Chapter 3

Impacts on the 3Es by xEV Penetration

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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.[3]

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),[4] 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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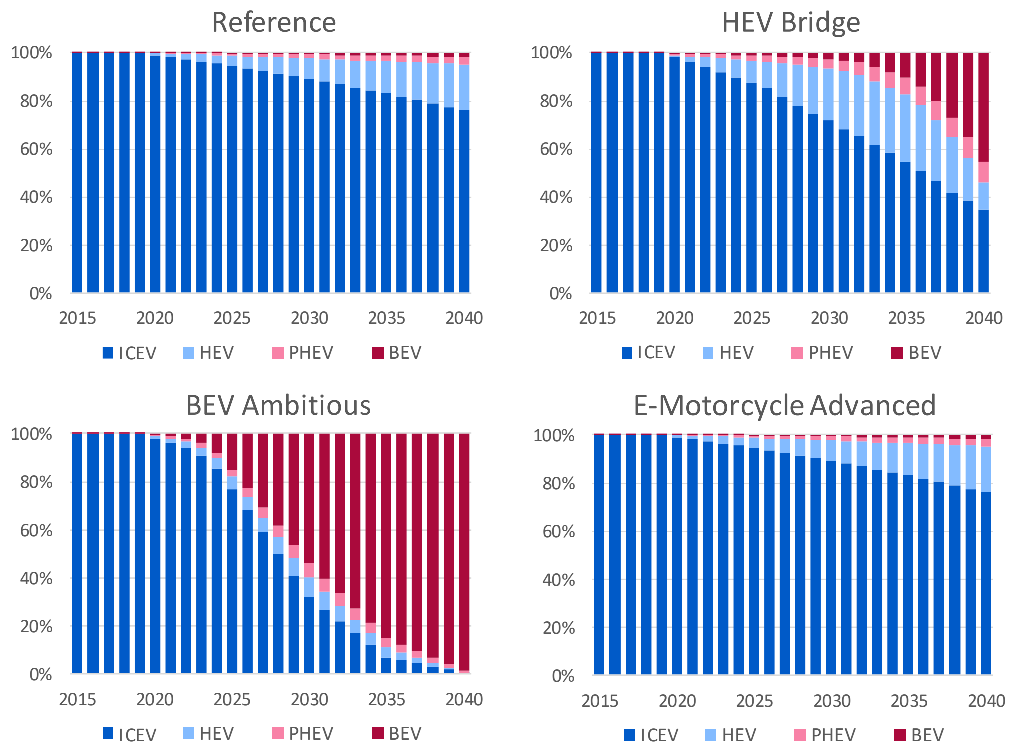
[3] There are many twists and turns in setting India's xEV targets. In 2017, the government announced a ban on ICEV sales in 2030, but withdrew it and changed the path to '30% electrified in 2030'. However, the government's think tank NITI Aayog has proposed again '100% electrified in 2030' in the new xEV roadmap being created. https://timesofindia.indiatimes.com/india/nitis-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).

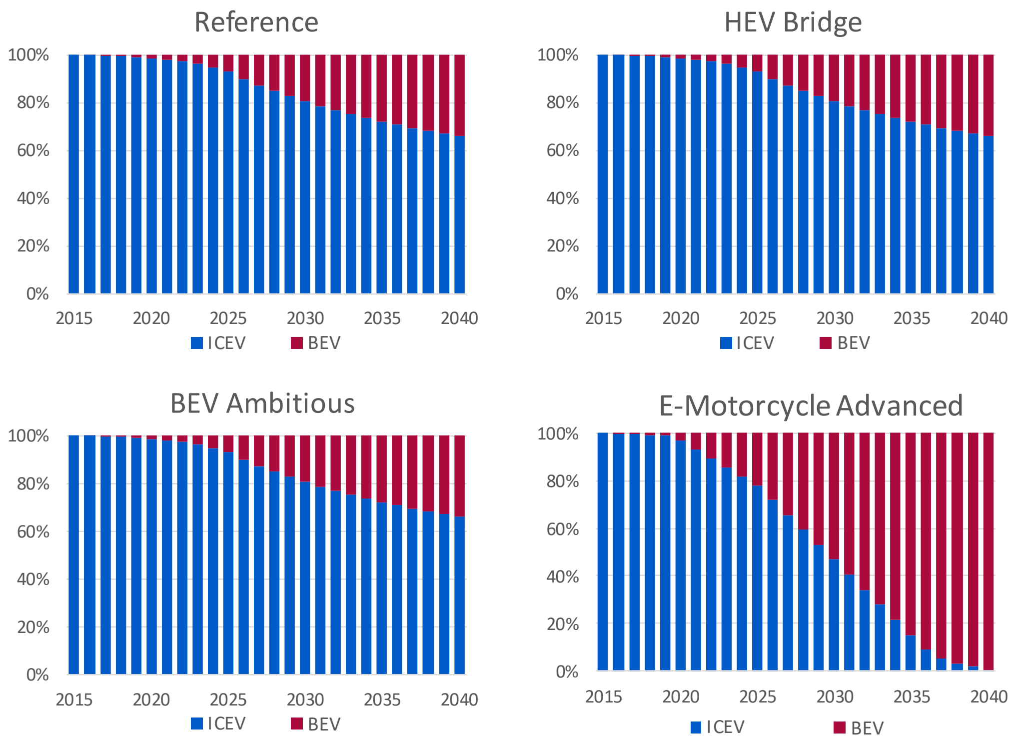
[4] This study focuses on PLDVs and motorcycles (buses and trucks are not covered).

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



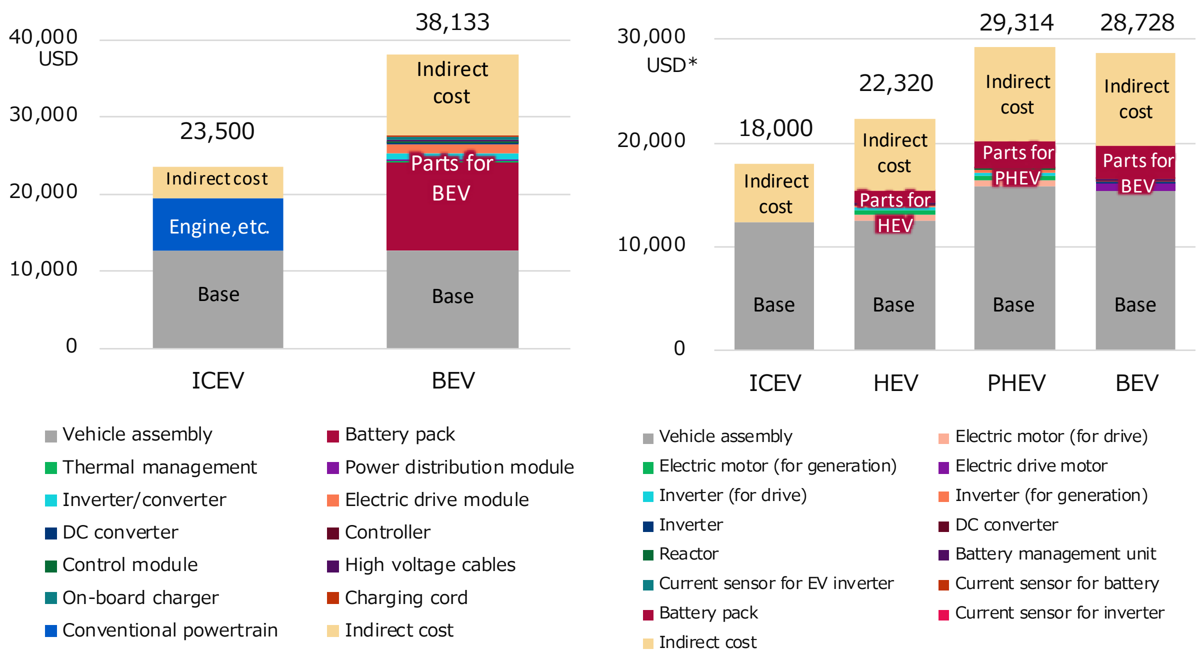
BEV = battery electric vehicle, ICEV = internal combustion engine vehicle.
Source: Authors' analysis.

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).

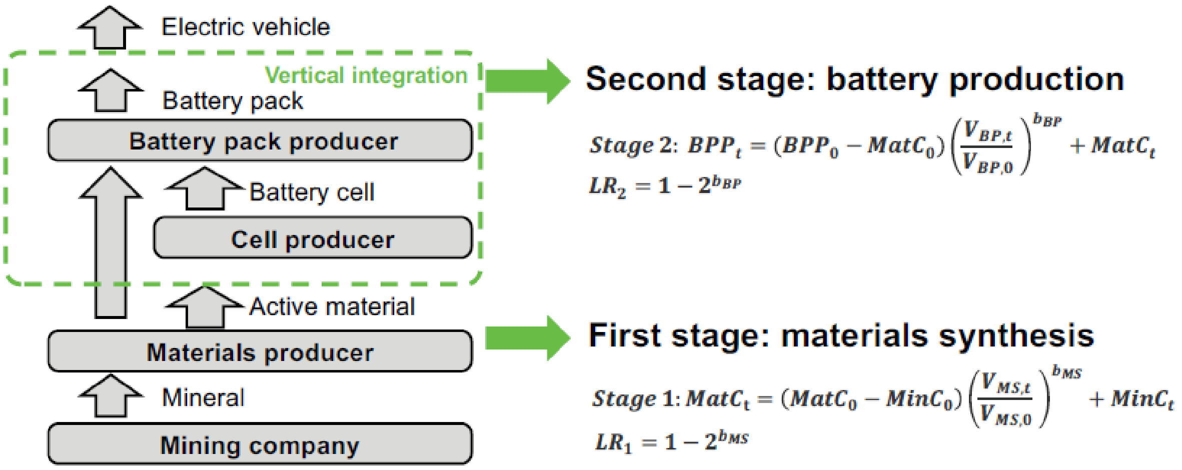
The outlook for battery prices and, consequently, vehicle prices, affects the subsidy needed to achieve the alternative xEVs scenario in this study. A learning curve model is often used to predict future technology cost. This method is based on an empirical rule that the production cost decreases as 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

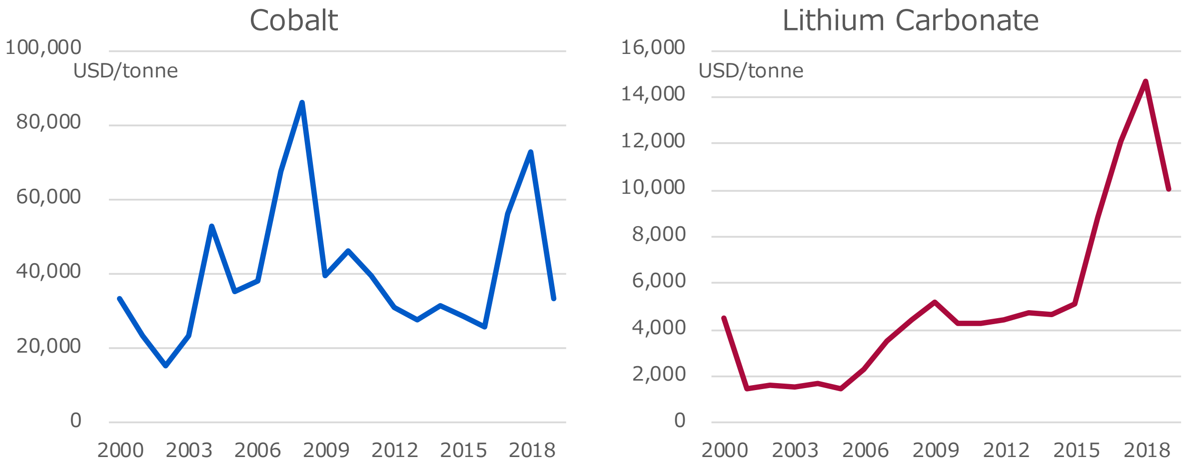


BPP = battery pack price, MatC = active materials costs, MinC = mineral costs, V_{BP} = cumulative production volume of battery pack, V_{MS} = cumulative production volume of materials synthesis, b_{BP}, b_{MS} = technology-specific experience index.
Source: MIT Energy Initiative (2019).

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,[5] 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),[6] 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).

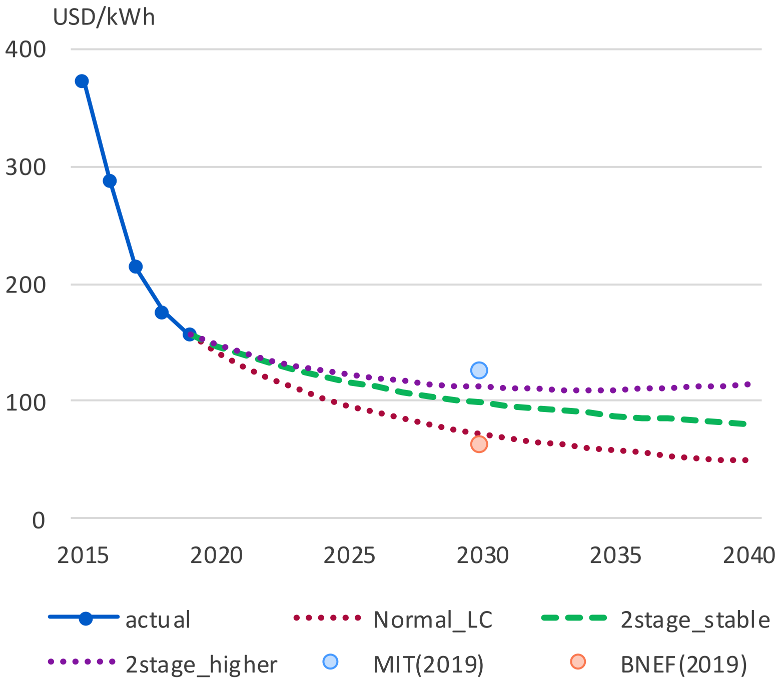
[5] The cumulative global battery production is estimated to reach about 3 TWh in 2030 and about 10 TWh in 2040 based on IEEJ Outlook 2020 (IEEJ, 2019). The learning rate (the rate of cost reduction when the cumulative production doubles) is set to 20%.
[6] The learning rates are referred to in the MIT Energy Initiative (2019).

Figure 3-5. Cobalt and Lithium Prices



Source: BP (2019).

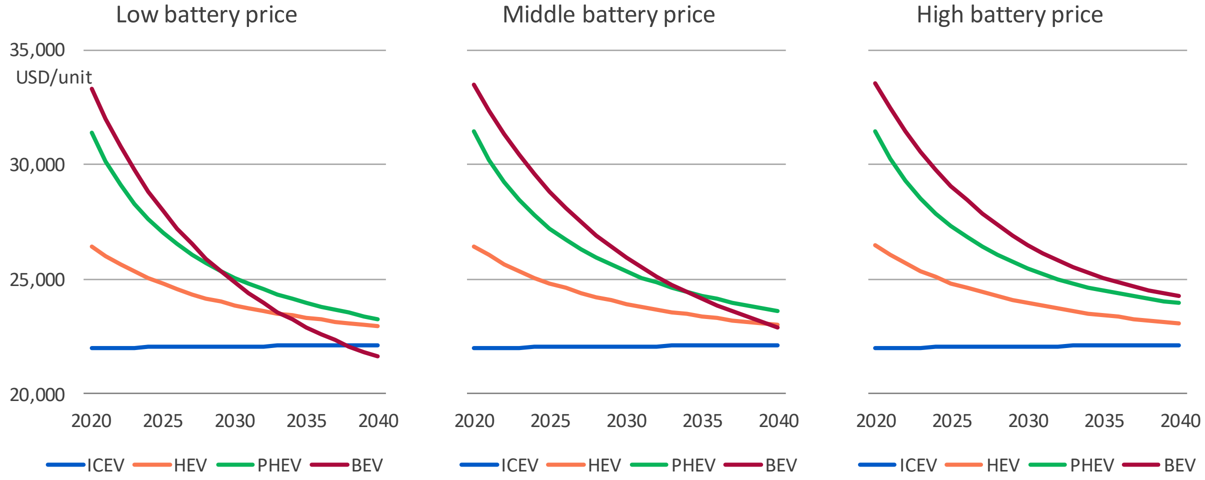
Figure 3-6. Battery Price Outlook by Using Learning Curve



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.

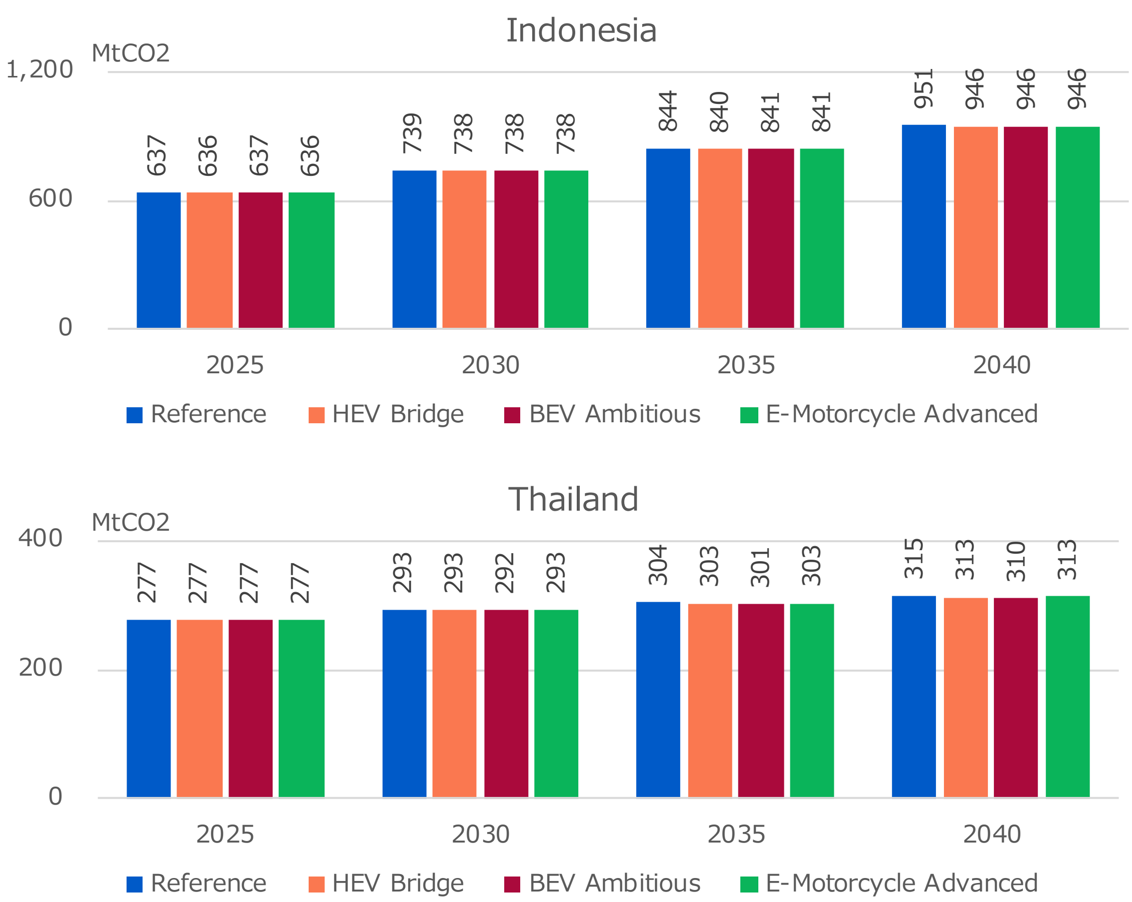
2 Results of Alternative Scenarios

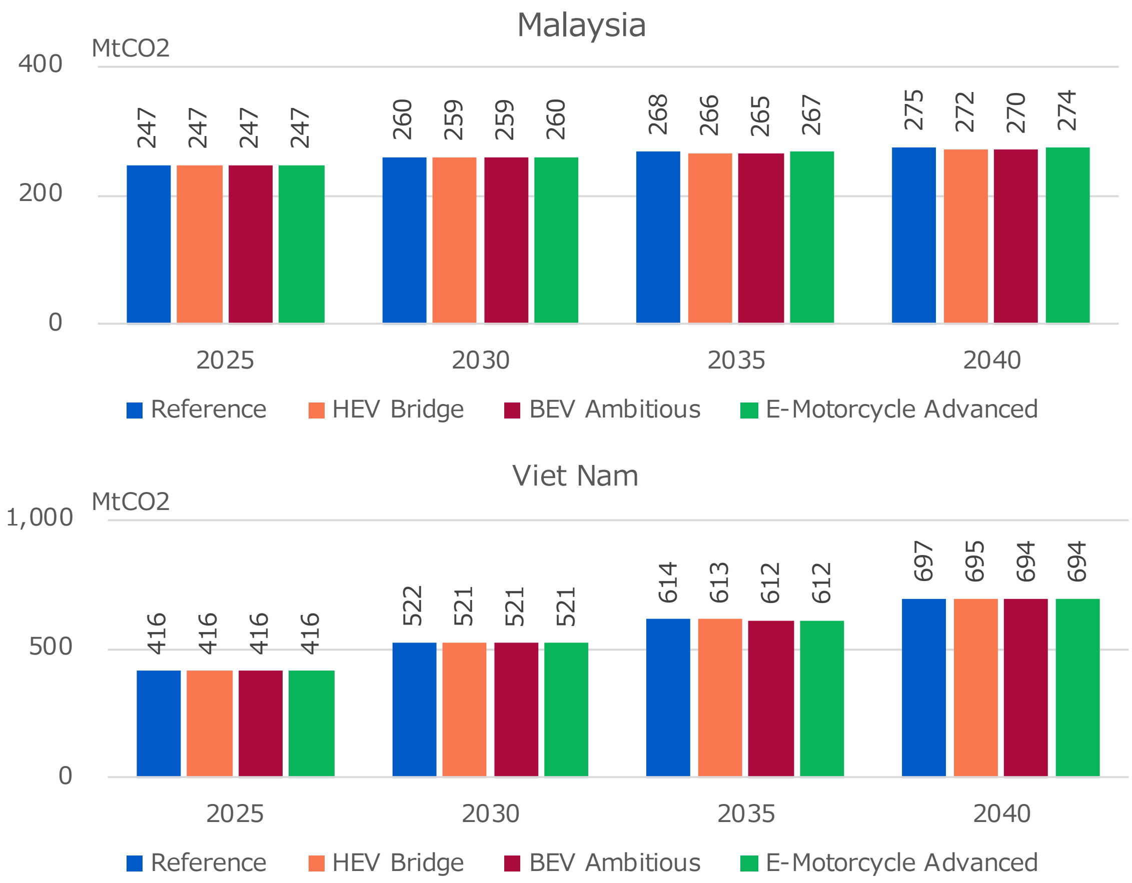
2.1 Energy and CO_2 emissions

Energy-related CO_2 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_2 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_2 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_2 Emissions by Scenario



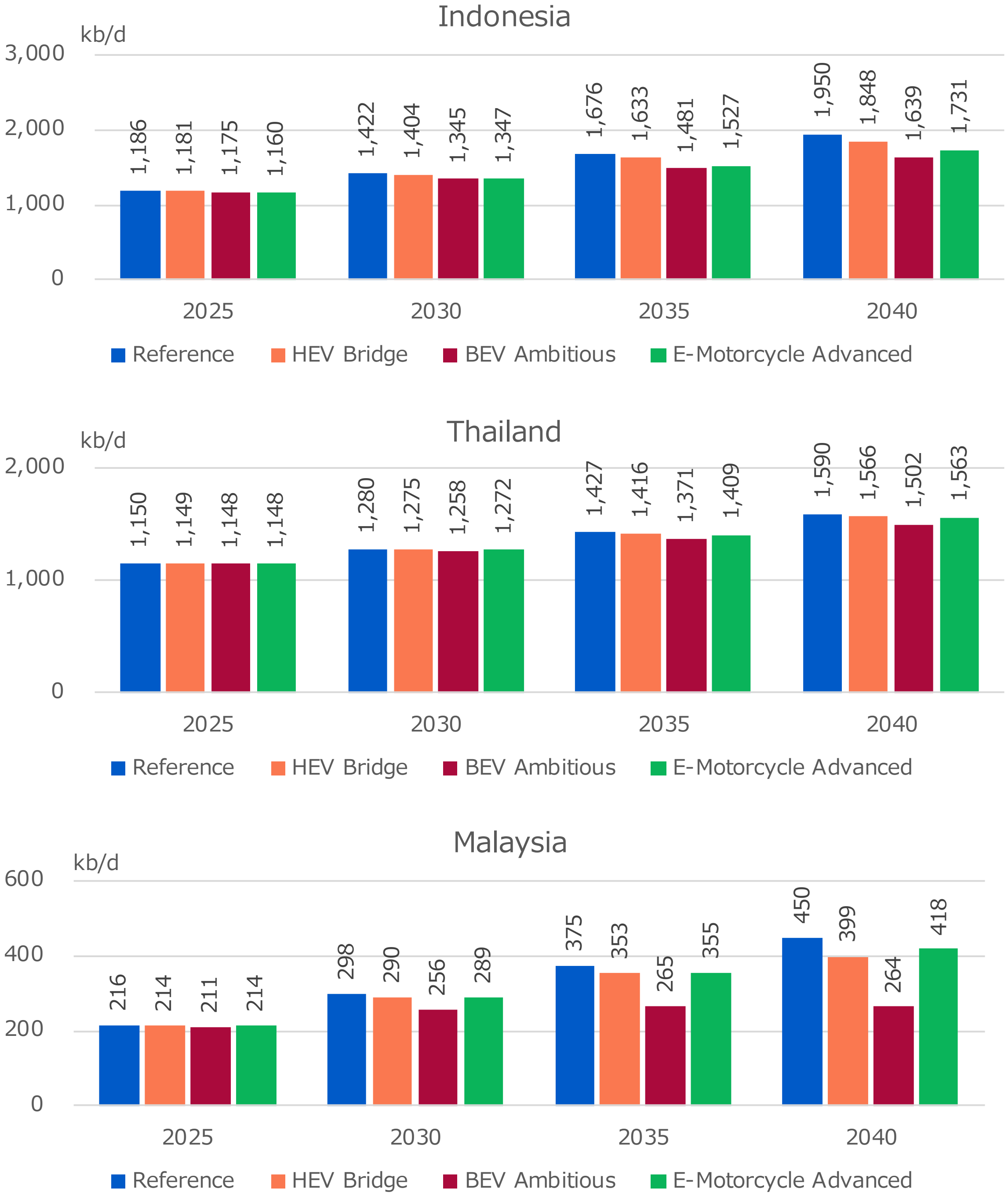


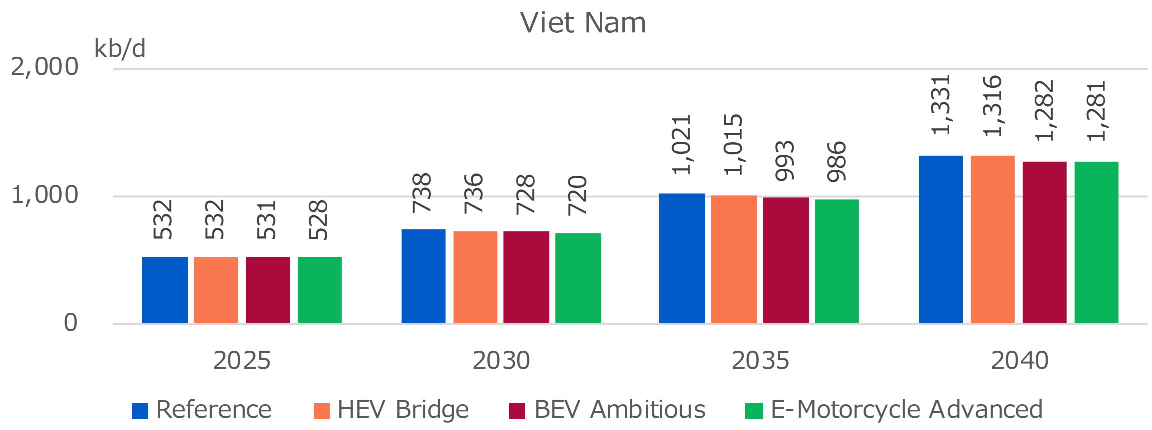
MtCO2 = million tonnes of carbon dioxide, BEV = battery electric vehicle, HEV = hybrid electric vehicle.
Source: Authors' analysis.

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.

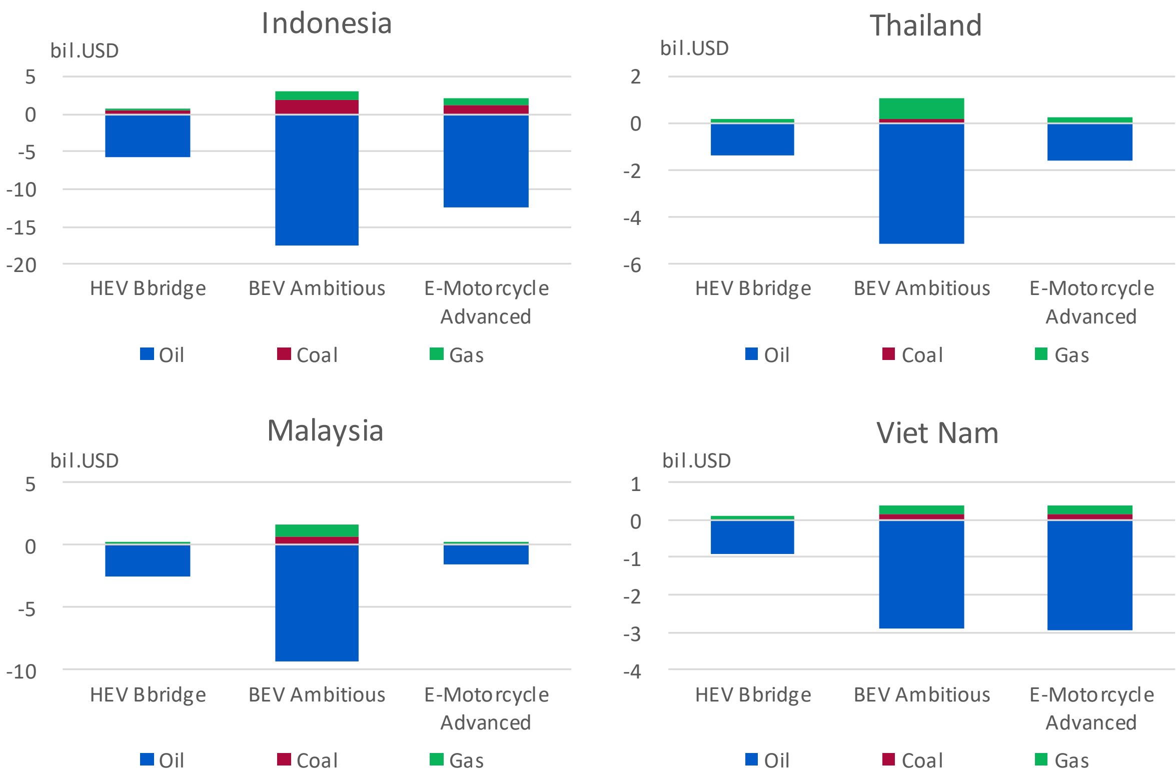
Figure 3-9. Oil Imports by Scenario





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*

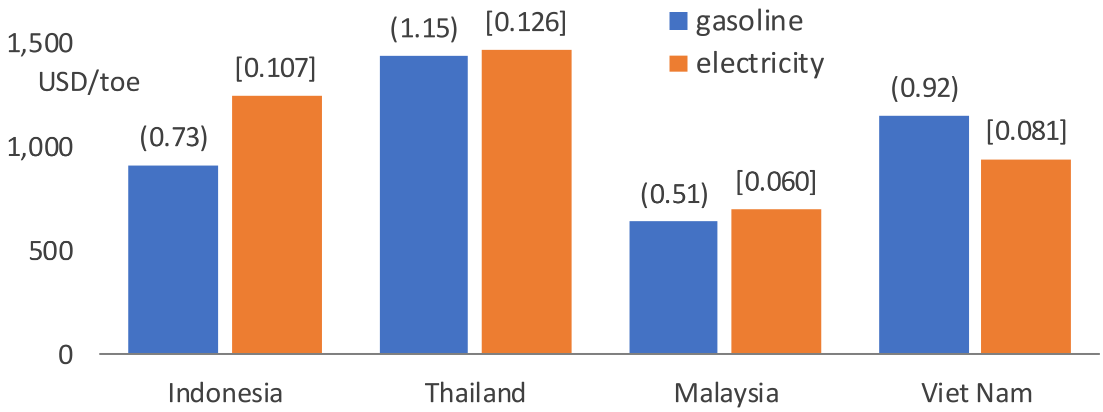
The subsidy calculation assumes the following:

- 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[7] 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



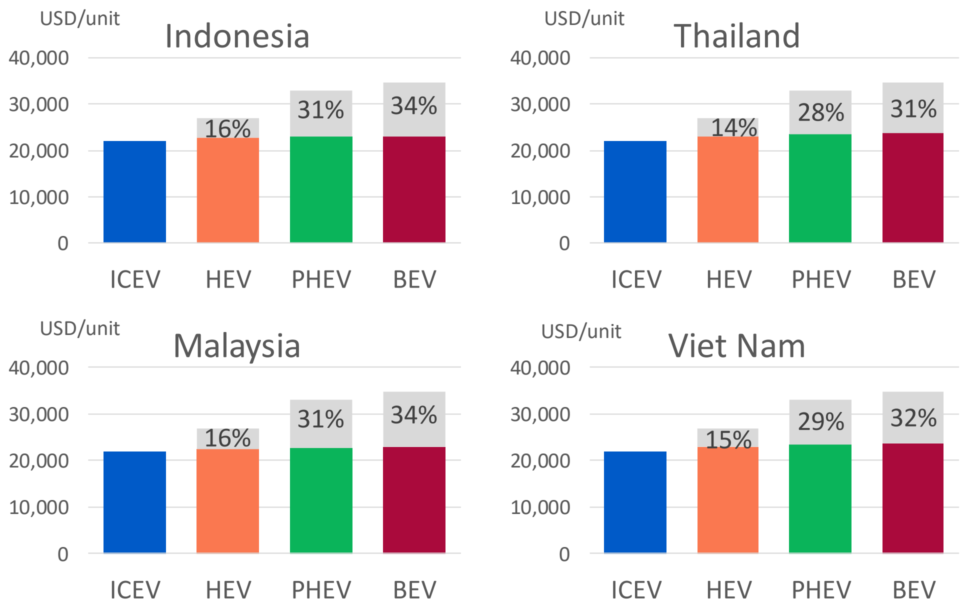
toe = tonnes of energy equivalent.
Note: The numbers in parentheses are (US$/L) and [US$/kWh] respectively.
Source: globalpetrolprices.com. Gasoline prices, litre, 7 October 2019, https://www.globalpetrolprices.com/gasoline_prices/Electricity prices for households, June 2019, https://www.globalpetrolprices.com/electricity_prices/

[7] 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.

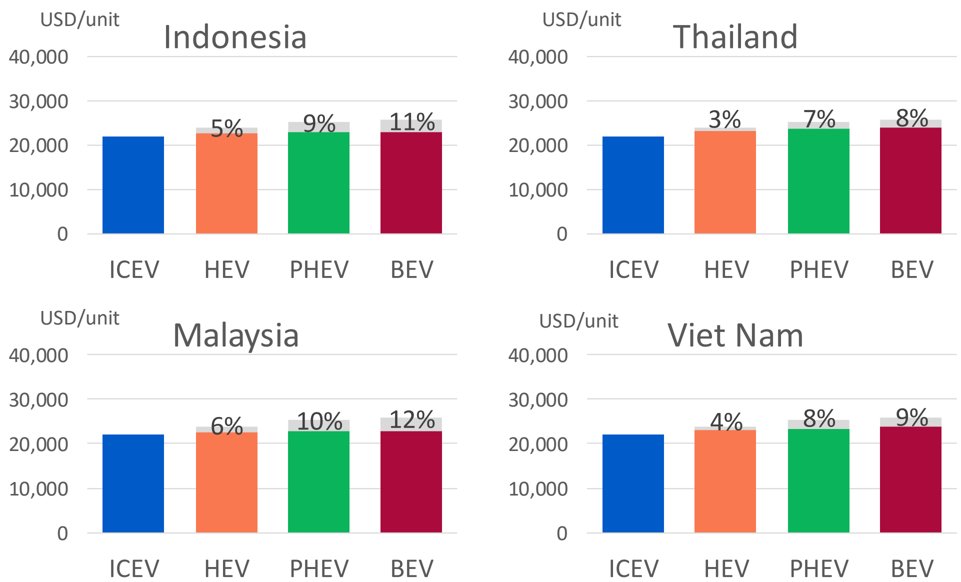
Figure 3-12 shows the xEV prices and the proportion of subsidies required. Currently, the subsidy rates are 14%–16% for HEVs, 28%–31% for PHEVs, and 31%–34% for BEVs. Subsidy rates are somewhat lower in Thailand and Viet Nam, as expected. In 2030, xEV prices fall and the subsidy rates drop significantly,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

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

- **2019**



- **2030**



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.

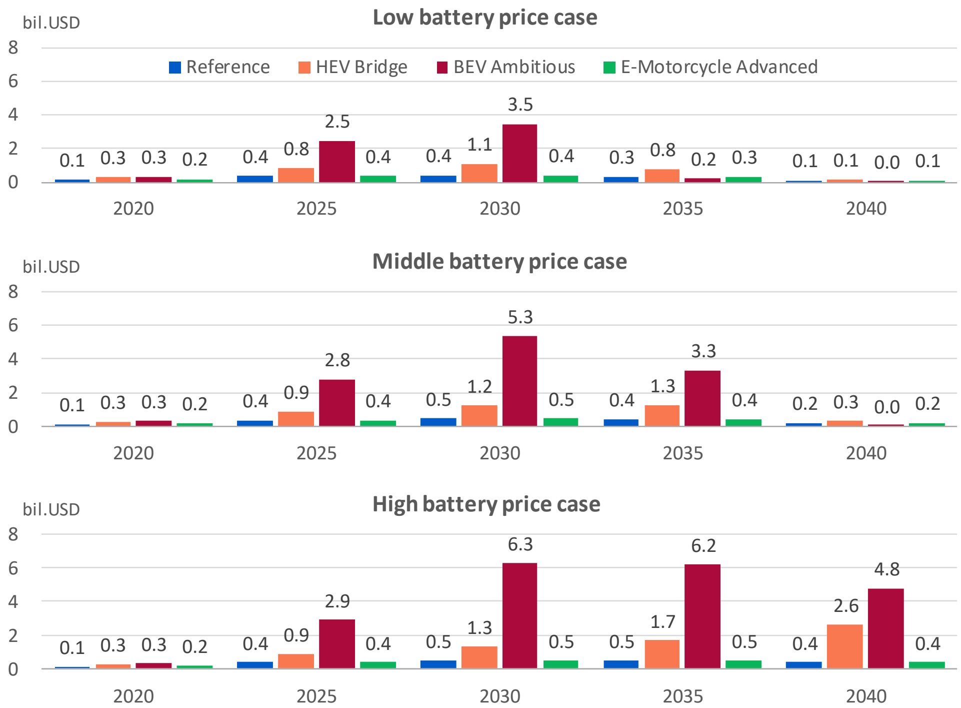
As the subsidy rates vary depending on the trend of battery prices, we also estimate total subsidy amounts for the low and high battery price cases.

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.

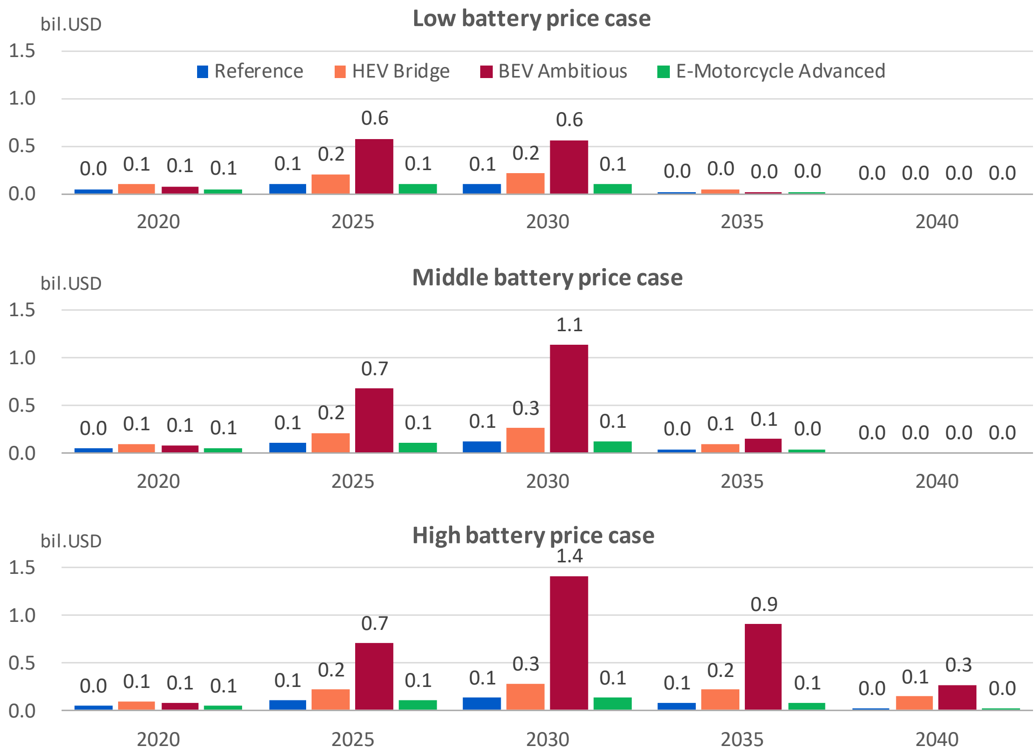
In the low battery price case, the total amount of subsidies is naturally small, with few required by around 2035. On the other hand, in the high battery price case, subsidies to xEVs will continue to be granted even in 2040. The cumulative subsidy amount through 2040 will increase by 1.3 to 1.6 times 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



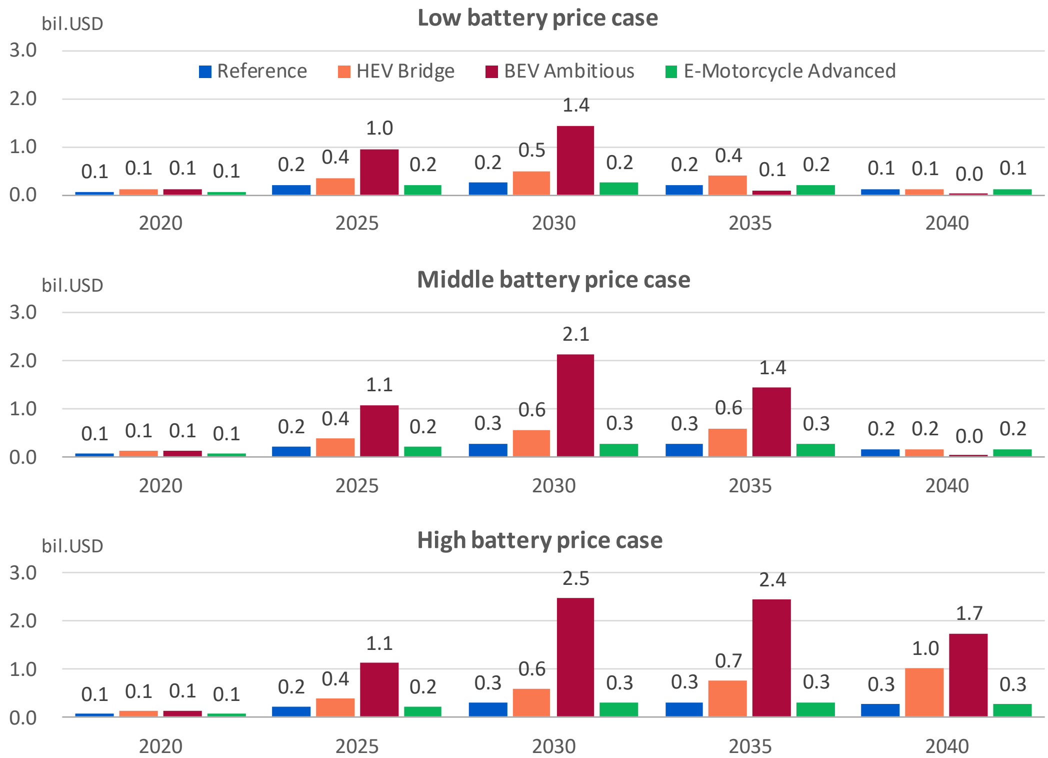
BEV = battery electric vehicle, HEV = hybrid electric vehicle.
Source: Authors' analysis.

Figure 3-14. Subsidy Amount to xEVs in Thailand



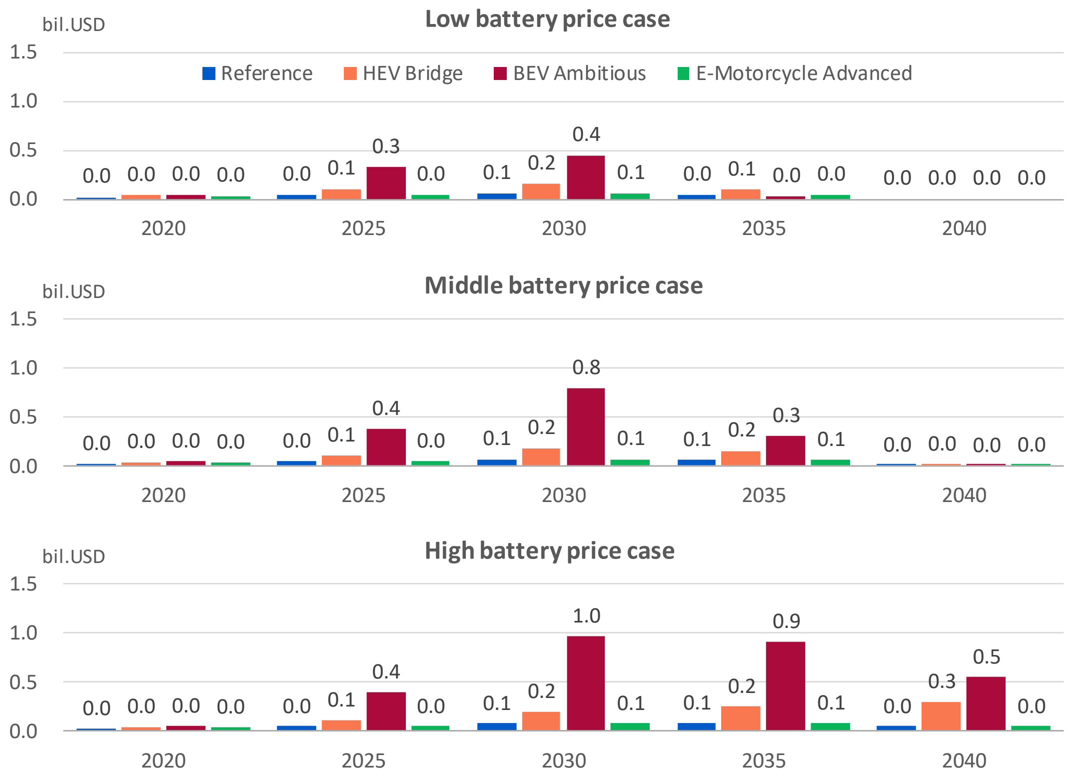
BEV = battery electric vehicle, HEV = hybrid electric vehicle.
Source: Authors' analysis.

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

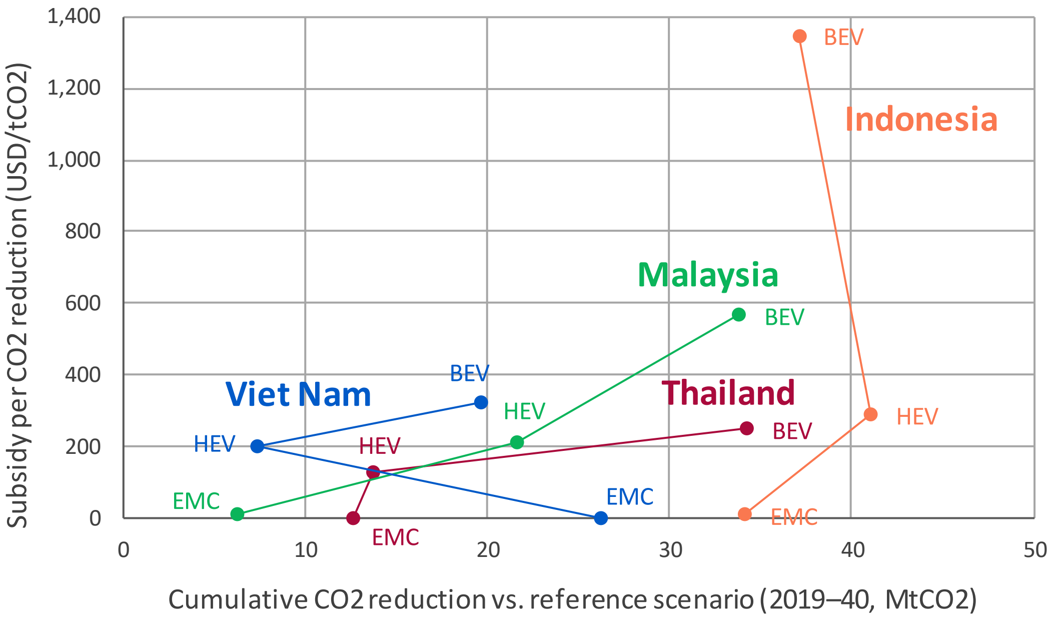
Figure 3-17 shows the cost-effectiveness of reducing CO_2 by calculating relations between the emissions savings and the subsidy amount. The horizontal axis shows cumulative CO_2 reduction and the vertical axis shows the reduction cost. In other words, the further the measure extends in the lower right in the diagram, the more cost-effective the scenario is in terms of CO_2 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_2 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_2 Reductions



CO2 = carbon dioxide, HEV= HEV Bridge scenario, BEV= BEV Ambitious scenario, EMC = E-Motorcycle Advanced scenario, MtCO2 = million tonnes of carbon dioxide.
Source: Authors' analysis.