Chapter 3

Total Cost of Ownership and Tipping Point of Electric Vehicles in ASEAN Countries

March 2023

This chapter should be cited as

ERIA Study team (2023), 'Total Cost of Ownership and Tipping Point of Electric Vehicles in ASEAN Countries', in Naoko Doi, Alloysius Joko Purtanto, Shigeru Suehiro, Toshiya Okamura, Kazuhisa Takemura, Masami Iwai, Akira Matsumoto, Keita Katayama (eds.), *Study on Policies and Infrastructure Development for the Wider Penetration of Electrified Vehicles in ASEAN Countries*. ERIA Research Project Report FY2022 No. 18, Jakarta: ERIA, pp.59-72.

Chapter 3

Total Cost of Ownership and Tipping Point of Electric Vehicles in ASEAN Countries

1. Introduction

Amongst the Association of Southeast Asian Nations (ASEAN) countries, diffusion of electric vehicles (EVs) has not made much progress. Of the five analysed countries, three have already announced EV targets, and actions are taken to promote the battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (xEVs) diffusion through providing incentives for consumers and making necessary investments in infrastructure. This chapter presents the analysis of total cost of ownership of EVs and a comparison with internal combustion engine (ICE) vehicles, hybrid electric vehicles (HEVs), and plug-in hybrid electric vehicles (PHEVs) for five countries in ASEAN: Brunei Darussalam, Indonesia, Malaysia, Thailand, and Viet Nam. The analysis reflects the country-specific factors, including travel distance, fuel economy, energy prices, costs for ownership such as registration fee, tax, and incentives. The total cost of ownership analysis can offer the insights into the cost competitiveness of EVs or identify the areas for further strengthening policy support.

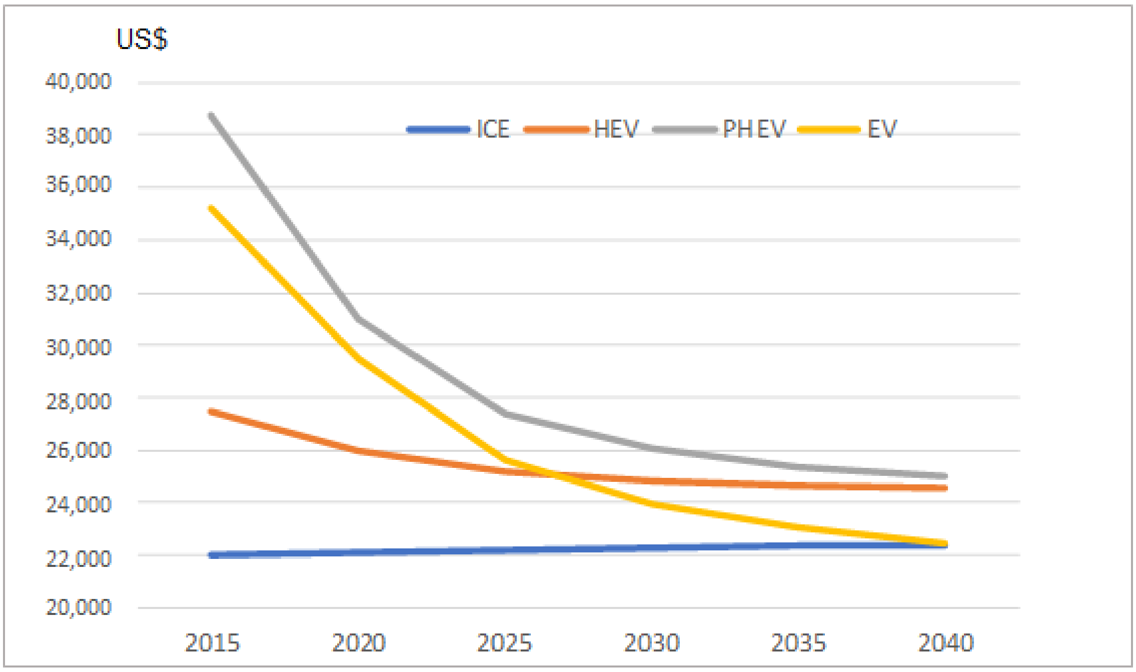
This chapter also presents the analysis results of the tipping point of EVs – when benefits of owing xEVs would surpass that of ICE vehicles and HEVs. Understanding the tipping point of EVs is an important reference as to when EVs would become cost competitive against ICE vehicles for policy planning, business development, and consumers' vehicle purchase. In this analysis, country-specific factors such as fuel economy of ICE vehicles, driving distance, and energy price are considered.

2. Study Method

Total cost of ownership is calculated by taking into consideration the annualised cost of vehicle by powertrain, payments for energy (gasoline, diesel, or electricity), and maintenance. The comparison is made by reflecting differentiated payments for registration, road tax, and excise tax depending on type of powertrain.

For the analysis of tipping point, vehicle costs are estimated up to 2040 (Figure 3.1). The estimated cost represents the basic technology cost, which excludes the other equipment such as safety and interior. The cost of ICE vehicles is assumed to increase slightly from the 2020 level as the technological requirements for fuel economy improve. The cost of HEVs will decline as the cost of batteries decreases; substantial cost reductions are expected with regard to PHEVs and EVs due to the estimated reduction in the cost of lithium-ion batteries.

Figure 3.1. Vehicle Cost Assumptions ($)



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

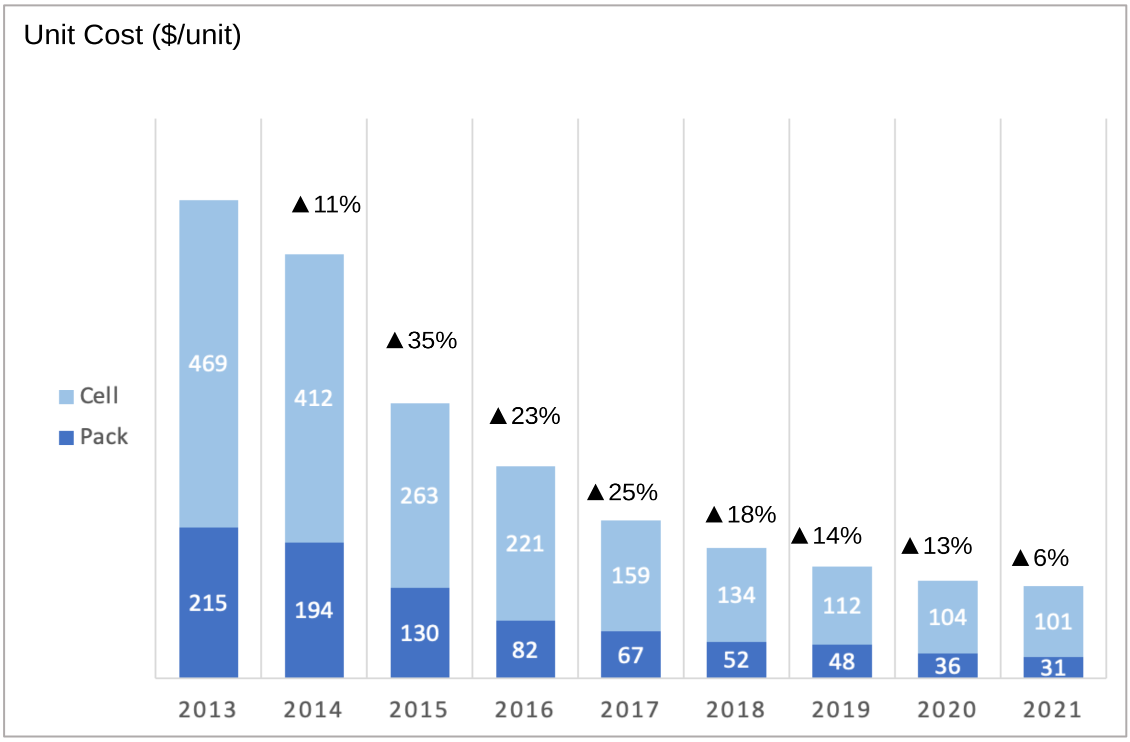
Source: Institute of Energy Economics, Japan (2018).

2.1. Estimation of the Cost of Lithium-Ion Batteries

The estimated cost of lithium-ion batteries is critically important for future cost estimations with regard to HEVs, PHEVs, and EVs. In fact, costs have been decreasing substantially over the past few years due to economies of scale, technological improvements, and the ongoing maturation of the manufacturing process (Figure 3.2). The cost of lithium-ion battery modules has decreased from $1,000 per kilowatt hour (kWh) in 2010 to $209 per kWh in 2017, a 79% reduction in 7 years, or an average annual reduction of 20%.

To estimate the cost of lithium-ion batteries, the learning curve analysis method is utilised. The basic concept of the learning curve analysis is that, as the quantity of production unit doubles, the cost of producing a unit decreases by a constant percentage. For example, an 80% learning curve implies that the cost associated with incremental output will decrease to 80% of the previous level (or a 20% reduction from the previous level).

Figure 3.2. Lithium-Ion Battery Module Cost Trends



kWh = kilowatt hour.
Note: The figures include the cell plus pack price.
Source: Bloomberg New Energy Finance (2017).

The learning curve can be explained as follows.

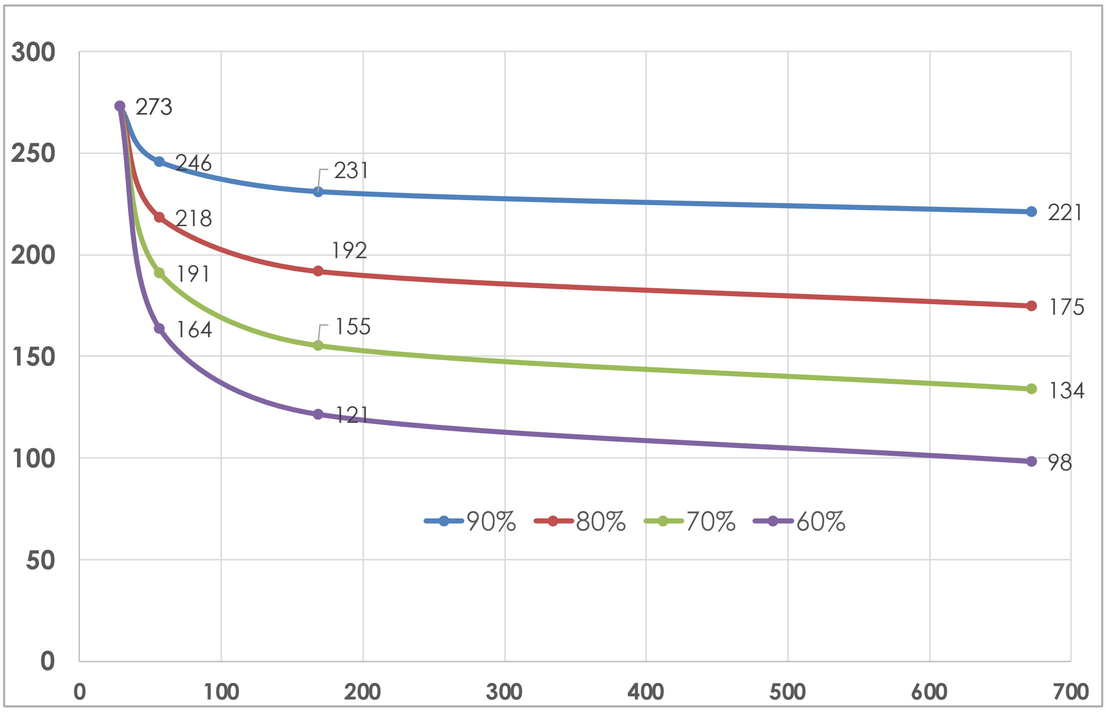
$$Y = AX^b$$

Y = average cost of unit X
A = the first unit cost
X = unit number (cumulative volume)

$$b = \text{slope coefficient} = \frac{\log(\text{slope of the learning curve})}{\log 2}$$

Figure 3.3, which presents an example of lithium-ion battery cost estimates using the learning curve, shows that the estimated cost per kWh differs when production units double, at different learning rate assumptions of 60%, 70%, 80%, and 90%. For example, when lithium-ion battery module production doubles from the current 28 GWh to 56 GWh, the cost is estimated to decrease from $209/kWh to $167/kWh at a learning rate of 80%. When production doubles further to 168 gigawatt hours (GWh), the cost is estimated at $147/kWh at the same learning rate.

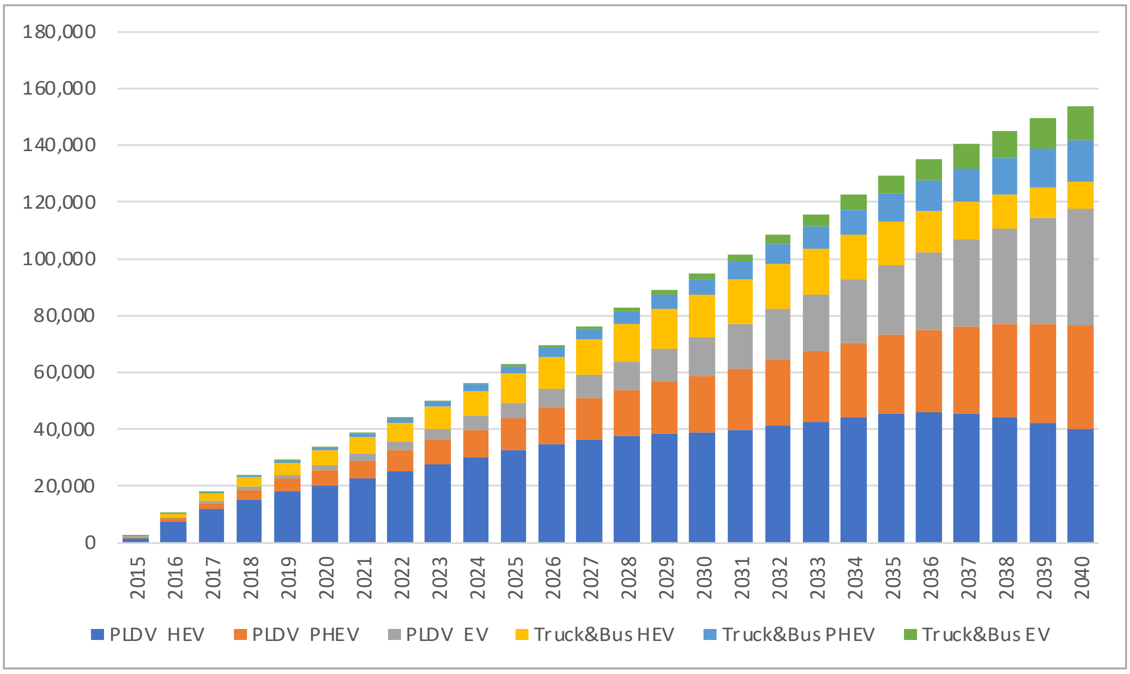
Figure 3.3. Example of Lithium-Ion Battery Cost Estimates Using the Learning Curve



kWh = kilowatt-hour, GWh = gigawatt-hour.
Source: Institute of Energy Economics, Japan (2022).

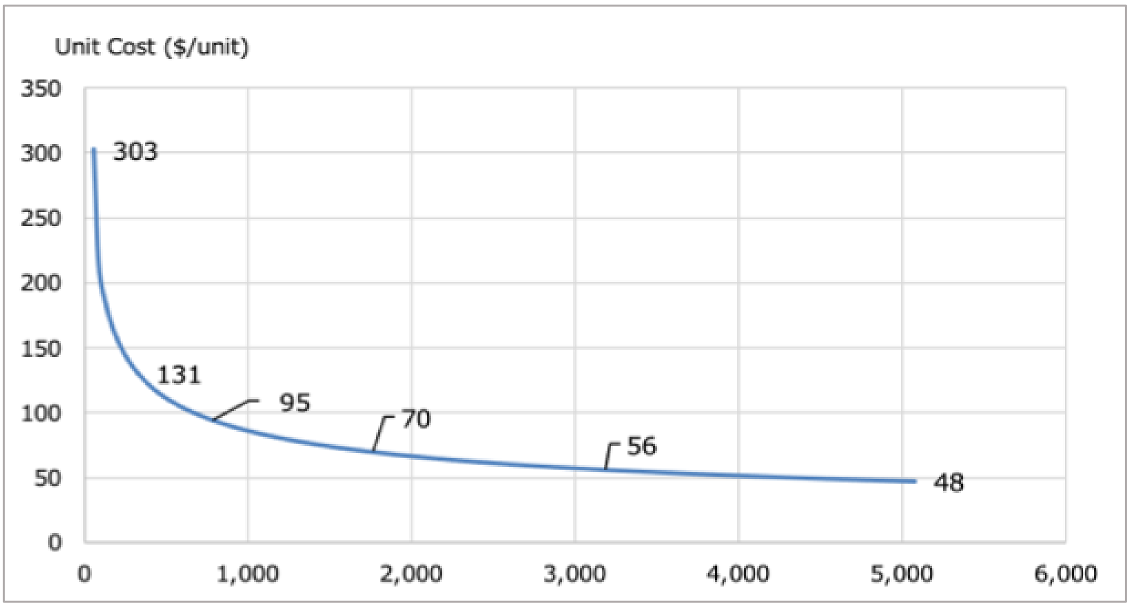
The cost estimate depends on the future production volume of lithium-ion battery modules. This analysis uses the outlook of the Institute of Energy Economics, Japan for lithium-ion battery modules (required to meet the future demand for HEVs, PHEVs, and EVs). The analysis assumes that EVs will account for 30% of total vehicle sales by 2030, and 100% by 2050. According to this analysis, the total production volume of lithium-ion batteries will reach a cumulative 5,076 GWh by 2040, compared to a mere 34 GWh in 2014 (Figure 3.4).

Figure 3.4. Global Outlook for Lithium-Ion Batteries for Hybrid Electric Vehicles, Plug-In Hybrid Electric Vehicles, and Electric Vehicles (Cumulative)



EV = electric vehicle, GWh = gigawatt-hours, HEV = hybrid electric vehicle, PHEV = plug-in hybrid electric vehicle, PLDV = passenger light-duty vehicle.
Source: Institute of Energy Economics, Japan (2021).

Figure 3.5. Estimated Cost of Lithium-Ion Batteries (2016–2040)



kWh = kilowatt hour.
Source: Institute of Energy Economics, Japan (2018).

Figure 3.5, which shows the estimated cost of lithium-ion battery modules up to 2040 at the learning rate of 75%. This demonstrates the estimated relationship between the cumulative production of lithium-ion batteries by 2040 and corresponding module cost per kWh. As the figure shows, this cost is projected to decline to $72/kWh by 2030, and further to $51/kWh by 2040.

2.2. Tipping Point Analysis Framework

Table 3.1 shows the total annual cost of using each type of passenger vehicle technology from 2015 to 2040. Gasoline or electricity costs for each type of technology (included in the table) are calculated by determining the energy requirements for driving a distance of 10,000 km per year. The maintenance cost is smaller for PHEVs and EVs compared with those for ICE vehicles and HEVs, due to their relatively simple technological composition. However, PHEVs and EVs require personal chargers, incurring additional costs.

Table 3.1. Cost of Driving by Type of Technology

		2015	**2020**	**2025**	**2030**	**2035**	**2040**
ICE							
Initial Vehicle Purchase	$/10 years	22000	22066	22165	22248	22319	22381
Vehicle Purchase	$/year	2420	2427	2438	2447	2455	2462
Gasoline	$/year	493.8	477.7	462.4	444.6	427.1	409.9
Maintenance	$/year	121.0	121.4	121.9	122.4	122.8	123.1
Total Annual Cost	**$/year**	**3035**	**3026**	**3022**	**3014**	**3005**	**2995**
HEV							
Initial Vehicle Purchase	$/10 years	27500	25992	25175	24835	24651	24537
Vehicle Purchase	$/year	2915	2755	2669	2633	2613	2601
Gasoline	$/year	334	304	297	291	284	277
Maintenance	$/year	73	69	67	66	65	65
Total Annual Cost	**$/year**	**3322**	**3128**	**3033**	**2989**	**2962**	**2943**
PHEV							
Initial Vehicle Purchase	$/10 years	38500	31000	27410	26083	25388	24959
Vehicle Purchase	$/year	4043	3255	2878	2739	2666	2621

		2015	2020	2025	2030	2035	2040
Gasoline+Electricity	$/year	229	208	206	204	201	199
Maintenance	$/year	101	81	72	68	67	66
Personal charger	$/year	72.8	58.6	51.8	49.3	48.0	47.2
Total Annual Cost	**$/year**	**4445**	**3603**	**3208**	**3060**	**2982**	**2932**
EV							
Initial Vehicle Purchase	$/10 years	35200	29502	25639	23974	23054	22472
Vehicle Purchase	$/year	3696	3098	2692	2517	2421	2360
Electricity	$/year	144.4	131.9	130.2	130.2	129.5	128.8
Maintenance	$/year	92	77	67	63	61	59
Personal charger	$/year	66.5	55.8	48.5	45.3	43.6	42.5
Total Annual Cost	**$/year**	**3999**	**3363**	**2938**	**2756**	**2654**	**2590**

EV = electric vehicle, HEV = hybrid electric vehicle, ICE = internal combustion engine, PHEV = plug-in hybrid electric vehicle.
Source: Institute of Energy Economics, Japan (2018).

In this study, a tipping point analysis is being made for passenger vehicles and motorcycles, whilst the analysis for buses and trucks is excluded as the standardised size for these modes cannot be obtained.

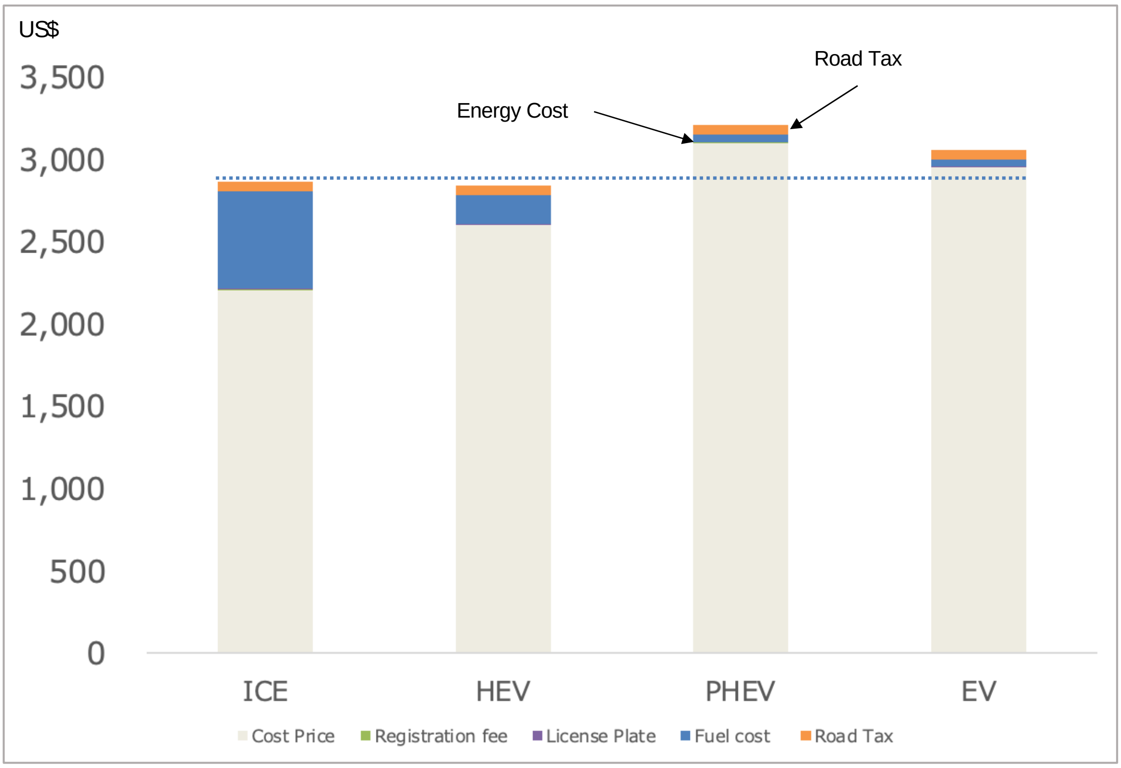
3. Analysis Results

3.1. Brunei Darussalam

Figure 3.6 shows Brunei's annualised total cost of passenger vehicle ownership in 2022. As the figure shows, no incentives are provided to EV owners yet, nevertheless, low electricity price at 0.08 cent/kWh would benefit the EV owners.

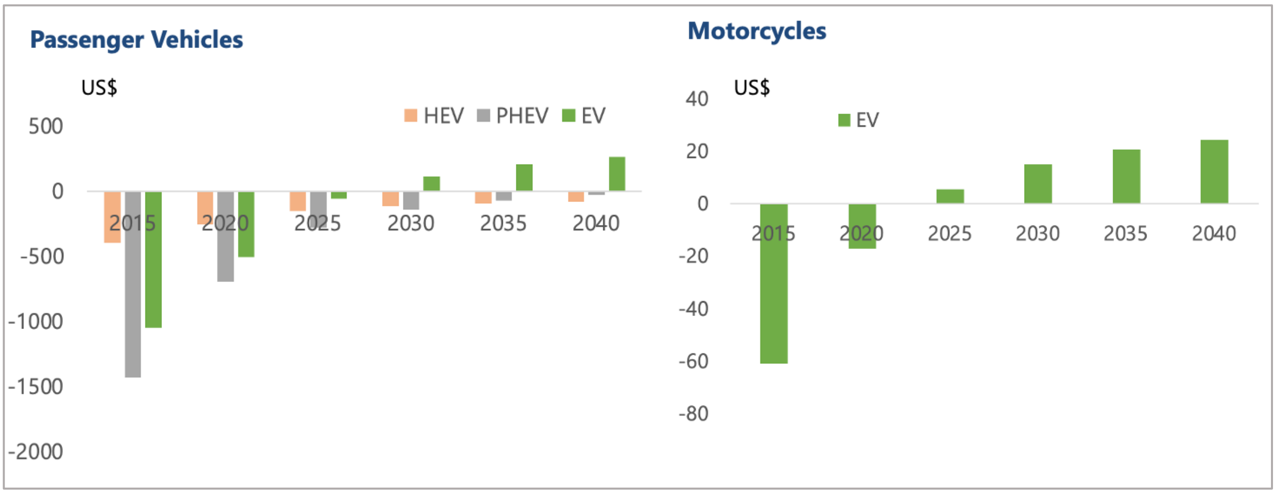
The tipping point for EV passenger vehicles would be sometime after 2030 due to the relative low gasoline/diesel price in contrast to electricity (Figure 3.7).

Figure 3.6. Brunei Darussalam's Total Cost of Passenger Vehicle Ownership (2022)



EV = electric vehicle, HEV = hybrid electric vehicle, ICE = internal combustion engine, PHEV = plug-in hybrid electric vehicle.
Source: Institute of Energy Economics, Japan (2022).

Figure 3.7. Brunei Darussalam's Tipping Point for Passenger Vehicles and Motorcycles



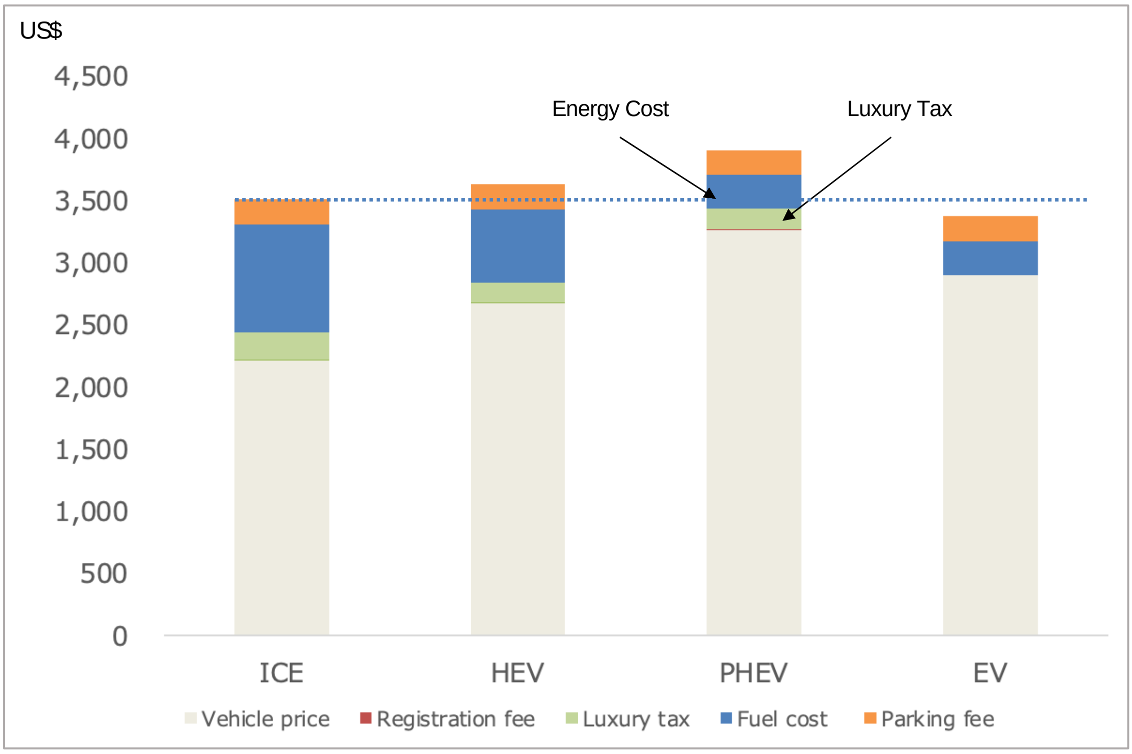
EV = electric vehicle, HEV = hybrid electric vehicle, PHEV = plug-in hybrid electric vehicle.
Source: Institute of Energy Economics, Japan (2022).

3.2. Indonesia

As Figure 3.8 shows, annualised EV's total cost of ownership for passenger vehicles is lower than ICE vehicles. In Indonesia, as the incentive for consumers, luxury tax is differentiated by powertrain. Besides, PLN offers a 30% electricity tariff discount between 10:00 pm to 5:00 am for those who own EVs.

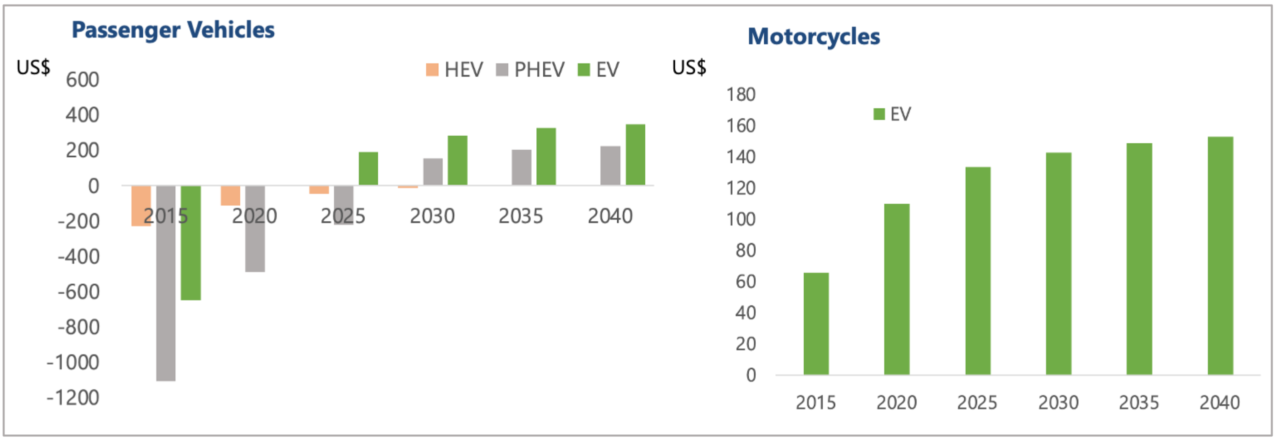
The tipping point for Indonesia's passenger vehicles would be sometime after 2025 (Figure 3.9). Relative low electricity price would benefit the EV owners. For buses and trucks, combination of low fuel economy of buses/trucks and relative low electricity price would benefit the EV owners.

Figure 3.8. Indonesia's Total Cost of Passenger Vehicle Ownership (2022)



EV = electric vehicle, HEV = hybrid electric vehicle, ICE = internal combustion engine, PHEV = plug-in hybrid electric vehicle.
Source: Institute of Energy Economics, Japan (2022).

Figure 3.9. Indonesia's Tipping Point for Passenger Vehicles, Buses and Trucks, and Motorcycles

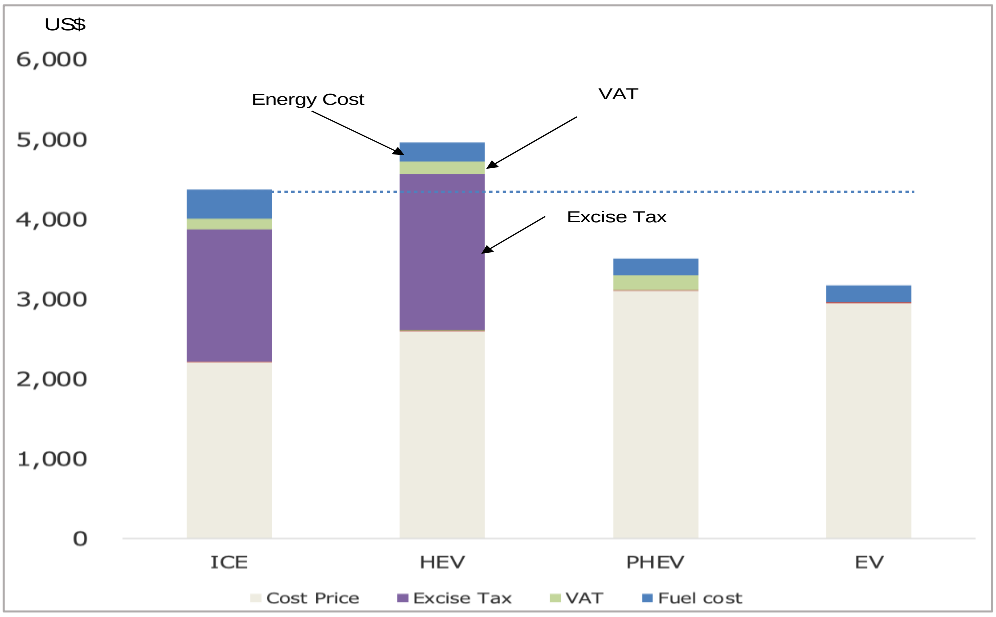


EV = electric vehicle, HEV = hybrid electric vehicle, PHEV = plug-in hybrid electric vehicle.
Source: Institute of Energy Economics, Japan (2022).

3.3. Malaysia

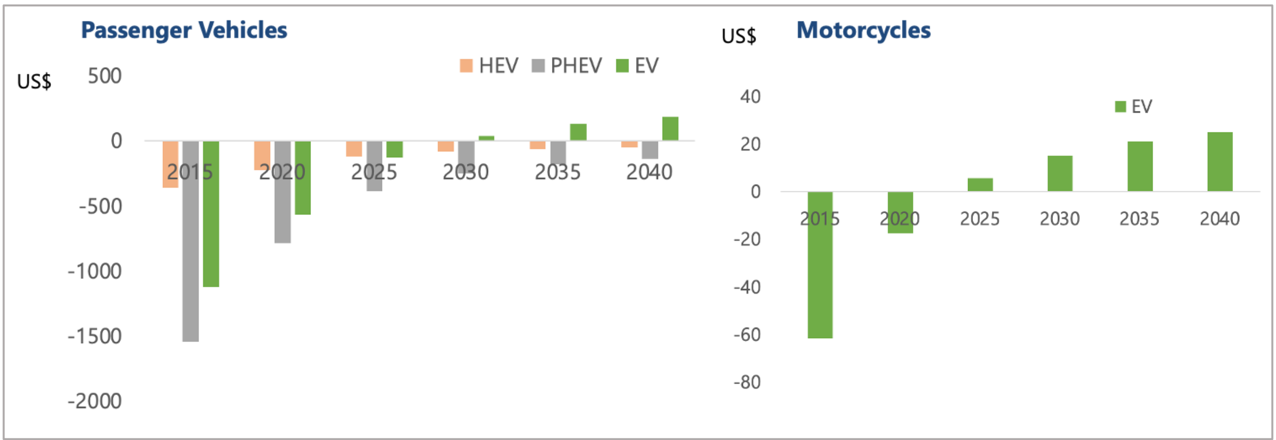
In Malaysia, various incentives are planned in the Low Carbon Mobility Blueprint 2021-2030, including the exemption of excise tax and value added tax (VAT). Exemption of excise tax would greatly benefit EV owners despite the low gasoline price at $0.466/litre. In contrast, as Figure 3.11 shows, unless economic incentives are provided, the cost of owning EVs would be much higher than that of ICE vehicles due mainly to the low gasoline/diesel price (46% lower than electricity in toe terms).

Figure 3.10. Malaysia's Total Cost of Passenger Vehicle Ownership (2022)



EV = electric vehicle, HEV = hybrid electric vehicle, ICE = internal combustion engine, PHEV = plug-in hybrid electric vehicle, VAT = value added tax.
Source: Institute of Energy Economics, Japan (2022).

Figure 3.11. Malaysia's Tipping Point for Passenger Vehicles, Buses and Trucks, and Motorcycles



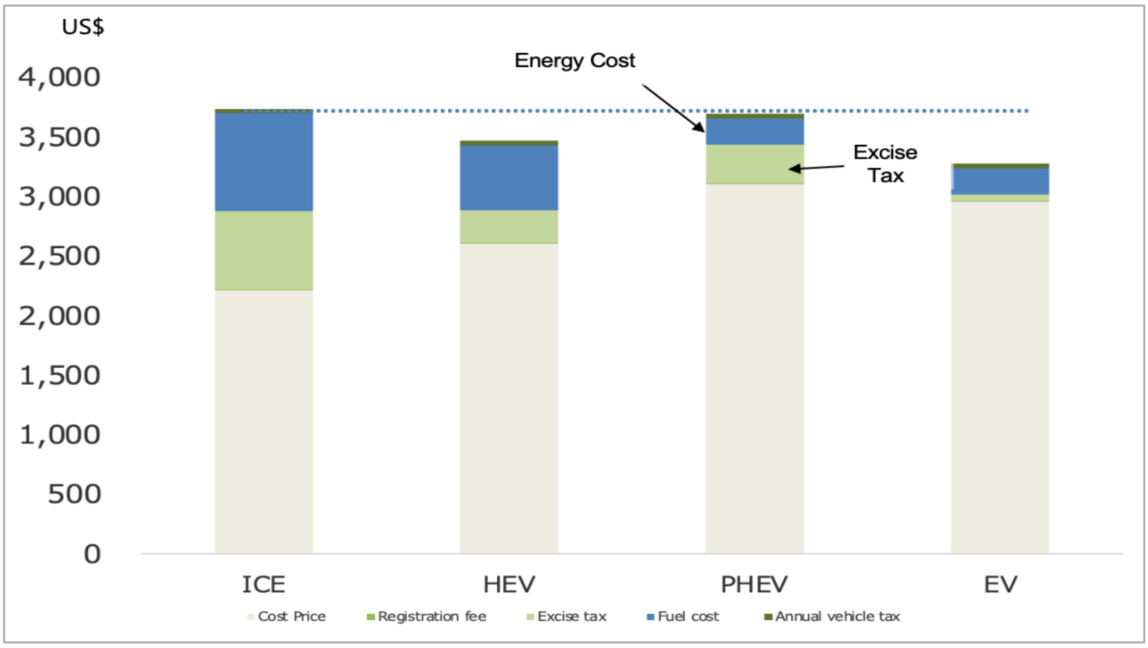
EV = electric vehicle, HEV = hybrid electric vehicle, PHEV = plug-in hybrid electric vehicle.
Source: Institute of Energy Economics, Japan (2022).

3.4. Thailand

As Figure 3.12 shows, incentives in the form of lower excise tax for EV owners and high gasoline price at US$1.435/litre would benefit the EV owners against that of ICE.

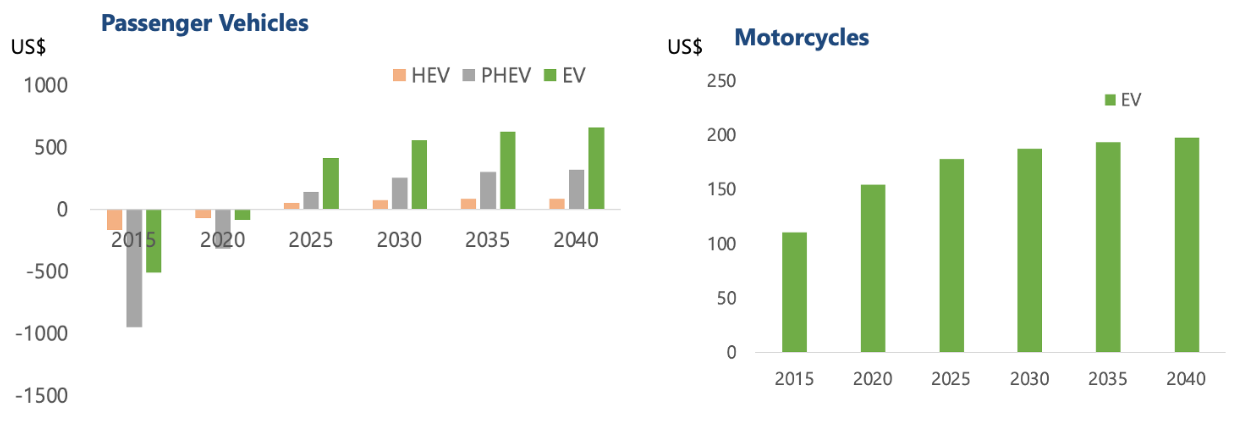
Unless economic incentives are provided, the cost of owning EVs would be much higher than that of ICE vehicles. Provision of economic incentives (in a form of tax waiver) needs to be maintained by 2025 (Figure 3.13).

Figure 3.12. Thailand's Total Cost of Passenger Vehicle Ownership (2022)



EV = electric vehicle, HEV = hybrid electric vehicle, ICE = internal combustion engine, PHEV = plug-in hybrid electric vehicle.
Source: Institute of Energy Economics, Japan (2022).

Figure 3.13. Thailand's Tipping Point for Passenger Vehicles, Buses and Trucks, and Motorcycles



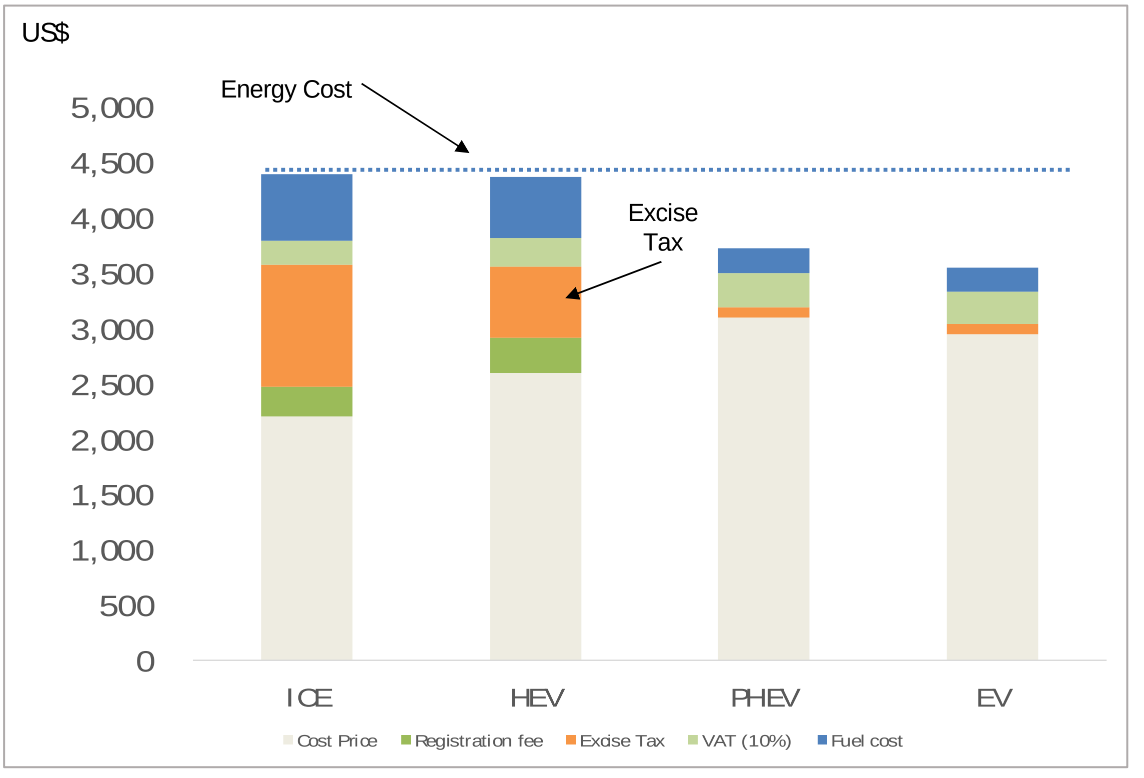
EV = electric vehicle, HEV = hybrid electric vehicle, PHEV = plug-in hybrid electric vehicle.
Source: Institute of Energy Economics, Japan (2022).

3.5. Viet Nam

As Figure 3.14 shows, incentives in the form of lower excise tax for EV owners and high gasoline price at US$1.324/litre (or low electricity price at 8 US cent/kWh) would benefit the EV owners against that of ICE.

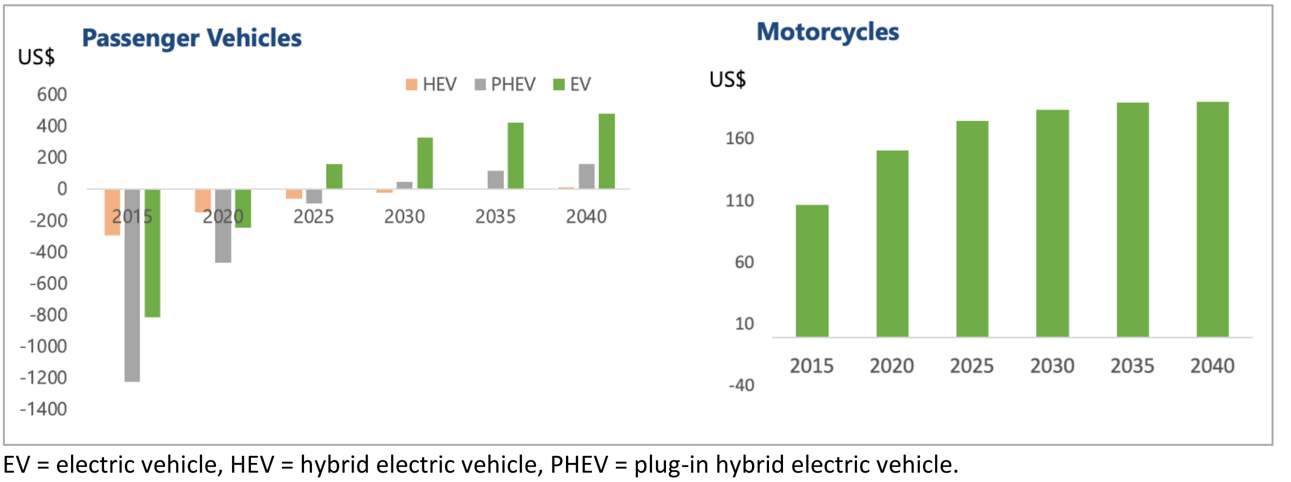
The tipping point for EVs for passenger vehicles would be sometime after 2025, whilst that for buses and trucks would be much earlier (Figure 3.15). Fuel efficiency of buses and trucks is low (almost one quarter of EVs); therefore, a combination of low fuel efficiency and low electricity price (44% lower than that of diesel) would benefit EV owners.

Figure 3.14. Viet Nam's Total Cost of Passenger Vehicle Ownership (2022)



EV = electric vehicle, HEV = hybrid electric vehicle, ICE = internal combustion engine, PHEV = plug-in hybrid electric vehicle.
Source: Institute of Energy Economics, Japan (2022).

Figure 3.15. Viet Nam's Tipping Point for Passenger Vehicles, Buses and Trucks, and Motorcycles



EV = electric vehicle, HEV = hybrid electric vehicle, PHEV = plug-in hybrid electric vehicle.
Source: Institute of Energy Economics, Japan (2022).

4. Conclusions

The five analysed ASEAN countries offer different incentives for the wider diffusion of EVs. The methods are mainly focused on passenger vehicle ownership, in a form of differentiated luxury tax (Indonesia), exemption of excise tax (Malaysia), and lower excise tax (Thailand and Viet Nam). Discounts on electricity prices as provided by Indonesia can benefit EV owners as well. No countries have yet provided subsidies for EV owners.

For passenger vehicles, the tipping point (when the benefit of owning EVs would surpass that of ICE vehicles) may come sometime between 2025 and 2030. However, it is important to note that the timing for the tipping point would be different based on the assumptions. Particularly, the main factor affecting the tipping point would be the declining cost of lithium-ion batteries. If the assumed 75% learning rate cannot be achieved (for the high demand surpassing that of supply) in the near-term, the tipping point would be delayed to a much later time. Other factors such as longer vehicle ownership and need for EV battery replacement (if it is beyond a 10-year lifetime) are not considered in this study. This would substantially increase the cost of passenger vehicle ownership, thus the tipping point would be delayed from the estimated timing.

Aside from the initial cost of vehicle purchase, operational costs – particularly energy prices – continue to be the important factor for an owner's decision on the vehicle purchase. Future 'average' electricity prices may increase because of the need for new replacement for low-carbon energy sources. Instead of providing the flat rate, time of use pricing for electricity may encourage the purchase of EVs.

The benefits of driving e-motorcycles have already outweighed that of conventional motorcycles (excluding the case in Brunei Darussalam). Charging infrastructure development as well as business development should be ready for the expected rise in e-motorcycles.