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Study on Electric Vehicle Penetrations' Influence on 3Es in ASEAN

Edited by

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Abbreviations and Acronyms

3Es	=	economy, energy, and environment
AC	=	alternating current
ASEAN	=	Association of Southeast Asian Nations
BEV	=	battery electric vehicle
CO_2	=	carbon dioxide
DC	=	direct current
ERIA	=	Economic Research Institute for ASEAN and East Asia
EV	=	electric vehicle
GDP	=	gross domestic product
GFEI	=	Global Fuel Economy Initiative
HEV	=	hybrid electric vehicle
ICEV	=	internal combustion engine vehicle
IEA	=	International Energy Agency
IEEJ	=	The Institute for Energy Economics, Japan
Mtoe	=	million tonne of oil equivalent
OECD	=	Organisation for Economic Co-operation and Development
PEV	=	plug-in electric vehicle
PHEV	=	plug-in hybrid vehicle
PLDV	=	passenger light-duty vehicle
TOU	=	time-of-use
xEV	=	electric vehicle (including HEV, PHEV, and BEV)

Executive Summary

Demand for automobiles to transport passengers and freight has been rapidly increasing in 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 whilst CO_2 emissions have increased. Automobile penetration is expected to rise as the economy grows, further increasing energy security and environmental concerns.

To tackle these issues, ASEAN countries have announced policies to promote electric vehicles (xEVs),[1] which reduce oil consumption and air pollution but increase demand for electricity. Depending on its power generation sector, a country might not achieve energy self-sufficiency or solve its environmental problems.

The study analyses xEV deployment's effects and side effects 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_2 emissions, and the macroeconomy to contribute to ASEAN members' automobile and energy policy planning. The study delivers the following outcomes.

1. Indonesia, Malaysia, Thailand, and Viet Nam may face challenges in the 3Es in the reference scenario, which assumes continued historical trends without strengthening policy measures.

    - ✓ Cars increase 2.5 times by 2040 due to high economic growth. Motorbikes, which are over three times more numerous than cars, increase 1.7 times.
    - ✓ Total primary energy demand increases by 3.2% annually in Indonesia, 4.3% in Viet Nam, 1.8% in Thailand, and 2.3% 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_2 emissions. CO_2 emissions increase annually by 3.5% in Indonesia and 5.2% 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_2 emissions grow at almost the same rate as energy demand.

- ✓ Rapidly increasing fossil-fuel demand results in lower energy self-sufficiency. One of the largest coal exporters, Indonesia keeps its energy self-sufficiency rate (ratio of domestic output to domestic consumption in a given year) over 100% but it drops significantly from today's level. Malaysia is a net export country today but becomes a net energy importer within 10 years.

[1] Including hybrid, plug-in hybrid, and battery electric vehicles.

- ✓ Net import bills dramatically increase in the four countries as oil self-sufficiency declines, even though Indonesia and Malaysia export coal and gas. Higher import bills might damage their economies.

2. The hybrid electric vehicle (HEV) bridge scenario and battery electric vehicle (BEV) ambitious scenario have the same effect on energy security and CO_2 emissions. The BEV scenario, however, needs investment funds and subsidies several times larger than in the HEV scenario.

- ✓ BEV penetration's effect of reducing CO_2 emissions is limited unless the power generation sector is decarbonised. ASEAN countries largely depend on coal-fired power generation.
- ✓ The energy self-sufficiency ratio does not vary much between each scenario because imports of petroleum products for vehicles decrease whilst imports of coal and natural gas for power generation increase. BEVs, however, improve the trade balance more than HEVs do.
- ✓ BEVs require several times the investment that HEVs do, and large investments in low-carbon power supply are required to make clean BEVs based on well to wheel.
- ✓ xEV penetration may need large subsidies to realise the scenarios. The total subsidy for the BEV scenario is several times that for the HEV scenario and puts pressure on government finances.

3. Charging infrastructure is a key requirement, but not the only one, for plug-in electric vehicles (PEVs), which include BEVs and plug-in hybrid electric vehicles (PHEVs).

- ✓ PEV charging infrastructure is more complex in technology, interoperability, standardisation, and impacts on electric power grid than the well-established ICEV refuelling infrastructure.
- ✓ The cost of rolling out public PEV charging facilities is high. National governments need to invest significantly at least at the beginning of PEV penetration whilst partnering with private business until markets reach a certain maturity.
- ✓ Central governments can implement measures to develop charging infrastructure, such as by providing rebates, tax breaks, low interest loans, and subsidies to private business to build infrastructure; building make-ready facilities for private business; partnering with private business to develop and operate stations; amongst others.
- ✓ Local or regional (urban) circumstances such as manufacturing maturity, business characteristics, and electricity supply profile need to be considered early to define a proper partnership approach and to discourage excessive intercity competition.

✓ A charging scheme strategy needs to be planned as early as possible to ensure that PEV penetration achieves its main objectives: reducing greenhouse gases by reducing the use of fossil-fuel–based power generation whilst ensuring that additional electricity demand does not further burden the electricity grid.

4. 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. Harmonise automobile and energy policies

Countering climate change by promoting xEVs is important, but the overall effects of well to wheel must be considered to make the most of vehicle electrification's environmental mitigation effects. It is critically important to coordinate policy goals.

II. Take a 'bridging' pathway to mitigate negative side effects

xEVs are more expensive than IECVs, and the amount of investments and subsidies needed to promote them might be enormous. Vehicle electrification must be affordable for consumers, businesses, and governments. Vehicles must be electrified at a speed that fully anticipates cost reduction.

III. Encourage support by local governments

Local as well as central governments can promote xEVs. Local measures are less cost intensive and include public procurement of xEVs, provision of free parking spaces and free charging at public stations, use of lanes reserved for public transport, and road toll exemptions or discounts.

IV. Develop charging infrastructure to facilitate PEV deployment

✓ Set targets for building charging infrastructure.

✓ Facilitate infrastructure investment, especially involving stakeholders in a transparent process whilst creating an open and competitive market for EV charging.

✓ Price electricity fairly and improve interoperability by standardising charging equipment and payment and communication systems.

V. Develop measures to ensure that PEV penetration objectives are achieved

✓ Prepare a strategy to implement charging schemes. In the early phase of PEV penetration, PEV charging has negligible impacts on the grid and power generation. At a certain PEV penetration level, additional electricity demand affects the grid. The strategy will relieve the pressure on the grid and maximise low-carbon power generation.

- ✓ Educate users on optimal PEV use and charging. Driving EVs requires behaviour change to optimise vehicle use and minimise costs.
- ✓ Construct an open data platform to gather information on public charging stations: their locations, types, modes, real-time occupation, and operators.

VI. Create a clear long-term vision for xEV deployment

Such a vision will encourage private investment. Concrete and reasonable policies are important to create a safe investment environment.

VII. Consider appropriate country-specific paths to vehicle electrification

- ✓ In Indonesia, vehicles are so numerous that electrification will be enormously expensive. Cost control is critical. The power generation mix must be decarbonised to make the most of the environmental mitigation effects of vehicle electrification.
- ✓ In Malaysia, gasoline is much cheaper than electricity, resulting in a longer payback period for BEV introduction and higher total subsidies. Reviewing energy prices can be a policy tool to diffuse BEVs.
- ✓ In Thailand, a car manufacturing base, overly rapid vehicle electrification might damage existing production systems. It is necessary to proceed with caution.
- ✓ Viet Nam has about 20 times more motorbikes than cars, and motorbikes consume as much oil as cars. If Viet Nam promotes bike electrification, air pollution and oil consumption could be reduced and costs kept down.

Chapter 1
Background and Objective of the Study

Demand for passenger and freight transportation in the Association of Southeast Asian Nations (ASEAN) is great and automobile use is rapidly spreading. The adverse effects are traffic congestion, traffic accidents, and air pollution, especially in urban areas. As demand for petroleum as automobile fuel has increased, oil self-sufficiency has declined greatly whilst CO_2 emissions have increased. Greater automobile penetration is expected as the economy grows, increasing energy security and environmental concerns.

To tackle these issues, ASEAN countries have announced policies to promote electric vehicles (xEVs), including hybrid (HEVs), plug-in hybrid (PHEVs), and battery electric vehicles (BEVs), and to develop infrastructure. For example, Indonesia will ban the sale of internal combustion engine vehicles (ICEVs) by 2040. Malaysia is planning to increase the number of passenger electric vehicles (EVs) to 100,000 by 2030 and establish 125,000 charging bases. Thailand has announced BEV investment incentives and the conversion of all 22,000 tuk-tuks to BEVs by 2025.

These measures 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 analyses EV deployment effects and side effects by 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_2 emissions, and the macroeconomy to contribute to ASEAN members' automobile and energy policy planning.

1. Objective of the Research

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

2. Methodologies of the Project

This study uses a macroeconomic energy 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, and CO_2 emissions) by the diffusion of xEVs, including HEVs, PHEVs, and BEVs, through scenario analysis.

✓ Target countries: Indonesia, Malaysia, Thailand, and Viet Nam

✓ Scenario plan: 1) xEV penetration pattern (sales share x%, etc.)

2) Power generation mix (increase in thermal power and renewables)

✓ Analysis scope: 1) Influence on energy self-sufficiency

2) Influence on CO_2 emissions

3) Influence on the macroeconomy (gross domestic product [GDP], trade, subsidies, etc.)

This study is unique because it is comprehensive: it analyses not only the reduction of CO_2 emissions from automobiles but also the impacts on energy self-sufficiency and the macroeconomy. Depending on national circumstances, reducing direct CO_2 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 impacts of shifting towards xEVs on 3Es, including energy mix, self-sufficiency, CO_2 emissions, GDP, energy trade, and subsidy amounts to xEVs.

Chapter 4 reviews the literature on the current situation, how infrastructure is rolled out in different regions, and policy measures that might achieve the purposes of deploying PEVs.

Chapter 5 presents policy implications.

Chapter 2

Economic and Energy Outlook up to 2040

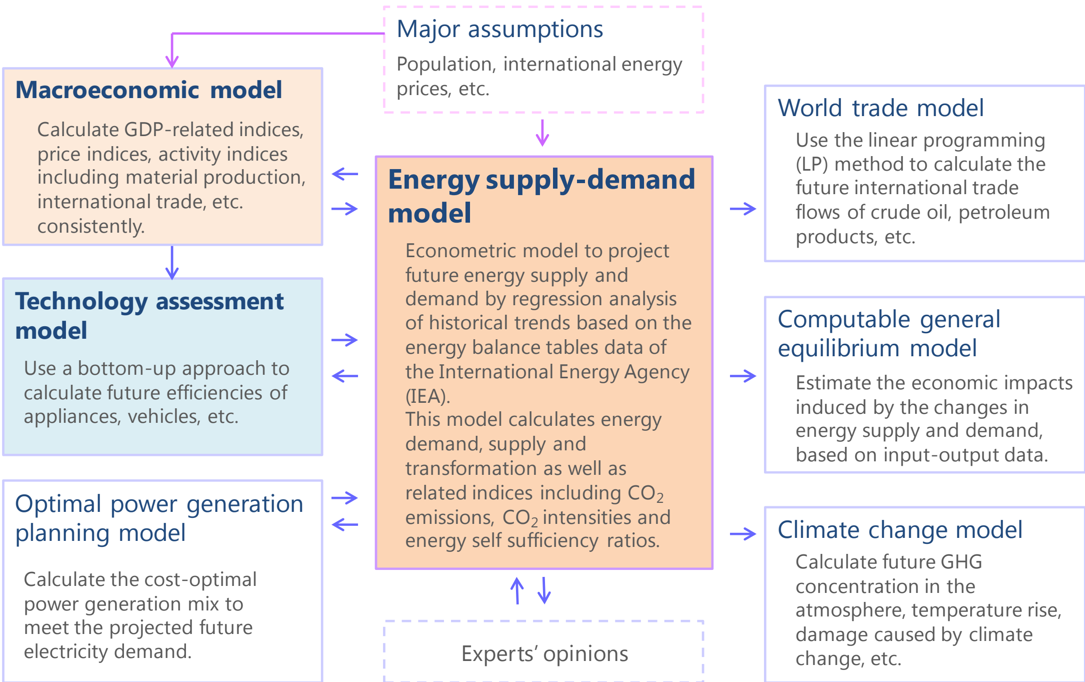
1. Modelling Framework

This study develops some scenarios focusing on xEV penetration and examines how each scenario might influence the 3Es. 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 is central to various models, allowing the projection of future energy supply and demand by regression analysis of historical trends. The energy demand and supply structure relies on the energy balance tables of the International Energy Agency (IEA). The model can calculate energy demand, supply, and transformation, as well as related indices, including CO_2 emissions and energy self-sufficiency rate.

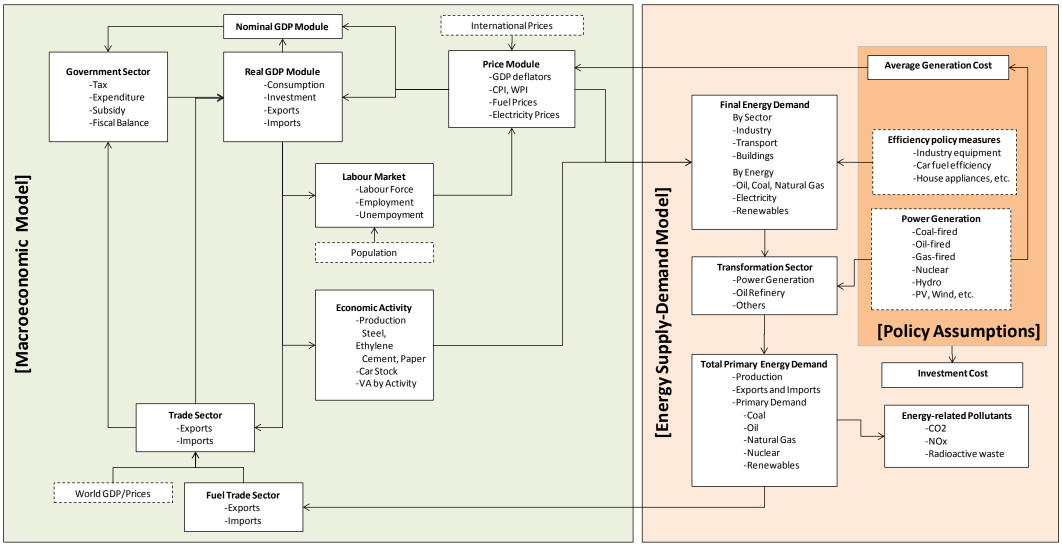
Figure 2.1: The Institute of Energy Economics, Japan's Energy Modelling Framework



Source: IEEJ (2018).

Changes in energy demand rest heavily on macroeconomic trends. To forecast the future energy supply and demand structure, therefore, we must reflect estimates through a macroeconomic model in an energy supply and demand analysis model. Changes in energy supply and demand structure, however, influence the macroeconomy through energy trade and costs. In other words, the macroeconomy and energy structure depend on each other. We can use an econometric model integrating a macroeconomic model and an energy supply–demand model to coherently project future macroeconomic and energy supply and demand structures (Figure 2.2).

Figure 2.2: Economic and Energy Model



Source: ERIA (2017).

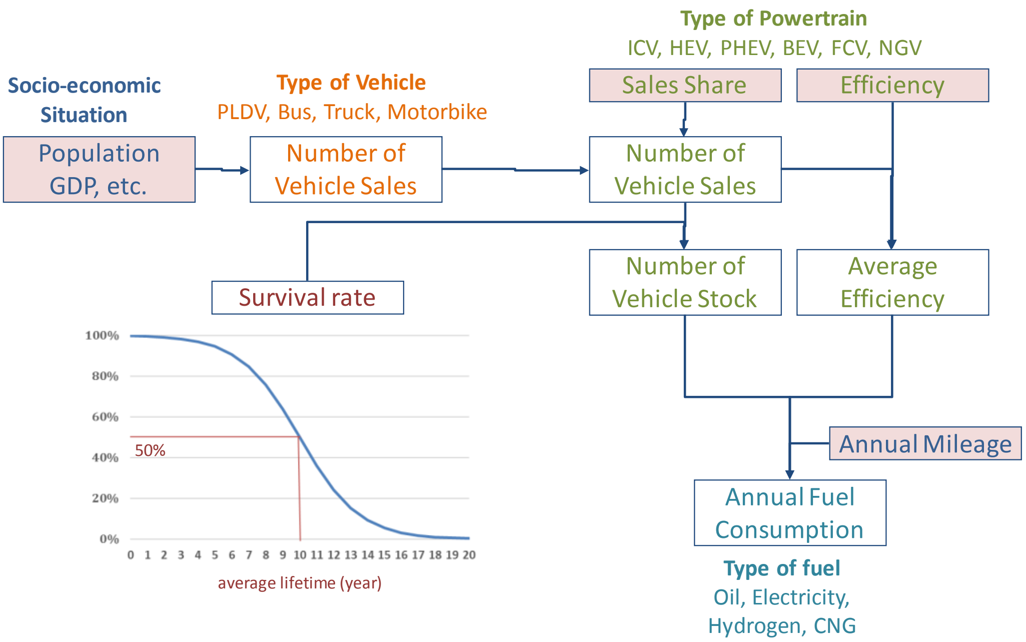
The macroeconomic model projects a commensurately balanced economic structure, including consumption, investment, trade, government, and general prices, and calculates economic activity indicators (including production and vehicle ownership) that directly and indirectly influence energy demand. The model 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 supply–demand equilibrium.

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

1.1 Technology Assessment Model for Automobiles

The technology assessment model 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 powertrain mix, especially electrification, could affect fuel demand in the road sector, this model considers six types of powertrain: 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.
Source: ERIA(2017)

After estimating future vehicle sales and shares of powertrain types (see the next section), the model estimates future vehicle stock by powertrain type, 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% of the rate as the average lifetime. When assuming fuel efficiency by 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.

1.2 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 the Napier's number (e). This ratio is considered selection probability: sales share.

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

i (type of powertrain) = ICV, HEV, PHEV, BEV, FCV, NGV

$$(\textbf{equation 2})\ Utility_i = U(Vehicle\ cost_i, Fuel\ cost_i, Crusing\ distance_i, GDP, etc.)$$

The utility is estimated by initial cost, running cost, income level, cruising distance, charging time, population, average mileage and fuelling time. When the initial and running cost is lower, the utility is higher. The utility for EVs depends on cruising distance. Higher income is assumed for users to afford to purchase more expensive cars.

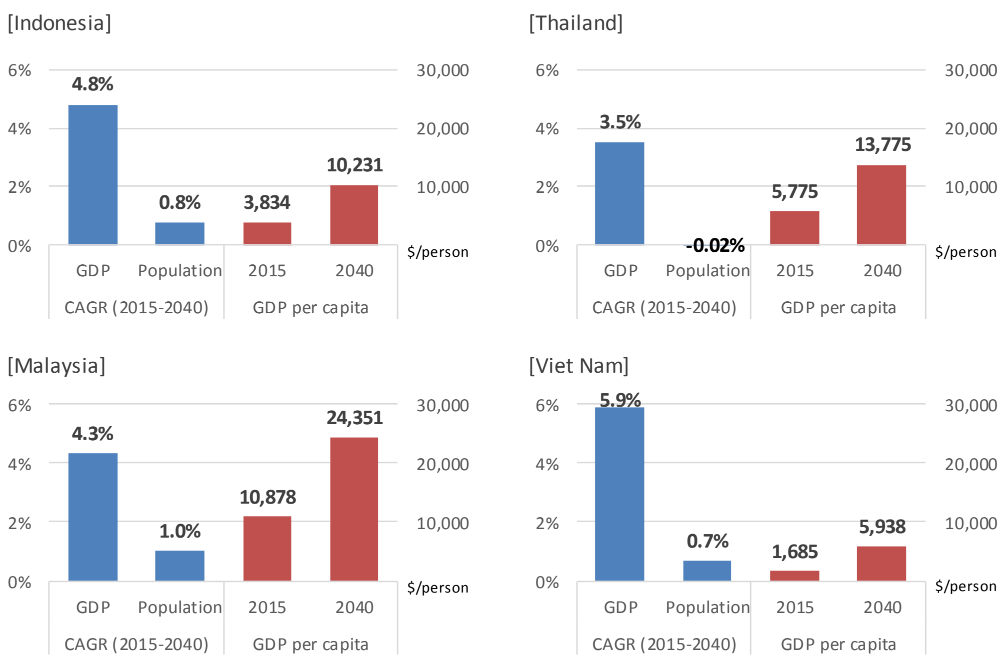
2. Main Assumptions for the Study

2.1. Demographic Assumptions

Population assumptions are from the United Nations' World Population Prospects (Figure 2.4). 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 (5.9%) and Indonesia (4.8%). Both countries have a young demographic structure and the potential to increase their low 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 (2018), United Nations (2017), and author's analysis.

2.2. Automobile Assumptions

When using the automobile model, various data such as number of vehicles owned, number of sales, fuel consumption, and travel distance are required for each vehicle and engine type. However, it is not easy to obtain these statistical data in ASEAN countries.

Data such as fuel consumption and mileage have to be estimated based on the literature survey Table 2.1 to Table 2.4 estimate average fuel efficiency and travel mileage by vehicle type. When calibrating them, we considered fuel consumption (IEA data) in the road sector as a control total.

Table 2.1: Calibration for Indonesia, 2015

	Actual	Calibration			Estimation	Actual
	No. of Stock*1 (1000unit)	Average Fuel Efficiency (km/L-gsl)	Average Mileage (km/yr)	Average Lifetime (Years)	Fuel Consumption (ktoe)	Fuel Consumption *2 (ktoe)
PLDV	13,481	11.8	10,000	10	9,073	
Bus	2,421	6.0	19,000	10	6,108	
Truck	6,611	5.6	14,000	15	13,167	
Motorbike	98,881	30.3	4,200	5	10,897	
Total					39,245	39,084

PLDV = passenger light duty vehicle.
Sources: Authors' analysis; *1: Badan Pusat Statistik (2018);
*2: International Energy Agency (2017).

Table 2.2: Calibration for Thailand, 2015

	Actual	Calibration			Estimation	Actual
	No. of Stock*1 (1000unit)	Average Fuel Efficiency (km/L-gsl)	Average Mileage (km/yr)	Average Lifetime (Years)	Fuel Consumption (ktoe)	Fuel Consumption *2 (ktoe)
PLDV	7,857	11.8	11,000	15	6,628	
Bus	582	5.8	15,000	15	1,565	
Truck	7,166	6.2	12,500	15	12,368	
Motorbike	20,519	39.0	5,000	10	2,087	
Total					22,648	22,691

PLDV = passenger light duty vehicle
Sources: Author's analysis; *1: Department of Land Transport (2018);
*2: International Energy Agency (2017).

Table 2.3: Calibration for Malaysia, 2015

	Actual	Calibration			Estimation	Actual
	No. of Stock*1 (1000unit)	Average Fuel Efficiency (km/L-gsl)	Average Mileage (km/yr)	Average Lifetime (Years)	Fuel Consumption (ktoe)	Fuel Consumption *2 (ktoe)
PLDV	13,167	12.3	15,000	20	14,426	
Bus	65	4.6	20,000	15	248	
Truck	1,198	5.1	18,000	15	3,712	
Motorbike	11,872	32.2	6,500	10	1,901	
Total					20,287	20,274

PLDV = passenger light duty vehicle
Sources: Author's analysis; *1: Malaysia Informative Data Centre (MysIDC) (2018); *2: International Energy Agency (2017).

Table 2.4: Calibration for Viet Nam, 2015

	Actual	Calibration			Estimation	Actual
	No. of Stock*1 (1000unit)	Average Fuel Efficiency (km/L-gsl)	Average Mileage (km/yr)	Average Lifetime (Years)	Fuel Consumption (ktoe)	Fuel Consumption *2 (ktoe)
PLDV	1,033	11.7	15,000	10	1,049	
Bus	118	4.6	18,000	10	365	
Truck	950	4.9	25,000	15	3,846	
Motorbike	45,398	35.1	5,000	5	5,135	
Total					10,395	10,390

PLDV = passenger light duty vehicle
Sources: Author's analysis; *1: Ministry of Transport (2018) and authors' estimation; *2: International Energy Agency (2017).

Whilst assuming constant average mileage during the outlook period, we also assumed that automobile fuel efficiency would gradually improve along with the technology (Table 2.5 to Table 2.8). Annual efficiency improvement rates are set based on historical trends: 0.5%–0.9% for ICEVs, 0.6%–0.7% for HEVs, 0.4%–0.5% for PHEVs,[1] and 0.2%–0.4% for BEVs.

[1] For PHEVs, efficiency is calculated by weighted-averaging HEV efficiency and BEV efficiency, assuming that 60%–70% of travel mileage is driven by electric motor.

Table 2.5: Fuel Economy in 2017 and 2040 (km/L-gasoline eq.), Indonesia

	ICV	HEV	PHEV	BEV
PLDV	12.3	24.6	39.2	49.0
Bus	6.4	9.5	19.5	25.3
Truck	6.0	9.0	19.6	23.9
Motorbike	30.8	-	-	115.0

	ICV	HEV	PHEV	BEV
PLDV	15.2	28.8	44.2	54.5
Bus	7.6	10.9	21.5	27.7
Truck	7.2	10.3	21.6	26.1
Motorbike	34.7	-	-	120.6

BEV = battery electric vehicle, ICV = internal combustion engine vehicle, PHEV = plug-in hybrid vehicle, PLDV = passenger light duty vehicle
Source: GFEI (2016), GFEI and IEA (2014), and authors' analyses.

Table 2.6: Fuel Economy in 2017 and 2040 (km/L-gasoline eq.), Thailand

	ICV	HEV	PHEV	BEV
PLDV	12.7	25.2	38.9	50.3
Bus	6.2	9.4	21.8	24.9
Truck	6.7	10.0	23.2	26.5
Motorbike	40.2	-	-	150.2

	ICV	HEV	PHEV	BEV
PLDV	17.1	31.7	46.3	58.5
Bus	7.5	10.7	23.9	27.2
Truck	8.0	11.4	25.5	29.0
Motorbike	45.3	-	-	157.6

BEV = battery electric vehicle, ICV = internal combustion engine vehicle, PHEV = plug-in hybrid vehicle, PLDV = passenger light duty vehicle
Source: GFEI (2016), GFEI and IEA (2014), and authors' analyses.

Table 2.7: Fuel Economy in 2017 and 2040 (km/L-gasoline eq.), Malaysia

	ICV	HEV	PHEV	BEV
PLDV	13.6	27.2	38.1	54.3
Bus	5.0	7.5	15.1	20.1
Truck	5.5	8.3	16.0	22.1
Motorbike	33.2	-	-	124.0

	ICV	HEV	PHEV	BEV
PLDV	17.3	32.5	43.9	61.1
Bus	6.0	8.6	16.6	22.0
Truck	6.6	9.5	17.6	24.2
Motorbike	37.4	-	-	130.0

BEV = battery electric vehicle, ICV = internal combustion engine vehicle, PHEV = plug-in hybrid vehicle, PLDV = passenger light duty vehicle
Source: GFEI (2016), GFEI and IEA (2014), and authors' analyses.

Table 2.8: Fuel Economy in 2017 and 2040 (km/L-gasoline eq.), Viet Nam

	ICV	HEV	PHEV	BEV
PLDV	12.7	25.2	35.3	50.3
Bus	5.1	7.6	16.0	20.3
Truck	5.6	8.4	13.9	22.3
Motorbike	35.7	-	-	133.3

	ICV	HEV	PHEV	BEV
PLDV	17.1	31.7	42.4	58.5
Bus	6.9	9.6	19.0	23.6
Truck	7.6	10.6	16.7	26.0
Motorbike	40.2	-	-	139.9

BEV = battery electric vehicle, ICV = internal combustion engine vehicle, PHEV = plug-in hybrid vehicle, PLDV = passenger light duty vehicle
Source: GFEI (2016), GFEI and IEA(2014), and authors' analyses.

Automobile sale prices are an important element of the multinomial logit model. The prices are common in the four countries and assumed to gradually decline (but rise only for ICEVs) along the learning curve (Table 2.9). Learning rates are set as 101% for the base component and 80% for the battery system. For other components of specific powertrains, the rates are set as 90%–95% for HEVs, 85% for PHEVs, and 80%–85% for BEVs.

Table 2.9: Assumptions for List Price in 2017 and 2040 (US$ in 2010 / unit)

	ICV	HEV	PHEV	BEV
PLDV	22,000	27,500	38,720	35,200
Bus	67,000	77,050	184,250	167,500
Truck	47,000	58,750	82,720	75,200
Motorbike	1,500	-	-	2,400

	ICV	HEV	PHEV	BEV
PLDV	22,169	25,347	27,564	24,401
Bus	67,547	74,052	91,378	77,398
Truck	47,384	54,913	54,743	50,238
Motorbike	1,498	-	-	1,837

BEV = battery electric vehicle, ICV = internal combustion engine vehicle, PHEV = plug-in hybrid vehicle, PLDV = passenger light duty vehicle
Source: Mitsubishi Fuso, Toyota, Nissan, Hino, and authors' analyses.

2.3. Reference Scenario

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

2.3.1. Automobile Penetration

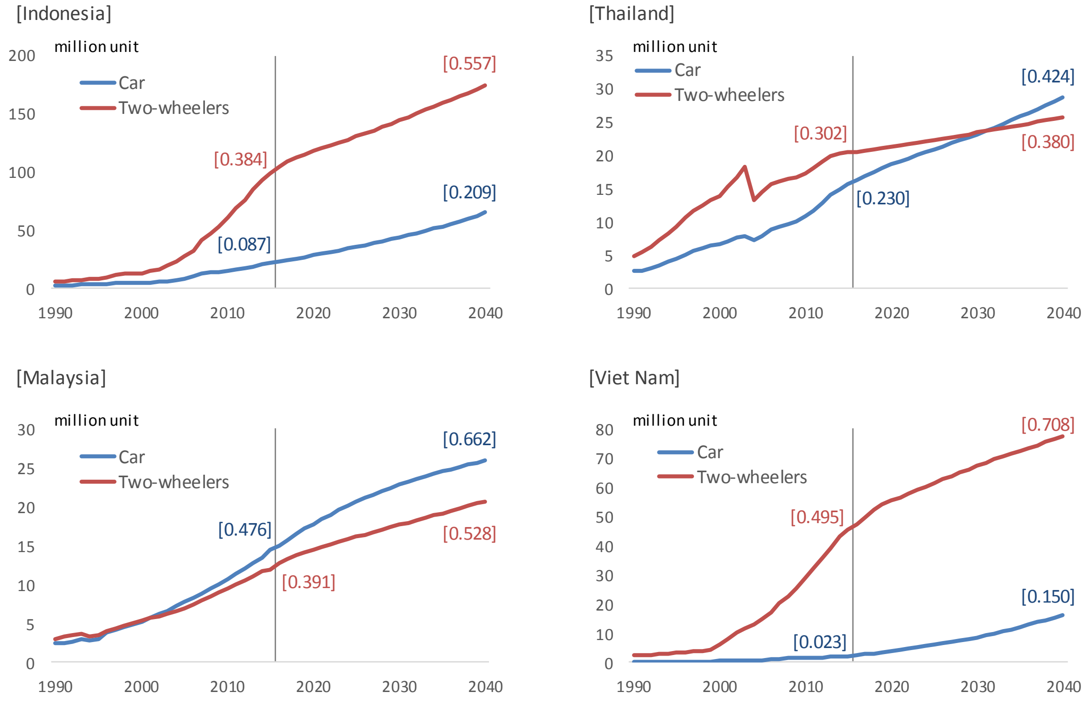
Assuming the above, car (PLDV, bus, truck) stock[2] in the four countries is projected to increase 2.5 times to 136 million units by 2040, from 122 per 1,000 people in 2015 to 258 in 2040, which is still much lower than the OECD average of 589 per 1,000 people in 2015. Cars in Viet Nam increase about eight times and in Indonesia three times. Growth in

[2] We do not consider the effects of carsharing, the future of which is challenging to estimate.

Thailand and Malaysia is less than two times because ownership rates are already relatively high.

Motorbikes, which are more than three times the number of cars today, increase 1.7 times. Growth is more moderate than for cars in all countries. Each country except Malaysia has higher motorbike than car ownership. In Viet Nam, especially, nearly 500 per 1,000 people own motorbikes and that number could increase to about 700.

Figure 2.5: Outlook for Vehicle Stock

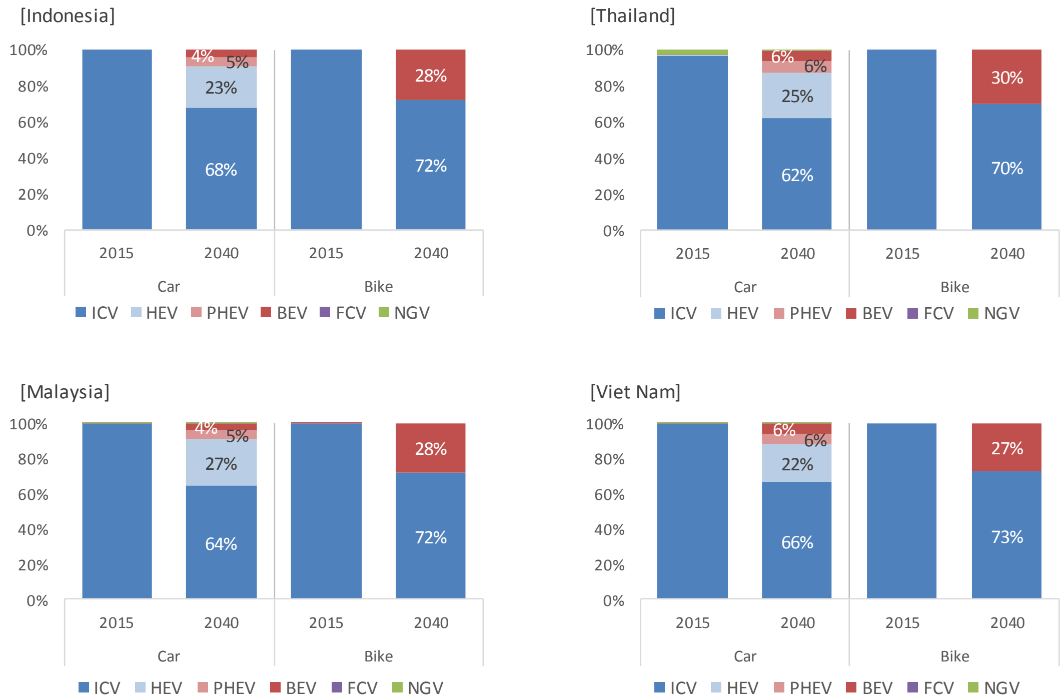


Sources: Indonesia: BPS – Statistics Indonesia (2018); Viet Nam: Ministry of Transport (2018); Thailand: Department of Land Transport (2018); Malaysia: Malaysia Informative Data Centre (MysIDC) (2018); authors' analyses.

For the mix by powertrain, conventional ICEVs keep dominant up to 2040 and hybrid electric vehicles gradually increase their sales share to around 25% in the reference scenario. Sales of PHEVs increase to 5%–6% of total car sales by 2040, and EV sales account for only 4%–6% due to higher cost and shorter cruising distance than that of other powertrains.

Electric bikes will make up around 30% of the motorbike market due to the small price gap between ICEVs and BEVs.

Figure 2.6: Sales Share by Powertrain



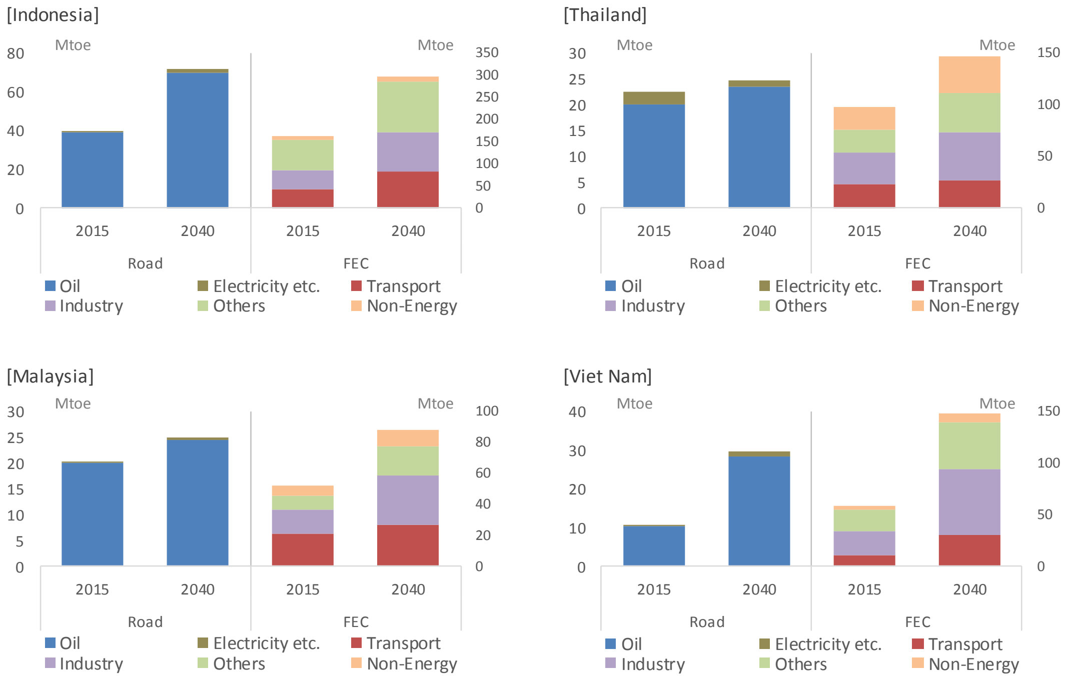
BEV = battery electric vehicle, FCV = fuel-cell vehicle, HEV = hybrid electric vehicle, ICEV = internal combustion engine vehicle, NG.V = natural gas vehicle, PHEV = plug-in hybrid vehicle
Source: Authors' analysis.

2.3.2. Fuel Consumption in the Road Sector

Fuel consumption, mostly oil, in the road sector increases 1.6 times by 2040 in the four countries. Growth is slow relative to stocks due to efficiency improvement, including the shift to HEVs from ICEVs. Consumption in Viet Nam rapidly increases, almost triples by 2040, whilst in Thailand and Malaysia, oil consumption for automobiles peaks and then declines before 2040.

Energy demand in the transport sector, including the road sector, rapidly increases but shares in final energy consumption stay at today's level in Indonesia and Viet Nam. For Thailand and Malaysia, transport sector shares in final energy consumption decline by 6 and 10 percentage points in 2040 from today, respectively.

Figure 2.7: Energy for the Road Sector and Total Final Consumption



Mtoe= million ton of oil equivalent, FEC=final energy consumption
Source: IEA (2017), authors' analysis.

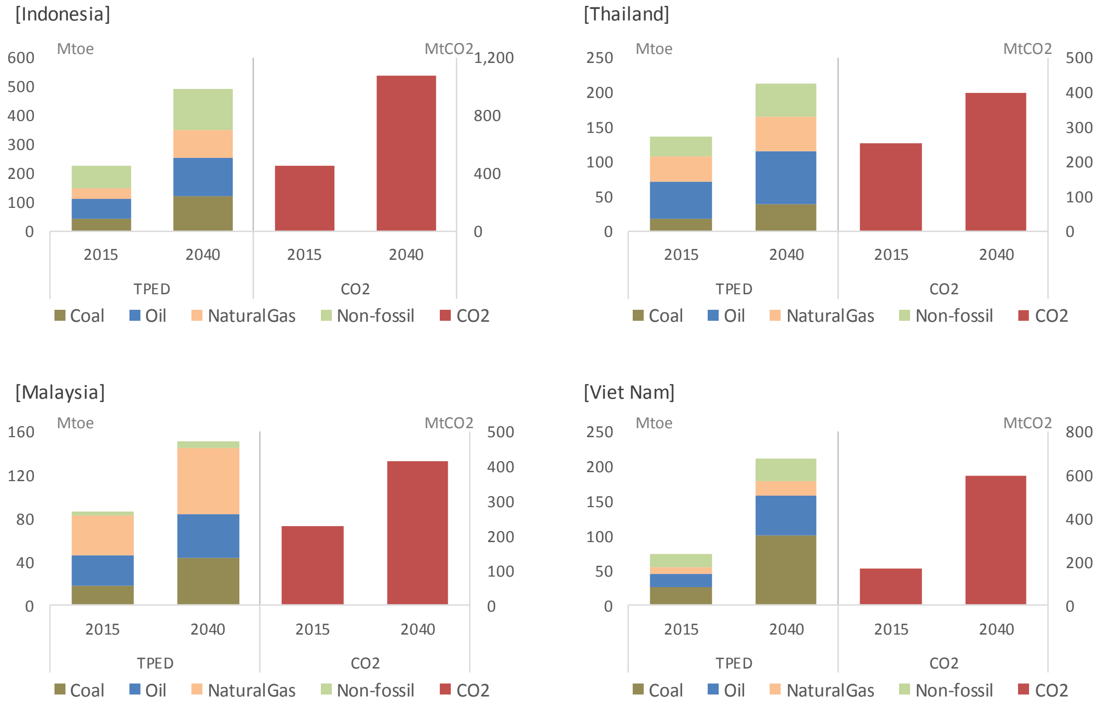
2.3.3. Primary Energy Demand and CO_2 Emissions

Total primary energy demand, which combines final energy consumption and the transformation sector, including power generation, increase annually by 3.2% in Indonesia, 4.3% in Viet Nam, 1.8% in Thailand, and 2.3% in Malaysia. These growth rates are much lower than their economic growth rates, which means that energy efficiency is rapidly improving.

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

Maintaining high fossil-fuel dependency leads to increasing CO_2 emissions. CO_2 emissions increase annually by 3.5% in Indonesia and 5.2% in Viet Nam, higher than energy-demand growth, meaning that their energy mix becomes more carbon intensive. In Thailand and Malaysia, CO_2 emissions grow at almost the same rate as energy demand.

Figure 2.8: Primary Energy Demand and CO_2 Emissions



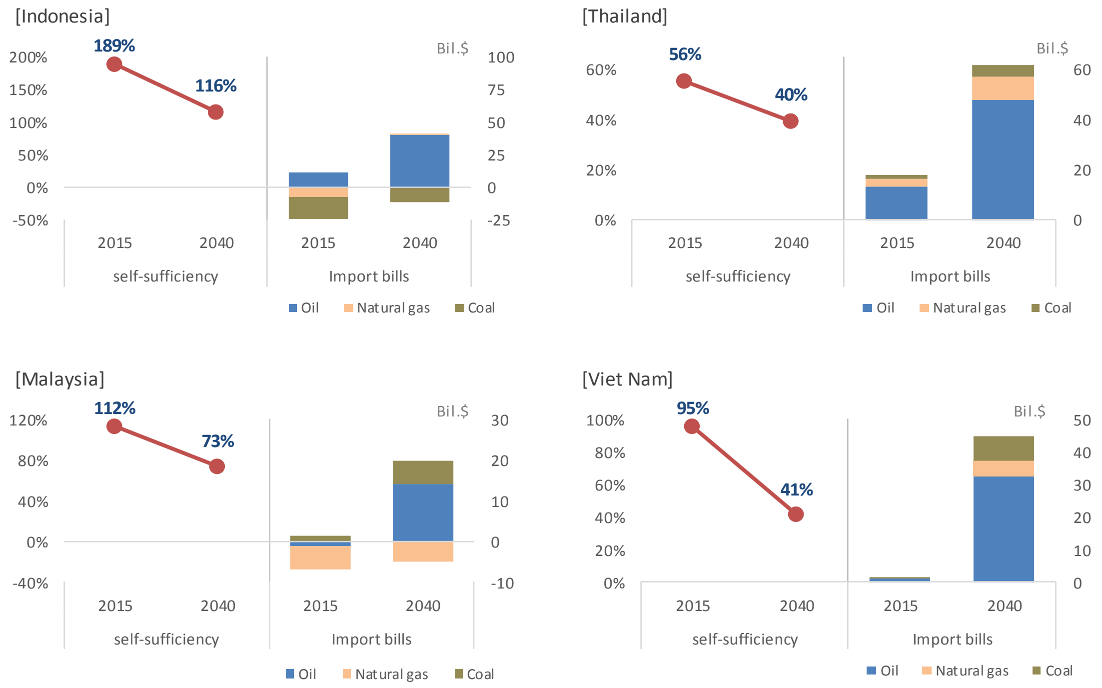
CO2 = carbon dioxide, MtCO2=million ton of carbon dioxide, Mtoe= million ton of oil equivalent, TPED = total primary energy demand.
Source: IEA (2017), authors' analysis.

2.3.4. Energy Self-sufficiency

High fossil-fuel dependency results in lower energy self-sufficiency. One of the largest coal exporters, Indonesia maintains its self-sufficiency at over 100% but it drops significantly from today's level. Malaysia is a net energy export country today but will become a net energy importer within 10 years. Thailand and Viet Nam are already net importers and their self-sufficiency rates decrease further.

Net import bills (imports less exports) dramatically increase in the four countries as their oil self-sufficiency declines, even though Indonesia and Malaysia export coal and gas, because oil import prices on a calorific basis are much higher than coal and gas export prices.

Figure 2.9: Energy Self-sufficiency and Net Import Bills



Bil.$ = US billion dollars.
Source: IEA (2017), authors' analysis.

Chapter 3

Impacts on the 3Es by xEV Penetration

1. Alternative Scenarios

The four countries may have challenging issues 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 EV Penetration

Remarkable vehicle technology development in recent years has accelerated the penetration of EVs, although their market share is still small. Various countries have announced policies to promote xEVs, including a ban on ICEVs from 2030, not only to mitigate climate change but also to improve air quality in big cities and reduce crude oil imports.

Some alternative scenarios confirm that promoting xEVs will have an impact on the 3Es. The policy target scenario achieves the government target for xEV penetration. Indonesia announced a policy to ban sales of ICEVs by 2040 whilst a Ministry of Industry roadmap targets increasing the sales share of low carbon emission vehicles (HEVs, PHEVs, BEVs) to 20% by 2025. Thailand targets introducing 1.2 million PHEVs and BEVs by 2036. Malaysia targets introducing 202,000 BEVs (100,000 cars, 2,000 buses, 100,000 motorcycles) by 2030. Viet Nam has no numerical target for xEVs.

The BEV ambitious scenario sets BEV market share at almost 100% by 2040. The HEV bridge scenario is assumed to start with low-cost HEVs, and BEVs are gradually introduced starting around 2030 when the cost of BEVs starts to decline.

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. Market share is assumed to reach almost 100% by 2040.

1.2. Scenario Assumptions for Power Generation Mix

EV penetration's impact on energy and the economy largely depends on the power generation mix. Therefore, we consider alternative scenarios for power generation mix and for xEV dissemination. In the reference scenario, the power generation mix is based on past trends and power development plans. Each government sets the target for introducing renewable energy sources.

Indonesia aims to use renewable energy to cover 23% of primary energy supply by 2025, which requires 26% renewable energy share for the power generation mix. In Malaysia, the minister for energy, science, technology, environment, and climate said that the share of renewable energy in the power generation mix will be increased by 20% by 2030. Viet Nam aims to raise the share of renewable energy in the power generation mix to 32% by 2030 and 43% by 2050 (Ministry of Industry and Trade, 2015). The policy target scenario sets the power generation mix up to 2040 according to these government targets. In Thailand, which has no government target for renewable energy, the policy target scenario follows the Thailand Power Development Plan (Ministry of Energy, 2015).

1.3. Alternative Scenarios

In addition to the reference scenario, four alternative scenarios are set for xEVs and one for power generation mix. We analyse seven alternative scenarios and compare them with the reference scenario to quantitatively examine the influence of the 3Es (Table 3.1).

- Scenario 0: Continuing historical trends without strengthening policy measures.
- Scenario 1: Gradual transition from HEV to BEV penetration under the reference power generation mix
- Scenario 2: Rapid transition to BEV with 100% sales in 2040 under the reference power generation mix
- Scenario 3: Rapid transition to battery motorcycles with 100% sales in 2040 under the reference power generation mix
- Scenario 4: xEV penetration with the policy target under the targeted (and cleaner) power generation mix
- Scenario 5: Gradual transition from HEV to BEV penetration under the targeted (and cleaner) power generation mix
- Scenario 6: Rapid transition to BEV with 100% sales in 2040 under the targeted (and cleaner) power generation mix
- Scenario 7: Rapid transition to battery motorcycles with 100% sales in 2040 under the targeted (and cleaner) power generation mix

Table 3.1: Alternative Scenarios

		Power Generation Mix Scenario	
		Reference	Policy Target (RE advanced)
xEV Scenario	Reference	0	-
	Policy target	-	4
	HEV bridge (start with HEV, then to BEV)	1	5
	BEV ambitious (nearly 100% sales in 2040)	2	6
	E-motorcycle advanced (nearly 100% sales in 2040)	3	7

BEV = battery electric vehicle; e-motorcycle = electric motorcycle; HEV = hybrid electric vehicle; xEVs = electric vehicles (including HEV, PHEV, and BEV).

Source: Authors.

1.4. Assumptions for Investments and Subsidies

In analysing the alternative scenarios, we estimate the amount of required investment (vehicles, charging equipment, power generation equipment) as the additional investment from the reference scenario. In more detail, the investment amount for vehicles is calculated by summing up vehicle price (Table 2-9) multiplied by sales number by powertrain type for each scenario. The same applies for charging equipment and power generation equipment. The additional investment is considered part of demand in GDP each year, which will stimulate economic activity.

The alternative scenarios for xEVs might not be realised unless strong promotion policies such as economic incentives are implemented. Therefore, subsidies for xEVs are necessary and we estimate the total subsidy amount for each scenario. Subsidies to xEVs are granted to shorten the payback period to half the average lifetime. The payback period is a usage period in which the vehicle price and the total fuel cost of driving are equal for ICEVs and xEVs. If xEV prices are lowered due to technological progress, subsidies will stop when the payback period falls below half the average life time.

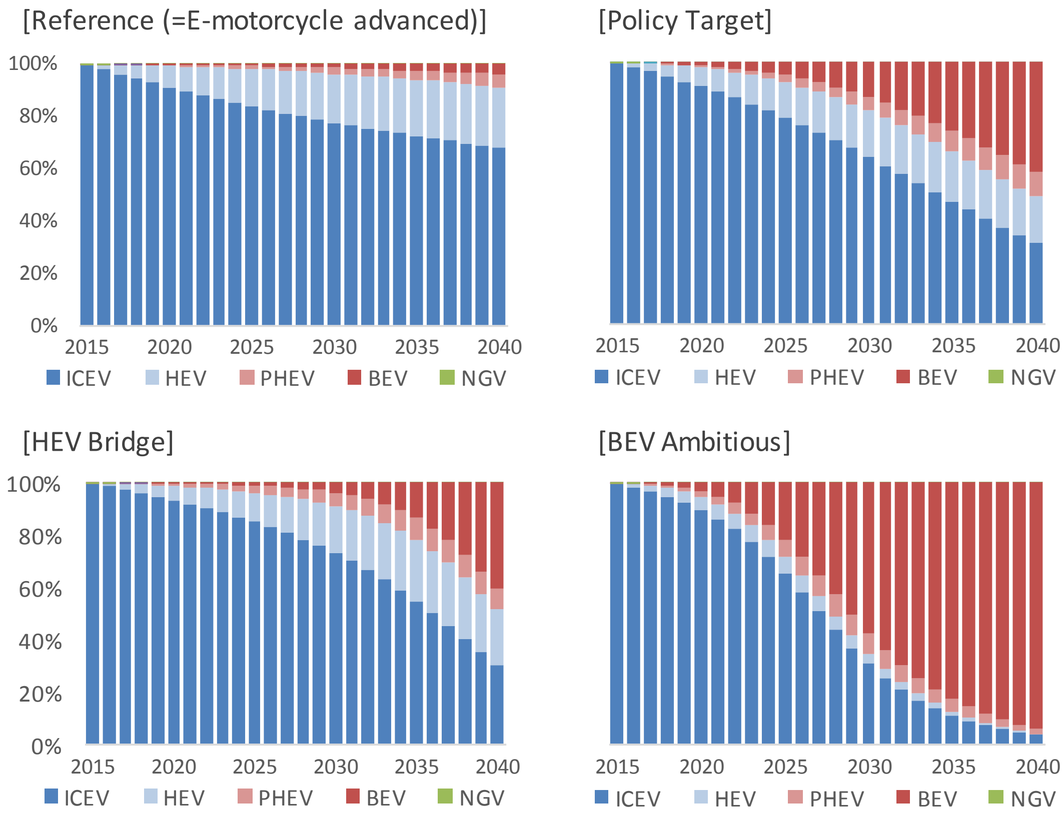
2. Results of Alternative Scenarios

2.1. Indonesia

In 2016, Indonesia had 23.7 million cars, accounting for about 40% of all cars in ASEAN. With high economic growth of about 5% per year, the country will have 2.8 times more cars by 2040. The country has 104.8 million motorcycles, more than four times the number of cars, or 400 motorcycles per 1,000 people. As incomes increase, motorcycles will increase

1.7 times in 2040, more slowly than cars. Powertrain sales share of cars and motorcycles by scenario are shown in Figure 3.1 and Figure 3.2.

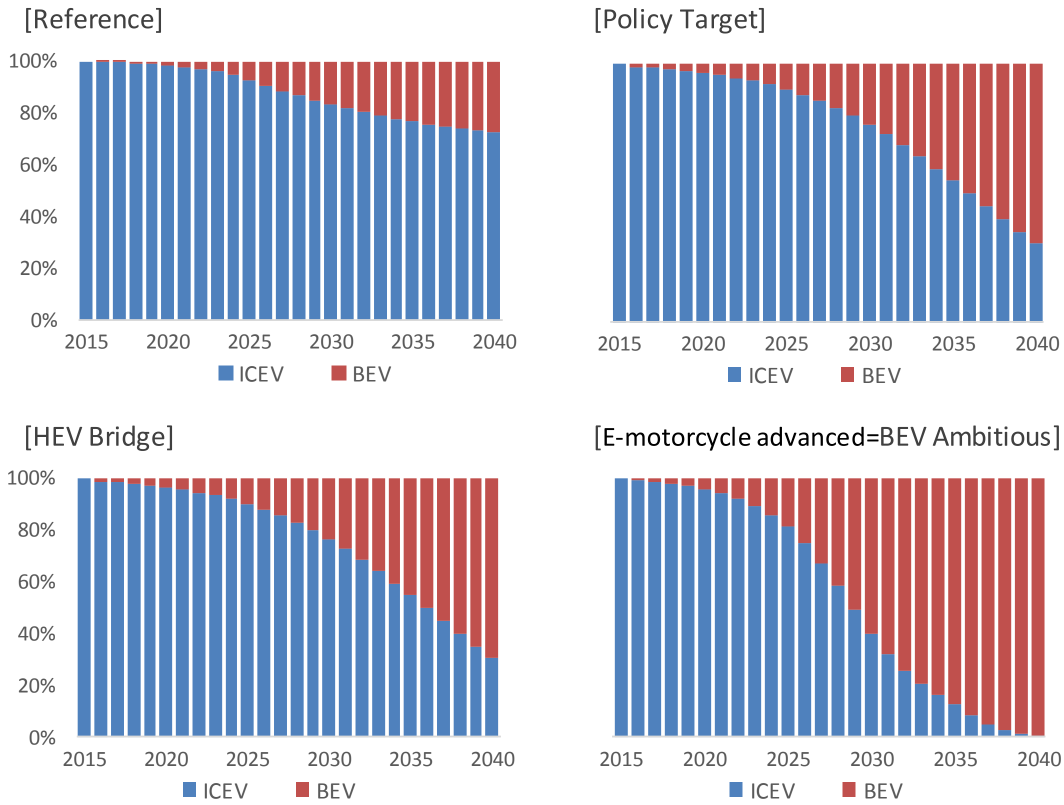
Figure 3.1: Powertrain Sales Share of Cars by Scenario, Indonesia



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.

Source: Authors' analysis.

Figure 3.2: Powertrain Sales Share of Motorcycles by Scenario, Indonesia

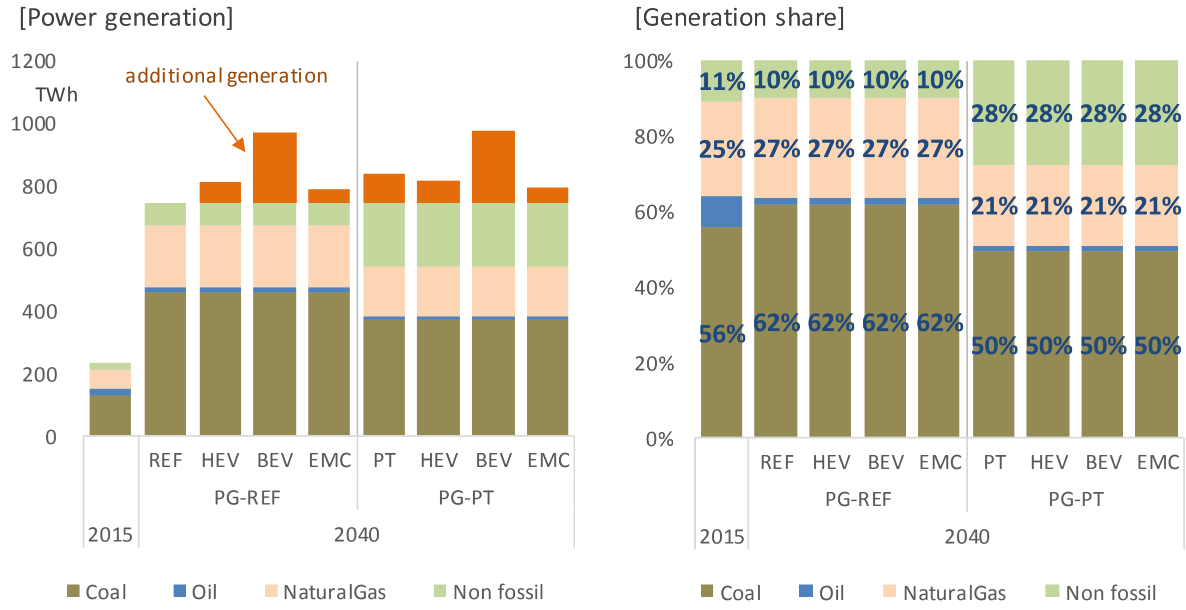


BEV = battery electric vehicle, FCV = fuel-cell vehicle, HEV = hybrid electric vehicle, ICEV = internal combustion engine vehicle, NGV = natural gas vehicle, PHEV = plug-in hybrid vehicle

Source: Authors' analysis.

Electricity demand will increase due to EV penetration. In 2040, in the BEV ambitious scenario, required power generation increases by 220 TWh or 30% more than in the reference scenario, where power generation mix is 62% coal, 27% gas, and 9% non-fossil fuel (CO_2 emissions per kWh are 666 g-CO_2/kWh). In the policy target scenario, power generation mix is 51% coal, 21% gas, and 25% non-fossil fuel (CO_2 emissions per kWh are 535 g-CO_2/kWh), promoting low carbonisation.

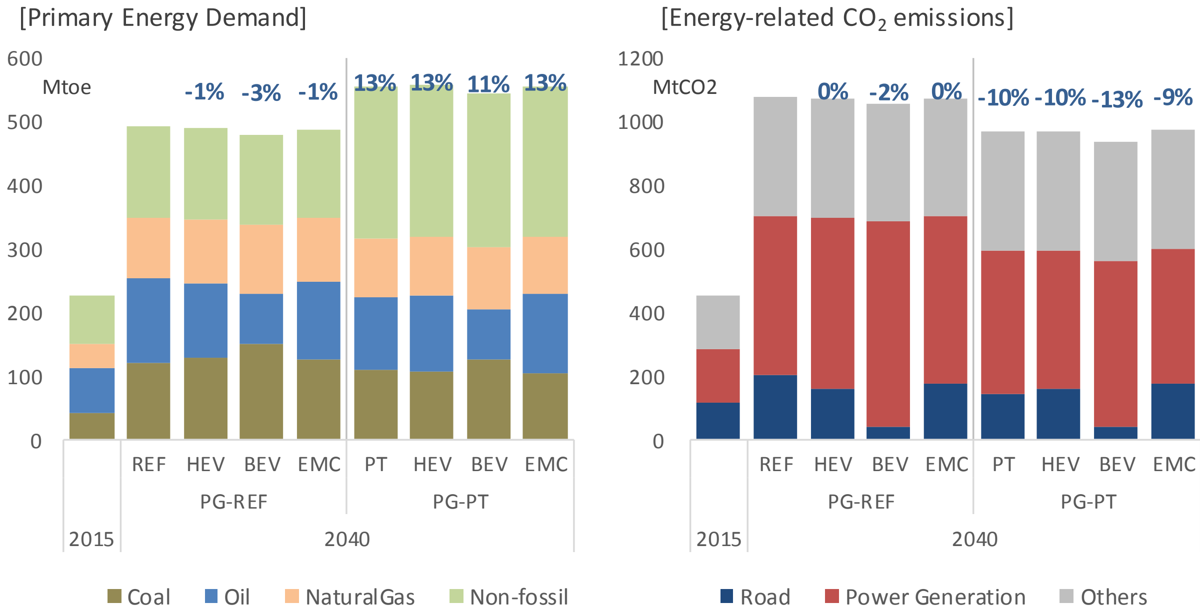
Figure 3.3: Power Generation and Generation Mix, Indonesia



BEV = battery electric vehicle ambitious, EMC = electric motorcycle advanced, HEV = hybrid electric vehicle bridge, REF = reference, PG = power generation, PT = policy target.
Note: Not including electricity imports.
Source: IEA (2017), authors' analysis.

Primary energy demand in the reference scenario for the power generation mix in the HEV bridge scenario and in the BEV ambitious scenario decreases by only 1% and 3%, respectively, compared with the reference scenario (Figure 3-4). The reason is that in the BEV ambitious scenario, oil demand in the transport sector decreases (52 Mtoe), whilst fuel input to the power generation sector increases (44 Mtoe). xEV penetration does not lead to large emission reductions, and the difference in emissions between the HEV bridge and the BEV ambitious scenarios is only around 2%. In the policy target scenario for power generation mix, the difference in emissions between the HEV bridge and the BEV ambitious scenarios increases to about 3%. In the policy target scenario for power generation mix, primary energy demand increases because the share of geothermal power generation with low conversion efficiency (5%) is high.

Figure 3.4: Primary Energy Demand and Energy-related CO_2 Emissions, Indonesia



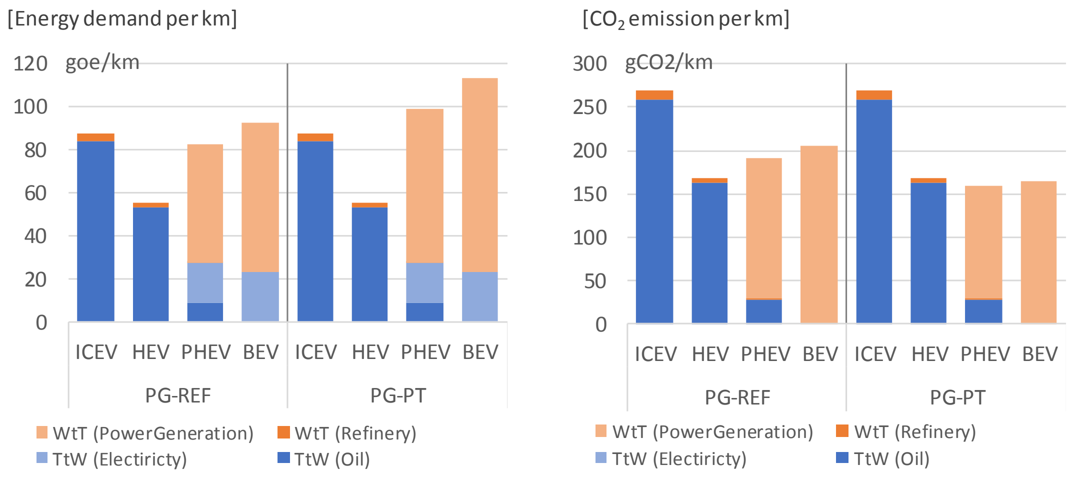
BEV = battery electric vehicle ambitious, EMC = electric motorcycle advanced, HEV = hybrid electric vehicle bridge, REF = reference, PG = power generation, PT = policy target.

Notes: 1. % shows the change rate from the reference scenario. 2. Replacing fossil-fuel thermal powers with geothermal power (primary conversion efficiency of 5%) increases primary energy.

Source: IEA (2017), authors' analysis.

In 2040, BEVs consume more energy than ICEVs because consumption is small in tank to wheel but large in well to tank. Energy consumption in well to tank under the policy target scenario for power generation mix increases because the share of geothermal power generation with low conversion efficiency is high. BEVs produce less CO_2 emissions than ICEVs and a certain CO_2 reduction effect can be expected. However, BEVs' CO_2 emissions in the reference scenario for power generation mix are larger than HEVs' (Figure 3-5). In the policy target scenario for power generation mix, BEVs' CO_2 emissions are slightly lower than HEVs'.

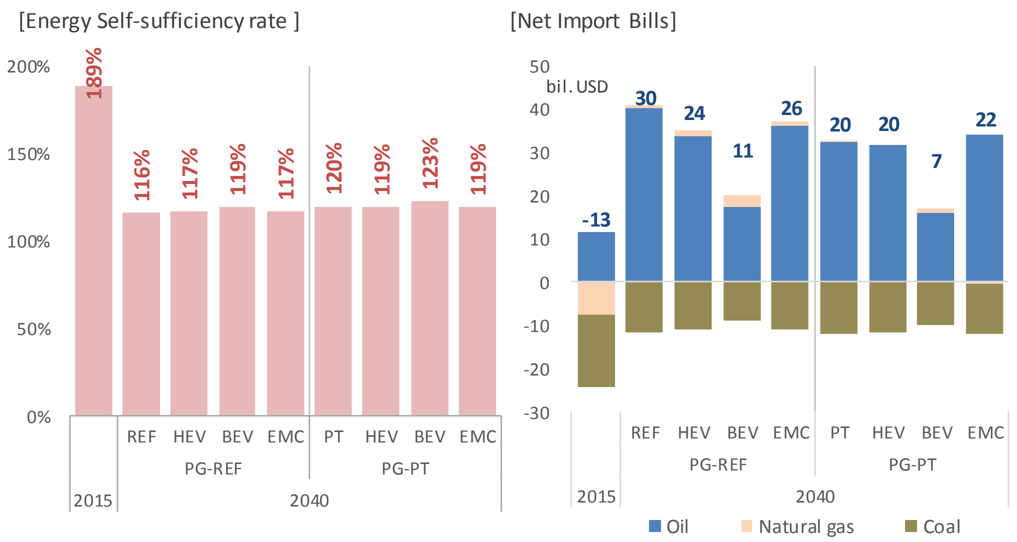
Figure 3.5: Well to Wheel by Powertrain, 2040, Indonesia



BEV = battery electric vehicle ambitious, EMC = electric motorcycle advanced, HEV = hybrid electric vehicle bridge, REF = reference, PG = power generation, PT = policy target, TtW = tank to wheel, WtT = well to tank.
Note: Well to tank does not include energy consumption in fossil-fuel production and transport.
Source: Authors' analysis.

Indonesia's energy self-sufficiency drops significantly in 2040 but the difference between scenarios is not large. The net import value of energy in the reference scenario in 2040 is US$30 billion but that in the BEV ambitious scenario greatly decreases to US$11 billion. The net import value of energy in the policy target scenario for power generation mix is further reduced.

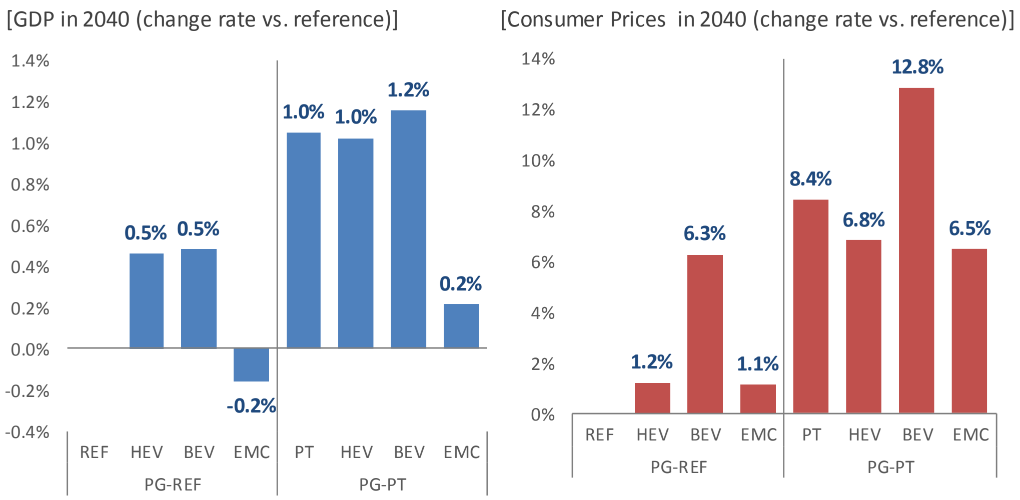
Figure 3.6: Energy Self-sufficiency Rate and Net Import Bills, Indonesia



BEV = battery electric vehicle ambitious, EMC = electric motorcycle advanced, HEV = hybrid electric vehicle bridge, REF = reference, PG = power generation, PT = policy target,
Source: IEA (2017), authors' analysis.

xEVs' impact on GDP is slightly positive because suppression of net imports such as petroleum and investments (additional cost for conventional technology) in xEVs (and low-carbon power) stimulate the economy.[3] The economic impact of the e-motorcycle advanced scenario is insignificant. Investments in xEVs (and low-carbon power) do not expand production investments or supply capacity. As a result, supply and demand are tight and general prices rise greatly. In 2040, consumer prices in the BEV ambitious + policy target scenario for power generation mix are 13% higher than in the reference scenario.

Figure 3.7: Impacts on GDP and Consumer Prices, Indonesia



BEV = battery electric vehicle ambitious, EM C= electric motorcycle advanced, HEV = hybrid electric vehicle bridge, REF = reference, PG = power generation, PT = policy target.
Source: IEA (2017), authors' analysis.

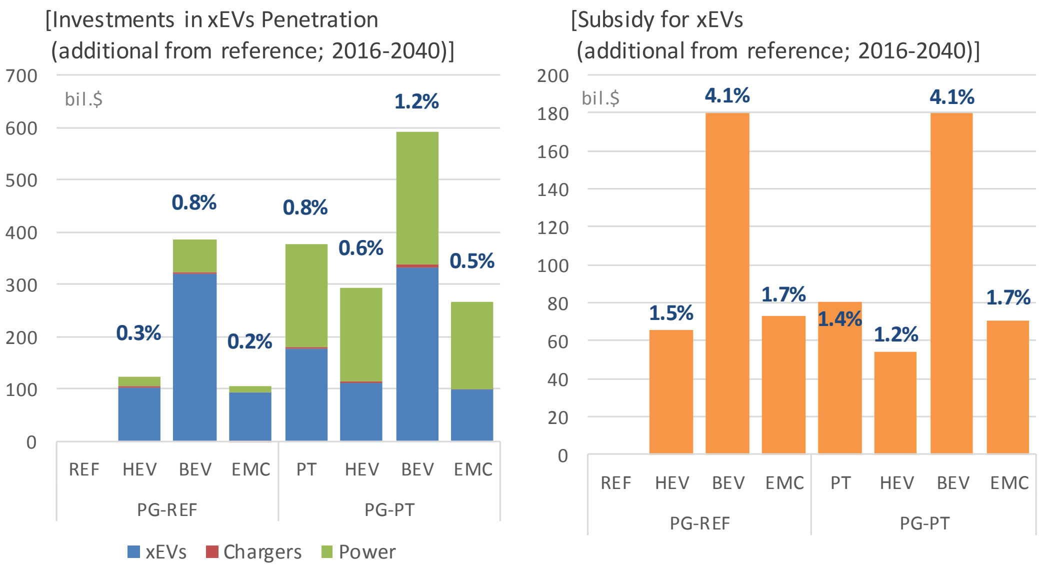
Investment in xEV penetration (vehicles, charging facilities, power-generating equipment) reaches US$123 billion (cumulative in 2016–2040) in the HEV bridge scenario and US$386 billion in the BEV ambitious scenario. Cumulative investment accounts for 0.3% and 0.8% of cumulative GDP, respectively. In the policy target scenario for power generation mix, further investments in low-carbon power are required.

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. Assuming grant subsidies that shorten the payback period to half the average lifetime, the total subsidy is US$65 billion (cumulative in 2016–2040) in the HEV bridge scenario and US$180 billion in the BEV ambitious scenario. Cumulative subsidy accounts for 1.5% and 4.1% of the cumulative government budget, respectively. However, subsidies to energy (gasoline, diesel oil, and electricity) are not considered. When BEVs increase, oil demand decreases and electricity demand increases. If the dropped subsidy for

[3] Purchase of personal passenger cars and motorcycles is not investment but consumption. Budget-constrained consumers will not stimulate the economy.

oil exceeds the additional subsidy for electricity, the total amount may decrease, but if the subsidy for electricity is larger, the total amount increases.

Figure 3.8: Investments and Subsidy for xEVs, Indonesia

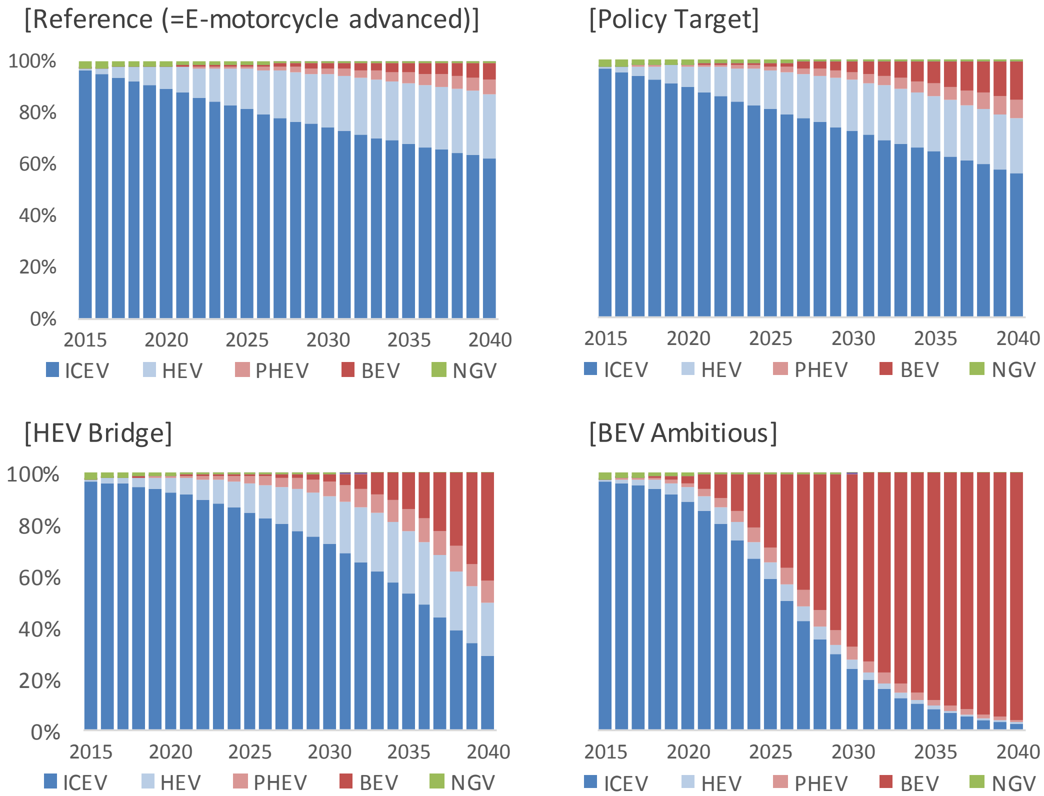


BEV = battery electric vehicle ambitious, EMC = electric motorcycle advanced, HEV = hybrid electric vehicle bridge, REF = reference, PG = power generation, PT = policy target.
Notes: 1. Assuming grant subsidies that shorten the payback period to half the average lifetime. 2. % shows investment ratios of GDP and subsidy ratios of government revenue.
Source: IEA (2017), authors' analysis.

2.2. Thailand

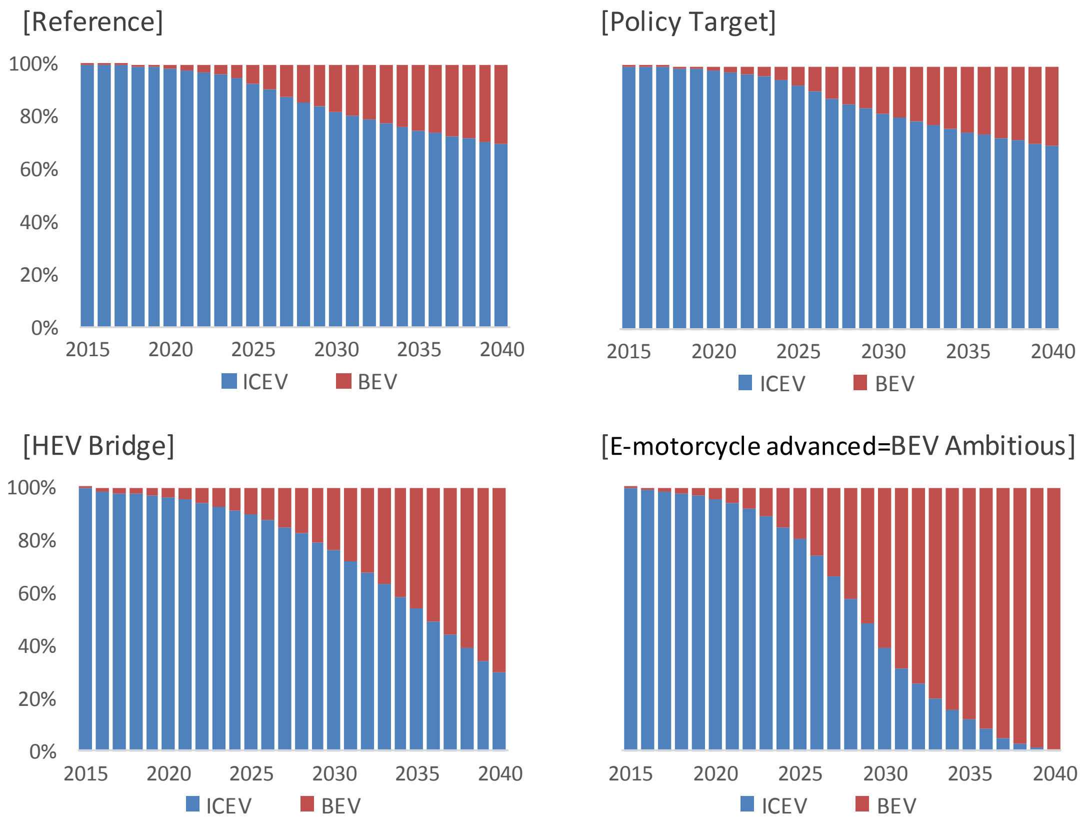
In 2016, Thailand had 16.2 million cars, accounting for less than 30% of all cars in ASEAN. With relatively moderate economic growth and an ageing society, the country will see the number of cars in 2040 increase 1.8 times, less than in other ASEAN countries. The country has 20.5 million motorcycles. As people shift from motorcycles to cars, motorcycles in 2040 will increase 1.3 times and outnumber cars. Powertrain sales share of cars and motorcycles by scenario are shown in Figure 3 and Figure 3.

Figure 3.9: Powertrain Sales Share of Cars by Scenario, Thailand



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.
Source: Authors' analysis.

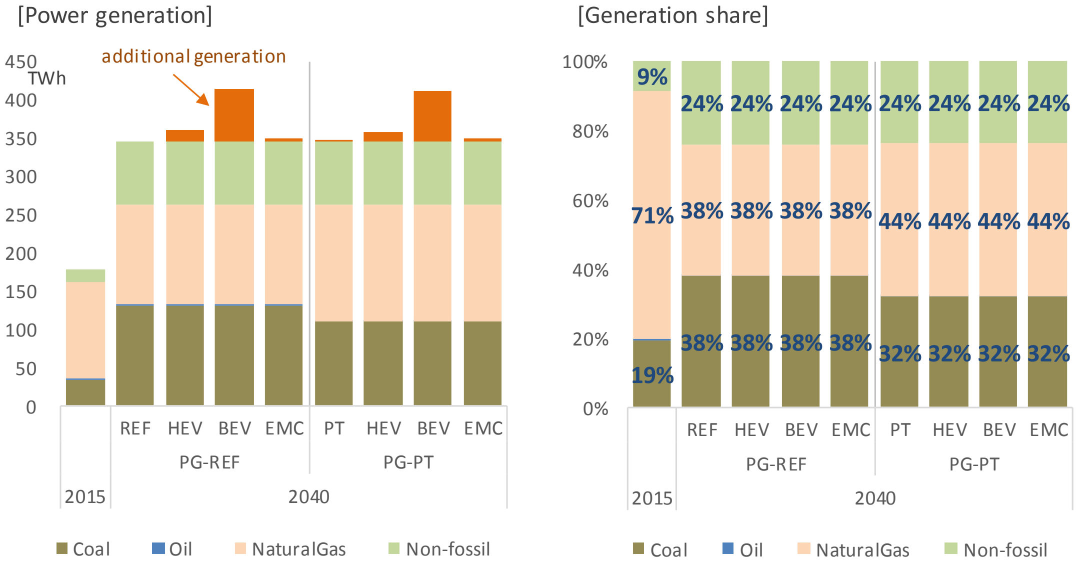
Figure 3.10: Powertrain Sales Share of Motorcycles by Scenario, Thailand



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.
Source: Authors' analysis.

Electricity demand will increase due to EV penetration. In 2040, in the BEV ambitious scenario, required power generation increases by 69 TWh or 20% more than in the reference scenario, where power generation mix is 38% coal, 38% gas, and 24% non-fossil fuel (CO_2 emissions per kWh are 490 g-CO_2/kWh). In the policy target scenario, power generation mix is 32% coal, 44% gas, and 24% non-fossil fuel (CO_2 emissions per kWh are 464 g-CO_2/kWh), promoting low carbonisation.

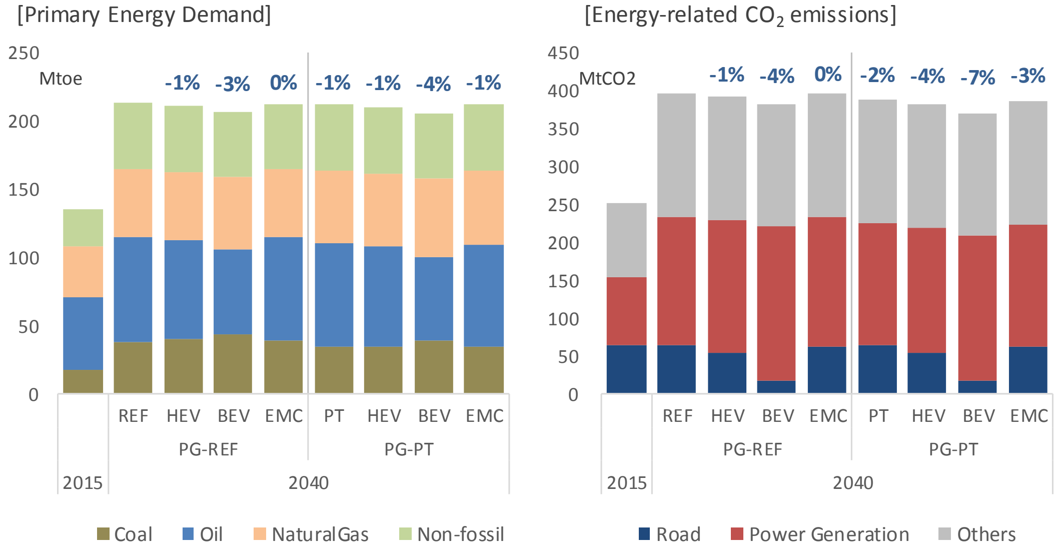
Figure 3.11: Power Generation and Generation Mix, Thailand



BEV = battery electric vehicle ambitious, EMC = electric motorcycle advanced, HEV hybrid electric vehicle bridge, REF = reference, PG = power generation, PT = policy target.
Note: Not including electricity imports.
Source: IEA (2017), authors' analysis.

Primary energy demand under the reference scenario for the power generation mix in the HEV bridge scenario and in the BEV Ambitious scenario decreases by 1% and 3%, respectively, compared with the reference scenario (Figure 3.12). The reason is that in the BEV ambitious scenario, oil demand in the transport sector decreases (15 Mtoe), whilst fuel input to the power generation sector increases (12 Mtoe). xEV penetration does not lead to large emission reductions, and the difference in emissions between the HEV bridge and the BEV ambitious scenarios is only around 3%.

Figure 3.12: Primary Energy Demand and Energy-related CO_2 Emissions, Thailand

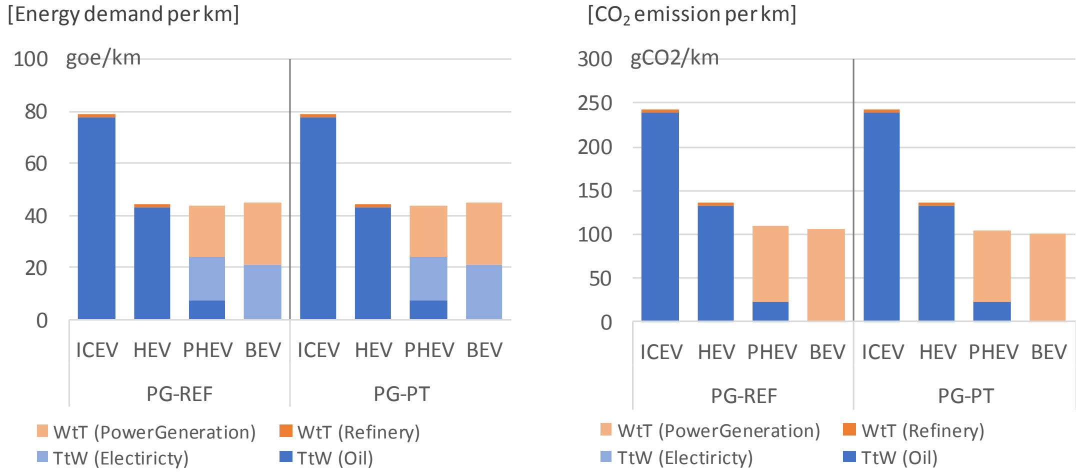


BEV = battery electric vehicle ambitious, EMC = electric motorcycle advanced, HEV = hybrid electric vehicle bridge, REF = reference, PG = power generation, PT = policy target.
Note: % show change rates from the reference scenario.
Source: IEA (2017), authors' analysis.

In 2040, BEVs consume less energy than ICEVs and almost the same as HEVs because consumption is small in tank to wheel but large in well to tank. BEVs produce less CO_2 emissions than HEVs and a certain CO_2 reduction effect can be expected. In terms of energy consumption and CO_2 emissions, however, there is not so much difference between policy target and reference scenarios (Figure 3.13).

Thailand's energy self-sufficiency drops significantly in 2040 but the difference between scenarios is not large. The net import value of energy in the reference scenario in 2040 is US$62 billion but that in the BEV ambitious scenario greatly decreases to US$50 billion. In the policy target scenario for power generation mix, the energy import value is slightly larger because the share of gas-fired power generation with high gas price is high.

Figure 3.13: Well to Wheel by Powertrain in Cars in 2040, Thailand

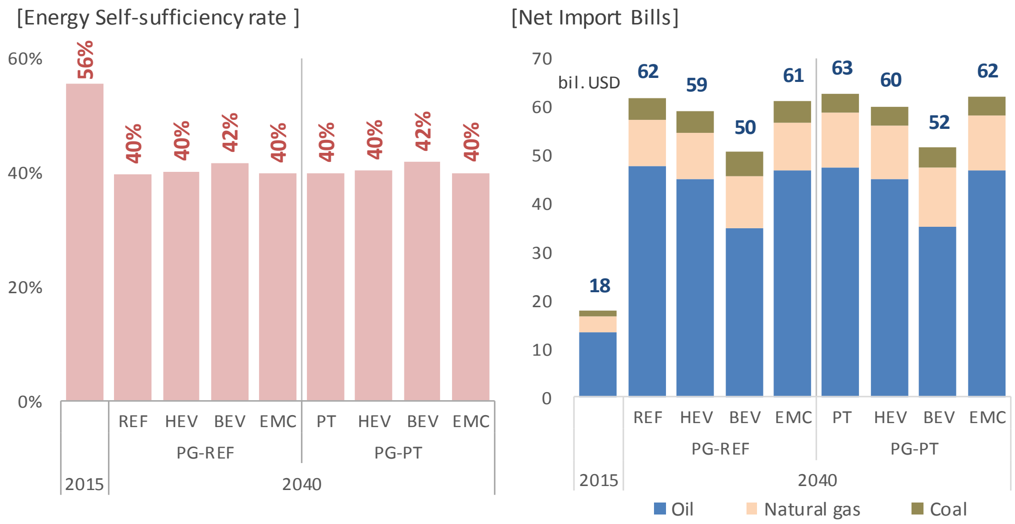


BEV = battery electric vehicle ambitious, EMC = electric motorcycle advanced, HEV = hybrid electric vehicle bridge, REF= reference, PG = power generation, PT = policy target, ,WtT = well to tank, TtW = tank to wheel.

Note: Well to tank does not include energy consumption in fossil-fuel production and transport.

Source: Authors' analysis.

Figure 3.14: Energy Self-sufficiency Rate and Net Import Bills, Thailand

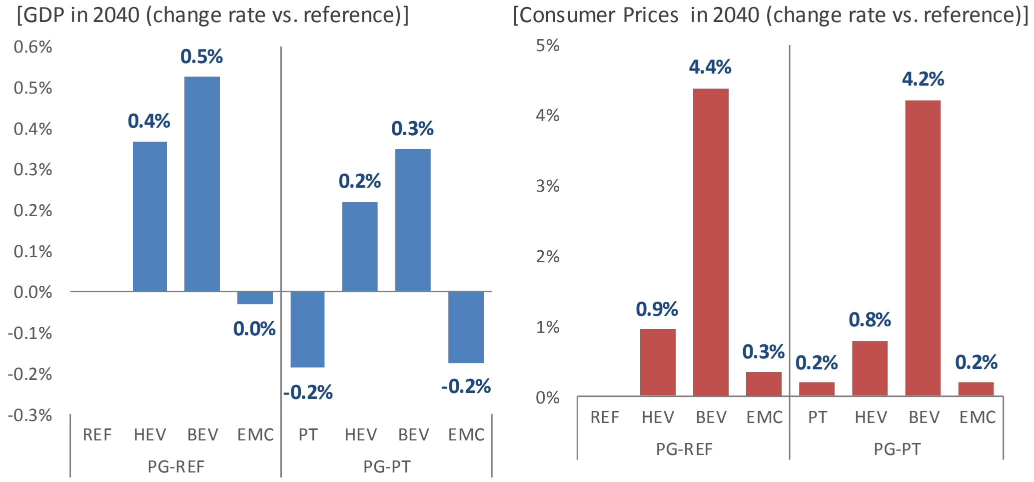


BEV = battery electric vehicle ambitious, EMC = electric motorcycle advanced, HEV = hybrid electric vehicle bridge, REF = reference, PG = power generation, PT = policy target.

Source: IEA (2017), authors' analysis.

xEVs' impact on GDP is slightly positive because suppression of net imports such as petroleum and investments (additional cost for conventional technology) in xEVs (and low-carbon power) stimulate the economy. The economic impact of the e-motorcycle advanced scenario is insignificant. In the policy target scenario for power generation mix, the positive impact on GDP is small because energy import value is slightly larger than in the reference scenario. Investments in xEVs (and low-carbon power) do not expand production investments or supply capacity. As a result, supply and demand in the economy are tight and general prices rise greatly. In 2040, consumer prices in the BEV ambitious + policy target scenario for power generation mix are 4% higher than in the reference scenario.

Figure 3.15: Impacts on GDP and Consumer Prices, Thailand

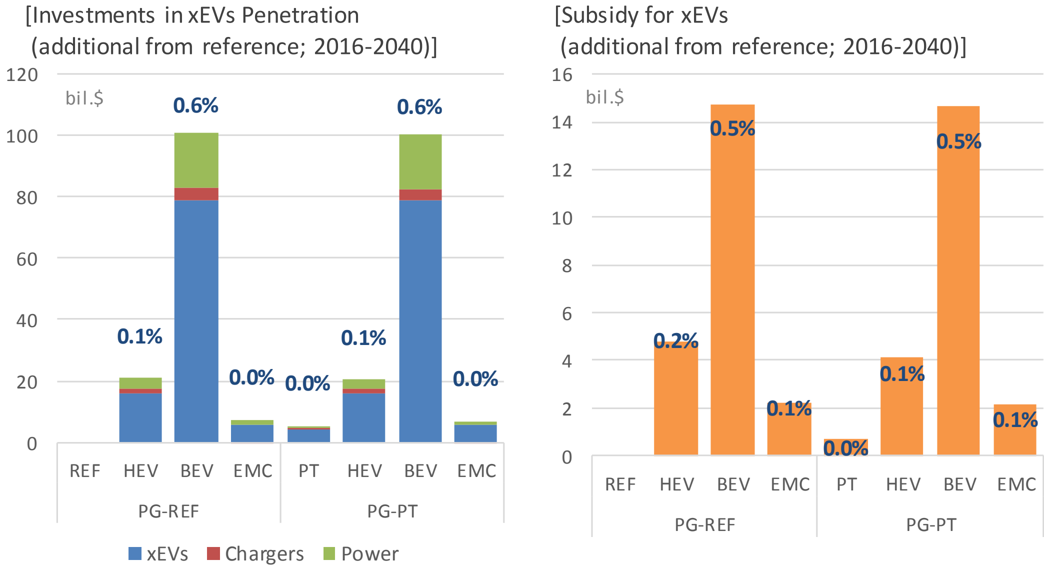


BEV = battery electric vehicle ambitious, EMC = electric motorcycle advanced, HEV = hybrid electric vehicle bridge, REF = reference, PG = power generation, PT = policy target.
Source: IEA (2017), authors' analysis.

The investment in xEV penetration (vehicle, charging facility, power-generating equipment) reaches US$21 billion (cumulative in 2016–2040) in the HEV bridge scenario and US$101 billion in the BEV ambitious scenario. Cumulative investment amounts account for 0.1% and 0.6% of cumulative GDP, respectively.

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. Assuming grant subsidies that shorten the payback period to half the average lifetime, the total subsidy is US$5 billion (cumulative in 2016–2040) in the HEV bridge scenario and US$15 billion in the BEV ambitious scenario. Cumulative subsidy accounts for 0.2% and 0.5% of the cumulative government budget, respectively. However, subsidies to energy (gasoline, diesel oil, and electricity) are not considered. When BEVs increase, oil demand decreases and electricity demand increases. If the dropped subsidy for oil exceeds the additional subsidy for electricity, the total amount may decrease, but if the subsidy for electricity is larger, the total amount increases.

Figure 3.16: Investments and Subsidies for xEVs, Thailand

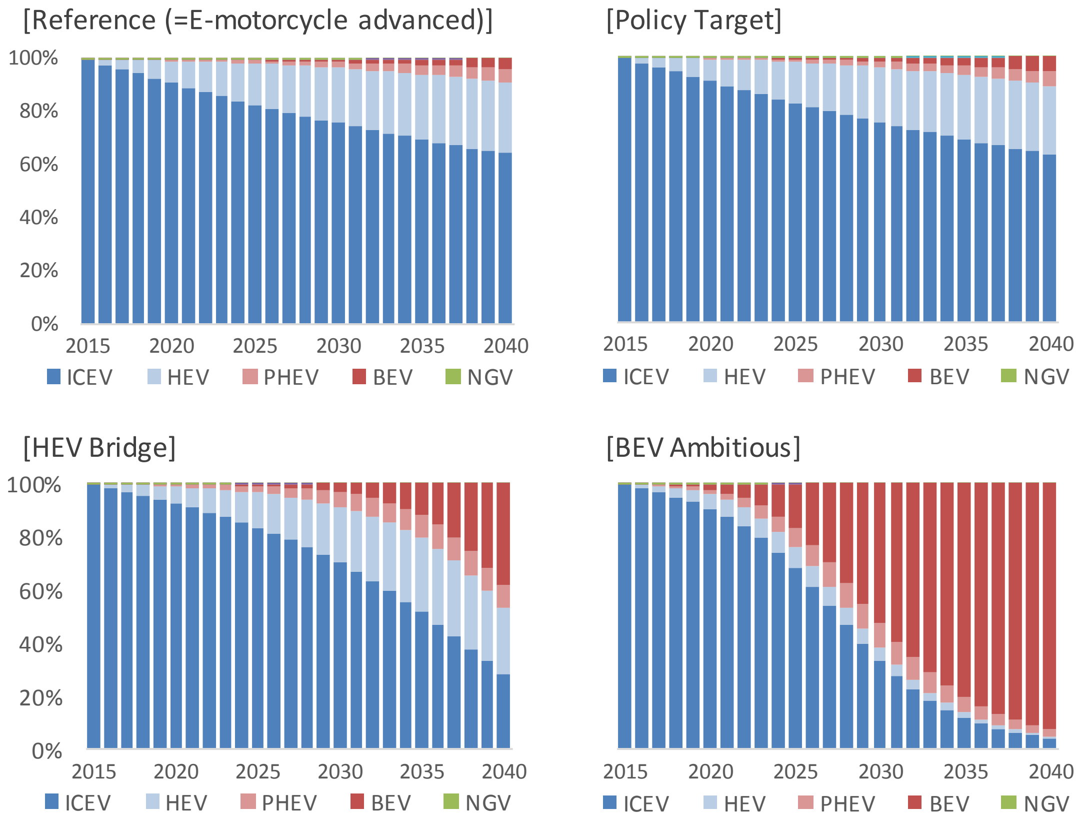


BEV = battery electric vehicle ambitious, EMC = electric motorcycle advanced, HEV = hybrid electric vehicle bridge, REF = reference, PG = power generation, PT = policy target.
Notes: 1: Assuming grant subsidies that shorten the payback period to half the average lifetime. 2. % shows investment ratios of GDP and subsidy ratios of government revenue.
Source: IEA (2017), authors' analysis.

2.3. Malaysia

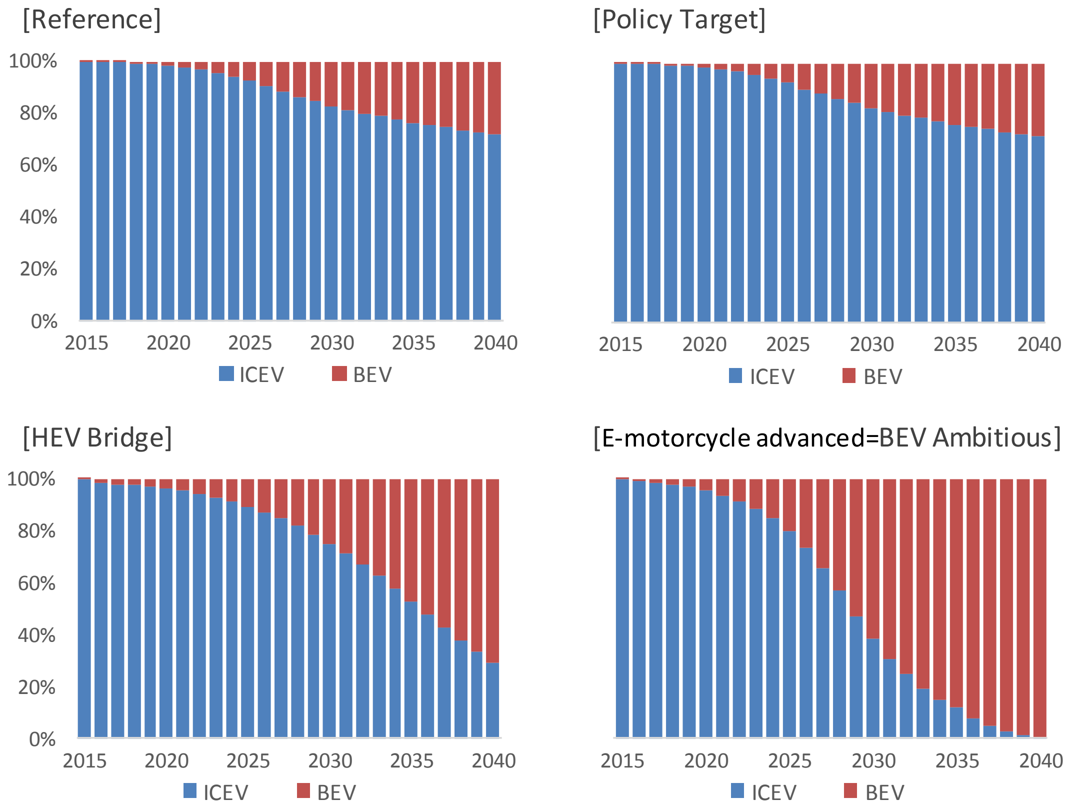
In 2016, Malaysia had 14.9 million cars, or about 485 cars per 1,000 people, which is around five times the average for ASEAN. With annual economic growth of 4%, the country will have 1.7 times more cars in 2040, and car ownership will exceed the current OECD average. The country has 12.7 million motorcycles, slightly fewer than cars. In 2040, motorcycles will increase 1.6 times, more slowly than cars. Powertrain sales share of car and motorcycles by scenario are shown in Figure 3.17 and Figure 3.18.

Figure 3.17: Powertrain Sales Share of Cars by Scenario, Malaysia



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.
Source: Authors' analysis.

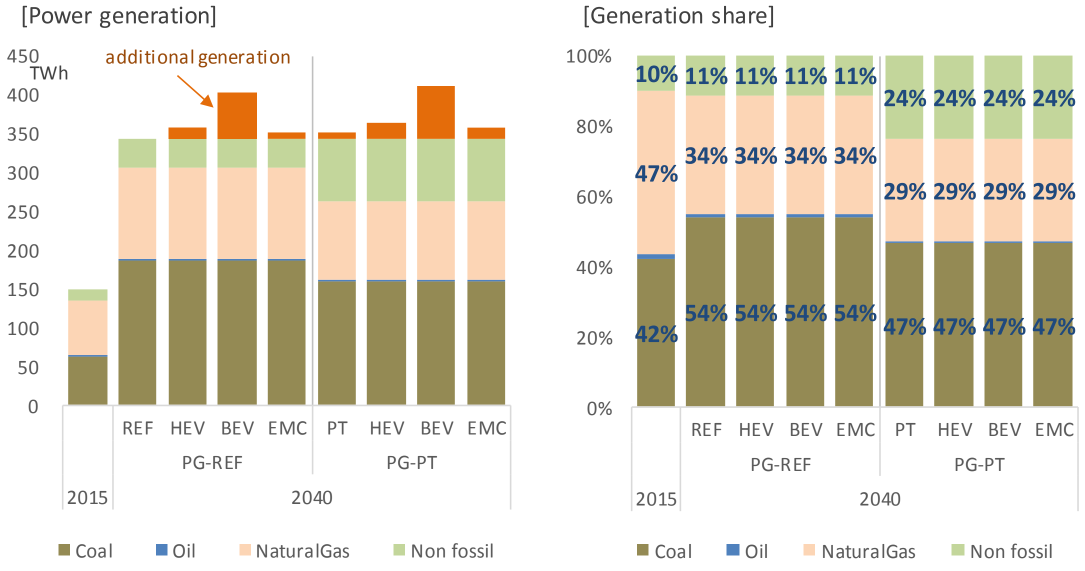
Figure 3.18: Powertrain Sales Share of Motorcycles by Scenario, Malaysia



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.
Source: Authors' analysis.

Electricity demand will increase due to EV penetration. In 2040, in the BEV ambitious scenario, required power generation increases by 58 TWh or 17% more than in the reference scenario, where power generation mix is 54% coal, 34% gas, and 11% non-fossil fuel (CO_2 emissions per kWh are 642 g-CO_2/kWh). In the policy target scenario, power generation mix is 47% coal, 29% gas, and 24% non-fossil fuel (CO_2 emissions per kWh are 551 g-CO_2/kWh), promoting low carbonisation.

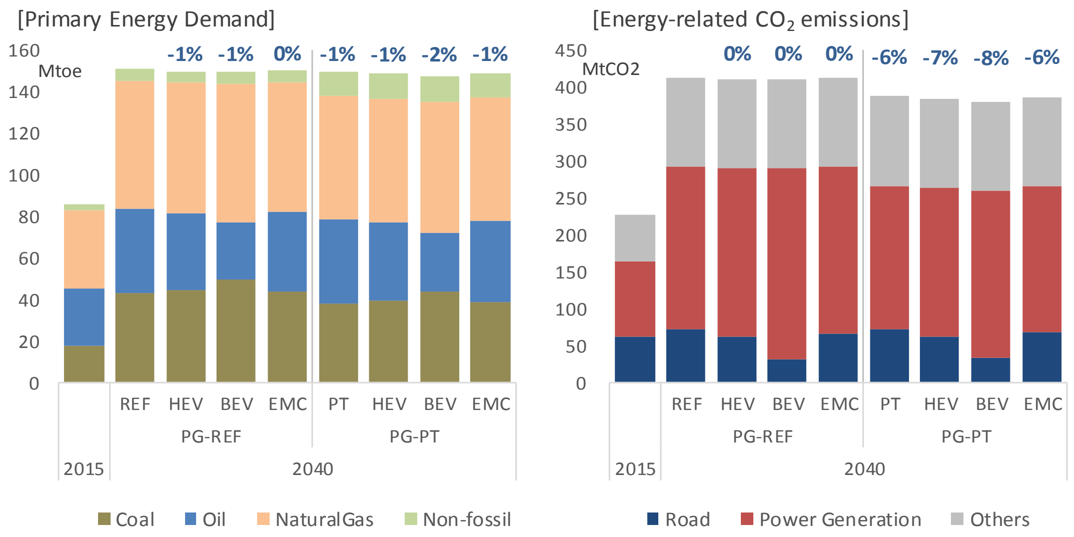
Figure 3.19: Power Generation and Generation Mix, Malaysia



BEV = battery electric vehicle ambitious, EMC = electric motorcycle advanced, HEV = hybrid electric vehicle bridge, REF = reference, PG = power generation, PT = policy target.
Note: Not including electricity imports.
Source: IEA (2017), authors' analysis.

Primary energy demand under the reference scenario for the power generation mix in the HEV bridge scenario and in the BEV ambitious scenario both decrease by only 1% compared with the reference scenario (Figure 3-20). The reason is that in the BEV ambitious scenario, oil demand in the transport sector decreases (13 Mtoe), whilst fuel input to the power generation sector increases (12 Mtoe). The scenarios contribute little to emission reductions. In the policy target scenario for power generation mix, the difference in emissions between the HEV bridge and the EV ambitious scenarios increases to about 1%.

Figure 3.20: Primary Energy Demand and Energy-related CO_2 Emissions, Malaysia

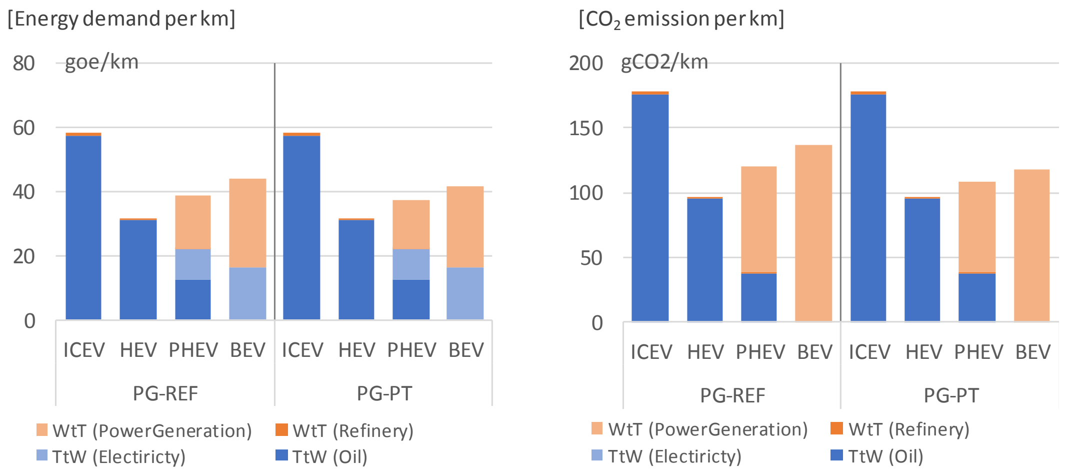


BEV = battery electric vehicle ambitious, EMC = electric motorcycle advanced, HEV = hybrid electric vehicle bridge, REF = reference, PG = power generation, PT = policy target.
Note: % show change rates from the reference scenario.
Source: IEA (2017), authors' analysis.

In 2040, BEVs consume less energy than ICEVs and more than HEVs because energy consumption is small in tank to wheel but large in well to tank. BEVs produce less CO_2 emissions than ICEVs and a certain CO_2 reduction effect can be expected. However, BEVs' CO_2 emissions in the policy target scenario for power generation mix remain larger than HEVs'.

Malaysia's energy self-sufficiency drops significantly in 2040 but the difference between scenarios is not large. The net import value of energy in the reference scenario in 2040 is US$14 billion but that in the BEV ambitious scenario greatly decreases to US$6 billion. The net import value of energy in the policy target scenario for power generation mix is further reduced.

Figure 3.21: Well to Wheel by Powertrain in Cars in 2040, Malaysia

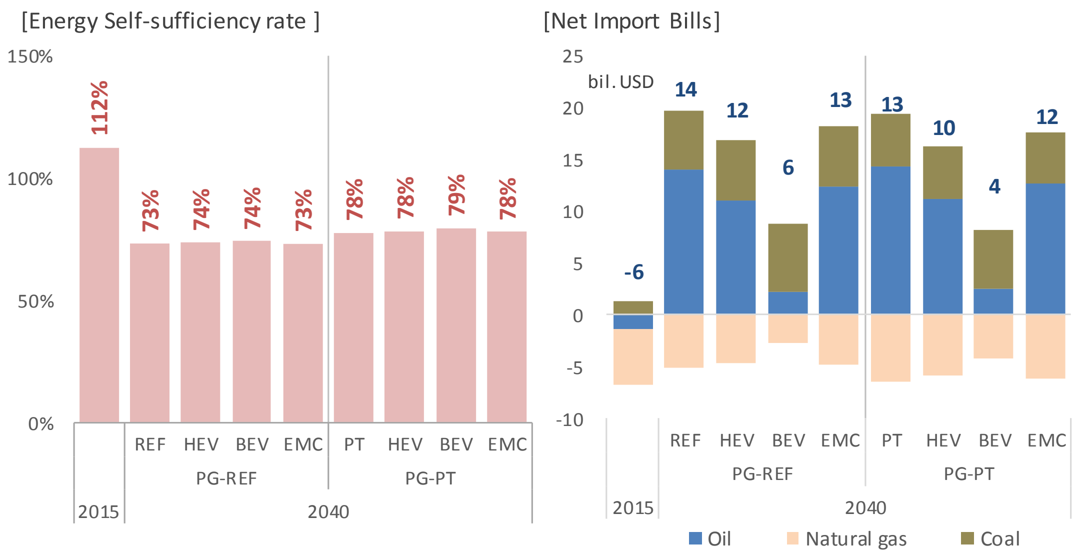


BEV = battery electric vehicle ambitious, EMC = electric motorcycle advanced, HEV = hybrid electric vehicle bridge, REF = reference, PG = power generation, PT = policy target, TtW = tank to wheel, WtT = well to tank.

Note: Well to tank does not include energy consumption in fossil-fuel production and transport.

Source: Authors' analysis.

Figure 3.22: Energy Self-sufficiency Rate and Net Import Bills, Malaysia

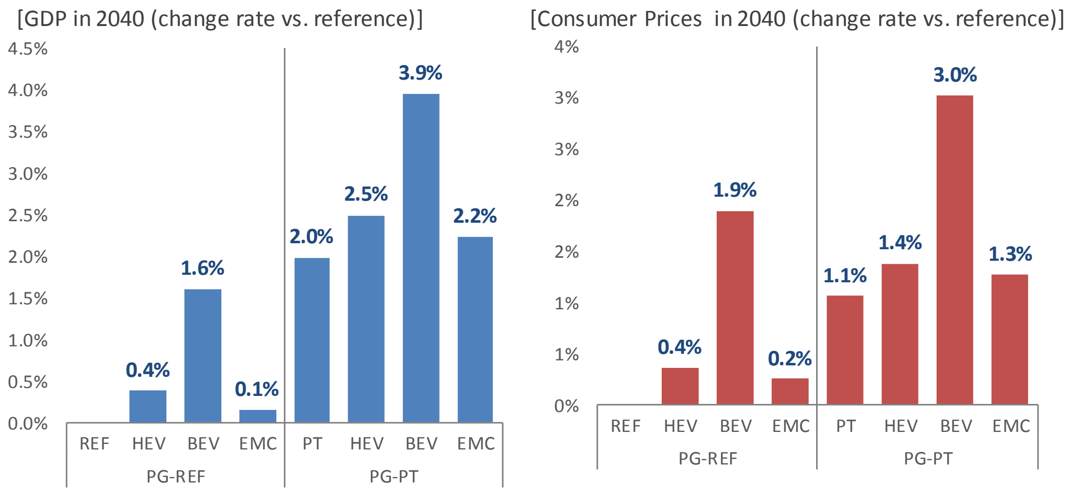


BEV = battery electric vehicle ambitious, EMC = electric motorcycle advanced, HEV = hybrid electric vehicle bridge, REF = reference, PG = power generation, PT = policy target.

Source: IEA (2017), authors' analysis.

xEVs' impact on GDP is positive because suppression of net imports such as petroleum and investments (additional cost for conventional technology) in xEVs (and low-carbon power) stimulate the economy. The economic impact of the e-motorcycle advanced scenario is insignificant. Investments in xEVs (and low-carbon power) do not expand production investments or supply capacity. As a result, supply and demand are tight and general prices rise greatly. In 2040, consumer prices in the BEV ambitious + policy target scenario for the power generation mix are 3% higher than the reference scenario.

Figure 3.23: Impacts on GDP and Consumer Prices, Malaysia

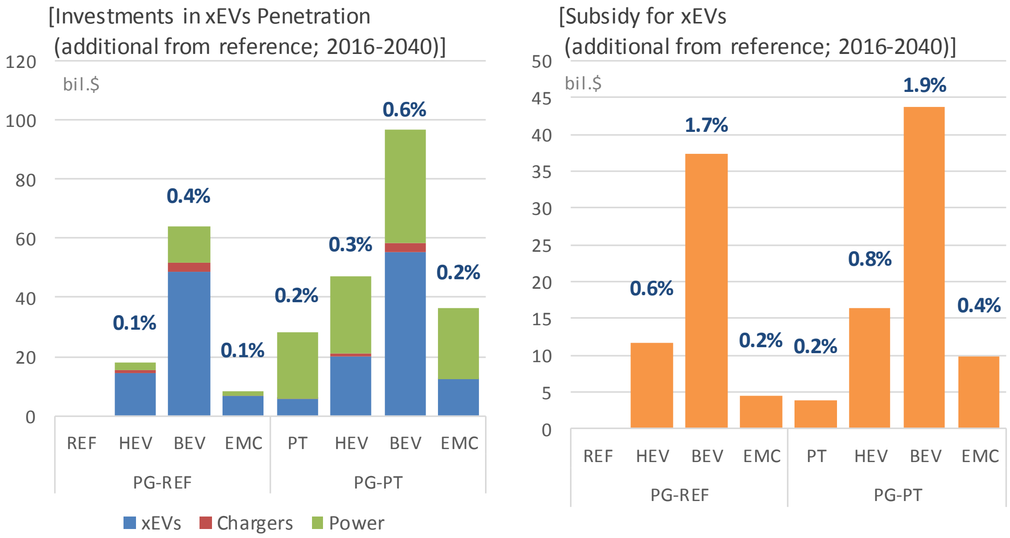


BEV = battery electric vehicle ambitious, EMC = electric motorcycle advanced, HEV = hybrid electric vehicle bridge, REF = reference, PG = power generation, PT = policy target.
Source: IEA (2017), authors' analysis.

Investment in xEV penetration (vehicle, charging facility, power-generating equipment) reaches US$18 billion (cumulative in 2016–2040) in the HEV bridge scenario and US$64 billion in the BEV ambitious scenario. Cumulative investment accounts for 0.1% and 0.4% of cumulative GDP, respectively. In the policy target scenario for power generation mix, further investments for low-carbon power are required.

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. Assuming grant subsidies that shorten the payback period to half the average lifetime, the total subsidy is US$12 billion (cumulative in 2016–2040) in the HEV bridge scenario and US$37 billion in the BEV ambitious scenario. Cumulative subsidy accounts for 0.6% and 1.7% of the cumulative government budget, respectively. However, subsidies to energy (gasoline, diesel oil, and electricity) are not considered. When BEVs increase, oil demand decreases and electricity demand increases. If the dropped subsidy for oil exceeds the additional subsidy for electricity, the above total amount may decrease, but if the subsidy for electricity is larger, the total amount increases.

Figure 3.24: Investments and Subsidy for xEVs, Malaysia

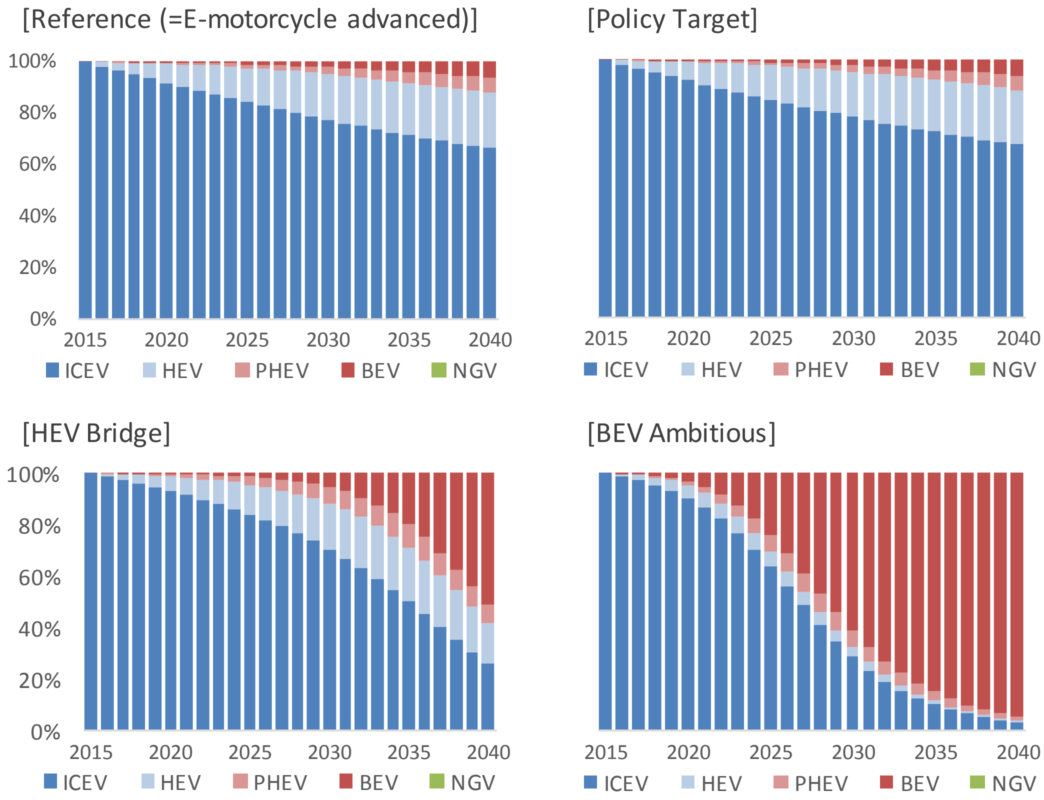


BEV = battery electric vehicle ambitious, EMC = electric motorcycle advanced, HEV = hybrid electric vehicle bridge, REF = reference, PG = power generation, PT = policy target.
Notes: 1. Assuming grant subsidies that shorten the payback period to half the average lifetime. 2. % shows investment ratios of GDP and subsidy ratios of government revenue.
Source: IEA (2017), authors' analysis.

2.4. Viet Nam

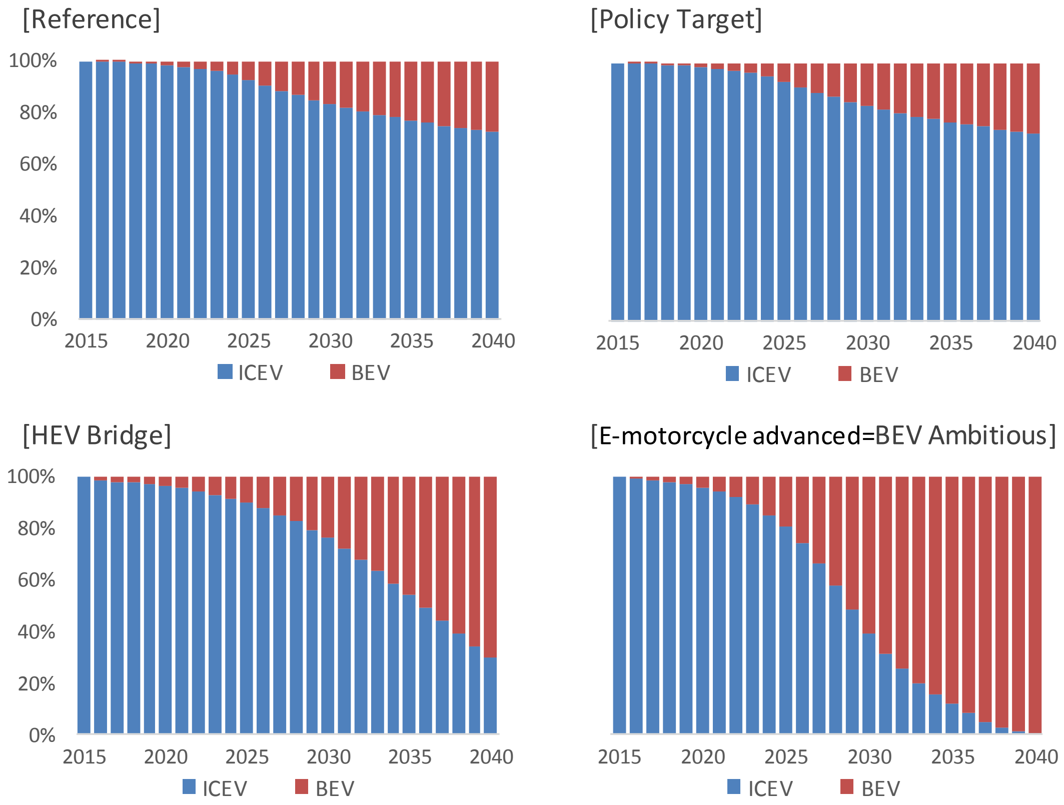
In 2016, Viet Nam had 2.5 million cars, or 27 cars per 1,000 people, far fewer than in other ASEAN countries. With high economic growth of 6% per year, the country will have 6.5 times more cars in in 2040. The country has 47.1 million more motorcycles than cars, with 500 motorcycles per 1,000 people. Because people can shift from motorcycles to cars, motorcycles will increase 1.6 times in 2040, more slowly than cars. Powertrain sales share of cars and motorcycles by each scenario are shown in Figure 3 and Figure 3.

Figure 3.25: Powertrain Sales Share of Cars by Scenario, Viet Nam



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.
Source: Authors' analysis.

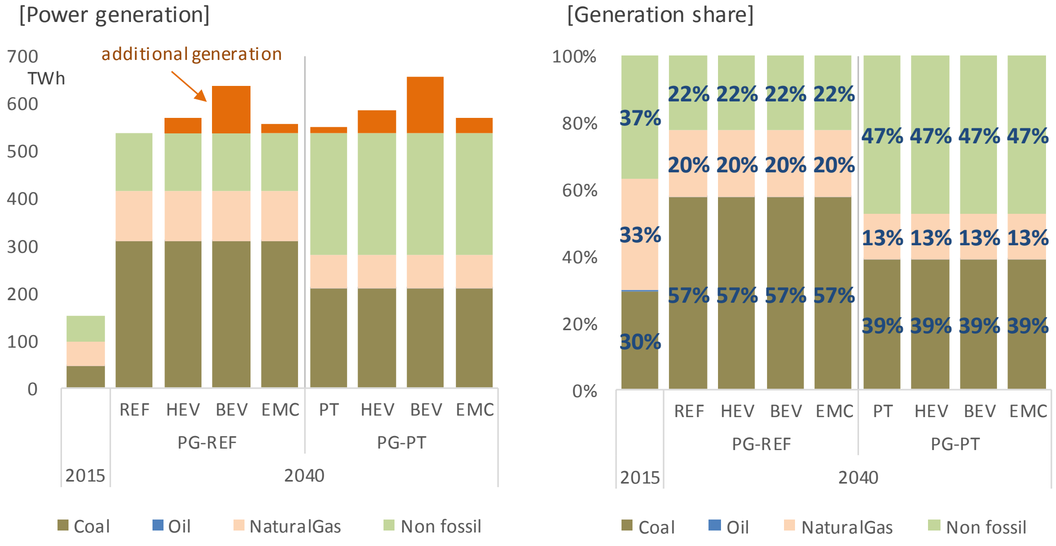
Figure 3.26: Powertrain Sales Share in Motorcycles by Scenario, Viet Nam



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
Source: Authors' analysis.

Electricity demand will increase due to EV penetration. In 2040, in the BEV ambitious scenario, required power generation increases by 100 TWh or 19% more than in the reference scenario, where power generation mix is 57% coal, 20% gas, and 22% non-fossil fuel (CO_2 emissions per kWh are 614 g-CO_2/kWh). In the policy target scenario, power generation mix is 39% coal, 13% gas, and 47% non-fossil fuel (CO_2 emissions per kWh are 416 g-CO_2/kWh), promoting low carbonisation.

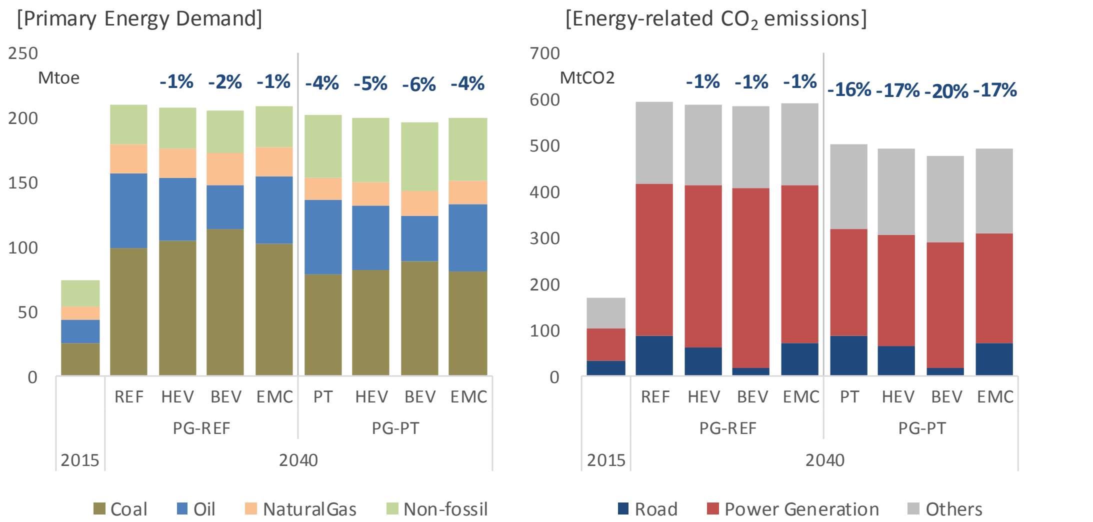
Figure 3.27: Power Generation and Generation Mix, Viet Nam



REF = reference, PT = policy target, HEV = HEV bridge, BEV = BEV ambitious, EMC = e-motorcycle advanced, PG = power generation.
Note: Not including electricity imports.
Source: IEA (2017), authors' analysis.

Primary energy demand under the reference scenario for the power generation mix in the HEV bridge scenario and in the BEV ambitious scenario decreases by only 1% and 2%, respectively, compared with the reference scenario (Figure 3-28). The reason is that in the BEV ambitious scenario, oil demand in the transport sector decreases (23 Mtoe), whilst fuel input to the power generation sector increases (19 Mtoe). xEV penetration does not lead to large emission reductions, and the difference in emissions between the HEV bridge and the BEV ambitious scenarios is insignificant. In the policy target scenario for power generation mix, the difference in emissions between the HEV bridge and the BEV ambitious scenarios increases to about 3%.

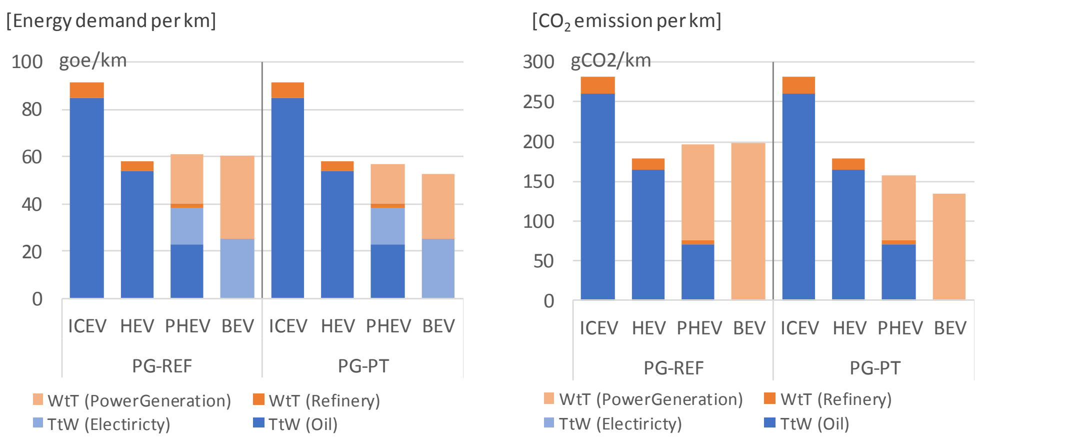
Figure 3.28: Primary Energy Demand and Energy-related CO_2 Emissions, Viet Nam



BEV = battery electric vehicle ambitious, EMC = electric motorcycle advanced, HEV = hybrid electric vehicle bridge, REF = reference, PG = power generation, PT = policy target.
Notes: 1. % shows the change rate from the reference scenario. 2. Replacing by geothermal power (primary conversion efficiency of 5%) increases the primary energy.
Source: IEA (2017), authors' analysis.

In 2040, BEVs consume less energy than ICEVs and almost the same as HEVs because consumption is small in tank to wheel but large in well to tank. BEVs produce less CO_2 emissions than ICEVs and a certain CO_2 reduction effect can be expected. However, BEVs' CO_2 emissions in the reference scenario for power generation mix are larger than HEVs' (Figure 3.29). In the policy target scenario for power generation mix, BEVs' CO_2 emissions are lower than HEVs'.

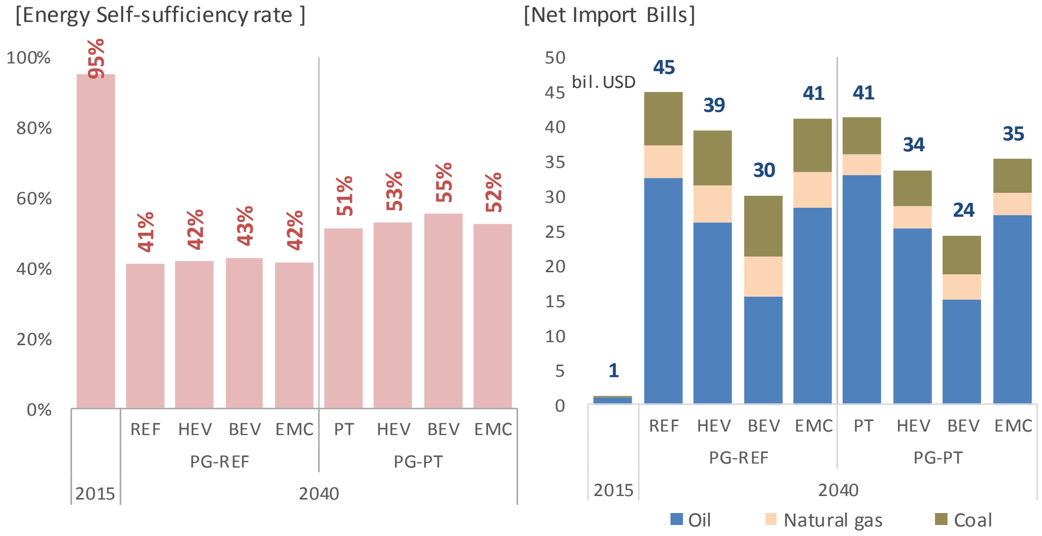
Figure 3.29: Well to Wheel by Powertrain in Cars in 2040, Viet Nam



BEV = battery electric vehicle ambitious, EMC = electric motorcycle advanced, HEV = hybrid electric vehicle bridge, REF = reference, PG = power generation, PT = policy target, TtW = tank to wheel, WtT = well to tank.
Note: Well to tank does not include energy consumption in fossil fuel production and transport.
Source: Authors' analysis.

Viet Nam's energy self-sufficiency drops significantly in 2040 but the difference between scenarios is not large. The net import value of energy in the reference scenario in 2040 is US$45 billion but that in the BEV ambitious scenario greatly decreases to US$30 billion. The net import value of energy in the policy target scenario for power generation mix is further reduced.

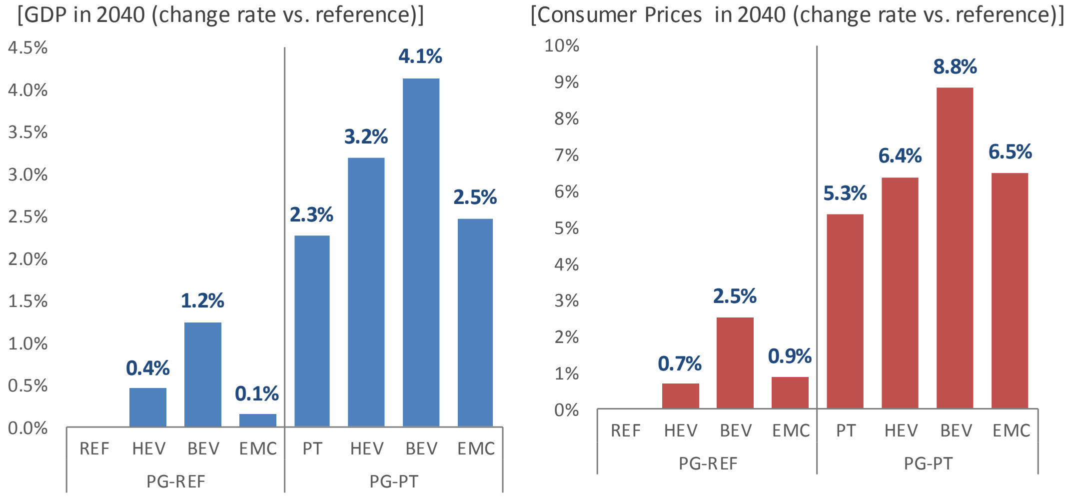
Figure 3.30: Energy Self-sufficiency Rate and Net Import Bills, Viet Nam



BEV = battery electric vehicle ambitious, EMC = electric motorcycle advanced, HEV = hybrid electric vehicle bridge, REF = reference, PG = power generation, PT = policy target.
Source: IEA (2017), authors' analysis.

xEVs' impact on GDP is slightly positive because suppression of net imports such as petroleum and investments (additional cost for conventional technology) in xEVs (and low-carbon power) stimulate the economy. The economic impact of the e-motorcycle advanced scenario is insignificant. Investments in xEVs (and low-carbon power) do not expand production investments or supply capacity. As a result, supply and demand are tight and general prices rise greatly. In 2040, consumer prices in the BEV ambitious + policy target scenario for power generation mix are 9% higher than in the reference scenario.

Figure 3.31: Impacts on GDP and Consumer Prices, Viet Nam

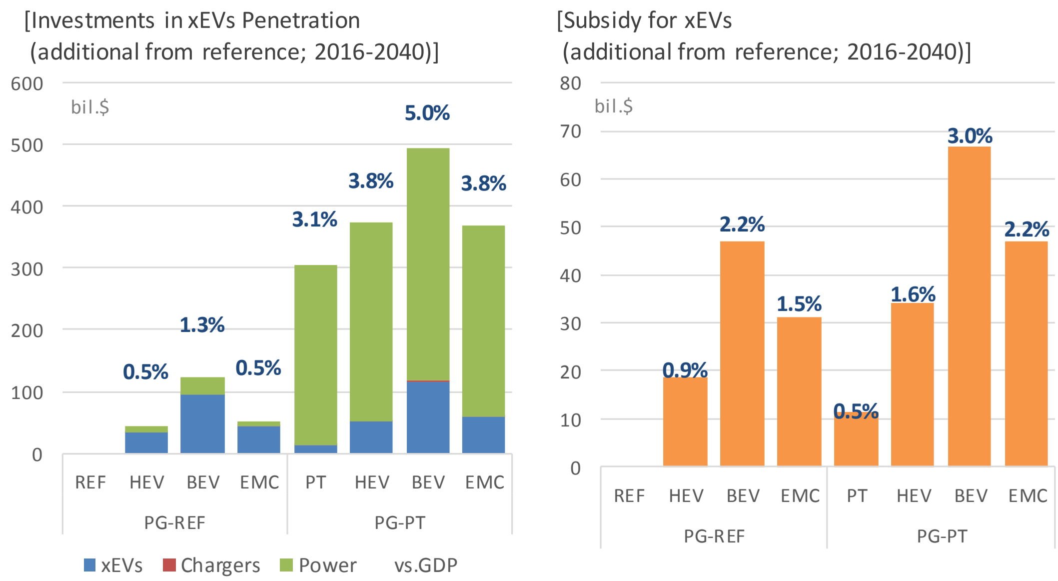


BEV = battery electric vehicle ambitious, EMC = electric motorcycle advanced, HEV = hybrid electric vehicle bridge, REF = reference, PG = power generation, PT = policy target.
Source: IEA (2017), authors' analysis.

Investment in xEV penetration (vehicle, charging facility, power-generating equipment) reaches US$44 billion (cumulative in 2016–2040) in the HEV bridge scenario and US$123 billion in the BEV ambitious scenario. Cumulative investment accounts for 0.5% and 1.3% of cumulative GDP, respectively. In the policy target scenario for power generation mix, further investments for low-carbon power are required.

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. Assuming grant subsidies that shorten the payback period to half the average lifetime, the total subsidy will be US$19 billion (cumulative in 2016–2040) in the HEV bridge scenario and US$47 billion in the BEV ambitious scenario. Cumulative subsidy accounts for 0.9% and 2.2% of the cumulative government budget, respectively. However, subsidies to energy (gasoline, diesel oil, and electricity) are not considered. When BEVs increase, oil demand decreases and electricity demand increases. If the dropped subsidy for oil exceeds the additional subsidy for electricity, the above total amount may decrease, but if the subsidy for electricity is larger, the total amount increases.

Figure 3.32: Investments and Subsidy for xEVs, Viet Nam



BEV = battery electric vehicle ambitious, EMC = electric motorcycle advanced, HEV = hybrid electric vehicle bridge, REF = reference, PG = power generation, PT = policy target.
Notes: 1. Assuming grant subsidies that shorten the payback period to half the average lifetime. 2. % shows investment ratios of GDP and subsidy ratios of government revenue.
Source: IEA (2017), authors' analysis.

3. Implications of the Results

The influence of xEV penetration on overall energy demand and CO_2 emissions is not large. BEVs, especially, will decrease oil demand in the transport sector but increase fuel input to the power generation sector. If CO_2 emissions are not reduced in the power generation sector, BEV penetration will have limited effect on reducing CO_2 emissions, which is a big issue in ASEAN countries that largely depend on coal-fired power generation. The energy self-sufficiency ratios in each scenario are not much different because imports of petroleum products for vehicles will decrease whilst imports of coal and natural gas for power generation will increase.

Even if coal and natural gas imports increase, a decrease in imports of petroleum products leads to a decrease in net imports of energy because the unit cost of petroleum products per calorific value is higher than that of coal and gas. BEVs improve the trade balance more than HEVs do, which has a positive impact on the economy. Investment in xEVs stimulates the economy. BEVs have a slightly bigger effect on the economy than HEVs do because investment in BEVs is bigger than in HEVs. Since investment in the xEV environment does not contribute to expanding the supply capacity of goods and services, supply and demand in the whole economy will tighten and general prices will rise greatly.

The required investments in xEV penetration, including vehicles, charging facilities, and power-generation capacity, are large. Investment costs for BEVs are several times more than for HEVs. Investment in low-carbon power supply such as renewable energy is required to make clean BEVs based on well to wheel. Fund procurement for xEV penetration must be considered. The HEV bridge and BEV ambitious scenarios may not be realised in business as usual unless subsidies bridge the price differences between ICEVs and xEVs. Total subsidies for BEVs will be several times those for HEVs and put pressure on government finances.

The HEV bridge and BEV ambitious scenarios are not significantly different in their influence on the 3Es' energy and environment (CO_2 emissions). The influence of the 3Es' economy on GDP is also small but the BEV ambitious scenario greatly increases prices. The scenario also has implementation costs such as investment funds and subsidies for xEV penetration, which are several times larger than for the HEV bridge scenario.

CHAPTER 4

Investment in and Planning of Charging Infrastructure

1. Introduction

Several ASEAN countries have strategies for low-emission mobility, with decreasing oil import dependency as a main objective. The strategies emphasise, amongst others, removing obstacles to electrification of transport to promote market development of road PEVs, especially cars, powered two-wheelers, and light-duty vehicles or vans.

Removing obstacles means that ASEAN countries must secure critical technological system requirements: road EV manufacturing and its supporting or supplier industries, and the corresponding EV charging infrastructure.

Only two countries in ASEAN produce and commercialise PEVs – Thailand and Malaysia.

Thailand's first EV development roadmap, the Electric Vehicle Promotion Plan, was approved by the government in March 2015. In 2017, the Board of Investment (BoI) approved incentive measures for manufacturers of BEVs, HEVs, and PHEVs, mostly in the form of corporate tax exemptions for 5 to 8 years. The project to develop next-generation automotive vehicles with a focus on EVs was included in the Eastern Economic Corridor, approved in February 2018, to spur investment. In March 2019, the BoI agreed to renew the investment package for HEVs to lure more investment in EVs. Interested investors are required to submit their applications for HEVs in 2019 and to assemble BEVs within 3 years. HEV and PHEV sales rose by 24.7% in 2017 to 11,945 units whilst BEV sales reached 165 units (Nicholls et al., 2018). All vehicles sold in that year totalled 870,748 units. By 2036, Thailand targets having1.2 million electric cars in its streets and setting up 690 charging stations.

Malaysia started its EV programme earlier than Thailand. In 2011, the government exempted from excise duties and import taxes completely built-up, fully imported hybrid cars to encourage manufacturers to invest in EV production in the country. After the policy failed to boost foreign investment, the government abandoned it in 2014 and extended it only for completely knocked-down models assembled in Malaysia. The government now prefers to deal with manufacturers individually, a strategy that appears to work with several foreign original equipment manufacturers.

A recent tripartite agreement between TNBES, PetDag, and GreenTech Malaysia has resulted in the installation of 100 charging stations across the country in 2018. As of end 2018, EV charging stations amount to 251 units located across the Peninsular (Weng, 2019) GreenTech Malaysia is under the purview of the Ministry of Energy, Science, Technology, Environment and Climate Change to spearhead the development and promotion of green technology as a strategic engine for socio-economic growth in line with Green Technology Master Plan 2017–2030. The number of new registered hybrid vehicles, including conventional HEVs and, in the recent years, PHEVs, has increased from 138 in 2010 to more than 9,000 in 2017. Malaysia aims to build 125,000 charging stations by 2020.

Since January 2018, the ASEAN Free Trade Agreement has dropped import duties for vehicles originating in other ASEAN countries to 0%. Investment in the domestic EV manufacturing industry might benefit the countries if the final purchasing price of the vehicles can compete with those of imported vehicles.

Whilst EV manufacturing and its support industries might rely mostly on integration with global value chains, developing charging points needs significant domestic public and private investment. This chapter focuses on building the decision-making framework for charging infrastructure investment to encourage EV deployment.

We start with a brief introduction on the state of charging technology development, including the different charging technologies and modes, and the need for standardisation to ensure interoperability. We then discuss the costs of the different charging technologies, followed by a synthesis of the 'chicken and egg' relationship between charging infrastructure and the EV penetration rate. The most-used indicator is the number of PEVs per charging point. Some argue that developing more charging infrastructure will stimulate PEV penetration, but it is often the electric car manufacturers that encourage deploying the infrastructure (Li et al., 2016).

We go on to present possible policy measures to facilitate the rolling out of charging infrastructure based on practices in several PEV front-runner countries, and the different charging scheme strategies to ensure that PEV deployment objectives are achieved. We close with recommendations for ASEAN governments.

2. Charging Infrastructure: An Introduction

ICEV users would benefit from refuelling station networks being located nearly everywhere. But PEV charging infrastructure is in its early development stage, especially in ASEAN countries.

In principle, a PEV can simply be plugged into a home wall-mounted box, which is the simplest EV service equipment, but home-charging is not as simple as it seems and the long charging time is its main inconvenience. Increasing grid pressure is a risk as home-charging takes place mainly in the late afternoon after working hours, when household electricity demand is peaking. These are the main reasons for developing different types of chargers and installing them in public spaces such as parking lots, workplaces, pump stations, and motorway rest areas.

2.1. Charger Types

Chargers on the market can, in principle, be divided into slow and fast. Slow chargers use an alternating current (AC) under 400 volts whilst fast chargers use a direct current (DC) of 400 volts and above. Most charging stations are slow and more than 88% have 22 kW power or lower. This category includes 2.3 kW household plugs that take about 9 hours to completely recharge a common PEV. Most PEVs can be home-charged via an AC outlet of 3.3–11 kW.

Slow chargers are level 1 (120 volts) and level 2 (200–240 volts) and suitable for short trips, whilst DC fast chargers, most often found in public locations such as motorway rest areas, are best for longer journeys (Hall and Lutsey, 2017). Both recharging times are significantly longer than ICEV refuelling time.

Table 4.1 classifies chargers into four modes, each corresponding to a specific charging speed, required voltage, electric current, and level of communication between vehicle and power outlet.

Slow chargers are also often grouped into slow and semi-fast. It takes 6–8 hours to fully charge a pure BEV using slow chargers with a single-phase 3.3 kW of power and 120–240 volts. This practice corresponds to home-charging using share circuit without any safety protocol.

With slow to semi-fast chargers, charging time should be reduced from 4 hours to 1. Facilities with power greater than 3.3 kW but less than 22 kW can be found in households, workplaces, and public spaces. Chargers with power lower than 22 kW allow a maximum speed up to 2 hours of charging and can be applied to shared or dedicated circuits with safety protocols. Facilities with power higher than 22 kW reduce charging time down to 1 hour. Semi-fast chargers are installed mostly in public charging facilities often equipped with an active communication line between the charging point and the vehicle.

Finally, the DC fast chargers allow BEVs to be fully charged in less than an hour. They are often installed in motorway service areas or in urban dedicated charging stations where long charging time is less tolerated.

Table 4.1: Different Modes of Plug-in Electric Vehicle Charging

Mode	Name	Power (kilowatt)	Current	Phase	Charging time	Place	Voltage (volt)	Power range (ampere)	Communication level	Further description
1	Slow	3.3	AC	Single	6–8 hours	Household, workplace wall box	120–240	Up to 16	N/A	Shared circuit without safety protocols
2	Slow, semi-fast	7.4	AC	Single	3–4 hours	Household, workplace wall box and public charging poles	120–240	Over 16 and up to 32	Semi-active connection to vehicle to communicate for safety purpose	Shared or dedicated circuit with safety protocols, including grounding detection, overcurrent protection, temperature limits, and a pilot data line
3	Slow, semi-fast or fast	10	AC	Three	2–3 hours		240	Any	Active connection between charger and vehicle	Wired-in charging station on a dedicated circuit, mode-2 safety protocols, active communication line with the vehicle, i.e., smart charging suitability
		22	AC	Three	1–2 hours	Mostly public charging poles				
4	Fast	50	DC	–	20–30 minutes	Motorway service area or dedicated charging stations in urban areas (current standard)	400		Active connection between charger and vehicle	Mode-3 features with more advanced safety and communication protocols
		120	DC		10 minutes	Motorway service area or dedicated charging stations in urban areas (future standard)				

AC = alternating current, DC = direct current.

Source: Bakker (2013), Hall and Lutsey (2017), and Spöttle (2018).

The situation is, however, complicated. Compatibility between PEVs and charging point technology standards is an issue as there are at least five technology standards or connector types:

- Type-1 AC. Amongst the most popular PEV connectors in this category are some produced by the Japanese manufacturer Yazaki, following the North American SAE J1772 standard. They are mostly slow chargers and can be found in North America and Japan.
- Type-2 AC. Most are fabricated by the German company Mennekes, following the AC charging technology standard gaining market share in Europe and China. This type is compatible with most PEVs and AC chargers and can facilitate not only single-phase but also three-phase AC charging.
- Type-3 AC. Built by the PEV Plug Alliance, mostly in Italy and in France, and used only up to 2012, when the Type-2 AC became dominant in Europe.
- Type-4 DC. Also known as the Japanese standard, CHAdeMO. It was the first widespread technical standard for DC fast charging developed by a Japanese consortium. This type is found not only in Japan but also in European countries, mostly in France.
- CCS or combined charging system. The combined AC and DC fast-charging plugs are CCS Combo 1, preferred by US car manufacturers, and CCS Combo 2, preferred by Germans.
- Tesla supercharger infrastructure. This DC fast charger is used mostly in North America.

2.2. Standardisation and Interoperability

Charging stations are considered interoperable if they can serve a large variety of PEV models and offer payment methods accessible to all PEV drivers (Spöttle et al., 2018). Standardisation guarantees interoperability, provides clarity to manufacturers, allows for economies of scale, and ensures compliance with safety standards. PEV charging interoperability means that PEV users can charge their cars at any charging point using their usual choice of authorisation and payment method.

Charging infrastructure – at least the physical equipment, payment systems, and charging protocol – must be standardised. Section 2.1 shows how different charging equipment types can coexist in one country or region. In Europe, for example, Type-2 AC and Type-3 AC coexisted, as did CHAdeMO and CCS Combo 2. In 2014, European Commission Directive 2014/94/EU required that all providers of public chargers include a Type-2 AC connector where level-2 or fast AC charging is available, and a CCS connector where level-3 charging is provided. In Southeast Asia, the rolling out of charging infrastructure is still in its development phase, but some trends are visible: Type-2 connectors are available for AC charging, and CCS Combo connectors are also available for DC charging in Thailand, Malaysia, and Singapore. CHAdeMO is available in Thailand and Malaysia.

Many charging station network operators in the early years of PEV penetration developed their own payment systems. PEV users normally subscribe to a charging station operator and cannot always charge or pay at a station belonging to another operator. A simple solution is for the user to subscribe to more than one operator. A more sophisticated solution is to allow roaming between operators as mobile phone network operators have been doing for years.

Finally, charging activity needs protocols that standardise the communication interface between the car, the charging stations, and the system that oversees monitoring and managing of the charging station, including the roaming platforms. That system is usually referred to as the charge point operator (CPO) or charging service operator (CSO). For example, Europe has the open clearing house protocol (OCHP) supported by national charging infrastructure providers in Belgium, Germany, the Netherlands, Luxembourg, Austria, Ireland, and Portugal; open charge point protocol (OCPP), initiated by ElaadNL, which is also involved in OCHP; and open charge point interface (OCPI), supported by European operators.

2.3. Cost of Charging Infrastructure

Simple home charging can compete with more efficient gasoline cars and are even significantly cheaper when a time-of-use (TOU) electricity tariff with lower prices in off-peak periods is in place. More powerful home charging is sensitive to capital cost but competitive with moderately efficient ICEVs and would be substantially cheaper under a TOU regime (Lee and Clark, 2018).

The issue, however, is how to develop non-home-based charging points or stations as home charging has limitations. Developing such stations needs significant investment, supporting regulations, an adequate business model, and, in many places, central government intervention or initiatives.

China's central government has funded a programme in 88 pilot cities, led by Shanghai, Beijing, and Shenzhen, to provide one charging point for every eight PEVs. The charging points are grouped into stations, which must be no more than 1 km from any point within the city centre (NDRC [2015], quoted by Hall and Lutsey [2017]).

The 13th Five-Year Plan (2016–2020) states that China shall build a nationwide charging-station network that will fulfil the power demand of 5 million EVs by 2020 (Xin, 2017). State Grid Corp of China, the state-owned electric utility monopoly, had built more than 40,000 charging stations by 2016 and was planning to build a network of 120,000 public-individual charging points for electric cars by 2020, throughout major regions in China (Chen, 2018).. China's National Energy Administration says that the country had a total of 450,000 stationary charging points in 2017, including around 210,000 publicly accessible units (Ying and Xuan, 2018).

Singapore's Land Transport Authority announced in 2016 it would install 2,000 charging points, and in 2017 reached an agreement with a private company, BlueSG Pte Ltd., to launch a nationwide car-sharing programme with a fleet of 1,000 PHEVs. The company planned to install and operate the charging points. Singapore Power Group, the state-owned electricity and gas distribution company, plans to roll out 1,000 charging points by 2020, of which 250 would be 50 kW fast DC chargers able to fully charge a car in 30 minutes. Normal slow chargers cost around US$3,700 whilst fast chargers cost US$48,000. By September 2018, HEVs made up 4.3% of the total of around 615,000 registered vehicles, PHEVs 0.06%, and BEVs 0.08% (Tan, 2018). Many industrial players think the lack of charging facilities has been a main cause of slow PEV penetration.

In Japan, the government created the massive Next Generation Vehicle Charging Infrastructure Deployment Promotion Project to fund charging stations around cities and highway rest stations in 2013 and 2014 (CHAdeMO Association, 2016). The nationwide Nippon Charge Service, a joint project of the state-owned Development Bank of Japan with Nissan, Toyota, Honda, Mitsubishi, and Tokyo Electric Power Company, operates almost 7,500 stations.

In the US, by 2017, around 47,000 charging outlets had been built all over the country, the General Services Administration had installed EV charging stations for federal employees and other authorised users, and more than 10 states were offering rebates and tax credits to commercial customers and homeowners for installing charging stations (Lu, 2018).

In several PEV front-runner countries in Europe, the public sector and private investors financed early charging infrastructure when the use of chargers was not yet high enough to be profitable. Public subsidies will be phased out in 2020–2025. Technological acceptance and spread and economies of scale should stimulate similar developments in other European countries (Transport & Environment, 2018) (see section 3 of this paper).

What follows is a summary of public charging facility costs in PEV front-runner countries. We focus on the top priority for ASEAN countries, which is to develop slow or semi-fast level-2 charging facilities, and on fast-charging infrastructure, whose installation will be much more limited, depending on mobility purposes and needs.

Slow to Semi-fast AC Charging Facility Costs

Table 4.2 shows that the hardware costs of slow to semi-fast charging facilities are comparable, even between the US and Europe and India.

Table 4.2: Examples of Slow and Semi-fast Charging Facility Purchase and Installation Costs

Countries (Currency)	Application	Costs	Included Items	Report
United States (US$, 2017)	L2 – home	450–1,000 (50–100)	Charging station hardware (additional electrical material costs in parentheses)	RMI (2017)
	L2 – parking garage	1,500–2,500 (210–510)		
	L2 – curb side	1,500–3,000 (150–300)		
France, Germany, Italy, Netherlands, Spain, UK (euro, 2017)	3.7 kW new residential building	1,170	Materials (for installation, including cables); wall-box (hardware of charging station, excluding cables); and labour (around 20% of total costs)	CREARA Analysis (2017)
	3.7 kW operating residential building	1,280		
	7.4 kW new nonresidential building	1,760		
	7.4 kW operating nonresidential building	2,025		
Germany (euro, 2017)	>3.7 kW – one charging point	1,200	Complete hardware, including communication and smart meter	NPE (2018)
	11 kW or 22 kW – two charging points	5,000		
India (US$, 2019)	Bharat charger AC 001-1 point(s)-3 phase 415 volt-3 x 3.3 kW	980	Approximate cost, including goods and services tax at 18%	ISGF (2018)
	Type-2 AC Charger-1 point(s)-7.2 kW	1,050		
	CCS-2-1 point(s)-3 phase 415 volt-25 kW	9,800		
European Union 28 average (euro, 2018)	AC mode 2 – home (up to 11 kW)	< 800	Purchase cost for a single charging point, not installation, grid connection, or operational costs	Spöttle et al. (2018)
	AC mode 2 – commercial (up to 19.4 kW)	< 2,000		
	AC mode 3 – fast (22 kW of 43 kW)	1,000 – 4,000		

Source: Authors' compilation

In the US, a simple home 3.7 kW charger costs only around US$500, whilst a 7.2 kW charger that can fully charge a PEV in around 4 hours costs around US$1,000 – almost the same as in Europe and India, which shows that local content of charger production in India is low. For chargers of 22 kW or more, costs in India are much higher than in the US or Europe, which means India still does not enjoy economies of scale for charging hardware production.

The charger's power, electric power phases, and number of charging points are amongst the factors that determine the cost of PEV charger hardware and material.

Home installations are used less intensively and have lower safety requirements and are, therefore, less costly than public stations, which are much more sophisticated and might include liquid-crystal display (LCD) screens, advanced payment and data tracking communication, and dual-port power routing capabilities (RMI, 2017).

Installation methods significantly affect total installation costs: installation from scratch is always cheaper than from partially make-ready facilities such as those that are pre-piped or pre-cabled. Several European governments stimulate development of partially make-ready charging facilities by the private sector, e.g., building or utility owners (CREARA Analysis, 2017).

Fast DC Charging Facility Costs

DC level-3 charging stations reduce charging time but they cost significantly more than a level-2 charger because of two factors: expensive equipment and the frequent need to install a 480 V transformer. Fast-charger hardware is significantly more expensive than level 2, and in the US a transformer might cost another US$10,000–US$20,000 (Cleantechnica, 2018). Installing DCFC in the US typically costs as much as US$50,000. Inclusion of project development, design, permits, and system upgrades can rise the total cost of DCFC deployment as high as US$300,000 each (Fitzgerald, 2018).

Table 4.3: Examples of Fast-Charging Facility Purchase and Installation Costs

<table>
<tr><th>Countries (Currency)</th><th>Application</th><th>Costs</th><th>Included items</th><th>Report</th></tr>
<tr><td>United States (US$, 2017)</td><td>DC fast charging</td><td>12,000–35,000 (300–600)</td><td>Charge station hardware (plus extra electrical materials)</td><td>RMI (2017)</td></tr>
<tr><td>Germany (euro, 2017)</td><td>50 kW</td><td>25,000</td><td>Complete hardware, including communication and smart meter</td><td>NPE (2018)</td></tr>
<tr><td rowspan="2">European Union 28 average (euro 2018)</td><td>DC fast – standard (20 kW–50 kW)</td><td>20,000</td><td rowspan="2">Purchase cost for a single charging point, not installation, grid connection, or operational costs</td><td rowspan="2">Spöttle et al. (2018)</td></tr>
<tr><td>DC high power – fast (100 kW–400 kW)</td><td>40,000–60,000</td></tr>
</table>

Fast-charging stations need to achieve a sufficiently high utilisation ratio to compensate for the high total cost of installation and operation where grid impact will be low. DC fast-charging hubs should serve high-usage fleets and ride-hailing vehicles, ideally along high-usage corridors and commuting routes around major cities, and rest areas for interurban trips on major highways (Lee and Clark, 2018).

3. Correlation between Plug-In Electric Vehicles and Charging Infrastructure

Since 2011, we have witnessed the unprecedented growth of PEV sales and the number of charging infrastructure points in different parts of the world.

The European Alternative Fuels Observatory (2019) database shows that in European Union (EU) 28 and in four non-EU countries (Iceland, Norway, Switzerland, Turkey), PEV sales have increased from only 11,500 units in 2011 to nearly 386,000 in 2019. The database reveals that recharging infrastructure points in Europe have increased from 3,200 in 2010 to 161,000 in 2019 – nearly five-fold per year.

PEV ownership and public charging infrastructure data was collected from 14 countries[4] that have the highest EV uptake, because the data was available for local EV uptake and public charging infrastructure. These national markets include about 90% of global EV sales (Hall and Lutsey, 2017).

Public charging infrastructure is key to EV market growth. Rough apparent patterns are observed between EV uptake and charging infrastructure availability, with substantial variability across markets. The development of a robust charging infrastructure network is a key requirement for large-scale transition to electromobility, but there is no universal benchmark for the number of EVs per public charge point (Hall and Lutsey, 2017).

Table 4.4 shows that the average ratios of PEVs to charging station in EV front-runners vary greatly between or even within regions.

Table 4.4: Indicated Average Ratios of Electric Vehicles per Public Charge Point

Country	Region	Electric vehicle/Public charge point ratio	Source
China	China average	8 (pilot cities) 15 (other cities)	NDRC (2015)*
World	Worldwide	8 (2015), 15 (2016)	IEA Electric Vehicle Initiative (2016, 2017)*
United States	United States average	7-14	Cooper and Schefter (2017); EPRI (2014)*
		24	Wood et al. (2017)*
	California	27	CEC and NREL (2017)*
European Union	European Union average	10	European Parliament (2014)*
	The Netherlands	3.6	Spöttle et al. (2018)
	Norway	15.2	
	Germany	6.7	
	The UK	9.7	
	France	7.6	

* From Hall and Lutsey (2017).

[4] Austria, Belgium, Canada, China, Denmark, Finland, Germany, Japan, the Netherlands, Norway, Sweden, Switzerland, the United States, and the United Kingdom.

EU data shows that the PEV market share of new registrations rises as the vehicle to charging point ratio drops from 25 to 5. A low ratio would benefit PEV uptake but infrastructure coverage denser than 1 charging point per 10 PEVs would be inefficient: sales numbers become insensitive with a decreasing ratio. The high costs of additional charging infrastructure, therefore, do not justify high investments (Harrison and Thiel, 2017).

A study on the relationship between the number of PEVs and the publicly accessible charging points in Europe (EU 28 + Norway) demonstrate two interesting findings. First, with some variation in the countries' national context, the density of charging infrastructure generally correlates positively with PEV adoption. A range of other factors are proven or suspected to be correlated with PEV uptake, such as model availability, financial incentives, urban density, etc. Charging infrastructure is necessary but not enough for PEV adoption. Most front-runner countries have applied a demand-oriented approach to rolling out charging infrastructure. Second, the ideal ratio of PEVs per charging point will, in the long run, lie between 10 and 16 (Spöttle et al., 2018).

The rollout of charging infrastructure may be oriented towards demand or coverage. The demand-oriented approach assumes that charging infrastructure should be constructed where existing and future demand can be determined and aims for optimal allocation and utilisation of all charging points and avoids redundancies. The coverage-oriented approach is premised on public infrastructure guaranteeing a minimum standard of service to the widest possible public by minimising the distance between the charging points. None of the front-runner countries take the coverage-oriented approach, except the US, with its designated alternative fuel corridors; China, which has required 88 pilot cities to install a charging network with charging points positioned no farther than 1 km from any point within the city centre; and Norway, where the government financed the deployment of at least two fast-charging stations every 50 km on all main roads by 2017 (Figenbaum, 2019).

3.1. Facilitating Charging Infrastructure Investment

Developing charging infrastructure needs significant investment. The public sector cannot bear the total burden and needs to attract private investors. The main challenge is convincing investors that the investment will be profitable as there are not yet enough EVs on the road.

Some EV front-runner country strategies for rolling out charging facilities are summarised below.

3.1.1. China

The world leader in number of EVs sold, China started in 2009 with the ‘10 cities, 10,000 vehicles’ business model to promote EV development, but established targets only in June 2012: 500,000 vehicles by 2015 and 5 million by 2020.

The programme’s first step was top-down selection of experimental sites where the central government could either test policy or try out innovative practices. The second step – evaluation and absorption – combined bottom-up and top-down approaches. Central government agents evaluated the performance of pilot projects whilst local participants reported their progress to the central authorities, documenting the most advanced practices for wider diffusion. The third step – diffusion by the central government – popularised successful practices through the media and endorsement by leading politicians. The final step was the learning and feedback loop between the evaluation and absorption process and diffusion (Marquis et al., 2013).

Five models were created in the pilot cities: state leadership in Beijing, based on public sector support; platform-led business in Shanghai, replicating international models; cooperative commercialisation in Shenzhen, based on a leasing model through strategic partnership; flexible rental in Hangzhou; and fast-charging models in Chongqing, which is close to the Three Gorge Power Grid.

The city-based pilot programmes, however, focused on local goals and firms rather than a long-term national agenda. Competition for central government support eroded cities' willingness to cooperate with each other on setting national or international standards and goals; manufacturers or players were barred from entering other cities.

3.1.2. United States

EVs are becoming more popular in the US. California leads with 2% PEV share of total road vehicles, followed by Hawaii (1.2%), Colorado (0.56%), Texas (0.23%), and Ohio (0.15%). Measures in urban areas promoted PEV charging facilities (Fitzgerald, 2017):

- development of make-ready locations by utilities that would support a variety of third-party charging stations (California, Colorado);
- implementation of TOU rates that encourage users to charge during off-peak periods (California, Ohio, Hawaii);
- provision of significant rebates of charging development for privates (Colorado, Texas); low-interest loans for businesses, non-profits, public schools, and local governments for installing charging stations (Ohio); and grants to build stations (Texas);
- legal framework that favours private ownership of charging stations by allowing private companies to resell electricity supplied by a public utility to charge EVs (Colorado);
- partnership between public utilities and private companies in developing and operating charging stations (Texas); and
- explicit right to site charging on premise for multifamily dwellings and townhouses (Hawaii).

3.1.3. Europe

Measures taken by two PEV front-runner European countries – the Netherlands and Germany – are summarised below:

- **The Netherlands**. Between 2010 and 2014, seven grid operators (state owned and regional) invested in developing charging infrastructure (Living Lab Smart Charging, 2017), which was later included in the Green Deal Electric Transport Programme (2016–2020) backed by a consortium of central and regional governments, grid operators, the automotive sector, and universities. The programme provides funding for public charging poles equally from government, municipalities, and market players, and for installation of the Netherlands Knowledge Platform on Public Charging Infrastructure (Hamelink, 2016). The programme not only develops charging facilities but also the roaming system and implements international protocol standards.

- **Germany**. The country has several financial support programmes at different government levels. The Federal Ministry of Transport's programme for EV charging infrastructure and the regional model of electromobility finance and/or subsidise development of charging infrastructure that require local or private investment.

In other European countries – front runners or followers – state-owned agencies, with or without big private partners such as grid operators, first financed or organised deployment of charging infrastructure. Agencies or consortia then offered financing programmes to the private sector or local government to develop charging infrastructure.

3.2. Charging Scheme Strategy

The expansion of PEVs and their demand for charging facilities have become increasingly important. The associated electricity demand will affect energy markets and the grid infrastructure. Studies on Portugal (Nunes, 2015) and the EU (Kasten and Purwanto, 2016) show the impact of EVs once they make up 5%–10% of total road vehicles.

The amount of electricity needed to meet additional demand and the greenhouse gas emissions produced to generate electric power are calculated based on the average of total power plant mix. PEVs' environmental performance would be better than conventional vehicles' if additional demand were met by a low-carbon intensive energy mix. Even if there were 300 million electric cars, if power generation were not decarbonised, CO_2 emissions would be insignificantly reduced by less than 1% (Sauer, 2019). Electric vehicles may reduce local pollution but not global emissions.

China, the EV front runner in Asia, is struggling to curb the share of coal-fired-based electric energy from 75% to 50% and to increase that of renewable sources from 25% to 50% in 2030, bringing down power generation carbon intensity by one-third and ensuring that EVs will be less carbon intensive than they are now. China uses more electricity from coal-fired generating plants during fast-charging peak demand periods and after working hours in the evening. Slow charging during off-peak hours, when energy from renewables such as wind turbines is available, would reduce CO_2 (Chen et al., 2018).

When and how PEVs are charged determine which generation plants satisfy additional electricity demand and have an impact on emissions. Depending on their total system and marginal costs, different types of power plants may increase production. Including this charging scheme in the analysis might change the calculation results.

Uncontrolled or user-driven charging occurs mostly after work in the evening, when electricity demand is already high, increasing system load and costs of utilities (Brandmayr et al., 2017).

User-driven charging would raise severe concerns about generation adequacy and may jeopardise the stability of the power system (Schill and Gerbaulet, 2015). Fast-charging stations use large amounts of power for short periods of time, meaning that expensive upgrades will be needed for a relatively low use rate (Hall and Lutsey, 2017). In the US, if EVs constitute 25% of all road vehicles, uncontrolled charging would increase electricity peak demand by 19%, but spreading charging over the evening hours would increase demand by only 0%–6% (Fitzgerald, 2017).

Reducing carbon emissions and the load on the local grid will be solved only by charging management schemes, some of which are described below.

- **Off peak or network-oriented charging**. Includes policies and structures that encourage off-peak-period charging, including workplace or daytime charging and night-time home charging, to avoid network congestion and physical capacity constraints. This strategy should increase system stability and grid functioning, but producing electricity during low-demand periods using conventional energy sources might have negative environmental effects.
- **Cost-oriented charging**. This strategy aims to reduce EV charging cost by shifting the charging time to periods of low energy prices. EV owners could benefit from low energy costs, and load patterns might be smoothed as the low charging cost period coincides often with low demand. Additional conventional production during low-cost periods could have negative environmental effects. Some findings are the following (Schill and Gerbaulet, 2015). First cost-driven charging promotes renewable energy more than user-driven charging, but cost-driven charging might also increase the use of the emission-intensive lignite power generation. Germany, for example, has the lowest marginal costs for thermal technology and uses more hard coal than user-driven strategies. Second, cost-driven charging reduces unused generated power more than uncontrolled charging. The opposite happens in countries with a high share of renewables, such as Denmark, which has a low share of emission-intensive generators and high share of wind power. Using a cost-driven charging system, Germany and ASEAN countries will reduce CO_2 emissions only if they build more renewable-energy generators. Cost-driven charging will work only if emission externalities are correctly priced.
- **Smart charging**. Includes controlled charging and demand response. A simpler solution such the use of in-vehicle timers to take advantage of TOU rates could help minimise stress on the electrical grid whilst also saving money for consumers. Smart charging strategies are less practical for DC fast charging than for level-2 charging as drivers expect fast charging to be available on demand (Hall and Lutsey, 2017). As the fast charging market continues to grow, fast chargers should be placed near adequate high-capacity electrical infrastructure.
- **Combined smart and cost-oriented charging**. Decreasing real-time price increases renewable energy share, such as wind as it is available during that period. The variability of wind power drops as its share increases. In this situation, CO_2

emissions could be higher than the average of the total power plant energy mix, if coal, for example, due to its low marginal costs, dominates the lower-price part of the merit order (Dallinger et al., 2012).

- **Renewable energy-oriented charging** or **low emission-oriented charging**. Aims to increase environmental performance or avoid negative impact of greenhouse gases and air pollutant emissions. The measure shifts charging times to periods of high or surplus renewable energy generation, resulting in reduced additional production by conventional plants. However, conditions vary in different energy systems and this strategy requires sufficient renewable power generation to meet additional electricity demand.

3.3. Conclusion

PEVs are amongst the most viable means to reduce the use of fossil fuel, reduce greenhouse gases, and improve air quality. The issue is how to accelerate market penetration.

- PEV charging infrastructure is more complex than ICEV refuelling infrastructure, in terms of technology, interoperability, standardisation, and impacts on the electric power grid.
- Charging infrastructure is necessary for PEV deployment but is not the only determining factor.
- The cost of rolling out public PEV charging facilities is high. National governments need to initiate significant investment at least at the beginning of PEV penetration whilst partnering with private companies until markets mature.
- Central governments should facilitate the development of charging infrastructure by providing rebates, tax breaks, low-interest loans, and subsidies to private companies to build infrastructure; building make-ready facilities for private companies to continue; and partnering with private companies in developing and operating stations.
- Local or regional circumstances such as manufacturing maturity, business characteristics, and electricity supply profile need to be considered early on to define a proper partnership approach and discourage excessive intercity competition.
- The charging scheme strategy needs to be planned as early as possible to ensure that PEV penetration reduces greenhouse gases by using less fossil-fuel–based power whilst ensuring that additional electricity demand does not further burden the electricity grid.

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. Harmonise Automobile and Energy Policies

Dissemination of xEVs can reduce oil consumption but not always CO_2. BEVs emit no CO_2 (tank to wheel) but electricity generation (well to tank) emits a large amount of CO_2. Reducing CO_2 emissions will be limited unless the power generation mix is decarbonised. Many ASEAN countries rely heavily on cheap coal-fired thermal power, which is not always a low-carbon generation mix. Climate-change countermeasures that promote xEVs are important, but the overall effects of well to wheel must be considered.

Automobile and energy policies must be harmonised to make the most of vehicle electrification. If different government sections govern policies, as they do in many countries, they must coordinate closely.

Low-carbon power sources such as renewable energy are expensive, and if they are introduced too quickly, the result will be increasing electricity retail prices or total subsidies. Power generation must be decarbonised and side effects mitigated. The various policy goals must be coordinated to prepare for the substantial introduction of xEVs.

2. Take a 'Bridging' Pathway to Mitigate Negative Side Effects

xEVs are more expensive than ICEVs. xEVs need a huge amount of investment and economic incentives such as subsidies to disseminate them. Rather than promoting the spread of expensive BEVs early (BEV ambitious scenario), they should be gradually introduced as technology reduces their cost (HEV bridge scenario).

The same applies to introducing low-carbon power sources, which are essential to spread BEVs. Rushing to introduce expensive low-carbon power now would result in increasing electricity retail prices or total subsidies.

Vehicle electrification must be affordable for consumers, businesses, and governments. To mitigate negative side effects, vehicles should be electrified at a speed that fully anticipates cost reduction. Controlling cost is crucial for transition management.

3. Encourage Support by Local Governments

Central and local governments can promote xEV penetration. Some local support needs to comply with national authorities but other local support can be implemented alone. Local measures are less costly.

Local governments can use xEVs for to transport the public, the elderly, and municipal workers. Local governments can offer free parking for xEVs and free charging at public stations, permit xEV drivers to use lanes reserved for public transport, and offer road toll exemptions or discounts. If these measures are implemented by a group of neighbouring local governments, their effects may be greater than if implemented by a single local government.

4. Recommendations for Developing Charging Infrastructure to Facilitate PEV Deployment

- **Set targets for building charging infrastructure by a certain time**. Targets should be derived from PEV deployment targets described in a clear roadmap, based on national targets to reduce fossil-fuel use and imports, reduce greenhouse gases as defined in nationally determined contributions, and improve urban air quality. Governments should do the following:
    - Determine whether the development approach should be demand or coverage oriented.
    - Elaborate on guidelines to develop and distribute charging infrastructure. Define the main development axes to determine the focus of deployment between location and/or ownership patterns, e.g., privately owned (housing, residential areas, workplaces) or public (charging stations, urban and interurban stations, network of high-speed chargers along highways).
    - Define different types of charging speed and technology.
- **Define measures to facilitate infrastructure investment, especially to involve stakeholders in a clear, open, and transparent process whilst creating an open and competitive market for EV charging**. Installing chargers, especially DC fast chargers, is expensive. Making a business case for installing them is difficult as there are not yet enough EVs on the road. Recovering the capital cost of charging facilities, especially fast ones, is extremely slow. Rebates and other incentives for homeowners and businesses to install chargers are needed. Governments must enable private installers or owners to secure profit sooner by, for example, allowing utilities to rate-base at least the make-ready portion of charging infrastructure and providing installation wiring. An alternative is for public utilities to make significant short-term investments until owning and operating charging stations is sustainable. Finally, tax holidays for installing and operating charging infrastructure, especially fast chargers, can stimulate investment and reduce the cost of capital. Utilities can be allowed to take advantage of their low cost of capital to extend their distribution networks and create make-ready locations for charging stations, or to install and

operate charging stations. In all cases, utility investment should be based on smart-performance–based regulations to ensure that the public receives good value.

- **Define measures to encourage the use of facilities**. Government cannot only rely on measures to reduce the cost of acquiring EVs but also needs to reduce the operating costs borne by users. The first measure is ensuring that the EV charging price maximises benefit to users without jeopardising electricity load to the grid or the price paid by other electricity users for other purposes, and that low-income communities will not suffer due to electrification of mobility. The second measure concerns interoperability, including standardisation not only of the physical charging equipment but also of payment and communication. Charging development currently takes a bottom-up approach through the independent efforts of numerous companies and governments and is not planned for interoperability. All players should develop cooperative billing arrangements such as using a standardised communication system in the form of open protocol.

5. Recommendations to Ensure PEV Penetration Objectives

- **Prepare a strategy to implement different charging schemes.** The impacts of PEV charging on the grid and power generation are currently negligible. But battery costs are declining continuously, electricity is cheaper than gasoline and diesel, and urban mobility and car ownership are rising in ASEAN countries. All these factors might lead to a tipping point for EV market penetration. A strategy is needed to implement different charging schemes to avoid pressure on the electric grid and to maximise the use of low-carbon power generation.
- **Educate EV users on how to optimally use and charge PEVs**. EV drivers should learn to optimise the use of their vehicles, including by planning trips and charging to minimise costs, and being aware of the infrastructure network.
- **Build an open data platform to gather information on public charging stations, their locations, types, modes, real-time use, and operators**. The platform should help users optimise their mobility and use of the electric grid whilst meeting transport demand.

6. Have a Clear Vision for xEV Deployment

Developing a roadmap for vehicle electrification is essential as is harmonising automobile and energy and environmental policies. Prior coordination is desirable amongst stakeholders: ministries, central and local governments, automobile manufacturers, petroleum and electricity suppliers, public transport operators, charging equipment operators, and consumers. They should not be burdened by policy.

A clear long-term vision will encourage private investment; obscure and frequently changing policies will not. It is needed to show not only a mere penetration target but also the necessary policies in a concrete manner to meet the target. Gasoline and diesel subsidies will advance electrification. Concrete and reasonable policies are important elements of a safe private investment environment.

7. Consider Appropriate Country-specific Pathways

Pathways to vehicle electrification vary by country and region.

Indonesia

The car penetration rate is low but the number of vehicles is large, and the cost of electrification is high. The ratio of total investment and total subsidy to economic and financial scale is high, and cost control is important. Motorcycles are about five times more numerous than other vehicles and changing from a motorcycle to a car has low electrification costs. BEVs do not greatly reduce CO_2 emissions, and the power generation mix must be decarbonised.

Malaysia

Malaysia has a high income level and a high car penetration rate. Whilst electrification investment is small, the xEV subsidies are large relative to the fiscal budget, and the degree of financial burden should be examined. The gasoline price under the managed float system is much lower than the electricity price, resulting in a longer payback period for BEVs, and then the huge amount of subsidy will be needed. Reviewing energy prices can be a policy tool for BEV diffusion.

Thailand

Thailand has a cleaner power generation mix than its neighbours and can more easily benefit from vehicle electrification. The ratio of amount of investment and subsidy to economic and financial scale is lower than in other countries. However, it is important to see Thailand, which has established its position as a car production base, from an industrial-policy perspective. Too-rapid vehicle electrification might damage production systems and it is necessary to proceed with caution.

Viet Nam

Viet Nam has about 20 times more motorbikes than cars. The motorbikes consume as much oil as cars, so if Viet Nam promotes electrification of relatively cheap motorbikes, it could reduce air pollution and oil consumption whilst keeping costs down. Because the investment and subsidy burden is large, EVs should be introduced after their cost becomes sufficiently low.

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