Chapter 3

Tank-to-Wheel CO_2 Emission from Biofuels

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Chapter 3

Tank-to-Wheel CO_2 Emissions from Biofuels in East Asia Summit Countries

1. Introduction

1.1. Background

With an increasing trend of electric vehicle (EV) technology disrupting conventional internal combustion engine (ICE) technology, the future scenario of vehicle mix will change according to policy drive, technology readiness, and cost competitiveness. With recent carbon neutral commitment in the United Nations Climate Change Conference (COP26), the transport sector also holds responsibility in reducing net greenhouse gas emissions (GHG) from balancing the mix of EV and ICE with carbon-neutral biofuel blend.

1.2. Objective and Scope

The objective of this chapter is to establish the business-as-usual (BAU) landscape of the current vehicle ecosystem in select Association of Southeast Asian Nations (ASEAN) Member States (Indonesia, Malaysia, Philippines, Thailand, and Viet Nam) and India, with projection of vehicle growth in the future. Once the BAU landscape is established, a scenario analysis can be conducted with assumption of EV and biofuel mix in the future. Finally, energy consumption and GHG emissions can be analysed as a result of collective efforts on EV and biofuel in the transport sector.

1.3. Methodology

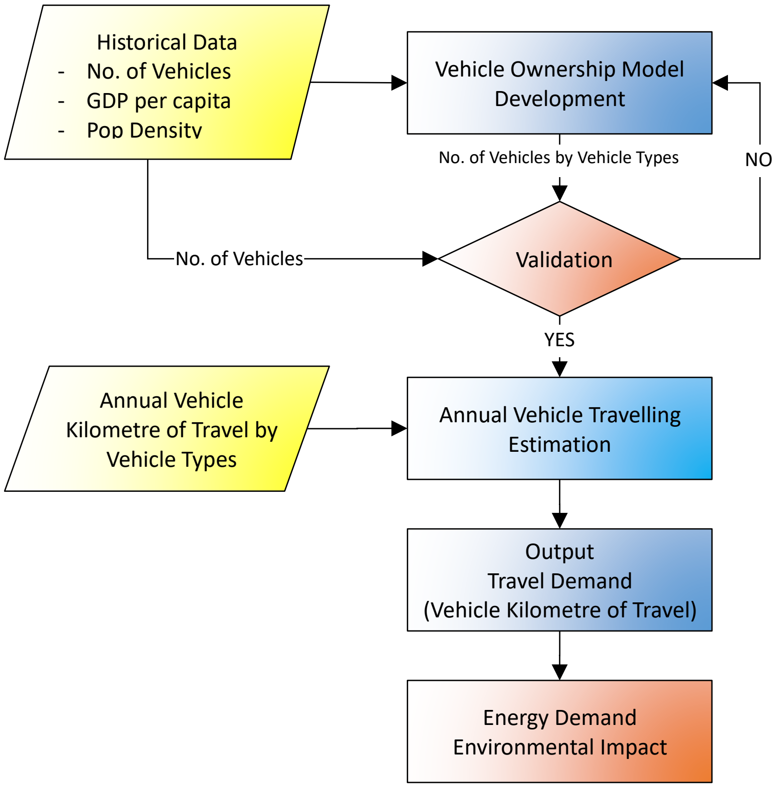
In order to analyse the energy use pattern in the transport sector with capability to predict energy demand with resulting emissions, a bottom-up approach, rather than a top-down approach, is undertaken due to its capability in accounting for the flow of energy based on a simple engineering relationship (Table 3.1) (UNFCC, 2005). Inputs of traveling demand, fuel consumption, and vehicle numbers from various types into the bottom-up model can yield the estimation of energy demand, as schematically shown in Figure 3.1 (LEAP, 2022). Amongst many others, the Low Emissions Analysis Platform (LEAP) system (LEAP, 2022) will be utilised to construct the energy demand model in this study.

Table 3.1. Differences between Top-down and Bottom-up Approach in Energy Model

Top-down	Bottom-up
Use aggregated economic data	Use detailed data on fuels, technologies, and policies
Assess costs/benefits through impact on output, income, GDP	Assess costs/benefits of individual technologies and policies
Implicitly capture administrative, implementation, and other costs	Can explicitly include administration and programme costs
Assume efficient markets, and no 'efficiency gap'	Do not assume efficient markets, overcoming market barriers can offer cost-effective energy savings
Capture intersectoral feedbacks and interactions	Capture interactions amongst projects and policies
Commonly used to assess impact of carbon taxes and fiscal policies	Commonly used to assess costs and benefits of projects and programmes
Not well suited for examining technology-specific policies.	

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

Figure 3.1. Flow of Bottom-up Energy Demand Model



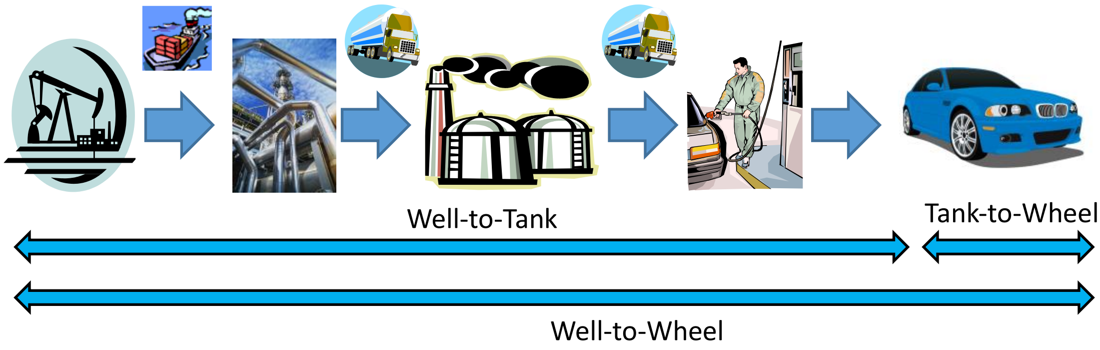
				Energy demand module			
Sector	Sub-sector	End-use	Device	Energy intensity			Energy demand
Transport sector	Transport mode	Modal split	Vehicle kilometre of travel	Type of fuel used	Fuel economy of vehicle		Scenario analysis
(vehicle)	(%)	(%)	(kilometre)	(%)	(GJ per veh-km)		(GJ or ktoe)

GJ = gigajoule, ktoe = kilotonne of oil equivalent.

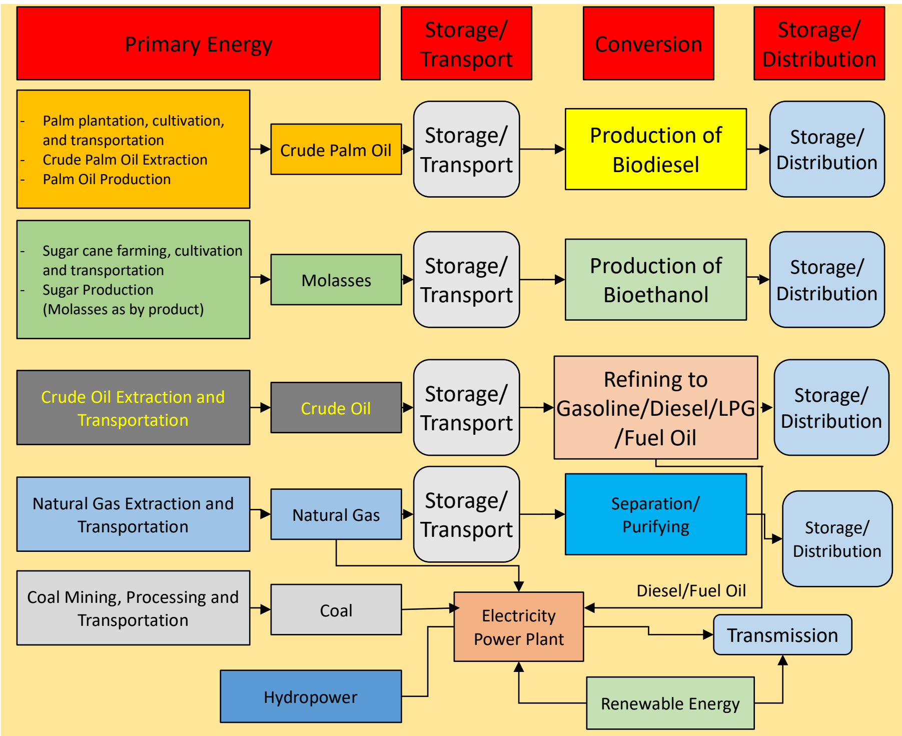
Source: LEAP (2022).

Figure 3.2. Schematic Concept of Life Cycle Inventory

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



(b) Detail Example on Various Transportation Fuels



Source: Pongthanaisawan (2012).

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

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

For model calibration, it will be benchmarked against historic data of energy consumption. For the GHG module, well-to-wheel analysis (taking results from Chapter 2 into account) of fossil, biofuel, and electricity generation will be reviewed with an emphasis on gathering secondary data on biofuel (both ethanol and biodiesel), as well as national inventory data on electricity generation for EVs (Figure 3.2) (Pongthanaisawan, 2012). With careful calibration on both energy consumption and GHG emissions, the final model with a database will be utilised to investigate various effects from energy policy.

2. Energy Demand Model

2.1. Model Setup

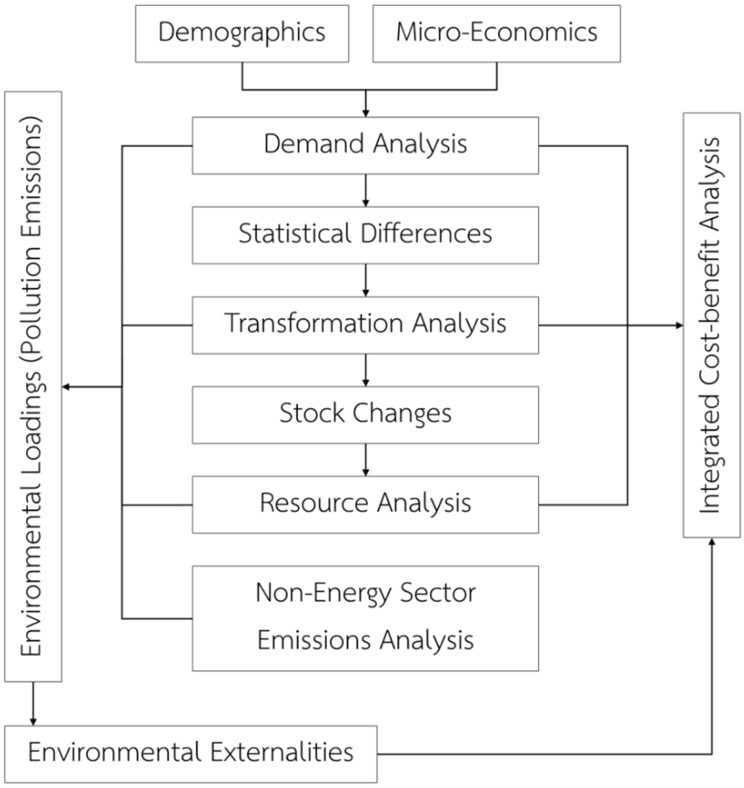
The choice of a bottom-up energy model approach in the present study is the LEAP system (LEAP, 2022), developed by the Stockholm Environment Institute. LEAP modeling capabilities are highlighted in Table 3.2, with the calculation flows shown in Figure 3.3.

Table 3.2. Key Characteristics of LEAP

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

Source: LEAP (2022).

Figure 3.3. LEAP Calculation Flows



Source: LEAP (2022).

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

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

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

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

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

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

2.2. Estimation of the Number of Vehicles (NV)

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

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

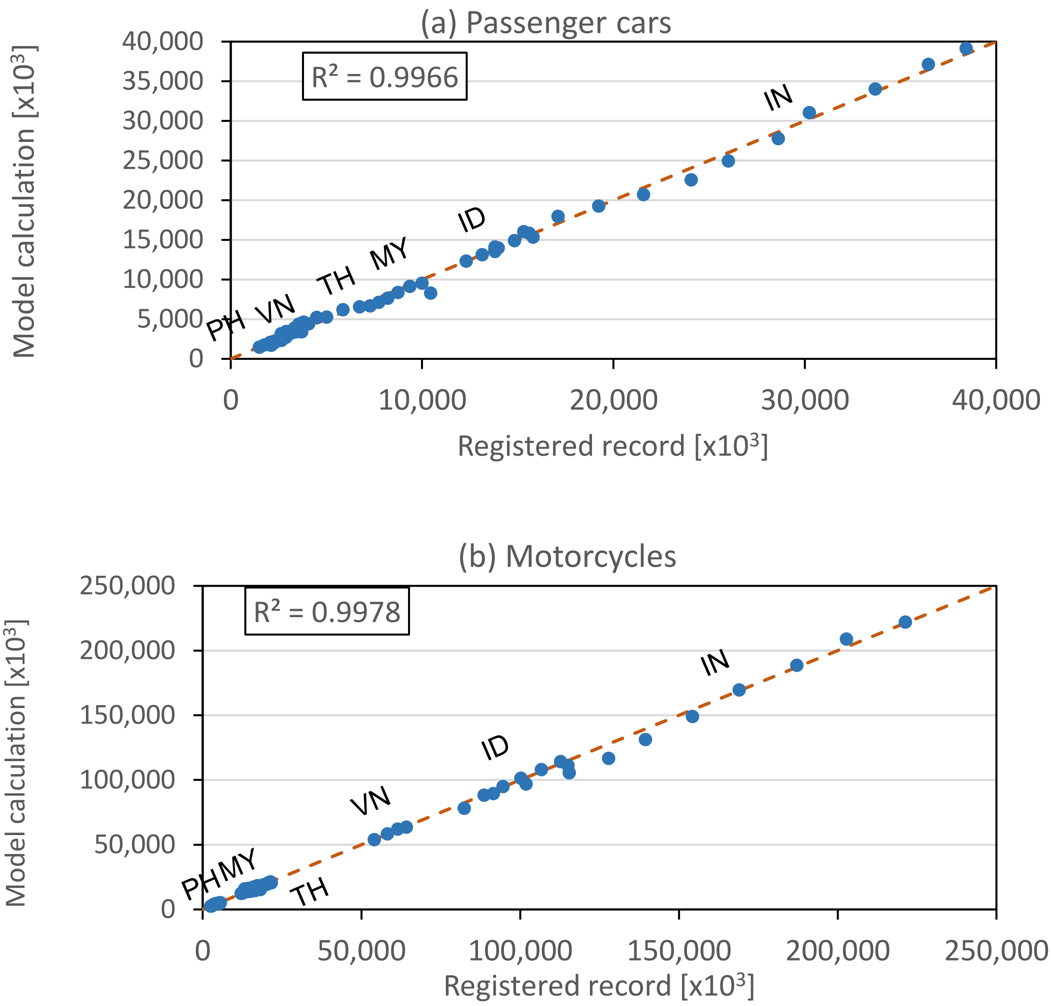
where

VO	= vehicle occupancy (number of vehicle/1,000 population)
S	= saturation level of VO (number of vehicle/1,000 population)
GDPpCap	= GDP per capita ($US/person or B/person)
PopDen	= population density (person/sq km)
a, b, and c	= coefficient from curve fitting with historical data

In this study the numbers of passenger cars and motorcycles from six considered countries (Indonesia, Malaysia, Philippines, Thailand, Viet Nam, and India) are fitted with historical records provided to working group members. The model calculated results are validated with historical registered record for passenger cars and motorcycles as shown in Figure 3.4. The models of vehicle numbers are shown in Table 3.3 for passenger cars and Table 3.4 for motorcycles. Noted that the GDP (at constant price) represents the household economic situation in each country (World Bank, 2022a). The population data are collected from the

World Bank (World Bank, 2022b). However, the Thailand data are collected from the Bank of Thailand (Bank of Thailand, 2022).

Figure 3.4. Validation of Vehicle Numbers for Five ASEAN Countries and India for (a) Passenger Cars and (b) Motorcycles



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

Table 3.3. Models of Passenger Car Numbers

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

*All countries' GDP are in US dollars, except Thailand's GDP is in Thai baht.
Source: Authors.

Table 3.4. Models of Motorcycle Numbers

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

*All countries' GDP are in US dollars, except Thailand's GDP is in Thai baht.
Source: Authors.

The saturation levels of the S-curve logistic function are shown in the formulas, 812 for passenger cars and 600 for motorcycles, while Viet Nam's motorcycles have 750 saturation level higher than other countries, according to the specific situation in Viet Nam. In the vehicle stock model, the new vehicles (vehicle sales) were calculated from simplified percent of new vehicle numbers by total on-road vehicle numbers, which are shown in Table 3.5 for various East Asia Summit countries.

Table 3.5. Percent of New Vehicle Numbers by On-Road Vehicle Numbers

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

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

2.3. Estimation of Vehicle Kilometre of Travel

The second variable, vehicle kilometre of travel (VKT), is the distance travelled by each considered vehicle. The VKT will govern how much fuel or energy is consumed for each vehicle type within a unit distance. The VKT values in this study were collected from some member countries but Thailand's data are not available and are presumed (Table 3.6).

Table 3.6. Vehicle Kilometre of Travel

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

Note: *Thailand data is used where data from member countries are not available.
VKT = vehicle kilometre of travel.
Source: Authors.

2.4. Estimation of Fuel Economy

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

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

Where gasoline is fuelled by gasoline and ethanol fuels, diesel is fuelled by diesel and biodiesel fuels. The share of PHEV fuel usage between gasoline (gasoline and ethanol) and electricity are 68.25% and 31.75%, respectively, estimated from the United States' fuel economy database (US-EPA, 2022). The fuel economy of passenger cars and motorcycles with various fuel/technology are shown in Table 3.7.

Table 3.7. Assumption of Fuel Economy

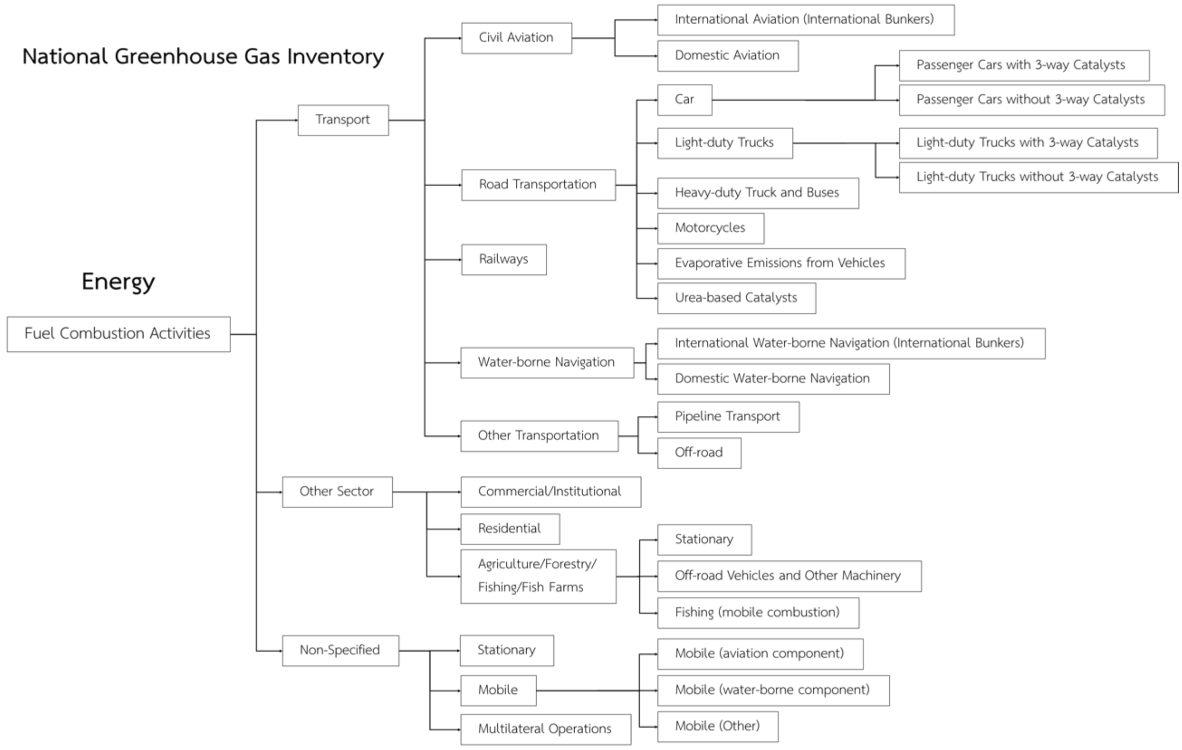
	Passenger Cars					Motorcycles	
	Gasoline	Diesel	PHEV		BEV	Gasoline	eMC
			Gasoline	Electricity			
Indonesia	10.99	9.71	5.25	48.31	10.73	3.60	2.88
Malaysia*	7.86	8.08	3.75	34.55	16.18	2.44	3.49
Philippines	12.62	10.53	6.02	55.47	16.18	2.44	3.49
Thailand*	7.86	8.08	3.75	34.55	16.18	2.44	3.49
Viet Nam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

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

2.5. Tank-to-Wheel Greenhouse Gas Emissions

The tank-to-wheel greenhouse gas (TTW GHG) emissions are calculated according to the Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories (IPCC, 2006) in this study. For fuel combustion in road transportation, the emissions factors are selected according to the Technology and Environmental Database as shown in Figure 3.5.

Figure 3.5. Activity and Source Structure in the Energy Sector



Source: IPCC (2006).

The TTW GHG emissions are defined from the fundamentals of combustion reaction. In the combustion process, the complete combustion products are mainly CO_2 and water (H_2O). CO_2 is the major greenhouse gas emissions. In addition, the other emissions also affect the global warming impacts, two major species are methane (CH_4) and nitrous oxide (N_2O). Tier 2 is selected in this study to collect TTW GHG emissions for considered fossil fuel. The emissions levels are assumed according to current emissions standards for new vehicles and the share of vintage vehicles in the considered region as shown in Table 3.8.

Table 3.8. Chosen Vehicle Models to Represent TTW GHG Emissions

Type of Vehicle	Chosen Vehicle Model
Gasoline passenger cars (for all gasoline combustion including HEV and PHEV)	European cars moderate control gasoline
Diesel passenger cars	European cars moderate control diesel
Gasoline motorcycles	European motorcycles >50 cc 4 stroke Uncontrolled gasoline

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

As above mentioned, the TTW GHG emissions for fossil fuel combustion in road transportation comprise CO_2, CH_4, and N_2O. These emissions are converted into the CO_2-equivalent unit by multiplied with the global warming potentials (GWP) as shown in Table 3.9.

Table 3.9. Global Warming Potentials of GHG Emissions from Combustion Process

	CO_2	CH_4	N_2O
GWP (kg in $CO_{2,eq}$/kg of considered emissions)	1	25	296

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

Besides fossil fuel combustion, biofuels are considered as carbon neutral fuels. It means that the CO_2 produced during biofuel combustion is equivalent to the CO_2 quantity absorbed in the photosynthesis process of biofuel plantation.

2.6. Projection of Socioeconomic Variables

The bottom-up model was developed according on socioeconomic variables. In this study, the number of vehicles were defined as S-curve logistic function of two socioeconomic variables, e.g. the gross domestic product (GDP) and population defined in this section.

2.6.1. Gross Domestic Product

The GDP information was collected at the 2015 constant prices in US dollar (World Bank, 2022a) with an exception for Thailand. The data are available to year 2020. Thailand's GDP is collected from the Bank of Thailand (Bank of Thailand, 2022) in baht at 2002 constant prices. The current GDP value and growth rate are shown in Table 3.10.

Table 3.10. Projection of Gross Domestic Product

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

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

2.6.2. Population (Capita, Cap)

Similar to GDP information, the population of considered countries is collected from the World Bank (World Bank, 2022b) with an exception for Thailand. Thailand's population was collected from the Bank of Thailand (Bank of Thailand, 2022). The current populations and growth rates are shown in Table 3.11.

Table 3.11. Population Projection by Country

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

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

3. Scenario Analysis

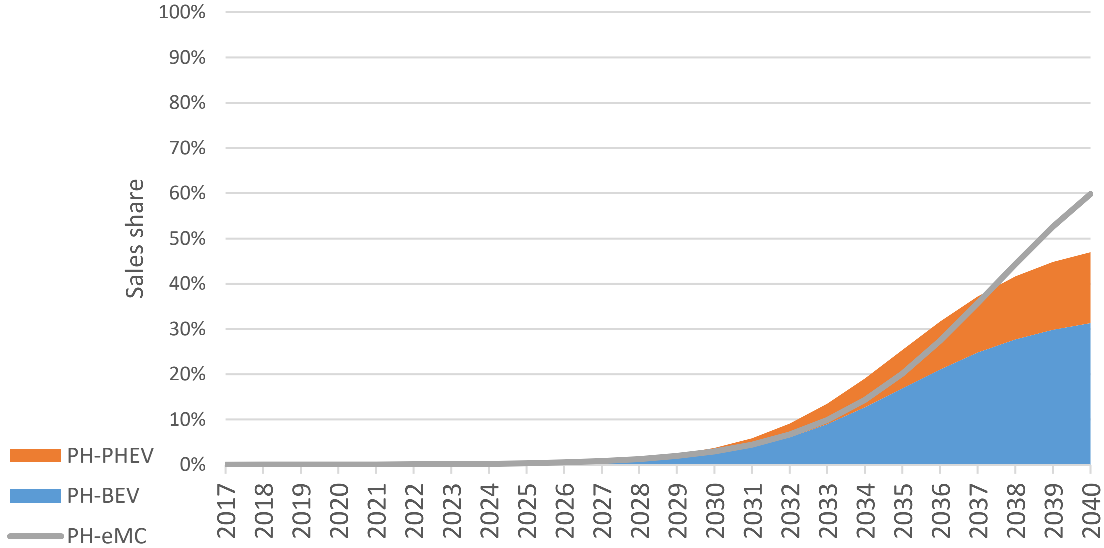
3.1. Scenario Definition

As mentioned above, road transportation was modelled as NV (passenger cars and motorcycles) with additional information of VKT and FE. The road transportation model was calculated between 2022–2040 according to a limit of EV projection. The BAU scenario was developed to be the baseline projection if there will not be any electric vehicle promotion or biofuel support. The share of ICE-to-EV was defined to be unchanged from the current situation, as well as the biofuel fraction. Otherwise, the EV scenario and biofuel scenario were developed to project the impacts of each energy strategies. The definition of EV- and biofuel scenarios are shown in comparing the BAU scenario in this section.

3.1.1. Electric Vehicle Scenario

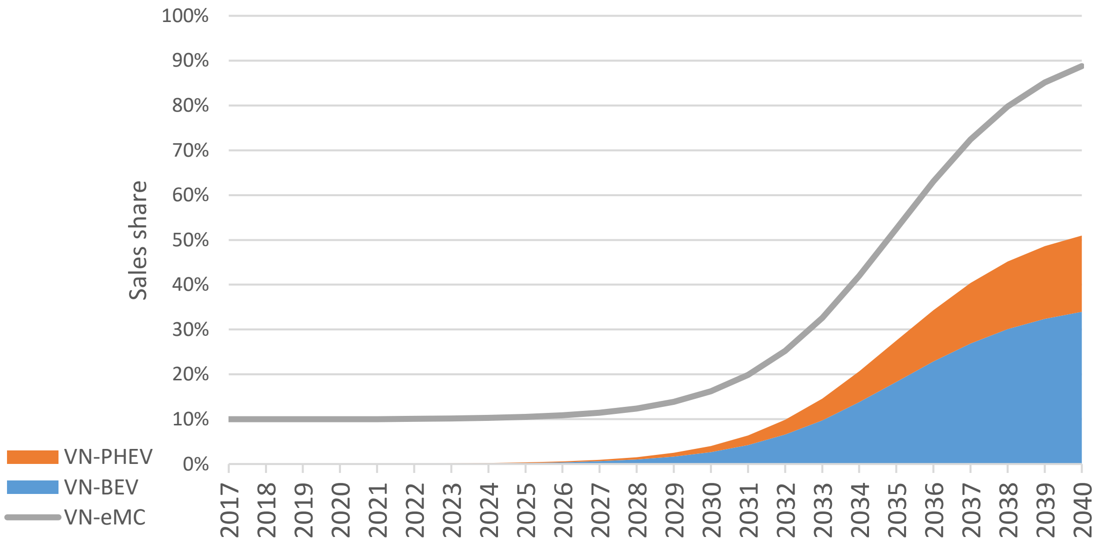
The EV scenario is defined so that EVs can penetrate the automotive market. The potentials of EV penetration in considered countries were collected according to information shared by the working group members who composed national targets, government plans, projection of the industrial sector, etc. However, the EV share for the Philippines and Viet Nam is defined according to the EV projection from Bloomberg New Energy Finance (BNEF, 2021) as shown in Figure 3.6 and Figure 3.7, respectively. The EV share (and EV sale numbers for Indonesia and Thailand) within the total vehicle sales are shown in Table 3.12.

Figure 3.6. Projection of Electric Vehicle Sales Share, Philippines (passenger cars and motorcycles)



BEV = battery electric vehicle, PHEV = plug-in hybrid electric vehicle, eMC = electric motorcycle, PH = Philippines.
Source: BNEF (2021).

Figure 3.7. Projection of Electric Vehicle Sales Share, Viet Nam (passenger cars and motorcycles)



BEV = battery electric vehicle, PHEV = plug-in hybrid electric vehicle, eMC = electric motorcycle, VN = Viet Nam.
Source: BNEF (2021).

Table 3.12. Electric Vehicle Penetration in Five Selected ASEAN Countries and India

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

Sources: *BNEF (2021); authors.

3.1.2. Biofuel Scenario

Biofuel has a potential to replace some portion of fossil fuel in the automotive energy consumption. The carbon neutrality feature, which means the CO_2 produced in the use phase is equal to that absorbed during the biofuel crop cultivation, is the most advantageous on applying biofuel to each energy consumed sector. In the road transport sector, two biofuels play a major role in replacing both conventional fuels, i.e. gasoline and diesel. The maximum blended fractions of ethanol and biodiesel are limited with some technical issues and also the available quantities of biofuel raw materials in each country or region. In fact, biofuels are blended at various fractions in the retail fuel stations, such as 7% biodiesel blend (B7), B10, and B20 for biodiesel blending in diesel fuel and 10% ethanol blend (E10), E20, and E85 for ethanol blending in gasoline fuel (called gasohol fuel). However, the averaged blended fraction is defined as all the biofuel quantity (from various retail fuel types, i.e. B7, B10, and B20 for biodiesel and E10, E20, and E85 for ethanol) divided by the total retail fuel consumption (gasoline kind and diesel kind). The average blended fractions are assumed from national targets, government plans, projection of available supply projection, industrial sector projection, etc. The ethanol blended fraction (in gasohol fuel) is assumed to be similar for both passenger cars and motorcycles. The average blended fraction of ethanol and biodiesel are shown for the biofuel scenario, in comparison to the BAU scenario (Table 3.13).

Table 3.13. Target of Biofuel Blended Fractions in Gasoline and Diesel Fuels

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

Source: Authors.

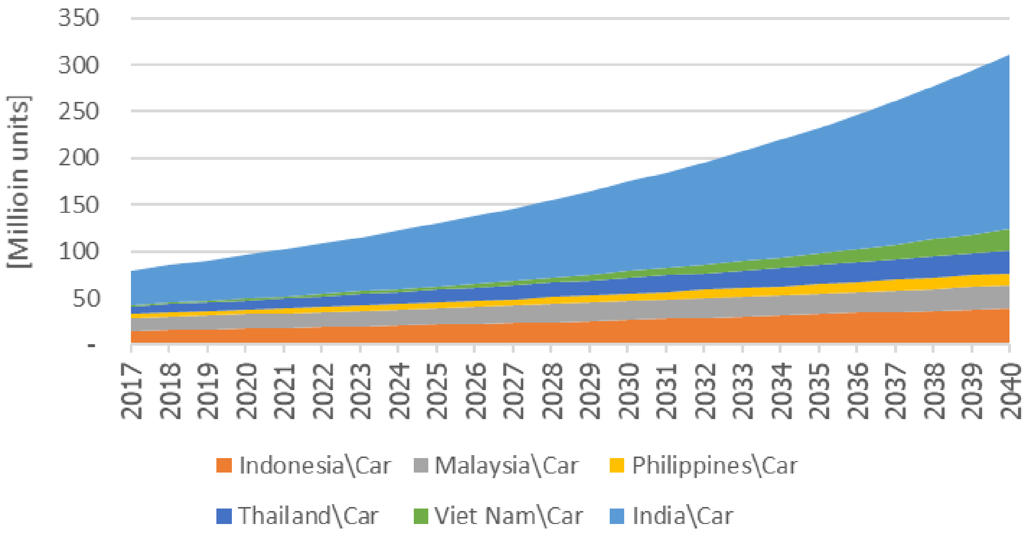
3.2. Perspective of Private Passenger Transport

As mentioned above, the energy demand and TTW GHG emissions are calculated using a bottom-up approach. The number of vehicle models will be projected from the current to the final year of model calculation (2040). The energy demand can be calculated by the assumption of fuel consumption and vehicle kilometre of travel (VKT). Finally, the TTW GHG emissions that relate to the quantity of fuel/energy consumption can be calculated using the Technology and Environmental Database and global warming potentials (GWPs). In this section the projection of vehicle numbers, energy demand, and TTW GHG emissions from the 'BAU scenario' will be shown first in Section 3.2, followed by impacts of 'EV penetration scenario' and 'biofuel promotion scenario' in Section 3.3.

3.2.1. Business-as-Usual: Projection of Vehicle Numbers

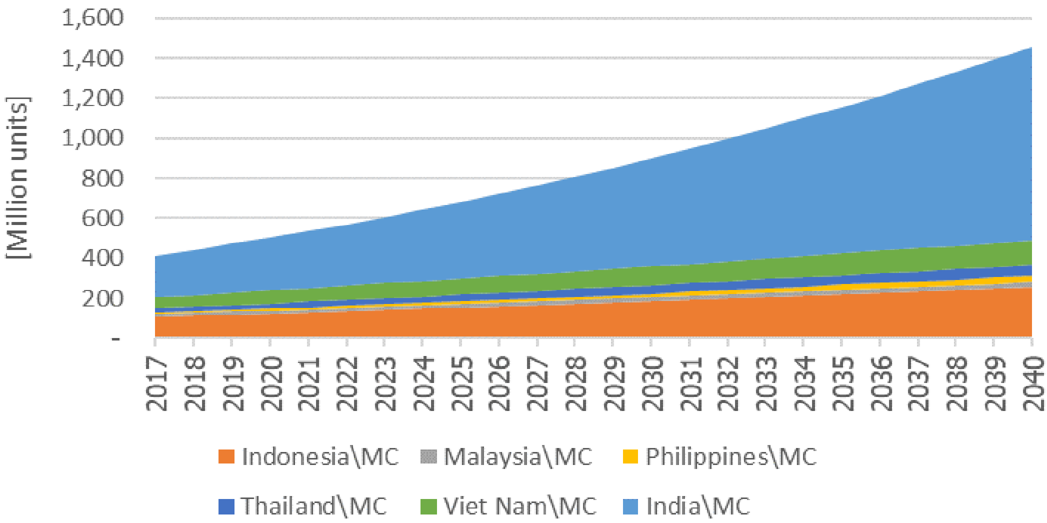
From various socioeconomic activities in the five ASEAN countries and India, the number of passenger cars, as well as motorcycles can be projected from the current year to the final projection year, as shown in Figure 3.8 and Figure 3.9, respectively. The results show that India will have the highest vehicle numbers for both passenger cars and motorcycles. For motorcycles, the three leading countries with high volumes are India, Indonesia, and Viet Nam.

Figure 3.8. Number of Passenger Cars in BAU Scenario



BAU = business-as-usual.
Source: Authors.

Figure 3.9. Number of Motorcycles in BAU Scenario

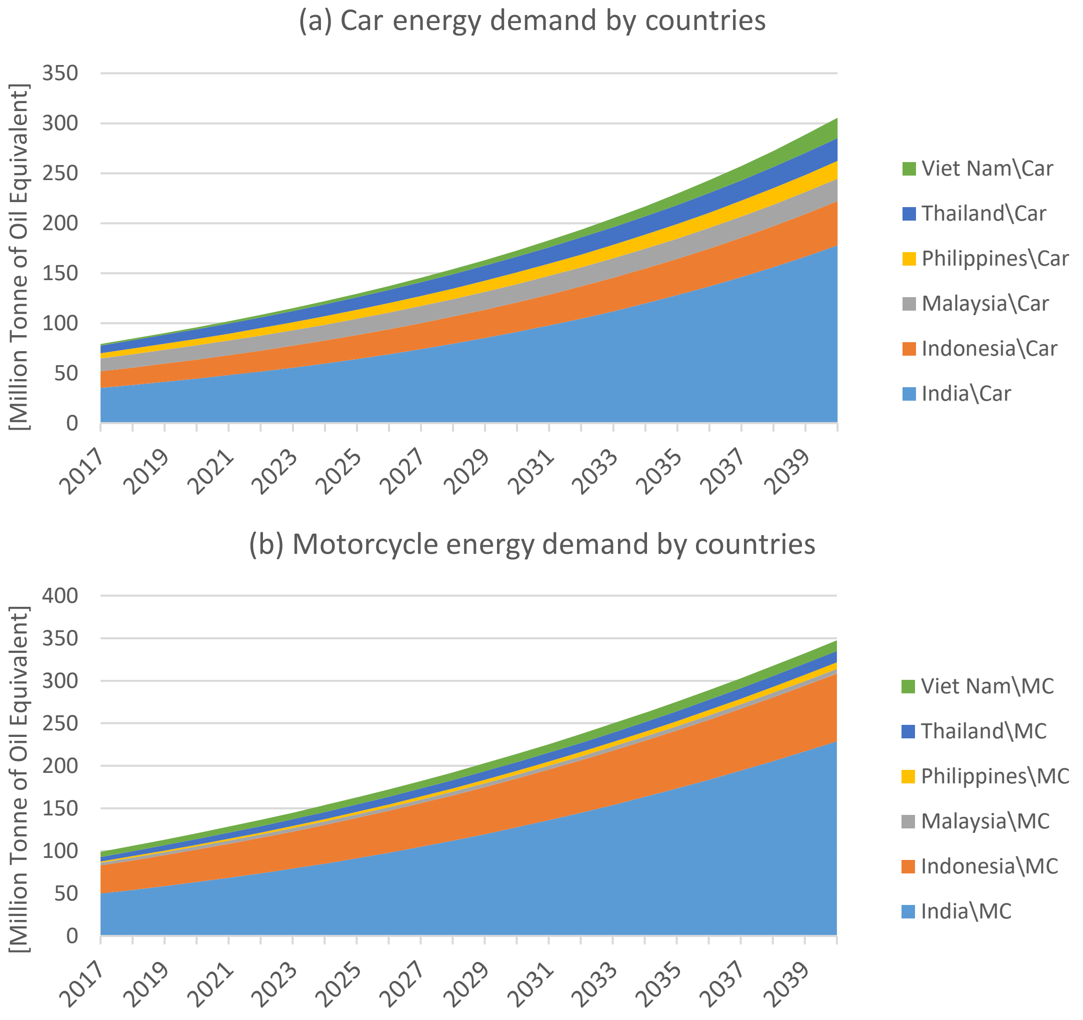


BAU = business-as-usual, MC = motorcycle.
Source: Authors.

3.2.2. Business-as-Usual: Projection of Energy Demand and Tank-to-Wheel Greenhouse Gas Emissions

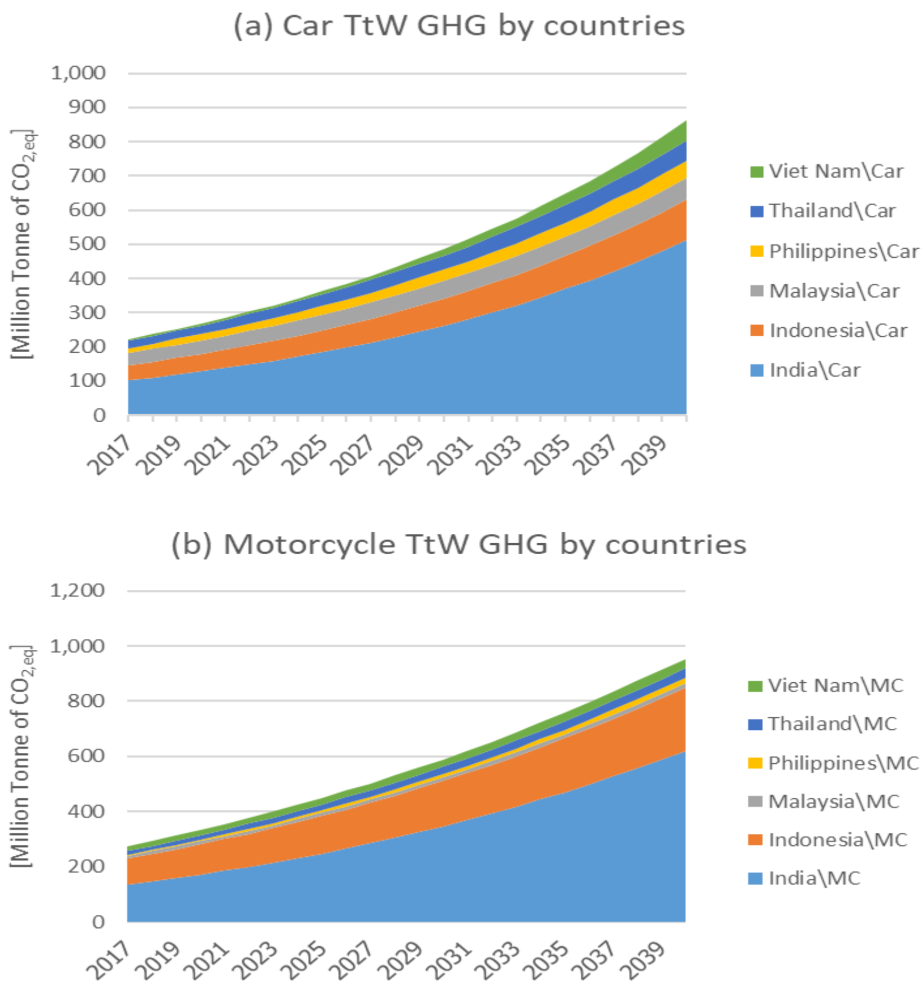
Proportional to the vehicle number, India will also require the highest energy demand for road transportation, followed by Indonesia. Besides, the other countries will require similar levels of energy demand, as shown in Figure 3.10 The same trend can be indicated for the projection of TTW GHG emission by countries, as shown in Figure 3.11. It is worth noting that although motorcycles consume less energy per unit compared to cars, many more units of motorcycles collectively results in higher energy consumption and hence TTW GHG emissions in the six countries. This observation is evidence for policy implications in the motorcycle sector.

Figure 3.10. Projection of Energy Demand by Country in BAU Scenario.



BAU = business-as-usual.
Source: Authors.

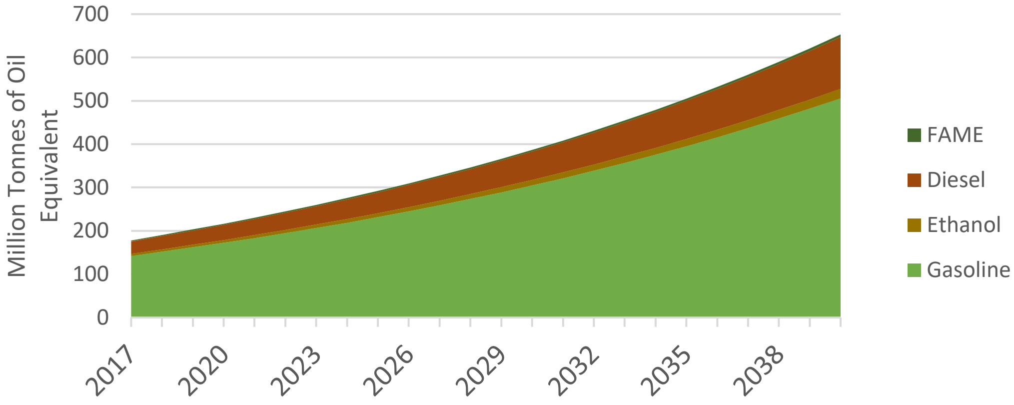
Figure 3.11. Projection of TTW GHG Emissions by Country in BAU Scenario



BAU = business-as-usual, TTW GHG = tank-to-wheel greenhouse gas.
Source: Authors.

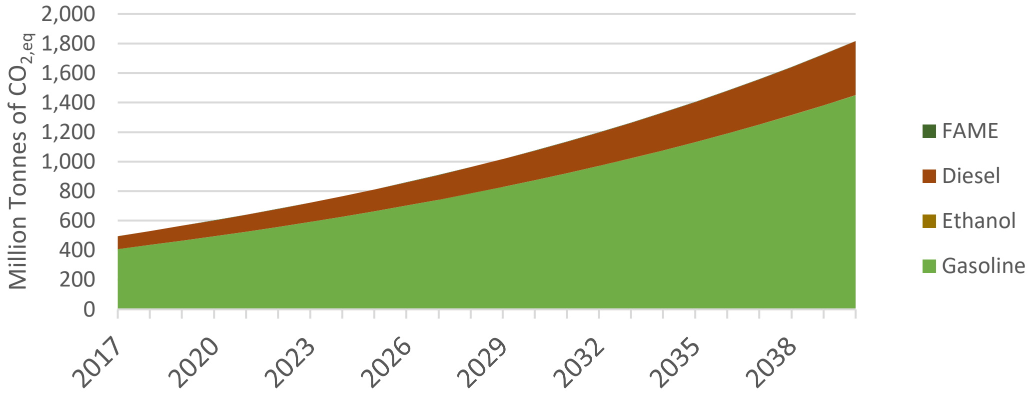
Investigations into the fuel type used in road transportation (cars and motorcycles) show that gasoline vehicles dominate light duty passenger vehicles in the five ASEAN countries and India. Gasoline and ethanol share the biggest portion in both energy demand projection with highest potentials of producing TTW GHG emissions up to 2040. The projection of energy demand and TTW GHG emissions with fuel variants are showed in Figure 3.12 and Figure 3.13, respectively. For Figure 3.13, ethanol and biodiesel, which are globally accepted as TTW carbon neutral fuels, are not presented in the graph.

Figure 3.12. Projection of Energy Demand by Fuel in BAU Scenario



BAU = Business-as-Usual, FAME = Faster Adoption and Manufacturing of Hybrid & Electric Vehicles.
Source: Authors.

Figure 3.13. Projection of TTW GHG Emissions by Fuel in BAU Scenario



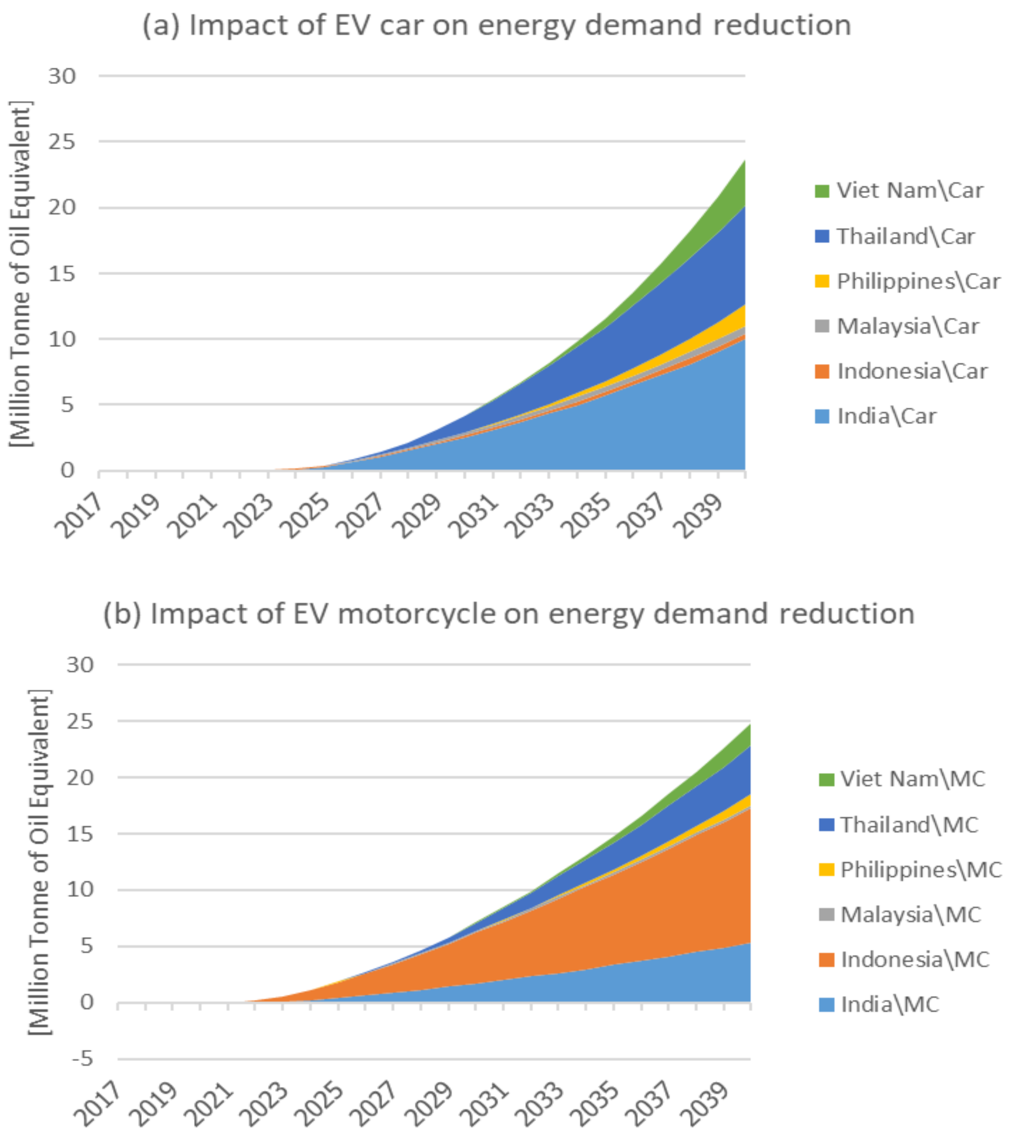
FAME = Faster Adoption and Manufacturing of Hybrid & Electric Vehicles, TTW GHG = tank-to-wheel greenhouse gas.
Source: Authors.

3.3. Impact of Electric Vehicles and Biofuel Scenario

3.3.1. Impact of Electric Vehicle Penetration (EV Scenario)

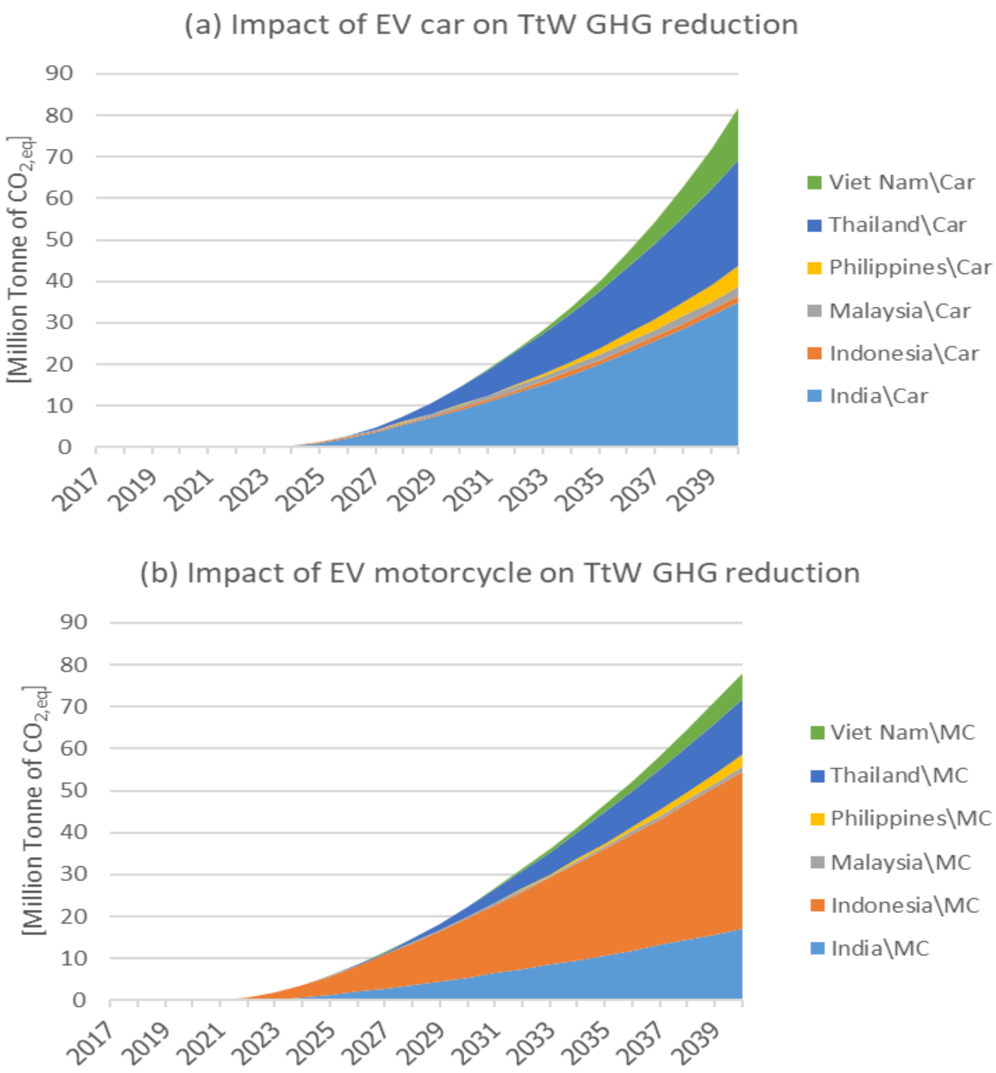
In this section, the impact of EV penetration will be shown for both energy demand and TTW GHG emissions projection in comparison with the BAU scenario. The results indicate that EVs can help reduce energy demand with their better energy efficiency in powertrain, as shown in **Error! Not a valid bookmark self-reference.**. The co-benefit of better energy efficiency, as well as zero-tailpipe (zero TTW GHG emissions), can be illustrated by reduced TTW GHG emissions shown in Figure 3.15. Again, it is interesting to see that the motorcycle segment has similar potential to reduce energy consumption and TTW GHG emissions as the car segment. Hence, policy direction to decarbonise the transport sector in motorcycles could be as effective as in car segment.

Figure 3.14. Impact of Electric Vehicle Penetration on Energy Demand Reduction



Source: Authors.

Figure 3.15. Impact of Electric Vehicle Penetration on Reduction of TTW GHG Emissions

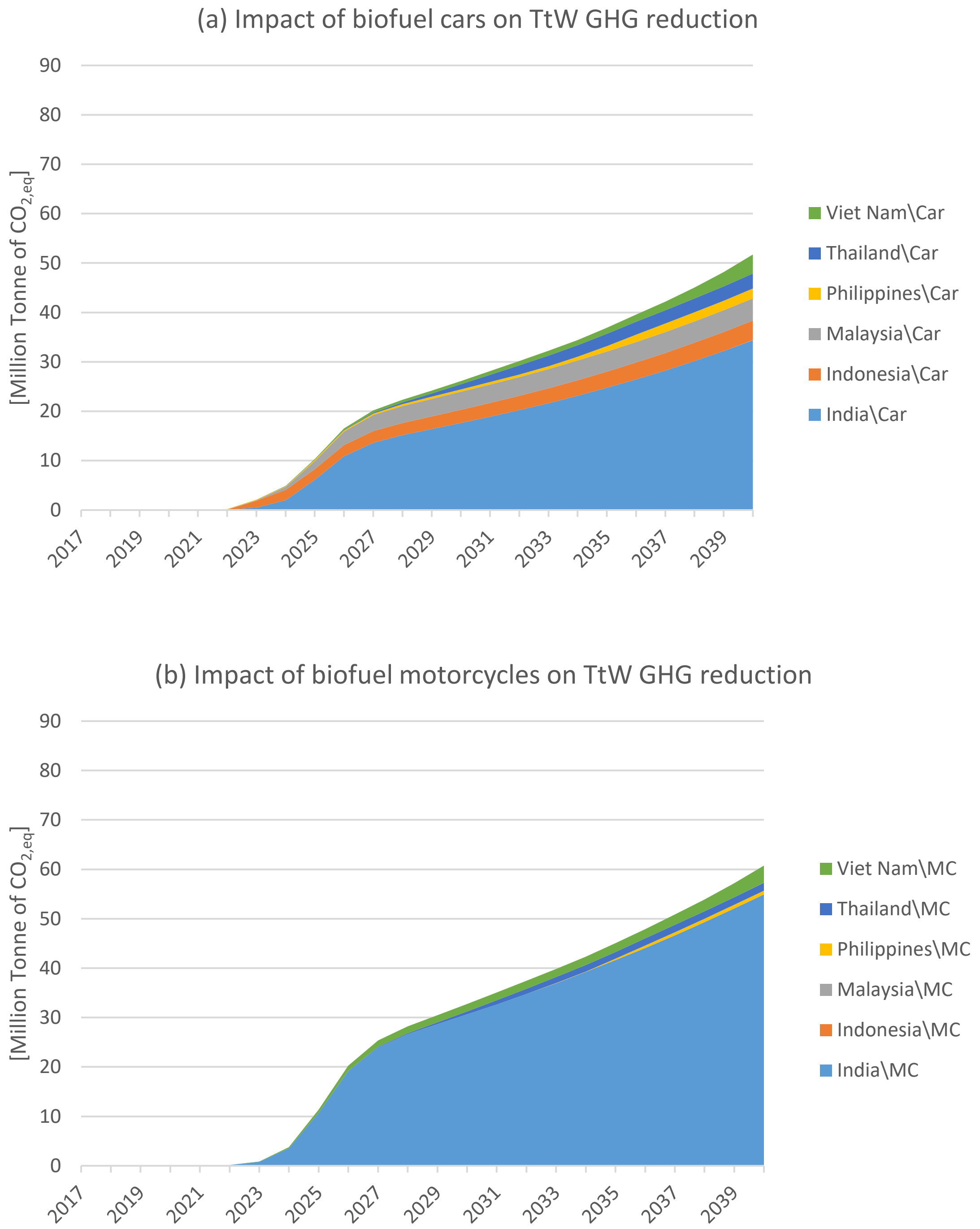


TTW GHG = tank-to-wheel greenhouse gas.
Source: Authors.

3.3.2. Impact of Biofuel Promotion (Biofuel Scenario)

Unlike the EV scenario, the biofuel proportion in gasoline and diesel fuel cannot significantly help reduce energy consumption due to the use of internal combustion engine (ICE) powertrains for biofuel. However, biofuel can help reduce TTW GHG emissions as it is a carbon neutral fuel. The impacts of biofuel promotion on TTW GHG emissions are compared with the BAU scenario (Figure 3.16).

Figure 3.16. Impact of Biofuel Promotion on Reduction of TTW GHG Emissions



TTW GHG = tank-to-wheel greenhouse gas.
Source: Authors.

4. Discussion

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

With relatively robust vehicle ownership model, the BAU setting for energy consumption and WTT GHG emissions can be set as a baseline for investigation into the impact from EVs and biofuel policy. With best available projection of EVs and biofuel, the impact of energy consumption and TTW GHG emissions can be quantitatively illustrated. Further refinement of model assumption, as well as data input, could help improve the accuracy of the present model. However, the present model highlights the importance of the motorcycle segment, which has potential to reduce energy consumption and TTW GHG emissions as much as the car segment collectively in these six countries. Policies to support decarbonisation of the road transport sector by motorcycles must be equally treated as policies for the car segment.

References

Bank of Thailand (2022), 'Thailand's Macro Economic Indicators', https://www.bot.or.th/App/BTWS_STAT/statistics/BOTWEBSTAT.aspx?reportID=409&language=ENG (accessed 19 July 2022).

Bloomberg New Energy Finance (BNEF) (2021), 'The Rise of Electric Vehicles: Global Trends and Implications for ASEAN', *iEVTech2021*, 14 October.

Button, K., N. Ngoe, and J. Hine (1993), 'Modeling Vehicle Ownership and Use in Low Income Countries', *Journal of Transport Economics and Policy,* 27(1), pp.51–67.

Chollacoop, N. et al. (2003), 'Potential of Greenhouse Gas Emission Reduction in Thai Road Transport by Ethanol Bus Technology', *Applied Energy*, 102, 112–123. http://dx.doi.org/10.1016/j.apenergy.2012.07.039

Chollacoop, N., P. Saisirirat, T. Fukuda, and A. Fukuda (2011), 'Scenario Analyses of Road Transport Energy Demand: A Case Study of Ethanol as a Diesel Substitute in Thailand', *Energies*, 4(1), 108–125. https://doi.org/10.3390/en4010108

Dargay, J., D. Gately, and M. Sommer (2007), 'Vehicle Ownership and Income Growth, Worldwide: 1960–2030'. *The Energy Journal,* 28(4), pp.143–70.

Intergovernmental Panel on Climate Change (IPCC) (2006), *IPCC Guidelines for National Greenhouse Gas Inventories, Volume 2, Energy, IPCC National Greenhouse Gas Inventories Programme.* Technical Support Unit, Institute for Global Environmental Strategies (IGES).

Laoonual, Y., N. Chindaprasert, and J. Pongthanaisawan (2008), 'Assessment of E85 Promotion Policy in Transportation Energy Sector', Final Report submitted to TRF.

Low Emissions Analysis Platform (LEAP) Software version 2020.1.63. Stockholm Environment Institute, Somerville, MA, US. http://leap.sei.org (accessed 30 April 2022).

Nagai, Y., A Fukuda, Y. Okada, and Y. Hashino (2003), 'Two-Wheeled Vehicle Ownership Trends and Issues in the Asian Region', *Journal of The Eastern Asia Society for Transportation Studies,* 5, pp.135–46.

Pongthanaisawan, J. (2012), 'Energy Demand of Road Transport Sector and Fuel/vehicle Technology Alternatives for Greenhouse Gas Emissions Mitigation in Thailand', PhD thesis, Joint Graduate School of Energy and Environment, Bangkok.

United Nations Framework Convention on Climate Change (UNFCCC) (2005), UNFCC Mitigation Assessments. http://unfccc.int/resource/cd_roms/na1/mitigation/Module_5/Module_5_1/a_Mitigation_assessment_tools_energy/Module5_1.ppt

United States Environment Protection Agency (US-EPA) (2022), Fuel Economy Data. www.fueleconomy.gov/feg/download.shtml

World Bank (2022a), Gross Domestic Products at 2015 Constant $US. https://data.worldbank.org/indicator/NY.GDP.MKTP.KD (accessed May 2022).

World Bank (2022b), Population Data https://data.worldbank.org/indicator/SP.POP.TOTL (accessed May 2022).