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# The Influence on Energy and the Economy of Electrified Vehicles Penetration in ASEAN

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## **The Influence on Energy and the Economy of Electrified Vehicles Penetration in ASEAN**

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## List of Abbreviations and Acronyms

3Es	=	economy, energy, and environment
ASEAN	=	Association of Southeast Asian Nations
BEV	=	battery electric vehicle
CKD	=	complete knockdown
ERIA	=	Economic Research Institute for ASEAN and East Asia
GDP	=	gross domestic product
HEV	=	hybrid electric vehicle
ICEV	=	internal combustion engine vehicle
IEA	=	International Energy Agency
IEEJ	=	The Institute for Energy Economics, Japan
kWh	=	kilowatt hour
Mtoe	=	million tonnes of oil equivalent
PHEV	=	plug-in hybrid vehicle
PLDV	=	passenger light-duty vehicle
US\$	=	United States dollar
xEV	=	electric vehicle (including HEV, PHEV, and BEV)

## Executive Summary

Demand for automobiles to transport passengers and freight has been rapidly increasing amongst members of the Association of Southeast Asian Nations (ASEAN), giving rise to traffic congestion and air pollution. As demand for petroleum increases, the region's oil self-sufficiency has declined greatly and CO<sub>2</sub> emissions have increased. Automobile penetration is expected to rise as ASEAN economies grow, further increasing energy insecurity and environmental concerns.

To tackle these issues, ASEAN countries have announced policies to promote electric vehicles (xEVs),<sup>1</sup> which reduce oil consumption and air pollution but increase demand for electricity; depending on its power generation sector, a country might not solve its environmental problems. On the other hand, countries are also trying to promote industry in the field of xEVs. There are also movements to attract overseas companies and domestic production of automobiles and batteries.

The study analyses the effects of xEVs on the economy, energy, and environment (3Es) – the basic principle of energy policy. Through analysing qualitative and quantitative information on energy supply and demand structures, impacts on CO<sub>2</sub> emissions, and the macroeconomy and employment, the study delivers the following outcomes.

1. Indonesia, Malaysia, Thailand, and Viet Nam may face challenges in the 3Es in the following reference scenario, which assumes continued historical trends without strengthening policy measures:
  - ✓ The number of cars increases 2.3 times by 2040 due to high economic growth. Motorbikes, which are over three times more numerous than cars, increase 1.5 times.
  - ✓ Total primary energy demand increases by 2.6% annually in Indonesia, 5.1% in Viet Nam, 1.6% in Thailand, and 2.1% in Malaysia. Coal demand grows at higher rates in each country to meet rapidly increasing electricity demand.
  - ✓ High fossil-fuel dependency leads to increasing CO<sub>2</sub> emissions, which increase annually by 2.9% in Indonesia and 5.8% in Viet Nam – rates that are higher than energy-demand growth, meaning that their energy mix becomes more carbon-intensive. In Thailand and Malaysia, CO<sub>2</sub> emissions grow at almost the same rate as energy demand.

We set scenarios for xEV penetration and look at their respective impact on energy and the economy. The battery electric vehicle (BEV) Ambitious scenario sets that BEVs will rapidly penetrate and get almost 100% market share by 2040. Meanwhile, the hybrid electric vehicle (HEV) Bridge scenario is assumed to start with low-cost HEVs, with BEVs being gradually introduced starting after 2030 when their cost starts to decline.

- ✓ BEV penetration's ability to reduce CO<sub>2</sub> emissions is limited unless the power generation

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<sup>1</sup> Including hybrid, plug-in hybrid and battery electric vehicles.

sector is decarbonised. ASEAN countries largely depend on coal-fired power generation.

- ✓ xEV penetration may need large subsidies to realise both of the scenarios. The total subsidy for the BEV scenario is several times that for the HEV scenario and puts pressure on government finances.
- ✓ Governments should calculate the cost-effectiveness of subsidies with respect to the amount of CO<sub>2</sub> reduction.

2. It is necessary to pay attention to other economic activities affected by xEV penetration. The production of BEVs with a small number of material parts might reduce automotive industry employment compared to the production of internal combustion engine vehicles (ICEVs) and HEVs.

- ✓ The ripple effects of xEV-related expenditure on production and employment are almost negative in the four countries. The negative effects will be even greater if they rely on importing xEVs / battery packs.
- ✓ If people use daily fuel savings for other goods and services, xEV penetration would bring job creation, especially in the E-Motorcycle Advanced scenario, where the e-motorcycle share is assumed to reach almost 100% by 2040.
- ✓ The BEV Ambitious scenario has negative effects on employment because expensive xEVs curtail other expenditures, but they turn to positive effects by 2040 due to larger fuel savings.

3. Introducing xEVs into ASEAN countries would fulfil various policy purposes, but their massive deployment might have negative economic side effects. xEV penetration needs realistic and affordable policies. We recommend the following:

**I. Decarbonise power generation**

It is important to decarbonise the power supply along with the penetration of xEVs, considering the overall effects of well-to-wheel. Promoting HEVs can reduce CO<sub>2</sub> emissions without depending on the power supply mix, until it becomes clean. It is critically important to coordinate policy goals.

**II. Consider the cost required for penetration**

Vehicle electrification must be affordable for consumers, businesses, and governments. The subsidies needed to promote xEVs might be enormous, until their prices fully decrease, but which, especially battery cost, are still uncertain due to the international mineral prices. Fuel price policy would be also important for giving economic incentives to xEV users, leading to smaller subsidies.

**III. Pay attention to xEV ripple effects**

The production of BEVs with a small number of material parts might reduce the employment of the automotive industry compared to the production of ICEs and HEVs. However, promoting e-motorcycles may stimulate job creation in the whole economy, if the savings in daily fuel

expenditure can be diverted into other goods and services.

#### **IV. Consider appropriate country-specific pathways**

Appropriate pathways to vehicle electrification vary by country and region.

- ✓ In Indonesia, none of the xEV scenarios contributes significantly to CO<sub>2</sub> reduction due to the power generation mix. Regarding reducing fuel import bills, the BEV Ambitious scenario is the most effective, even though fuel demand for power generation increases. In view of subsidy costs and the economic/employment ripple effect, the HEV Bridge scenario should be adopted for passenger light-duty vehicles (PLDVs) rather than the BEV Ambitious scenario. In addition, it is desirable to promote e-motorcycles at the same time where motorcycles are popular.
- ✓ In Malaysia, the BEV Ambitious scenario has a greater CO<sub>2</sub> reduction effect than other scenarios. The cost-effectiveness of subsidies is significantly higher than in the HEV Bridge scenario because the total subsidy amounts are larger due to the relatively low gasoline price. Furthermore, the BEV Ambitious scenario has a big negative effect on employment, so the HEV Bridge scenario should be adopted. On the other hand, the E-Motorcycle Advanced scenario has small effect on both CO<sub>2</sub> reduction and employment since the number of motorcycles on the road is not large.
- ✓ In Thailand, the BEV Ambitious scenario has a greater CO<sub>2</sub> reduction effect than other scenarios, but the total amount of subsidies is also large. It will bring better effects by 2040; however, it needs to cope with the large subsidy expenditures and the negative effects on employment around 2025–2030. It is desirable to promote e-motorcycles at the same time due to their higher cost-effectiveness.

In Viet Nam, where many motorcycles are on the road, the E-Motorcycle Advanced scenario should be promoted for its superior CO<sub>2</sub> reduction effects and cost-effectiveness. Further, its positive effects on employment are much larger than the other PLDV scenarios. Given the current situation of complete knockdown (CKD) producing and importing most PLDVs, production effects are not great in the BEV Ambitious scenario, but positive employment effects can be seen by diverting fuel cost savings into consumption on other goods and services. However, achieving this scenario requires large subsidies.

# Chapter 1

## Background and Objective of the Study

Demand for passenger and freight transportation in Association of Southeast Asian Nations (ASEAN) members is high and regional automobile use is rapidly spreading. The adverse effects are traffic congestion, traffic accidents, and air pollution, especially in urban areas. At the same time as demand for petroleum has increased, oil self-sufficiency has declined greatly, with CO<sub>2</sub> emissions increasing. Greater automobile penetration is expected as regional economies grow, increasing energy security and environmental concerns.

To tackle these issues, ASEAN countries have promoted electric vehicles (xEVs), including hybrid electric vehicles (HEVs), plug-in hybrid electric vehicles (PHEVs), and battery electric vehicles (BEVs), and developed associated infrastructure. This will reduce oil consumption and air pollution, but increase demand for electricity. Depending on their power generation sectors (generation mix, input fuels, etc.), countries might not become energy self-sufficient or solve their environmental problems.

This study projects xEV deployment effects to around 2040 on the economy, energy, and environment (3Es) – the basic principle of energy policy. The study analyses qualitative and quantitative information on energy supply and demand structure, impacts on CO<sub>2</sub> emissions, and the macroeconomy to contribute to ASEAN members' automobile and energy policy planning.

### 1 Objective of the Research

- ✓ Analyse the effect of xEV penetration on ASEAN countries' 3Es.
- ✓ Estimate the benefits and costs of xEVs in ASEAN countries.
- ✓ Determine the implications for energy policy and supply industries in ASEAN countries.

### 2 Methodologies of the Project

This study uses a model in which the macroeconomy and the energy supply–demand structure are interdependent to consistently evaluate the impacts on the 3Es (including energy structure, macroeconomy, subsidy amount and CO<sub>2</sub> emissions) by the diffusion of xEVs through scenario analysis. In addition, we will use an Input–Output model to confirm the impact of the spread of xEVs on production and employment.

- ✓ Target countries: Indonesia, Malaysia, Thailand, and Viet Nam
- ✓ Scenario plan: 1) xEV penetration pattern (sales share percentage, etc.)  
2) Battery cost trend (affecting xEV prices)

- ✓ Analysis scope:
  - 1) Influence on energy demand and CO<sub>2</sub> emissions
  - 2) Influence on subsidy amounts on xEVs
  - 3) Influence on production and employment structure

This study is unique because it is comprehensive, analysing not only the reduction of CO<sub>2</sub> emissions from automobiles, but also the impacts on the macroeconomy. Depending on national circumstances, reducing direct CO<sub>2</sub> emissions from automobiles might not necessarily lead to better energy security or macroeconomy. We therefore depict a different future landscape and perform a multifaceted analysis that is not limited to the automobile sector to identify the advantages and disadvantages of each scenario.

### **3 Report Structure**

**Chapter 1** presents the study background, objectives, and methodologies.

**Chapter 2** presents the modelling framework and the reference scenario as a baseline for evaluating the effects of alternative scenarios.

**Chapter 3** presents the impacts of shifting towards xEVs on CO<sub>2</sub> emissions and subsidy amounts to xEVs, using the economic-energy model.

**Chapter 4** presents the impacts of shifting towards xEVs on production and employment, using input–output analysis.

**Chapter 5** presents policy implications.

# Chapter 2

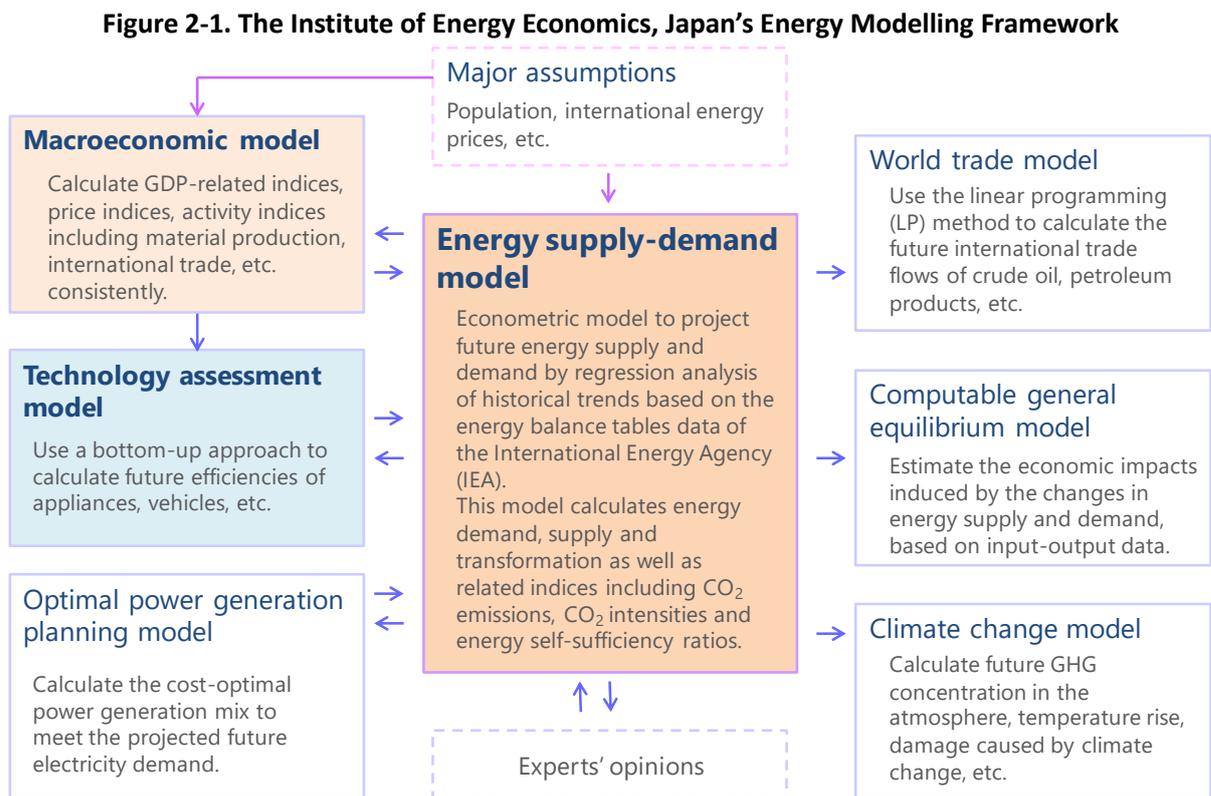
## Economic and Energy Outlook up to 2040

### 1 Modelling Framework

This study develops some scenarios focusing on xEV penetration and examines how each scenario might influence the energy and economy. To quantitatively assess the influences, we build economic and energy models for Indonesia, Thailand, Malaysia, and Viet Nam.

#### 1.1 Economic and Energy Analysis Model

We use the energy analysis model of the Institute of Energy Economics, Japan (IEEJ) (Figure 2-1). The energy supply–demand model allows the projection of future energy supply and demand by regression analysis of historical trends. The model, which can calculate energy demand, supply, and transformation, as well as related indices, including CO<sub>2</sub> emissions and energy self-sufficiency rate, relies on the energy balance tables of the International Energy Agency (IEA).

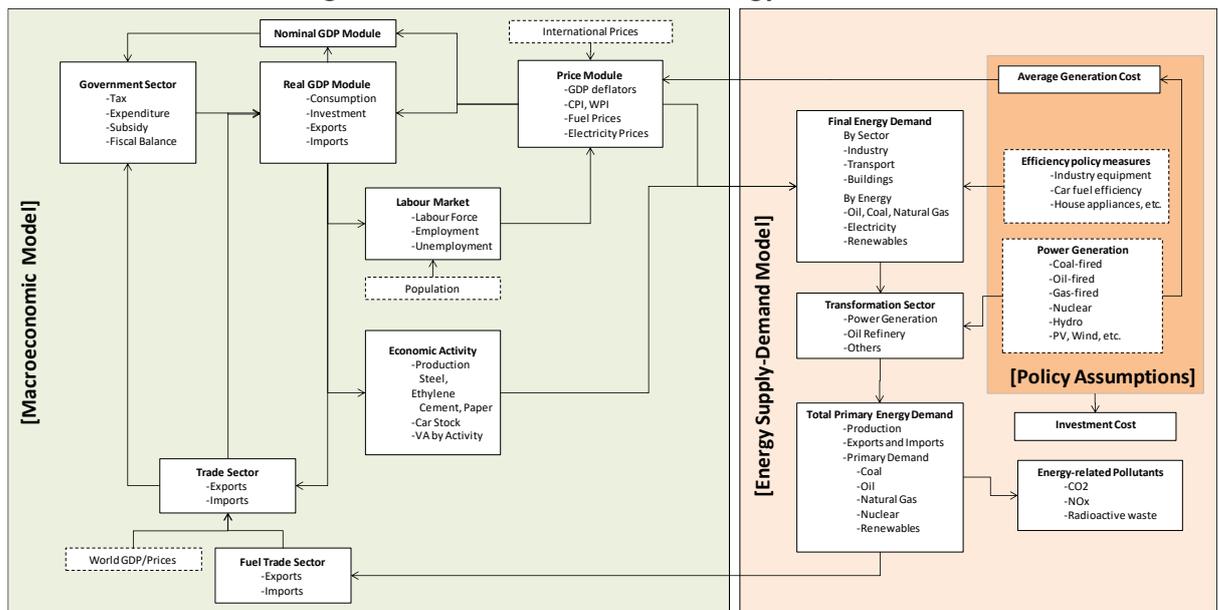


GHG = greenhouse gas, GDP = gross domestic product.

Source: IEEJ (2019).

Energy supply and demand structure changes influence the macroeconomy through energy trade and costs. In other words, the macroeconomy and energy structure depend on each other. Econometric models that integrate them can project future macroeconomic and energy supply and demand structures (Figure 2-2).

**Figure 2-2. Macroeconomic and Energy Model**



CPI = consumer price index, WPI = wholesale price index, VA = value added, PV = photovoltaic, GDP = gross domestic product.

Source: ERIA (2019).

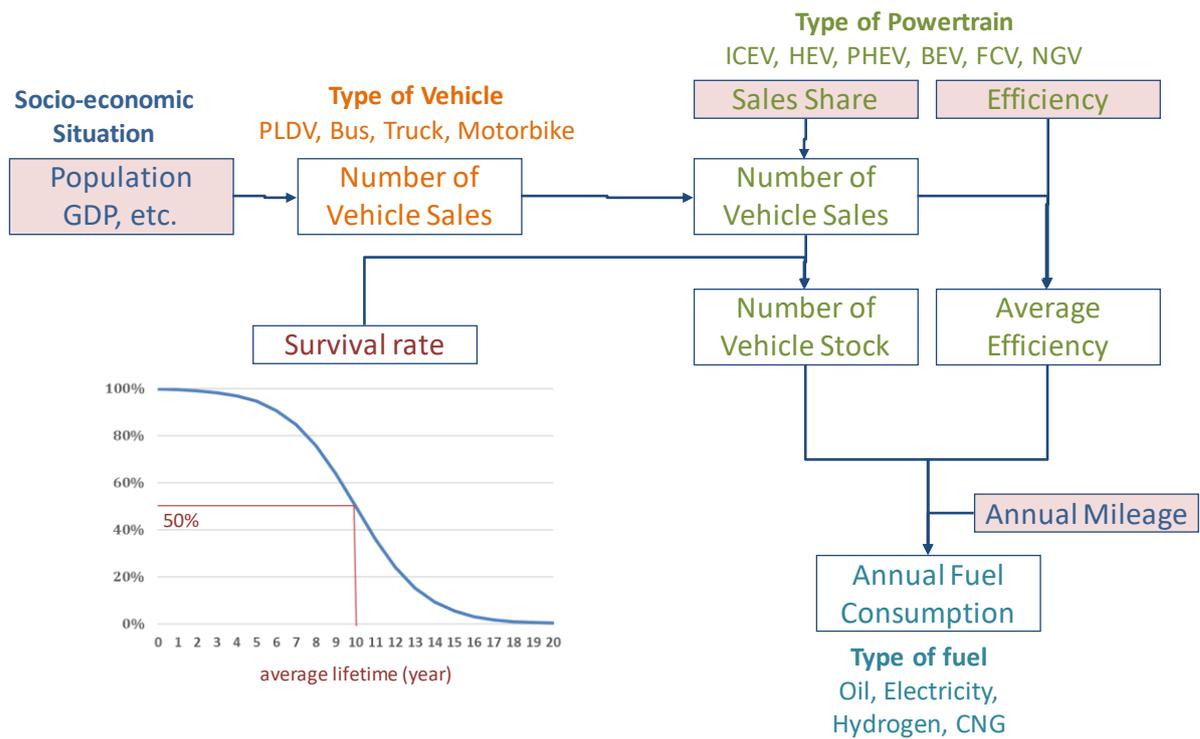
The macroeconomic model projects a commensurately balanced economic structure, including consumption, investment, trade, government, and general prices, and calculates economic activity indicators (including production and vehicle ownership) that directly and indirectly influence energy demand. The model is an econometric one that includes interdependent variables and allows prices and other variables to serve as coordinators amid a widening supply–demand gap to achieve partial equilibrium.

Assumptions for more energy-efficient household appliances and automobiles are needed for the energy supply–demand model. These assumptions are based on the technology assessment model, which uses the bottom-up approach to calculate future efficiencies of appliances, vehicles, etc.

### 1.2 Technology Assessment Model for Automobiles

The technology assessment for automobiles employs the turnover model, which deals with four vehicle types: passenger light-duty vehicle (PLDV), bus, truck, and motorbike (Figure 2-3). To analyse how a powertrain mix, especially electrification, could affect fuel demand in the road sector, this model considers six types of powertrain: internal combustion engine vehicle (ICEV), HEV, PHEV, BEV, fuel-cell vehicle, and natural-gas vehicle.

**Figure 2-3. Technology Assessment Model (Vehicle Turnover Model)**



BEV = battery electric vehicle, FCV = fuel-cell vehicle, HEV = hybrid electric vehicle, ICEV = internal combustion engine vehicle, NGV = natural gas vehicle, PHEV = plug-in hybrid vehicle, PLDV = passenger light-duty vehicle, CNG = compressed natural gas, GDP = gross domestic product.

Source: ERIA (2019)

After estimating future vehicle sales and shares of powertrain types (see the next section), the model estimates future stock, based on the survival rate. The survival rate describes how many vehicles are on the road in a certain year after being sold. A logistic curve is utilised to shape survival rates and set 50% as the average lifetime. When addressing the powertrain type for each year’s sales, the model can estimate average fuel efficiency on the road.

Total fuel consumption in each year can be calculated by multiplying the number of vehicles, average fuel efficiency, and annual mileage. Fuel types analysed in this study are oil, electricity, hydrogen, and compressed natural gas.

### 1.3 Multinomial Logit Model for Powertrain Choice

Powertrain sales shares are estimated using the multinomial logit model. We set utilities for using each powertrain and then calculate the ratio of the exponential function of its utility using Napier’s number (e). This ratio is considered selection probability: sales share.

$$(equation 1) Sales Share_i = \frac{\exp(Utility_i)}{\sum_i \exp(Utility_i)}$$

*i* (type of powertrain) = ICEV, HEV, PHEV, BEV, fuel-cell vehicle, natural gas vehicle

(equation 2)  $Utility_i = U(\text{Vehicle cost}_i, \text{Fuel cost}_i, \text{Cruising distance}_i, \text{GDP}, \text{etc.})$

The utility is estimated by initial cost, running cost, income level, cruising distance, charging time, and so on. When the initial and running cost is lower, the utility is higher. The utility for xEVs depends on cruising distance. Higher income is assumed for users that purchase more expensive cars.

**2 Reference Scenario**

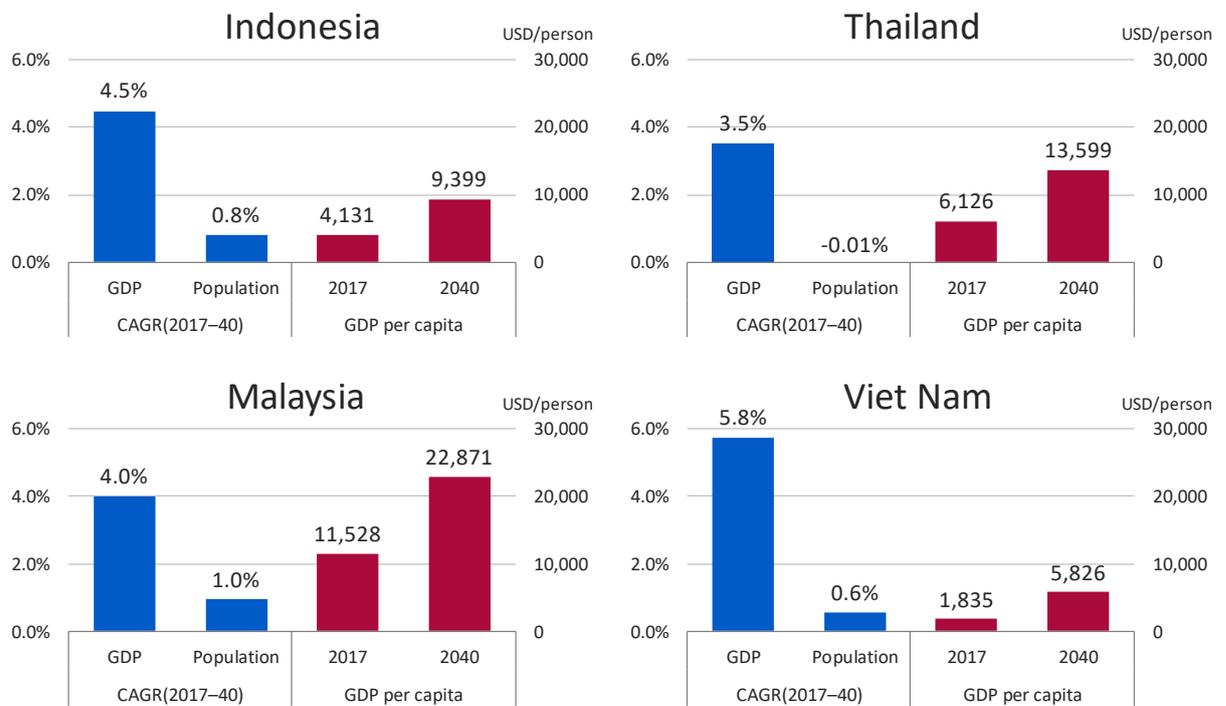
A reference scenario is used as the baseline to evaluate quantitative effects of alternatives. The reference scenario is assumed to continue historical trends without strengthening policy measures.

**2.1 Demographic Assumptions**

Population assumptions are from the United Nations’ World Population Prospects (Figure 2-4). According to the reference scenario, population will grow at about 1% annually until 2040 in Indonesia, Malaysia, and Viet Nam. In Thailand, population will peak by 2030, then decline almost to today’s level due to ageing.

Average GDP growth will be higher in Viet Nam (5.8%) and Indonesia (4.5%). Both countries have a young demographic structure and the potential to increase their GDP per capita. Malaysia, a richer country, is also growing steadily at about 4%. In Thailand, economic growth will be more moderate than in other countries due to demographic factors.

**Figure 2-4. Assumptions for GDP and Population**



GDP = gross domestic product, CAGR = compound annual growth rate.

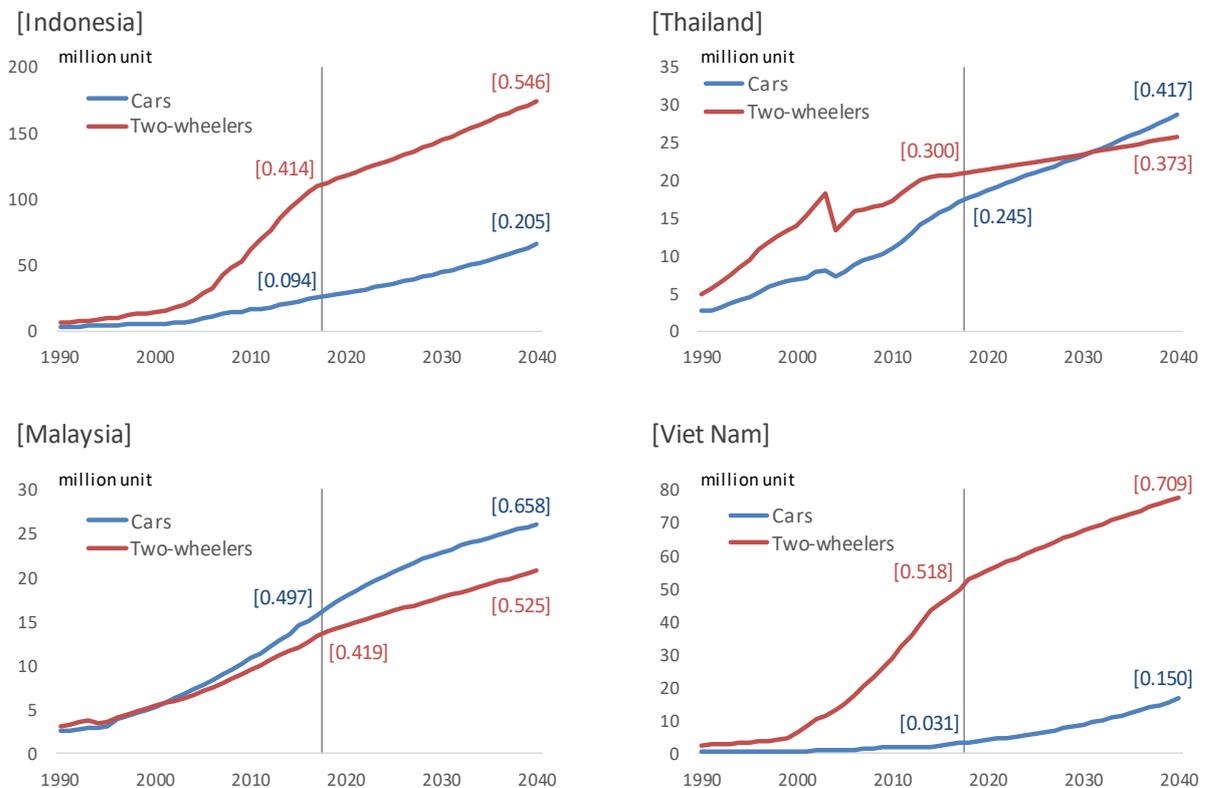
Sources: World Bank (2019), United Nations (2019), and author’s analysis.

## 2.2 Automobile Penetration

According to the reference scenario, the car (PLDV, bus, and truck) stock<sup>2</sup> in the four countries is projected to increase 2.3 times to 136 million units by 2040 (Figure 2-5), from 131 per 1,000 people in 2017 to 255 in 2040, which is still much lower than the Organisation for Economic Co-operation and Development average of 617 per 1,000 people in 2017. Cars in Viet Nam will increase more than five times and in Indonesia around three times. Growth in Thailand and Malaysia will be less than two times because ownership rates are already relatively high.

Motorcycles, which are more than three times the number of cars today, will increase 1.5 times. Growth will be more moderate than for cars in all countries. Each country except Malaysia will have higher motorbike than car ownership. In Viet Nam, especially, more than 500 per 1,000 people own motorbikes and that number could increase to about 700 by 2040.

**Figure 2-5. Outlook for Vehicle Stock**



Note: Numbers in parentheses show stocks per person.

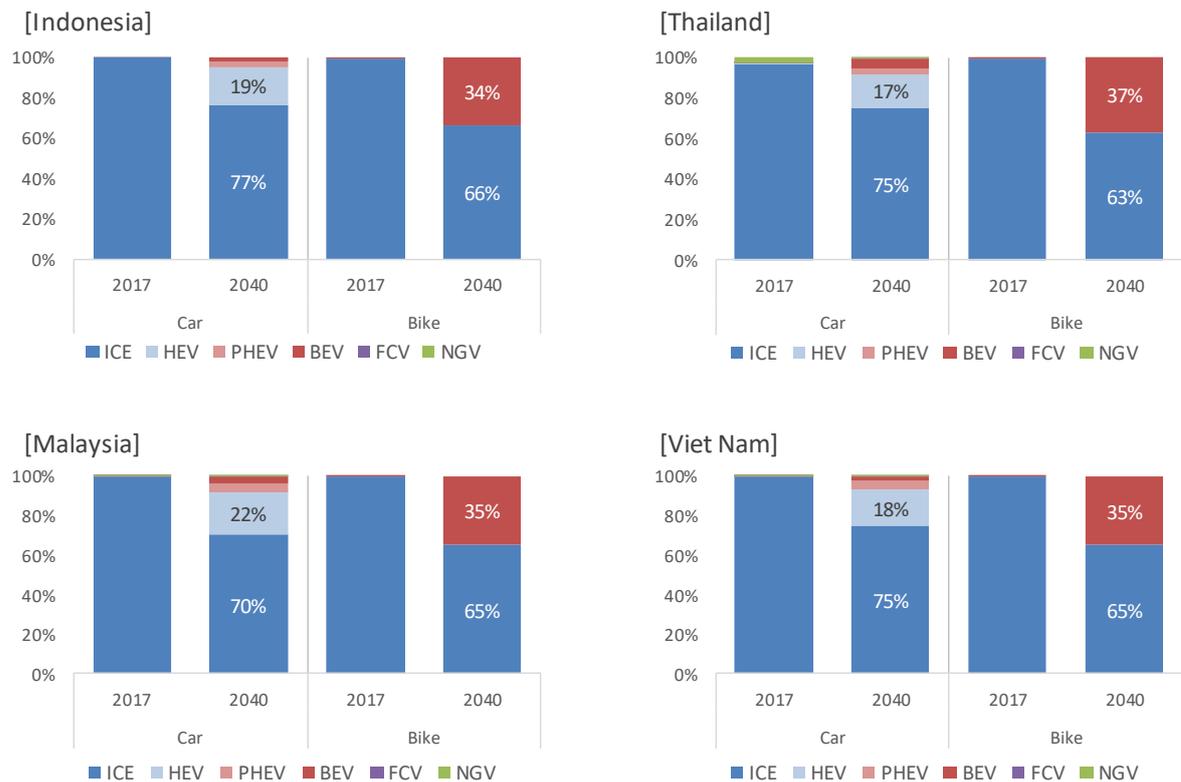
Sources: Indonesia: BPS – Statistics Indonesia (2018) <https://www.bps.go.id/> (accessed 1 August 2019); Viet Nam: Ministry of Transport (2018) <https://mt.gov.vn/en/Pages/default.aspx> (accessed 1 August 2019); Thailand: Department of Land Transport (2018) <https://www.dlt.go.th/en/> (accessed 1 August 2019); Malaysia: Malaysia Informative Data Centre (2018) <https://mysidc.statistics.gov.my/index.php?lang=en> (accessed 1 August 2019); and authors' analyses.

<sup>2</sup> We do not consider the effects of carsharing, the future of which is challenging to estimate.

For the mix by powertrain (Figure 2-6), conventional ICEVs will remain dominant up to 2040 and HEVs will gradually increase their sales share to around 20% in the reference scenario. Sales shares of PHEVs and BEVs will increase to only around 3% of total car sales by 2040 due to higher costs and shorter cruising distances than those of other powertrains.

E-motorcycles will make up around 35% of the motorcycle market due to the small price gap between ICEVs and BEVs.

**Figure 2-6. Sales Share by Powertrain**



BEV = battery electric vehicle, FCV = fuel-cell vehicle, HEV = hybrid electric vehicle, ICE = internal combustion engine vehicle, NGV = natural gas vehicle, PHEV = plug-in hybrid vehicle.

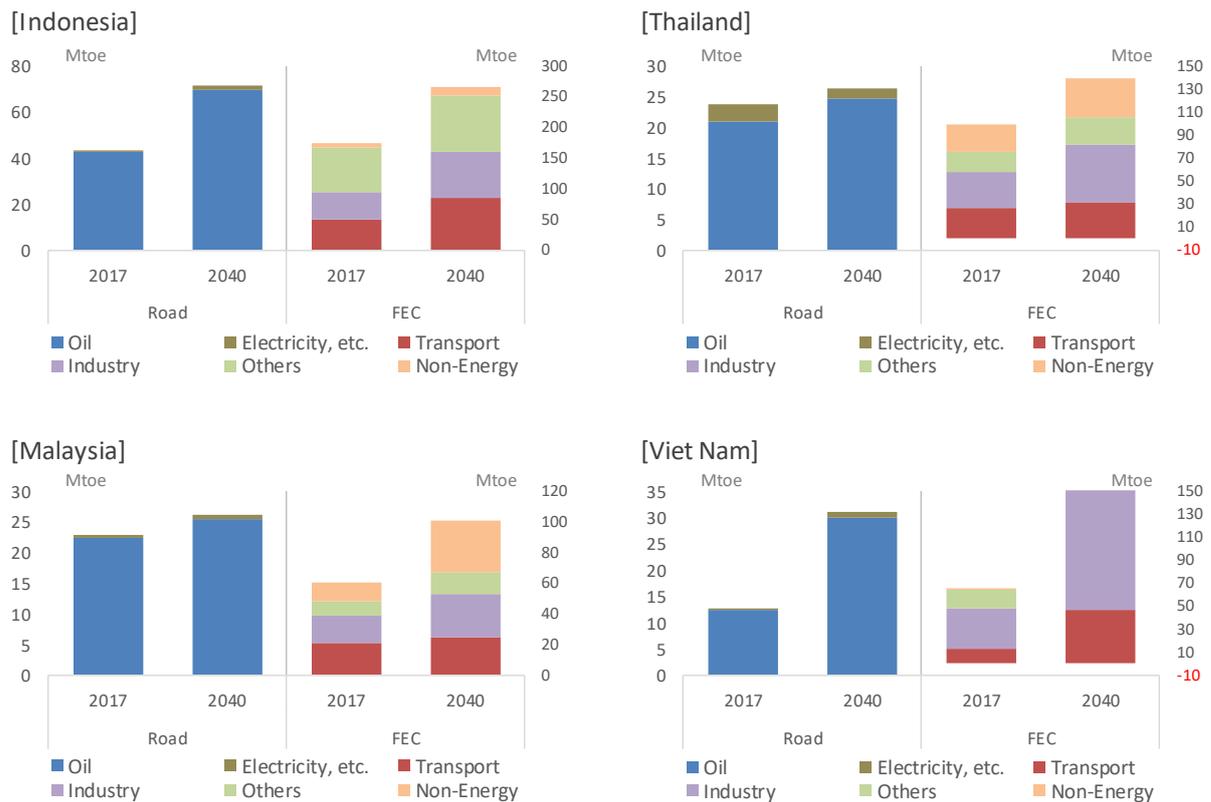
Source: Authors' analysis.

### 2.3 Fuel Consumption in the Road Sector

According to the reference scenario, road sector fuel consumption, mostly oil, will increase 1.5 times by 2040 in the four countries (Figure 2-7). Growth of energy demand will be slow relative to car stocks due to efficiency improvements, including the shift to HEVs from ICEVs. Consumption in Viet Nam will increase by 2.5 times by 2040, whilst in Malaysia, oil consumption for automobiles will peak and then decline before 2040.

Energy demand in the transport sector, including the road sector, will rapidly increase. Transport sector shares in the final energy consumption will rise by 4% in Indonesia and Viet Nam, respectively. Meanwhile, in Thailand and Malaysia, the shares in the final energy consumption will decline by 5 and 10 percentage points, respectively, in 2040 from today.

**Figure 2-7. Energy for the Road Sector and Total Final Consumption**



Mtoe = million tonnes of oil equivalent, FEC= final energy consumption.

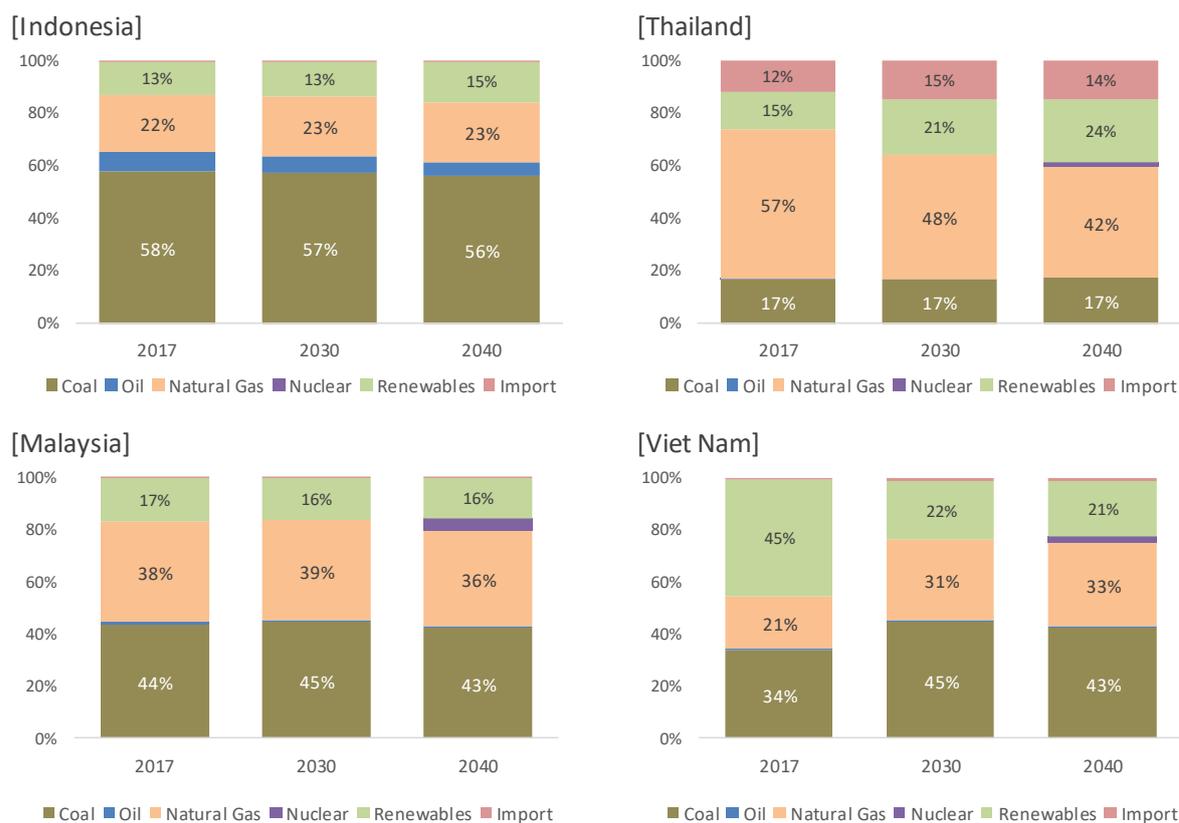
Source: IEA (2019a), IEEJ (2019), and authors' analysis.

## 2.4 Primary Energy Demand and CO<sub>2</sub> Emissions

According to the reference scenario, the demand for electricity will grow faster than other fuels, along with developments in the economy and living standard improvements. In the four countries, the power demand will increase by 4.2% annually, and the share of electricity demand in the final consumption will increase from 16% today to 23% in 2040. The power demand will increase by 2.8 times in Indonesia and 3.6 times in Viet Nam, while, in Thailand and Malaysia, the demand will increase at a relatively slow pace, by 2.0 times and 1.8 times, respectively.

The growing demand for electricity will mainly be met by thermal power generation with its relatively low cost and abundant resources (Figure 2-8). In Indonesia, coal-fired power will remain mainstream, with more than 50% of the generation mix. In Thailand, the proportion of natural gas will decrease, while renewable energy, such as solar and biomass, will increase. In Malaysia, the dependency on the thermal generation will remain unchanged but nuclear power is expected to be introduced. In Viet Nam, thermal power generation will meet the growing electricity demand. The share of renewable energy, mainly hydropower, will dramatically decrease.

**Figure 2-8. Power Generation Mix**



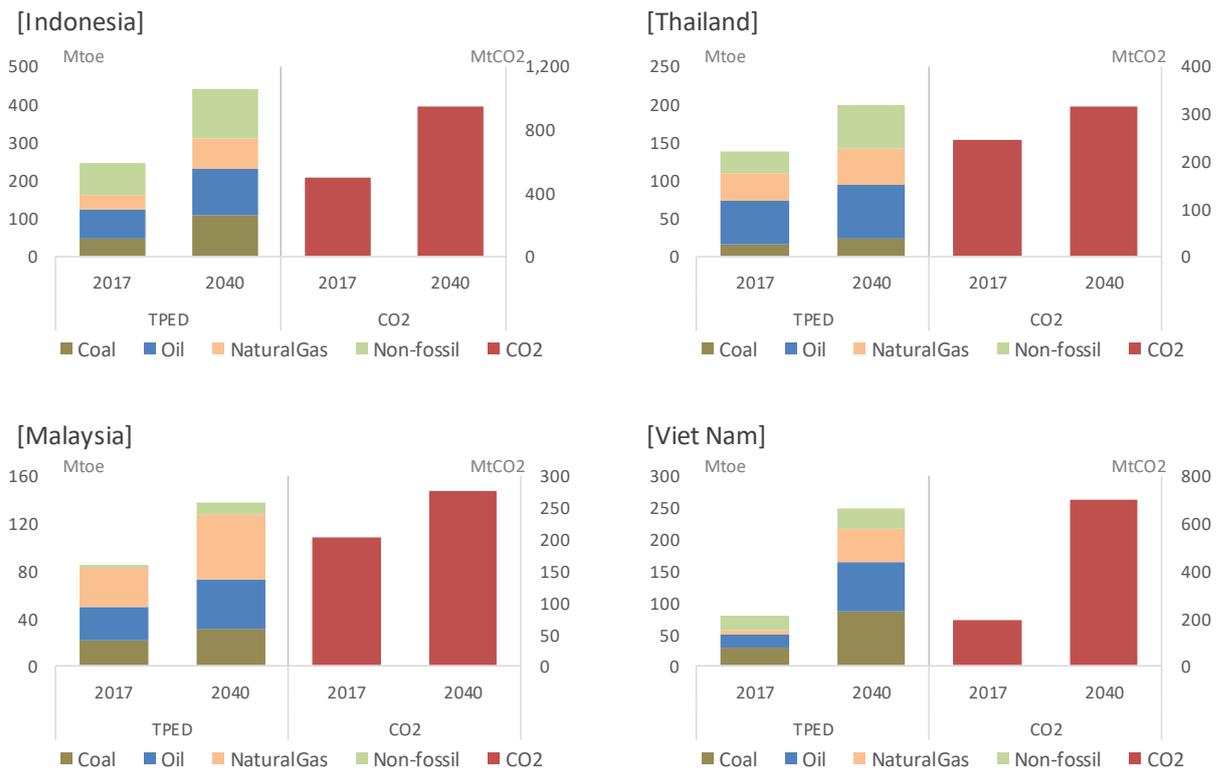
Source: IEA (2019a), IEEJ (2019), and authors' analysis.

Total primary energy demand, which combines the final energy consumption and the transformation sector, including power generation, will increase annually by 2.6% in Indonesia, 5.1% in Viet Nam, 1.6% in Thailand and 2.1% in Malaysia (Figure 2-9). These growth rates are much lower than their economic growth rates, which means that energy efficiency is rapidly improving.

Coal demand will grow at higher rates than other fuels in each country, especially in power generation, to meet rapidly growing electricity demand. Gas demand will also grow rapidly due mainly to its use in the generation sector. Oil demand, mainly for transport and building, and chemical feedstock will grow more slowly than other fossil fuels. Fossil-fuel dependence ratios will still be high, at 70%–90% in 2040, similar to the today's levels.

Maintaining high fossil-fuel dependency will lead to increasing CO<sub>2</sub> emissions, which will increase annually by 2.9% in Indonesia and 5.8% in Viet Nam, higher than energy-demand growth, meaning that their energy mix will become more carbon-intensive (Figure 2-9). Meanwhile, in Thailand and Malaysia, CO<sub>2</sub> emissions will grow at lower rate than energy demand growth.

**Figure 2-9. Primary Energy Demand and CO2 Emissions**



CO2 = carbon dioxide, MtCO2= million tonnes of carbon dioxide, Mtoe= million tonnes of oil equivalent, TPED = total primary energy demand.

Source: IEA (2019a), authors' analysis.

## Chapter 3

### Impacts on the 3Es by xEV Penetration

#### 1 Alternative Scenarios

The four countries may have challenges related to the 3Es in the reference scenario. Therefore, this study sets alternative scenarios for xEV penetration and power generation mix, and then evaluates their impacts on the 3Es in each country.

##### 1.1 Scenario Assumptions for xEV Penetration

Remarkable vehicle technology development in recent years has accelerated the penetration of xEVs, although their market share is still small. European countries have indicated their intention to start to ban ICEV sales after 2025 (Norway), at the latest 2040 (France, etc.), and some cities have banned ICEV traffic after the 2020s. In Asia, China introduced New Energy Vehicle (NEV) mandate policy in 2019, and India aims for 30% xEVs in the sales basis by 2030.<sup>3</sup>

ASEAN countries also aim for xEV penetration, but there is still no roadmap that covers the entire car market until 2040. Therefore, we set scenarios for xEV penetration (Figures 3-1 and 3-2),<sup>4</sup> and look at their respective impact on energy and the economy. The BEV Ambitious scenario sets that BEVs will rapidly penetrate and get almost 100% market share by 2040. This scenario is considered similar to the target path for some European countries. Meanwhile, the HEV Bridge scenario is assumed to start with low-cost HEVs, with BEVs being gradually introduced starting after 2030 when their cost starts to decline. The motorcycle sales structures in both scenarios are the same as in the reference scenario.

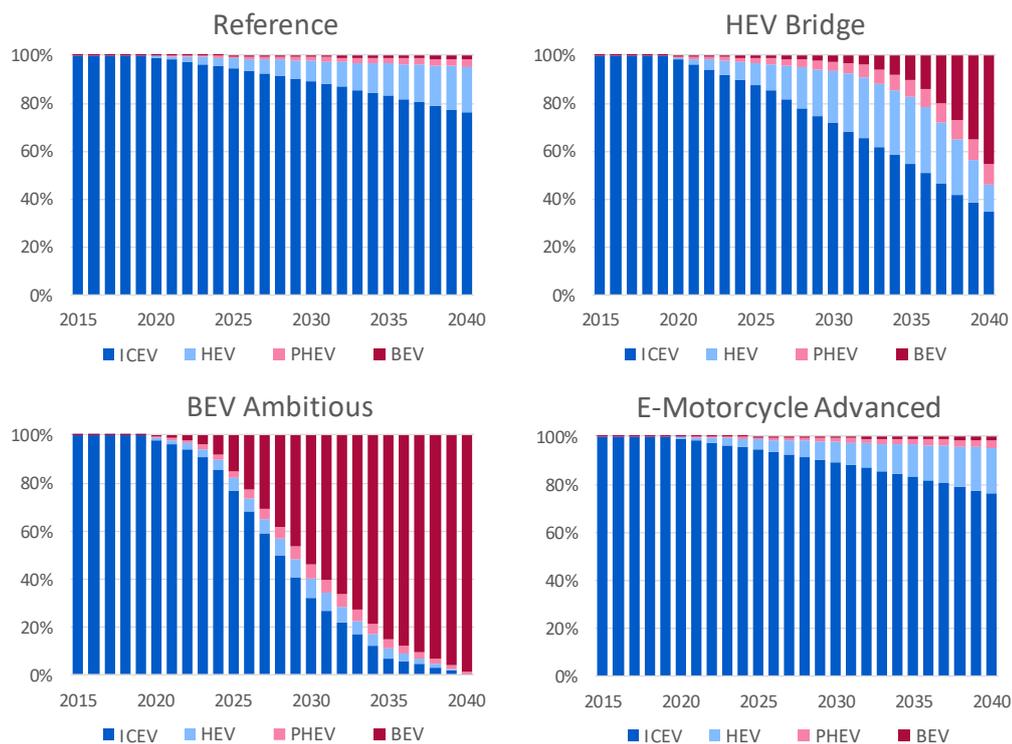
The E-Motorcycle Advanced Scenario considers the large number of motorcycles in ASEAN countries. It is highly possible that e-motorcycles will become popular soon because they are cheaper to produce than cars. The e-motorcycles share is assumed to reach almost 100% by 2040, while the car sales mix is same as one in the reference scenario.

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<sup>3</sup> There are many twists and turns in setting India's xEV targets. In 2017, the government announced a ban on ICEV sales in 2030, but withdrew it and changed the path to '30% electrified in 2030'. However, the government's think tank NITI Aayog has proposed again '100% electrified in 2030' in the new xEV roadmap being created. <https://timesofindia.indiatimes.com/india/niti-new-road-map-only-electric-vehicles-to-be-sold-after-2030/articleshow/69833770.cms> (accessed 13 September 2020); <https://www.timesnownews.com/business-economy/industry/article/only-electric-vehicles-to-be-sold-after-2030-in-india-niti-aayog/438731>(accessed 13 September 2020).

<sup>4</sup> This study focuses on PLDVs and motorcycles (buses and trucks are not covered).

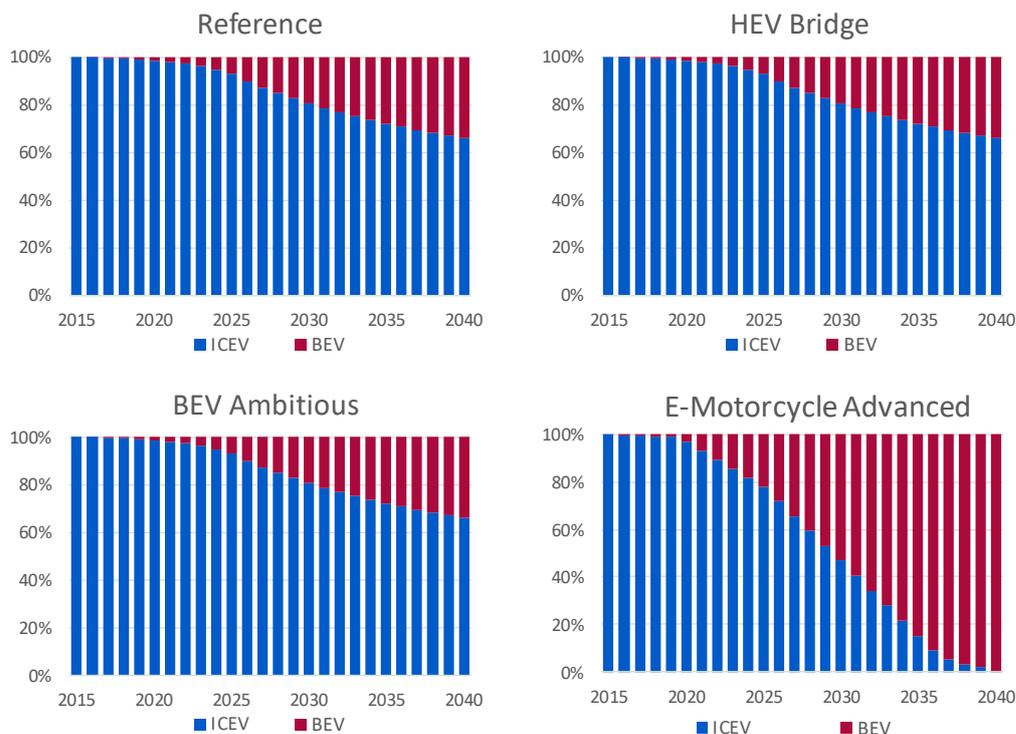
**Figure 3-1. Powertrain Sales Share of PLDVs by Scenario**



BEV = battery electric vehicle, HEV = hybrid electric vehicle, ICEV = internal combustion engine vehicle, PHEV = plug-in hybrid vehicle, PLDV = passenger light duty vehicle.

Source: Authors' analysis.

**Figure 3-2. Powertrain Sales Share of Motorcycles**



BEV = battery electric vehicle, ICEV = internal combustion engine vehicle.

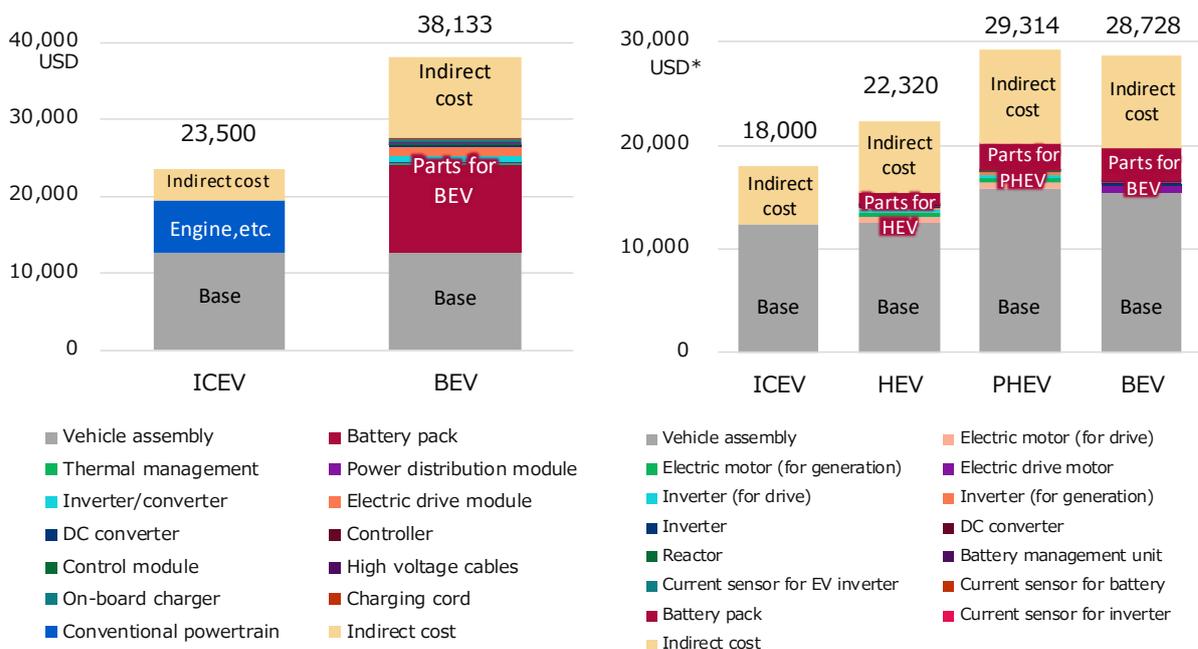
Source: Authors' analysis.

## 1.2 Scenario Assumptions for Battery Price

Whether or not xEVs can spread depends largely on vehicle prices. In particular, the battery price trends are key. Although battery prices have fallen sharply in recent years, battery prices are US\$156 per kWh (Bloomberg NEF, 2019) as of 2019, accounting for about 10%–30% of BEV prices (Figure 3-3).

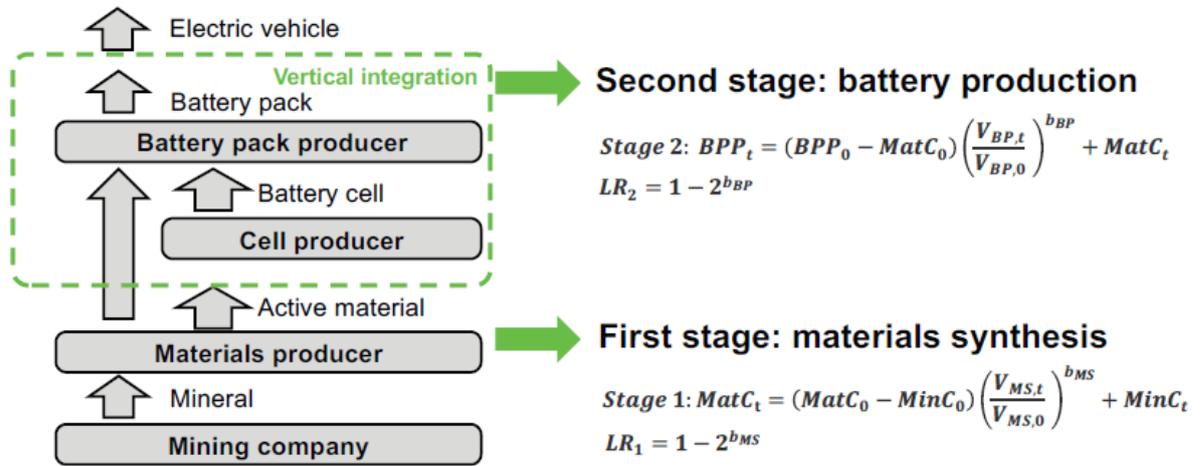
The outlook for battery prices and, consequently, vehicle prices, affects the subsidy needed to achieve the alternative xEVs scenario in this study. A learning curve model is often used to predict future technology cost. This method is based on an empirical rule that the production cost decreases as the cumulative production amount increases. Based on this approach, Bloomberg NEF (2019) forecasts US\$62 per kWh by 2030. On the other hand, MIT Energy Initiative (2019) uses a more sophisticated two-stage learning curve model. This model considers battery manufacturing process and a learning curve is applied in each two-stage process: materials synthesis and battery pack production (Figure 3-4). In the MIT model, mineral raw materials such as lithium, cobalt and nickel are determined by the international markets, so they are included as floor costs outside the learning curve. MIT Energy Initiative (2019) forecasts US\$124 per kWh in 2030 and warned it could not be under US\$100.

**Figure 3-3. Examples of Cost Structure for xEVs**



BEV = battery electric vehicle, HEV = hybrid electric vehicle, ICE = internal combustion engine vehicle, PHEV = plug-in hybrid vehicle, DC = direct current, EV = electric vehicle, JPY = Japanese yen, US\$ = US dollar.  
 Note: \* converting with 100 JPY/US\$  
 Source: ICCT (2019) and CRISER (2015)

**Figure 3-4. Structure of the Battery Supply Chain and Mathematical Model of a Two-Stage Learning Curve**



BPP = battery pack price, MatC = active materials costs, MinC = mineral costs,  $V_{BP}$  = cumulative production volume of battery pack,  $V_{MS}$  = cumulative production volume of materials synthesis,  $b_{BP}$ ,  $b_{MS}$  = technology-specific experience index.

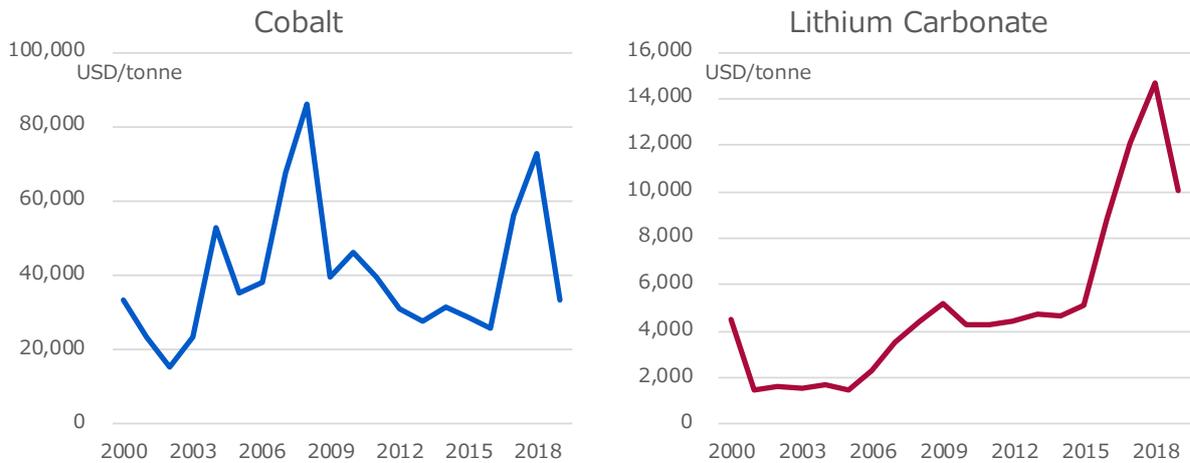
Source: MIT Energy Initiative (2019).

In consideration of the uncertainty of the battery cost outlook, three cost trends are assumed by using a normal learning curve and a two-step learning curve in this analysis. First, using the normal learning curve model,<sup>5</sup> battery costs drop to US\$72 per kWh in 2030 and US\$49 in 2040 (low price case). Next, using the two-step learning curve model, we set two cases: 1) case where the mineral raw material prices remain constant (middle-price case); and 2) case where the prices increase by 5% annually (high price case),<sup>6</sup> considering the uncertainty of the international mineral prices (Figure 3-5). In the middle-price case, battery prices fall to US\$99 per kWh in 2030 and US\$81 in 2040, while they drop to US\$112 in 2030 but after that increase slightly to US\$114 in 2040 in the high-price case. On the whole, the low-price case is close to Bloomberg NEF's 2019 outlook and the high-price case is close to MIT's 2019 outlook (Figure 3-6).

<sup>5</sup> The cumulative global battery production is estimated to reach about 3 TWh in 2030 and about 10 TWh in 2040 based on IEEJ Outlook 2020 (IEEJ, 2019). The learning rate (the rate of cost reduction when the cumulative production doubles) is set to 20%.

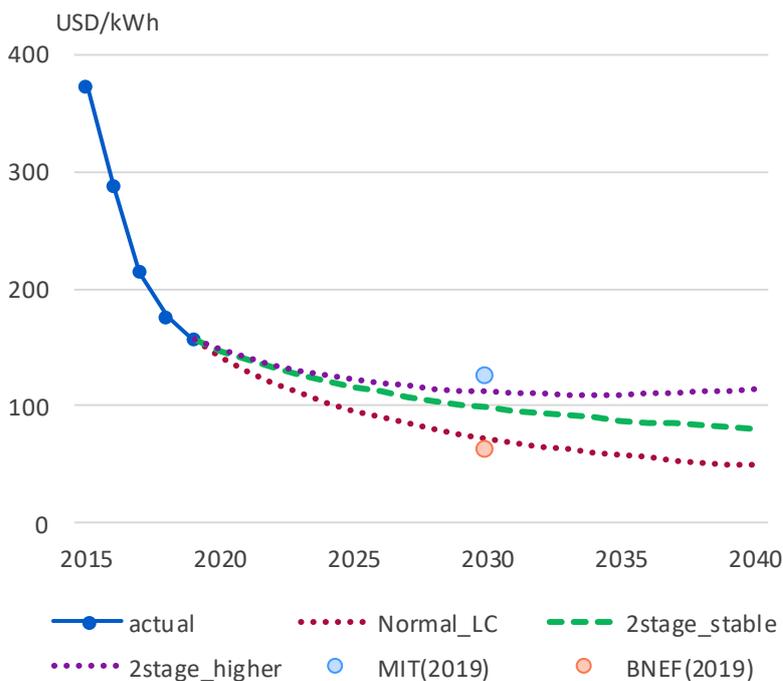
<sup>6</sup> The learning rates are referred to in the MIT Energy Initiative (2019).

**Figure 3-5. Cobalt and Lithium Prices**



Source: BP (2019).

**Figure 3-6. Battery Price Outlook by Using Learning Curve**

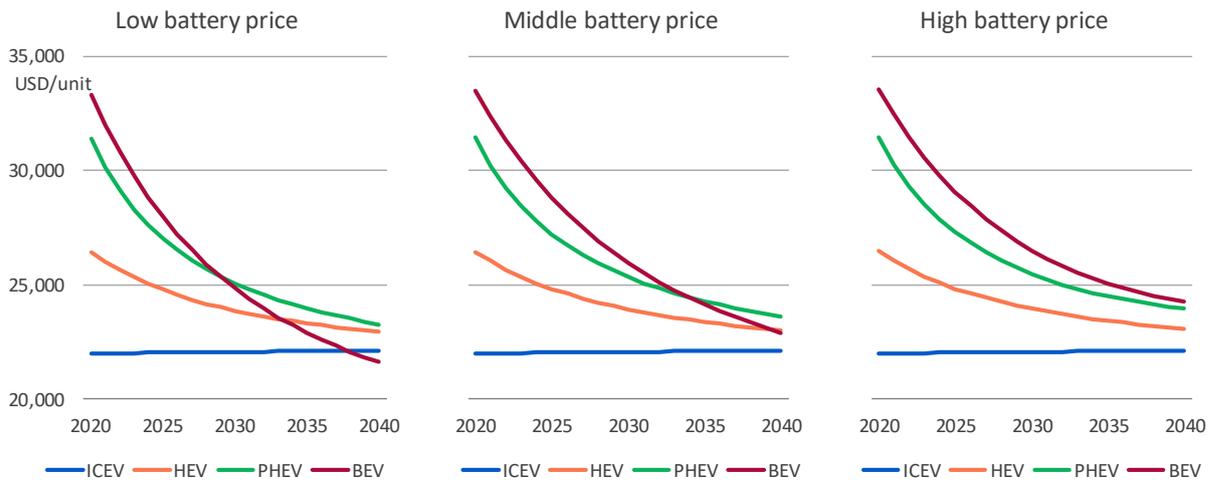


BNEF = Bloomberg NEF.

Source: Bloomberg NEF (2019), MIT Energy Initiative (2019), and authors' analysis.

Figure 3-7 shows vehicle price trends for xEVs based on the outlook of battery prices. In the low-price case, BEVs become cheaper than HEVs in the early 2030s and also cheaper than ICEVs in the late 2030s. In the middle-price case, BEVs and HEVs become at about the same price in 2040. And in the high-price case, BEV prices remain the highest amongst xEVs, even in 2040.

**Figure 3-7. xEV Prices by Battery Price Case (common to all countries)**



BEV = battery electric vehicle, HEV = hybrid electric vehicle, ICEV = internal combustion engine vehicle, PHEV = plug-in hybrid vehicle.  
Source: Authors' analysis.

### 1.3 Alternative Scenarios and Cases

In addition to the reference scenario, three alternative scenarios are set for xEVs. Meanwhile, three cases are set for battery price. We analyse 12 scenarios and cases and compare them with the reference scenario to quantitatively examine the influence of the 3Es (Table 3-1).

**Table 3-1. Alternative Scenarios**

		Case on Battery price		
		Low price	Middle price	High price
Scenario on xEVs	Reference	L1	M1	H1-
	HEV Bridge (start with HEV, then to BEV)	L2	M2	H2
	BEV Ambitious (nearly 100% sales in 2040)	L3	M3	H3
	E-Motorcycle Advanced (nearly 100% sales in 2040)	L4	M4	H4

BEV = battery electric vehicle, E-Motorcycle = electric motorcycle, HEV = hybrid electric vehicle, xEVs = electric vehicles (including HEV, PHEV, and BEV).  
Source: Authors.

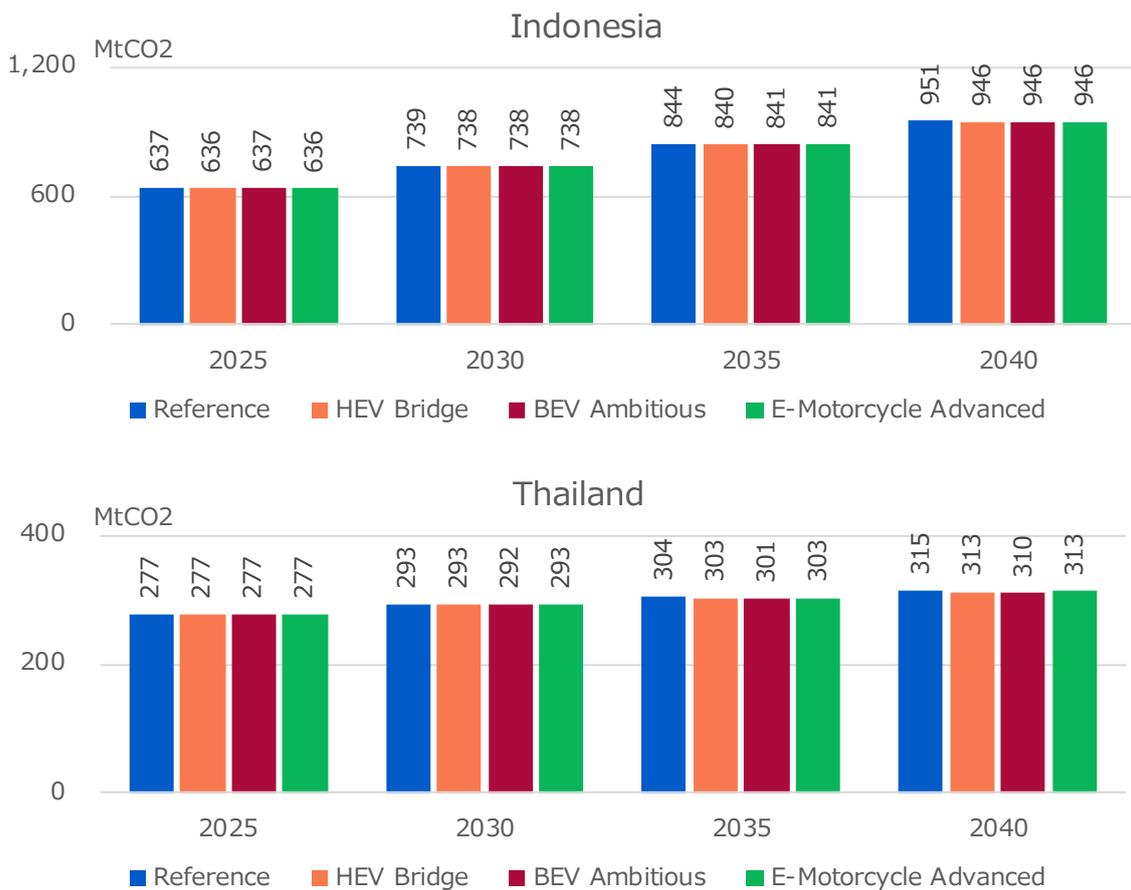
## 2 Results of Alternative Scenarios

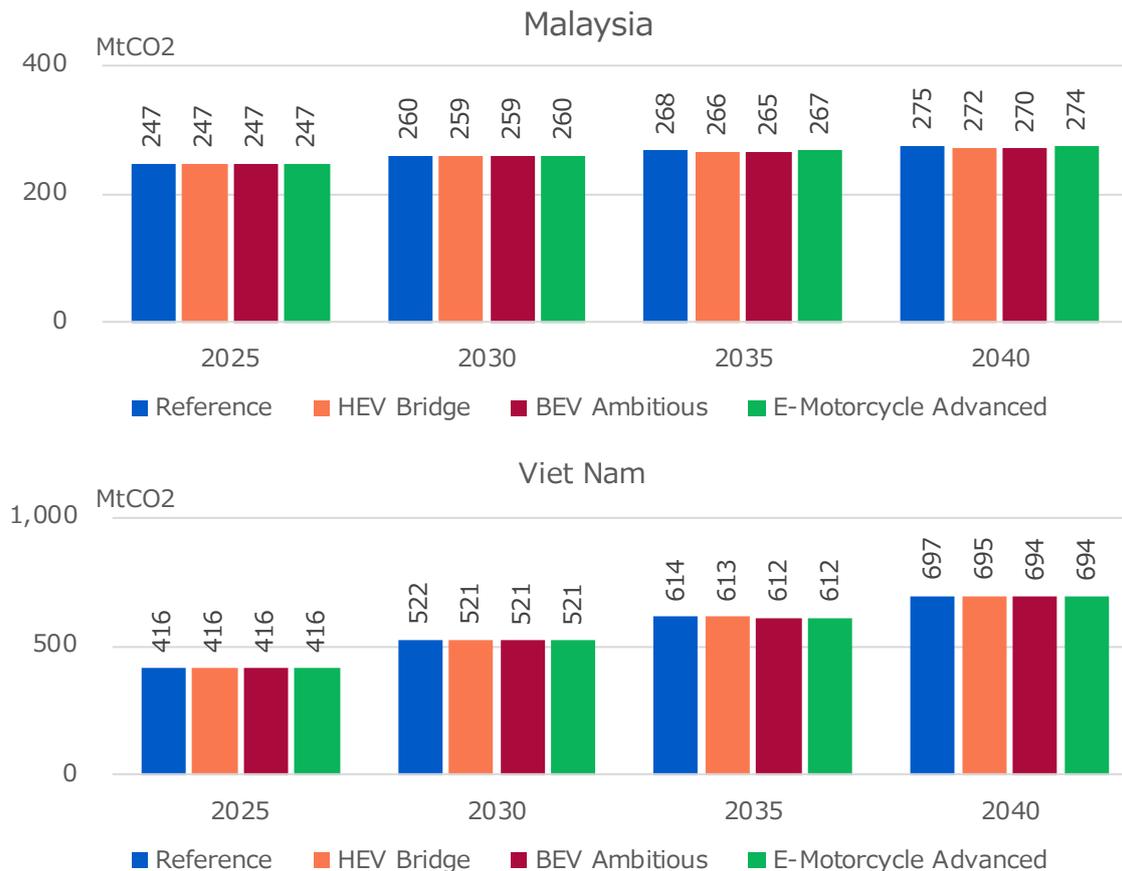
### 2.1 Energy and CO<sub>2</sub> emissions

Energy-related CO<sub>2</sub> emissions do not differ greatly between the scenarios (Figure 3-8). This is because the emissions decline in the automotive sector due to the spread of xEVs is offset by the emissions addition in the power generation sector. In detail, however, the BEV Ambitious scenario emits the lowest CO<sub>2</sub> compared to other scenarios in 2040. It is followed by the HEV Bridge scenario and then the E-Motorcycle Advanced scenario. In Indonesia, the alternative xEV scenarios have almost the same impact on CO<sub>2</sub> emissions due to its relatively dirty power generation mix. In Viet Nam, the E-Motorcycle Advanced has the same reduction effect as the BEV Ambitious.

Looking at the time series from 2020 to 2030, there is almost no change in each scenario. In Indonesia, the emissions in the BEV Ambitious scenario are marginally lower than the reference scenario in 2025, but higher than the HEV Bridge and the E-Motorcycle Advanced scenarios. After 2035, xEVs becomes more widespread, and the emissions reduction effect between the scenarios is finally visible, but still only marginal.

**Figure 3-8. Energy-related CO<sub>2</sub> Emissions by Scenario**



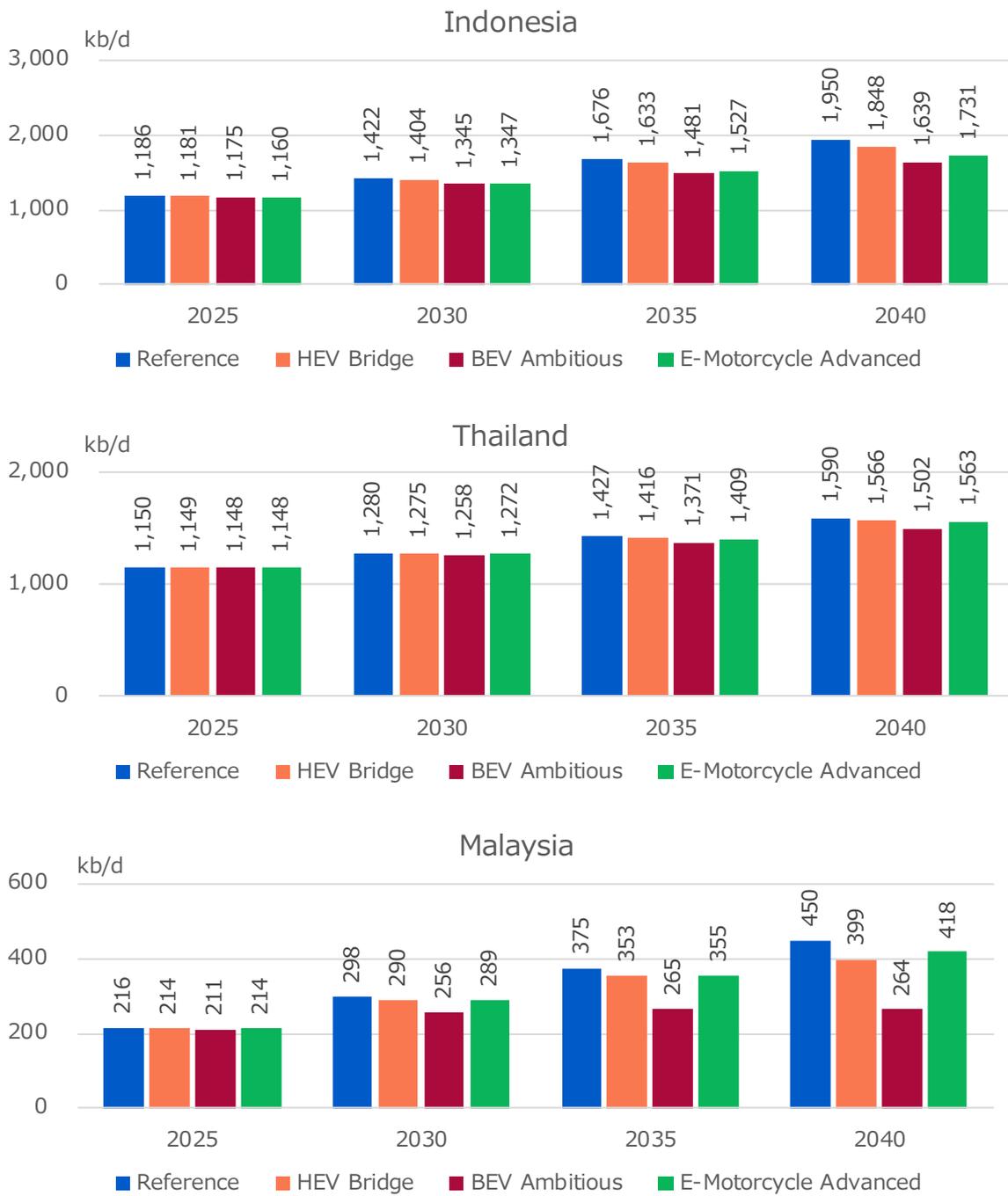


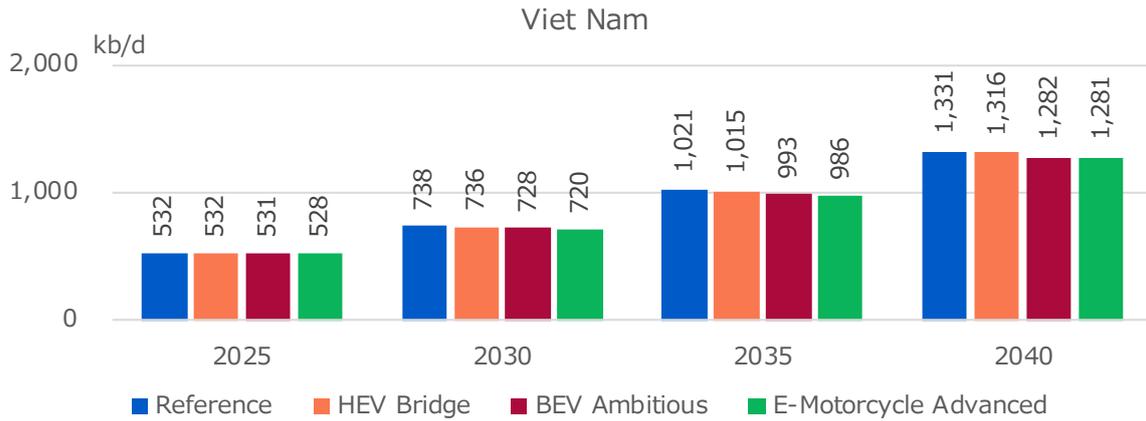
MtCO<sub>2</sub> = million tonnes of carbon dioxide, BEV = battery electric vehicle, HEV = hybrid electric vehicle.  
 Source: Authors' analysis.

To reduce dependence on oil imports is also one of the objectives for promoting xEVs in each country. Looking at the reduction in oil imports, there are differences between the scenarios (Figure 3-9). In all countries, the BEV Ambitious scenario has the greatest effect on reducing oil imports, followed by the E-Motorcycle Advanced scenario (in Malaysia, followed by the HEV Bridge scenario). In Malaysia, an oil-producing country, large differences between the scenarios are seen due to the small amount of oil imports.

In the alternative xEV scenarios, the demand for coal and natural gas in the power generation sector increases (namely, imports increase or exports decrease), even though oil demand decreases compared to the reference scenario. However, since the oil price per calorific value is higher than others, the BEV Ambitious brings in the greatest savings in terms of total fossil fuel import bills, except in Viet Nam, where the E-Motorcycle Advanced scenario brings in the largest savings (Figure 3-10). A savings of import bills can reduce the income outflow, resulting in positive effects on the domestic economy.

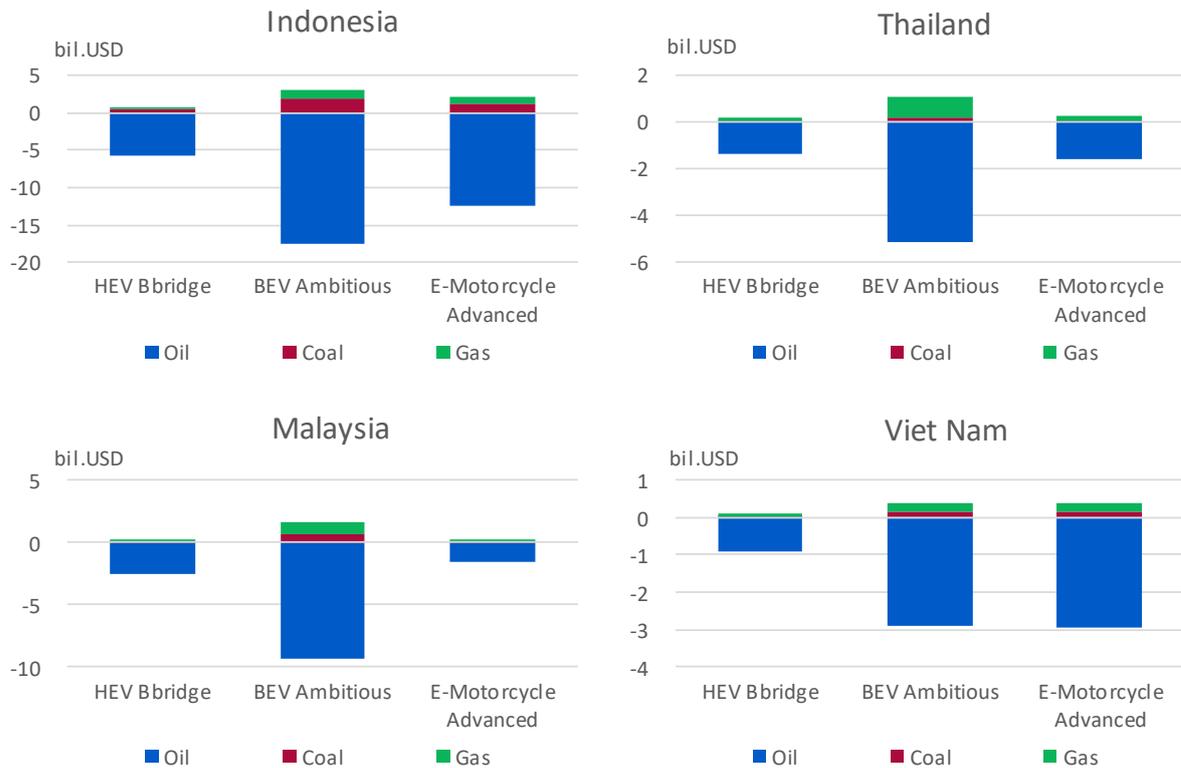
**Figure 3-9. Oil Imports by Scenario**





kb/d = kilo barrel per day, BEV = battery electric vehicle, HEV = hybrid electric vehicle.  
 Source: Authors' analysis.

**Figure 3-10. Net Import Bills of Fossil Fuels by Scenario (vs. Reference, 2040)**



bil.US\$ = billions of US dollars, BEV = battery electric vehicle, HEV = hybrid electric vehicle.  
 Source: Authors' analysis.

### 3 Subsidy Analysis

#### 3.1 Subsidy Assumptions

Even though xEVs' prices have been decreasing, they are still more expensive than ICEs. At present, in terms of PLDVs, the HEV price is about 1.2 times of ICEVs, while the PHEV price is 1.5 times, and the BEV price is 1.6 times. On the other hand, considering the excellent fuel economy of xEVs,

running fuel costs can be significantly reduced. However, it takes more than 10 years to recover the initial cost difference. Given the price difference between ICEVs and xEVs, the HEV Bridge and the BEV Ambitious scenarios may not be realised in business as usual. To encourage purchase, subsidies will be required to bridge the price differences between ICEVs and xEVs.

For each scenario, we calculate how much subsidy would be necessary and assume a level sufficient to pay off the total cost (vehicle cost + fuel cost) of the ownership difference between ICEVs and xEVs in 5 years.

**(equation 3)**  $(xEVs\ price - subsidy) + fuel\ cost * 5\ years = ICE\ price + fuel\ cost * 5\ years$

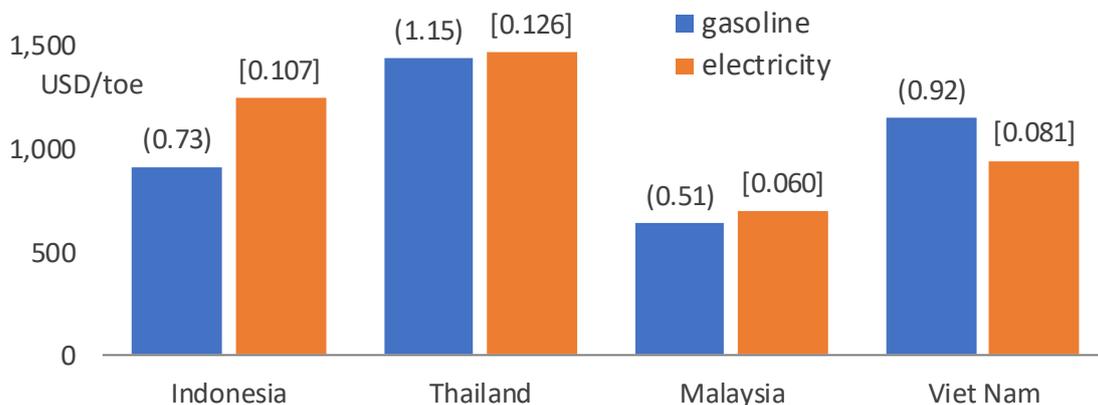
The subsidy calculation assumes the following:

- Vehicle prices: see Figure 3-7.
- Discount rate: 5%.
- Fuel efficiency: 20 km/L for ICEVs, 35 km/L for HEVs, 8 km/kWh for BEVs.
- Annual mileage: 10,000 km/year.

The above are common to all countries. However, gasoline and electricity prices vary from country to country. When gasoline prices are relatively high compared to electricity prices, running fuel costs are significantly reduced and upfront costs are recovered quickly, resulting in fewer subsidies being granted.

Figure 3-11 shows the current gasoline and electricity prices<sup>7</sup> in each country. They are fixed until 2040 in this study because it is not easy to predict them. Fewer subsidies are expected in Thailand and Viet Nam, where gasoline prices are relatively high.

**Figure 3-11. Gasoline and Electricity Prices**



toe = tonnes of energy equivalent.

Note: The numbers in parentheses are (US\$/L) and [US\$/kWh] respectively.

Source: globalpetrolprices.com. Gasoline prices, litre, 7 October 2019,

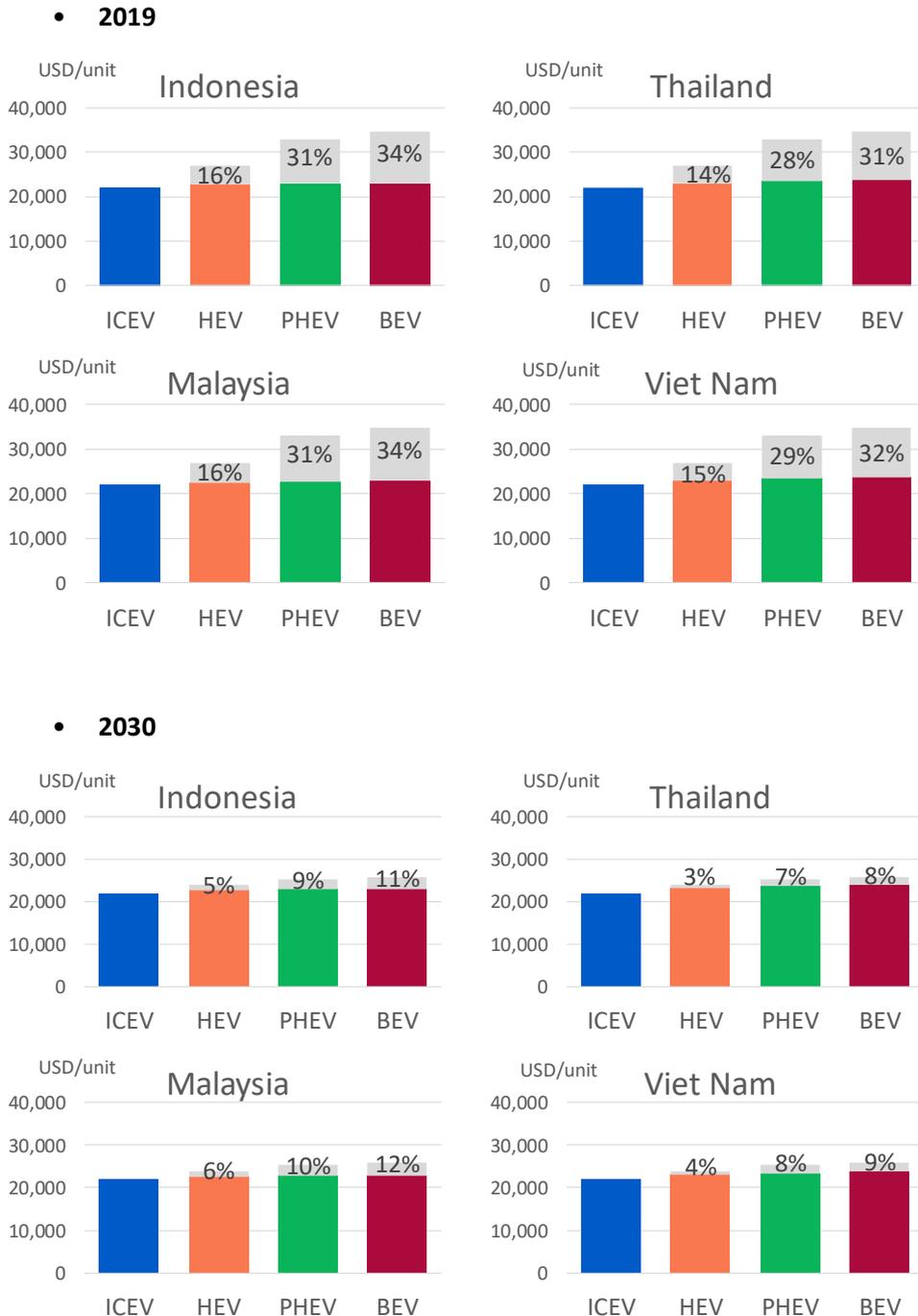
[https://www.globalpetrolprices.com/gasoline\\_prices/](https://www.globalpetrolprices.com/gasoline_prices/)Electricity prices for households, June 2019,

[https://www.globalpetrolprices.com/electricity\\_prices/](https://www.globalpetrolprices.com/electricity_prices/)

<sup>7</sup> PHEVs and BEVs can be charged not only at home but also at public charging facilities. However, the household prices are adopted in this study, because it is difficult to set the charging prices in the public equipment.

Figure 3-12 shows the xEV prices and the proportion of subsidies required. Currently, the subsidy rates are 14%–16% for HEVs, 28%–31% for PHEVs, and 31%–34% for BEVs. Subsidy rates are somewhat lower in Thailand and Viet Nam, as expected. In 2030, xEV prices fall and the subsidy rates drop significantly, and almost no subsidies are needed in 2040.

**Figure 3-12. PLDV Price in 2019 and 2030 in the Middle Battery Price Case**



BEV = battery electric vehicle, HEV = hybrid electric vehicle, ICEV = internal combustion engine vehicle, PHEV = plug-in hybrid vehicle.

%; subsidy rate = subsidy / xEVs price.

Source: Authors' analysis.

On the other hand, the price differences between e-motorcycles and conventional motorcycles are smaller than those in the case of PLDVs, and the up-front cost will be quickly covered by fuel cost reductions, so the subsidy rates are relatively low (12% for Indonesia, 6% for Thailand, 14% for Malaysia and 8% for Viet Nam). Furthermore, almost no subsidies to e-motorcycles are needed in the mid-2020s due to their price drop.

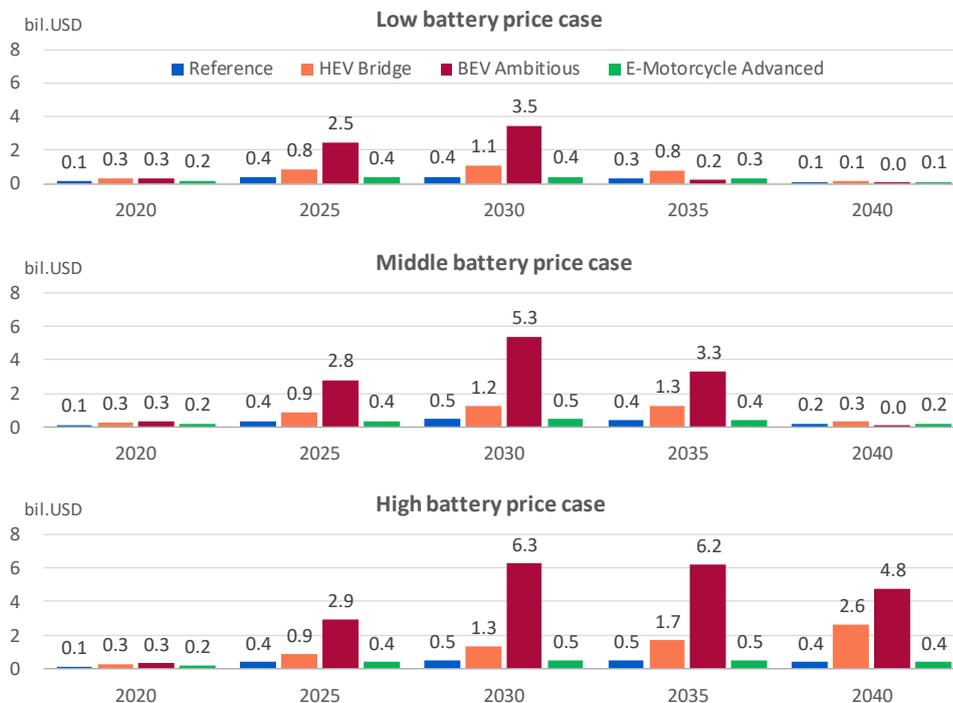
As the subsidy rates vary depending on the trend of battery prices, we also estimate total subsidy amounts for the low and high battery price cases.

### 3.2 Results

We calculated the total subsidy to xEVs for each scenario by multiplying the subsidy by the sales number (Figures 3-13 to 3-16). In the middle battery price case, the total subsidy increases significantly until around 2030, along with xEVs sales, which is almost the same in each country. After that, the total subsidy amount gradually decreases because the price decrease overwhelms the sales increase. The tendency is remarkable in the BEV Ambitious scenario, and the cumulative subsidy through 2040 is 2.6 to 3.1 times that of the HEV Bridge scenario. In the E-Motorcycle Advanced scenario, there is almost no subsidy, which is almost the same as the reference scenario.

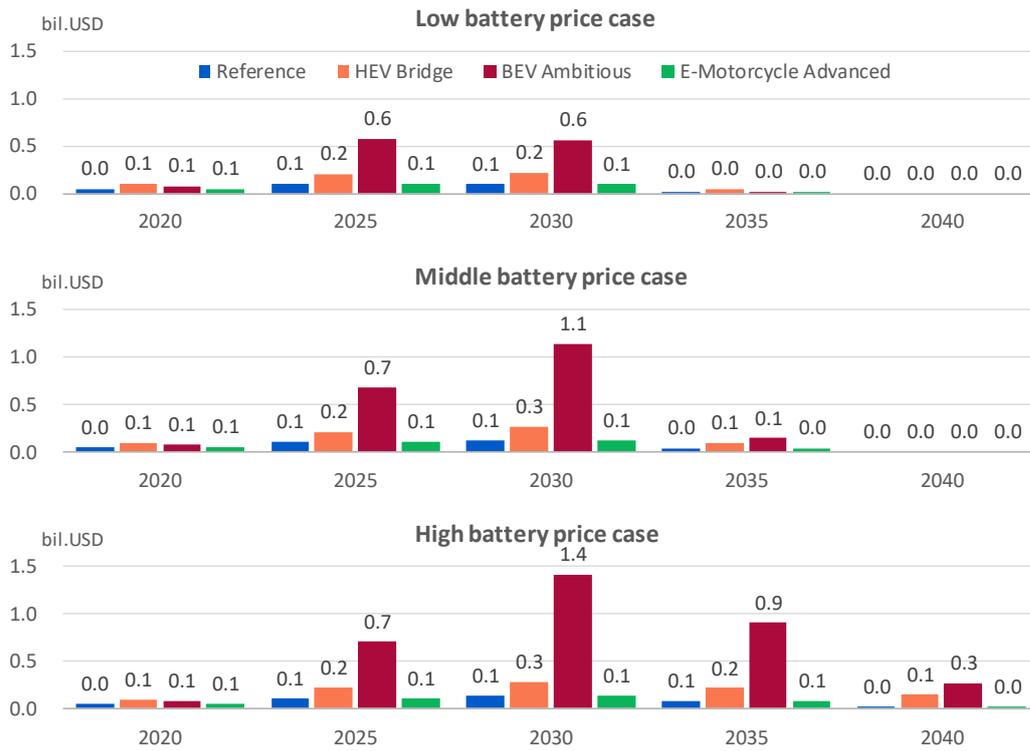
In the low battery price case, the total amount of subsidies is naturally small, with few required by around 2035. On the other hand, in the high battery price case, subsidies to xEVs will continue to be granted even in 2040. The cumulative subsidy amount through 2040 will increase by 1.3 to 1.6 times in the HEV Bridge scenario and by 1.5 to 1.8 times in the BEV Ambitious scenario, respectively, as compared to the middle battery price case.

**Figure 3-13. Subsidy Amount to xEVs in Indonesia**



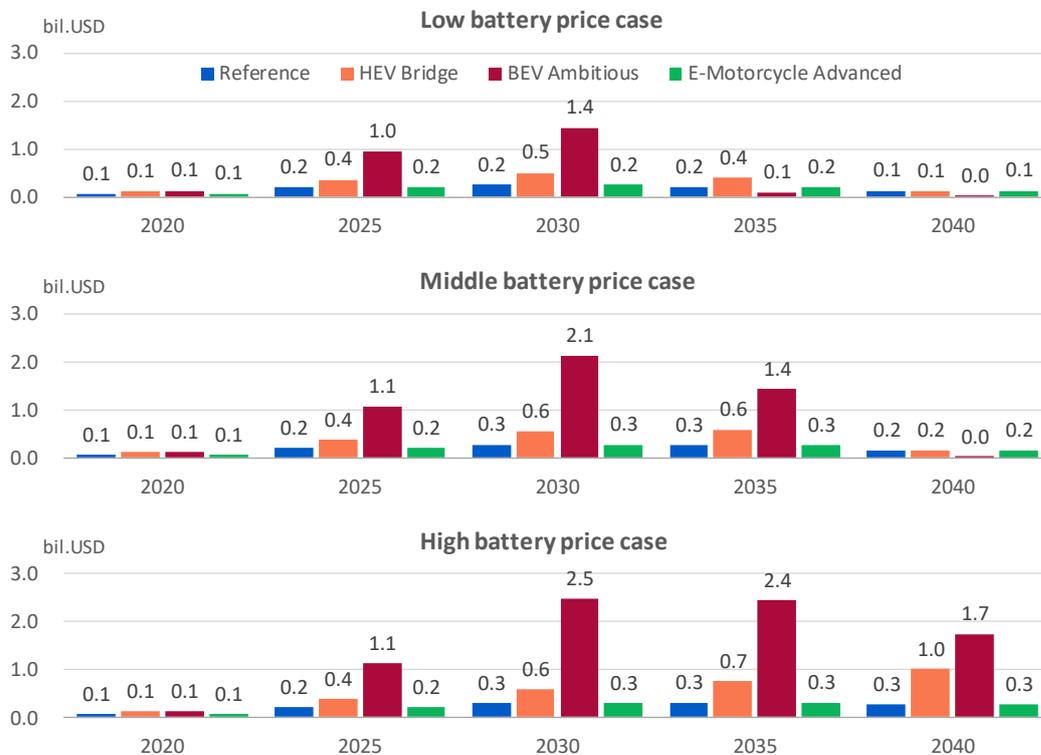
BEV = battery electric vehicle, HEV = hybrid electric vehicle.  
 Source: Authors' analysis.

**Figure 3-14. Subsidy Amount to xEVs in Thailand**



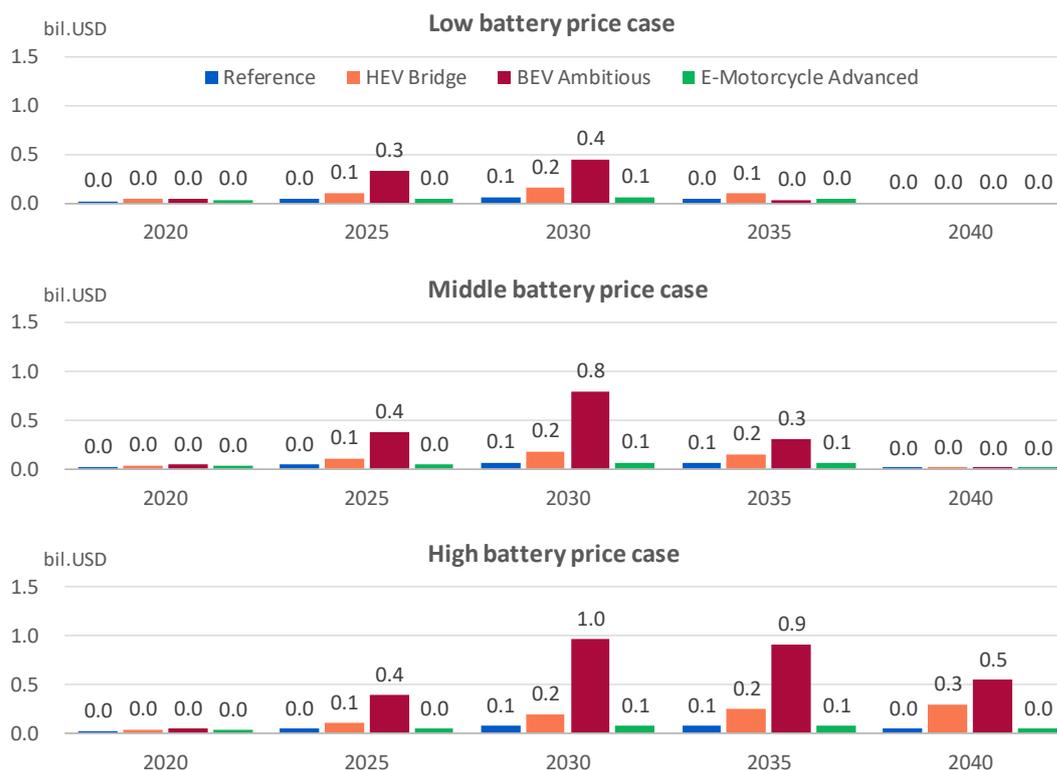
BEV = battery electric vehicle, HEV = hybrid electric vehicle.  
Source: Authors' analysis.

**Figure 3-15. Subsidy Amount to xEVs in Malaysia**



BEV = battery electric vehicle, HEV = hybrid electric vehicle.  
Source: Authors' analysis.

**Figure 3-16. Subsidy Amount to xEVs in Viet Nam**



BEV = battery electric vehicle, HEV = hybrid electric vehicle.

Source: Authors' analysis.

### 3.3 Key Implications from Subsidy Analysis

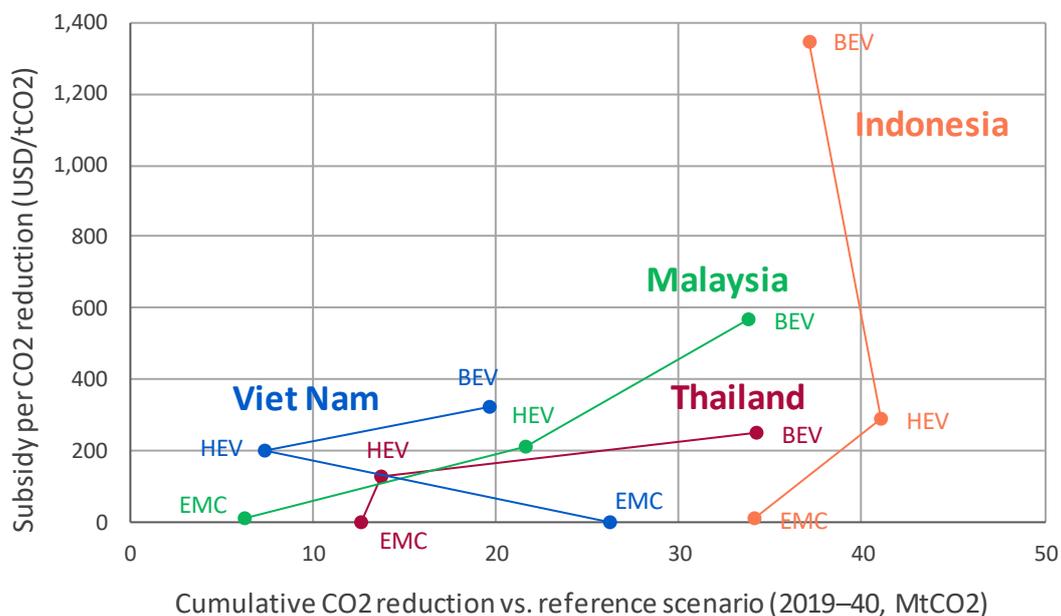
Figure 3-17 shows the cost-effectiveness of reducing CO<sub>2</sub> by calculating relations between the emissions savings and the subsidy amount. The horizontal axis shows cumulative CO<sub>2</sub> reduction and the vertical axis shows the reduction cost. In other words, the further the measure extends in the lower right in the diagram, the more cost-effective the scenario is in terms of CO<sub>2</sub> reductions.

In Indonesia, the HEV Bridge scenario is located at the lower right of the BEV Ambitious scenario, that is, the HEV Bridge scenario is better than BEV Ambitious scenario in terms of both cost and reduction effect. The BEV Ambitious scenario is inferior to the HEV Bridge scenario in reduction effect because the power supply mix is not clean enough. Seeing the position relationship between the HEV Bridge scenario and the E-Motorcycle Advanced scenario, we cannot say which is better. However, the HEV Bridge scenario and the E-Motorcycle Advanced scenario can be adopted at the same time.

In Viet Nam, we can easily see that E-Motorcycle Advanced scenario is the most cost-effective one. The CO<sub>2</sub> reduction effects in the E-Motorcycle Advanced scenario are large in both Viet Nam and Indonesia where there are a lot of motorcycles on the road.

In Malaysia, the HEV Bridge scenario has lower reduction costs, while the BEV Ambitious scenario can reduce more emissions. If cost is more important, the HEV Bridge scenario should be adopted. In Thailand as well, the cost is lower in the HEV Bridge scenario, while the emissions savings are larger in the BEV Ambitious scenario. However, the cost in the BEV Ambitious scenario is lower than in other countries, and the scenario may be pursued in view of the amount of reduction effect.

**Figure 3-17. Subsidy vs. CO<sub>2</sub> Reductions**



CO<sub>2</sub> = carbon dioxide, HEV= HEV Bridge scenario, BEV= BEV Ambitious scenario, EMC = E-Motorcycle Advanced scenario, MtCO<sub>2</sub> = million tonnes of carbon dioxide.  
 Source: Authors' analysis.

# Chapter 4

## Impacts on Industry by xEV Penetration

### 1 Brief Introduction of Input–Output analysis

Input-output analysis is an economic model that estimates the effect of changes in one or several activity sectors, or the effect of consumption changes on the rest of the economy.

Input-output tables describe and synthesise all goods and services operations in the form of commodities and activity sectors and give coherent representations of national or regional production. Input-output tables were invented by French physician and economist François Quesnay in his *Tableau Économique* in 1758 and can be considered the first attempt of economists to visually represent the circulation of welfare, i.e. revenues, spending, and goods in a particular state (Phillips, 1955). Input-output model and technique development is attributed to the American-Soviet economist, Wassily Leontief (Isard and Kaniss, 1973).

Berman and Plemmons (1987) pointed out that Leontief’s input–output analysis deals with one particular question: *what level of output should each of  $n$  industries in a particular economic situation produce, in order that it will just be sufficient to satisfy the total demand of the economy for that product?* Departing from this question, we provide a brief but simple explanation of input–output analysis in this sub-section.

In input–output analysis, production activities of a national or regional economy are grouped into  $n$  sectors of industries with the input–output table providing transactions of commodities amongst the sectors. The flows of transactions move as follows: to produce one unit of commodity  $j$ , sector  $j$  needs  $t_{ij}$  units of the  $i$  good as inputs for  $i=1, \dots, n$ , and producing  $\lambda$  units of output of the  $j$  commodity requires  $\lambda t_{ij}$  units of the  $i$  commodity. These coefficients,  $t_{ij}$ , are usually called input or technical coefficients and are usually assumed to be constant.

These coefficients of the production of each sector indicate how many units of output of  $i$  sector are needed to produce one unit of the output of  $j$  sector. Shown under any sector column of the table, they represent the relative importance of the output of the sector indicated by each sector row. This output is the equivalent amount of the input absorbed by each sector.

Defining  $X_i$  as the output of the  $i$  commodity per fixed unit of time, then part of this gross output is consumed as the input needed for production activities of the  $n$  sectors. If  $\sum_{j=1}^n t_{ij} X_j$  represents the unit of the  $i$  commodity consumed in production activities, then  $d_i$ , that is, the final use or final demand or the net output, can be defined as:

$$\text{(equation 1)} \quad d_i = X_i - \sum_{j=1}^n t_{ij} X_j$$

We can consider  $d_i$  as the contribution of the open sector of the economy such as investment, consumption or consumer purchase and export, etc.

Letting  $X$  and  $d$  be the  $n$ -vectors with components  $X_i$  and  $d_i$ , respectively, we can obtain the system of linear equation:

**(equation 2)**  $(I - T)X = d$

The coefficient matrix:

**(equation 3)**  $A = (I - T)$

is a matrix of size  $(n \times n)$  that can be solved for the gross output non-negative vector:

**(equation 4)**  $X = A^{-1}d$

The constants  $t_{ij}$  and  $d_i$  and the solutions  $X_i$  in **equation (1)** should satisfy the non-negativity constraint where gross output equals the sum of intermediate demand and final demand, as shown:

**(equation 5)**  $X_i = \sum_{j=1}^n t_{ij}X_j + d_i$

Where the final demand is composed by consumption ( $C_i$ ), investment ( $I_i$ ) and export ( $E_i$ ) of the  $i$  sector, we can also state,

**(equation 6)**  $X_i = \sum_{j=1}^n t_{ij}X_j + (C_i + I_i + E_i)$

Knowing the matrix of technical coefficients ( $T$ ), we can calculate the matrix  $A$  by using **equation (3)**; consequently, we can find  $X_i$  by solving **equation (4)**. We can calculate then the output needed from each sector ( $X_i$ ) when we know the demand or consumption, i.e.  $d$  of each of them. The change in consumption of the sector 1, namely  $d_1$ , shall change the total output of each sector  $X_1, X_2, X_3$ , etc. since to produce more of commodity 1, there is a need also to increase commodities 1, 2, and so on, as they are needed in the production of the commodity 1.

At the same time, gross input (purchase) is the sum of intermediate inputs and primary inputs. Primary inputs can be represented by various elements such as wage or employees' compensation, consumption of fixed capital, operating surplus, net taxes, value added, imports, etc., in sector  $j$ . In **equation (7)** below, we assume only one of them, i.e. value added ( $V_j$ ), and also that  $t_{ij}X_i$  has included already imported products.

**(equation 7)**  $X_j = \sum_{i=1}^n t_{ij}X_i + V_j$

In Table 4-1, rows represent input and columns represent output. Each sector is therefore both a user of inputs and a producer of outputs. The necessary condition of the input–output table is the total output must be equal to total input.

**(equation 8)**  $X_i = X_j$

Since  $\sum_{i=1}^n t_{ij}X_j = \sum_{j=1}^n t_{ij}X_j$

**(equation 9)**  $V = C + I + E$

The sum of the total income generated by a production system is equal to the total value of finished goods and services purchased by the final sectors for consumption, investment, and net exports.

Table 4-1 shows a hypothetical input–output transaction table.

**Table 4-1. A Hypothetical Open Input–Output Table**

	Intermediate use (columns)						Using sectors (inputs) – Final use			Total Output		
Producing sector (rows)	1	2	.	.	j	.	.	n	Consumption	Investment	Export	
1	$t_{11}X_1$	$t_{12}X_2$	.	.	$t_{1j}X_j$	.	.	$t_{1n}X_n$	$C_1$	$I_1$	$E_1$	$X_1$
2	$t_{21}X_1$	$t_{22}X_2$	.	.	$t_{2j}X_j$	.	.	$t_{2n}X_n$	$C_2$	$I_2$	$E_2$	$X_2$
.	.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.	.
$i$	$t_{i1}X_1$	$t_{i2}X_2$	.	.	$t_{ij}X_j$	.	.	$t_{in}X_n$	$C_i$	$I_i$	$E_i$	$X_i$
.	.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.	.
$n$	$t_{n1}X_1$	$t_{n2}X_2$	.	.	$t_{nj}X_j$	.	.	$t_{nn}X_n$	$C_n$	$I_n$	$E_n$	$X_n$
Value added	$V_1$	$V_2$	.	.	$V_j$	.	.	$V_n$	$V_C$	$V_I$	$V_E$	$V$
<b>Total inputs</b>	<b><math>X_1</math></b>	<b><math>X_2</math></b>	.	.	<b><math>X_j</math></b>	.	.	<b><math>X_n</math></b>	<b><math>C</math></b>	<b><math>I</math></b>	<b><math>X_E</math></b>	<b><math>X</math></b>

Source: Authors.

Berman and Plemmons (1987) showed another way to calculate added value using an associated price valuation system, which gives the pricing or value side of the input–output relationship.

Let  $c_j$  be the cost of the  $j$  commodity given by the total sum of all cost of inputs contributed by all sectors.

$$\text{(equation 11)} \quad c_j = \sum_{i=1}^n t_{ij}p_i \quad \text{with } 1 \ll j \ll n$$

The net revenue per unit output of the  $j$  commodity or the value added per unit output  $v_j$  is given by the following equation.

$$\text{(equation 12)} \quad v_j = p_j - \sum_{i=1}^n t_{ij}p_i$$

The relationship can also be represented by a system of linear equations:

$$\text{(equation 13)} \quad v^t = p^t - p^t T$$

or

$$\text{(equation 14)} \quad v^t = p^t A \quad \text{where } A = I - T$$

$p$  is the price vector and  $v$  is the valued added vector. **Equations (4)** and **(13)** can be linked in the

following relation.

$$\text{(equation 15)} \quad \sum_{i=1}^n v_i x_i = \sum_{j=1}^n p_j d_j$$

The left side of **equation (15)** can be called the national or regional product, while the right side can be called the national or regional income. Herewith, the national income equals the national product.

The above explanation represents what we can call the *open* and *static* Leontief model, which is the input–output technique that we use in this study. The term ‘open’ refers to the model’s inclusion of an open sector that lies outside the system, i.e. final demand. In a ‘closed’ model, the open sector as the final demand does not exist, as it is absorbed into the system as just another industry. Finally, the term ‘static’ means that the technical coefficients and final demand (open sector) are assumed to be constant. In the ‘dynamic’ model, the temporal aspect is included to allow us to analyse the change of output in different time points.

## 2 Review of Input–Output Analysis Use on Electric Vehicle Penetration Impacts

Input–output analysis has been used to assess the impacts of xEV penetration usually through two aspects of a car’s lifecycle, namely manufacturing and use. Manufacturing of xEVs may include not only all activities related to car construction, i.e. electrical equipment fabrication, battery production, all related supporting industries, metal products, textiles, etc., but also activities related to the construction of charging infrastructures. The use of xEVs signifies the shift of conventional transport fuel consumption to electric energy. Input-output technique allows simulating both aspects and capturing their impacts on various sectors.

In this sub-section, we review the use of input–output technique to analyse the impacts of xEV penetration. It does not aim to be comprehensive, but instead points out the main indications of what we can do to analyse xEV penetration using the technique.

Winnebrake et al. (2017), using some input–output analysis at city-, state-, and national-level studies in the US, but without giving too much detail, summarised how the effects of xEV penetration can be captured in the economy.

In terms of car manufacturing, Winnebrake et al. (2017) found it generated economic activity and job production through incremental increases in vehicle costs and increased demand in sector producing vehicles, components and charging infrastructures. Regarding car use, they found several impacts; amongst others, these were (i) the reduction of petroleum consumption and fuel costs that provided some savings to drivers’ pocket and household budget; (ii) the injection of petroleum fuel savings towards other goods and services in local economy that created new jobs and boosts economic output typically measured as gross domestic product or GDP; and (iii) the potential reduction of electricity rates to all utility consumers.

Leurent and Windisch (2013) explained how they use input–output technique in their model to calculate costs and benefits of xEV regarding public finance in France. They created a new sector (commodity) of xEV and estimated its technical (input) coefficients based on detailed costs in producing xEVs with cost elements comparable to those of ICEV manufacturing. Included in the cost elements were, amongst others, automobile construction (engine), metallurgy and metal processing, equipment manufacture, electrical and electronic equipment and components, business services including research and development, etc. In terms of vehicle use, the authors calculated the annual per-car energy and fuel consumption, as well as the tax exclusive total costs of vehicle use (including

insurance and maintenance), of both ICEVs and PHEVs based on assumptions on the average mileage, fuel economy, and battery efficiency. Finally, they set annual per-car value-added tax, energy surcharge, production tax, gross social contributions and unemployment benefits that differed based on the paper's simulated scenarios. Doing the latter allows the authors to play with fiscal instruments that affect the final demand (production tax, energy surcharge, value added tax, etc.) and the primary input (social contribution, unemployment benefits, etc.).

Finally, the effect of electric vehicle usage on the power generation sector, i.e. the energy used to generate electricity and the resulting emissions, is an important aspect that potentially can also be analysed using input–output technique. This effect has been much analysed since the existing input–output tables usually represent the power generation sector in an aggregated manner. Several authors have provided methods to disaggregate the sector. For example, Lidner et al. (2013) proposed a method to disaggregate the power generation sector in China into transmission and distribution sectors, as well as into eight sub-sectors representing different types of technology in power plants, e.g. subcritical coal, hydro, etc. The work of Marriott (2007) built upon the existing US economic input–output tool, adding detail about the electricity industry, specifically by differentiating amongst the various functions of the sector, and the different means of generating power. His work included construction of a flexible framework for creating new industry sectors, supply chains and emission factors for the generation, transmission and distribution portions of the electricity industry.

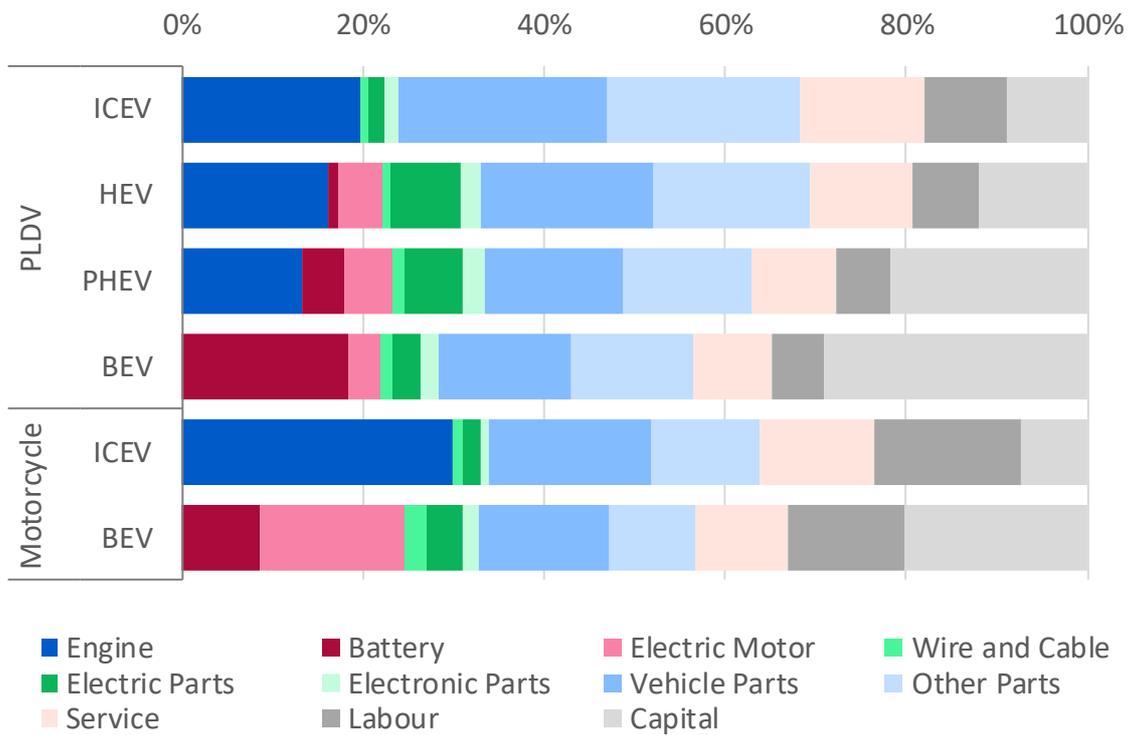
### **3 Modelling an Input–Output Analysis Framework**

#### **3.1 Creating Input–Output Tables for xEV Analysis**

The input–output tables should be prepared for each country. We will use the input–output tables in the Global Trade Analysis Project (GTAP) 10 database because we can analyse commonly to all countries. The GTAP 10 database is the project's centrepiece, covering 121 countries, and the base year of the input–output tables is 2014. However, the input–output tables are classified into 65 industries, and there is only one automobile manufacturing sector, which this study addresses. Therefore, we add some xEV-related sectors for our analysis (Table 4-2).

We break down the automobile manufacturing sector into the four powertrain types (only for PLDVs and motorcycles). For the input columns, xEV input coefficients (input ratio of raw materials, etc. to production value) are estimated based on various information, including ICCT (2019) and CRISER (2015) (Figure 4-1). For estimation, the battery size is set as 2 kWh for HEVs, 10 kWh for PHEVs, 40 kWh for BEVs, and 1 kWh for e-motorcycles. The battery pack price is assumed to be US\$160 per kWh. For the output rows, the final demand is only accounted, assuming there is no intermediate demand for the PLDVs and motorcycles by each industry.

**Figure 4-1. Input Structure for xEVs**



BEV = battery electric vehicle, HEV = hybrid electric vehicle, ICEV = internal combustion engine vehicle, PHEV = plug-in hybrid vehicle, PLDV = passenger light duty vehicle.

Source: Authors' analysis.

**Table 4-2. Comparison of Industry Category (GTAP vs. This Study)**

GTAP		This Study	
1	Rice	1	
2	Wheat	2	
3	Other Grains	3	
4	Veg and Fruit	4	
5	Oil Seeds	5	
6	Cane and Beet	6	
7	Fibres crops	7	
8	Other Crops	8	
9	Cattle	9	
10	Other Animal Products	10	
11	Raw milk	11	same as the left
12	Wool	12	
13	Forestry	13	
14	Fishing	14	
15	Coal	15	
16	Oil	16	
17	Gas	17	
18	Other Mining Extraction (formerly omn)	18	
19	Cattle Meat	19	
20	Other Meat	20	
21	Vegetable Oils	21	
22	Milk	22	
23	Processed Rice	23	
24	Sugar and molasses	24	
25	Other Food	25	
26	Beverages and Tobacco products	26	
27	Manufacture of textiles	27	
28	Manufacture of wearing apparel	28	
29	Manufacture of leather and related products	29	
30	Lumber	30	
31	Paper and Paper Products	31	
32	Petroleum and Coke	32	Petroleum
		33	Coke
33	Manufacture of chemicals and chemical products	34	
34	Manufacture of pharmaceuticals, medicinal chemical and botanical products	35	
35	Manufacture of rubber and plastics products	36	
36	Manufacture of other non-metallic mineral products	37	
37	Iron and Steel	38	
38	Non-Ferrous Metals	39	same as the left
39	Manufacture of fabricated metal products, except machinery and equipment	40	
40	Manufacture of computer, electronic and optical products	41	
41	Manufacture of electrical equipment	42	
42	Manufacture of machinery and equipment n.e.c.	43	
		44	Engine
		45	Electric Motor
		46	Electric Parts
		47	Wire and Cable
		48	Battery
		49	Electronic Parts
		50	Vehicle Parts
43	Manufacture of motor vehicles, trailers and semi-trailers	51	ICE
		52	HEV
		53	PHEV
		54	BEV
		55	Motorcycle
		56	E-motorcycle
		57	Manufacture of other motor vehicles, trailers and semi-trailers
44	Manufacture of other transport equipment	58	
45	Other Manufacturing	59	
46	Electricity; steam and air conditioning supply	60	
47	Gas manufacture, distribution	61	
48	Water supply; sewerage, waste management and remediation activities	62	
49	Construction	63	
50	Wholesale and retail trade; repair of motor vehicles and motorcycles	64	
51	Land transport and transport via pipelines	65	
52	Water transport	66	
53	Air transport	67	
54	Warehousing and support activities	68	same as the left
55	Information and communication	69	
56	Accommodation, Food and service activities	70	
57	Other Financial Intermediation	71	
58	Insurance (formerly isr)	72	
59	Real estate activities	73	
60	Other Business Services nec	74	
61	Other Services (Government)	75	
62	Education	76	
63	Human health and social work	77	
64	Recreation and Other Services	78	
65	Dwellings	79	

GTAP = Global Trade Analysis Project, BEV = battery electric vehicle, HEV = hybrid electric vehicle, ICE = internal combustion engine vehicle, PHEV = plug-in hybrid vehicle.

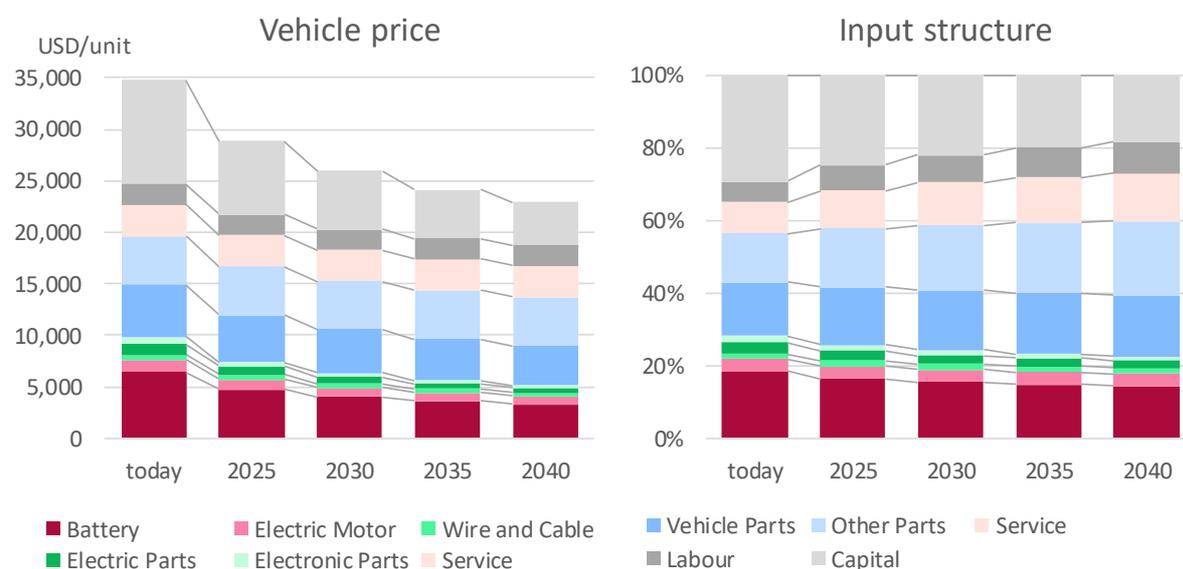
Source: GTAP (2019) and Authors.

Major auto parts, such as engines, motors, and batteries, should be also treated separately in order to understand the impact of xEV production. The input columns refer to a Japanese detailed input–output table (with 509 industries), because automobile production is systematised and the input structure of each part is generally considered to be common throughout the world. For the output rows, intermediate demand for the parts is assumed to be only from the automobile manufacturing industries and is estimated based on the input structure of xEVs.

In addition, we split the ‘Petroleum and Coke’ sector into petroleum and coal products to see the impact of xEVs’ fuel demand. According to the IEA Energy Balance Table, no coal products are produced in any country, so petroleum product data for input column and output row are same as the original ‘petroleum and coke’ data, and the coal product column and row are treated as zero.

We assume that the industrial structures remain unchanged until 2040, except the xEV cost structure. The prices of xEVs are assumed to fall as shown in the Middle Battery Case in Figure 4-2.

**Figure 4-2. Cost Structures for BEVs in the Middle Battery Price case**



BEVs = battery electric vehicles.

Source: Authors’ analysis.

### 3.2 Creating Employment Table

Employment tables (the number of employees in each industry sector) should be prepared to analyse the ripple effect on employment. We create an employment table for each country based on the International Labour Organization’s (ILO) ILOSTAT database, since GTAP does not have employment tables. However, the statistics on the number of employees are categorised into only 14 industries in ILOSTAT (2020). Therefore, in order to split into 79 industries in the input–output tables in this study (Table 4-3), we estimate them based on the Japanese employment table (with 387 industries).

The estimation procedure is as follows.

First, for each industry (i) in the ILO category, the total of labour income ( $Y_{ij}$ ) in the input–output table is divided by the number of employees ( $L_i$ ) of the ILO statistics to calculate income per employee ( $w_i$ ).

**(equation 4)**  $w_i = \Sigma(Y_{ij}) / L_i$

Next, we estimate the income per employee in the ILO category ( $w_i$ ) and the input–output category ( $w_{ij}^l$ ) based on the Japanese employment table with the more detailed industry category. By multiplying the income per capita in the ILO category by the ratio of income amongst industries in Japan, we get the income ( $w_{ij}$ ), reflecting wage differences amongst industries.

**(equation 5)**  $w_{ij} = w_i * w_{ij}^l / w_i^l$

Then, we divide the labour income by the income per employee to calculate the number of employees ( $L_{ij}$ ) in the input–output category.

**(equation 6)**  $L_{ij} = Y_{ij} / w_{ij}$

Finally, we handle them by multiplying adjustment factor ( $a_i$ ) so that the total number of employees in the input–output category matches the number of employees in the ILO category. In this study, we use  $L_{ij}^e$  as the number of employees by industry in the input–output category.

**(equation 7)**  $L_{ij}^e = L_{ij} * a_i, \Sigma(L_{ij} * a_i) = L_i$

Table 4-4 shows employment intensities (the number of employees per production value in each industry), calculated based on the estimated employment table. The ripple effects on employment are measured by multiplying those of production by the employment intensities.

**Table 4-3. Comparison of Industry Category (ILO vs. This Study)**

ILO		This Study	
1	Agriculture; forestry and fishing	1	Rice
		2	Wheat
		3	Other Grains
		4	Veg and Fruit
		5	Oil Seeds
		6	Cane and Beet
		7	Fibres crops
		8	Other Crops
		9	Cattle
		10	Other Animal Products
		11	Raw milk
		12	Wool
		13	Forestry
		14	Fishing
2	Mining and quarrying	15	Coal
		16	Oil
		17	Gas
		18	Other Mining Extraction (formerly omn)
3	Manufacturing	19	Cattle Meat
		20	Other Meat
		21	Vegetable Oils
		22	Milk
		23	Processed Rice
		24	Sugar and molasses
		25	Other Food
		26	Beverages and Tobacco products
		27	Manufacture of textiles
		28	Manufacture of wearing apparel
		29	Manufacture of leather and related products
		30	Lumber
		31	Paper and Paper Products
		32	Petroleum
		33	Coke
		34	Manufacture of chemicals and chemical products
		35	Manufacture of pharmaceuticals, medicinal chemical and botanical products
		36	Manufacture of rubber and plastics products
		37	Manufacture of other non-metallic mineral products
		38	Iron and Steel
		39	Non-Ferrous Metals
		40	Manufacture of fabricated metal products, except machinery and equipment
		41	Manufacture of computer, electronic and optical products
		42	Manufacture of electrical equipment
		43	Manufacture of machinery and equipment n.e.c.
		44	Engine
		45	Electric Motor
		46	Electric Parts
		47	Wire and Cable
		48	Battery
		49	Electronic Parts
		50	Vehicle Parts
		51	ICE
		52	HEV
		53	PHEV
		54	BEV
		55	Motorcycle
		56	E-motorcycle
		57	Manufacture of other motor vehicles, trailers and semi-trailers
		58	Manufacture of other transport equipment
		59	Other Manufacturing
4	Utilities	60	Electricity; steam and air conditioning supply
		61	Gas manufacture, distribution
		62	Water supply; sewerage, waste management and remediation activities
5	Construction	63	Construction
6	Wholesale and retail trade; repair of motor vehicles and motorcycles	64	Wholesale and retail trade; repair of motor vehicles and motorcycles
7	Transport; storage and communication	65	Land transport and transport via pipelines
		66	Water transport
		67	Air transport
		68	Warehousing and support activities
		69	Information and communication
8	Accommodation and food service activities	70	Accommodation, Food and service activities
9	Financial and insurance activities	71	Other Financial Intermediation
		72	Insurance (formerly isr)
10	Real estate; business and administrative activities	73	Real estate activities
		74	Other Business Services nec
11	Public administration and defence; compulsory social security	75	Other Services (Government)
12	Education	76	Education
13	Human health and social work activities	77	Human health and social work
14	Other services	78	Recreation and Other Services
		79	Dwellings

BEV = battery electric vehicle, HEV = hybrid electric vehicle, ICE = internal combustion engine vehicle, PHEV = plug-in hybrid vehicle, ILO = International Labour Organization.

Source: ILOSTAT (2020) and Authors.

**Table 4-4. Employment Intensity (Labours / million US\$)**

Sector	Indonesia	Thailand	Malaysia	Viet Nam
Rice	217.6	334.1	37.9	643.9
Wheat	195.0	460.1	0.4	29.2
Other Grains	943.2	912.6	20.8	2214.6
Veg and Fruit	225.5	213.9	17.6	554.6
Oil Seeds	873.5	841.6	88.7	1640.9
Cane and Beet	199.1	223.5	22.7	562.5
Fibres crops	520.3	394.9	28.0	501.3
Other Crops	267.0	326.9	30.0	712.8
Cattle	137.3	305.4	21.2	384.2
Other Animal Products	91.9	97.7	12.9	192.0
Raw milk	101.2	213.7	6.8	11.1
Wool	121.0	167.0	4.2	15.0
Forestry	125.1	224.3	16.6	497.6
Fishing	101.3	32.5	15.8	242.3
Coal	7.1	3.3	1.5	15.6
Oil	4.2	3.0	1.8	13.4
Gas	4.4	4.0	2.9	21.2
Other Mining Extraction (formerly omn)	39.7	6.8	1.9	36.9
Cattle Meat	33.6	24.5	19.4	4.5
Other Meat	99.7	21.7	21.7	48.3
Vegetable Oils	31.6	5.2	1.5	30.7
Milk	28.3	12.3	2.2	42.6
Processed Rice	2.7	12.8	0.9	15.8
Sugar and molasses	13.1	14.0	0.0	23.5
Other Food	38.5	17.5	7.1	29.9
Beverages and Tobacco products	34.3	14.5	4.5	65.4
Manufacture of textiles	29.4	25.5	6.8	37.6
Manufacture of wearing apparel	51.4	32.6	16.9	25.5
Manufacture of leather and related products	50.9	18.8	11.9	33.6
Lumber	46.5	30.2	12.2	36.9
Paper and Paper Products	22.3	16.0	7.7	30.7
Petroleum	0.0	0.0	0.0	0.0
Coke	1.7	1.9	0.3	5.1
Manufacture of chemicals and chemical products	13.4	7.6	2.6	21.8
Manufacture of pharmaceuticals, medicinal chemical and botanical products	23.9	16.4	4.7	37.3
Manufacture of rubber and plastics products	43.3	38.1	10.6	80.2
Manufacture of other non-metallic mineral products	35.9	15.4	10.4	42.8
Iron and Steel	12.6	10.2	3.2	13.7
Non-Ferrous Metals	16.8	18.3	3.8	24.2
Manufacture of fabricated metal products, except machinery and equipment	18.4	14.9	7.1	56.0
Manufacture of computer, electronic and optical products	9.1	6.4	5.8	19.5
Manufacture of electrical equipment	16.3	7.1	4.5	24.3
Manufacture of machinery and equipment n.e.c.	22.3	9.5	6.2	34.4
Engine	23.4	26.9	11.3	39.9
Electric Motor	39.1	45.1	18.8	66.9
Electric Parts	26.4	30.4	12.7	45.1
Wire and Cable	19.1	22.0	9.2	32.6
Battery	0.8	0.8	0.8	0.8
Electronic Parts	31.8	36.7	15.3	54.4
Vehicle Parts	21.1	24.3	10.1	36.0
ICE	10.7	12.4	5.2	18.3
HEV	8.8	10.1	4.2	15.0
PHEV	7.2	8.2	3.4	12.2
BEV	6.8	7.8	3.3	11.6
Motorcycle	20.1	23.2	9.7	34.4
E-motorcycle	16.1	18.5	7.8	27.5
Manufacture of other motor vehicles, trailers and semi-trailers	25.6	8.2	5.7	36.2
Manufacture of other transport equipment	26.5	13.3	5.3	44.0
Other Manufacturing	20.5	21.6	11.5	47.9
Electricity; steam and air conditioning supply	3.6	5.8	0.4	16.8
Gas manufacture, distribution	20.2	2.7	5.7	35.9
Water supply; sewerage, waste management and remediation activities	60.8	22.4	16.3	25.6
Construction	31.3	68.7	25.9	115.2
Wholesale and retail trade; repair of motor vehicles and motorcycles	151.3	70.8	21.2	301.4
Land transport and transport via pipelines	79.4	22.4	22.7	137.6
Water transport	17.6	17.9	1.8	50.5
Air transport	8.1	2.7	2.6	18.7
Warehousing and support activities	67.6	24.7	18.1	155.5
Information and communication	53.7	26.7	12.4	154.6
Accommodation, Food and service activities	145.7	108.8	63.1	330.9
Other Financial Intermediation	33.2	19.6	7.1	107.7
Insurance (formerly isr)	74.5	24.3	7.8	65.9
Real estate activities	34.2	13.1	9.0	33.6
Other Business Services nec	111.7	48.7	36.9	85.2
Other Services (Government)	106.4	68.5	40.8	304.5
Education	251.7	86.6	80.4	391.1
Human health and social work	32.2	25.7	23.5	63.9
Recreation and Other Services	148.0	50.1	45.4	468.4
Dwellings	0.0	0.0	0.0	0.0

BEV = battery electric vehicle, HEV = hybrid electric vehicle, ICE = internal combustion engine vehicle, PHEV = plug-in hybrid vehicle.

Source: Authors' analysis.

### 3.3 PLDV-related Expenditure

For the ripple effect analysis, we estimate the expenditure related to the xEV penetration for each scenario. Expenditure for PLDVs and motorcycles include the spending for vehicles, refuelling/charging equipment, and daily fuel/electricity. They are estimated for 2025, 2030, 2035, and 2040, and recalculated as additional expenditure from today.

The total spending per vehicle is calculated by summing up the sales volume times the vehicle prices for ICEVs and xEVs. Neither taxes, subsidies, insurance nor other peripheral expenses are included. The sales volume of each powertrain type naturally depends on each scenario and each vehicle price adopts the Middle Battery Price case (see Figure 3-7).

The installation cost of fuelling/charging equipment is calculated as the number of equipment units times the installation cost per unit. The installation cost per unit depends on the situation and additional functions, but we assume them as in Table 4-5 according to various information, including ERIA (2019).

**Table 4-5. Assumptions for Costs of Refuelling / Charging Equipment**

	Home/Public	Charging Levels	US\$/unit
<b>Charging Equipment</b>	Home	Level 2	500
	Public	Level 2	5,000
		Level 3	25,000
<b>Refuelling Station</b>	Public	-	300,000

According to TriggerEnergy, Level 1; Chargers run off of standard 110v and very simple accessories typically included with most electric vehicles. Depending on your type of electric vehicle, a Level 1 Charger will take 8–15 hours to fully charge from 0%–100%.

Level 2; Chargers run off of 240v current and charge at a much faster rate. Depending on your type of electric vehicle, a Level 2 Charger will take approximately 4 to 8 hours to charge from 0%–100%.

Level 3; Fast Chargers are much higher-end units with their own dedicated electrical lines and can charge many electric vehicles from 0%–100% in as little as 20 minutes.

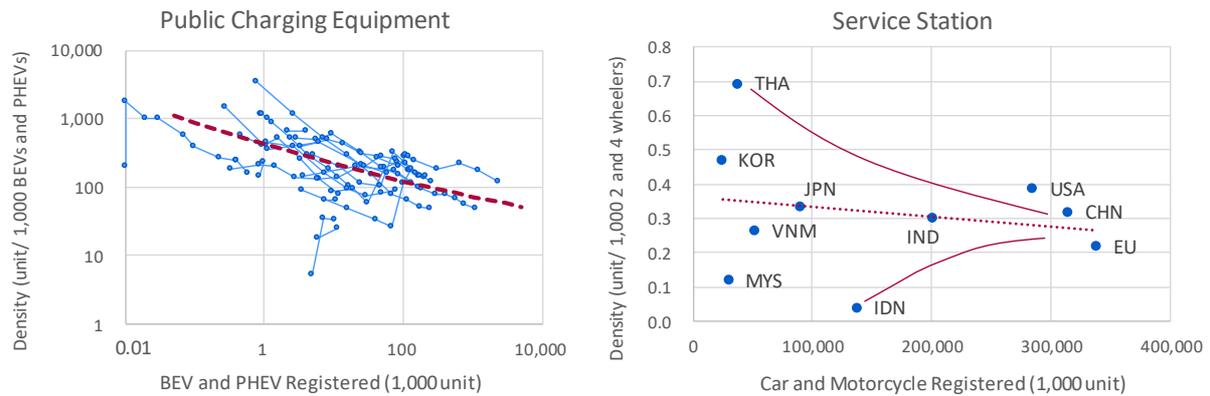
<https://triggerenergy.com/how-much-do-ev-charging-stations-cost/> (accessed 20 January 2020)

Source: Authors' analysis.

The installed equipment number is calculated by multiplying the number of gasoline/electric vehicles registered by the equipment density rate (= number of equipment per number of vehicles). According to density rates for gas stations estimated based on various information, we assume that the rates converge to the level of developed countries along with the spread of car ownership (Figure 4-3 right). Further, we assume that the density rates will gradually decrease in Thailand and increase in Malaysia and Indonesia.

The density rates for public charging equipment are assumed to decrease gradually as BEVs and PHEVs spread, based on the time-series and cross-section data (IEA, 2019b) (Figure 4-3 left). Of these, we assume 10% are fast chargers (Level 3) and the rest are slow chargers (Level 2). The small chargers for home (and workplace, etc.) are assumed to be installed at the rate of one unit per BEV and PHEV.

**Figure 4-3. Public Refuelling / Charging Station Density per Vehicles Registered**



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

CHN = China, EU = European Union, IDN = Indonesia, IND = India, JPN = Japan, KOR = Korea,

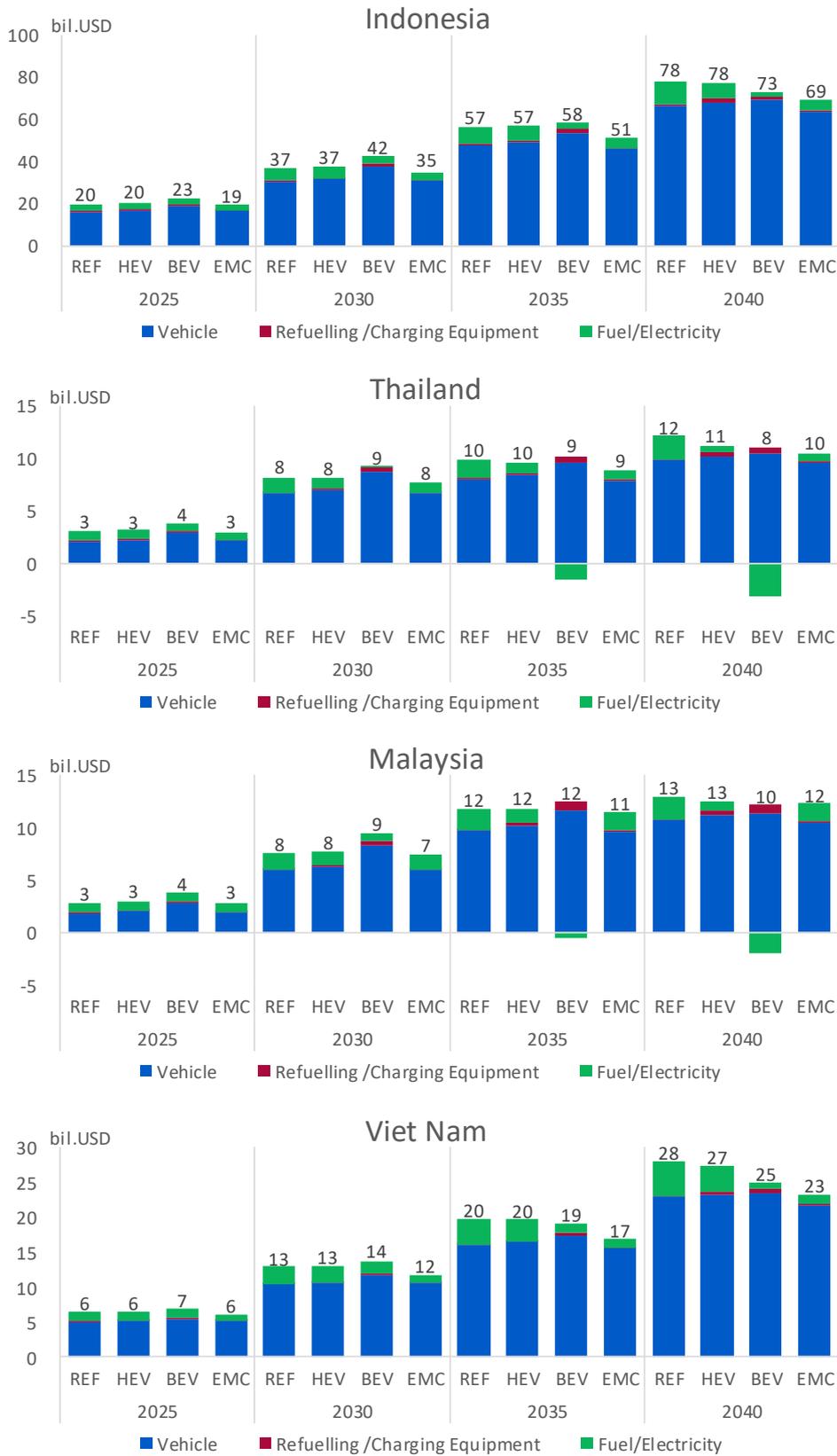
MYS = Malaysia, THA = Thailand, USA = United States of America, VNM = Viet Nam.

Source: IEA (2019b) and Authors' analysis.

The daily fuel/electricity cost for running vehicles is calculated by multiplying gasoline / electricity price by average fuel efficiency and annual mileage, which are the same as section 3.1.

Figure 4-4 shows additional PLDV-related expenditures, needed from today. The expenditure for purchasing vehicles gradually increases as the car and motorcycle become widespread in the four countries. In the HEV Bridge and the BEV Ambitious scenarios, expenditures are more than in the reference scenario due to xEVs' cost. Although expenditures on installing refuelling/charging facilities are not large, they are higher in the BEV Ambitious scenario because the total amount for charging equipment is greater than on service stations. Daily fuel/electricity cost basically increases with the spread of motor vehicles, but they are suppressed in the alternative xEV scenarios. The spending in the BEV Ambitious scenario is even lower than at present in Thailand and Malaysia.

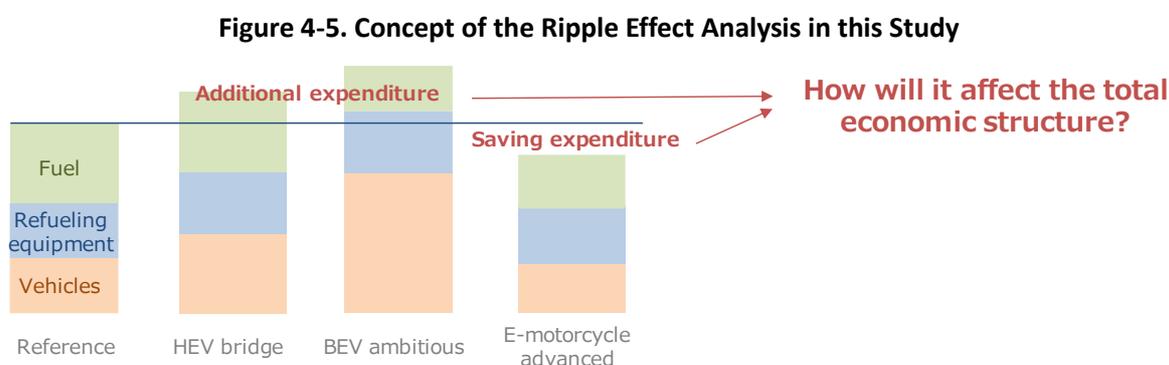
**Figure 4-4. PLDV-related Expenditure by Scenario (including motorcycles)**



bil.US\$ = billions of US dollars. REF=Reference, HEV= HEV Bridge, BEV= BEV Ambitious, EMC = E-Motorcycle Advanced, PLDV = passenger light duty vehicle.  
Source: Authors' analysis.

#### 4 Analysis Results and Implications

This section sees the ripple effects of PLDV-related expenditure on production and employment by the scenario. To evaluate the economic impacts of xEV penetration, the ripple effects in the alternative scenarios are assessed by using additional/saving spending relative to the reference scenario (Figure 4-5).



BEV = battery electric vehicle, HEV = hybrid electric vehicle.  
Source: Authors.

We analyse the effects based on some cases. Sub-section 4.1 shows the results of the base case where some xEVs are produced in the domestic factories at the same ratio as ICEs are today and the necessary battery packs are also domestically produced. Sub-section 4.2 shows the results of the Importing Battery case, where they are fully imported from foreign countries, while sub-section 4.3 shows the ones in the Importing xEVs case, where they are fully imported. Finally, sub-section 4.4 shows the ripple effects when assuming the budget constraint, which means additional expenditure and savings are offset.

**Table 4-6. Cases for Input–Output Analysis**

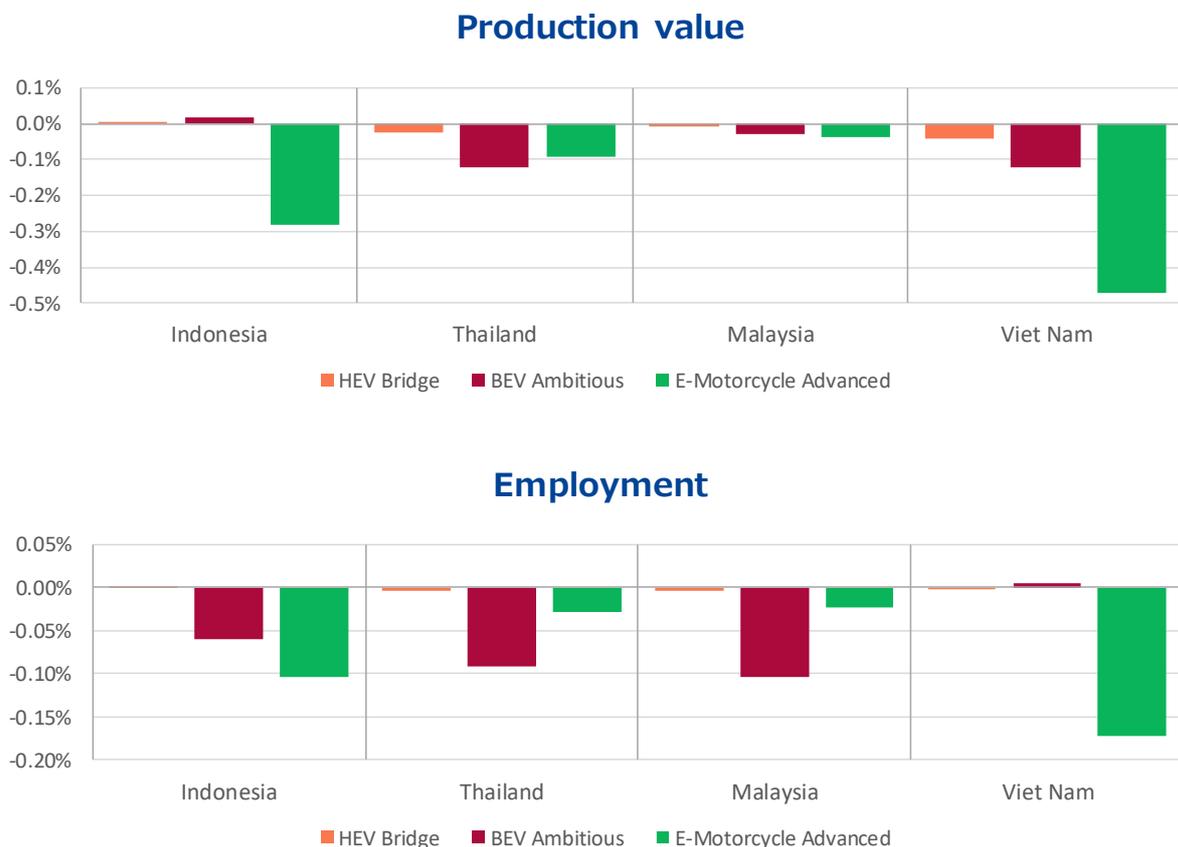
	Base case	Importing battery case	Importing xEVs case	Budget constraint case
xEVs supply	Today's ICEV production/import ratio	Same as Base	All imported	Same as Base
Battery supply	All domestically produced	All imported	None	Same as Base
Budget	Free	Same as Base	Same as Base	Constraint

ICEV = internal combustion engine vehicle, xEVs = electric vehicles.  
Source: Authors.

#### 4.1 Base Case

Figure 4-6 shows the cumulative ripple effects on production and employment up to 2040 for each scenario compared with the reference scenario. Negative numbers mean that the economic impacts by spreading xEVs are worse than the reference scenario.

**Figure 4-6. Ripple Effects during Outlook Period vs. Today's Level**



BEV = battery electric vehicle, HEV = hybrid electric vehicle.

Note: Effects comparing with the reference scenario.

Source: Authors' analysis.

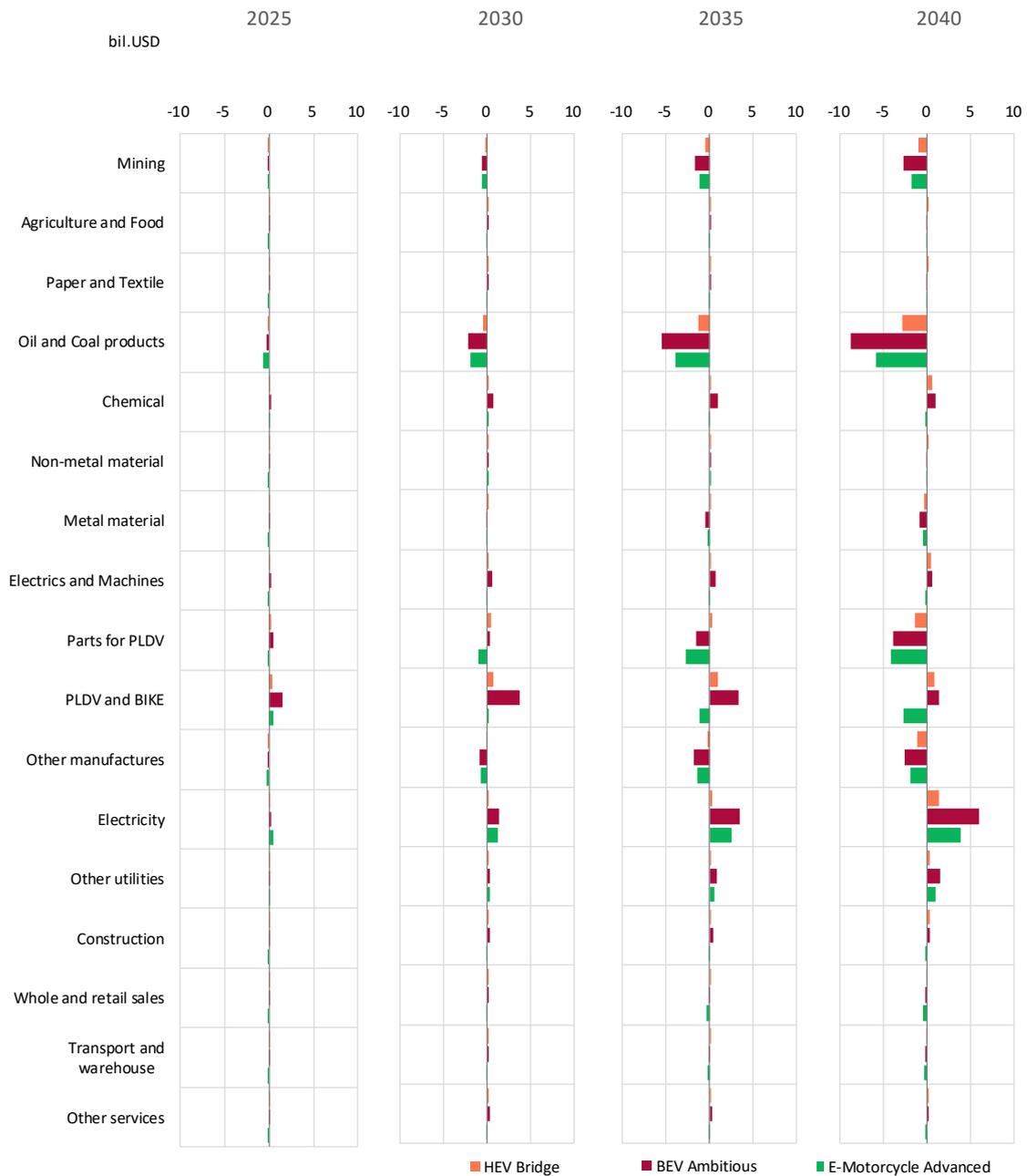
Negative values in many regions and scenarios are seen. The E-Motorcycle Advanced scenario has a large negative ripple effect due to the small difference in vehicle prices between ICEs and BEVs, and the large savings in the daily fuel costs, particularly in Indonesia and Viet Nam, where motorcycles are widely spread. The BEV Ambitious and the HEV Bridge have negative effects (except in Indonesia, where they are barely positive), and the negative effects in the former are larger than those in the latter. This is because producing battery packs has a smaller ripple effect than producing parts related to internal combustion engines; further, the negative effects of petroleum fuel supply overwhelm the positive effects of electricity supply (Figures 4-7 to 4-10). Although the higher electricity demand needs more fuels such as coal and natural gas, economic impacts are negative in the mining industries.

In terms of employment, the negative ripple effects in the BEV Ambitious are much greater than that in the HEV Bridge, especially in Thailand and Malaysia, where the BEV Ambitious has the worst impact

amongst the alternative xEV scenarios. Employment required to producing battery packs is less than the producing parts related to internal combustion engines, so that it shows noticeable negative effects in employment in the BEV Ambitious and the E-Motorcycle Advanced.

In Viet Nam, the HEV Bridge and the BEV Ambitious have little impact on domestic employment as most of the PLDV vehicles are produced in CKD style.

**Figure 4-7. Production Ripple Effects by Sector (Indonesia)**

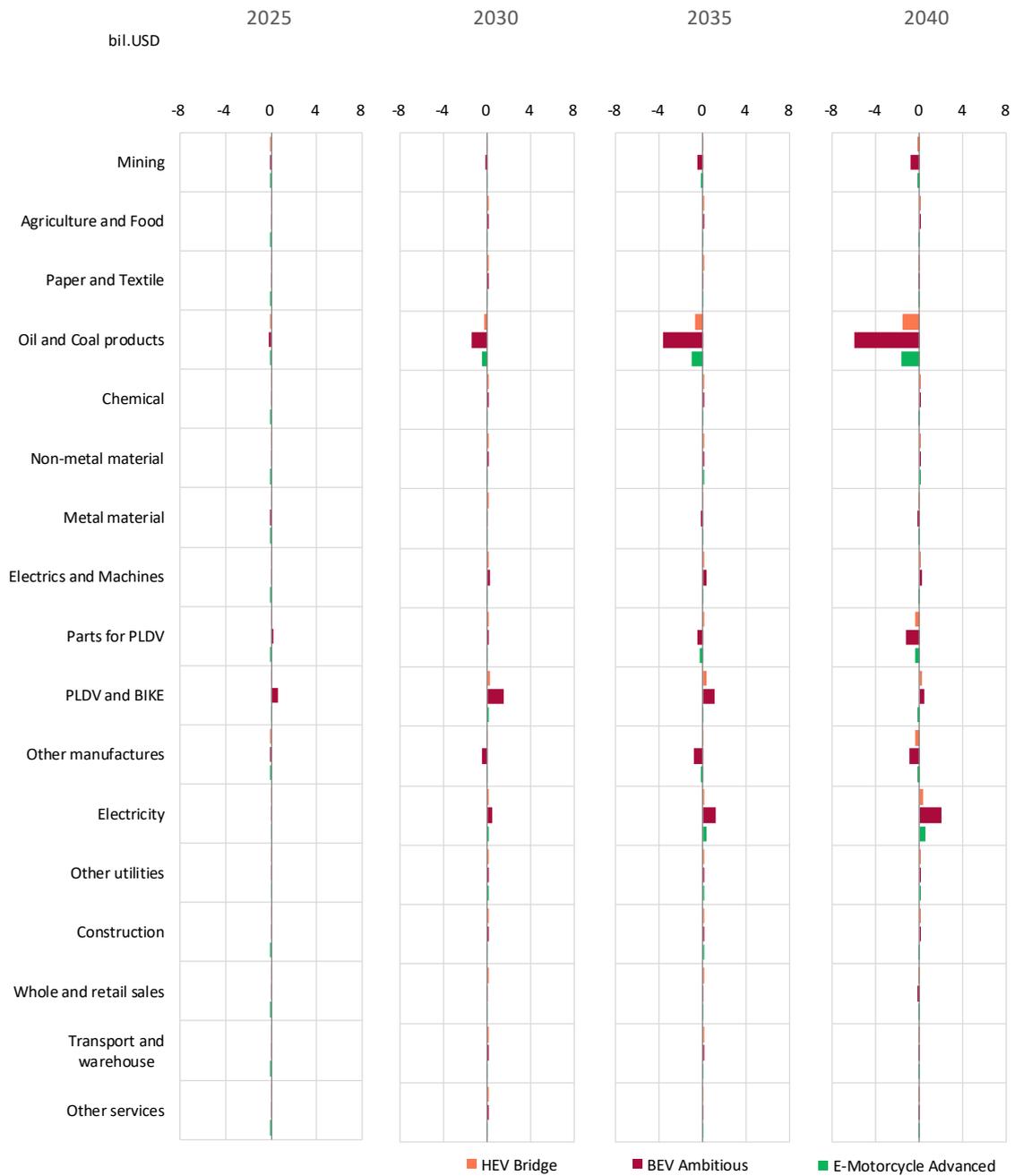


bil.US\$ = billions of US dollars, PLDV = passenger light-duty vehicle, BEV = battery electric vehicle, HEV = hybrid electric vehicle.

Note: Effects comparing with the reference scenario.

Source: Authors' analysis.

**Figure 4-8. Production Ripple Effects by Sector (Thailand)**

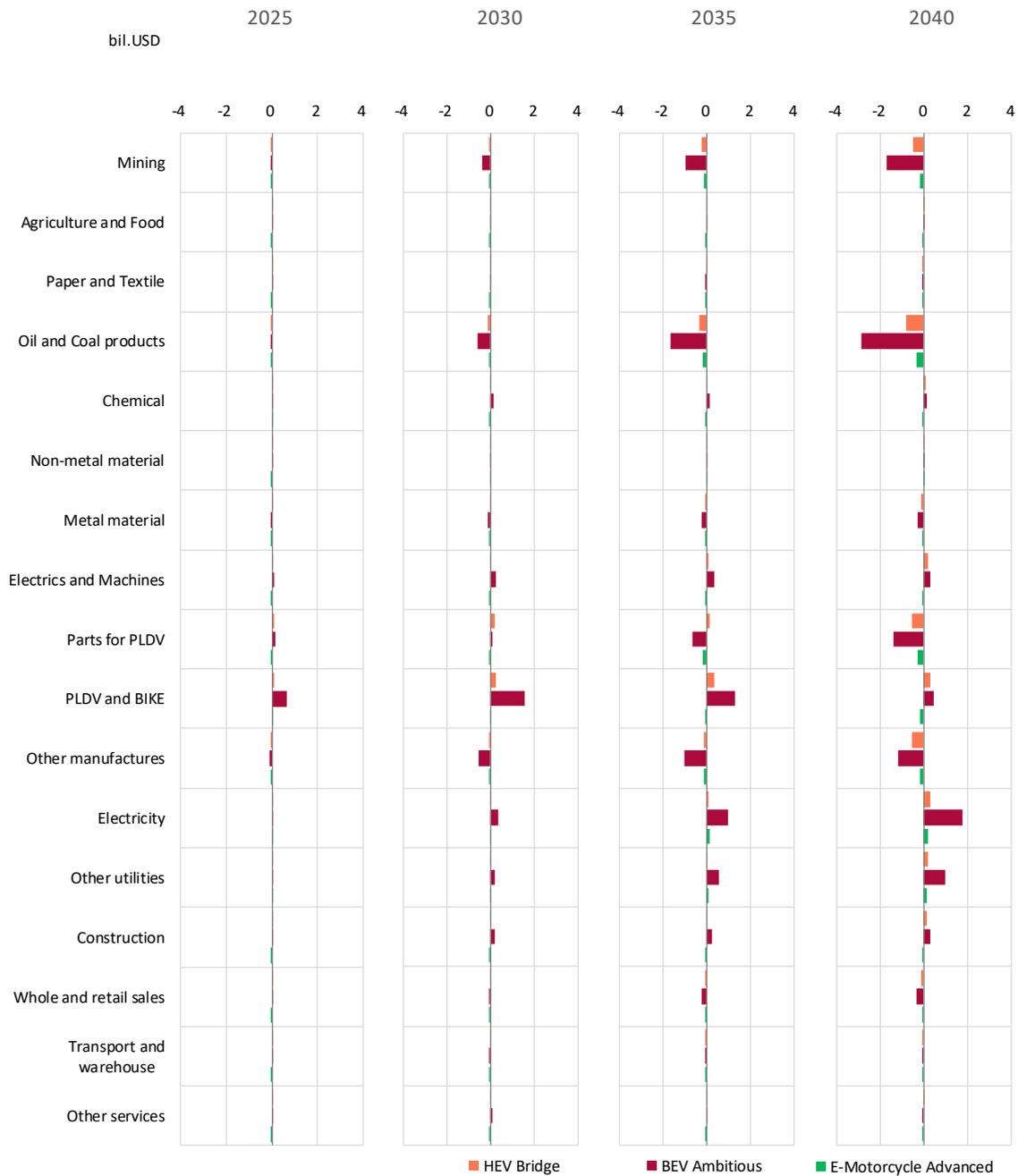


bil.US\$ = billions of US dollars, PLDV = passenger light-duty vehicle, BEV = battery electric vehicle, HEV = hybrid electric vehicle.

Note: Effects comparing with the Reference scenario.

Source: Authors' analysis.

**Figure 4-9. Production Ripple Effects by Sector (Malaysia)**

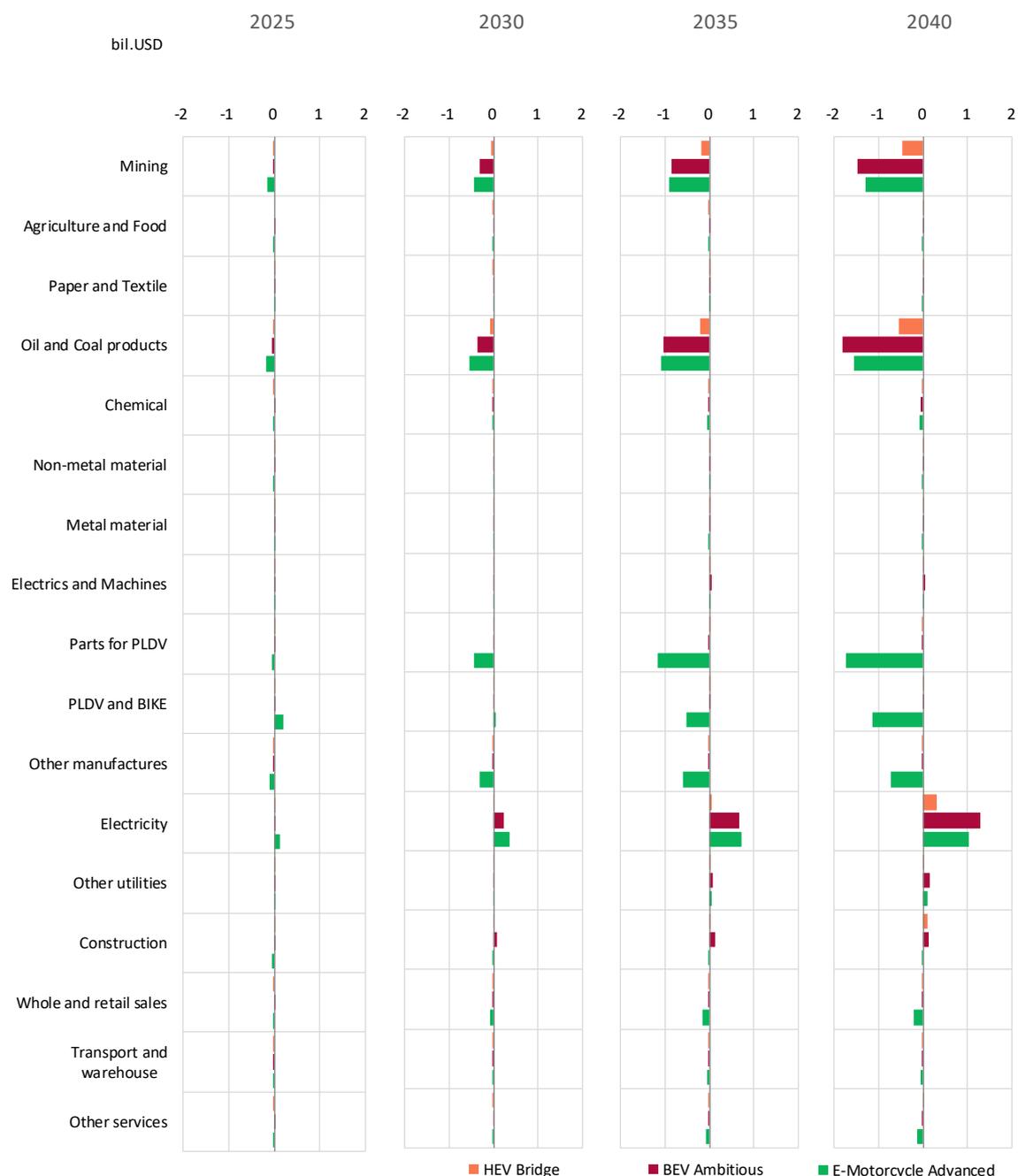


bil.US\$ = billions of US dollars, PLDV = passenger light-duty vehicle, BEV = battery electric vehicle, HEV = hybrid electric vehicle.

Note: Effects comparing with the reference scenario.

Source: Authors' analysis.

**Figure 4-10. Production Ripple Effects by Sector (Viet Nam)**



bil.US\$ = billions of US dollars, PLDV = passenger light-duty vehicle, BEV = battery electric vehicle, HEV = hybrid electric vehicle.

Note: Effects comparing with the reference scenario.

Source: Authors' analysis.

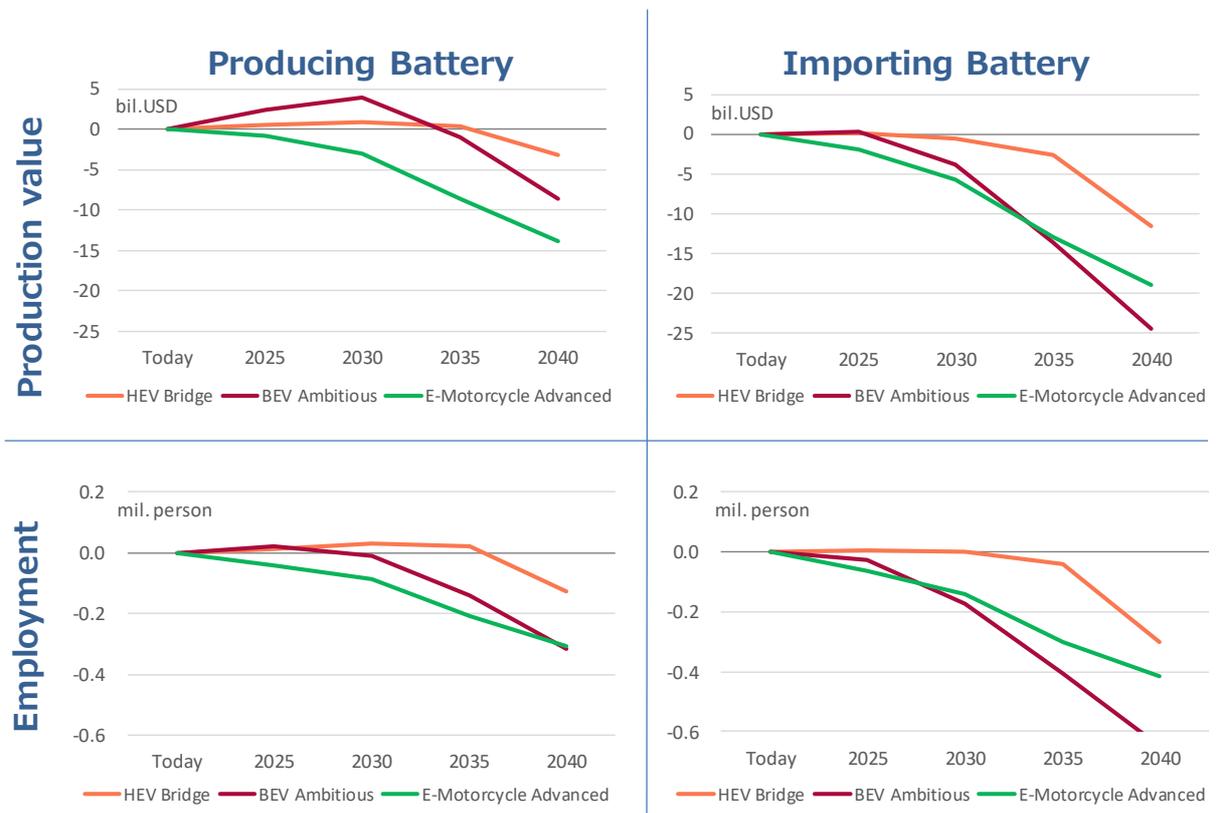
## 4.2 Importing Battery Pack Case

The xEV penetration has even more negative effects when relying on importing battery packs (Figures 4-11 to 4-14). The BEV Ambitious scenario had positive ripple effects from around 2025 to 2030 when producing batteries domestically; meanwhile, the positive effects almost disappear when relying on imports. The negative effects of both production and employment become greater in 2040 than when

using domestic batteries.

In Viet Nam, however, the economic impacts do not depend on whether producing or importing batteries in the BEV Ambitious and the HEV Bridge, due to PLDVs being produced in CKD style.

**Figure 4-11. Ripple Effects (Indonesia)**

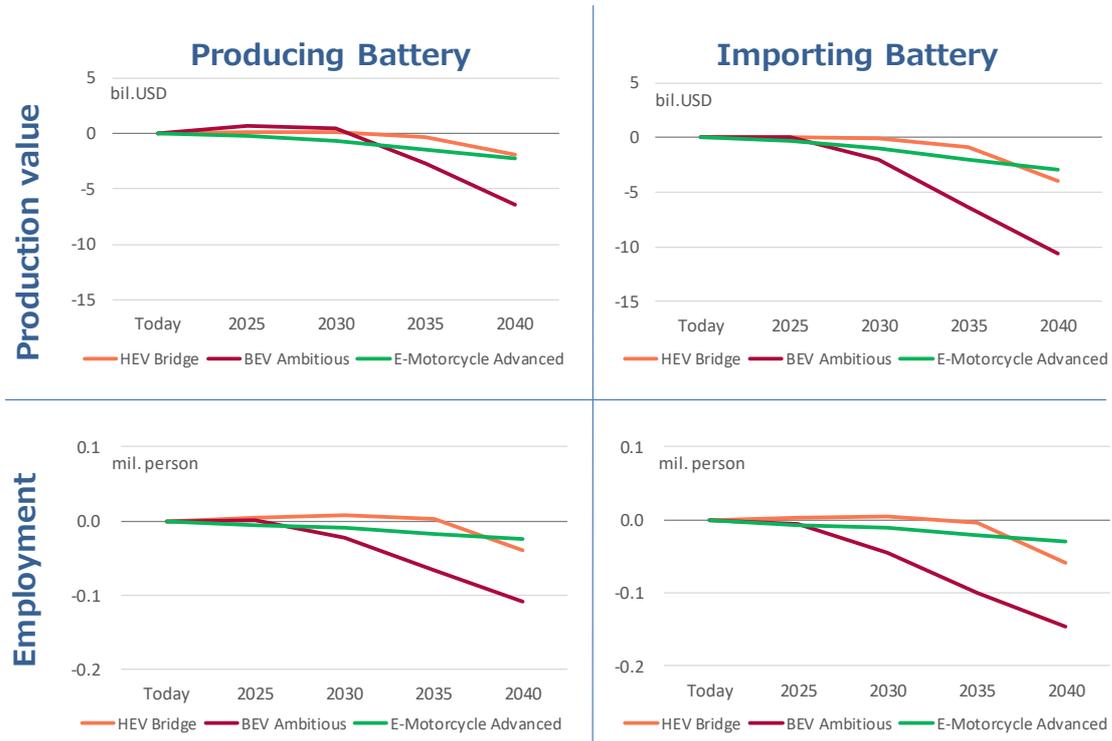


bil.US\$ = billions of US dollars, BEV = battery electric vehicle, HEV = hybrid electric vehicle.

Note: Effects comparing with the reference scenario at the base case.

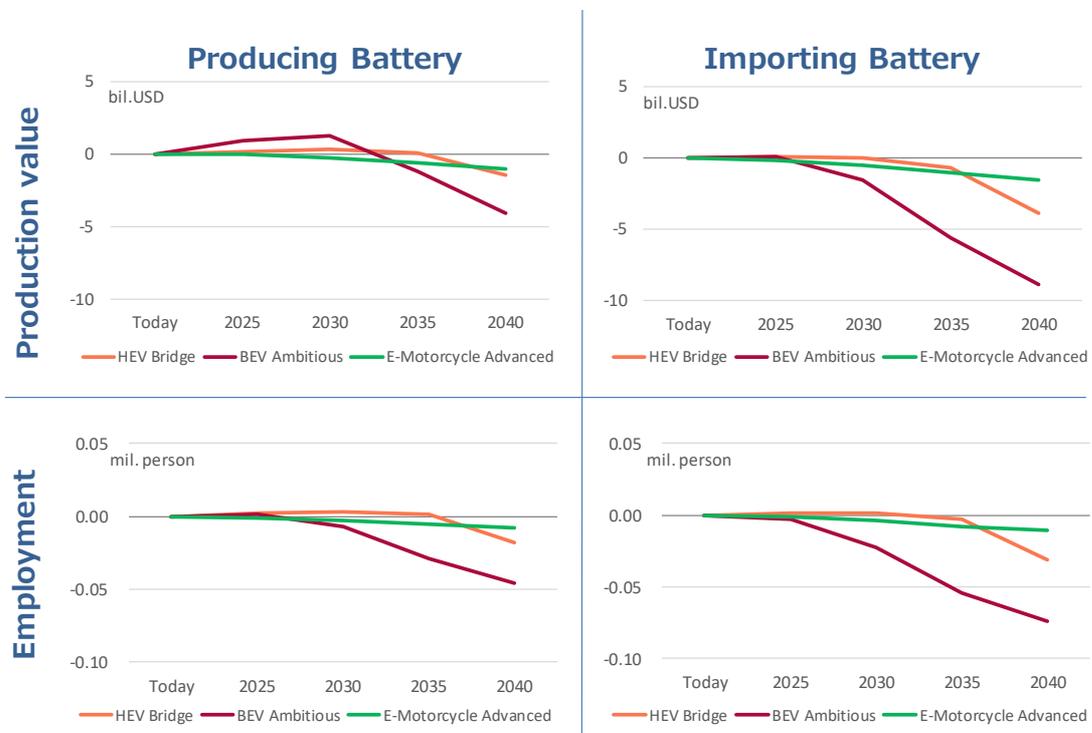
Source: Authors' analysis.

**Figure 4-12. Ripple Effects (Thailand)**



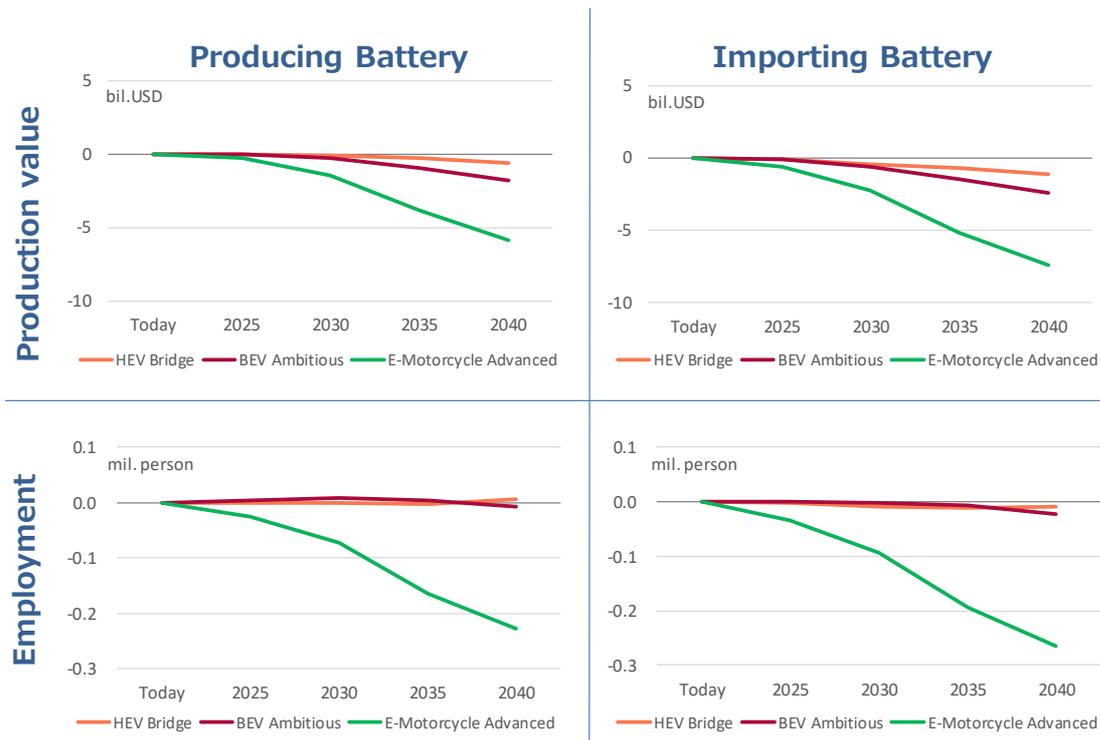
bil.US\$ = billions of US dollars, BEV = battery electric vehicle, HEV = hybrid electric vehicle.  
 Note: Effects comparing with the reference scenario at the base case.  
 Source: Authors' analysis.

**Figure 4-13. Ripple Effects (Malaysia)**



bil.US\$ = billions of US dollars, BEV = battery electric vehicle, HEV = hybrid electric vehicle.  
 Note: Effects comparing with the reference scenario at the base case.  
 Source: Authors' analysis.

**Figure 4-14. Ripple Effects (Viet Nam)**



bil.US\$ = billions of US dollars, BEV = battery electric vehicle, HEV = hybrid electric vehicle.

Note: Effects comparing with the reference scenario at the base case.

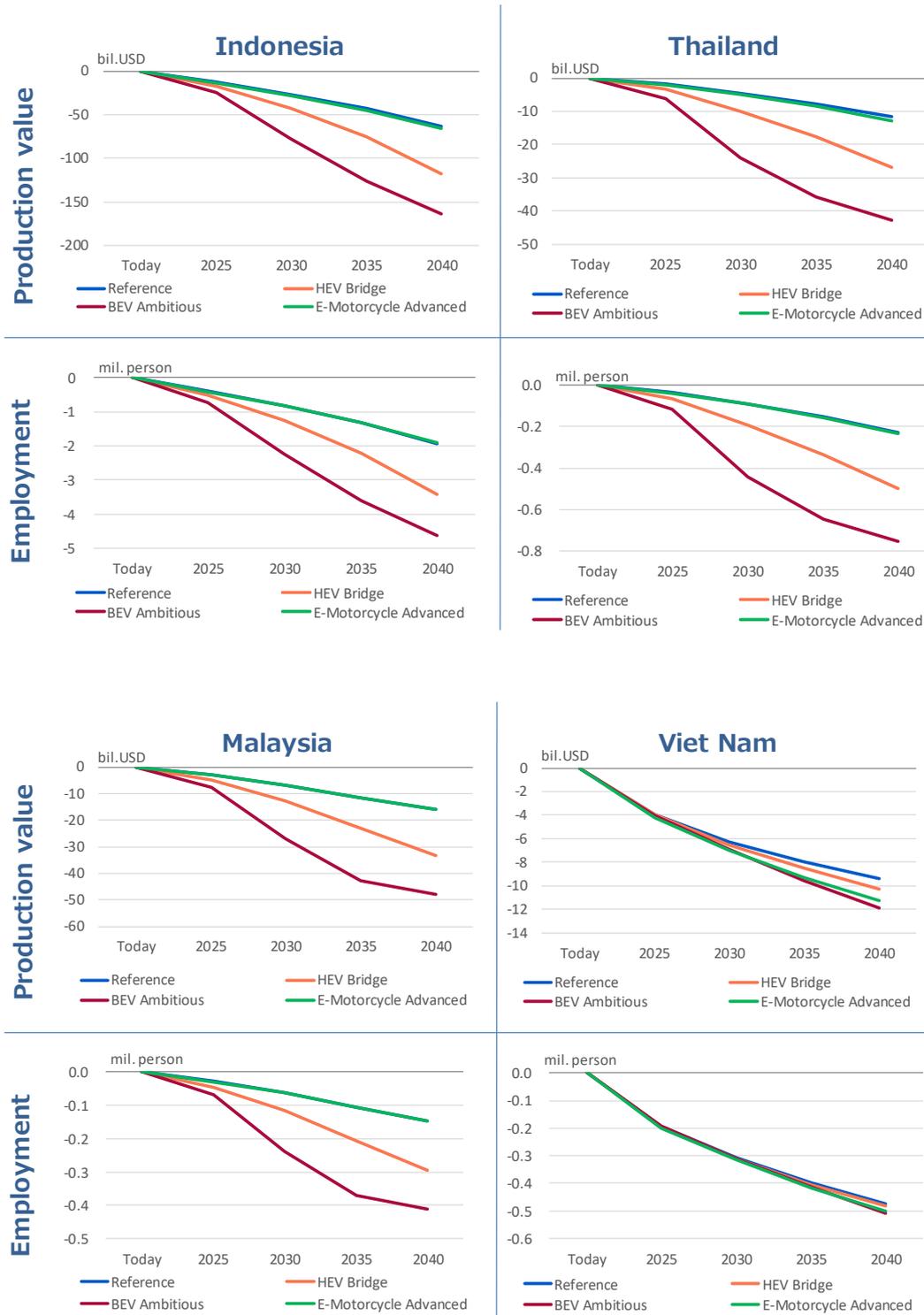
Source: Authors' analysis.

### 4.3 Importing xEVs Case

The xEV penetration has many more negative effects when relying on also importing xEVs, and not only battery packs (Figure 4-15). The BEV Ambitious scenario, in which a large number of expensive BEVs are imported, has the greatest negative impacts on the economy and employment throughout the period.

In Viet Nam, most of the automobiles depend on imports and CKD production; therefore, the impacts in both the HEV Bridge and the BEV Ambitious scenarios are not much different from ones in the Reference scenario, compared to other countries. Rather, the effects due to the shift from domestic motorcycle production to e-bike imports are more noticeable than in other countries.

**Figure 4-15. Ripple Effects at the Importing xEVs case**



bil.US\$ = billions of US dollars, BEV = battery electric vehicle, HEV = hybrid electric vehicle.

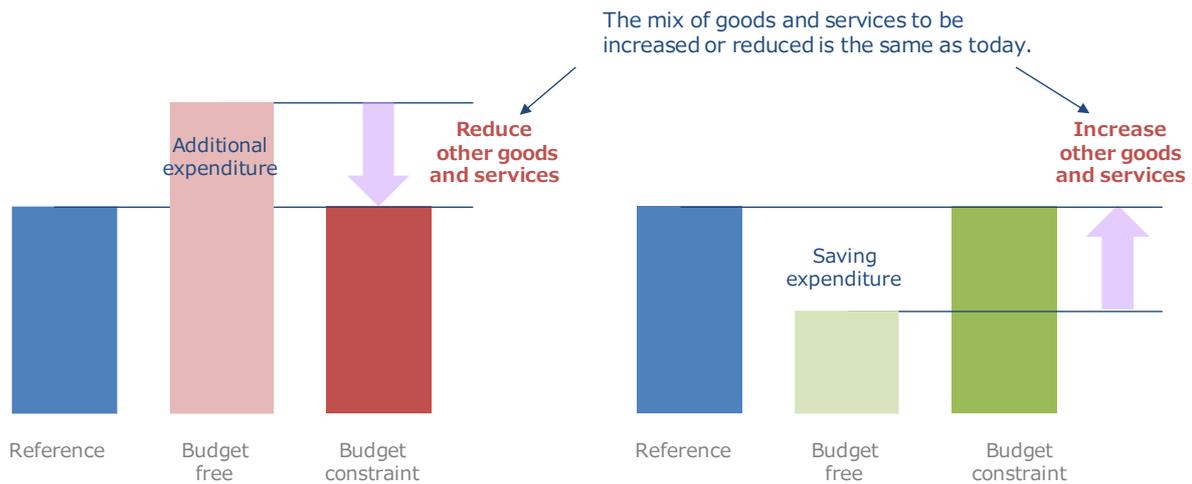
Note: Effects comparing with the reference scenario at the base case.

Source: Authors' analysis.

#### 4.4 Budget Constraint Case

Here, we estimate the ripple effects when expenditure on other goods and services increase/decrease in the same amount of money as the changes in xEV-related expenditure relative to the reference scenario, namely, under the budget constraint (Figure 4-16). Spending/saving amounts regarding goods and services are applied at the same ratio as the current expenditure composition. The total expenditure amount for each alternative xEVs scenario is the same as the reference scenario, but the ripple effect depends on the expenditure composition.

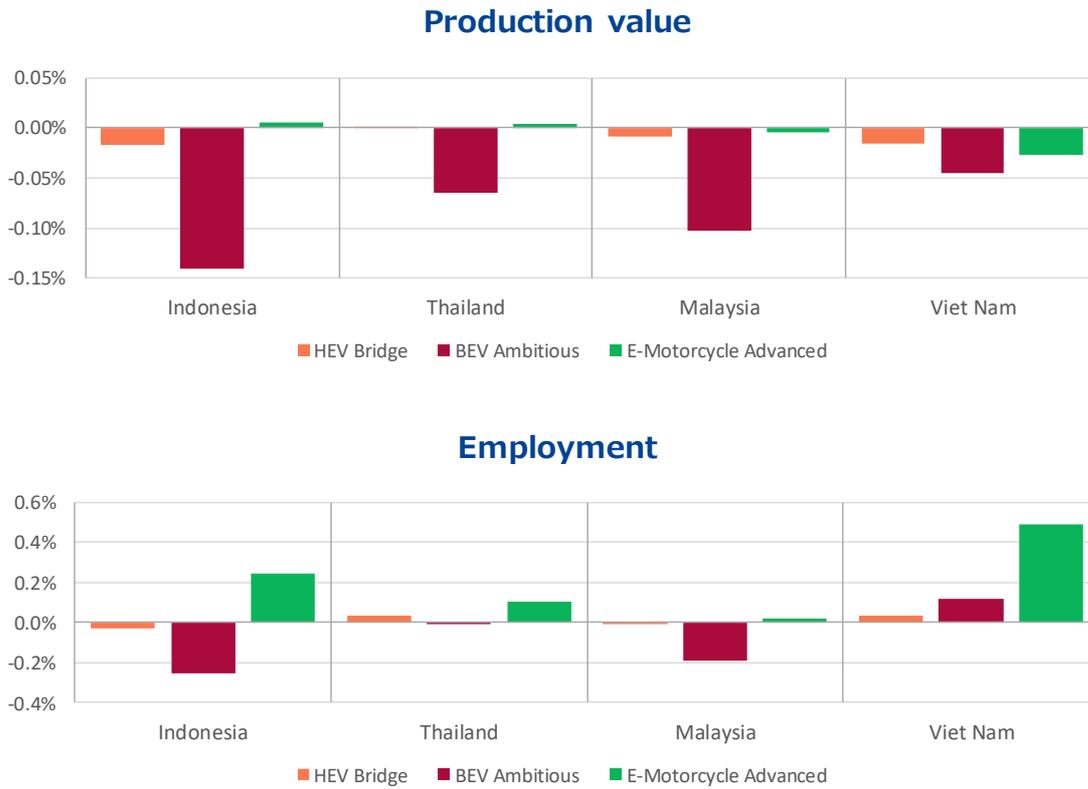
**Figure 4-16. Concept of the Budget Constraint in this Study**



Source: Authors.

The production ripple effect is naturally smaller than when there is no budget constraint (Figure 4-17). Amongst the scenarios, the BEV Ambitious has the largest negative impacts on any country. This is because producing battery packs has a smaller ripple effect than producing parts related to internal combustion engines. On the other hand, the impacts on employment are larger than without budget constraints. This is because, in general, the agriculture and service industries are more labour-intensive than the manufacturing industries, and therefore have greater effect on employment per unit of production. The positive effect of the E-Motorcycle Advanced is greatest, particularly in Indonesia and Viet Nam. Being able to turn the expenditure on vehicle fuels into other goods and services has a greater job creation effect, particularly in the service sectors and the agricultural sectors (through the expansion of food demand). On the other hand, the BEV Ambitious has large negative effects in Indonesia and Malaysia.

**Figure 4-17. Ripple Effects during Outlook Period vs. Today's Level (Budget Constraint)**



BEV = battery electric vehicle, HEV = hybrid electric vehicle.

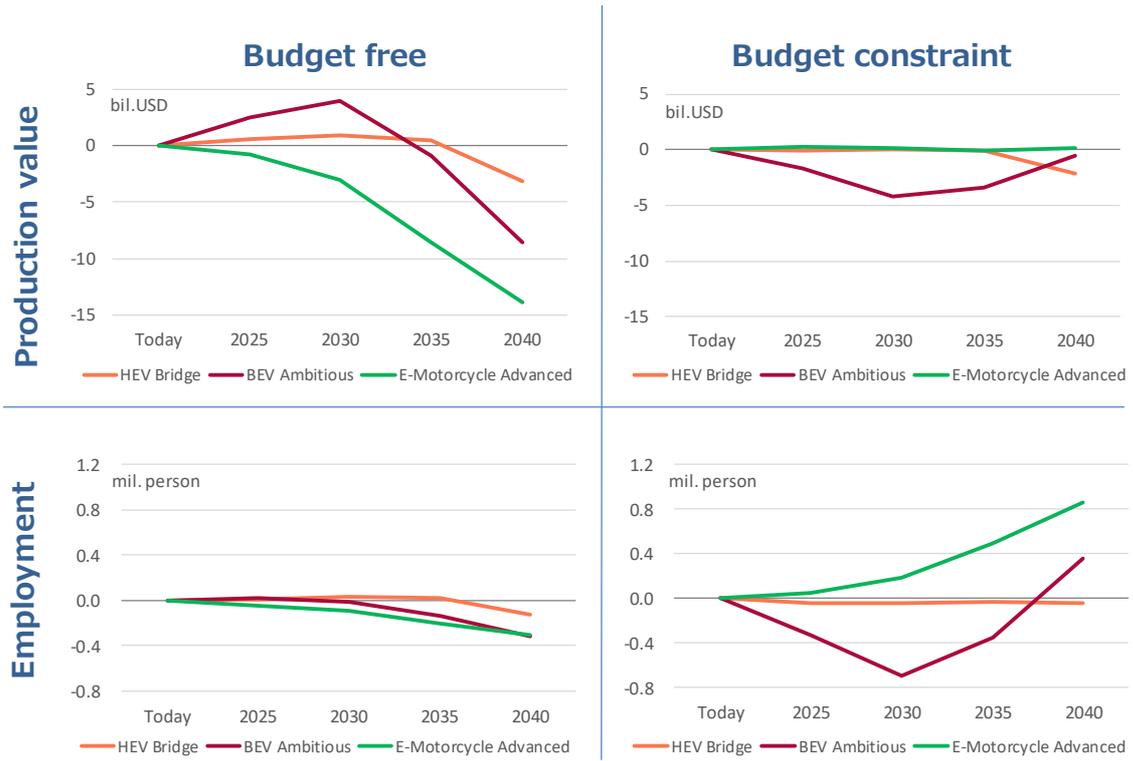
Note: Effects comparing with the reference scenario.

Source: Authors' analysis.

Looking at the time series results on the production effects, the deviations from the reference scenario are naturally tiny due to the assumptions of the budget constraint, but the slightly negative effects are seen in the BEV Ambitious scenario (Figures 4-18 to 4-21). On the other hand, looking at the impacts on employment under the budget constraint, the BEV Ambitious has negative effects, but they turn positive along with increasing fuel cost savings.

As of 2040, the BEV Ambitious will have the largest positive effect amongst the scenarios in Thailand and Malaysia. The E-Motorcycle Advanced will enhance job creation effects along with increasing spending on other goods and services, and have the largest positive effect amongst the scenarios in Indonesia and Viet Nam.

Figure 4-18. Ripple Effects (Indonesia)

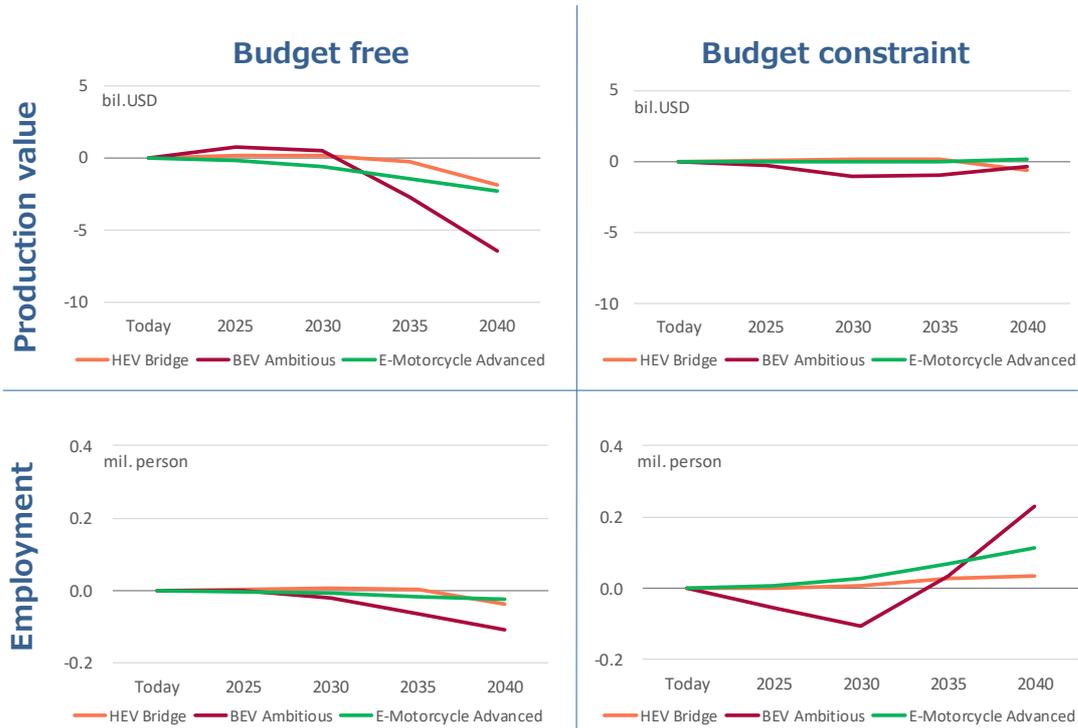


bil.US\$ = billions of US dollars, BEV = battery electric vehicle, HEV = hybrid electric vehicle.

Note: Effects comparing with the reference scenario.

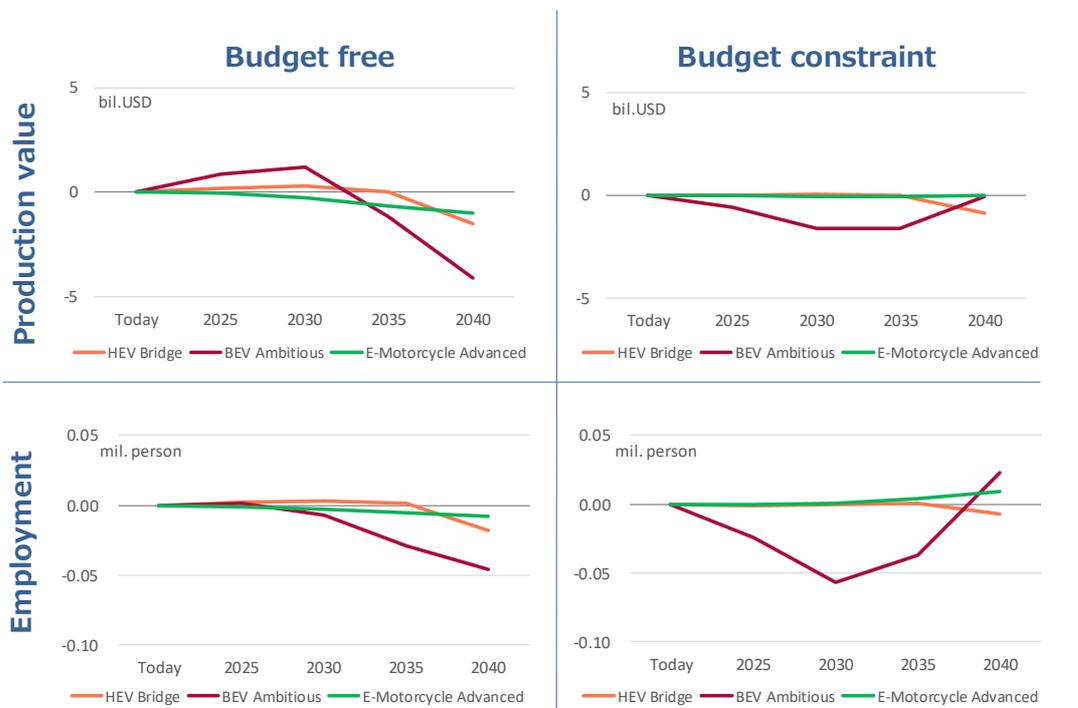
Source: Authors' analysis.

**Figure 4-19. Ripple Effects (Thailand)**



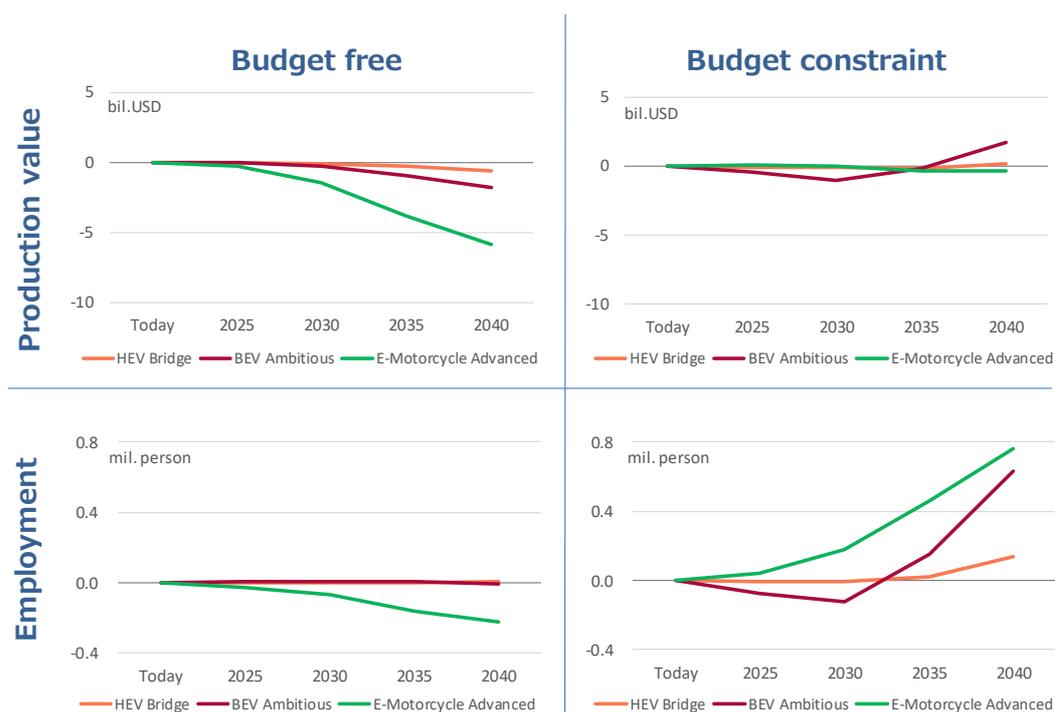
bil.US\$ = billions of US dollars, BEV = battery electric vehicle, HEV = hybrid electric vehicle.  
 Note: Effects comparing with the reference scenario.  
 Source: Authors' analysis.

**Figure 4-20. Ripple Effects (Malaysia)**



bil.US\$ = billions of US dollars, BEV = battery electric vehicle, HEV = hybrid electric vehicle.  
 Note: Effects comparing with the reference scenario.  
 Source: Authors' analysis.

**Figure 4-21. Ripple Effects (Viet Nam)**



bil.US\$ = billions of US dollars, BEV = battery electric vehicle, HEV = hybrid electric vehicle.  
 Note: Effects comparing with the reference scenario.  
 Source: Authors' analysis.

#### 4.5 Key Implications from Input–Output Analysis

The ripple effects of xEV-related expenditure on production and employment are almost negative in the four countries. This is because the production ripple effects of the battery packs are smaller than that of the internal combustion engines, and the total expenditure decreases due to the daily fuel expenditure savings. The negative effects will be even greater if they rely on importing xEVs / battery packs.

On the other hand, in the case of budget constraint, the job creation effects are quite large in the E-Motorcycle Advanced scenario. When the money from the fuel savings is used for other goods and services, employment increases in the agriculture and the service industries. Meanwhile, the BEV Ambitious scenario has negative effects on employment because the expensive xEVs curtail other expenditures, but they turn into positive effects by 2040 due to the larger fuel saving effects. In terms of cumulative effects over the estimation period, however, the effects on employment are negative.

Assuming the budget constraint, Indonesia and Viet Nam, which have many motorcycles, should adopt the E-Motorcycle Advanced scenario from the viewpoint of job creation. In Thailand as well, the E-Motorcycle Advanced scenario has the largest employment effects amongst the scenarios, even though they are relatively small. In Malaysia, only the E-Motorcycle Advanced scenario has positive effects, but they are quite small. In Thailand and Malaysia, the BEV Ambitious scenario has the greatest employment effects as of 2040, but they should consider the path leading to them.

# Chapter 5

## Policy Implications

xEVs will help ASEAN countries enhance energy security, save on energy import bills, mitigate climate change, and improve urban air quality. Massive xEV deployment, however, may have negative side effects. This chapter recommends policies for realistic and affordable xEV penetration.

### **1. Decarbonise the Power Generation**

If the increase in power demand accompanying the spread of xEVs is covered by thermal power such as coal-fired sources, there is little effect on CO<sub>2</sub> reduction. ASEAN countries will tend to be more dependent on thermal power generation, which involves large-scale power generation facilities, as demand for electricity is expected to increase rapidly for residential, commercial and industrial use. Especially in Indonesia, where coal-fired power accounts for more than 50% of the power generation mix, substantial CO<sub>2</sub> reduction cannot be expected via BEV penetration.

It is important to decarbonise the power supply along with the penetration of xEVs. However, there is no need to give up using coal, which is relatively inexpensive and abundant in the region, and economies should introduce more efficient coal-fired power generation facilities. Meanwhile, one of the options is to promote HEVs, which can reduce CO<sub>2</sub> emissions without depending on the power supply mix, until it becomes clean.

### **2. Consider the Cost Required for Penetration**

Currently, the vehicle prices of xEVs are high, and the difference from the ICEVs should be regarded as an additional cost. In general, it is unlikely that individual consumers will bear this cost, and it requires economic incentives such as subsidies and tax cuts. Although the battery cost, a major factor of the pricey vehicle, have been falling, xEVs are still far from popular without subsidies. In the current situations, promoting vehicle electrification would require substantial subsidies.

The battery cost is expected to continue to fall in the future, but the outlook, including the international mineral prices, is still uncertain. If the cost does not drop as expected, more subsidies would be necessary for promoting xEVs. This should be done carefully, along with the fiscal situation.

In addition, fuel price policy would be important for the spread of xEVs. There is little incentive for consumers to purchase more fuel-efficient xEVs if fuel prices are low. Therefore, it is necessary to provide incentives by subsidy. Conversely, if the fuel price is relatively high, daily fuel cost savings by xEVs increase, and the initial vehicle cost can be recovered earlier. In other words, subsidies can be reduced. To spread xEVs, it is necessary to consider the consistency of various policies.

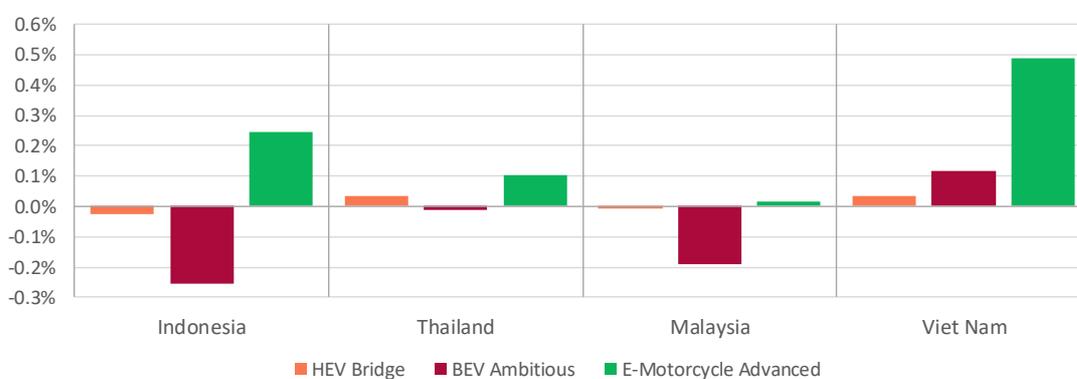
### **3. Pay Attention to Ripple Effects by xEVs**

It is necessary to pay attention to other economic activities affected by xEV penetration. The production of BEVs with a small number of material parts might reduce automotive industry

employment compared with the production of ICEVs and HEVs. Furthermore, as xEVs become more widespread, the negative economic ripple effects increase through the petroleum industry, due to a massive decrease in the fuel demand.

However, xEV penetration may create additional production and employment in the whole economy, that is, if the savings in daily fuel expenditure can be diverted into other goods and services. In general, the service industries have higher employment intensities (required number of employees per production value) than the fuel supply industry. Especially in Indonesia and Viet Nam, where many motorcycles are on road, promoting e-motorcycles may stimulate job creation in the service industries (Figure 5-1). On the other hand, in the case of PLDVs, employment creation effects are small or even negative, because other consumption is sacrificed to purchase the expensive xEVs.

**Figure 5-1. Ripple Effects on Employment during Outlook Period vs. Today's Level (Budget constraint)**



BEV = battery electric vehicle, HEV = hybrid electric vehicle.

Note: Effects comparing with the reference scenario.

Source: Authors' analysis.

#### 4. Consider Appropriate Country-specific Pathways

Appropriate pathways to vehicle electrification vary by country and region.

##### Indonesia

The main objective of developing BEVs in Indonesia is to reduce CO<sub>2</sub> emissions and the amount of fuel imports as outlined in the release of the 2019 Presidential Decree. However, none of the xEV scenarios contributes significantly to CO<sub>2</sub> reduction due to the power generation mix. Decarbonising the power supply is one of the essential and urgent issues. On the other hand, the BEV Ambitious scenario brings in the largest savings of the fuel import bills. In views of subsidy cost and economic/employment ripple effect, the HEV Bridge scenario should be adopted for PLDVs rather than the BEV Ambitious scenario. In addition, it is desirable to promote the electrification of motorcycles at the same time in the countries where motorcycles are popular.

##### Thailand

In Thailand, the BEV Ambitious scenario has a greater CO<sub>2</sub> reduction effect than other scenarios. The total amount of subsidies is also large, but it is slightly higher than the HEV Bridge in terms of cost-

effectiveness (Figure 5-2). The BEV Ambitious scenario brings better effects in 2040; however, it needs to cope with the large subsidy expenditures and the negative effects on employment around 2025–30. It is desirable to promote the electrification of motorcycles at the same time due to higher cost-effectiveness.

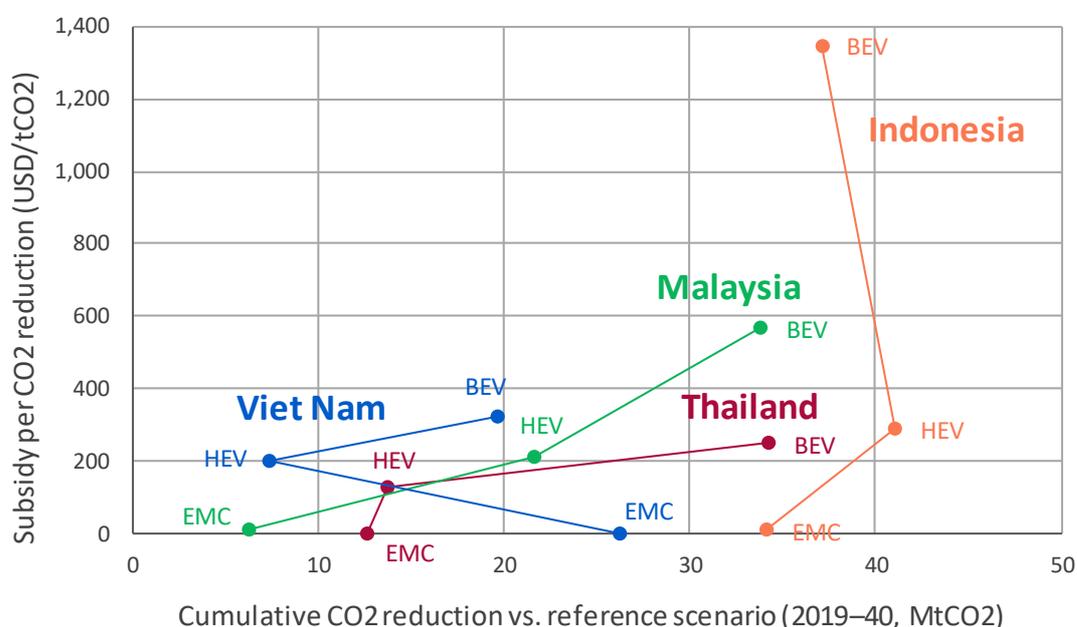
### Malaysia

In Malaysia, the BEV Ambitious scenario has a greater CO<sub>2</sub> reduction effect than other scenarios. Unlike in Thailand, however, the cost-effectiveness of subsidies is significantly higher than in the HEV Bridge scenario because the total subsidy amounts are larger due to the relatively low gasoline price (Figure 5-2). Furthermore, the BEV Ambitious scenario brings a big negative effect on employment, so the HEV Bridge scenario should be adopted. On the other hand, the E-Motorcycle Advanced scenario has a small effect on both CO<sub>2</sub> reduction and employment since the number of motorcycles on road is not large.

### Viet Nam

In Viet Nam, where many motorcycles are on road, the E-Motorcycle Advanced scenario should be promoted in terms of CO<sub>2</sub> reduction effects and cost-effectiveness (Figure 5-2). Furthermore, positive effects on employment are much larger than the other PLDV scenarios. Given the current situation of CKD producing and importing most PLDVs, production effects are not great in the BEV Ambitious scenario, but positive employment effects can be seen by diverting fuel cost savings into consumption on other goods and services. However, achieving this scenario requires large subsidy expenditures.

**Figure 5-2. Subsidy vs. CO<sub>2</sub> Reductions**



CO<sub>2</sub> = carbon dioxide, MtCO<sub>2</sub> = million tonnes of carbon dioxide, HEV= HEV Bridge, BEV= BEV Ambitious, EMC= E-Motorcycle Advanced.

Source: Authors' analysis.

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