Vehicle
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
LT-LEDS	Long-term Low Greenhouse Gas Emission Development Strategy
MAA	Malaysia Automotive Association
MARii	Malaysia Automotive Robotics and IoT Institute
MEMR	Ministry of Energy and Mineral Resources
MOF	Ministry of Finance
MOI	Ministry of Industry
MPOB	Malaysian Palm Oil Board
N_2O	Nitrous Oxide
Nd	Neodymium
NDC	Nationally Determined Contribution
NEP	National Energy Plan
NITI	National Institution for Transforming India
NSTDA	National Science and Technology Development Agency
NTPC	National Thermal Power Corporation
NV	Number of Vehicles
PBOI	Philippine Board of Investments
PDOE	Philippine Department of Energy
PHEV	Plug-in Hybrid Electric Vehicle
PLN	Indonesian State Electricity Company
PUVMP	Public Utility Vehicle Modernization Program
R&D	Research and Development
RE	Renewable Energy
RUPTL	Indonesia National Electricity Supply Business Plan
SDG	Sustainable Development Goal
SDS	Sustainable Development Scenario
STEPS	Stated Policies Scenario
TAT	Turnaround Time
TCO	Total Cost of Ownership
TISI	Thai Industrial Standards Institute

TTW	Tank-to-Wheel
t/y	Tonne per Year
UGM	Universitas Gadjah Mada, Indonesia
UNEP	United Nations Environment Programme
UNFCC	United Nations Framework Convention on Climate Change
US	United States
US-EPA	United States Environment Protection Agency
USGS	United States Geological Survey
VAMA	Vietnam Automobile Manufacturers' Association
VAT	Value-added Tax
VKT	Vehicle Kilometre of Travel
WTT	Well-to-Tank
WTW	Well-to-Wheel
xEV	Electrified Vehicle
ZEV	Zero-emission Vehicle

Executive Summary

The importance of reducing greenhouse gas (GHG) emissions in the transport sector has attracted attention worldwide, especially since the adoption of the Paris Agreement in 2015. To meet this target, East Asia Summit (EAS) countries have been making great efforts to introduce biofuels on a large scale, considering the potential of these resources. Meanwhile, the introduction of electrified vehicles (xEVs) is now expanding rapidly, and these can be another efficient option for reducing GHG emissions in the transport sector. Therefore, creating a future mobility fuel scenario with a balance of biofuel vehicles and xEVs is necessary.

In this regard, this project aims to analyse the future scenario of EAS mobility, which will contribute greatly to the Sustainable Development Goals (SDGs) (Goals 7, 12, and 13) in consideration of the balance amongst reducing transport carbon dioxide (CO_2), biofuel use, and the demand for mineral resources. The outcomes will contribute to the EAS Energy Research Road Map (Pillar 3: Climate Change Mitigation and Environmental Protection corresponding to the Association of Southeast Asian Nations (ASEAN) Plan of Action for Energy Cooperation 2016–2025, 3.5 Programme Area No.5: Renewable Energy, and 3.6 Programme Area No.6: Regional Energy Policy and Planning).

In fiscal year (FY) 2020, existing biofuel policies and implementation plans were updated from selected EAS countries as a foundation to accommodate emerging electric vehicle (EV) trends during the mobility energy transition. As a result, information on biofuel policies and implementation mechanisms, as well as potential CO_2 reductions, was collected. Moreover, progress on the sustainability assessment of biofuels in the East Asia region was evaluated with examples of some of the participating countries using the sustainability indicators proposed by the earlier ERIA project on 'Sustainable Biomass Utilisation Vision in East Asia'.

In FY2021, well-to-tank (WTT) GHG emissions from producing biofuels, tank-to-wheel (TTW) GHG emissions from using biofuels, and demand and CO_2 emissions from producing mineral resources considering mobility electrification were evaluated. For WTT GHG emissions, despite some variations in the emissions values from the different feedstock and countries, these were all lower than their fossil fuel counterparts (i.e. 2.92 kilogrammes/litre gasoline as compared to ethanol and 83.8 gCO_2 eq/megajoule diesel as compared to biodiesel). Moreover, the TTW GHG emissions are calculated according to the Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories (IPCC, 2006) in this study. For fuel combustion in road transportation, the emissions factors are selected according to the Technology and Environmental Database. The TTW GHG emissions from fossil fuel combustion in road transportation comprise CO_2, methane (CH_4), and nitrous oxide (N_2O). These emissions are converted into the CO_2-equivalent units by multiplying them by the global warming potentials (GWP).

For the mineral resources demand, the demand for neodymium (Nd) is predicted to be a minimum of 4,075 tonnes/year (t/y) in 2040. If the recycle rate is 100%, secondary resources can cover 28.2% of total Nd demand in EAS countries. The total demand for cobalt is predicted to be 53,324 t/y in 2040. If the recycle rate is 100%, secondary resources can cover 16.1% of cobalt demand in EAS countries. However, considering that production of Nd was 43,200 t/y of rare earth oxide (REO) and cobalt was 140,000 t/y in 2020 (USGS, 2021), it is predicted to be difficult for the world supply to meet the target of EAS mobility electrification regarding the large increase in demand in China, the European Union (EU), and the United States (US).

Following this progress, this report assesses the relationship between WTW GHG reduction of biofuel implementation and mobility electrification. In addition, it examines the mobility scenarios of EAC countries, considering mineral resource constraints, the price of EVs, domestic (charging) facilities, and taxation systems. Finally, the priorities for biofuels and EVs in each country, as well as the expected policies and actions for implementing biofuels and EVs, are analysed.

First, the landscape of the current vehicle ecosystem in select ASEAN Member States (Indonesia, Malaysia, Philippines, Thailand, and Viet Nam) and India is examined with the same projection of vehicle growth in the future as the previous study (ERIA, 2022), but with an updated grid emission factor to assess GHG emissions as a result of collective efforts on EVs and biofuels in the transport sector. In particular, three different scenarios are considered based on the assumption of EVs and biofuels from the previous study (ERIA, 2022) and improvements in the electricity source. Moreover, mineral demand from the implementation of EVs (in this case Nd and cobalt) is estimated and compared with the supply forecast from the United States Geological Survey (USGS) and the International Energy Agency's (IEA) demand forecast. The results show that the motorcycle segment in these six countries emits similar GHGs as the car segment, and the electrification effect from the current target could achieve about 5% decarbonisation in each sector. Further grid emission factor improvement from the current policy could help further decarbonise by less than 2%, implying that further consideration may be needed to improve grid emissions. On the other hand, biofuel policy could help each sector decarbonise by 10%. For the demand for neodymium and cobalt, the demand of EAS countries is predicted to cover about 37% (for neodymium) and 41% (for cobalt) of the world's total demand for EVs forecasted by the IEA's Stated Policies Scenario. Considering the large increase in demand in Europe, the US, China, and other EV-implementing countries, EAS countries' share of global demand is expected to create fierce competition with other countries.

Second, the barriers to implementing the vehicle electrification scenario in EAS countries are based on the collected data and analysis from the Working Group members. To accelerate the introduction of EVs, the recommendations to overcome these barriers will be explained and analysed. By analysing the barrier conditions, recommendations, and the availability of biofuel resources and other renewable energies, the future mobility scenario for each country is identified to find the appropriate emission reduction measures considering each country's characteristics.

In conclusion, the balance between biofuels and EVs is important in all EAS countries. In particular, the conclusion is that whilst mineral resource constraints are important for EVs, price, infrastructure, and policy support are even more important. Comparing by country, Thailand and Indonesia can introduce biofuels and EVs in parallel, whilst the Philippines, Viet Nam, and Malaysia will give priority to biofuels in the initial stage, as they can utilise existing infrastructure and will introduce EVs in the future when the price of EVs declines and infrastructure is in place.

The results of this study will contribute greatly to the SDGs (Goals 7, 12, and 13) in consideration of the balance amongst transport CO_2 reduction, biofuel use, and the demand for mineral resources. The outcomes will contribute to the EAS energy research roadmap (Pillar 3: Climate Change Mitigation and Environmental Protection corresponding to the ASEAN Plan of Action for Energy Cooperation 2016–2025, 3.5 Programme Area No.5: Renewable Energy, and 3.6 Programme Area No.6: Regional Energy Policy and Planning).

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Economic Research Institute for ASEAN and East Asia (ERIA) (2022), 'Analysis of Future Mobility Fuel Scenarios Considering the Sustainable Use of Biofuels and Other Alternative Vehicle Fuels in East Asia Summit Countries – Phase II', *ERIA Research Project* 2021 No.16. Jakarta: ERIA.

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Chapter 1
Introduction

1. Background and Objectives of the Research

The importance of reducing greenhouse gas (GHG) emissions in the transport sector has attracted attention worldwide, especially since the adoption of the Paris Agreement in 2015. To meet this target, East Asia Summit (EAS) countries have been making great efforts to introduce biofuels on a large scale, considering the potential of these resources. Meanwhile, the introduction of electrified vehicles (xEVs) is now expanding rapidly, and these could be another efficient option for reducing GHG emissions in the transport sector. Therefore, creating a future mobility fuel scenario with a balance of biofuel vehicles and xEVs is necessary.

The National Institute of Advanced Industrial Science and Technology (AIST) in Japan has been studying future mobility scenarios of EAS countries since 2014. In the AIST and Economic Research Institute for ASEAN and East Asia (ERIA) project, the scenarios for India, Indonesia, and Thailand were examined considering the potential of biofuels and xEVs and the constitution of power generation. As a result, well-to-wheel CO_2 emissions were estimated for several scenarios by creating energy mix models.

However, in that project, the sustainability of biofuels and xEVs was not taken into consideration. The diffusion of xEVs can contribute to a reduction in CO_2 emissions but may increase the demand for mineral resources induced by motors and batteries.

In this regard, this project aims at analysing the future scenario of EAS mobility, which highly contributes to the Sustainable Development Goals (SDGs) (Goals 7, 12, and 13) in consideration of the balance amongst transport CO_2 reduction, biofuel use, and demand for mineral resources. The outcomes will contribute to the EAS energy research roadmap (Pillar 3: Climate Change Mitigation and Environmental Protection corresponding to the ASEAN Plan of Action for Energy Cooperation 2016–2025, 3.5 Programme Area No.5: Renewable Energy, and 3.6 Programme Area No.6: Regional Energy Policy and Planning).

In fiscal year (FY) 2020, existing biofuel policies and implementation plans were updated from selected EAS countries as a foundation to accommodate emerging electric vehicle trends during the mobility energy transition (ERIA, 2021). As a result, information on biofuel policies and implementation mechanisms, as well as potential CO_2 reductions, was collected.

In FY2021, well-to-tank (WTT) GHG emissions from producing biofuels, tank-to-wheel (TTW) GHG emissions from using biofuels, and demand and CO_2 emissions from producing mineral resources considering mobility electrification were evaluated. For WTT GHG emissions, despite some variations in the emissions values from the different feedstock and countries, these were all lower than their fossil fuel counterparts (ERIA, 2022).

Following this progress, this report assesses the relationship between WTW GHG reduction of biofuel implementation and mobility electrification. In addition, the mobility scenarios of EAC countries are examined, considering mineral resource constraints, the price of EVs, domestic (charging) facilities, and taxation systems. Finally, the priorities for biofuels and EVs in each country, as well as the expected policies and actions of implementing biofuels and EVs are analysed.

2. Study Methods

The topics and methods of study are as follows. The target EAS countries are India, Thailand, Indonesia, the Philippines, Malaysia, and Viet Nam.

(1) Evaluation of the potential for biofuels and their sustainability, including fuels from unconventional resources.

1st year	➢ Collate the existing research on biofuel sustainability assessment in EAS countries. ➢ Review the most updated biofuel sustainability standards. ➢ Identify the need for updating the research.
2nd year	➢ Collect additional information/data for updating the research as identified in the first year. ➢ Collect the existing research, which assesses the potential of biofuels from residual waste (and agricultural waste, etc.) ➢ Conduct additional assessments for updating the research results.
3rd year	➢ Interpret the research results after scientific validation. ➢ Prepare policy briefs to address policy concerns and needs vis-à-vis biofuel sustainability in EAS countries.

(2) Assessment of well-to-wheel CO_2 reduction considering the sustainability of biofuels and mineral resources.

1st year	➢ Updating the current biofuel policies of the countries to assess well-to-wheel CO_2 reduction. ➢ Evaluate the relationship between demand for xEVs and the consumption of mineral resources (cobalt, nickel, and rare earths) using an AIST original database of critical raw materials.
2nd year	➢ Estimate the well-to-wheel CO_2 reduction by biofuels and xEVs in EAS countries. ➢ Material flow analysis of mineral resources considering the supply chains for ores, alloys, devices (batteries and motors) and xEVs. ➢ Forecast the demand of xEVs and CO_2 emissions by mineral resources until 2050 in EAS countries considering the production capacity of mineral resources.
3rd year	➢ Scenario analysis of various biofuel policies in terms of CO_2 reduction.

	➢ Case study of the mobility scenario considering the balance between CO_2 reduction and the potential of biofuels/mineral resources.

3. Policy Recommendations

(1) Mobility scenario and strategy of EAS countries.

(2) Reduction of transport energy consumption and CO_2 emissions in EAS countries.

(3) Implementation of sustainable transport energy, which highly contributes to SDGs.

4. Timeline/Schedule

Timeline of FY2022–2023:

January 2023 1st working group meeting

April 2023 2nd working group meeting

June 2023 Submission of report

September 2023 Publication of report

Timeline of the total project: September 2021–June 2023

References

Economic Research Institute for ASEAN and East Asia (ERIA) (2021), 'Analysis of Future Mobility Fuel Scenarios Considering the Sustainable Use of Biofuels and Other Alternative Vehicle Fuels in East Asia Summit Countries', *ERIA Research Project* 2020 No. 18. Jakarta: ERIA.

ERIA (2022), 'Analysis of Future Mobility Fuel Scenarios Considering the Sustainable Use of Biofuels and Other Alternative Vehicle Fuels in East Asia Summit Countries – Phase II', *ERIA Research Project* 2021 No.16. Jakarta: ERIA.

Chapter 2

Well-to-Wheel CO_2 Emissions from Biofuels and EVs and Mineral Resource Consumption in East Asia Summit Countries

1. Introduction

1.1. Background

From the progress of the ERIA project for fiscal year (FY) 2021–2022, well-to-tank (WTT) and tank-to-wheel (TTW) GHG emissions from using biofuels, as well as GHG reduction amounts were estimated based on the Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories (IPCC, 2006). Moreover, the GHG reduction amount for using EVs was estimated. Additional scenarios were defined and analyzed in the report by adding a study on the emission factor of grid electricity.

In continuation of the previous study (ERIA, 2022), the increasing trend of electric vehicle (EV) technology will continue to disrupt conventional internal combustion engine (ICE) technology in the Association of Southeast Asian Nations (ASEAN) and India, and the future scenario vehicle mix will change due to new policy drives, commercial technology readiness, and affordable costs. The recent carbon-neutral commitments at the 2021 United Nations Climate Change Conference (COP26) have started to impact the transport sector through electrification with a cleaner grid emission factor, as well as an appropriate blend of ICEs with carbon-neutral biofuels. This year, the upstream GHG emissions are included in the analysis, and the GHG emission factors of the grid electricity are added for the EV scenario to analyze the impact if renewable energy is added to the country electricity mix.

Meanwhile, using EVs will cause large increases in demand for mineral resources, such as neodymium (used in permanent magnets for high-efficiency motors) and cobalt (used as cathodes for lithium-ion batteries). From the progress of FY2021–2022, the change in mineral resource demand associated with automobile electrification is estimated, as well as the recycle potential in EAS countries.

However, in order to examine the future mobility scenario in EAS countries, the relationship of the GHG reduction amount between biofuels implementation and EVs must be assessed. Moreover, it will also be necessary to assess whether the increase in demand for mineral resources will cause a supply-demand gap in the future. Therefore, in this chapter, the relationship between the WTW GHG reduction of biofuel implementation and mobility electrification is assessed. In addition, the potential for a supply-demand gap in the future due to increased demand for mineral resources is assessed.

1.2. Objective and Scope

The objective of this chapter is to further explore the landscape of the current vehicle ecosystem in select Association of Southeast Asian Nations (ASEAN) Member States (Indonesia, Malaysia, Philippines, Thailand, and Viet Nam) and India, with the same projection in vehicle growth in the future as that from the previous study (ERIA, 2022), but with an updated grid emission factor to assess

GHG emissions as a result of the collective efforts for EVs and biofuels in the transport sector. In this chapter, three different scenarios are considered based on the assumption of EVs and biofuels from the previous study (ERIA, 2022) and improvements in the electricity source.

The future scenarios for EVs in EAS countries contribute to the regional Sustainable Development Goals (SDGs) (Goals 7, 12, and 13). However, there is a mineral resources limitation for realising this EV environment. Therefore, in this chapter, mineral demand from the implementation of EVs (in this case, neodymium and cobalt demand) and the supply forecast from materials mining production based on United States Geological Survey (USGS) estimates are compared. In addition, forecasts from the International Energy Agency (IEA) of the materials demand for realising EVs and for other sectors are also assessed and compared to see the trendline for neodymium and cobalt demand at the global scale for not only the EV sector but also for other sectors.

1.3. Methodology

In order to analyse the energy use pattern in the transport sector and be able to predict the energy demand and the resulting emissions, a bottom-up approach, rather than a top-down approach, is undertaken due to its capability in accounting for the flow of energy based on a simple engineering relationship (Table 2.1) (UNFCC, 2005). Inputs of travelling demand, fuel consumption, and vehicle numbers of various types into the bottom-up model can yield the estimation of energy demand, as schematically shown in Figure 2.1 (LEAP, 2022). Amongst many others, the Low Emissions Analysis Platform (LEAP) system (LEAP, 2022) will be utilised to construct the energy demand model in this study.

Table 2.1. Differences between the Top-down and Bottom-up Approaches in the Energy Model

Top-down	Bottom-up
Uses aggregated economic data	Uses detailed data on fuels, technologies, and policies
Assesses costs/benefits through impacts on output, income, and GDP	Assesses costs/benefits of individual technologies and policies
Implicitly captures administrative, implementation, and other costs	Can explicitly include administration and programme costs
Assumes efficient markets, and no 'efficiency gap'	Does not assume efficient markets, so overcoming market barriers can offer cost-effective energy savings
Captures intersectoral feedback and interactions	Captures interactions amongst projects and policies
Commonly used to assess the impact of carbon taxes and fiscal policies	Commonly used to assess the costs and benefits of projects and programmes
Not well suited for examining technology-specific policies	

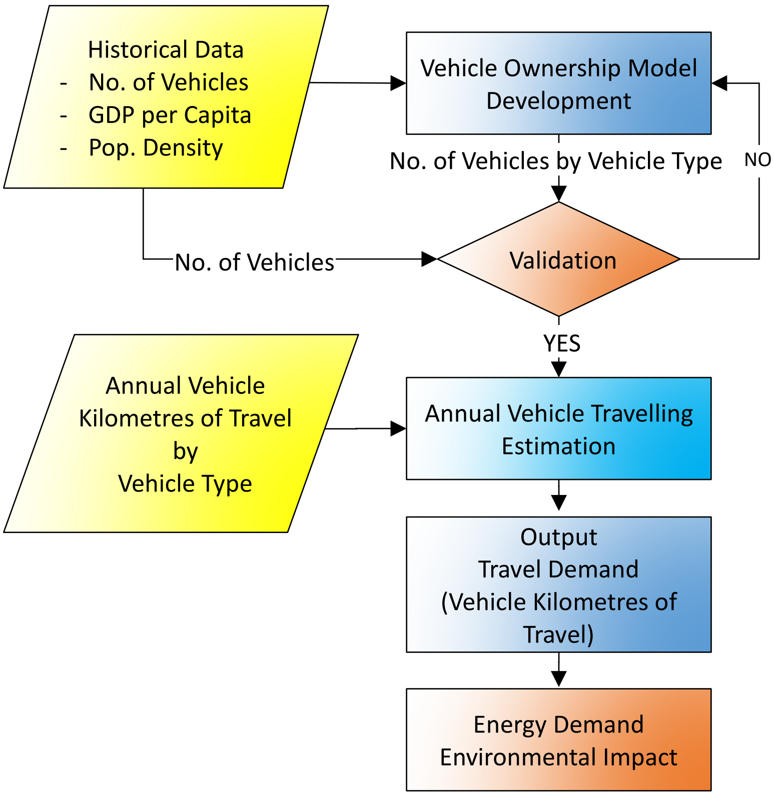
GDP = gross domestic product.
Source: UNFCC (2005).

A bottom-up engineering energy demand model is composed of main variables, such as:

- number of vehicles
- fuel economy, and
- vehicle kilometres of travel (VKT).

For model calibration, the model will be benchmarked against historic data on energy consumption. For the GHG module, well-to-wheel analysis from the previous study (ERIA, 2022) will be revised for cleaner electricity generation through the grid emission factor from the available national policy, as shown in Figure 2.2 (Pongthanaisawan, 2012). With careful calibration of both energy consumption and GHG emissions, the final model with a database will be utilised to investigate various effects of energy policy.

Figure 2.1. Flow of the Bottom-up Energy Demand Model

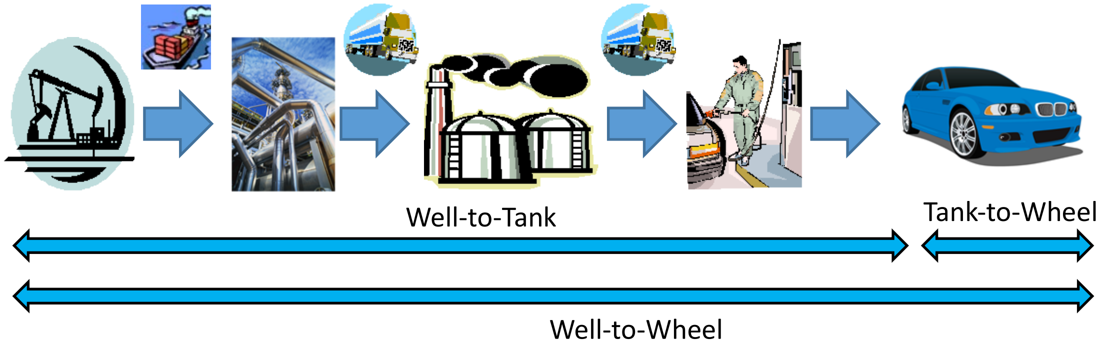


				Energy demand module			
Sector	Sub-sector	End-use	Device	Energy intensity			Energy demand
Transport sector	Transport mode	Modal split	Vehicle kilometre of travel	Type of fuel used	Fuel economy of vehicle	⇨	Scenario analysis
(vehicle)	(%)	(%)	(kilometre)	(%)	(GJ per veh-km)		(GJ or ktoe)

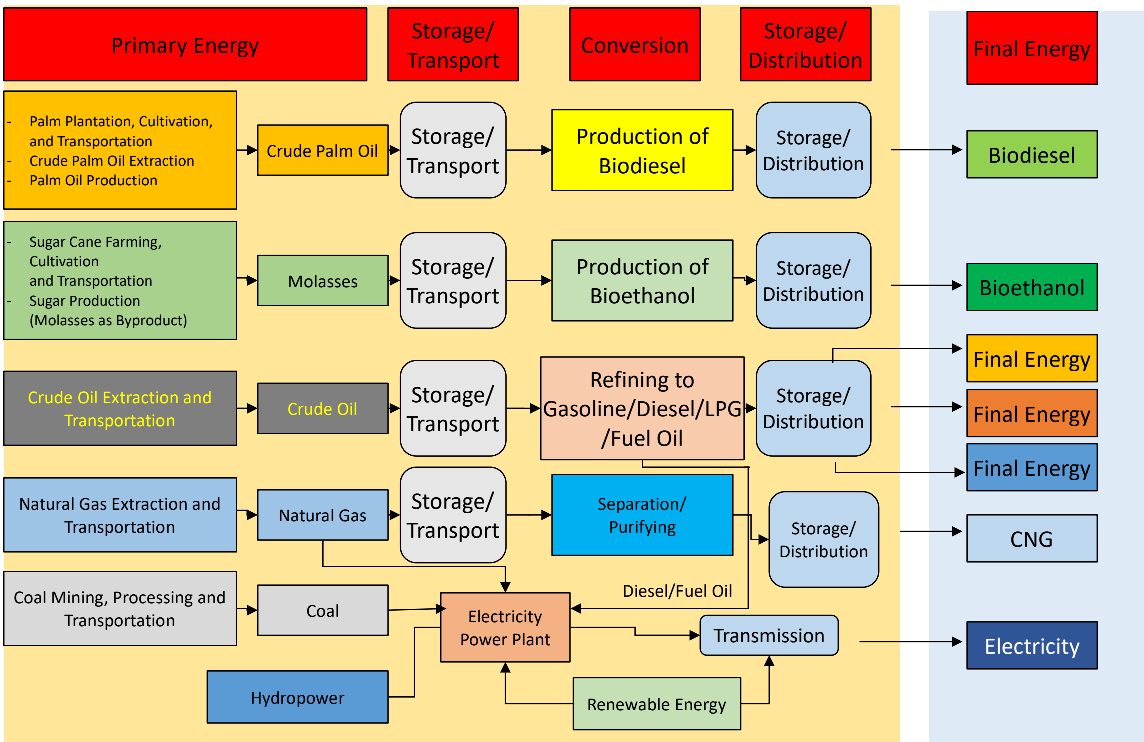
GDP = gross domestic product, GJ = gigajoule, ktoe = kilotonne of oil equivalent.
Source: LEAP (2022).

Figure 2.1. Schematic Concept of Life Cycle Inventory

(a) Concept of Well-to-Tank, Tank-to-Wheel, and Well-to-Wheel



(b) Detailed Examples of Various Transportation Fuels



CNG = compressed natural gas, LPG = liquefied petroleum gas.
Source: Pongthanaisawan (2012).

For mineral resource demand, the neodymium (Nd) and cobalt (Co) demand forecasts until 2040 for the vehicle electrification scenario in EAS countries were estimated in the second year of this ERIA project. In this chapter, ERIA's estimation results will be compared with the IEA's forecasts for Co and Nd demand used for vehicle electrification and for all applications in the world. In order to assess the amount of Co and Nd supply that will be available until 2040, mining production data for Nd and Co based on the USGS were also compared.

As explained, in the second year project report, the demand for Nd and Co was predicted by estimating the number of vehicle sales. The number of vehicles sales in EAS countries was estimated using the Vehicle Ownership Model, which can be modelled as the S-Curve logistic function (Button, Ngoe, and Hine, 1993; Chollacoop et al., 2003; Chollacoop et al., 2011; Dargay, Gately, and Sommer, 2007; Nagai et al., 2003) of gross domestic product per capita and population density. Then, the model was investigated and validated by the Low Emissions Analysis Platform (LEAP) system software. The share/percentage of electric vehicle sales to whole vehicle sales was estimated by considering the input data from the working members of this ERIA report regarding vehicle electrification policy combined with the data on EV share from Bloomberg projections for EAS countries.

The demand for Nd and Co was calculated by integrating the data on the amount (contained rate) of Nd and Co in these automobiles with the number of automobiles that were sold during these projections. The contained rate of Nd per vehicle for four-wheelers and two-wheelers is based on a research paper by Yang et al. (2016). Then, Co contained per vehicle for four-wheelers and two-wheelers was estimated based on the company's original data collected by an expert's interview and the Joint Research Centre report, combined with Epic Cycle data.

Based on the report, *The Role of Critical World Energy Outlook Special Report Minerals in Clean Energy Transitions*, published by the IEA (2021), global Nd and Co demand for vehicle electrification was forecasted with two scenarios, the Sustainable Development Scenario (SDS) and the Stated Policies Scenario (STEPS). The IEA also forecasted Nd and Co demand for all usages and all sectors (not only for electric vehicles) with the same two scenarios for 2020, 2030, and 2040.

Moreover, the USGS report, *Mineral Commodity Summaries*, explains the export, import, mining production, reserves, etc. of the minerals. Based on USGS production data from 1994 to 2021, Nd and Co production until 2040 was forecasted assuming that this production (until 2021) would increase at the same rate through 2040. The demand for Nd and Co through 2040 was compared to this production.

2. Energy Demand Model

2.1. Model Setup

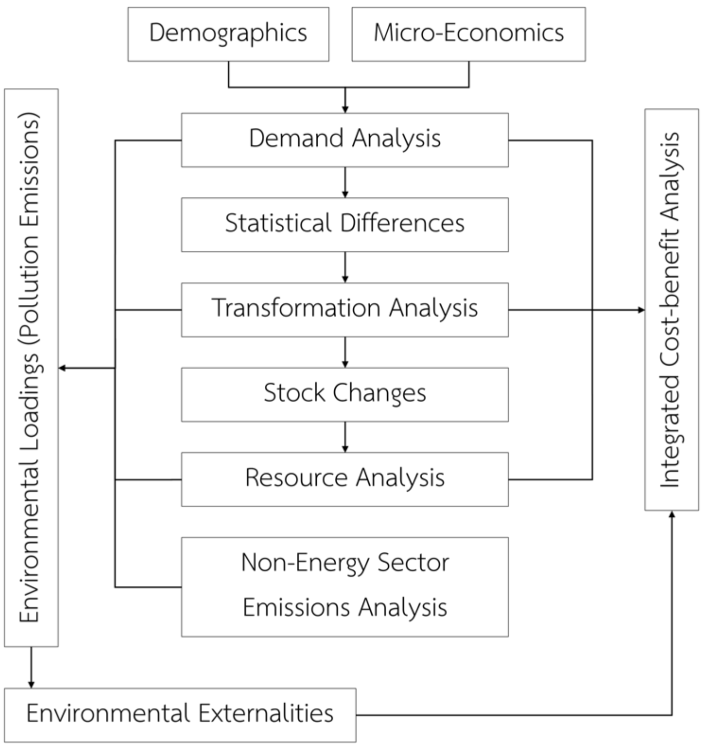
The choice for the bottom-up energy model approach in the present study is the LEAP system (LEAP, 2022), developed by the Stockholm Environment Institute. The LEAP modelling capabilities are highlighted in Table 2.2, with the calculation flows shown in Figure 2.3.

Table 2.2. Key Characteristics of LEAP

Aspect	Characteristics
Energy Demand	✓ Hierarchical accounting of energy demand (activity levels x energy intensities) ✓ Choice of methodologies ✓ Optional modelling of stock turnover
Energy Conversion	✓ Simulation of any energy conversion sector (electric generation, transmission and distribution, combined heat and power, oil refining, charcoal making, coal mining, oil extraction, ethanol production, etc.) ✓ Electric system dispatch based on electric load-duration curves ✓ Exogenous and endogenous modelling of capacity expansion
Energy Resources	✓ Tracks requirements, production, sufficiency, imports and exports ✓ Optional land-area based accounting for biomass and renewable resources
Costs	✓ All system costs: capital, operations and maintenance, fuel, costs of saving energy, environmental externalities
Environment	✓ All emissions and direct impacts of the energy system ✓ Non-energy sector sources and sinks

Source: LEAP (2022).

Figure 2.2. LEAP Calculation Flows



Source: LEAP (2022).

As mentioned above, important assumptions or variables for the energy demand model are:

1. Estimation of the number of vehicles (NV)
2. Estimation of the distances travelled by each vehicle (VKT)
3. Estimation of the fuel economy of each vehicle (FE)

In this study, the energy demand and CO_2 emissions are calculated for five ASEAN countries, i.e. Indonesia, Malaysia, the Philippines, Thailand, and Viet Nam, and India from the current situation to 2040. It is noted that these three variables are not regularly updated so certain assumptions must be made from the engineering aspects, such as the type of engine (spark-ignition vs compression-ignition), engine age, and fuel ratio used (liquid with blended biofuels or gas). The projections for energy demand and CO_2 emissions of the considered vehicles are calculated in the road transportation model via the Low Emission Analysis Platform (LEAP). LEAP is a widely used commercial software tool for energy policy analysis and climate change mitigation assessment developed at the Stockholm Environment Institute. The energy demand is determined according to the bottom-up approach as per the following equation. Hence, the influential energy consumed by branches of different vehicle technologies, fuels, and vehicle segments can be indicated. Besides the TTW CO_2 emissions, GHG emissions can also be analysed by multiplying the energy consumption results with the emissions factor of concordance for vehicle technologies, fuels, as well as vehicle segments.

$$ED = \sum_{i,j} NV_{i,j} \cdot FC_{i,j} \cdot VKT_i$$

where *i* is the considered vehicle (segment or technology), *j* is the type of fuel or energy used, *NV* is the number of vehicles, *FC* is fuel consumption (fuel units/km, where the fuel unit must correspond to the unit of energy demand, i.e. fuel physical unit or energy unit), and *VKT* is the vehicle kilometre of travel (km).

Two vehicle types are considered: passenger cars and motorcycles. The various technologies and fuels used are simplified into gasoline vehicles (fuelled with gasohol fuel at the averaged ethanol fraction), diesel vehicles (only for passenger cars, fuelled with diesel fuel with averaged biodiesel fraction), and electric vehicles for every considered country.

2.2. Estimation of the number of vehicles (NV)

For passenger cars and motorcycles, the vehicle numbers can be estimated by realising the past data and trend of vehicle growth in a mathematical model, often called the Vehicle Ownership Model, which can be defined in an S-curve logistic function (Button, Ngoe, and Hine, 1993; Chollacoop et al., 2003; Chollacoop et al., 2011; Dargay, Gately, and Sommer, 2007; Nagai et al., 2003). The relationship between vehicle numbers, which are described by vehicle ownership (vehicle numbers per 1,000 people), and the household economic situation is modelled in logarithmic form with a saturation level. An example of such a function (Laoonual, Chindaprasert, and Pongthanaisawan, 2008) is:

$$ln\left(\frac{S - VO}{VO}\right) = a + b \ln GDPpCap + c \ln PopDen$$

where,

VO = vehicle occupancy (number of vehicles/1,000 population)

S = saturation level of VO (number of vehicles/1,000 population)

GDPpCap = GDP per capita (US$/person or B/person)

PopDen = population density (persons/sq. km)

a, b, and c = coefficient from curve fitting with historical data

In this study, the calculated numbers of passenger cars and motorcycles from six considered countries (Indonesia, Malaysia, the Philippines, Thailand, Viet Nam, and India) are adjusted with historical records provided to working group members. The model's calculated results are validated with historical registered records for passenger cars and motorcycles as shown in Figure 2.4. The models of vehicle numbers are shown in Table 2.3 for passenger cars and Table 2.4 for motorcycles. It is noted that GDP (in constant prices) represents the household economic situation in each country (World Bank, 2022a). The population data are collected from the World Bank (World Bank, 2022b). However, the Thailand data are collected from the Bank of Thailand (Bank of Thailand, 2022).

Figure 2.4. Validation of Vehicle Numbers for Five ASEAN Countries and India for (a) Passenger Cars and (b) Motorcycles

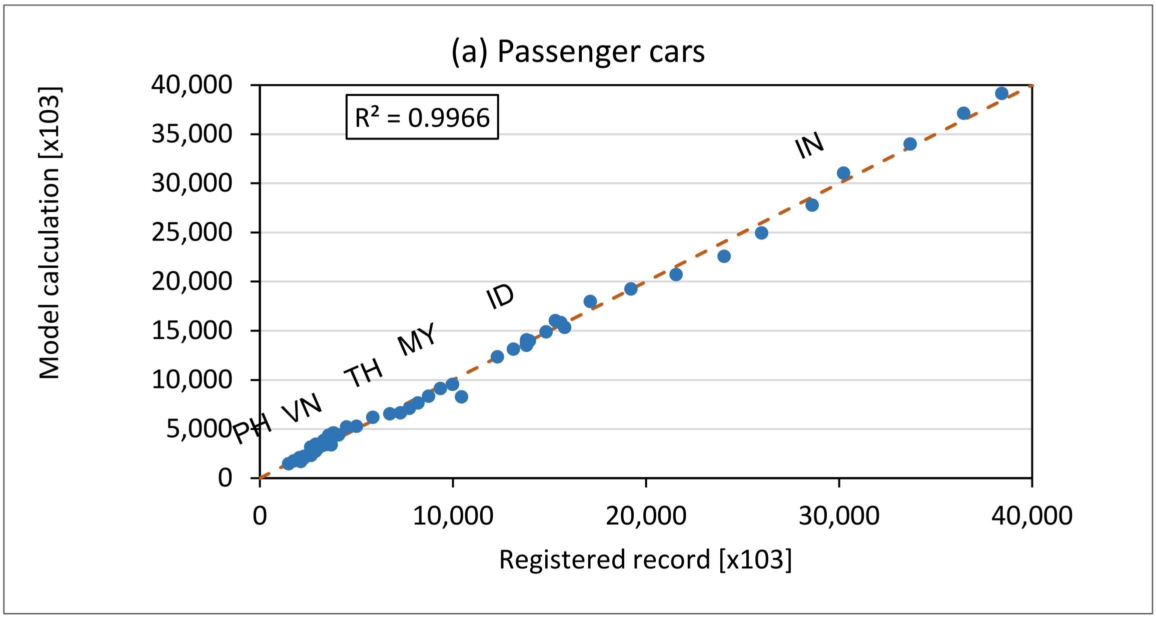
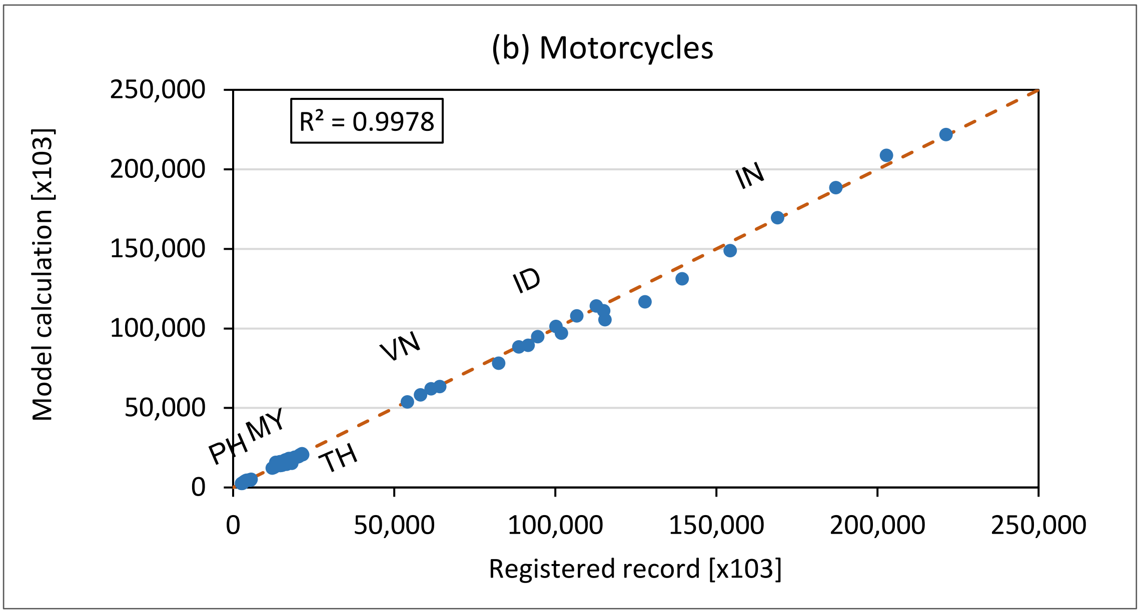


Figure 2.4. *Continued*



ID = Indonesia, IN = India, MY = Malaysia, PH = Philippines, TH = Thailand, VN = Viet Nam.
Source: ERIA (2022).

Table 2.3. Models of Passenger Car Numbers

Country	Abbr.	Vehicle ownership models (VO)	R^2
Indonesia	ID	$ln\left(\frac{VO}{812-VO}\right) = -14.4341 + 1.4378 \cdot ln(GDPpCap)$	0.97
Malaysia	MY	$ln\left(\frac{VO}{812-VO}\right) = 0.6636 \pm 0.0558 \cdot ln(GDPpCap)$	0.99
Philippines	PH	$ln\left(\frac{VO}{812-VO}\right) = -7.4109 + 0.5178 \cdot ln(GDPpCap)$	0.94
Thailand	TH	$ln\left(\frac{VO}{812-VO}\right) = -31.3784 + 2.4819 \cdot ln(GDPpCap)$	0.95
Viet Nam	VN	$ln\left(\frac{VO}{812-VO}\right) = -26.2333 + 2.8790 \cdot ln(GDPpCap)$	0.99
India	IN	$ln\left(\frac{VO}{812-VO}\right) = -14.7426 + 1.5071 \cdot ln(GDPpCap)$	0.99

Note: GDP for all countries is in US dollars, except Thailand's GDP, which is in Thai baht.
Source: ERIA (2022).

The saturation levels of the S-curve logistic function are shown in the formulas, 812 for passenger cars and 600 for motorcycles, whilst Viet Nam's motorcycles have a saturation level higher than that of other countries, at 750, due to the specific situation in the country. In the vehicle stock model, new vehicles (vehicle sales) were calculated from the simplified percentage of new vehicle numbers of the total on-road vehicle numbers, which are shown in Table 2.5 for various East Asia Summit countries.

Table 2.4. Models of Motorcycle Numbers

Country	Abbr.	Vehicle ownership model (VO)	R^2
Indonesia	ID	$ln\left(\frac{VO}{600-VO}\right) = -30.8405 + 3.8369 \cdot ln(GDPpCap)$	0.96
Malaysia	MY	$ln\left(\frac{VO}{600-VO}\right) = -21.0808 + 2.3701 \cdot ln(GDPpCap)$	0.82
Philippines	PH	$ln\left(\frac{VO}{600-VO}\right) = -14.8897 + 1.5192 \cdot ln(GDPpCap)$	0.94
Thailand	TH	$ln\left(\frac{VO}{600-VO}\right) = -10.6937 + 0.8968 \cdot ln(GDPpCap)$	0.81
Viet Nam	VN	$ln\left(\frac{VO}{750-VO}\right) = -42.3103 + 5.6086 \cdot ln(GDPpCap)$	0.99
India	IN	$ln\left(\frac{VO}{600-VO}\right) = -15.8026 + 1.9490 \cdot ln(GDPpCap)$	0.81

Note: GDP for all countries is in US dollars, except Thailand's GDP, which is in Thai baht.
Source: ERIA (2022).

Table 2.5. Percentage of New Vehicle Numbers by On-road Vehicle Numbers

	Cars	Motorcycles
Indonesia	5.75%	5.84%
Malaysia	3.67%	3.69%
Philippines	10.64%	19.68%
Thailand	5.85%–3.26%	9.76%–6.35%
Viet Nam	10.26%	5.03%
India	8.77%	9.3%

Source: Calculated from historical vehicle numbers (sale and on-road), except for Thailand where the values are calculated from the sales projections of Thailand's National EV Policy Committee and projections of vehicle ownership models (2022–2035).

2.3 Estimation of vehicle kilometres of travel

The second variable, vehicle kilometres of travel (VKT), is the distance travelled by each considered vehicle. The VKT governs how much fuel or energy is consumed for each vehicle type within a unit distance. The VKT values in this study were collected from some member countries, but Thailand's data are used where those data from member countries are not available, as shown in the note for Table 2.6.

Table 2.6. Vehicle Kilometres of Travel

	Cars	Motorcycles
Indonesia	12,723	10,800
Malaysia*	20,230	17,820
Philippines*	20,230	17,820
Thailand*	20,230	17,820
Viet Nam	13,723	7,225
India*	20,230	17,820

* Thailand's data are used where data from member countries are not available.
Source: ERIA (2022).

2.4. Estimation of Fuel Economy

The last collected variable is the fuel economy (FE) of each vehicle type. Together with VKT, the FE directly gives the total fuel or energy needed. As mentioned, all three variables (NV, VKT, and FE) are not regularly updated, so certain assumptions must be made from the engineering aspects. Likewise, the FE must be specified according to engineering parameters, such as the type of engine (spark-ignition vs compression-ignition), engine age, and fuel ratio used (liquid with blended biofuels or gas). The vehicles in this study were therefore simplified into those with a spark-ignition engine, diesel (compression-ignition) engine, electrified vehicle (plug-in hybrid electric vehicle [PHEV], and battery electric vehicle [BEV]). Gas fuels were neglected in this work, whilst biofuels were assumed to be blended with mean blended ratios (different from practical blended ratios, i.e. gasohol E10, gasohol E85, biodiesel B7, biodiesel B30, but calculated from the consumption of various fuels; e.g. if gasohol E10 and gasohol 20% ethanol blend (E20) are used in similar quantities, the mean blended ratio will equal to E15). In this study, the fuel/technology of the considered vehicles is composed of:

- Passenger cars: gasoline, diesel, PHEV, BEV
- Motorcycles: gasoline, and electric motorcycles (eMCs)

Gasoline is fuelled by gasoline and ethanol fuels, diesel is fuelled by diesel and biodiesel fuels. The shares of PHEV fuel usage between gasoline (gasoline and ethanol) and electricity are 68.25% and 31.75%, respectively, estimated from the United States' fuel economy database (US-EPA, 2022). The fuel economy of passenger cars and motorcycles with various fuel/technology is shown in Table 2.7.

Table 2.7. Assumptions of Fuel Economy

	Passenger Cars					Motorcycles	
	Gasoline	Diesel	PHEVs		BEVs	Gasoline	eMCs
			Gasoline	Electricity			
Indonesia	10.99	9.71	5.25	48.31	10.73	3.60	2.88
Malaysia*	7.86	8.08	3.75	34.55	16.18	2.44	3.49
Philippines	12.62	10.53	6.02	55.47	16.18	2.44	3.49
Thailand*	7.86	8.08	3.75	34.55	16.18	2.44	3.49
Viet Nam	8.02	7.52	3.83	35.25	14.74	1.90	2.00
India*	7.86	8.08	3.75	34.55	16.18	2.44	3.49

PHEV = plug-in hybrid electric vehicle, BEV = battery electric vehicle, eMC = electric motorcycle.
* Thailand's data are used where data from member countries are not available.
Note: Fuel economy is in the unit of litres/100 kilometres for gasoline and diesel, and kilowatt hours/100 kilometres for the consumed electricity of EVs (PHEVs, BEVs, and eMCs).
Source: ERIA (2022).

2.5. Tank-to-wheel Greenhouse Gas Emissions

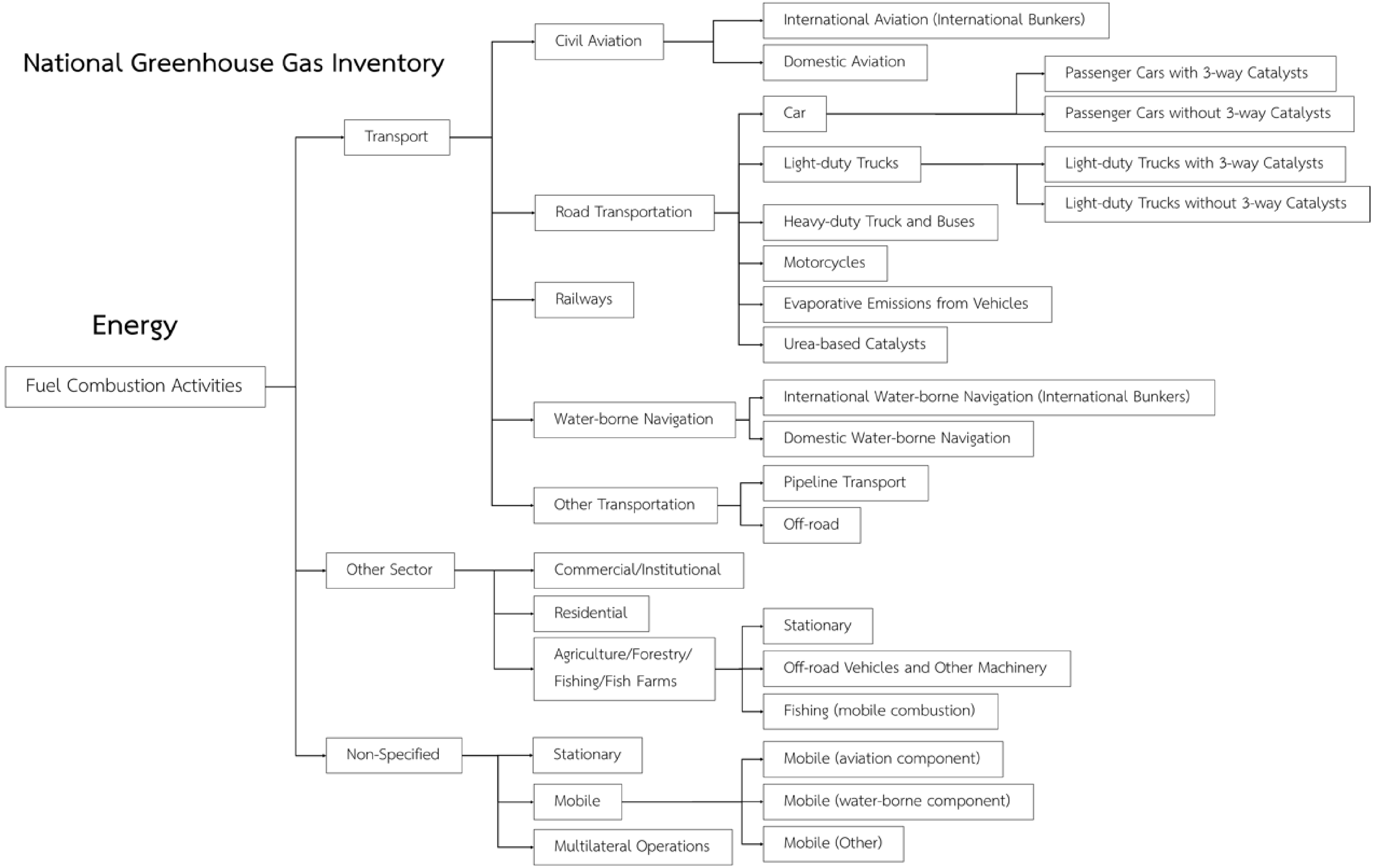
The tank-to-wheel greenhouse gas (TTW GHG) emissions are calculated according to the Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories (IPCC, 2006) in this study. For fuel combustion in road transportation, the emissions factors are selected according to the Technology and Environmental Database, as shown in Figure 2.5.

The TTW GHG emissions are defined from the fundamentals of the combustion reaction. In the combustion process, the complete combustion products are mainly CO_2 and water (H_2O). CO_2 is a major GHG emission. Emissions of methane (CH_4) and nitrous oxide (N_2O) also have major impacts on global warming. The IPCC Tier 2 scheme is selected in this study to collect TTW GHG emissions for the considered fossil fuels. The emissions levels are assumed according to the current emissions standards for new vehicles and the share of vintage vehicles in the considered region, as shown in Table 2.8.

As mentioned, the TTW GHG emissions for fossil fuel combustion in road transportation comprise CO_2, CH_4, and N_2O. These emissions are converted into the CO_2-equivalent units by multiplying by the global warming potentials (GWP) as shown in Table 2.9.

In contrast with fossil fuel combustion, biofuels are considered carbon-neutral fuels. This means that the CO_2 produced during biofuel combustion is equivalent to the CO_2 quantity absorbed in the photosynthesis process of biofuel plantation.

Figure 2.3. Activity and Source Structure in the Energy Sector



Source: IPCC (2006).

Table 2.8. Chosen Vehicle Models to Represent TTW GHG Emissions

Type of Vehicle	Chosen Vehicle Models in LEAP
Gasoline passenger car (for all gasoline combustion, including HEV and PHEV)	European cars, moderate control, gasoline
Diesel passenger car	European cars, moderate control, diesel
Gasoline motorcycle	European motorcycle > 50 cc 4 stroke Uncontrolled gasoline

HEV = hybrid electric vehicle, PHEV = plug-in hybrid electric vehicle, TTW GHG = tank-to-wheel greenhouse gas.
Source: IPCC (2006).

Table 2.9. Global Warming Potential of GHG Emissions from the Combustion Process

	CO_2	CH_4	N_2O
GWP (kg in CO_2 eq/kg of considered emissions)	1	25	296

GHG = greenhouse gas, GWP = global warming potential, kg = kilogramme.
Source: IPCC (2006).

2.6. Well-to-tank greenhouse gas emissions

To investigate the impacts of alternative technologies, which comprise carbon-neutral fuels (such as biodiesel and bio-ethanol) and electric vehicles, the WTT GHG emissions are added to fulfil the GHG emissions along the energy life cycle (fuel production and used phase). The upstream GHG emissions of electric vehicles are added in terms of the GHG emission factors of the grid electricity in various countries. This information was shared in the working group. In addition, the upstream GHG emissions of vehicles with combustion engines are collected through the fuel processes. For example, the fossil fuel processes comprise oil and gas production (oil extraction and drilling), oil and gas transportation (from the well to the refinery plant), the crude oil refinery process, commercial fuel transportation (from the refinery plant/fuel storage to the fuel retail station). The TWW emissions of the fossil fuels and biofuels used in this study are shown in Table 2.10.

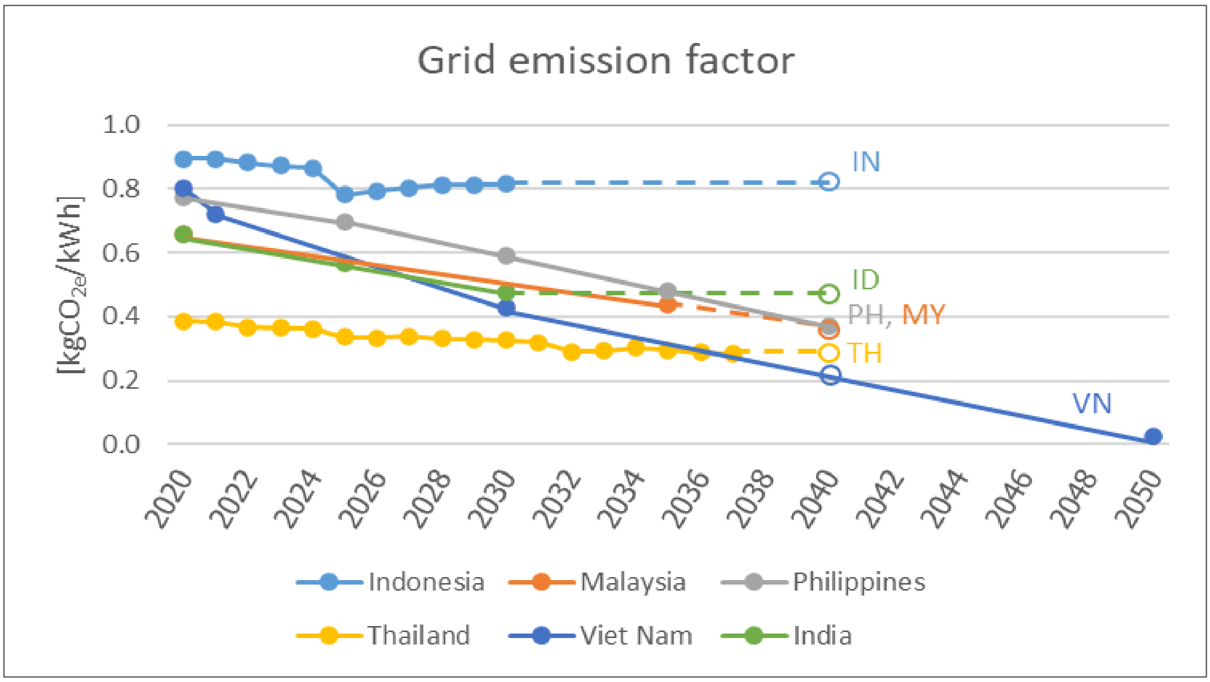
Table 2.10. Well-to-Tank Emission Factors of Fossil Fuels and Biofuels

Fuel	Well-to-Tank Emission Factor (kg CO_2/litre, kg CO_2/kg CNG)
Gasoline	0.2977
Diesel	0.3062
LPG	0.8582
CNG	0.6164
Biodiesel (FAME)	1.1780
Ethanol	0.6803

CNG = compressed natural gas, LPG = liquefied petroleum gas.
Source: TIIS, Thai National Life Cycle Inventory Database; Permpool and Gheewala (2017); Silalertruksa and Gheewala (2011)

The GHG emission factors of the grid electricity in the selected ASEAN countries and India are collected from the available policies and illustrated in Figure 2.6 with references shown in Table 2.10. The filled dots represent the grid emission factor data from the indicated policy reference with a solid line connecting each year. The unfilled dots show the projected GHG emission factors by the authors connected with dashed lines.

Figure 2.4. GHG Emission Factors of Grid Electricity in ASEAN Countries and India



ID = Indonesia, IN = India, MY = Malaysia, PH = Philippines, TH = Thailand, VN = Viet Nam.
Source: See Table 2.11.

Table 2.11. Sources of Grid Emission Factors for Selected ASEAN Countries and India

	Source
Indonesia (ID)	Indonesia's State Electricity Company (Perusahaan Listrik Negara, PLN)
Malaysia (MY)	Calculated from the Global Environment Facility shown in the GEF-7 Malaysia National Dialogue
Philippines (PH)	Philippine Energy Plan 2020–2040
Thailand (TH)	Thailand Power Development Plan 2018 (PDP2018-2037)
Viet Nam (VN)	Viet Nam's Eight National Power Development Plan (PDP8)
India (IN)	Ministry of Power, Central Electricity Authority, Government of India, *Report on Optimal Generation Mix: Version 2.0*, April 2023

Source: Philippines Department of Energy; Thailand Power Development Plan 2018 rev.1; Viet Nam's Eight National Power Development Plan (PDP8); Ministry of Power, Central Electricity Authority, Government of India.

2.7. Projection of Socioeconomic Variables

The bottom-up model was developed according to socioeconomic variables. In this study, the number of vehicles was defined using an S-curve logistic function of two socioeconomic variables, GDP and population.

2.7.1. Gross Domestic Product

The gross domestic product (GDP) information was collected at 2015 constant prices in US dollars (World Bank, 2022a) with the exception of Thailand. The data were available to the year 2020. Thailand's GDP was collected from the Bank of Thailand (Bank of Thailand, 2022) in baht at 2002 constant prices. The current GDP values and growth rates are shown in Table 2.12.

Table 2.7. Projection of Gross Domestic Product

	Current Value (billion)	Currency Unit	Growth Rate
Indonesia	1,027.60	US dollars	2.98%
Malaysia	344.10	US dollars	2.97%
Philippines	358.29	US dollars	3.18%
Thailand	10,266.61	Thai baht	3.96%
Viet Nam	258.51	US dollars	5.43%
India	2,500.13	US dollars	4.84%

Sources: World Bank (2022a); Bank of Thailand (2022).

2.7.2 Population (capita, cap)

Similar to the GDP information, the population of the considered countries was collected from the World Bank (World Bank, 2022b) with the exception of Thailand. Thailand's population data were collected from the Bank of Thailand (Bank of Thailand, 2022). The current population and growth rates are shown in Table 2.13.

Table 2.8. Population and Population Growth Rates by Country

	Current Population (millions)	Population Growth Rate
Indonesia	273.52	1.15%
Malaysia	32.37	1.34%
Philippines	109.12	1.42%
Thailand	69.80	0.68%
Viet Nam	97.34	0.99%
India	1,366.42	1.07%

Sources: World Bank (2022a); Bank of Thailand (2022).

3. Well-to-wheel CO_2 Emissions from Biofuels/EVs in East Asia Summit Countries

In the current study, the GHG emissions are composed of both the upstream (well-to-tank) and used-phase (tank-to-wheel) processes. The impacts of GHG emissions for EVs with the improvement of electricity sources are focused on as well as the impacts of carbon-neutral fuel during the production phase. The considered scenarios are separated into three scenarios, with the assumptions for EVs and biofuels from the previous study (ERIA, 2022) shown in Table 2.14, as follows:

(1) Business-as-Usual (BAU) scenario: Focus on EV penetration without an improvement in electricity sources (electricity produced from conventional sources, i.e. coal, natural gas, or fossil fuels), shown as 'EV-NoBiofuel-NoGridImprove'.

(2) EVs with renewable electricity sources: This scenario is defined to analyse the impacts if the government invests in renewable power plants, such as solar PV and wind power, shown as 'EV-NoBiofuel-GridImprove'.

(3) Biofuel addition: As on-the-road vehicles comprise both new vehicles and on-road stock vehicles, biofuels are considered in this scenario as another option for on-road stock vehicles, which still use conventional combustion engines and will last long in the system, shown as 'EV-Biofuel-GridImprove'.

Table 2.9. Assumption for (a) Electric Vehicle Penetration and (b) Biofuel Blending in Five Selected ASEAN Countries and India

(a)		Business-as-Usual Scenario		EV Scenario	
	Projection year	Passenger cars	Motorcycles	Passenger cars	Motorcycles
Indonesia (Number)	2022	0	0	750	5,000
	2025	0	0	10,598	1,760,000
	2030	0	0	NA (assume constant share)	2,450,000
Malaysia (%)	2022	0.00%	0.00%	0.00%	0.00%
	2030	0.00%	0.00%	10.00%	15.00%
Philippines* (%)	2022	0.02%	0.04%	0.02%	0.04%
	2030	0.02%	0.04%	17.00%	8.00%
	2040	0.02%	0.04%	47.00%	55.00%
Thailand (Number)	2022	0	0	30,000	40,000
	2025	0	0	225,000	360,000
	2030	0	0	440,000	650,000
	2035	0	0	1,154,000	1,800,000
Viet Nam* (%)	2022	0.00%	12.00%	0.00%	12.00%
	2030	0.00%	12.00%	5.00%	45.00%
	2040	0.00%	12.00%	51.00%	95.00%
India (%)	2021	0.00%	2.39%	0.00%	2.39%
	2022	0.00%	2.39%	1.00%	2.39%
	2030	0.00%	2.39%	12.00%	2.39%

Sources: *BNEF (2021); ERIA (2022).

Table 2.10. ***Continued***

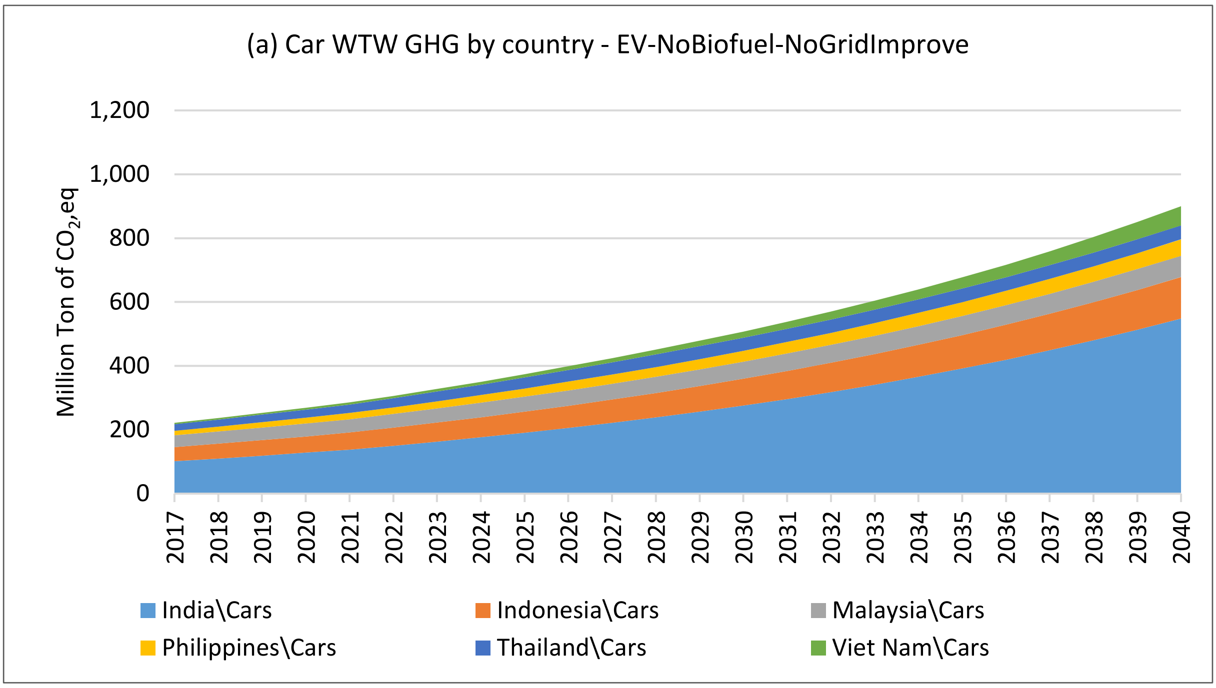
(b)		Business-as-Usual Scenario		Biofuel Scenario	
	Projection year	**Ethanol (%)**	**Biodiesel (%)**	**Ethanol (%)**	**Biodiesel (%)**
Indonesia	2022	0.0%	30.0%	0.0%	30.0%
	2024	0.0%	30.0%	0.0%	40.0%
Malaysia	2022	0.0%	10.0%	0.0%	10.0%
	2025	0.0%	10.0%	0.0%	20.0%
	2030	0.0%	10.0%	0.0%	30.0%
Philippines	2022	10.0%	2.0%	10.0%	2.0%
	2026	10.0%	2.0%	10.0%	4.0%
	2030	10.0%	2.0%	10.0%	7.0%
	2040	10.0%	2.0%	15.0%	7.0%
Thailand	2022	14.2%	9.4%	14.2%	9.4%
	2037	14.2%	9.4%	20.0%	15.0%
Viet Nam	2022	5.0%	0.0%	5.0%	0.0%
	2030	5.0%	0.0%	13.0%	0.0%
	2050	5.0%	0.0%	25.0%	0.0%
India	2022	10.0%	0.1%	10.0%	0.1%
	2030	10.0%	0.1%	20.0%	5.0%

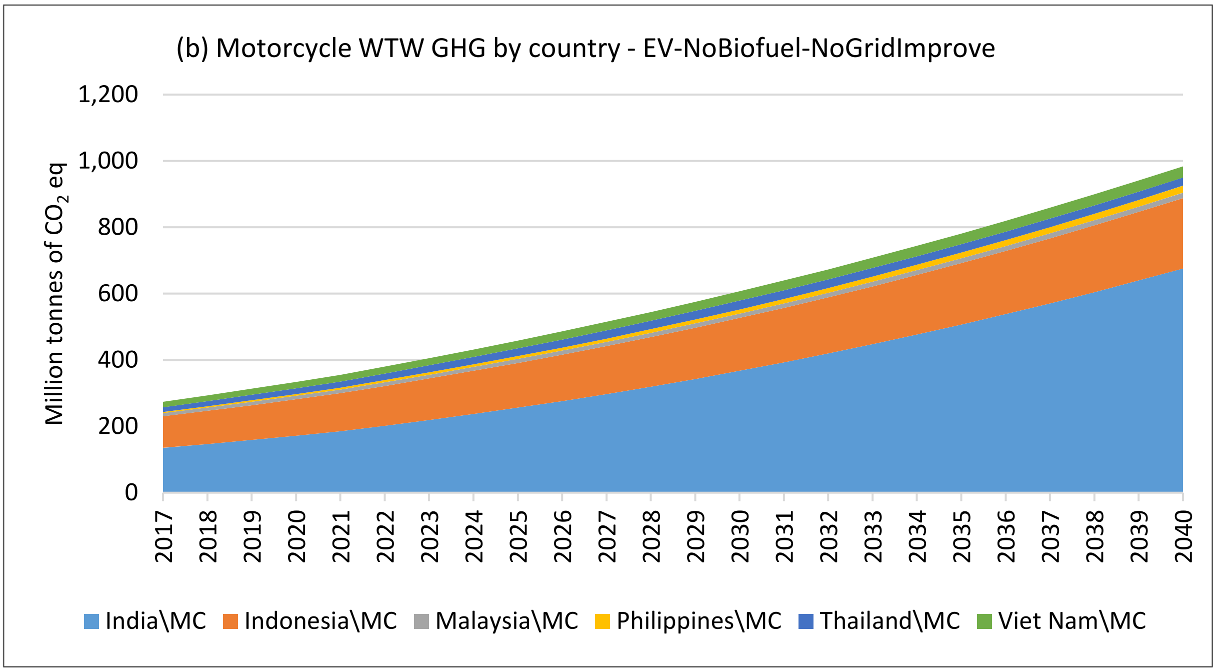
Sources: ERIA (2022).

The results for the GHG emissions calculated from these three scenarios are shown in Figure 2.7, Figure 2.8, and Figure 2.9.

To conclude the observed results of the alternative scenarios considered in this study, the projections of the well-to-wheel emissions from car and motorcycle vehicles in 5 ASEAN countries and India are compared with the baseline scenario defined as the projected scene with the current situations of EV, grid electricity emissions, and biofuel status, as shown Figure 2.10. The impact of EVs on decarbonising cars and motorcycles in 5 ASEAN countries and India is about 4.84% and 5.77%, respectively. With further improvement in grid emissions from renewable energy according to Figure 2.6, a small decarbonisation impact can be reached, 1.44% for cars and 0.76% for motorcycles, implying that the current grid emission factor target may not be enough. On the other hand, biofuel policy could help to decarbonise the transport sector further to 9.46% for cars and 10.57% for motorcycles.

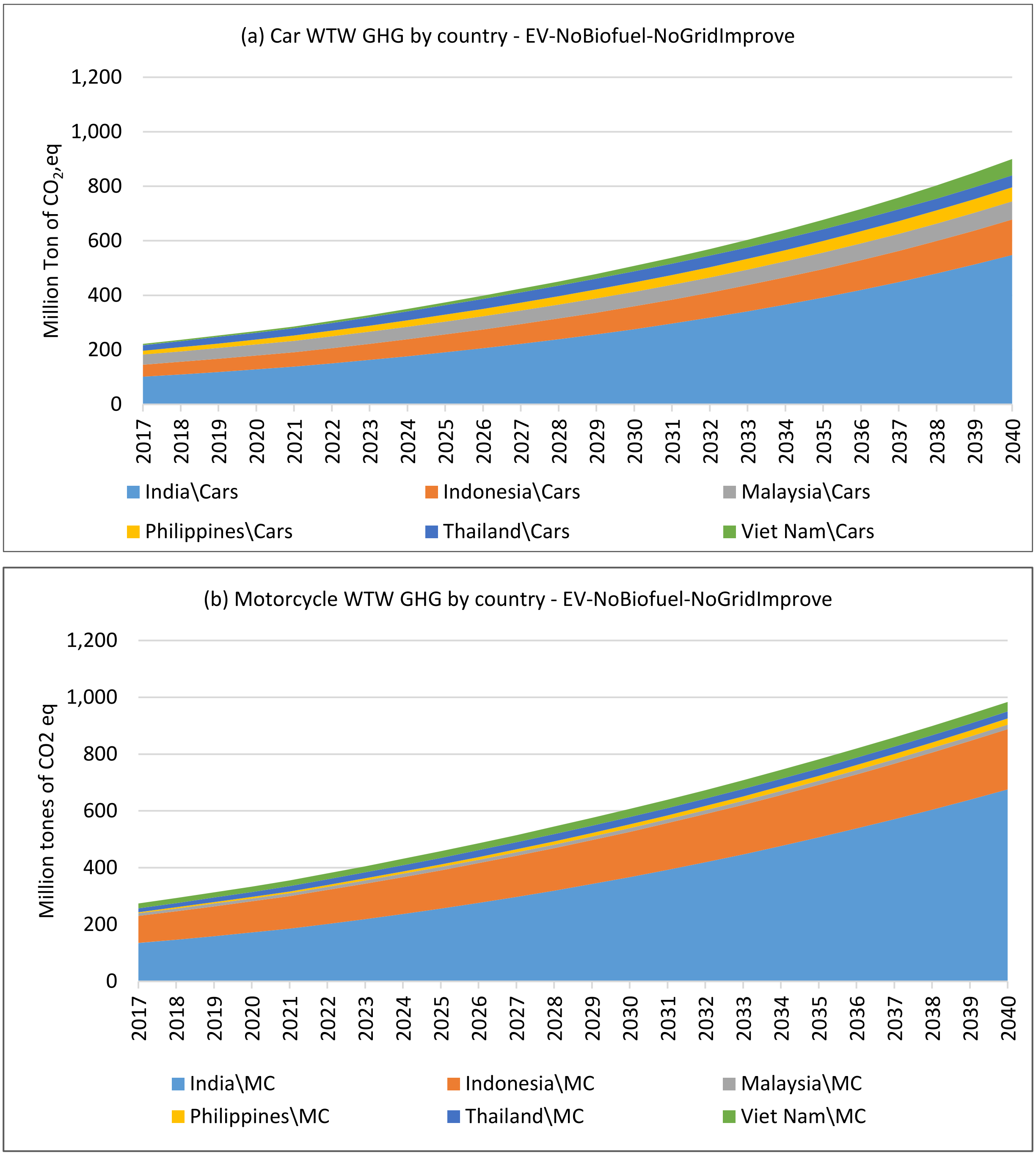
Figure 2.5. Projection of Well-to-Wheel Emissions for EV Penetration Without Improvement in Electricity Sources (a) Cars and (b) Motorcycles – 'EV-NoBiofuel-NoGridImprove'





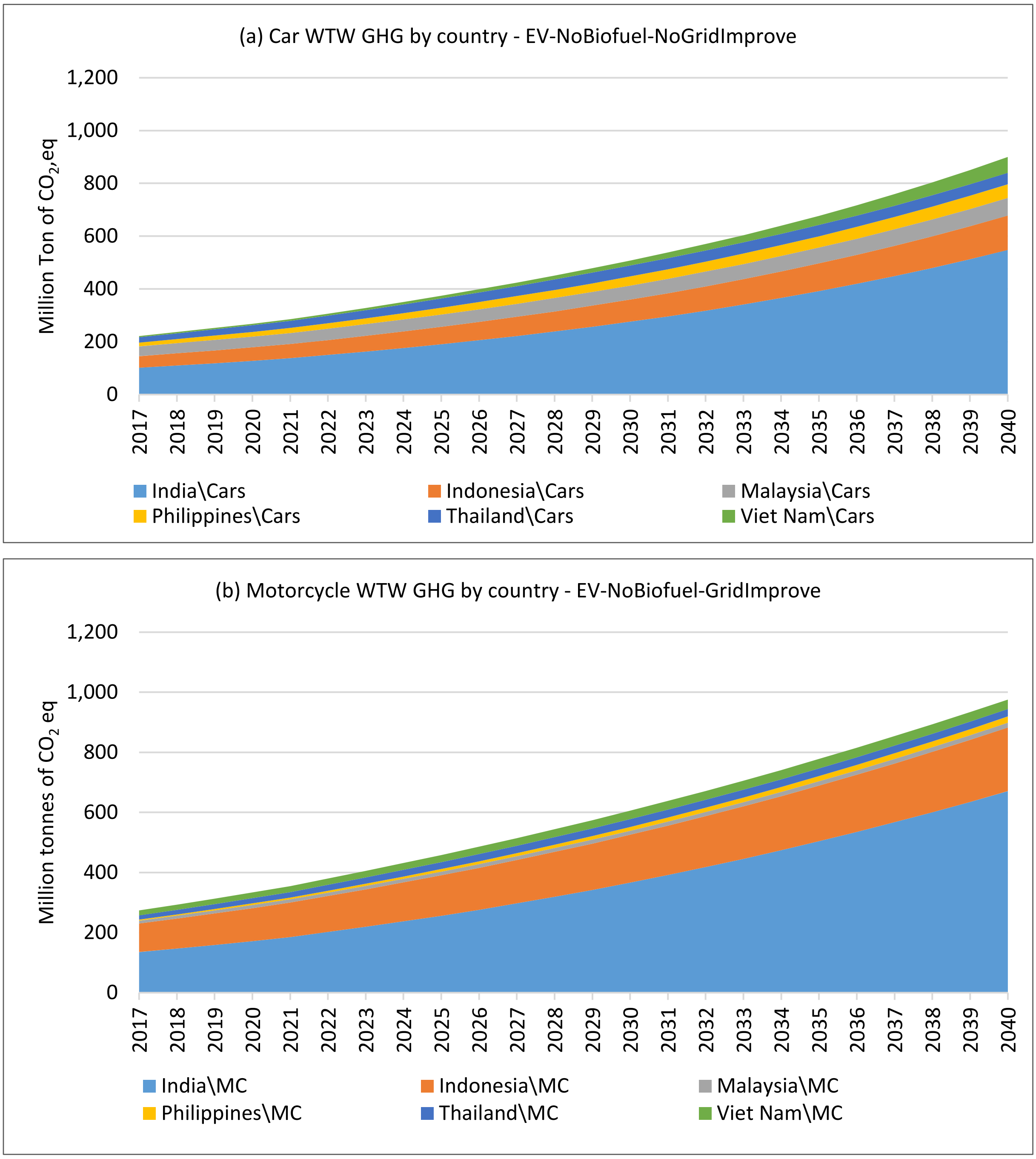
MC = motorcycles.
Source: Authors.

Figure 2.6. Projection of Well-to-Wheel Emissions for EV Penetration with Improvement in Electricity Sources (by Applying Renewable Electricity, e.g. solar PV, wind) (a) Cars and (b) Motorcycles – 'EV-NoBiofuel-GridImprove'



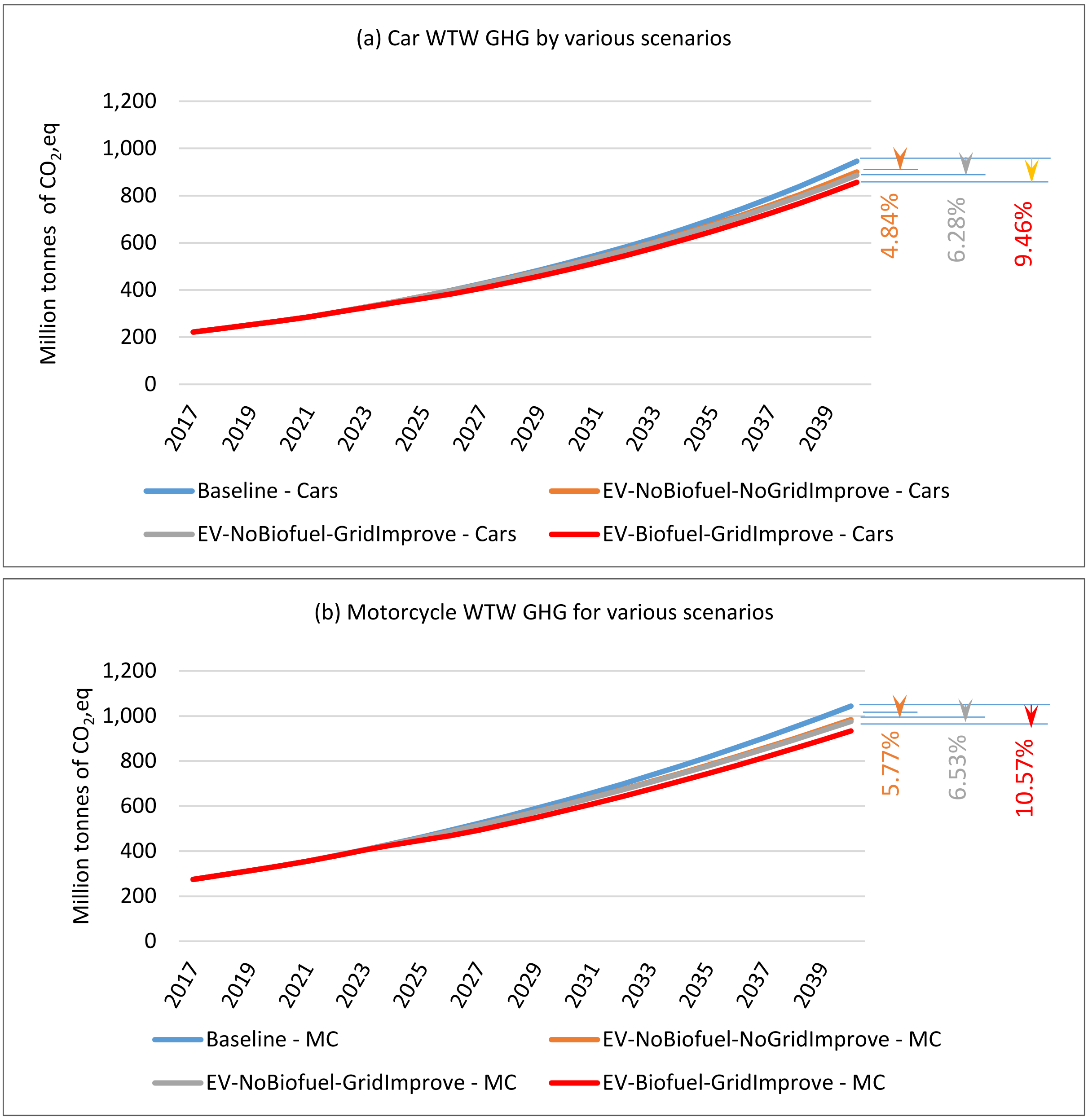
MC = motorcycles.
Source: Authors.

Figure 2.7. Projection of Well-to-Wheel Emissions When Applying Biofuel Policy for On-road Conventional Vehicles (a) Cars and (b) Motorcycles – 'EV-Biofuel-GridImprove'



MC = motorcycles.
Source: Authors.

Figure 2.8. Projection of Total Well-to-Wheel Emissions from (a) Cars and (b) Motorcycles in 5 ASEAN Countries and India



MC = motorcycles.
Source: Authors.

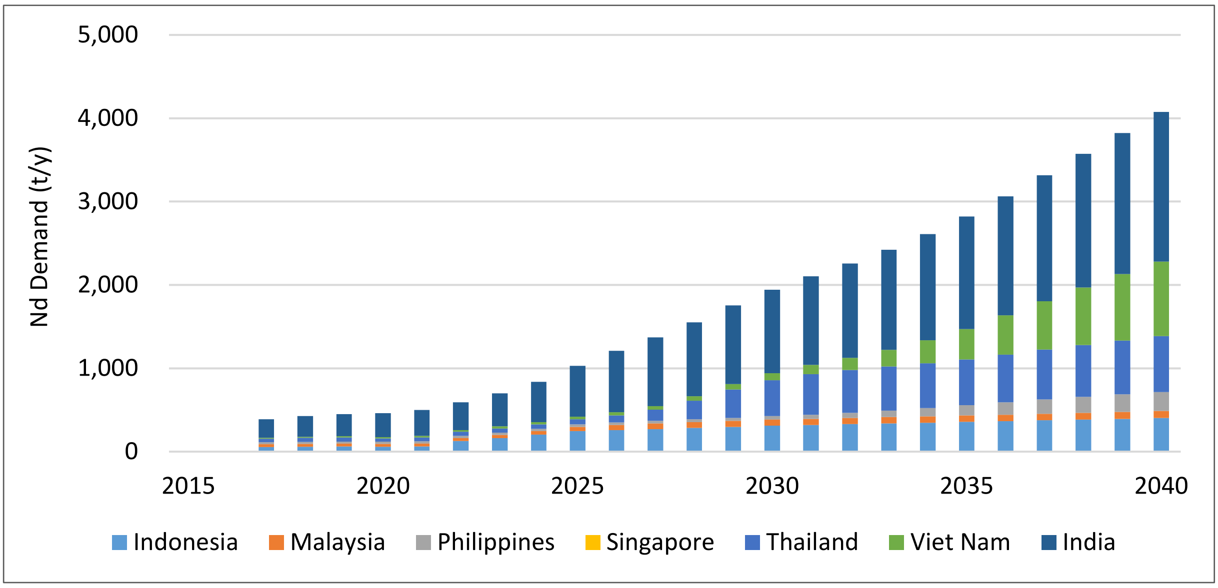
4. Mineral Resources Consumption of EVs in EAS Countries and USGS, IEA, and ERIA Project Forecasts for Neodymium and Cobalt

This section explains the results of the forecasts for demand for Nd and Co by implementing the mobility electrification of vehicles. This section also compares these results with the IEA and USGS report, which forecasted the global demand and supply of Nd and Co until 2040.

Figures 2.11 and 2.12 show the demand for Nd and Co that are used in permanent magnets and lithium-ion battery cells until 2040. Each figure shows the total demand for Nd and Co in Indonesia, Malaysia, the Philippines, Thailand, Viet Nam, and India.

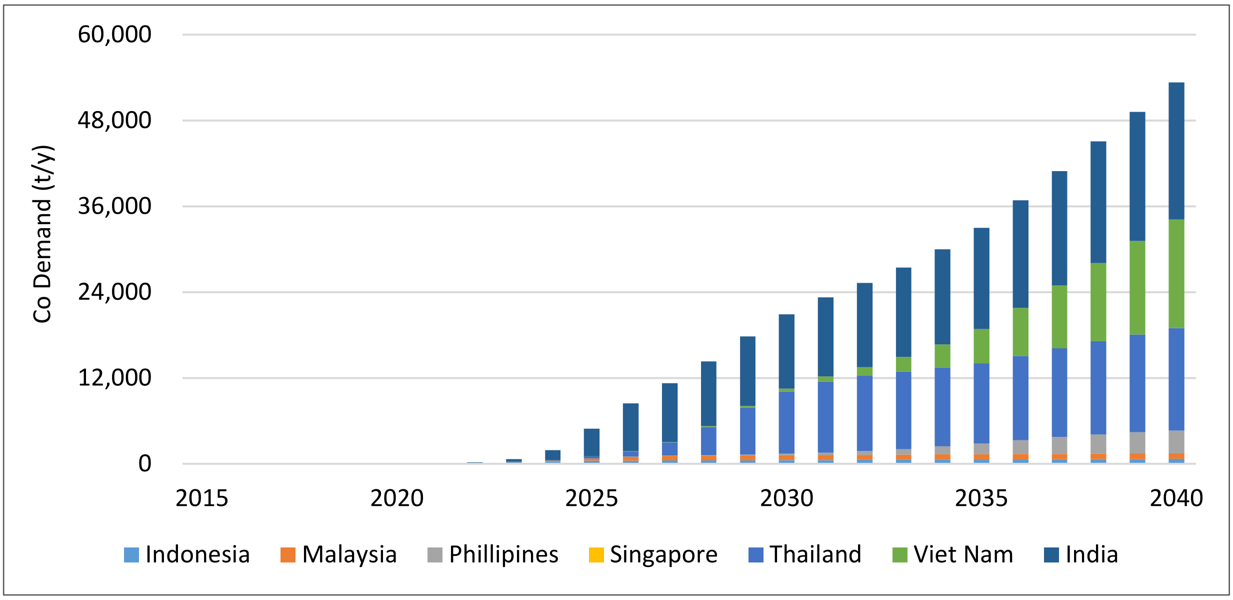
Based on Figures 2.11 and 2.12, the demand for Nd is predicted to be 4,075 t/y in 2040. India, Viet Nam, and Thailand cover 82.51% of all Nd demand in EAS countries, and India is predicted to have the largest demand for Nd in the future. Moreover, the demand for Co is predicted to be 53,32 t/y in 2040 and India, Viet Nam, and Thailand also cover 91.26% of all the demand in EAS countries.

Figure 2.11. Neodymium Demand Forecast



Nd = neodymium, t/y = tonnes/year.
Source: Authors.

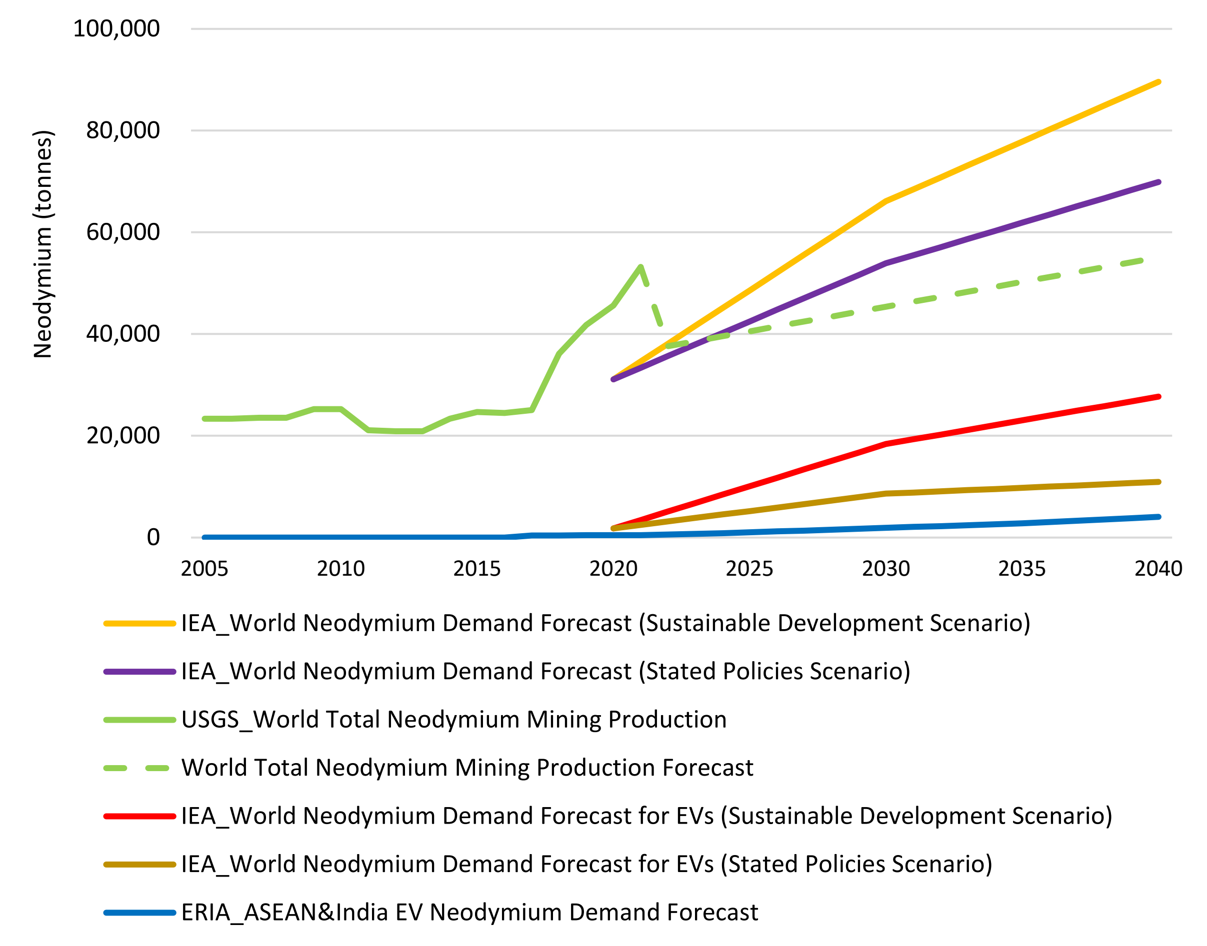
Figure 2.12. Cobalt Demand Forecast



Co = cobalt, t/y = tonnes/year.
Source: Authors.

Figure 2.13 shows the supply and demand for Nd until 2040 based on the USGS, IEA, and ERIA project. By comparing the IEA world Nd demand (of EVs) forecast of the Stated Policies Scenario (in 2040, 10.94 k-tonnes/y) and the forecast for EAS countries (4.08 k-tonnes/y), it was found that EAS countries account for about 37% of the world's total Nd demand.

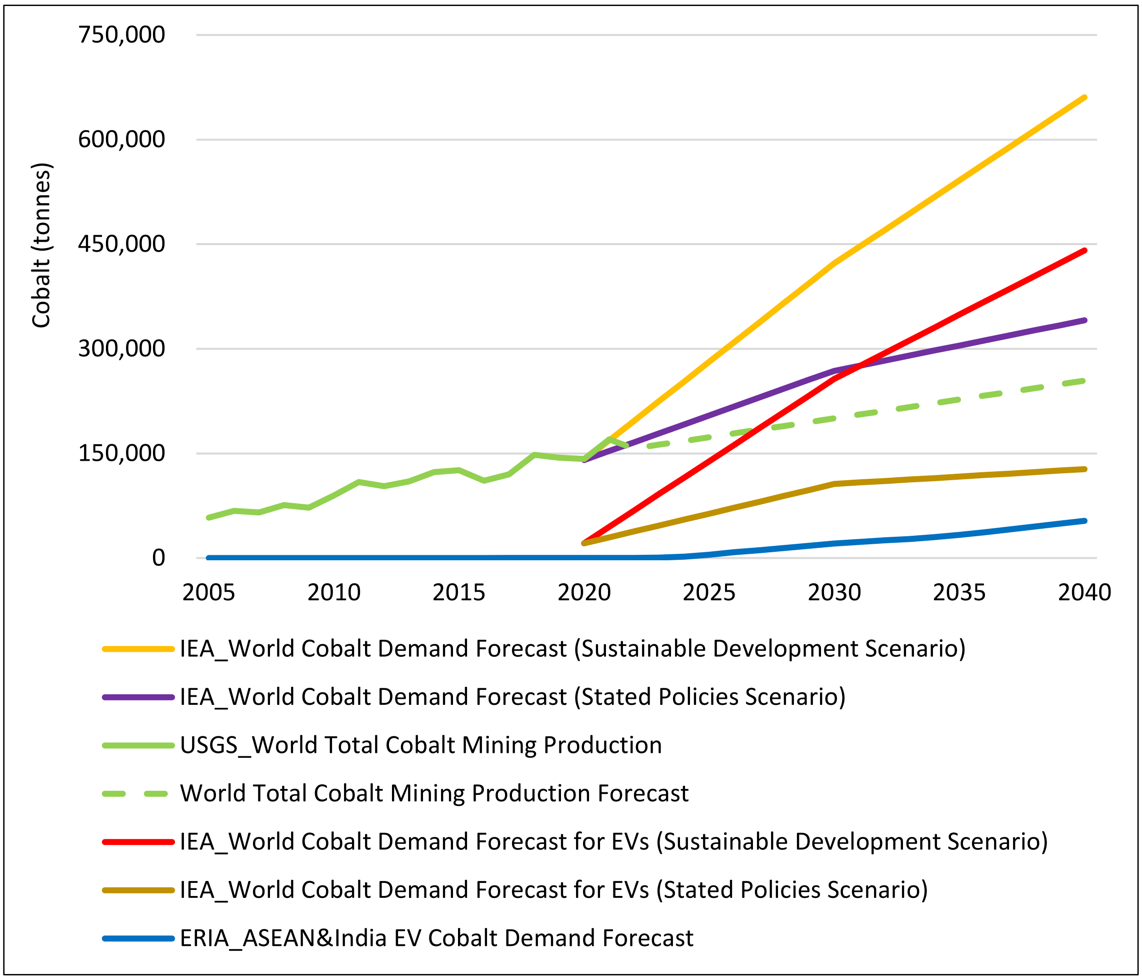
Figure 2.13. USGS, IEA, and ERIA Project Forecast for Neodymium



ERIA= Economic Research Institute for ASEAN and East Asia, IEA=International Energy Agency, USGS= United States Geological Survey.
Source: Authors.

Figure 2.14 shows the supply and demand for Co until 2040 based on the USGS, IEA, and ERIA project. By comparing the IEA world Nd demand (of EVs) forecast of the Stated Policies Scenario (in 2040, 127.4 k-tonnes/y) and the forecast for EAS countries (53.3 k-tonnes/y), it was found that EAS countries account for about 41% of the world's total Co demand.

Figure 2.14. USGS, IEA, and ERIA Project Forecast for Cobalt



ERIA= Economic Research Institute for ASEAN and East Asia, IEA=International Energy Agency, USGS= United States Geological Survey.
Source: Authors.

5. Discussion

This chapter further explores a bottom-up energy demand model for the transport sector from the previous study (ERIA, 2022), focusing on cars and motorcycles in Malaysia, the Philippines, Thailand, Viet Nam, and India using the well-respected Low Emissions Analysis Platform (LEAP) system with input data on population, GDP, vehicle history and projection, vehicle kilometres travelled (VKT), and fuel economy. The best available assumption must be made when data are not available to construct models for EVs and biofuel forecasts.

With a relatively robust vehicle ownership model, the BAU setting for energy consumption and WTT GHG emissions can be set as a baseline for an investigation into the impacts of EVs and biofuel policy. Additional grid emission improvement by renewable energy is quantitatively assessed for a reduction in transport GHG emissions. As pointed out in the previous study (ERIA, 2022), the motorcycle segment in these six countries emits similar GHG emissions to the car segment, and the electrification effect from the current target could achieve about 5% decarbonisation in each sector. Further grid emission factor improvement from the current policy could help further decarbonise by less than 2%, implying that further consideration may be needed to improve grid emissions. On the other hand, biofuel policy could help each sector decarbonise by 10%.

This chapter also explains the result of neodymium and cobalt demand for vehicle electrification in EAS countries until 2040. This result is compared to neodymium and cobalt supply from mining production by USGS and other demand forecasts from the IEA to see the trendlines for every forecast.

The demand for Nd for vehicle electrification in EAS countries is predicted to be 4,075 t/y in 2040. By comparing the IEA world Nd demand (of EVs) forecast of the Stated Policies Scenario, it was found that EAS countries account for about 37% of the world's total Nd demand for EVs. Considering the large increase in Nd demand in Europe, the US, China, and other EV-implementing countries, EAS countries' 37% share of global demand is expected to create fierce competition with other countries.

Regarding Co, the demand for vehicle electrification in EAS countries is forecasted to be 53,324 t/y. By comparing with the IEA world Nd demand (of EVs) forecast of the Stated Policies Scenario, it was found that EAS countries account for about 41% of the world's total Co demand for EVs. Therefore, Co is also expected to face fierce competition from other countries.

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Chapter 3

Future Mobility Scenarios for East Asia Summit Countries

1. Introduction

1.1. Background

The fiscal year (FY) 2021–2022 project report assessed the vehicle electrification penetration target for each EAS country based on the stated policies. However, in real conditions, this target cannot be achieved easily because each country is facing barriers to the introduction of electric vehicles (EVs). Each country has different barrier conditions, such as the high price of EVs, domestic charging facilities, and electrical supply, etc. Therefore, these barrier conditions in each country must be analysed to find the solutions and recommendations to accelerate the introduction of EVs, so the national targets for EV penetration can be achieved.

Some East Asia Summit (EAS) countries have abundant sources of biofuels and other renewable energies. To reduce GHG emissions, instead of depending mainly on EVs, the utilisation of biofuels may be the main priority for these countries. Considering this condition, the priority of adopting EVs and biofuels in each EAS country must be assessed to determine the expected policy and actions that each EAS country must take.

1.2. Objective and Scope

The objective of this chapter is to identify the barriers to implementing the vehicle electrification scenario in EAS countries based on the collected data and analysis from Working Group members. To accelerate the introduction of EVs, the recommendations to overcome these barriers will be explained and analysed. By analysing the barrier conditions, recommendations, and the availability of biofuel resources and other renewable energies, the future mobility scenario for each country is identified to find the appropriate emission reduction measures considering each country's characteristics.

2. Future Mobility Scenario

2.1. Thailand

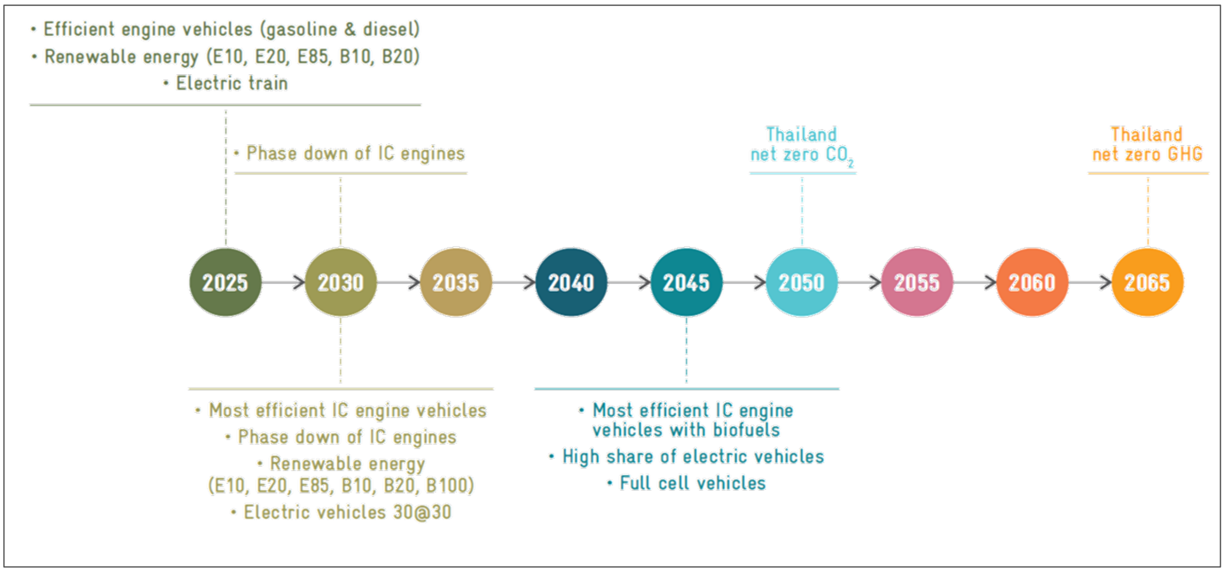
2.1.1 Current policy to promote EVs in Thailand

With Thailand's commitment to achieving carbon neutrality by 2050, Thailand's Long-term Low Greenhouse Gas Emission Development Strategy (LT-LEDS) was released in November 2022 (MONRE, 2022). It includes relevant national policies to decarbonise the transport sector via electric vehicles and biofuels, as shown in Figure 3.1. An EV target of 30@30 (30% EV vehicle production by 2030) with renewable energy in power generation is included in the draft National Energy Plan (NEP), as shown in Figure 3.2.

Figure 3.1. (a) Thailand's Long-term Low Greenhouse Gas Emission Development Strategy (LT-LEDS); (b) Timeline of Transport Decarbonisation via EVs and Biofuels

(a)

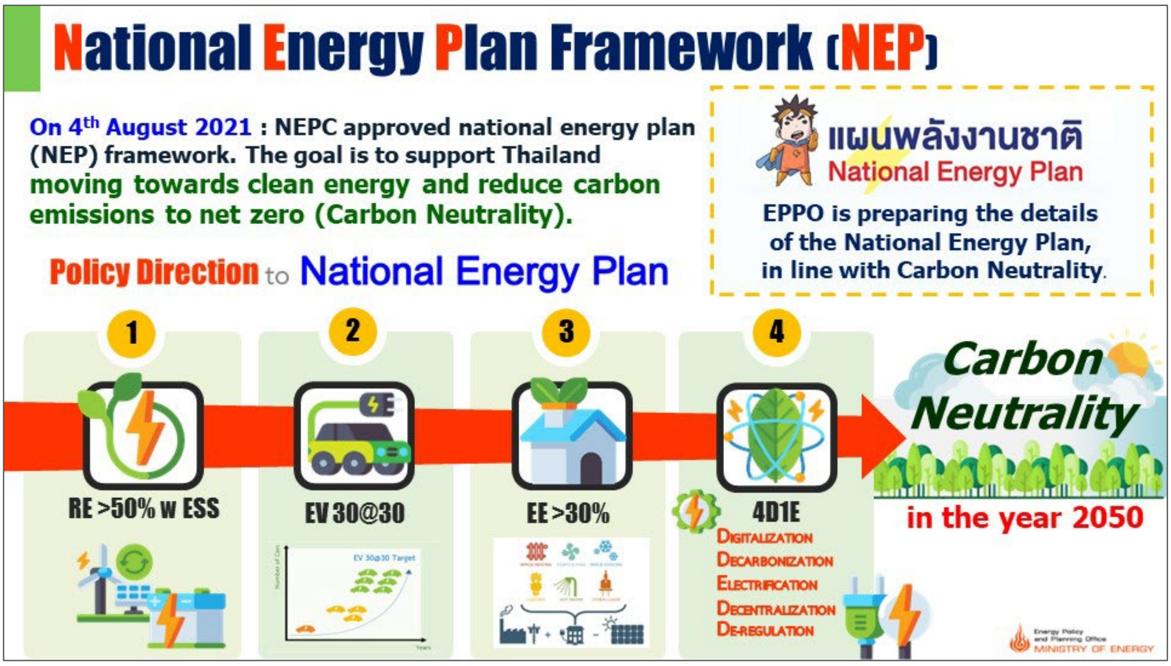
(b)



Source: MONRE (2022).

Figure 3.2. (a) Thailand's Draft National Energy Plan; (b) Details of Key Policies; (c) EV30@30 Target

(a)



(b)

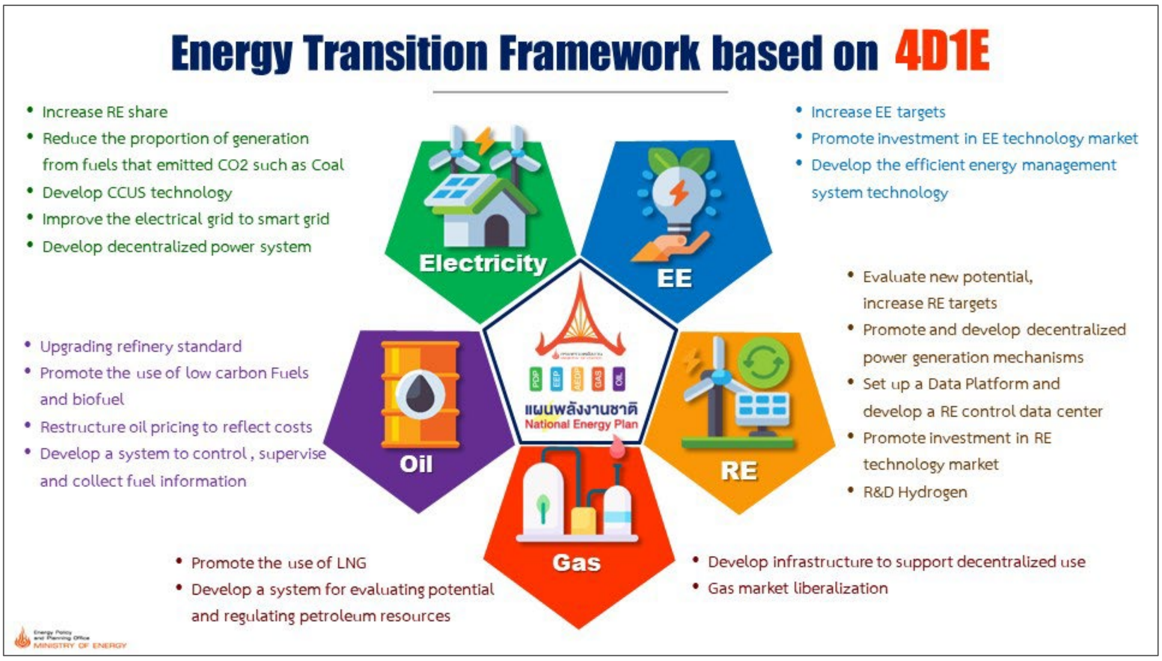


Figure 3.2. ***Continued***

(c)

Target	Type	Unit of ZEV per year		
		2025	2030	2035
Usage	Passenger Car/ Pick Up	225,000 (30%)	440,000 (50%)	1,154,000 (100%)
	Motorcycle	360,000 (20%)	650,000 (40%)	1,800,000 (100%)
	Bus/ Truck	18,000 (20%)	33,000 (35%)	83,000 (100%)
	Tuk-Tuk (Tricycle)	500 (85%)	2,200 (100%)	2,800 (100%)
	Passenger ship	130 (12%)	480 (35%)	1,800 (100%)
	Train*	620 (70%)	850 (85%)	1,170 (100%)
Production	Passenger Car/ Pick Up	225,000 (10%)	725,000 (30%)	1,350,000 (50%)
	Motorcycle	360,000 (20%)	675,000 (30%)	1,850,000 (70%)
	Bus/ Truck	18,000 (35%)	34,000 (50%)	84,000 (85%)
	Tuk-Tuk (Tricycle)	500 (85%)	2,200 (100%)	2,800 (100%)
	Passenger ship	130 (12%)	480 (35%)	1,800 (100%)
	Train*	620 (100%)	850 (100%)	1,170 (100%)

ZEV = zero-emission vehicle.
* Electric train conversion.
Source: Energy Plan and Policy Office (2023).

The National Electric Vehicle Policy Committee, chaired by the Deputy Prime Minister, approved the 30@30 Policy Plan, which establishes a target for 30% zero-emission vehicles (ZEVs) by 2030 to be implemented in three phases as follows.

Phase 1 (2021–2022): The government will promote electric motorcycles and support infrastructure nationwide.

Phase 2 (2023–2025): The EV industry aims to produce and use 225,000 electric cars and pickup trucks, 360,000 electric motorcycles, and 18,000 electric buses/trucks by 2025, including the production of batteries. This first milestone is designed to deliver cost advantages via economies of scale.

Phase 3 (2026–2030): The '30@30 policy' target is to produce 725,000 electric cars and pickups and 675,000 electric motorcycles, accounting for 30% of all automotive production in 2030, including the domestic manufacture of batteries.

In 2022, the cabinet approved supported a scheme for battery electric vehicle (BEV) subsidies for electric vehicle models registered with the excise department under the general production conditions as follows:

- Must be committed to local assembly/production of BEVs.
- By 2024, the local assembly/production of BEV cars/motorcycles must be equal to completely built units (CBUs) imported during 2022–2023.
- In the case of an extension in the local assembly/production of BEV cars/motorcycles until 2025, local production must be at least 1.5x the number of CBU units during 2022–2023.

For the local assembly/production of BEVs, key components, such as batteries, power control unit inverters, and traction motors, must be sourced locally.

The supported models of BEVs (cars, pickups, and motorcycles) will be subsidised as follows from the excise department. There are three vehicle types included in this promoted package: BEV cars (separated into two groups with different retail prices), BEV pickup trucks, and electric motorcycles. The supported schemes are applied to the BEVs sold with promoted packages as followed:

A.1. BEV cars with a price of < B2.0 million. The supported package is comprised of:

- Import duty reduction for CBU BEV cars up to 40% (2022–2023).
- Excise tax reduction from 8% to 2% (2022–2025).
- Monetary support at B70,000/unit for BEVs with batteries < 30 kWh and B150,000/unit for BEVs with batteries > 30 kWh (2022–2025).

A.2. BEV cars with a price of B2.0 million–B7.0 million. The supported package is comprised of:

- Import duty reduction for CBU BEV cars up to 20% (2022–2023).
- Excise tax reduction from 8% to 2% (2022–2025).

B. BEV pickup trucks. The supported package is comprised of:

- Excise tax reduction to 0% (2022–2025).
- Monetary support at B150,000/unit for BEV pickup trucks with batteries > 30 kWh (2022–2025).

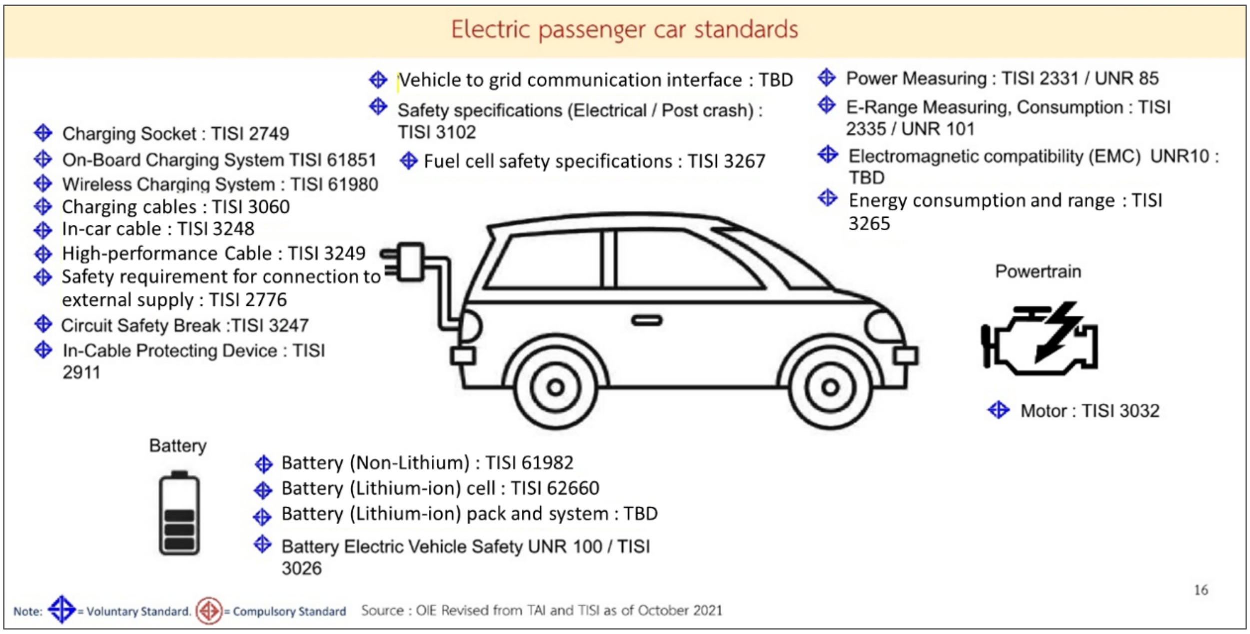
C. Electric motorcycles with a retail price of < B150,000. The supported package is monetary support at B18,000 for BEV motorcycles, both CBU and completely knocked down (CKD) units (2022–2025).

In addition, to enhance people's confidence in EV products, the Thai Industrial Standards Institute (TISI) has progressively issued industrial standards for electric car, electric motorcycle, and charging equipment, as shown in Figure 3.3.

With the abovementioned policies, and especially the 2022 subsidy scheme, new BEV sales increased dramatically in 2022 and continued in 2023. Figure 3.4(a) shows that there was a total of 32,081 EVs registered in Thailand, with 51.6% (16,540) electric motorcycles followed by 43% (13,805) electric cars. In 2022, Figure 3.4(b) shows that there was a total of 20,816 new EVs registered, with 47.6% (9,912) electric motorcycles followed by 46.5% (9,678) electric cars. It is worth noting the sharp increase in just 1 year (2022) alone for sales of new electric cars and motorcycles. This increase continued in 2023, and the 5-month statistics (January–May 2023) in Figure 3.4(c) show more EV sales than accumulated EVs until 2022 with a greater share of electric cars. This sharp increase in EV sales needs to be considered with the current charging infrastructure, shown in Figure. 3.5.

Figure 3.3. Thai Industrial Standards for (a) Electric Cars, (b) Electric Motorcycles, and (c) Charging Equipment

(a)



(b)

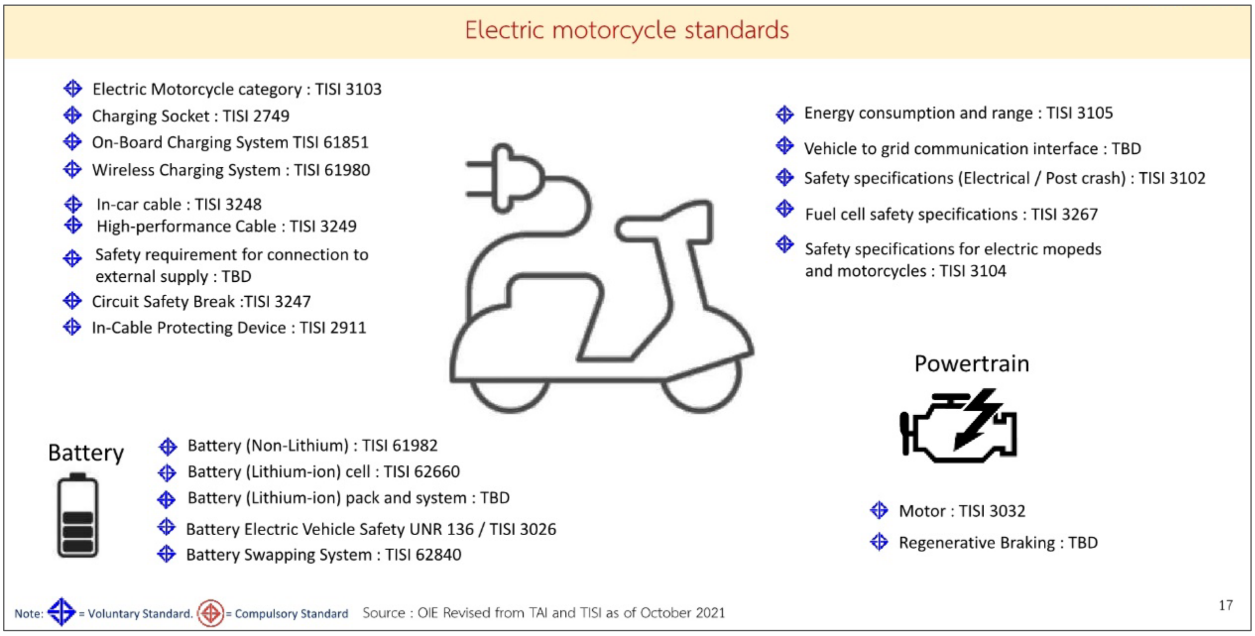
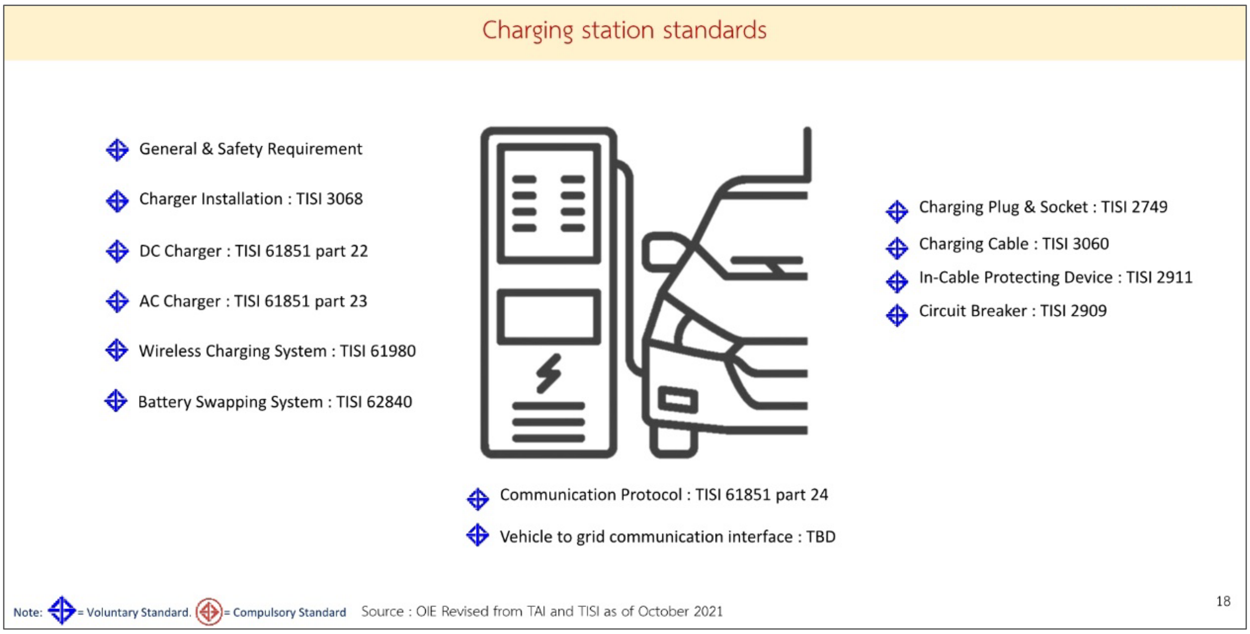


Figure 3.3. ***Continued***

(c)



Source: TISI (2022).

Figure 3.4. Number of xEV Registrations in Thailand: (a) Accumulated Records Up to 2022, (b) New Sale in 2022, and (c) New Sales During January–May 2023

(a)

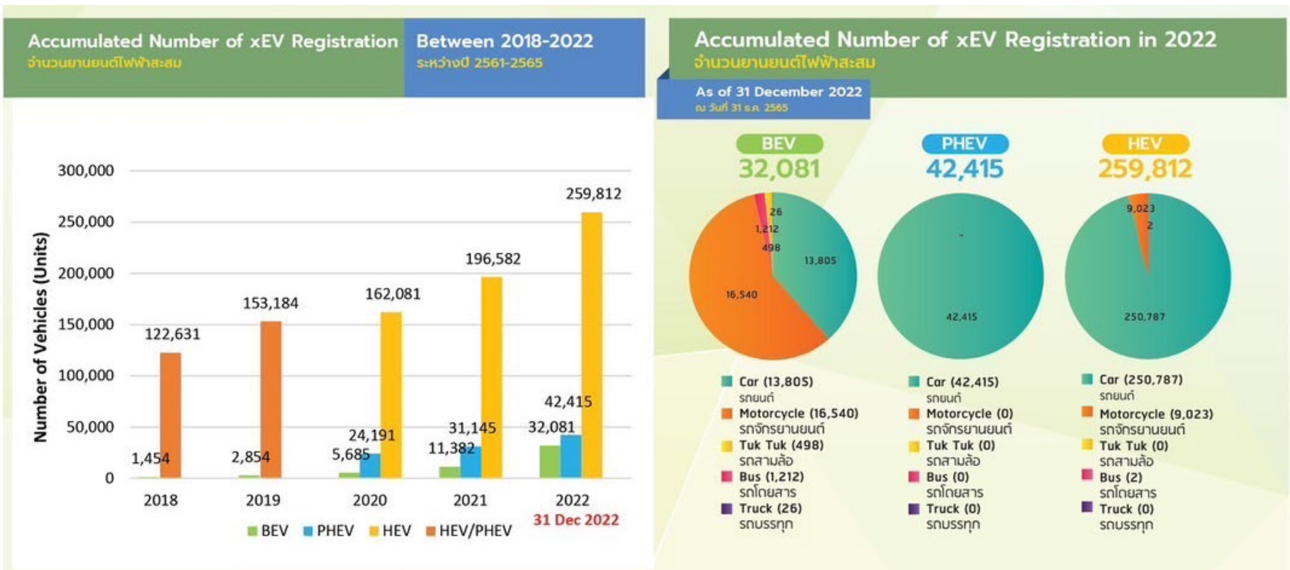
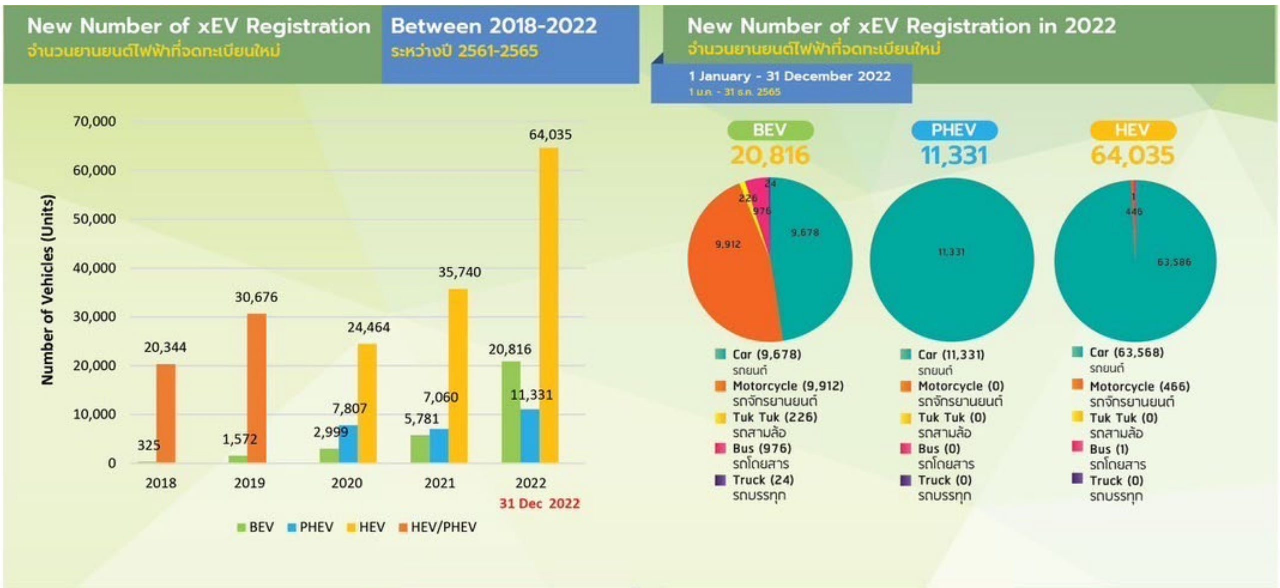
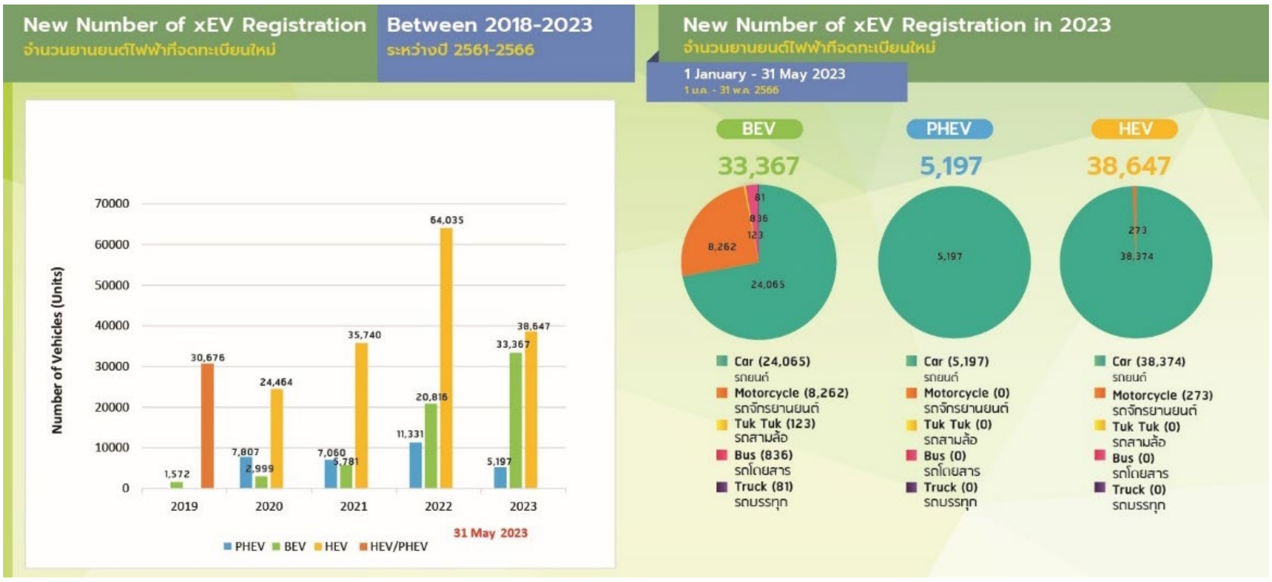


Figure 3.4. ***Continued***

(b)



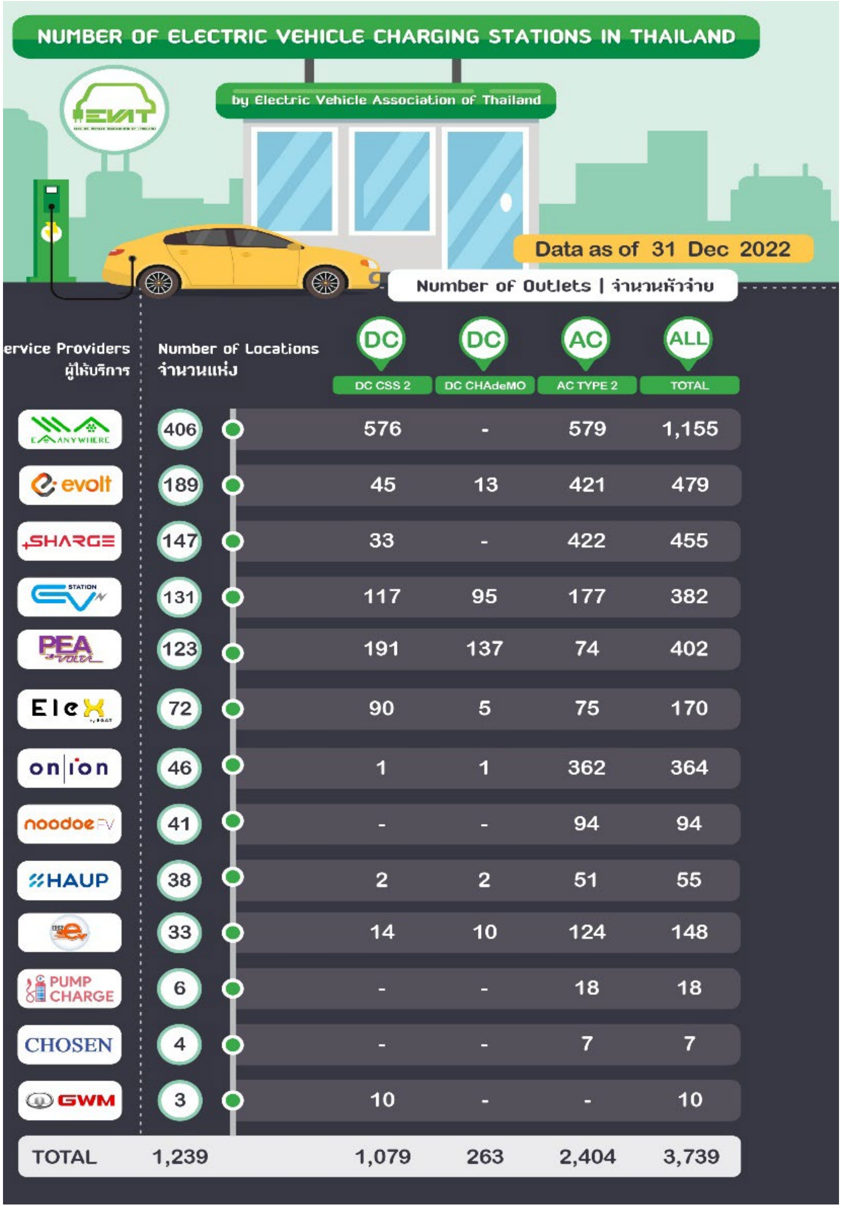
(c)



BEV = battery electric vehicle, HEV = hybrid electric vehicle, PHEV = plug-in hybrid electric vehicle, xEV = electrified vehicle.

Source: EVAT (2022-2023).

Figure 3.5. Number of Charging Stations in Thailand



ervice Providers ผู้ให้บริการ	Number of Locations จำนวนแห่ง	DC CSS 2	DC CHAdeMO	AC TYPE 2	ALL TOTAL
EA ANYWHERE	406	576	-	579	1,155
evolt	189	45	13	421	479
SHARGE	147	33	-	422	455
EV STATION	131	117	95	177	382
PEA VOLTA	123	191	137	74	402
EleX	72	90	5	75	170
on|ion	46	1	1	362	364
noodoe EV	41	-	-	94	94
HAUP	38	2	2	51	55
	33	14	10	124	148
PUMP CHARGE	6	-	-	18	18
CHOSEN	4	-	-	7	7
GWM	3	10	-	-	10
TOTAL	1,239	1,079	263	2,404	3,739

Source: EVAT (2022-2023).

2.1.2. Barriers to EV penetration in Thailand

Although public acceptance of electrified vehicles (xEVs) in Thailand has been reflected in new sales, there are three barriers to EV penetration identified according to the 30@30 plan, namely high insurance for EVs, low numbers of used EVs, and workforce upskilling. Regarding new BEVs, the insurance premium for BEVs can cost twice as much compared to internal combustion engine (ICE) vehicles of a similar retail price. This high insurance is due to the high cost of batteries, which cannot be domestically manufactured, so Thailand needs to solely rely on imports. Furthermore, since many commercially available BEVs in Thailand use Cell2Pack battery architecture, the whole battery pack (instead of the module) needs to be replaced if there is an accident, causing the insurance premium to increase. The second barrier of low used cars is also related to high battery costs, where newer models of BEVs have fewer warranty years for their batteries. The third barrier of the need to upskill the workforce for EVs ranges from the necessity for engineers in the assembly line to mechanics to fix EVs, as well as first responders at scenes of EV accidents for safe handling purposes.

2.13. Mobility scenario in the future

With Thailand having both feedstock resources for bioethanol (from sugarcane and cassava) and biodiesel (from oil palm), biofuel policy will still be part of the National Energy Plan, where E10-E20 and B10 would be solutions to decarbonise the current ICE fleets, whereas EV penetration will help decarbonise new vehicles. Balancing between EVs and ICEs in various vehicle sectors will depend on the total cost of ownership (TCO) comparison between EVs and ICEs.

2.2. Indonesia

During the COP 26 World Leaders Summit in Glasgow, Scotland, in November 2021, President Joko Widodo of Indonesia expressed Indonesia's ongoing contribution to addressing climate change. He emphasised the country's commitment to establishing a carbon net sink by 2030 through the development of an electric car ecosystem and the utilisation of clean energy sources like solar power energy and biofuels (Cabinet Secretariat of the Republic of Indonesia, 2021). In line with this government commitment, several strategic measures have been taken to expedite the advancement of the EV ecosystem in Indonesia. In 2019, the Indonesian President signed Presidential Regulation Number 55, which focuses on accelerating BEV programmes for road transportation. This was followed by the Ministry of Industry's Regulations Number 27 and 28 of 2020, which outline the development roadmap, components, and production of EVs.

2.2.1. Vehicle population and sales projections

According to data from Indonesia's Central Agency on Statistics (BPS), the number of registered vehicles in Indonesia has been consistently increasing. The number reached over 136 million units by the end of 2020 and approximately 148 million vehicles in total by 2022, consisting of 125 million motorcycles, 17 million cars, 237,000 buses, and 5.5 million trucks (BPS Indonesia, 2022). It should be noted that the number of buses may seem small due to the portion of actual buses being constructed from truck chassis. From 2020 to 2035, the Indonesian Ministry of Industry projects the production of four wheelers will increase from 1.5 million units annually to 4 million units, and the production of motorcycles will increase from 8 million units annually to 15 million units. Additionally, 30% of both vehicle types sold in 2035 are expected to be low-carbon emission vehicles, as shown in Table 3.2 (MOI Indonesia, 2020a).

In order to estimate the energy consumption for plug-in hybrid vehicle and battery electric vehicle charging, the National Electricity Company of Indonesia (PLN) projected the breakdown percentage of xEVs and predicted that they will reach 2.5% of domestic sales in 2025 (Table 3.3 and Figure 3.6).

Table 3.1. Number of Vehicles by Type in Indonesia

	2015	2016	2017	2018	2019	2020	2021*	2022*
Passenger Cars	12,304,221	13,142,958	13,968,202	14,830,698	15,592,419	15,797,746	16,457,552	17,241,115
Buses	196,309	204,512	213,359	222,872	231,569	233,261	234,561	237,157
Utility/Cargo	4,145,857	4,326,731	4,540,902	4,797,254	5,021,888	5,083,405	5,309,501	5,571,382
Motorcycles	88,656,931	94,531,510	100,200,245	106,657,952	112,771,136	115,023,039	120,080,555	125,302,025

* Estimation from vehicle wholesales from Gaikindo and AISI.
Source: BPS Indonesia (2022); Gaikindo (2023); AISI (2023).

Table 3.11. Indonesian Vehicle Sales Projections

Item			2020	2025	2030	2035
Motor Vehicles	Production	Total (Units)	1,500,000	2,000,000	3,000,000	4,000,000
		Percentage LCEV (%)	10	20	25	30
		Percentage LCGC (%)	25	20	20	20
	Sales	Total (Units)	1,250,000	1,690,000	2,100,000	2,500,000
	Exports	Total (Units)	250,000	310,000	900,000	1,500,000
Motorcycles	Production	Total (Units)	8,000,000	10,000,000	12,500,000	15,000,000
		Percentage Electric Motorcycle (%)	10	20	25	30
	Sales	Total (Units)	7,500,000	9,000,000	11,000,000	13,000,000
	Exports	Total (Units)	500,000	1,000,000	1,500,000	2,000,000

LCEV = low-carbon emission vehicle, LCGC = low-cost green car.
Source: MOI Indonesia (2020a).

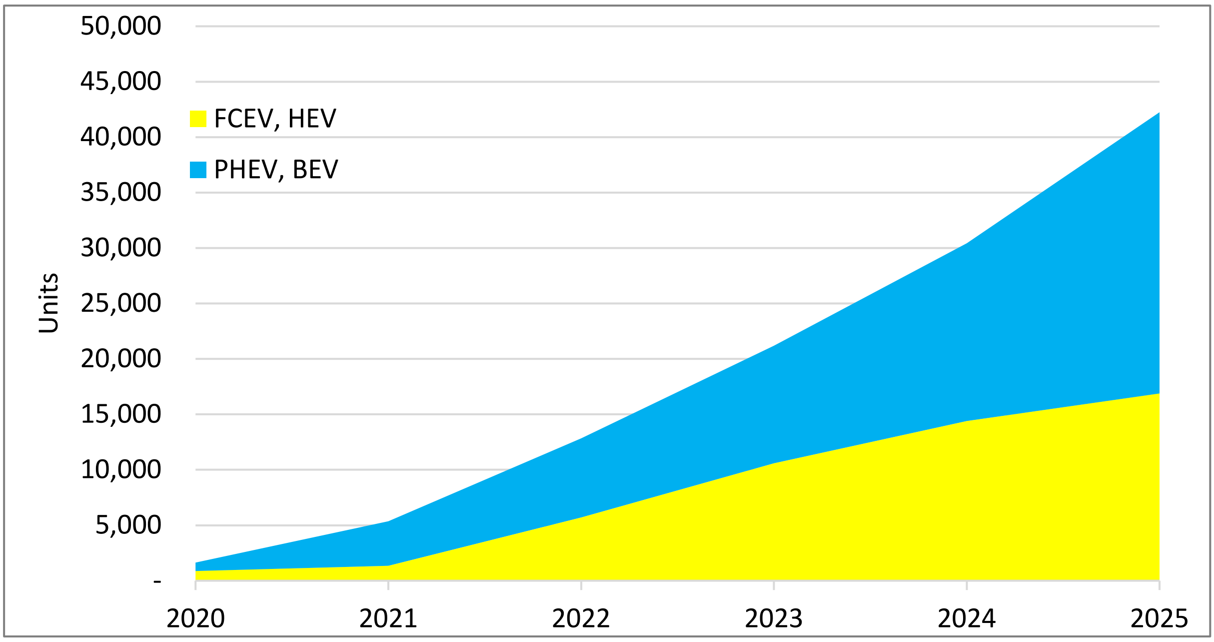
Table 3.12. EV Sales Projections by Indonesia's State Electricity Company

Parameter	2020	2021	2022	2023	2024	2025
Total	1,500,000	1,600,000	1,700,000	1,800,000	1,900,000	2,000,000
Wholesales	1,250,000	1,338,000	1,426,000	1,514,000	1,602,000	1,690,000
% Passenger Car	78.9%	78.9%	78.9%	78.9%	78.9%	78.9%
Passenger Car	986,124	1,055,547	1,124,971	1,194,394	1,263,817	1,333,240
Subtotal Sedan and Non-sedan	647,077	734,257	790,684	846,230	900,896	952,992
Energy Saving Car	310,423	315,938	321,456	326,968	332,483	337,998
% FCEV, HEV from Wholesales	0.07%	0.10%	0.40%	0.70%	0.90%	1.0%
% PHEV, BEV from Wholesales	0.06%	0.30%	0.50%	0.70%	1.00%	1.5%

Parameter	2020	2021	2022	2023	2024	2025
% xEV	0.13%	0.4%	0.90%	1.40%	1.90%	2.50%
FCEV, HEV	875	1,338	5,704	10,598	14,418	16,900
PHEV, BEV	750	4,014	7,130	10,598	16,020	25,350
Total Wholesales xEV	1,625	5,352	12,834	21,196	30,438	42,250

Source: Indonesia State Electricity Company (2020).

Figure 3.6. xEV Wholesale Projections



Source: Indonesia State Electricity Company (2020).

2.2.2. Indonesia's electric vehicle ecosystem

a. Indonesia's vehicle electrification policy

Currently, several Indonesian regulations have been implemented to accelerate and enforce the growth of the EV ecosystem. Presidential Regulation No. 55 of 2019 regarding the Acceleration of Battery Electric Vehicle Programs for Road Transportation was the policy that organised local content, incentives, infrastructure preparation, registration, and identification of vehicle electrification. Further monetary incentives were laid down by regulations such as Indonesian Government Regulation No. 8 of 2020, No. 74 of 2021, Jakarta Governor Regulation No. 3 of 2020, and Minister of Finance Regulation No. 38 of 2023, which followed the initial scheme to increase the market penetration of EVs.

With regard to the charging station infrastructure, specification, and safety and standards, the Minister of Energy and Mineral Resources published Regulation No. 1 of 2023 relating to the electric charging station infrastructure to initiate the preparation of EV ecosystems. Further, Presidential Decree No. 7

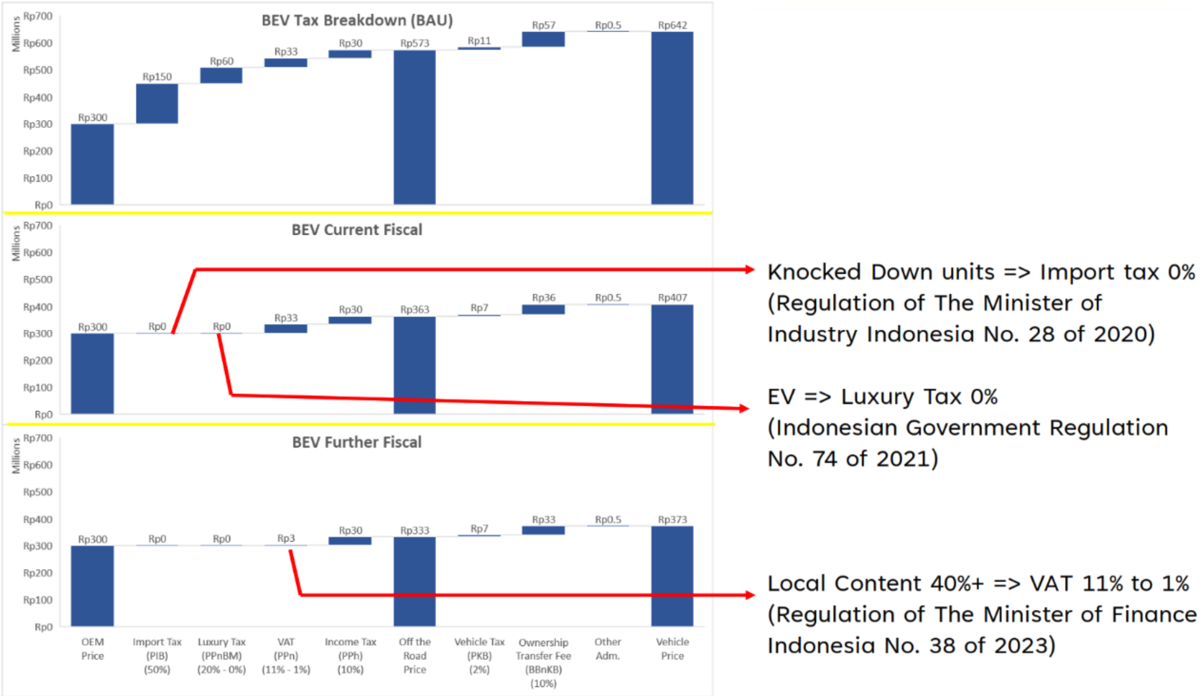
of 2022 enforces the use of BEVs as operational service vehicles for the central government and regional governments to accelerate EV usage by procuring new EVs or converting ICEs to EVs. Meanwhile, non-monetary incentives, such as the exemption of BEVs from license plate number-based road access limitations ('Ganjil-Genap'), have been implemented by Jakarta Governor Regulation No. 88 of 2019.

b. BEV tax breakdown

Vehicle purchasing in Indonesia is subject to several taxes regulated by the government and the Ministry of Finance. The current market situation shows that most EVs cost more than ICEs in the same segments. This is unsurprising as battery costs can be significant for EVs. In addition, for imported CBU vehicles, of which EVs in Indonesia tend to be, at least during the start, taxes levied can be high. Therefore, tax incentives have been issued to reduce the price gap between EVs and ICEs to increase the attractiveness of EVs.

Figure 3.7 shows the tax breakdown with several scenarios. The business-as-usual (BAU) scenario shows the typical tax breakdown for vehicles sold in Indonesia. As can be seen, the final cost paid by the customer can be twice the original equipment manufacturer cost. The current fiscal regime shows the lifting of the import and luxury taxes, which cuts approximately 36% of the EV price. Recently, the Ministry of Finance issued Regulation No. 28 of 2023. Therefore, in the future, the prices are expected to drop further with the reduction of value-added tax from 11% to 1% for EVs produced in Indonesia with local content higher than 40%.

Figure 3.7. BEV Tax Breakdown: BAU, Current, and Further Implementation



Source: Calculations from current study.

With regard to hybrid vehicles, including plug-in hybrids, according to Indonesian Government Regulation No. 74 of 2021, the luxury tax reduction can be applied based on fuel consumption or the emissions of a vehicle type as long as the gasoline/diesel engine capacity is less than 3,000 cc. The amount of the tax reduction is shown in Table 3.4.

Table 3.4. Hybrid EV Luxury Tax Reduction

HEV Type	Conditions Fulfilled			Reduction of Luxury Tax		
	Fuel Consumption (km/L)		**Emission (gr/km)**	**Initial Luxury Tax**	**Luxury tax reduced to % of initial**	**Final Luxury Tax**
Gasoline	>23	OR	<100	15%	40.0%	**6%**
Diesel	>26		<100	15%	40.0%	**6%**
Gasoline	15.5-18.4		125-150	15%	53.3%	**8%**
Diesel	17.5-20		125-150	15%	53.3%	**8%**
Gasoline	18.4-23		<125	15%	46.6%	**7%**
Gasoline	20-26		<125	15%	46.6%	**7%**
Gasoline Plug-in HEV (PHEV)	>28		<100	15%	33.3%	**5%**

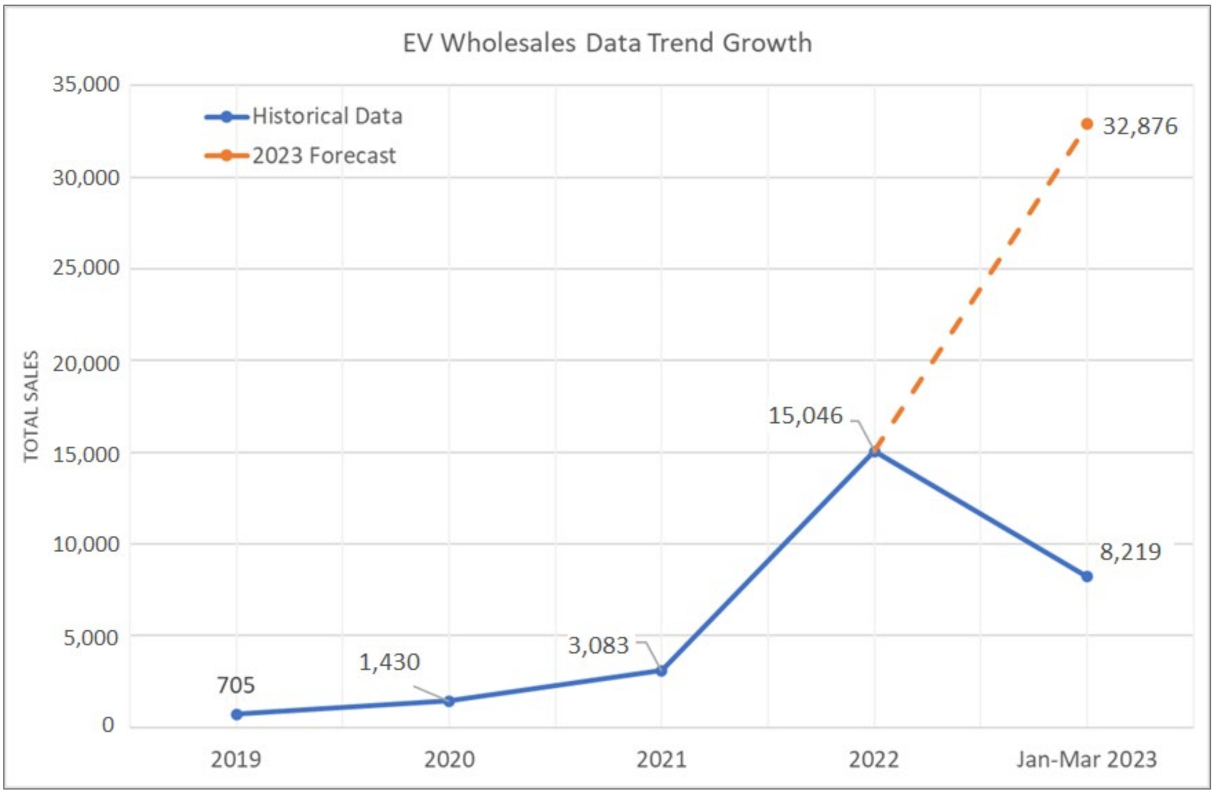
Source: Indonesian Government Regulation No. 74 of 2021.

c. **Indonesia's EV wholesales**

The Association of Indonesian Automotive Industries (GAIKINDO) publishes the sales volumes of EV wholesales annually as shown in Figure 3.8 and Tables 3.5 and 3.6. The historical data shows 100% sales growth each year until 2021, then growth increases almost fivefold in 2022. Based on this, vehicle sales are expected to increase up to 32,000 by the end of 2023 as shown in Figure 3. The composition of the total sales shows that 53.08% of the sales were HEVs, 46.67% were BEVs, and 0.25% were PHEVs (GAIKINDO, 2023).

Table 3.6 shows the details for EV wholesales by brand and type from 2019 until March 2023. With the introduction of new types and new brands, a large increase in EV wholesales can be seen from 2022. The Wuling Air EV shared the biggest EV portion of the 2022 sales and the Toyota Innova Zenix in the hybrid segment in early 2023.

Figure 3.8. EV Wholesales by Year



Source: GAIKINDO (2023).

Table 3.13. EV Wholesales by Vehicle Type

	2019	2020	2021	2022	2023*	Total
BEV	0	319	798	10,327	1,800	13,244
PHEV	20	6	35	10	1	72
HEV	685	1,105	2,250	4,709	6,314	15,063
Motorcycle	1,248	11,789	13,898	31,827**		58,762

Note: * : January–March; ** : January–October.
Source: GAIKINDO (2023).

Table 3.14. Details of 4-Wheeler EV Wholesales

No.	Brand	Type/Model	Fuel	2019	2020	2021	2022	Jan–Mar 2023
1	BMW	2Z62 I8	Hybrid		1			
		32AA X1 sDrive18i	Hybrid		1	2		
		i3s A/T	Hybrid			2		
		iX xDrive40 A/T	BEV					29
2	DFSK	Glory I-Auto	BEV		198	91		
		Gelora EC35 Blind Van (4X2) A/T	BEV			1	5	8
		Gelora EC36 Minibus 1.5 (4X2) A/T	BEV			1	6	18
3	Hyundai	Ioniq EV Prime	BEV		15	27	4	
		Ioniq EV Signature	BEV		45	201	41	
		Ioniq EV	BEV		22			
		Kona EV	BEV		38	360	20	
		Genesis G80 EV	BEV				134	
		Ioniq 5 Prime Reguler	BEV				36	10
		Ioniq 5 Prime Extended	BEV				79	73
		Ioniq 5 Signature Reguler	BEV				197	70
		Ioniq 5 Signature Extended	BEV				1,517	886
4	KIA	EV6	BEV					12
5	Lexus	Lexus GS450 Hybrid	Hybrid					
		Lexus LS 500 Hybrid	Hybrid				9	1
		Lexus UX 300e	BEV		1	22		
		ES 300 h	Hybrid			41	106	44
		UX 250h	Hybrid				18	
		UX 300e	BEV			26	127	27
		ES 300h Ultra Luxury	Hybrid			3	0	
		RX 350h	Hybrid					67
		RX 450h+	Hybrid					7
6	Mercedes Benz	EQS 450+ (V297)	BEV					13
7	Mini	Cooper SE Hatch A/T	BEV				32	17
8	Mitsubishi	Minicab Miev 2-Seater 4X2 A/T	BEV					1
		Minicab Miev 4-Seater 4X2 A/T	BEV					5
		Outlander PHEV	PHEV	20	6	35	10	1
9	MG Motor	ZS EV	BEV					2
10	Nissan	KICKS E-POWER	Hybrid		153	592	467	40

No.	Brand	Type/Model	Fuel	2019	2020	2021	2022	Jan–Mar 2023
		Leaf	BEV			42	63	26
		New X-Trail Hybrid 2.0 CVT	Hybrid					
11	Suzuki	All New Ertiga GX Hybrid MT	Hybrid					425
		All New Ertiga GX Hybrid AT	Hybrid					878
		All New Ertiga SS Hybrid MT	Hybrid					182
		ALL New Ertiga SS Hybrid AT	Hybrid					622
12	Toyota	All New Camry 2.5 Hybrid Mi	Hybrid	223	130	279	284	50
		All New Corolla Altis 1.8 Hybrid A/T	Hybrid	38	41	94	196	46
		All New Kijang Innova Zenix G Hev Cvt 2.0	Hybrid				422	597
		All New Kijang Innova Zenix V Hev Cvt 2.0	Hybrid				361	459
		All New Kijang Innova Zenix V Hev Cvt 2.0 Mod	Hybrid				534	761
		All New Kijang Innova Zenix Q Hev Cvt Tss 2.0	Hybrid				1,202	1,705
		Alphard 2.5 Hybrid	Hybrid	2				
		BZ4X EV	BEV				1	64
		Century Hybrid 5.0 A/T	Hybrid			1		
		Coms EV	BEV			20		
		Corolla Cross 1.8 A/T Hybrid	Hybrid		652	1,070	1,000	291
		Corolla Cross 1.8 A/T Hybrid GR Sport	Hybrid				1	119
		Crown 2.5 Hybrid	Hybrid	102				
		C+pod EV	BEV			7	12	
		C-HR 1.8 A/T Hybrid	Hybrid	320	126	157	109	20
		Prius	Hybrid		1	9		
13	Wuling	Air EV Standard Range	BEV				1,194	2
		Air EV Long Range	BEV				6,859	537
		Almaz RS Hybrid						104
Total				**705**	**1,430**	**3,083**	**15,046**	**8,219**

Source: GAIKINDO (2023).

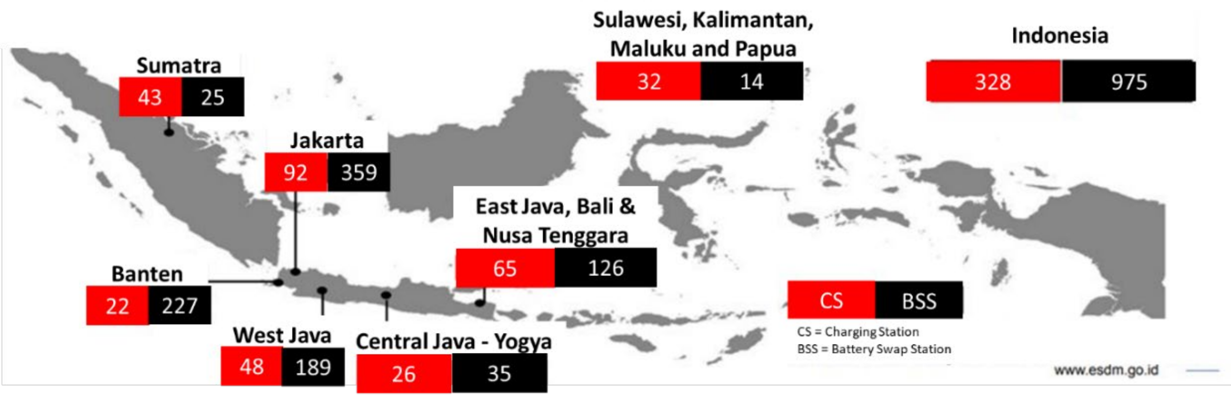
Based on the sales comparison between items, it would seem that for both BEVs and HEVs customers tended towards the higher-end models within a series. For example, in the BEV category, the Hyundai Ioniq 5 Signature sold significantly more (1,714 units) than the lower-tier Ioniq 5 Prime (115 units) in 2022. Meanwhile, for the HEV category, the same trend can be seen between the Kijang Innova Zenix variants Q (highest tier) with 1,202 units sold, V with 895 units, and G (lowest tier) with 422 units sold in 2022.

In addition, long-range variants are more desirable compared to base models, as can be seen from the significantly higher sales for extended variants of the Wuliing Air EV and the Hyundai Ioniq 5 Prime and Ioniq 5 Signature. The Wuling Air EV extended range sold around six times more than its standard range variant. The Ioniq 5 Signature extended range also sold more than seven times its standard range variant. Interestingly, for the lower tier Ioniq 5 Prime, the extended range version only sold twice the number of standard range units sold. This may indicate that customers are averse to the range limitations of BEVs, and customers with more disposable income would tend more towards avoiding range limitations.

d. Indonesia's EV charging infrastructure

Infrastructure preparation for EV charging stations has been developed by the government and national companies. As of December 2022, there were 328 charging stations and 975 battery swap stations in Indonesia, mostly placed on the islands of Java and Bali (Ministry of Energy and Mineral Resources, 2023).

Figure 3.9. Map of Charging and Battery Swap Stations, as of December 2022

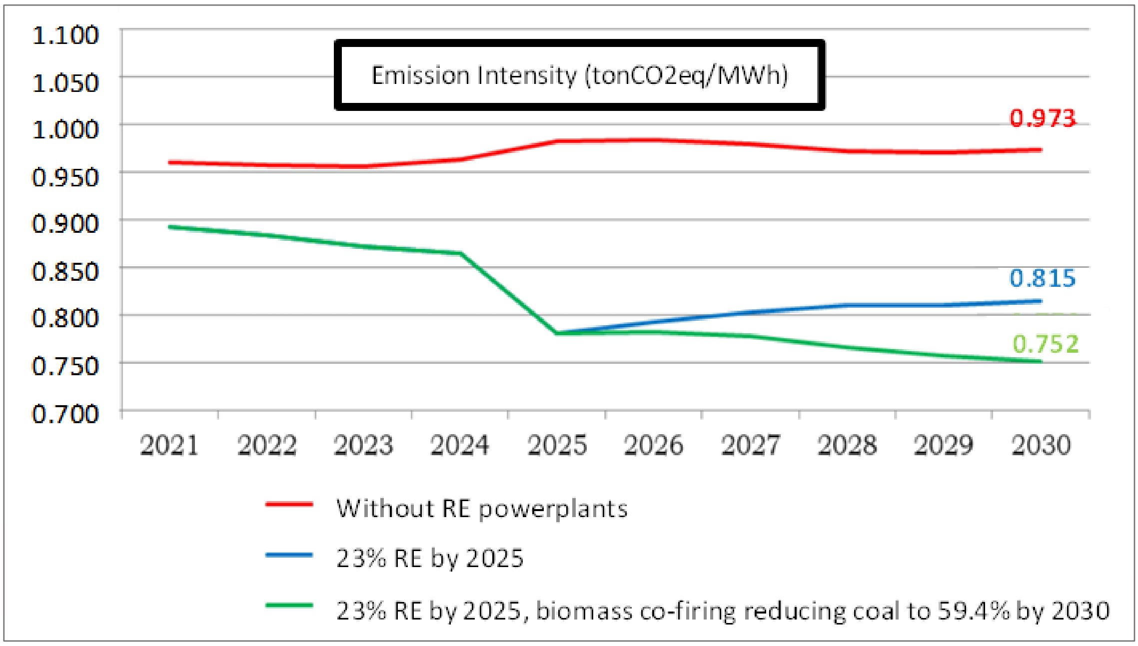


Source: Ministry of Energy and Mineral Resources (2023).

e. Indonesia's electric grid emissions

It should be noted that Indonesia's electric power generation contains a large portion of coal power plants. Therefore, the grid electricity emission factor of the State Electricity Company (PLN) tends to be high. According to the National Electricity Supply Business Plan (RUPTL) 2021–2030 released by the PLN, the projected carbon emissions intensity from power generation will be 0.752 tonnes CO_2 eq/MWh in 2030, assuming a renewable energy share of 23% and the utilisation of coal-biomass co-firing. Without power from renewable sources, the emission intensity will be 0.973 tonnes of CO_2 eq/MWh as shown in Figure 3.10.

Figure 3.10. Grid Electricity Emissions



RE = renewable energy.

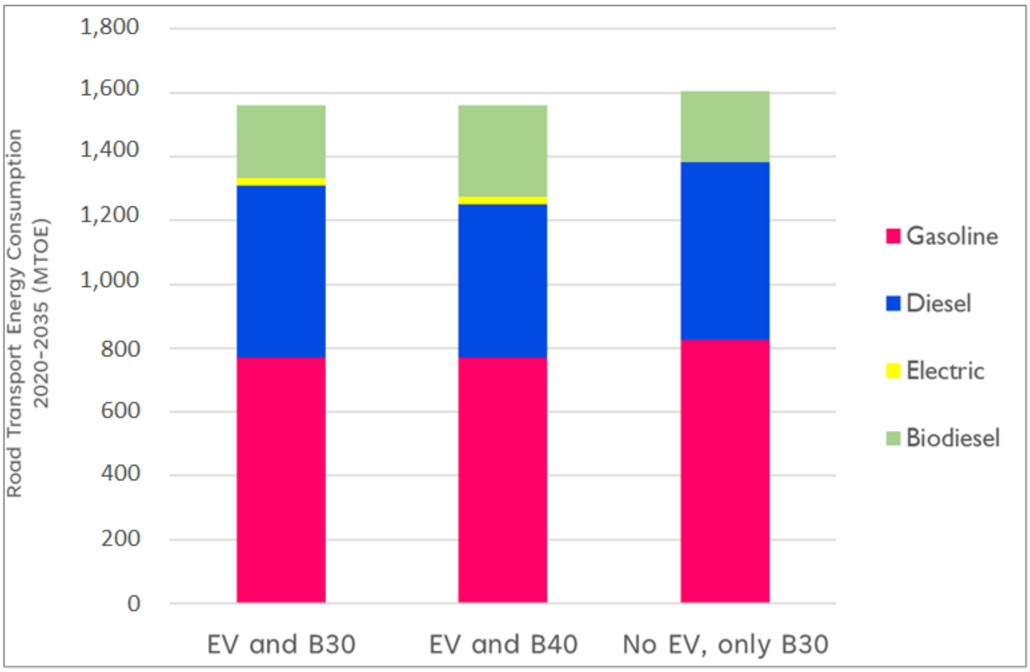
Source: Indonesia State Electricity Company (2021).

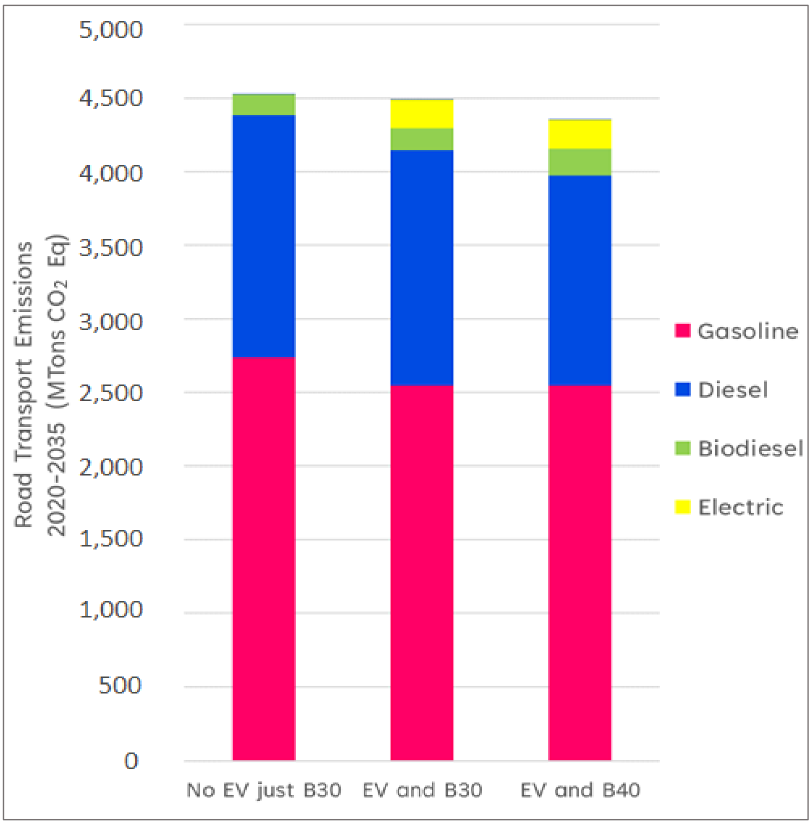
f. Modelling the government's xEV plan

The road transport energy consumption and emissions comparisons based on the Ministry of Energy targets given in Table 3.2, as shown in Figure 3.11, were calculated with the following assumptions:

1. All multi-wheel xEVs are BEVs.
2. Implementation of electric motorcycles
3. Car average annual mileage: 18,726 km/year
4. Bus and truck average annual mileage: 36,000 km/year
5. Motorcycle average annual mileage: 10,080 km/year

Figure 3.11. Comparison of Road Transport Energy Consumption and Emissions





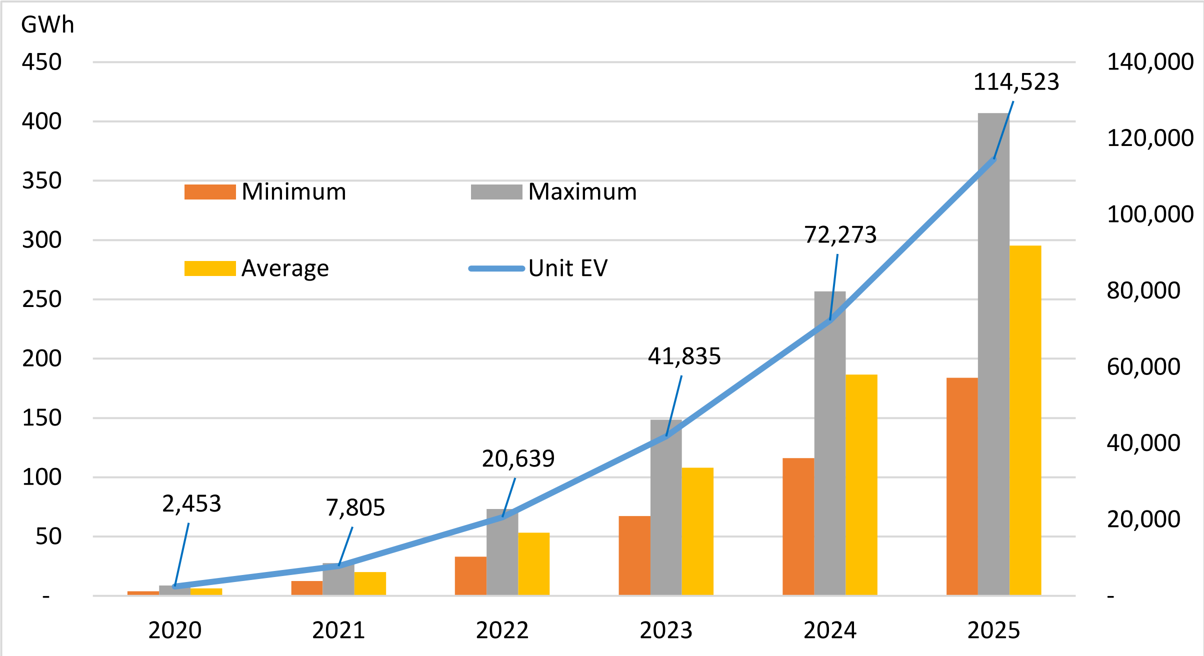
Source: Authors.

Due to the higher efficiency of BEVs, the total energy consumption will be reduced as more BEVs are introduced into the vehicle mix. However, the emissions reduction effect of xEVs is still limited due to the large specific emissions of Indonesian power generation on account of the large portion of coal-based power plants in the energy mix. Further, the number of xEVs in the vehicle population is small compared to the existing population of fossil fuel road vehicles. Therefore, the implementation of B40 gives a larger emissions reduction compared to the implementation of BEVs as older vehicles are also involved in reducing emissions through the usage of biodiesel. Therefore, to accelerate carbon reduction via electrification, it is thus important to improve the specific emissions by using more renewable energy power plants and establishing a policy to trade in old vehicles.

Figure 3.12 shows the results of an alternative calculation done using the PLN's vehicle forecast for the estimation of electrical energy demand due to new BEVs with the following assumptions:

1. Minimum annual mileage: 8,500 km/year
2. Maximum annual mileage: 18,800 km/year
3. Average annual mileage: 13,650 km/year
4. Energy consumption: 0.189 kWh/km
5. EV Units based on the PLN's forecast

Figure 3.12. Electrical Energy for EV Demand Forecast



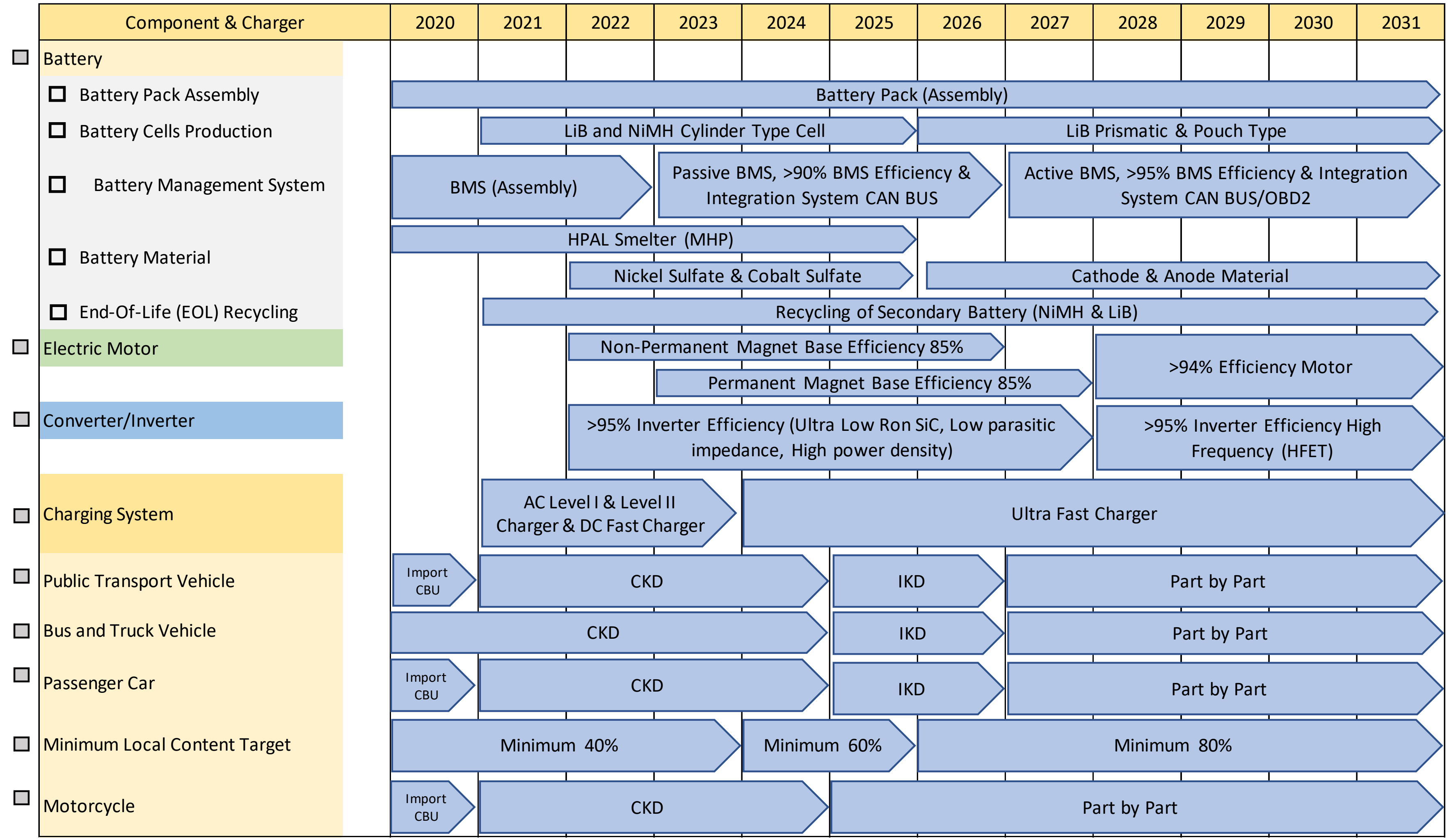
Note: Calculations based on Indonesia State Electricity Company (2021).
Source: Authors.

The planned electricity production in Java and Bali based on National Electricity Supply Business Plan is 205,536 GWh (2021) and 292,345 GWh (2030). Meanwhile, the Ministry of Energy forecasts 3 million electric cars and 15 million electric motorcycles in 2030, which will use approximately 30,000 GWh of electricity for energy recharging purposes, comprising approximately around 10% of the production of electricity in Java and Bali at that time.

g. BEV Components Roadmap

The Ministry of Industry has published a roadmap for EV components and chargers with specified targets until 2031 as shown in Figure 3.13. The roadmap is expected to enforce and guide the EV components manufacturers to implement the technologies and vehicle assembly.

Figure 3.13. Battery Electric Vehicle Components Roadmap



Source: Ministry of Industry (2022)

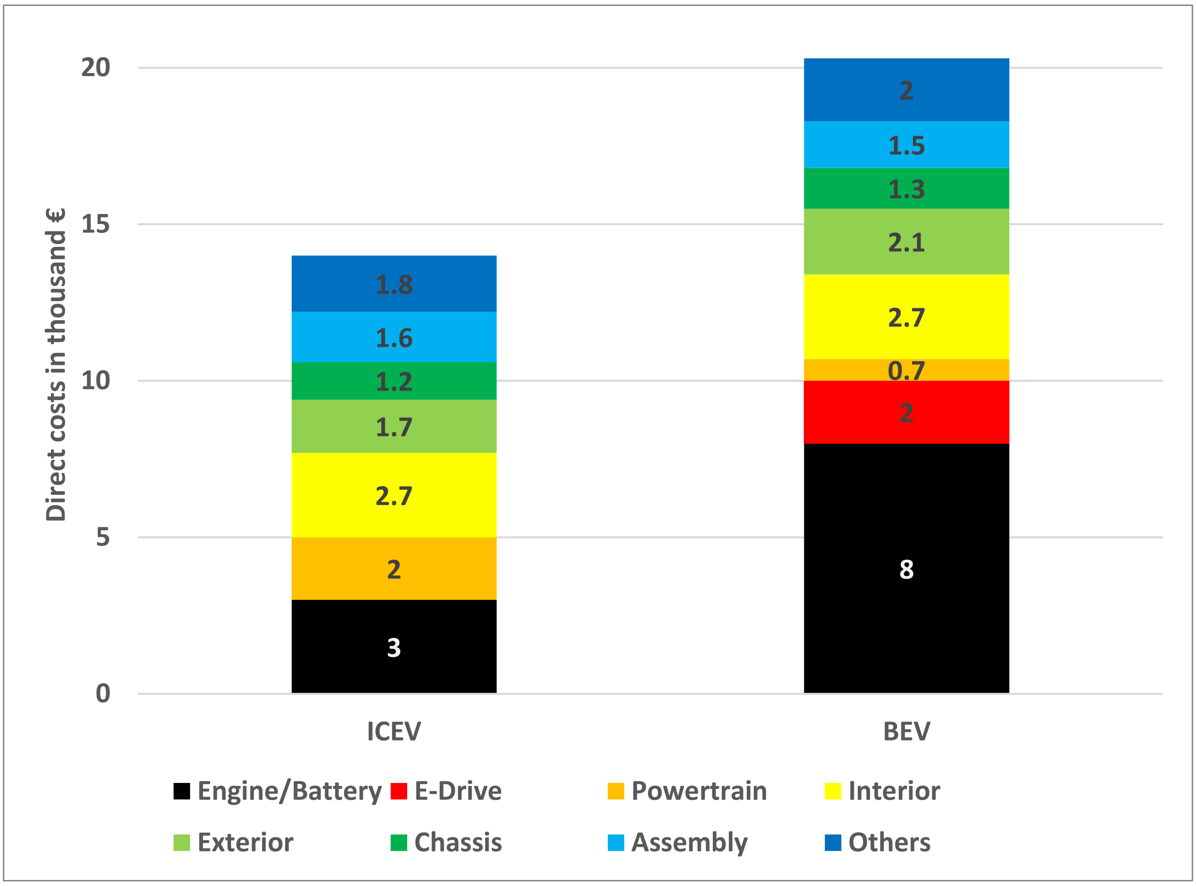
h. Challenges to developing the EV ecosystem

Based on the above, the barriers and challenges to developing the EV ecosystem in Indonesia are as follows:

- **Vehicle price**

EVs are generally more expensive than ICEs of the same class. The cost of EVs is mostly due to the high cost of batteries as the battery manufacturing cost comprises about 40% of the EV price, as shown in Figure 3.14 (Konig, 2021). In addition, whilst costs of battery production have reduced significantly within the last decade (Figure 3.15), the volume-weighted battery price rose in 2022 to an average of US$151/kWh (BloombergNEF, 2022), which might cause some disruptions to plans to decrease the price of EVS that have already forecasted a reduction in the battery price in the future.

Figure 3.14. Cost Structure of Current and Future BEVs Compared to ICEVs



Source: Konig (2021).

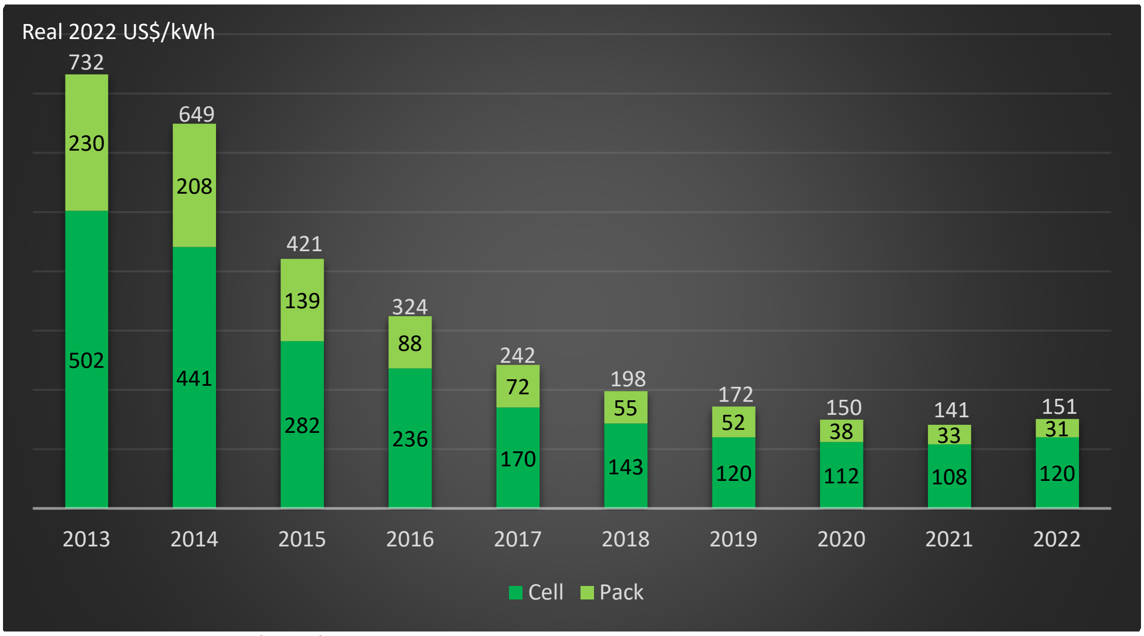
The issue of tax incentives as currently conducted by the government can mitigate this issue by narrowing the price gap between EVs and ICE vehicles. Additional non-monetary incentives, such as exemption from the vehicle access limitation rules can also increase the attractiveness of EVs. Localizing the production of EVs and their parts can contribute towards lowering costs, either by allowing access to tax reductions or by lowering production costs.

Currently, the Government of Indonesia, through the Ministry of Industry, is preparing strategic moves, such as the localisation of battery and other EV parts manufacturing to further reduce EV prices in Indonesia (MOI, 2022). Now, the buyers of EV cars enjoy further subsidies with a 10% reduction in value-added tax (VAT) if the EV production has a local content of at least 40% (MOF, 2023).

- **Driving range and charging times**

The sales trend of EVs shows that consumers tend to be wary of the limited range of EVs, thus preferring extended range variants and therefore limiting the market for lower range EVs, which are cheaper. The addition of infrastructure in the form of more public fast charging stations can contribute towards reducing this 'range anxiety'. Furthermore, the rate of charging is another important issue to consider since rapid charging might be a good solution to tackle range anxiety for long driving purposes, but these rapid charging stations demand high-intensity electricity infrastructure, which is also costly. In addition, power generation capacity must also be planned and constructed with this larger electricity demand in consideration.

Figure 3.15. Volume-weighted Average Li-ion Battery Pack and Cell Price Splits



Source: BloombergNEF (2022).

- **Reluctance to transition**

The transition towards EV usage mostly occurs in the wealthier populace. Whilst the high cost of EVs certainly contributes to this fact, the lack of familiarity with EVs or EV systems may also be an issue, as the wealthier populace can tolerate or afford a higher risk compared to the average Indonesian. Therefore, easing the transition via hybrid vehicles can be a possible option, as hybrid vehicles still feature the use of more familiar gasoline or diesel engines and, thus, can consume the more readily available gasoline or diesel fuels.

However, at the moment, incentives for hybrid vehicles are not as attractive as for BEVs. A more attractive incentive scheme for hybrid vehicles may lead to the acceptance of the populace to convert gradually by first using hybrids, which already contain EV technology, and still enjoy the benefit of the energy efficiency of EVs.

2.2.3. Biofuels development versus electric vehicle development

Considering the huge availability of both bioresources and other renewable energy resources inside the country, the Government of Indonesia has chosen not to prioritise EV development over biofuel development and, instead, is implementing both EV and biofuel development to accelerate the transition towards sustainable mobility. This is in line with the government's decision to set a target of achieving net-zero emissions by 2060.

On the biofuel side, Indonesia last year successfully tested the utilisation of B40 (a mixture of 40%-v palm biodiesel and 60%-v fossil diesel) and just recently started to increase the diesel fuel mix utilisation from B30 to B35. The utilisation of gasohol (a blend of fossil gasoline and bioethanol), which has been stopped for about 10 years due to a lack of financial incentives, will also be restarted in the form of E5 (5%-v bioethanol, 95%-v fossil gasoline) programmes in some areas of East Java province, where several fuel-grade bioethanol factories are located. Driven by the large availability of fatty oils (especially palm oil) inside the country, Indonesia is also developing the production and utilisation of various fatty oil-based bio hydrocarbon fuels, such as bio gasoline, bio hydrocarbon diesel, and jet biofuel.

In further attempts for the transition towards clean and sustainable mobility, the Government of Indonesia has recently also promoted the development of hydrogen fuel for use in fuel-cell vehicles (FCVs) as well as ICE vehicles. In this context, cost-effective ways of transporting and storing hydrogen will clearly be needed.

Thus, to summarise, the mobility scenario for Indonesia includes the development of EVs, biofuels, and hydrogen fuel.

2.3. India

To mitigate the climate change concern, India has targeted achieving net zero by 2070. To obtain sustainable energy security, India is going to increase not only the deployment of 45% renewable energy in its energy mix, primarily in the electricity sector, by 2030 but is also promoting biofuels and EVs on a larger scale. India aims for 20% ethanol blending by 2025 from the current 10% blending. The main objective of ethanol blending is to reduce India's petroleum imports and pollution emissions. Through 20% ethanol blending, India can save Rs1 trillion in foreign exchange.

However, the focus for larger reductions in transport pollution is the deployment of EVs on a larger scale. Currently, India has around 1.3 million EVs. The domestic EV market is expected to grow at a compound annual growth rate (CAGR) of 49% between 2022 and 2030 and is expected to hit 10 million units in annual sales by 2030 with 80% of new vehicle sales being electric by 2040. The government intends to have EV sales penetration of 30% for private cars, 70% for commercial vehicles, and 80% for two- and three-wheelers by 2030. Currently, India has about 5,151 charging stations, and this number is expected to reach 10,000 by 2025. There are about 400 EV manufacturers. Until 2022, EVs have brought reductions in carbon emissions of around 2,656.2 kilotonnes.

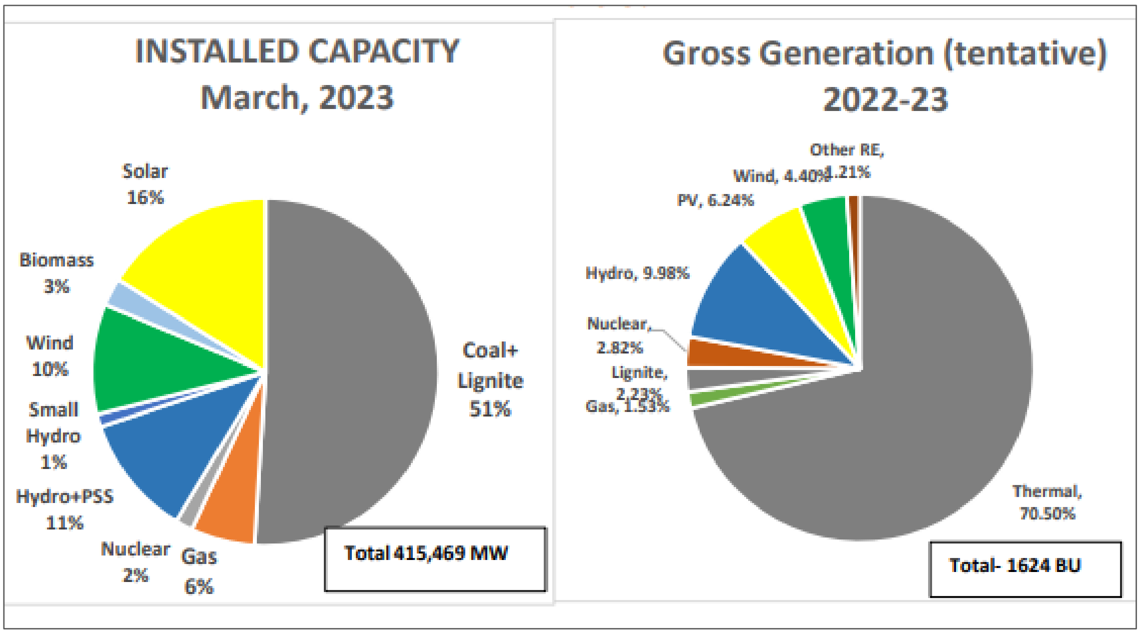
The second phase of the Faster Adoption and Manufacturing of Electric Vehicles (FAME) Scheme provides an opportunity to reflect on India's recent progress and the required next steps for moving towards an electric mobility future.

The FAME II scheme will cumulatively save 5.4 Mtoe of oil demand over its lifetime. This will result in a net reduction of 170 petajoules of energy and 7.4 million tonnes (MT) of CO_2 emissions over the deployed vehicles' lifetime.

- *India's fuel mix*

As of March 2023, the installed electricity capacity of the country was 415.4 GW, which comprised 236.68 GW from thermal (211.8 GW from coal and lignite; 24.8 GW from gas), 6.78 GW from nuclear, 171.8 GW from renewable energy (42.1 GW from hydro; 66.8 GW from solar; 42.6 GW from wind; 4.7 GW from small hydro; 4.8 GW from pump storage projects (PSP); and 10.8 GW from bio-power) (excluding 0.589 GW of diesel-based capacity). Figure 3.16 shows the fuel-wise generation capacity until 2022–2023.

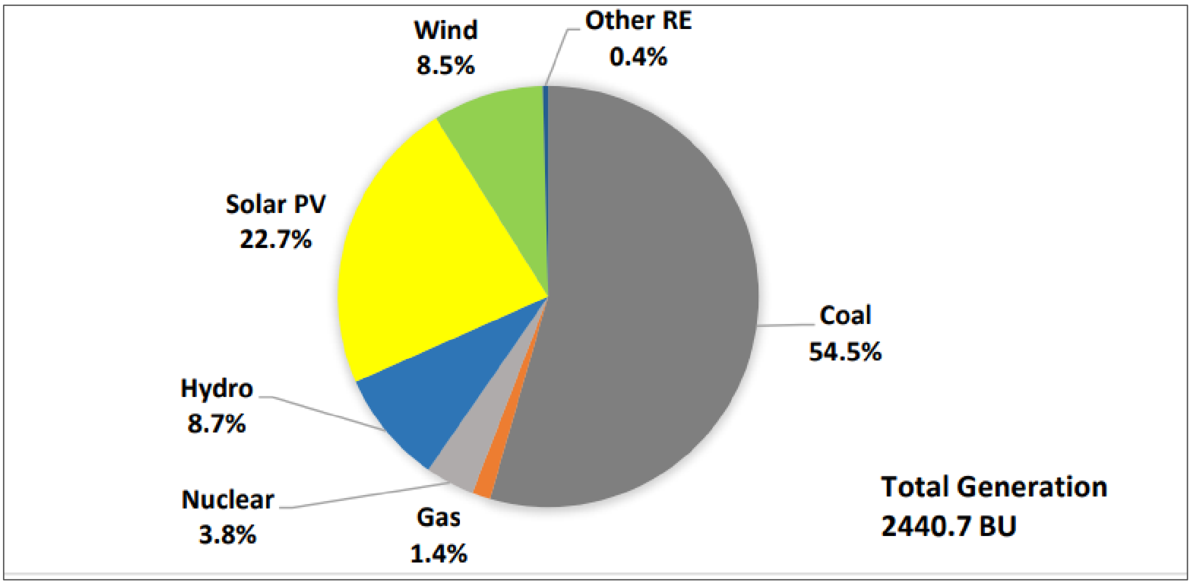
Figure 3.16. India's Installed Electricity Capacity, 2023, and Gross Generation, 2022–2023



PSS = power system stabiliser, PV = photovoltaic, RE = renewable energy.
Source: Central Electricity Authority, Government of India (2023).

As Figure 3.17 shows, the total installed generation capacity is projected to be 2,440.7 billion units (BU) in 2029–2030 from 1,624 BU in 2022–2023. The share of renewables is going to be around 45% by 2030.

Figure 3.17. Projected Generation Capacity by Source in 2029–2030

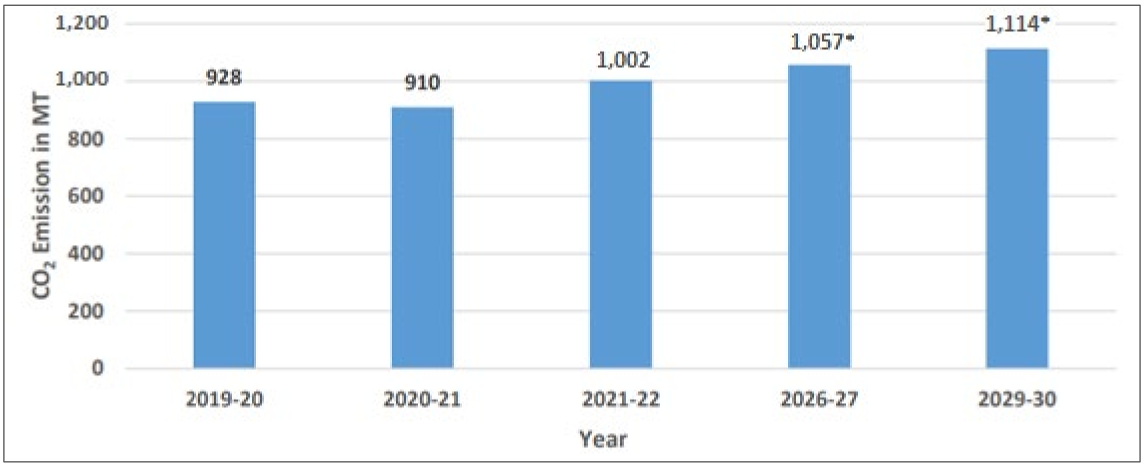


Source: Central Electricity Authority, Government of India (2023).

- *Projected CO_2 Emissions from the Power Sector*

The CO_2 emissions from the power sector during the year 2029–2030 are likely to be 1,114 MT (Figure 3.18). The average emission factor is likely to reduce to 0.477 kg CO_2/kWh net by 2029–2030.

Figure 3.18. Estimated CO_2 Emissions from the Power Sector, 2019–2030



* = projected emissions, MT = million tonnes.
Source: Central Electricity Authority, Government of India (2023).

In the transportation sector, India is poised to promote the use of biofuel, basically created through the blending of ethanol. It is expected that by 2025, India will achieve 20% ethanol blending from the current 10% blending rate. Table 3.7 shows the projected ethanol blending rate.

Table 3.7. Year-wise and Sector-wise Ethanol Production Projections

Ethanol Production Projections										
ESY	For Blending			Blending (in %)	For other uses			Total		
	Grain	Sugar	Total		Grain	Sugar	Total	Grain	Sugar	Total
2019-20	16	157	173	5	150	100	250	166	257	423
2020-21	42	290	332	8.5	150	110	260	192	400	592
2021-22	107	330	437	10	160	110	270	267	440	707
2022-23	123	425	542	12	170	110	280	293	535	828
2023-24	208	490	698	15	180	110	290	388	600	988
2024-25	438	550	988	20	190	110	300	628	660	1,288
2025-26	466	550	1,016	20	200	134	334	666	684	1,350

ESY = ethanol supply year.
Source: Foreign Agricultural Service, U.S. Department of Agriculture.
https://apps.fas.usda.gov/newgainapi/api/Report/DownloadReportByFileName?fileName=India%20-%20Grain%20 and%20Feed%20Update%20-%20February%202021_New%20Delhi_India_02-02-2021 (accessed 21 February 2021).

- *IEA estimates of biofuels*

The government has set targets for transport biofuels as a means to reduce the need for imported crude oil. India's new biofuel policy, announced in 2018, targets bioethanol blending in gasoline of up to 10% in 2022 and 20% in 2025 and plans for the construction of 12 biorefineries. Negligible quantities of biodiesel are produced today, although there are also targets to achieve blending rates in diesel of 5% by 2030. Table 3.8 shows the IEA's various estimates of fuel production.

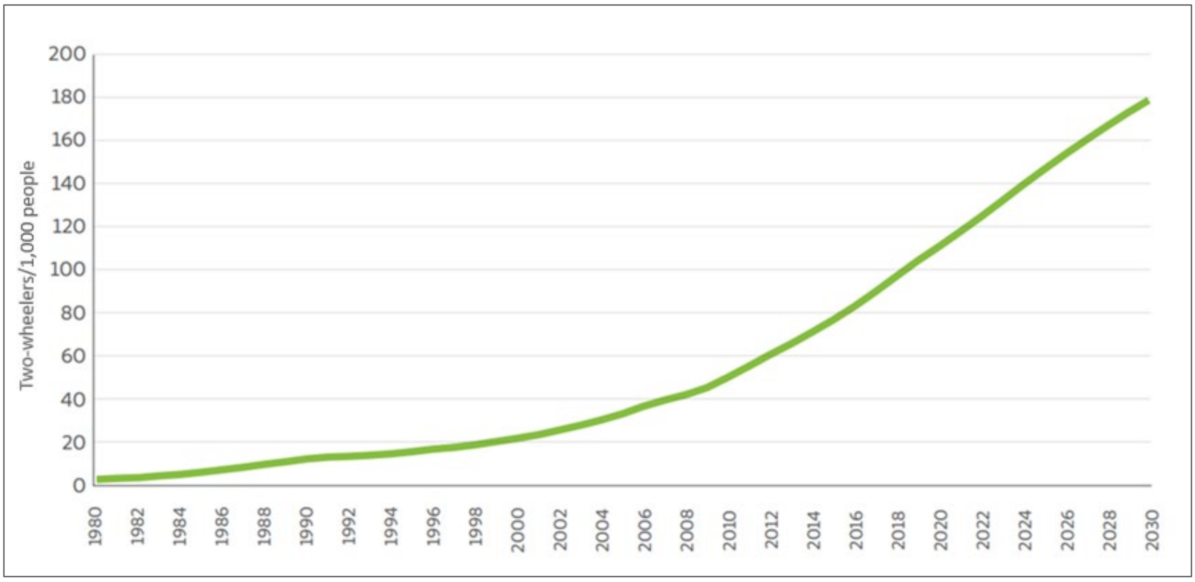
Table 3.8. Fuel Production Scenario

			STEPS		SDS		IVC	
	2000	2019	2030	2040	2030	2040	2030	2040
Coal production (Mtce)	**187**	**409**	**519**	**560**	**304**	**161**	**472**	**515**
Steam coal	163	369	474	512	270	133	428	470
Coking coal	16	25	23	24	23	23	23	24
Lignite and peat	7.9	14	22	23	11	5.2	21	21
Coal trade (Mtce)	**-20**	**-196**	**-193**	**-212**	**-151**	**-137**	**-188**	**-197**
Natural gas production (bcm)	**28**	**32**	**55**	**78**	**52**	**66**	**65**	**101**
Conventional gas	28	30	47	53	47	55	48	62
Coalbed methane	0.0	1.3	5.7	12	4.7	11	5.9	16
Other production	0.0	0.3	2.0	13	0.4	0.2	12	22
LNG imports (bcm)	**0.0**	**30**	**76**	**124**	**92**	**144**	**93**	**159**
Oil production (Mb/d)	**0.8**	**0.8**	**0.6**	**0.6**	**0.5**	**0.4**	**0.7**	**0.6**
Conventional crude oil	0.6	0.6	0.5	0.4	0.4	0.2	0.5	0.4
Natural gas liquids and other	0.2	0.2	0.2	0.2	0.1	0.2	0.2	0.3
Refining capacity (Mb/d)	**0.0**	**5.2**	**6.4**	**7.7**	**5.8**	**5.7**	**6.4**	**7.7**
Refinery runs	0.0	5.1	5.9	7.2	5.0	4.6	5.8	6.8
Other fuels (Mtoe)								
Traditional use of solid biomass	113	113	85	63	0	0	0	0
Modern solid biomass	35	67	93	112	95	117	98	116
Biofuels	0.1	1	5	10	9	14	5	10
Biogas, biomethane, low-carbon hydrogen	0	0	6	19	18	48	10	31

IVC = India Vision Case, LNG = liquefied natural gas, SDS = Sustainable Development Scenario, STEPS = Stated Policies Scenario.
Note: Nuclear fuels are not included. Other natural gas production includes shale and tight gas.
Source: IEA (2021).

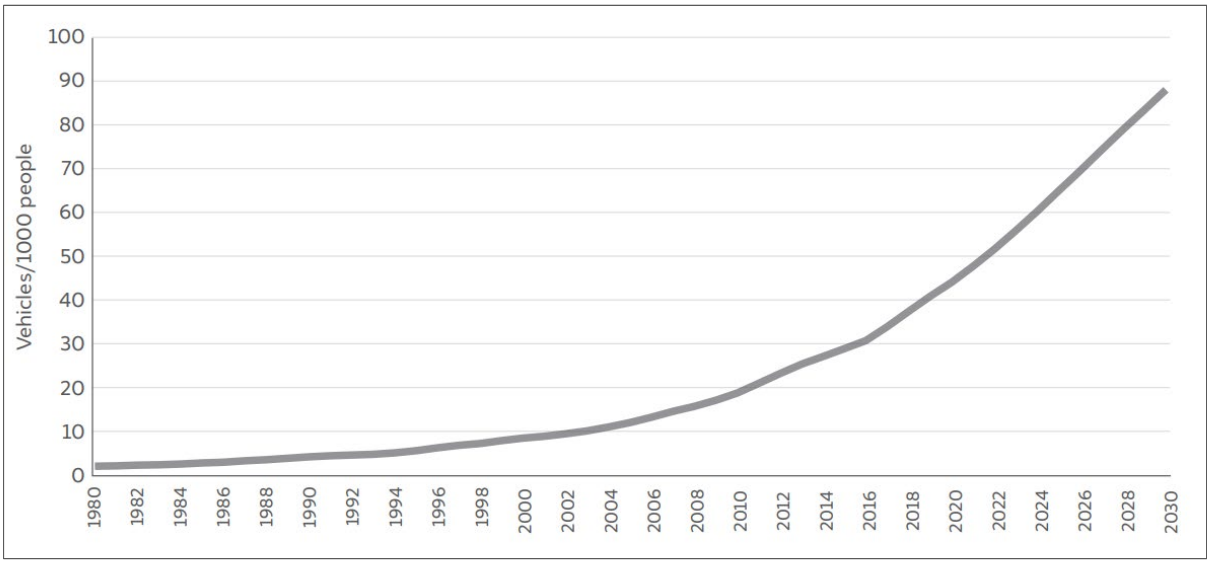
The following two graphs (Figure 3.19 and Figure 3.20) show the increasing trend of EVs (two-wheelers and people-owned vehicles) by 2030.

Figure 3.19. Two-Wheeler Ownership Projection for India



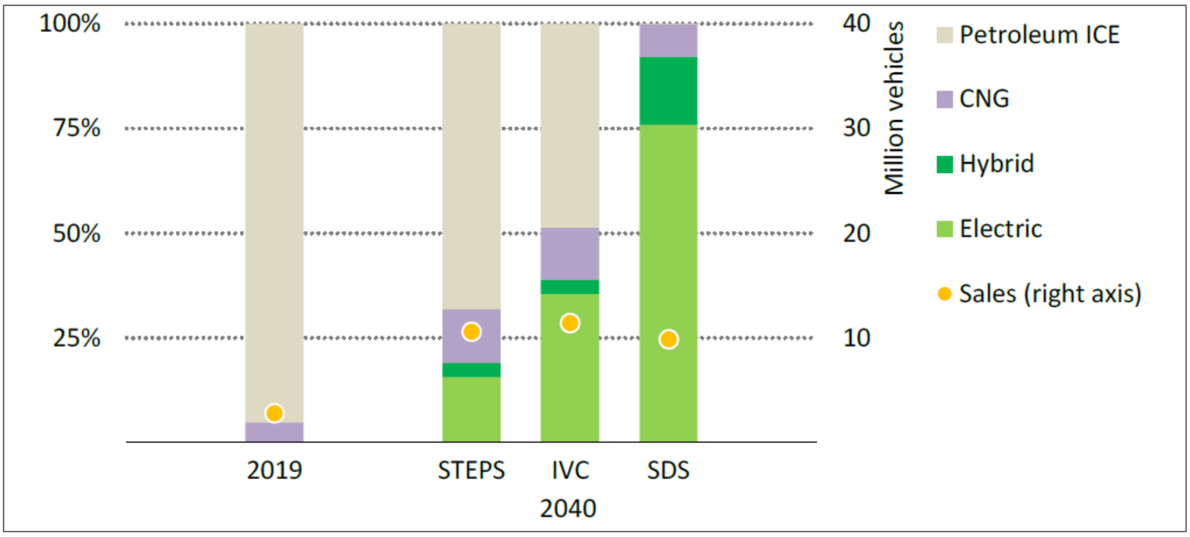
Source: Soman et al. (2020).

Figure 3.20. Vehicle Ownership Projection for India



Source: Soman et al. (2020).

Figure 3.21. Passenger Car Sales by Scenario, 2019 and 2040



CNG = compressed natural gas, ICE = internal combustion engine, IVC = India Vision Case, SDS = Sustainable Development Scenario, STEPS = Stated Policies Scenario.
Source: IEA (2021).

2.3.1 Barriers to EV deployment

Although the Government of India is promoting EV deployment on a larger scale, the irony is that widespread adoption has remained limited – only 4.7% of all vehicle sales in 2022 were EVs. There are many barriers, including infrastructure, investment, safety, battery, pricing, raw material availability, inconsistent policies, and taxation.

a. Investment challenge:

- **Investment gap:** For India to reach its EV target, the e-mobility sector is estimated to require an investment of at least US$192 billion by 2030. There are challenges in identifying high-quality opportunities. The trajectory of India's e-mobility sector growth is highly dependent on the accessibility to finance for players across the value chain. However, information asymmetry between investors and investees resulting from the nascency of the sector has limited investment into innovative companies. Insufficient knowledge is a challenge to investment in the sector. Investors are unable to fully understand the technology behind electric mobility and are hence unable to identify high-quality investment opportunities in the space limiting the perceived deal flow and pipeline. Many investors have been hesitant to invest in this sector due to the higher perceived risk from evolving technology and the pressure on returns due to a longer investment horizon.
- **Complexity in valuing company assets:** The cost of capital in the sector is very high as there is significant uncertainty around the useful life of EVs and their components. Investors perceive this space to be risky as they are unable to ascertain the value of company assets. There is little clarity around the salvage value of components and an almost non-existent secondary market for EVs and EV components.
- **Current macroeconomic environment not conducive to investments:** Start-ups have recognised that despite interest in the sector, current macroeconomic conditions are not

conducive to fundraising. The central bank has increased its interest rate by 225 basis points over 7 months to 6.25% in December 2022.

- **High upfront cost of EVs**: Through subsidies, lower tax rates, and reduced registration costs, the Government of India has reduced the price of EVs, with the goal of increasing uptake. However, the upfront cost of EVs, especially of larger vehicles, is still higher than that of their ICE counterparts. The high prices of EVs can be attributed to the cost of batteries and cell components, as well as the cost of R&D to develop the sophisticated technologies that are integrated into the vehicles. Price remains one of the key barriers to uptake, especially for personal-use vehicles.
- **Unconducive financing terms and lack of financing options for end users:** More than three-quarters of all vehicles sold in India are financed through credit, and loans for EVs comprise a mere 1% of all of India's vehicular loans. Very few banks are participating in the sector in India, with the State Bank of India being the primary lender in this market with its Green Car Loan. Most banks do not have a specialised product tailored to the sector.

b. Infrastructure challenges

- **Inadequate electrical supply network**: India has made large strides in increasing its energy capacity; however, the nation still has a peak power deficit as of December 2022. With an increase in EV adoption and hence the use of charging infrastructure, there will also be a rapid increase in the load on the electricity grid. The total electricity demand to power EVs is estimated to reach 69.6 TWh by 2030.
- **Charging Infrastructural obstacles:**
  - ➢ There is a lack of adequate charging stations: Around 400,000 charging stations will be required by 2030.
  - ➢ Tariffs for charging EVs: The state Distribution Companies (DISCOM) will decide the tariff prices for charging EVs. Therefore, the tariff prices for charging EVs will vary from state to state and lack uniformity.
  - ➢ Open access and captive consumption: The Charging Infrastructure (CI) Guideline has allowed the drawing of electricity from any DISCOM; however, the CI Guideline does not provide the price policy for drawing such electricity. Further, the CI Guideline does not stipulate the ambit of internal use in case of captive consumption usage of the internal usage of any company's own or leased fleet.
  - ➢ Additional electricity load: India is the third-largest electricity producer in the world. However, complicated electricity tariffs lead to a higher per-unit cost of electricity. Therefore, to successfully implement the CI Guideline, how the government will manage to provide cheap electricity and manage the additional electricity load is a question of great concern.
  - ➢ Service Provider Network: As per the CI Guideline, there is a Service Provider Network through which public charging station operators provide information to clients regarding the availability of charging points. After this, the client can book online the slot for charging an EV. It is also worth noting that the client data is stored by the Service Provider Network, so there may be a possibility of data leakage. Therefore, the CI Guideline could have also laid down the provisions for data protection.

- Battery swapping: The CI Guideline does not provide a methodology for battery swapping. Battery swapping is a concept that can save time on the charging of an EV battery. However, a proper method requires implementing battery swapping whilst considering the quality of the battery, the depreciation of the battery, and the cost of the battery.

c. Battery challenges

High-voltage batteries are sizeable and heavy, affecting the handling of an EV. Heavy batteries are prone to safety hazards and thermal runaway and are vulnerable to damage. The recycling/disposal of old batteries is also problematic. By 2040, there will be 340,000 MT of annual battery waste flows. Batteries are still the most expensive component of EVs, making up 50%–70% of a vehicle's cost. Battery manufacturing is facing an investment problem. According to a study by Arthur D. Little (2022), India will need 800 GWh of batteries to achieve its 2030 goal. India will require more than US$10 billion of investment focused on battery manufacturing to meet this demand. India is also facing supply chain problems for the rare earth materials used for EV batteries, like lithium, nickel, phosphate, manganese, graphite, and cobalt. The lithium-ion batteries alone consume 5 million tonnes/year of nickel, and consumption of lithium and cobalt could increase by 10–20 times in future. The chemical elements of the batteries, like lithium, nickel, cobalt, manganese, and titanium, increase the cost-effectiveness of the supply chain but also pose environmental concerns during the scrapping of the battery elements.

d. Financial barriers

India will require at least Rs19.7 trillion for its EV transition between 2020 and 2030.

- The size of the annual EV financing opportunity is pegged at only Rs3.7 trillion by 2030.
- High insurance rates, high interest rates, limited financing options, a high turnaround time, and low loan-to-value ratios limit the wide penetration of EVs.
- Banks and non-banking financial companies currently hesitate to finance EVs due to the product risk in addition to the credit risk and the lack of a second-hand market for EVs.
- Low-cost financing is a key barrier, and improving access to attractive financing solutions can be critical to driving EV demand in India, as financing is a key enabler.

e. Consumer perception

- High purchasing cost: The battery packs of an EV are expensive, and they need to be replaced more than once in their lifetime.
- Driving range of EVs: The driving range is recognised as the main barrier for EVs typically because EVs have a smaller range as compared to equivalent ICE vehicles. The shorter distance an EV can travel on a full charge or full tank is considered a significant drawback.
- Charging time: Level-1, level-2, and DC battery charging have high charging times. Although DC-level charging is relatively less time-consuming, Level-1 and level-2 battery charging available for personal EVs require more time and their charged span is also low.
- Disparity in electricity cost for charging tariffs: Electricity tariffs are a critical fiscal and regulatory tool available to the state government. Tariffs differ from one state to the next. Each state sets its

own rates for distinct consumer groups, therefore the two sides of the tariff, energy and demand charges, differ from one another.
- There are inadequate EV service stations and trained professionals.

2.3.2. Recommendations

- Create a robust network of battery charging.
- Wider adoption of vehicle-to-grid technology.
- Powering EVs through renewable sources of electricity to reduce GHG emissions.
- The majority of vehicles are not covered under FAME. LED battery-operated two- and three-wheelers should also be covered.
- To encourage foreign direct investment (FDI) and increased participation from lenders in the EV market, the National Institution for Transforming India (NITI) Aayog, along with the World Bank, is setting up a US$300 million first-loss risk-sharing instrument that will partly cover losses associated with EV loans. It will be a guarantee and hedging mechanism for lenders in case there is a payment delay on EV loans, effectively acting like a credit default swap. The programme will help reduce the cost of EV financing by up to 12%, resulting in up to US$1.5 billion in capital mobilisation and encouraging more lenders to participate in the ecosystem.
- Research on alternatives to lithium-ion should be promoted. The alternatives to lithium are still in the prototype stage. The most popular ones include sodium-ion, iron-flow, and magnesium-based and hemp-based batteries. However, a few common disadvantages with all these options are their large size, high reactivity, poor stability, and lower cell voltage. Reliance Industries is working on this. GAIL, Indian Oil, and the National Thermal Power Corporation (NTPC) are doing research on exploiting green hydrogen in EVs.
- There should be a common federal regulation on EVs since electricity comes under the concurrent list in India. This will help inform the setting of EV tariffs across India. Currently, different states have different regulations regarding EVs.
- In order to bring the overall cost of EVs down, a strong supply chain of EV raw materials is required. India should also adopt a strategy of diversification of the supply of rare earth materials.
- India should work heavily on public and economic diplomacy for the transfer of advanced technology and to attract higher FDI in EVs.
- The government should give more subsidies and tax relief to personal EV users.
- There is a strong need for patient capital. Considering the nascent stage of the sector, patient capital is the key to ensuring the growth of the sector. The e-mobility sector needs an approach like that of the defence and aerospace industry, where investors are willing to provide patient capital to companies and place the utmost importance on innovation and reliability.

2.4. Philippines

2.4.1. Priority for biofuels and EVs with the expected policy and actions of implementing biofuels and EVs in the Philippines

Compared to other EAS countries, the Philippine EV industry is still at its early stages of development and implementation, with the issuance of landmark policies, namely, the Republic Act (RA) No. 11697, otherwise known as the Electric Vehicle Industry Development Act (EVIDA), and its corresponding

Implementing Rules and Regulations on 15 April 2022 and 20 September 2022, respectively (Bacungan, 2022).

Based on the Philippine Department of Energy's (PDOE) draft Comprehensive Roadmap for the Electric Vehicle Industry (CREVI), which was recently presented through various public stakeholders' consultations in March 2023 and will be subject to finalisation as per the concerned stakeholders' consensus. The transportation model in the country is envisioned to diversify its current vehicle fleet with the introduction of EVs (PDOE, 2023a). The proposed CREVI shall serve as the national development plan for the domestic EV market considering the industry's sustainability, infrastructure, and ecological impacts whilst focusing on the four major local development components, namely: EVs and charging stations (EVCS), manufacturing, research and development, and human resource development (PDOE, 2023b).

The PDOE is targeting a 10% EV penetration rate in the country's road transport population by 2040 to be made up of buses, cars, tricycles, and motorcycles. This will be achieved through the following goals: '(1) increasing EV utilization rate, (2) deploying adequate EVCS nationwide, (3) establishing role in the EV import-export market, (4) encouraging sustainable economic growth and just e-mobility transition, and (5) promote innovation and competitiveness by supporting research and development on EV technology' (PDOE, 2023b).

To reinforce the government's plans for e-mobility, the PDOE has crafted other EV-related policies to further enable the local EV ecosystem, such as guidelines for the accreditation of EVCS providers, registration of EVCS, recognition and adoption of EV standard classifications on road transport, and unbundling of EVCS charging fees. These initiatives are consistent with the PDOE's goal of promoting and utilising cleaner energy fuels and transport technologies (Velasco, 2023).

According to the draft CREVI, the EV population is expected to be composed of battery electric vehicles (BEVs), hybrid electric vehicles (HEVs), plug-in hybrid electric vehicles (PHEVs), and light electric vehicles (LEVs, i.e. weighing below 50 kilogrammes, like personal mobility devices and e-kick-scooters), and there are two identified scenarios by 2040: (1) the Business-as-Usual (BAU) Scenario and (2) the Clean Energy Scenario (CES). Going from the BAU scenario to the CES, the target increases from a 10% to 50% EV share out of the total vehicle population as well as the level of government intervention, hence the difference in target projections. As seen in Tables 3.9 and 3.10, the EVIDA is split into the short, medium, and long term until 2040, with the end goal of a 100% renewable energy share in the energy power mix (PDOE, 2023b).

Table 3.9. Projection of Inventory for EV and EVCS Units

	BAU Scenario			**CES**		
	Short Term (2023–2028)	**Medium Term (2029–2034)**	**Long Term (2035–2040)**	**Short Term (2023–2028)**	**Medium Term (2029–2034)**	**Long Term (2035–2040)**
EV targets	311,700	580,600	852,200	2,454,200	1,851,500	2,001,600
EVCS	7,400	14,000	20,300	65,000	42,000	40,000

BAU = Business-as-Usual, CES = Clean Energy Scenario, EV = electric vehicle, EVCS = electric vehicles and charging stations.
Source: Draft CREVI, PDOE (2023b).

Table 3.10. Projection of EV Units per Vehicle Type

EV Type Targets		BAU Scenario			CES		
		Short Term (2023-2028)	Medium Term (2029-2034)	Long Term (2035-2040)	Short Term (2023-2028)	Medium Term (2029-2034)	Long Term (2035-2040)
Sedan, SUV, UV	HEV	81,500	49,000	36,600	415,000	234,000	107,000
	PHEV	13,600	24,600	36,600	69,000	80,000	107,000
	BEV	13,600	123,000	219,400	69,000	327,000	641,000
Tricycle	BEV	37,500	71,000	103,400	419,000	262,000	223,000
Motorcycle	BEV	164,900	311,800	454,400	1,480,000	947,000	922,000
Bus	BEV	600	1,200	1,800	2,200	1,500	1,600
Total		**311,700**	**580,600**	**852,200**	**2,454,200**	**1,851,500**	**2,001,600**

BAU = Business-as-Usual, CES = Clean Energy Scenario, EV = electric vehicle, SUV = sport utility vehicle, UV = utility vehicle.
Source: Draft CREVI, PDOE (2023b).

Also, as noted in the CREVI, the projections in the first version do not include any units involved in the Philippine Department of Transportation (DOTr) and Land Transportation Franchising Regulatory Board's Public Utility Vehicle Modernization Program (PUVMP). The said programme is under Department Order No. 2017-011 or the Omnibus Guidelines on the Planning and Identification of Public Road Transportation Services and Franchise Issuance of the Omnibus Franchising Guidelines, which mandates all PUVs to undergo standardisation of PUV fleets in the country to support the transport sector's convenient, accessible, safe, secure, and affordable programme. The PUVMP is slated to mainly affect the Philippines' king of the road – jeepneys – specifically the specifications of its engines (Viado, 2023).

Meanwhile, based on the 2020–2040 Philippine Energy Plan, the current biofuel blending rates for biodiesel and bioethanol are 2% (B2) and 10% (E10), respectively. Pursuant to RA No. 9367 of the Biofuels Act of 2006, after the first 4 years of implementation, the minimum blends of B2 and E5 shall not be decreased thereafter.

Consistent with this, the PDOE has been continuously undertaking various initiatives to support the transition to higher biofuel blends (i.e. B5 and E15/E20) such as a revisit of the blending requirements and available feedstock, review of the biodiesel and bioethanol mandates, collaboration with academic institutions/development partners/industry stakeholders on research, development, and demonstration activities geared towards the identification of viable feedstock for biofuel production. The Philippines, which is predominantly an agricultural country, has other potential alternative biofuel feedstock sources that remain to be unlocked and may be tapped and harnessed to address the issue of supply sustainability (PDOE, 2021). Thus, the DPOE is continuously providing technical support to high school and college students whose interests in their thesis and research studies are focused on identifying alternative and potential feedstock for biofuel production. This initiative is in the form of technical guidance and laboratory analysis to characterise the biodiesel and bioethanol produced from research projects.

The PDOE's implementation of higher biofuel blends may also be hastened through the development of indigenous biofuel feedstock. In the case of biodiesel, the potential feedstock includes (a) waste cooking oil, (b) microalgae, (c) rubber seed oil, and (d) palm oil. Whilst for bioethanol, the potential feedstock may include: (a) nipa sap, (b) cellulosic materials, i.e. bagasse and Napier grass, (c) cassava, and (d) microalgae, amongst others (PDOE, 2021).

2.4.2. The barriers to achieving the targets, the unintended consequences of EV introduction, and the way to overcome these barriers to improve EV introduction conditions in the Philippines

As the country's major policies on EVs were only put into law in 2022, and from the perspective of the ongoing formulation of other EV-related programmes and the drafted CREVI, the barriers to achieving the EV targets are primarily identified as challenges to be addressed in terms of EV market adoption, supply within the local industry, and the charging infrastructure, as shown in Tables 3.11–3.13. In terms of EV market adoption, the identified barriers are from the point of view of industry players in a relatively young EV environment, wherein primary concerns include financing support and reluctance due to unfamiliar technology – hence, the low demand turnout for EVs (PDOE, 2023b).

Table 3.11. Potential Barriers to EV Market Adoption

Market Development	**Financing**
▪ Flooding concerns ▪ Inadequate or lack of capacity to invest ▪ Inferior performance and features compared to conventional units ▪ Limited availability ▪ Higher total investment ▪ Negative technology reputation ▪ Technology scepticism due to lack of familiarity ▪ Technical support doubts ▪ Technology inertia	▪ Financially high-risk market ▪ Lack of familiarity with global EV financing services and practices ▪ Lack of familiarity with technology ▪ Limited government resources ▪ Unclear cost-benefit analysis **Technical Support** ▪ High spare parts costs due to low demand ▪ Limited financial capacity of local EV suppliers to stock a large volume of spare parts
Charging/Battery Swapping Services	**Battery Disposal**
▪ Lack of third-party battery leasing/swapping/charging/station providers ▪ Limited operator financial capacity to invest in spare batteries and swapping stations ▪ Varying battery/charging technical requirements	▪ Lack of knowledge of battery recycling technology

Source: Draft CREVI, PDOE (2023b).

For the EV industry supply, the identified barriers are from the point of view of the manufacturing players affected, as indicated in the previous table wherein EV market adoption is low. As there is not much market demand for local parts and components, the role of local suppliers is only secondary to international neighbouring counterparts wherein the cost is lower, and quantity is abundant (PDOE, 2023b).

Table 3.12. Potential Barriers to EV Industry Supply

<table>
<tr><th>EV Parts or Module Production</th><th>Supply or Vehicle Assembly</th></tr>
<tr><td>▪ Lack of local EV assembly demand
▪ Higher power and operating costs
▪ More established foreign competition
▪ Weak local parts and components supply chain
▪ Need for local development and manufacturing of cost-competitive EV parts in higher quantities</td><td rowspan="3">▪ Higher power and operating costs
▪ Lack of access and higher cost of higher quality EV components
▪ Lack of local demand
▪ Limited financial capacity to expand production
▪ Investments too small to meet incentive thresholds
▪ Strong threat from cheaper imported units
▪ Limited design flexibility and uneconomical production process due to lack of demand
▪ Weak local supply chain</td></tr>
<tr><th>Battery Cell Production</th></tr>
<tr><td>▪ Low purity of nickel reserves
▪ Foreign control of lithium battery raw material supply
▪ Lack of local battery cell demand
▪ High high-pressure acid leach investment cost
▪ Weak local supply chain
▪ Higher power and operating costs</td></tr>
</table>

Source: Draft CREVI, PDOE (2023b).

Lastly, the EV charging infrastructure was identified as a recurring barrier to increasing UV utilisation in the country. The seemingly low demand in the EV market is unattractive to investors of infrastructure as there is little to no market for the charging facilities at this time of the EVIDA implementation, wherein support policies and standards are subject to implementation (PDOE, 2023b).

Table 3.13. Potential Barriers to EV Charging Infrastructure

Charging Infrastructure
▪ Inadequate demand to attract battery-swapping leasing service providers ▪ Uncertain/inadequate demand to attract public charging system investors ▪ Varying battery systems slow down the attainment of economies of scale ▪ High charging infrastructure investment cost ▪ Lack of standard charging protocols

Source: Draft CREVI, PDOE (2023b).

Currently, several EV models are already available in the Philippine market, brought in by car manufacturers from different countries. However, the average market selling prices are still much more expensive than in other neighbouring countries, e.g. the BYD Dolphin is manufactured in China at ₱1,030,000 and sold for ₱1,888,000 in the Philippines. As the EVIDA is in its earlier phases of implementation, import costs and tax rates have highly impacted the current market prices for commercially available EV units (Policarpio, 2022). Thus, there is an image of exclusivity of EVs for the extreme upper classes of society, as Filipino passengers' average daily commutes usually revolve around tricycles, motorcycles, jeepneys, and buses, as constrained by their purchasing power (Philippine Board of Investments, 2021).

As of the end of 2021, the total number of EVCs in the country reached 327, and these were mostly located in the National Capital Region. One of the measures undertaken by the PDOE to encourage EV adoption is attracting more investors through the issuance of CREVI, consequentially ramping up the roll-out of infrastructure and increasing EV utilisation nationwide (Business World, 2023).

Further, pursuant to Rule VII of EVIDA's Implementing Rules and Regulations, which became effective in September 2022, an incentive strategy shall be crafted by the Philippine Board of Investments (PBOI) to 'narrow the cost gap between EVs and traditional motor vehicles and enable the shift of the local traditional motor vehicle industry to EVs', 'provide time-bound, targeted, performance-based, and transparent fiscal and non-fiscal support to attract EV and EV parts manufacturing', and 'set local production targets'. In addition, importers of completely built EV units can avail of the fiscal incentives through the exemption of payment duties for 8 years from the date the act came into effect, whilst imported capital equipment and components for manufacturing/assembly/construction/installation can also be evaluated for incentive entitlement depending on their Strategic Investment Priority Plan inclusion (PDOE, 2022a).

In terms of EV utilisation, fiscal incentives include a 30% discount for BEVs and a 15% discount for HEVs from vehicle registration and inspection fees with the Philippine Land Transportation Office. Moreover, there are also non-fiscal incentives available for the enjoyment of EV end-users, such as but not limited to, priority for vehicle registration and renewal, plate exemption from the number-coding scheme, expeditious processing of applications for franchises to operate/renew, and training programmes on EV assembly, use, maintenance, and repair. As for EV manufacturers and importers, the non-fiscal incentives available to them include the expeditious processing of applications for the importation of parts and components. Also, the government and other financial institutions are encouraged to provide concessional financial packages for EV industry players with preferential interest rates and payment schemes on offered consumer loans for EV and EVCS acquisition (PDOE, 2022a).

Lastly, with the issuance of the Office of the President's Executive Order No. 12, Series of 2023 on 13 January 2023, EV users can also take advantage of a tax break in the form of lower tariff rates (Office of the President of the Philippines, 2023).

2.4.3. Mobility scenario in the Philippines

The DOTr sees an immediate need for a green transport system to support the government's decarbonisation commitment and has started to formulate a transition roadmap for public transport to EVs with possible fiscal incentives to entice more buyers to shift to cleaner technologies for transportation (Inquirer, 2023). The agency believes that EV introduction can be the government's approach to balancing the country's economic issues and environmental commitments. As mobility does not only concern vehicles, improvements must also be done to other options, such as walking and cycling. As such, better traffic systems and pedestrian concourses, etc. (Manahan, 2023) are needed for a well-oiled and inclusive mobility scenario in the Philippines.

Meanwhile, some private stakeholders prefer a gradual transition as they deem the government's ongoing efforts to be lacking, primarily because of the current set of available fiscal incentives and the limited promotional campaigns for EV awareness for attracting potential customers. The country is still highly dependent on non-RE sources, with coal taking up the biggest chunk of the power mix, but it acknowledges that increasing EV utilisation will surely reduce carbon emissions resulting in better air quality (Cordero, 2023).

As the Philippines relies heavily on imported fossil fuel, continuous decarbonisation of the transportation sector in adherence with climate goals is needed as ICE vehicles are significant sources of GHG emissions, air pollution, and energy dependence. Despite the push for EVs due to their energy-efficient technology and the target of a 10% EV fleet share by 2040, a substantial share of the transportation sector is still to be catered by liquid fuels. At present, the EV fleet share in the country's current vehicle population is less than 1%.

With the continuously increasing demand for gasoline and diesel, biofuels can be readily utilised with the existing infrastructure, compared to EV deployment, which is in its early stage. Some of the common concerns for the Philippine EV and biofuels industry during its concurrent implementation are the EV travel distance/range, infrastructure, and logistics, taking into consideration the archipelagic nature of the country as well as the sustainability of feedstock. Based on existing laws and issuances, both the EV and biofuel targets are set to increase in the long term. Depending on the current administration's priorities, there is a need to find a balance between the two, with a similar end goal of reducing the use of imported fuel and carbon emissions.

Under the National Renewable Energy Program 2020–2040, the PDOE targets bringing the RE share in the power generation mix to 35% by 2030 and 50% by 2040 from the current 22%. By 2028, the RE sector is optimistic about achieving at least a 32% RE share in the power generation mix (PDOE, 2022b).

2.5. Viet Nam

2.5.1. Current status of EVs in Viet Nam

a. For electric two-wheelers (2Ws)

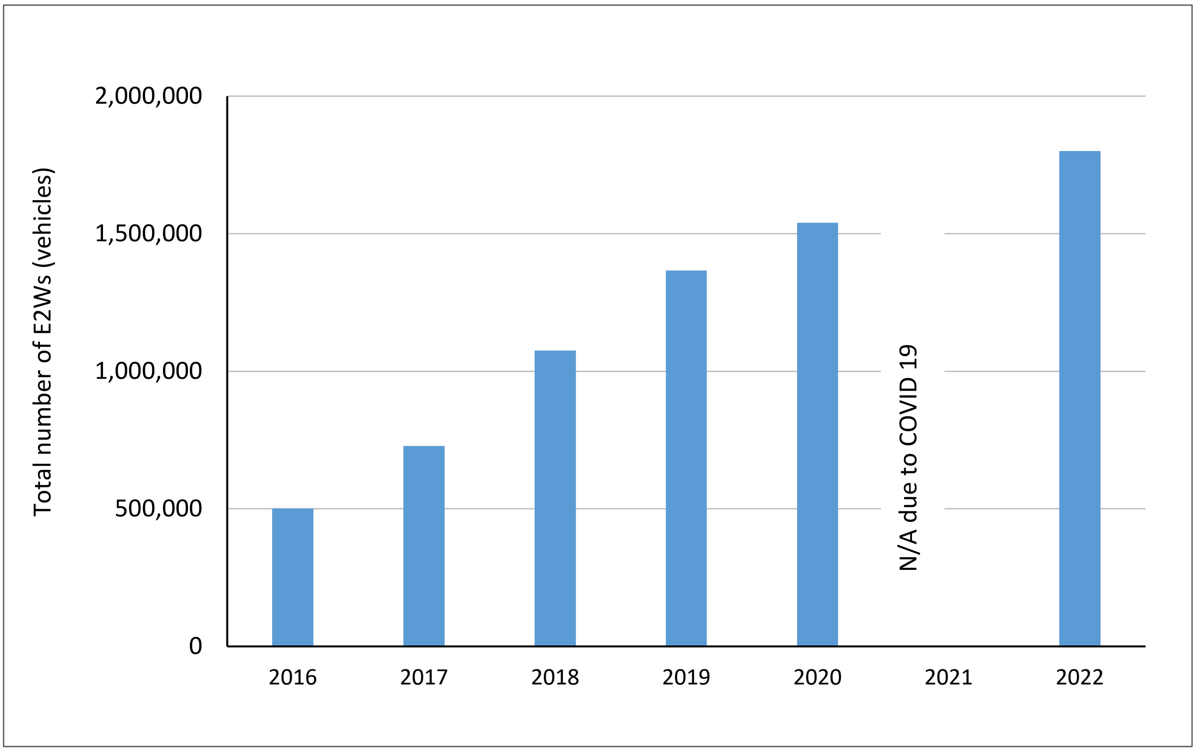
Two-wheelers (2Ws), including motorcycles and mopeds, are the most popular transportation means in Viet Nam. In 2021, about 2.5 million units of new 2Ws were sold, and there was a total of about 66.6 million units of 2Ws in use on the road (ERIA, 2022). The 2W market has so far been dominated by foreign brands (such as Honda, Yamaha, Suzuki, and Piaggio) with their internal combustion engine (ICE)-powered products. However, electric two-wheeler (E2W) sales have been increasing remarkably in recent years. In the period 2016–2019, a significant growth rate could be observed with an average of about 40%, but in the period 2019–2022, the growth rate slowed to above 10%, mainly caused by the COVID-19 pandemic, as shown in Figure 3.22 (TDSI, 2020; Vietnamnet, 2020). By the end of 2022, the number of E2Ws was about 1.8 million vehicles (Vietnam Plus, 2023), with a share of about 2.7% of all in-use 2Ws. The E2W market is dominated by local manufacturers, such as VinFast (a member of Vingroup), Pega, and Anbico, with some foreign brands, such as Dibao (Taiwan) and Yadea (Hong Kong), as shown in Figure 3.23 (Le, 2022).

Regarding battery type, most VinFast models are equipped with lithium-ion batteries, whilst models from Yadea are equipped with graphene batteries, and most of the remaining manufacturers mainly use lead-acid batteries. The E2W charging network is still limited in Viet Nam, and E2W users mainly charge their vehicles at home. However, VinFast has been investing in and providing charging infrastructure for both E2W and electric cars, with 150,000 charging ports covering 63 provinces and cities across Viet Nam. VinFast also offered battery-swapping services for some of its E2W models, but this service stopped at the end of 2022.

b. For electrified vehicles

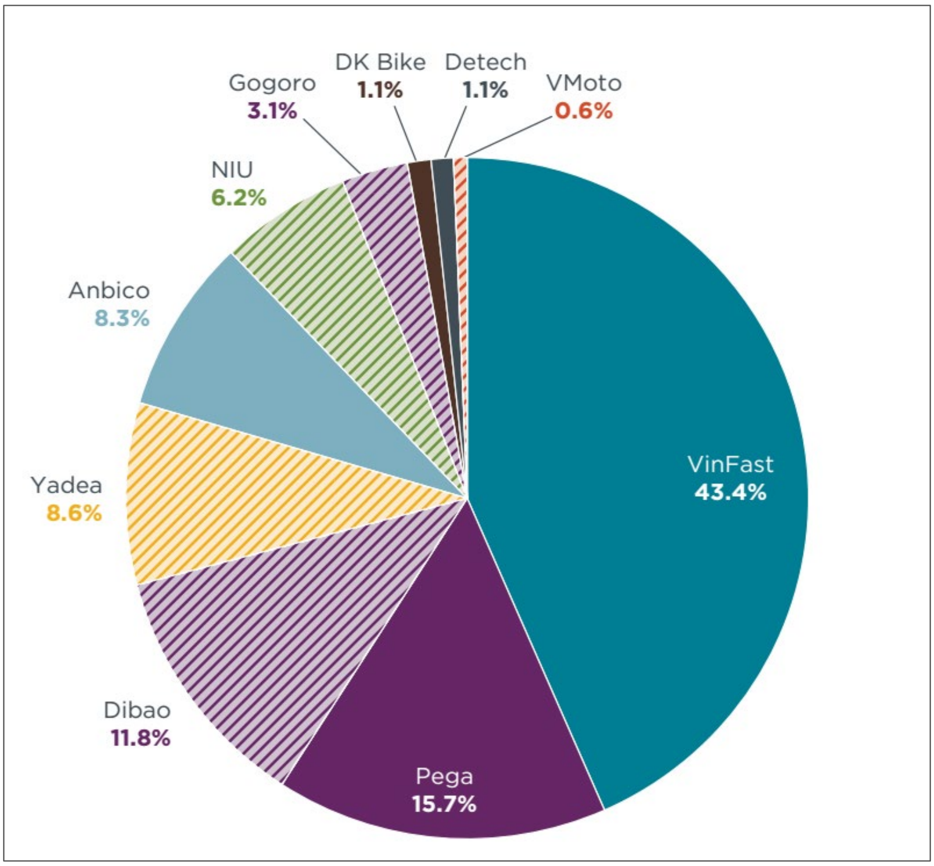
Electrified vehicles (xEVs, including HEVs and EVs) have increased dramatically in Viet Nam in recent years. Looking back to a few years ago, the number of xEVs was just about 1,000 vehicles by the end of 2020 (546 units of HEVs sold in 2020), in which EVs contributed just about 1% (ERIA, 2021). However, in 2021 and in the first 8 months of 2022, the number of hybrid electric vehicles (HEVs) sold was 2,285 and 1,954 units, respectively (Vietstock, 2022), with the domination of Toyota's hybrid models as shown in Figure 3.24. By the end of 2022, Toyota had sold about 5,300 HEVs in Viet Nam.

Figure 3.22. Total Number of In-use E2Ws



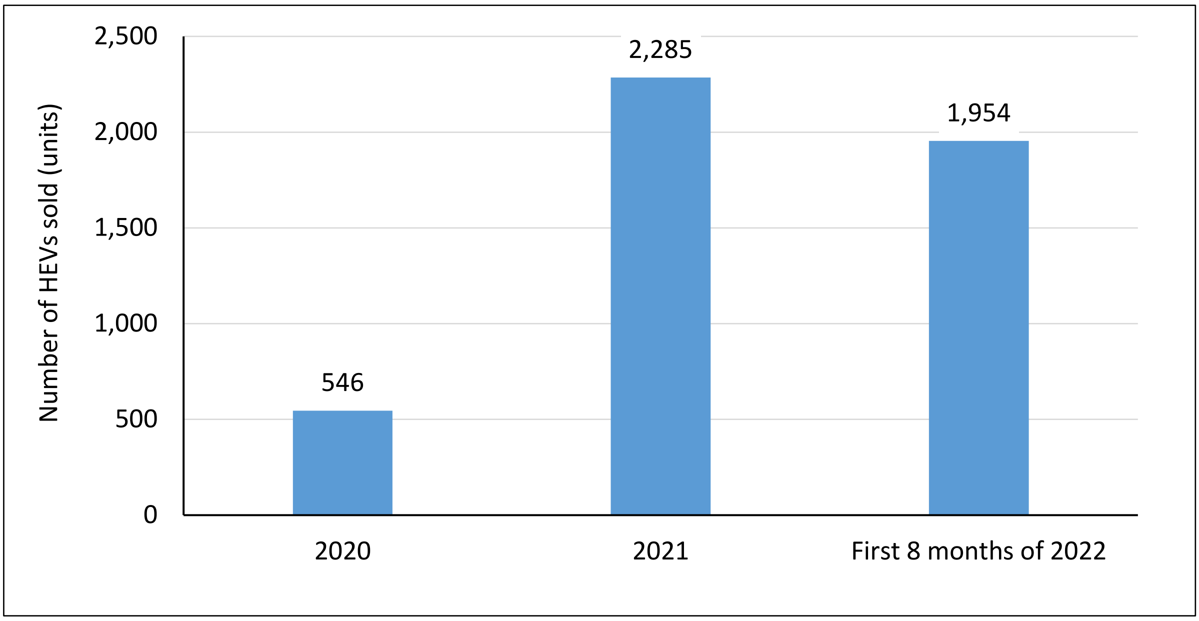
E2W = electric two-wheeler.
Source: TDSI (2020); Vietnamnet (2020).

Figure 3.23. E2W Market Share by Manufacturer in 2020



Source: Le (2022).

Figure 3.24. Number of HEVs Sold in Viet Nam



HEV = hybrid electric vehicle.
Source: Vietstock (2022).

For the EV market, there has also been a significant increase in the domination of EV models from VinFast, a local car maker and the only enterprise manufacturing EVs in Viet Nam. In 2022 and Q1 2023, VinFast sold more than 7,000 and 1,700 units of EVs, respectively (VnEconomy, 2023). VinFast is also building its own ecosystem and giving many incentives to customers, such as car warranties of up to 10 years and battery warranties of up to 10 years. It has also provided about 150,000 charging ports, covering 63 provinces and cities across Viet Nam, to help customers charge their EVs more easily and more conveniently. VinFast's charging stations include normal (AC 11 kW), fast (DC 30 kW and 60 kW), and super-fast (DC 250 kW) chargers for cars and AC 1.2 kW chargers for E2Ws. These charging stations are located at commercial centres, gas stations, supermarkets, bus stations, public parking spaces, apartment buildings, offices, and universities, etc. Due to not having charging standards yet, VinFast's charging stations currently follow European standards. Furthermore, Vingroup (the company that VinFast belongs to) has started to construct an EV battery plant to produce lithium iron phosphate batteries. Some EV models of foreign brands have also been introduced, such as the Hyundai Ioniq 5, Mercedes-Benz EQS, Taycan, and Hongqi E HS9, but their share is very small.

c. Current incentive policies for xEV development

To encourage the production and consumption of environmentally friendly products, the government has given incentives, such as reducing the excise tax rate and/or registration fee for xEVs and biofuel vehicles (National Assembly of Vietnam, 2016; National Assembly of Vietnam, 2022; Government of Viet Nam, 2022). The excise tax rate for conventional passenger cars of nine seats or less ranges from 35% to 150% depending on the vehicle model and cylinder capacity. The excise tax rate for electric cars of nine seats or less was 15% (before 1 March 2022), was reduced to 3% (applied from 1 March 2022 to 28 February 2027) and will be 11% (applied from 1 March 2027). For HEVs (PHEVs included) and bioenergy vehicles, whilst the proportion using gasoline energy does not exceed 70%, the excise tax rate shall be equal to 70% of the tax rate applicable to gasoline and diesel vehicles of the same cylinder capacity. On 15 January 2022, the government issued Decree No. 10/2022/ND-CP stipulating a registration fee rate of 0% for battery electric cars registered for the first time within 3 years from 1 March 2022. In the next 2 years, this fee will be equal to 50% of that of petrol and diesel cars with the same number of seats. For biofuel-powered cars, the excise tax rate is 50% of the rate for cars of the same class. The registration fee exemption is given for buses using clean energy, namely LPG, LNG, and electricity (Ministry of Finance, Viet Nam, 2015). The incentive policies mentioned are shown in Table 3.14.

Table 3.14. Current Incentive Taxes and Fees for xEVs and Biofuel-powered Vehicles

Vehicle	Excise tax	Registration fee
Conventional passenger car (up to 9 seats)	35%–150% (depending on cylinder capacity)	10%
Battery electric passenger car (up to 9 seats)	15% (before 1 March 2022), 3% (from 1 March 2022 to 28 Feb 2027), 11% (from 1 March 2027)	0% (within 3 years from 1 March 2022), 50% of the registration fee of the same-class conventional vehicle (within the next 2 years)
Battery electric van car (10–15 seats)	10% (before 1 March 2022), 2% (from 1 March 2022 to 28 Feb 2027), 7% (from 1 March 2027)	
Battery electric bus (16–23 seats)	5% (before 1 March 2022) 1% (from 1 March 2022 to 28 Feb 2027), 4% (from 1 March 2027)	
Battery electric automobiles for both passenger and cargo transportation	10% (before 1 March 2022) 2% (from 1 March 2022 to 28 Feb 2027), 7% (from 1 March 2027)	
Hybrid (energy from gasoline contributes less than 70% of the total energy used)	70% of Excise tax of the same class conventional vehicle	Equal to the rate for same-class ICE-powered vehicles
Biofuel vehicles	50% of Excise tax of the same class conventional vehicle	

Source: National Assembly of Vietnam, 2016; National Assembly of Vietnam, 2022; Government of Viet Nam, 2022; Ministry of Finance, Viet Nam, 2015.

In July 2022, the Vietnamese government issued Decision No. 876/QĐ-TTg approving the Action Program for Transition to Green Energy and Mitigation of Carbon Dioxide and Methane Emissions from Transportation (Vietnamese Primer Minister, 2022). The decision gives specific national objectives related to promoting electric vehicle development that include the following:

✓ *Roadmap for transition to green energy for road vehicles*

- In the 2022–2030 period:
  - Promote the manufacture, assembly, import, and transition to electric vehicles; promote blending and the use of E5 fuel for 100% of road motor vehicles.

- Develop charging infrastructure for meeting the demand of individuals and enterprises.
- Encourage the transition to green energy for new and existing bus stations and rest stops.

- By 2040, phase out the manufacture, assembly, and import of automobiles, motorcycles, and mopeds with fossil fuels for domestic use.
- By 2050:

- 100% of road motor vehicles and heavy equipment involved in traffic will be powered by *electric and green energies*; bus stations and rest areas meet green criteria; transition to use *electric and green energies* for all freight handling machinery.
- Complete charging infrastructure, provide green energy nationwide, and meet the demand of people and businesses.

✓ *Roadmap for public transport in urban areas (buses and taxis)*

- From 2025: The target is to use electric and green energies for 100% of new buses.
- From 2030: Achieve at least 50% of the vehicle fleet using *electric and green energies*; use *electric and green energies* for 100% of new taxis.
- By 2050, use *electric and green energies* for 100% of buses and taxis.

2.5.2. Barriers to electric vehicle development in Viet Nam

a. The EV development strategy target has not been set clearly

Decision No. 876/QĐ-TTg has set national objectives related to transiting fossil fuel-powered vehicles to electric and green energy vehicles. However, the term ‘green energy vehicle’ has not been defined, and the share of EVs and green energy vehicles has not been given either. Moreover, mandatory targets for EV production or sales over specific years in the future have not been set clearly. These targets are important for car makers to make their plans for EV production.

Recommendation:

The term ‘green energy vehicle’ should be defined more clearly, and the share of EVs and green energy vehicles in the future should be set in detail. Based on these targets, a mandate for EV production (including both E2Ws and electric cars) should be introduced. These targets could serve as a guideline for manufacturers to plan for EV production as well as green energy vehicle production.

b. Policy to support EV development is still limited

The supporting policies in Viet Nam, such as incentives on excise tax and registration fees for EVs, have been initially developed and implemented. However, the government has not yet given incentive policies on credit, investment, and trade for EV makers, whereas EV production plants often require large capital sources that are maintained for a long time, requiring banks to have large and long-term capital. Other policies to encourage consumers to buy EVs, such as tax exemptions/reductions, free parking, priority parking places, etc. and policies supporting EV charging infrastructure development have not been available.

Recommendation:

Incentive policies to promote investment in EV and battery production, development of their supply chains, and charging network and battery swapping systems should be promulgated.

Policies that provide priority to EVs over ICE-powered vehicles, such as priority parking places, free parking, exclusion from traffic restrictions, etc., should be given.

More stringent emission standards for ICE-powered vehicles should also be introduced and applied, especially for ICE 2Ws due to their major contribution to vehicle emissions. The more stringent emission standards could reduce the emissions from ICE-powered vehicles. They could also reduce the gap in production costs between ICE vehicles and EVs, causing manufacturers to consider shifting to investment in manufacturing EVs.

c. Charging infrastructure still lacking

The major considerations of Vietnamese consumers are the availability of charging stations and the travel range of EVs, which lead to the requirement for a widely accessible charging network, especially charging possibilities on highways and in remote areas. However, Viet Nam does not have a widespread charging station and swapping system, except for the charging stations of VinFast, which can only be used by VinFast's EV models. Moreover, the technical regulations and technical standards for charging stations and battery-swapping systems have not been established. In the meantime, VinFast's charging stations follow European standards. In addition, the lack of parking areas in some big cities, such as Hanoi and Ho Chi Minh City, is also a challenge to Vietnamese consumers when buying new cars, including EVs. Charging electric cars at home is unsuitable due to not having the required power source and/or not having a garage in a typical small house in the cities.

Recommendation:

All regulations and standards related to EVs, charging infrastructure, battery swapping systems, vehicle disposal, and the recycling of expired batteries need to be elaborated on and issued as soon as possible. The charging stations should be used for all EV brands available on the Viet Nam market now and in the future.

This should be supplemented by regulations requiring charging stations for new constructions, such as parking lots, supermarkets, and apartment buildings.

The power grid capacity should be recalculated carefully to meet the demand for EV charging.

d. The price of EVs is still high

Viet Nam has low-income levels, with average GDP per capita in 2022 of around US$4,100 (IMF, 2023), which is quite low for consumers to own cars, especially electric cars due to their higher cost compared to ICE-powered cars. Based on a recent consumer survey (World and Vietnam Report, 2023), from the consumer's point of view, the expected price is D10 million–D20 million (about US$430–US$860) for electric bicycles, D10 million–D40 million (about US$430–US$1,720) for electric motorbikes, and D550 million–D850 million (about US$23,600–US$36,500) for electric cars. The survey also shows that consumers consider environmental benefits and cost savings as two outstanding advantages of EVs compared to ICE vehicles, and they expect EVs on the market to vary by type and price. They are also very concerned about safety, battery life, charging time, travel distance, and technical support when purchasing EVs.

Recommendation:

It is necessary to have policies of direct support from the state budget to reduce investment costs, such as research and development costs (e.g. support for research and development, trading, and technology transfer processes) for EV production and assembly projects.

Policies aiming to reduce the cost of owning and operating EVs, such as vehicle purchase subsidies, tax exemptions, and tax reductions (including import tax), should be given. Battery leases are also good to offer to lower the EV upfront cost.

2.5.3. Expected policy and actions for implementing biofuels and EVs

a. For biofuels

To properly implement the roadmap of biofuel use mentioned in Decision No. 876/QĐ-TTg, ethanol and E5 fuels should be ready in terms of ethanol production, fuel blending, distribution as well as awareness of vehicle owners. Therefore, the expected policies and actions related to biofuel development include:

- ✓ A mandatory roadmap for E5 RON95 use from now to 2030 should be announced and strictly implemented in order to create an adequate bioethanol fuel market.
- ✓ Incentive policies to develop feedstock areas for bioethanol production and to invest in current bioethanol plants.
- ✓ Direct and/or indirect subsidies to reduce the price of E5 fuel in order to encourage consumers to use E5 fuel.
- ✓ Policies to give more benefits to distributors to encourage them to distribute E5 fuel instead of conventional gasoline.
- ✓ Importing bioethanol (if necessary) and/or biodiesel for blending could be considered.
- ✓ Raising awareness of vehicle owners about the benefits of biofuel.

b. For EVs

It can be seen that supporting policies for the EV industry in Viet Nam have been initially developed and implemented. For example, current incentives on excise tax and registration fees could reduce the price of EVs significantly, and this may encourage consumers to buy electric cars and also encourage investors to increase investment in EV production. However, to increase the share of EVs in the road vehicle fleet more quickly, better support and incentive policies are needed:

- ✓ Specific targets for EV production and charging infrastructure for each time period mentioned in Decision No. 876/QĐ-TTg should be set.
- ✓ There should be more incentive policies on credit, investment, and trade for EV makers and their supply chains as well as charging infrastructure systems.
- ✓ Supplement and complete standards/regulations for EVs and charging stations; investment support for R&D, the technology transfer of batteries, and battery recycling.

- ✓ Provide incentive policies/preferential treatment for EV holders in a certain period, for example, priority parking places, exemptions, and reductions of parking fees, etc.
- ✓ Control vehicle emissions more strictly, especially for ICE-powered 2Ws.
- ✓ Implement regulations for revoking and recycling expired/discarded vehicles.

2.5.4. Mobility scenarios

a. For biofuel

A detailed roadmap could be suggested to meet the target in Decision No. 876/QĐ-TTg:

- ✓ By 2025: Replace gasoline RON95-III with E5 RON95-III in the big cities.
- ✓ By 2027: Replace gasoline RON95-III with E5 RON95-III all over the country; replace gasoline RON95-V with E5 RON95-V in the big cities.
- ✓ By 2030: All gasoline in the market will be E5 fuel.

b. For EVs

Viet Nam has not yet provided a specific target for EV production and consumption. However, from the perspective and experiences of automobile manufacturers of road vehicle electrification, the Vietnam Automobile Manufacturers' Association (VAMA) have proposed three (fast, medium, and basic) scenarios for electrified vehicles in Viet Nam (Vietnam Plus, 2022). The fast scenario is to start electrifying vehicles from 2025 and reach 100% electrified vehicles by 2035, the medium scenario is to start electrifying vehicles from 2025 to 100% electrified vehicles by 2045, and the basic scenario is to start the process of electrifying vehicles from 2025 until reaching 100% electrified vehicles by 2050.

With the current capacity of the Viet Nam automobile market, VAMA also proposed a roadmap to develop electrified automobiles in three phases. Phase 1, during 2021–2030, is a starting stage that will reach a level of mechanisation in 2028 – approximately 1 million automobiles of all types will be produced, and ICE-powered vehicles still dominate. However, the number of electrified automobiles will gradually increase in this phase. Phase 2, during 2030–2040, is a rapid growth stage, and the number of electrified automobiles will reach 100%, equivalent to 3.5 million units. Phase 3, during 2040–2050, is a stable growth stage, and saturation will be reached at 4 million–4.5 million units.

2.6. Malaysia

Under its nationally determined contribution (NDC), Malaysia increased its mitigation ambition with an unconditional target to cut carbon intensity against GDP by 45% by 2030 compared to 2005 levels, an additional 10% being conditional on external support (UNDP Global Climate Promise, 2023). Malaysia aspires to achieve a net-zero greenhouse gas (GHG) emissions target by 2050 at the earliest (Ministry of Environment and Water, Malaysia, 2022). Various policies, strategies, and incentives have been formulated to achieve the carbon emissions reduction target. Based on energy demand by sectors in 2018, the transportation sector contributed about 24% of total energy use, followed by the power sector and non-energy uses at 13% each and industry at 12% (Ministry of International Trade and Industry, Malaysia, 2020).

To decarbonise the transportation sector, Malaysia has implemented a biodiesel programme and EV strategies. It implemented B10 for the transportation sector in 2019 and B20 in phases starting in 2020. Malaysia aims to have xEVs at 15% of the total industry volume by 2030, e-bikes at 15% of the total industry volume by 2030, e-buses at 20% of active permits by 2030, and an increased xEV share of 38% by 2040 (Ministry of Environment and Water, Malaysia, 2021; Economy Planning Unit, Prime Minister's Department, Malaysia, 2022). As of December 2022, more than 10,000 fully electric vehicles and over 100,000 electrified vehicles (including various hybrid types) have been registered in Malaysia. Under the deployment plan of EV initiatives, a total of 978 public EV charging stations were installed by March 2023. The target is to set up 10,000 charging points by 2025 (Ministry of Environment and Water, Malaysia, 2021).

Certainly, there are barriers that need to be overcome for achieving the EV target in Malaysia. The Malaysia Automotive Robotics and IoT Institute (MARii), an agency under the Ministry of Investment, Trade, and Industry (MITI) is spearheading the implementation of EV policy in the country. Below are some key points that need to be addressed to realise the EV target in Malaysia and suggestions to bridge EV implementation.

(a) Affordable ownership of EVs

The purchase price of EVs in Malaysia is generally more expensive compared to ICE vehicles. The high initial cost of EVs has restricted the wide adoption of EVs by the public. On average, the affordable car purchasing power of the low-to-medium-income population is between RM40,000 and RM100,000. This is based on the most popular passenger cars sold in Malaysia in 2022 (King, 2023). The consumer will choose to buy an EV if it is priced within a similar range. According to the Malaysia Automotive Association (MAA, 2023), a total of 720,658 vehicles were sold in Malaysia in 2022. The passenger cars segment contributed to 641,773 unit sales, whilst commercial vehicle sales were recorded at 87,885 units. Two local brands, Perodua and Proton, have dominated the market with sales volumes of 38.1% and 18.9% in 2022 (Statista Research Department, 2023). The most popular Perodua cars were Myvi, Bezza, and Axia with entry prices from RM46,500, RM36,600, and RM62,500, respectively (Perodua, 2023).

To attract more people to buy EVs, the government has extended the exemption of import duties on CBU EVs till 2024 and is offering a rebate of up to RM30,000 for locally assembled EVs. However, even the cheapest EVs offered in the market, the 2022 Ora Good Cat 400 Pro, still costs RM140,000. In contrast, there is a pool of other petrol-powered cars on the market to choose from, with some economy cars going for much less than that.

During the Malaysia Autoshow held in May 2023, the launch of Neta V at the price of RM99,800 created a new horizon in the EV market in Malaysia (WapCar, 2023). The car comes with a 5-year or 150,000 km warranty and an 8-year or 180,000 km battery warranty. Being the cheapest EV in the market, Neta V will still need to compete with Perodua Myvi, which is only 50% of the price.

Consumers will also compare the entire cost of ownership of a car, such as road tax and insurance. EVs are currently exempted from road tax from January 2022 until December 2025. Without the road tax exemption, the EV owner would be paying a higher road tax compared to owners of ICE vehicles. The road tax for EVs depends on the battery power output. A lower output EV of 80 kW entails a road tax flat rate of RM70, but the rate increases four-fold for a 100 kW car. With a power output of 500 kW, the road tax could go as high as RM10,000 which is much more expensive than the road tax of any ICE cars.

To lower the cost of ownership, the government could consider providing corporate tax incentives for companies that procure EVs or personal tax relief to encourage the public to own EVs. Guidelines and goals to reduce the carbon footprint for enterprises should be formulated and endorsed. This will create awareness amongst businesses to decarbonise, including consideration of how they transport goods and services to consumers. If the efforts of investing in EVs can be appreciated by the public and paid off by means of a green tax rebate mechanism, the cost of EVs could be compensated for.

(b) EV maintenance and talent development

EV adoption will change the entire ecosystem of the vehicle supply chain, which was set up for ICEs previously. Now, consumers' confidence in EV maintenance and breakdown services is generally low. Thus, the development of skilled workers is crucial for the aftersales services of EV vehicles, including services for power inverters, electric motors, battery management systems, batteries, onboard chargers, and charge ports, etc. This talent development will become an important segment to drive the penetration of EVs in order to build the confidence of consumers for owning EVs.

Under the stewardship of MARii, various skill development programmes related to the EV supply chain have been introduced together with the Department of Skills Development. Local universities will revise their teaching modules related to the automotive industry by introducing EV courses specifically designed to support the future workforce requirements of the EV ecosystem. Governments can also incentivise the current workforce in the automotive sector to take up various EV courses to prepare for workshops to undertake maintenance and repair work.

(c) Charging of EVs

The ease of charging EV cars is another main concern for EV owners. As of December 2022, more than 10,000 fully electric vehicles and over 100,000 electrified vehicles (including various hybrid types) have been registered in Malaysia. As of March 2023, the total number of public charging stations in Malaysia stood at 978, with 86% AC and 14% DC chargers (MARii, 2023). The government aims to install 10,000 charging points by 2030. People who intend to drive for long distances may not be enticed to buy EVs as they would need to plan their trips well to recharge in time before running out of power. The drivers must also ensure that their EVs are fully charged before going out for their next long drive. Petrol cars can be refilled within minutes, but charging EVs with a DC fast charger requires 20–30 minutes. An AC charger is a convenient choice, but it takes a long time (8–20 hours) to fully charge depending on the vehicle's battery size.

The distribution network of charging stations is mostly concentrated in city areas and mostly in parking bays of shopping malls. Once outside the region, owners face the challenge of locating charging stations, especially during unplanned journeys. At present, the number of providers and locations offering DC fast charging remains low. The installation cost of public fast chargers is a significant economic challenge, as setting up 10 rapid charging stations with 50 kW DC will cost between RM1.5 million and RM2 million (Muzir, 2022). The recent 2023 budget announced an allocation of RM90 million to Tenaga National Berhad to install EV charging facilities across 70 targeted locations (MIDA, 2023). Information gathering on EV users' driving patterns and routes is important to mitigate the wastage of underutilised charging stations. Charging infrastructure is a very complex part of EV planning. The type of charging to be employed, charging location, and burden on the grid are important factors to consider in EV charging infrastructure planning.

To overcome the charging issue, policy on installing charging stations should be included in the early urban development plan to avoid additional costs of laying power cables to cope with additional electricity demand for EV charging in the future. The type of standards for EV charging also needs to be addressed, as it will become very challenging since EV manufacturers from different regions will have different standards. Information on the commercial charging infrastructure should be made available to the public using a centralised database system. Information on charger map locations must be updated to provide drivers with the necessary information on the type of charging and chargers used and the cost of charging, etc.

(d) Green electricity supply

Consumers are knowledge-oriented. In the future, policies that the government wants to introduce must wholistically cover all aspects of sustainability. This means that those who are considering buying an EV will also think about whether the source of electricity that powers the EV is coming from sustainable resources. In Peninsular Malaysia, most electricity generation is from fossil-based power plants (coal, natural gas, and diesel). In 2018, natural gas constituted the largest portion of the total primary energy supply, at 41%, followed by crude oil and petroleum products and coal, which constituted 29% and 22%, respectively (Economy Planning Unit, Prime Minister's Department, Malaysia, 2022). To achieve the Low Carbon Nation Aspiration by 2040, the percentage of renewable energy in the total primary energy supply is targeted to increase from 7.2% in 2018 to 17% in 2040. At the same time, dependency on coal power plants will be reduced from 31.4% in 2018 to 18.6% in 2040 (Economy Planning Unit, Prime Minister's Department, Malaysia, 2022).

Currently, a 1.6% surcharge on the electricity bill is implemented to contribute towards the Renewable Energy Fund for the implementation of the Feed-in Tariff (FiT) mechanism since 1st December 2011. The surcharge could be revised to provide more opportunities for power producers to produce green electricity. A carbon tax could be introduced to support the deployment of clean electricity generation, which in return would serve to educate consumers on environmental protection and embracing EVs. An analysis of the life cycle assessment of driving an EV should be carried out by each EV manufacturer based on the different electricity supply scenarios. The GHG emission data should be made available on a mandatory basis in the user manual. At the end of the day, the consumer should be convinced that driving an EV will create less of an environmental impact than driving an ICE car.

(e) Battery cost and replacement

Batteries constitute one of the major cost components in EVs. Although most of the manufacturers provide battery warranties of up to 10 years or for 160,000 km, battery replacements after that are very expensive. The cost of a new EV battery is on par with the cost of replacing a gas engine, which can be more than RM30,000 (Wong, 2023). Like any other batteries, EV batteries' electricity holding capacity drops over time, or worse, they suffer from sudden battery failure. The battery degradation rate is subject to conditions of use and charge, such as overcharging, extreme temperatures, charging without a battery cool-down period, and using fast charging, etc. A degraded battery will have less mileage and reduced driving distance. The situation could become worse if a battery suddenly flattens before reaching its shelf life. Consumers may need to wait for a long time before they can receive a replacement battery.

Battery cost reduction measures should be identified to solve the high market price of EVs. The ideal way is to attract investment for local battery cell manufacturers that can overcome the high production costs, shortage of components, logistic costs, and sourcing of critical cell components, such as nickel, lithium, and cobalt, etc. With the increased demand and mass production of EVs, it is estimated that by 2025, the price of an EV can be reduced by about RM25,000 per vehicle (Baik et al., 2019). The growing EV market and increased competition between manufacturers to produce EV vehicle parts, high-density batteries, and fast-charging features will further curtail the EV retail price. Another option is to encourage EV manufacturers to provide batteries on a loan basis to customers. This means that consumers will buy EVs without batteries to lower the ownership cost and ease the burden of battery replacement costs.

(f) Cost of electricity

The cost of charging EVs is also a critical factor in achieving the EV target. Based on the current tariff rate in Malaysia, the cost per km for EVs is lower than for ICEs by 20%–30% (Carput, 2023). As petrol and diesel fuels are heavily subsidised by the government, the savings on fuel costs by switching to EVs are not significant compared to the high initial cost of EV ownership. The efforts of rationalisation of the fuel subsidy by the government could help to encourage EV adoption when the electricity cost per km for EVs is significantly lower than the fuel cost for ICEs.

Mobility scenario in the future for Malaysia

Malaysia, being the second-largest producer of palm oil has embarked on nationwide B10 and B20 (selected regions) biodiesel programmes. Unlike the EU, the majority of passenger cars in Malaysia are petrol vehicles. There is no mandatory bioethanol blending programme for petrol cars due to a lack of raw materials for bioethanol production. Thus, it is rational for Malaysia to increase the blending of biodiesel for commercial diesel vehicles whilst encouraging EV switching for passenger cars, which are mainly petrol vehicles. The biodiesel programme and EV adoption complement each other with the aim to decarbonise different segments in the transportation sector. The biodiesel programme will be expanded to B30 by 2030 according to the National Agricommodity Policy (DAKN) 2021-2030 and the National Automotive Policy 2020 (Ministry of Plantation and Commodities, Malaysia, 2021; Ministry of International Trade and Industry, Malaysia, 2020). Commercial diesel users are also encouraged to use B100 to further reduce their GHG emissions. EVs are expected to become more popular in the future when key barriers, such as charging infrastructure, initial cost of ownership, servicing and maintenance, battery replacement costs, and battery charging costs, are slowly addressed. The EV target set forth is achievable with incentives for EV ownership and efforts put forward by the government to generate more renewable energy.

3. Discussion

In this chapter, barriers to implementing the vehicle electrification scenario in EAS countries were collected and analysed, along with recommendations to overcome these barriers. From this analysis, the mobility scenario for each country was identified to find the appropriate emission reduction measures considering each country's characteristics.

In conclusion, since Thailand has both feedstock resources for bioethanol and biodiesel, biofuel policy will still be part of the National Energy Plan, where E10–E20 and B10 would be solutions to decarbonising the current ICE fleets, whereas EV penetration will help decarbonise new vehicles. The balance between EVs and ICEs in various vehicle sectors would depend on the comparison of the total cost of ownership between EVs and ICEs.

In Indonesia, considering the huge availability of both bioresources and other renewable energy resources inside the country, the Government of Indonesia has chosen not to prioritise EV development over biofuel development and, instead, implement both EV and biofuel development to accelerate the transition towards sustainable mobility. The government has recently also promoted the development of hydrogen fuel for use in fuel-cell vehicles (FCVs) as well as ICE vehicles. In this context, cost-effective ways of transporting and storing hydrogen will clearly be needed.

In India, the recommendation to implement EVs includes a robust network of battery charging, wider adoption of vehicle-to-grid technology, foreign direct investment, and increased participation from lenders in the EV market. There should be a common federal regulation on EVs since electricity comes under the concurrent list in India. This will help to achieve consistency in the setting of EV tariffs across India.

In the Philippines, gasoline and diesel demand are continuously increasing, and biofuels can be readily utilised with the existing infrastructure, compared to EV deployment, which is at an early stage. Some of the common concerns for the Philippine EV and biofuels industry during its concurrent implementation are the EV travel distance/range, infrastructure, and logistics, taking into consideration the archipelagic nature of the Philippines as well as the sustainability of its feedstock. Based on existing laws and issuances, both the EV and biofuel targets are set to increase in the long term. Depending on the current administration's priorities, there is a need to find a balance between the two with a similar end goal of reducing the use of imported fuel and carbon emissions.

In Viet Nam, a detailed roadmap of biofuels could be suggested to meet the target of Decision No. 876/QĐ-TTg. For example, by 2025, replace gasoline RON95-III with E5 RON95-III in the big cities; by 2027, replace gasoline RON95-III with E5 RON95-III all over the country and replace gasoline RON95-V with E5 RON95-V in the big cities; and by 2030, ensure that all gasoline in the market will be E5 fuel.

For EVs, Viet Nam has not yet provided a specific target for EV production and consumption. However, from the perspective and experience of automobile manufacturers of road vehicle electrification, the Vietnam Automobile Manufacturers' Association (VAMA) has proposed three scenarios for electrified vehicles in Viet Nam (Vietnam Plus, 2022). The fast scenario is to start electrifying vehicles from 2025 and reach 100% electrified vehicles by 2035, the medium scenario is to start electrifying vehicles from 2025 to 100% electrified vehicles by 2045, and the basic scenario is to start the process of electrifying vehicles from 2025 until reaching 100% electrified vehicles by 2050. With the current capacity of Viet

Nam's automobile market, VAMA has also proposed a roadmap to develop electrified automobiles in three phases.

In Malaysia, it is rational to increase the blending of biodiesel for commercial diesel vehicles whilst encouraging EV switching for passenger cars, which are mainly petrol vehicles. The biodiesel programme and EV adoption complement each other with the aim of decarbonising different segments of the transportation sector. The biodiesel programme will be expanded to B30 by 2030. Commercial diesel users are also encouraged to use B100 to further reduce their GHG emissions. EVs are expected to become more popular in the future, when key barriers such as charging infrastructure, the initial cost of ownership, servicing and maintenance, battery replacement costs, and battery charging costs are slowly addressed. The EV target set forth is achievable with incentives for EV ownership and efforts put forward by the government to generate more renewable energy.

To conclude, Table 3.15 shows the results of a comparative analysis of the potential, advantages, and barriers to EVs in each country.

Table 3.15. Comparative Analysis of the Potential, Advantages, and Barriers to EVs in Each Country

Country	Potential and Advantages	Barriers
Thailand	• EV promotion and supported charging infrastructure nationwide from the government • Subsidy for BEV models • Progressively issued industrial standards for electric cars, electric motorcycles, and charging equipment	• High insurance for EVs • Falling used car prices are also related to high battery costs, where newer models of BEVs have fewer battery warranty years • Necessity to upskill the workforce for EVs, ranging from engineers in the assembly line to mechanics to fix EVs
Indonesia	• Huge availability of both bioresources and other renewable energy resources inside the country • Government initial monetary and non-monetary incentives	• Electric cars are still expensive/unaffordable • Insufficient charging infrastructure • Lack of government incentives • Low availability of spare parts and repair and maintenance services • Local content requirements • Long charging times • Distance coverage is relatively short • Electricity supply (kWh/capita/year) is still low • Reluctance of transition
India	• Government is increasing the deployment of the renewable energy mix.	Investment challenges: • Investment gap

Country	Potential and Advantages	Barriers
	• Government is promoting biofuels (blending of ethanol) and EVs on a large scale.	• Complexity in valuing company assets • Current macroeconomic environment is not conducive to investments • High upfront costs of EVs Infrastructure challenges: • Inadequate electrical supply network • Charging infrastructure obstacles Battery challenges: • High-voltage batteries are sizeable and heavy, affecting the handling of EVs. Heavy batteries are prone to safety hazards, vulnerable damage, and thermal runaway. • Recycling/disposal of old batteries is problematic.
Philippines	• The Philippines is an agricultural country and has other potential biofuel feedstock sources. • Government fiscal and non-fiscal incentives.	• Market development: flooding concerns, inadequate or lack of capacity to invest, scepticism of technology due to lack of familiarity, etc. • Technical support: high spare parts costs due to low demand and limited financial capacity of local EV suppliers to stock a large volume of spare parts. • Battery disposal: lack of knowledge of battery recycling technology. • Charging/battery swapping services: lack of third-party battery leasing/swapping/charging/station providers, etc.
Viet Nam	• Government has given incentives, such as reducing the excise tax rate and/or registration fees for xEVs and biofuel vehicles.	• Target for EV development strategy has not been set clearly. • Policy to support EV development is still limited. • Lack of charging infrastructure.

Country	Potential and Advantages	Barriers
	• Significant increase with the domination of EV models from VinFast, a local car maker and the only enterprise manufacturing electric vehicles in Viet Nam.	• Price of EVs is still high.
Malaysia	• The government has extended the exemption of import duties on CBU electric vehicles until 2024. • EVs are currently exempted from road tax from January 2022 until December 2025. • Malaysia, being the second-largest producer of palm oil has embarked on a nationwide B10 and B20 (selected regions) biodiesel programme.	• High cost of EVs compared to ICEs. • Consumers' confidence in EV maintenance and breakdown services is generally low. • The ease of charging EV cars is another main concern for EV owners. Petrol cars can be refilled within minutes, but charging an EV with a DC fast charger will require 20–30 minutes. • The distribution network of charging stations is mostly concentrated in cities and mostly in parking bays of shopping malls. • In Peninsular Malaysia, most electricity generation is from fossil-based power plants (coal, natural gas, and diesel). • High battery cost and replacement cost.

Source: Thailand: Energy Plan and Policy Office (2023); TISI (2022); Indonesia: Mapa (2022); Veza (2022); Candra (2022); Indonesian Government Regulation No. 8 of 2020, No. 74 of 2021; Jakarta Governor Regulation No. 3 of 2020; Minister of Finance Regulation No. 38 of 2023; Jakarta Governor Regulation No. 88 of 2019; India: Central Electricity Authority, Government of India (2023); Foreign Agricultural Service, U.S. Department of Agriculture; Philippines: PDOE (2021); PDOE (2022a); Draft CREVI, PDOE (2023b); Vietnam: National Assembly of Vietnam (2016); National Assembly of Vietnam (2022); Government of Vietnam (2022); Ministry of Finance, Vietnam (2015); VnEeconomy (2023); Malaysia: Low Carbon Mobility Blueprint 2021-2030; National Energy Policy 2022-2040.

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Chapter 4

Conclusions and Recommendations

1. Introduction

The National Institute of Advanced Industrial Science and Technology (AIST) has been studying the future mobility scenarios of East Asia Summit (EAS) countries since 2014. In the past AIST–Economic Research Institute for ASEAN and East Asia (ERIA) project, the scenarios for India, Indonesia, and Thailand were examined considering the potential of biofuels and electrified vehicles (xEVs). As a result, well-to-wheel CO_2 emissions were estimated for several scenarios by creating an energy mix model.

However, in the previous project, the sustainability of biofuels and xEVs was not taken into consideration. The diffusion of xEVs can contribute to CO_2 reduction but may affect the mineral resource demand induced by motors and batteries. Therefore, the aim of this project is to analyse future scenarios of EAS mobility that contribute to the Sustainable Development Goals 7, 12, and 13 in consideration of the balance between transport CO_2 reduction, biofuel use, and mineral resources demand. The outcome will contribute to the EAS Energy Research Road Map (Pillar 3: Climate Change Mitigation and Environmental Protection), corresponding to the ASEAN Plan of Action for Energy Cooperation (APAEC) 2016–2025 (3.5 Programme Area No. 5: Renewable Energy and 3.6 Programme Area No. 6: Regional Energy Policy and Planning).

In fiscal year 2020, the first phase of this project was conducted. Biofuel policies and strategies, as well as existing research on biofuel sustainability, were assessed for the EAS countries (India, Thailand, Malaysia, Viet Nam, Indonesia, and the Philippines). Moreover, a database was created to evaluate well-to-wheel CO_2 reduction and mineral resource demand based on biofuel implementation and mobility electrification.

In fiscal year (FY) 2021, working group meetings were conducted in December 2021 and April 2021. As a result, 'well-to-tank' greenhouse gas (WTT GHG) emissions for producing biofuels, 'tank-to-wheel' GHG emissions for using biofuels, and demand and GHG emissions for producing mineral resources considering mobility electrification were evaluated. This chapter describes the conclusion and progress of each study (chapters).

In FY2022, working group meetings were conducted in January 2023 and April 2023. As a result, WTW GHG emissions for implementing biofuels and EVs were assessed for three different scenarios considering the improvement in energy sources. Moreover, mineral resources demand considering mobility electrification was evaluated and compared with supply data from the United States Geological Survey (USGS) and global demand forecasts of the International Energy Agency (IEA). Finally, barriers to implementing the vehicle electrification scenario in EAS countries were examined and the mobility scenario for each country was identified. This chapter describes the conclusion and progress of each study (chapters).

2. Tank-to-Wheel CO_2 Emissions from Biofuels/EVs and Mineral Resources Consumption in East Asia Summit Countries

In this chapter, GHG emissions considering the landscape of the current vehicle ecosystem in select Association of Southeast Asian Nations (ASEAN) Member States (Indonesia, Malaysia, Philippines, Thailand, and Viet Nam) and India are examined with the same projection of vehicle growth in the future as from the previous study (ERIA, 2022) but with an updated grid emission factor to assess GHG emissions as a result of collective efforts on EVs and biofuel in the transport sector. In particular, three different scenarios are considered based on the assumption of EVs and biofuel from the previous study (ERIA, 2022) and improvement in electricity sources.

This chapter further explores a bottom-up energy demand model for the transport sector from the previous study (ERIA, 2022), focusing on cars and motorcycles in selected countries using the well-respected Low Emissions Analysis Platform (LEAP) system with input data on population, GDP, vehicle history and projection, vehicle kilometres travelled (VKT), and fuel economy. The best available assumption must be made when data are not available to construct models for EVs and biofuel forecasts.

With the relatively robust vehicle ownership model, the Business-as-Usual (BAU) setting for energy consumption and WTT GHG emissions can be set as a baseline for investigation into the impacts of EVs and biofuel policy. Additional grid emission improvements from renewable energy are quantitatively assessed on reductions in transport GHG emissions. As pointed out in the previous study (ERIA, 2022), the motorcycle segment in these six countries emits similar GHGs to the car segment, and the electrification effect from the current target could achieve about 5% decarbonisation in each sector. Further grid emission factor improvement from the current policy could help further decarbonise by less than 2%, implying that further consideration may be needed to improve grid emissions. On the other hand, biofuel policy could help each sector decarbonise by 10%.

This chapter also explains the result of neodymium (Nd) and cobalt (Co) demand for vehicle electrification in EAS countries until 2040. This result is compared to Nd and Co supply from mining production by the USGS and other demand forecasts from the IEA to see the trendline for every forecast.

The demand of Nd for vehicle electrification in EAS countries is predicted to be 4,075 t/y in 2040. By comparing the IEA world Nd demand (of EVs) forecast of the Stated Policies Scenario, it was found that EAS countries account for about 37% of the world's total Nd demand for EVs. Considering the large increase in Nd demand in Europe, the United States, China, and other EV-implementing countries, EAS countries' 37% share of global demand is expected to create fierce competition with other countries.

Regarding Co, the demand for vehicle electrification in EAS countries is forecasted to be 53,324 t/y. By comparing the IEA world Co demand (of EVs) forecast of the Stated Policies Scenario, it was found that EAS countries account for about 41% of the world's total Co demand. Therefore, Co is also expected to create fierce competition with other countries.

3. Mobility Scenarios for East Asia Summit Countries

This chapter describes the conclusion of the barriers to implementing the vehicle electrification scenario in EAS countries based on the collected data and analysis from Working Group members. To accelerate the introduction of EVs, the recommendations to overcome these barriers will be explained and analysed. By analysing the barrier conditions, recommendations, and the availability of biofuel resources and other renewable energies, the future mobility scenario for each country is identified to find the appropriate emission reduction measures considering each country's characteristics.

In conclusion, Thailand has both feedstock resources for bioethanol and biodiesel, and E10-E20 and B10 would be solutions for decarbonising the current ICE fleets, whereas EV penetration will help decarbonise new vehicles. In Indonesia, considering the huge availability of both bioresources and other renewable energy resources inside the country, the Government of Indonesia has chosen not to prioritise EV development over biofuel development and, instead, is implementing both EV and biofuel development to accelerate the transition towards sustainable mobility. In the Philippines, gasoline and diesel demand are continuously increasing, and biofuels can be readily utilised with the existing infrastructure, compared to EV deployment, which is in its early stages. Some of the common concerns for the Philippine EV and biofuels industry during the concurrent implementation are the EV travel distance/range, infrastructure, and logistics, taking into consideration the archipelagic nature of the Philippines as well as the sustainability of feedstock. Viet Nam has not yet provided a specific target for EV production and consumption, but the Vietnam Automobile Manufacturers' Association (VAMA) has proposed three scenarios for electrified vehicles in Viet Nam. The fast scenario is to start electrifying vehicles from 2025 and reach 100% electrified vehicles by 2035, the medium scenario is to start electrifying vehicles from 2025 to 100% electrified vehicles by 2045, and the basic scenario is to start the process of electrifying vehicles from 2025 until reaching 100% electrified vehicles by 2050. In Malaysia, it is rational to increase the blending of biodiesel for commercial diesel vehicles whilst encouraging EV switching for passenger cars, which are mainly petrol vehicles. The biodiesel programme and EV adoption can complement each other with the aim to decarbonise different segments of the transportation sector. EVs are expected to become more popular in the future when key barriers, such as charging infrastructure, initial cost of ownership, servicing and maintenance, battery replacement cost, and battery charging cost, are slowly addressed.

Table 4.1 shows the result of the comparative analysis of the potential, advantages, and barriers for EVs in each country. In this analysis, the challenges, as well as policy recommendations for implementing EVs, were examined for each country.

Table 4.1. Comparative Analysis of the Potential, Advantages, and Barriers to EVs in Each Country

Country	Potential and Advantages	Barriers
Thailand	• EV promotion and supported charging infrastructure nationwide from the government • Subsidy for BEV models • Progressively issued industrial standards for electric cars, electric motorcycles, and charging equipment	• High insurance for EVs • Falling used car prices are also related to high battery costs, where newer models of BEVs have fewer battery warranty years • Necessity to upskill the workforce for EVs, ranging from engineers in the assembly line to mechanics to fix EVs
Indonesia	• Huge availability of both bioresources and other renewable energy resources inside the country • Government initial monetary and non-monetary incentives	• Electric cars are still expensive/unaffordable • Insufficient charging infrastructure • Lack of government incentives • Low availability of spare parts and repair and maintenance services • Local content requirements • Long charging times • Distance coverage is relatively short • Electricity supply (kWh/capita/year) is still low • Reluctance of transition
India	• Government is increasing the deployment of the renewable energy mix. • Government is promoting biofuels (blending of ethanol) and EVs on a large scale.	Investment challenges: • Investment gap • Complexity in valuing company assets • Current macroeconomic environment not conducive to investments • High upfront cost of EVs Infrastructure challenges: • Inadequate electrical supply network • Charging infrastructure obstacles Battery challenges: • High-voltage batteries are sizeable and heavy, affecting the handling of

Country	Potential and Advantages	Barriers
		EVs. Heavy batteries are prone to safety hazards, vulnerable damage, and thermal runaway. • Recycling/disposal of old batteries is problematic.
Philippines	• The Philippines is an agricultural country and has other potential biofuel feedstock sources. • Government fiscal and non-fiscal incentives.	• Market development: flooding concerns, inadequate or lack of capacity to invest, scepticism of technology due to lack of familiarity, etc. • Technical support: high spare parts costs due to low demand and limited financial capacity of local EV suppliers to stock a large volume of spare parts. • Battery disposal: lack of knowledge of battery recycling technology. • Charging/battery swapping services: lack of third-party battery leasing/swapping/charging/station providers, etc.
Viet Nam	• Government has given incentives, such as reducing the excise tax rate and/or registration fees for xEVs and biofuel vehicles. • Significant increase with the domination of EV models from VinFast, a local car maker and the only enterprise manufacturing electric vehicles in Viet Nam.	• Target for EV development strategy has not been set clearly. • Policy to support EV development is still limited. • Lack of charging infrastructure. • Price of EVs is still high.
Malaysia	• The government has extended the exemption of import duties on CBU electric vehicles until 2024. • EVs are currently exempted from road tax from January 2022 until December 2025. • Malaysia, being the second-largest producer of palm oil has embarked on a nationwide B10 and B20 (selected regions) biodiesel programme.	• High cost of EVs compared to ICEs. • Consumers' confidence in EV maintenance and breakdown services is generally low. • The ease of charging EV cars is another main concern for EV owners. Petrol cars can be refilled within minutes, but charging an EV with a DC fast charger will require 20–30 minutes. • The distribution network of charging stations is mostly concentrated in

Country	Potential and Advantages	Barriers
		cities and mostly in parking bays of shopping malls. • In Peninsular Malaysia, most electricity generation is from fossil-based power plants (coal, natural gas, and diesel). • High battery cost and replacement cost.

Source: Thailand: Energy Plan and Policy Office (2023); TISI (2022); Indonesia: Mapa (2022); Veza (2022); Candra (2022); Indonesian Government Regulation No. 8 of 2020, No. 74 of 2021; Jakarta Governor Regulation No. 3 of 2020; Minister of Finance Regulation No. 38 of 2023; Jakarta Governor Regulation No. 88 of 2019; India: Central Electricity Authority, Government of India (2023); Foreign Agricultural Service, U.S. Department of Agriculture; Philippines: PDOE (2021); PDOE (2022a); Draft CREVI, PDOE (2023b); Vietnam: National Assembly of Vietnam (2016); National Assembly of Vietnam (2022); Government of Vietnam (2022); Ministry of Finance, Vietnam (2015); VnEeconomy (2023); Malaysia: Low Carbon Mobility Blueprint 2021-2030; National Energy Policy 2022-2040.

4. Conclusion and Future Aspects

Following the FY2021 project results, this study assessed the WTW GHG emissions for implementing biofuels, and EVs were assessed for three different scenarios considering the improvement in energy sources. Moreover, mineral resources demand considering mobility electrification was evaluated and compared with the supply data of the USGS and the global demand forecast of the IEA. Finally, barriers to implementing the vehicle electrification scenario in EAS countries were examined and the mobility scenario of each country was identified.

In conclusion, the balance between biofuel and EVs is important in all EAS countries. In particular, whilst mineral resource constraints are important for EVs, price, infrastructure, and policy support are even more important. Comparing by country, Thailand and Indonesia can introduce biofuels and EVs in parallel, whilst the Philippines, Viet Nam, and Malaysia should give priority to biofuels in the initial stage, as they can utilise existing infrastructure and introduce EVs in the future when the price of EVs declines and infrastructure is in place.

For further studies, the implementation of biofuels must be assessed from wider perspectives. For example, producing and using biofuels will influence energy, food, and water consumption in many EAS countries. Identifying these synergies, as well as the multi-benefits between biofuel, energy, and water, can highly contribute to the achievement of the SDGs.