Chapter 2

Well-to-Wheel CO_2 Emissions from Biofuels and EVs and Mineral Resources Consumption in East Asia Summit Countries

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Chapter 2

Well-to-Wheel CO_2 Emissions from Biofuels and EVs and Mineral Resource Consumption in East Asia Summit Countries

1. Introduction

1.1. Background

From the progress of the ERIA project for fiscal year (FY) 2021–2022, well-to-tank (WTT) and tank-to-wheel (TTW) GHG emissions from using biofuels, as well as GHG reduction amounts were estimated based on the Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories (IPCC, 2006). Moreover, the GHG reduction amount for using EVs was estimated. Additional scenarios were defined and analyzed in the report by adding a study on the emission factor of grid electricity.

In continuation of the previous study (ERIA, 2022), the increasing trend of electric vehicle (EV) technology will continue to disrupt conventional internal combustion engine (ICE) technology in the Association of Southeast Asian Nations (ASEAN) and India, and the future scenario vehicle mix will change due to new policy drives, commercial technology readiness, and affordable costs. The recent carbon-neutral commitments at the 2021 United Nations Climate Change Conference (COP26) have started to impact the transport sector through electrification with a cleaner grid emission factor, as well as an appropriate blend of ICEs with carbon-neutral biofuels. This year, the upstream GHG emissions are included in the analysis, and the GHG emission factors of the grid electricity are added for the EV scenario to analyze the impact if renewable energy is added to the country electricity mix.

Meanwhile, using EVs will cause large increases in demand for mineral resources, such as neodymium (used in permanent magnets for high-efficiency motors) and cobalt (used as cathodes for lithium-ion batteries). From the progress of FY2021–2022, the change in mineral resource demand associated with automobile electrification is estimated, as well as the recycle potential in EAS countries.

However, in order to examine the future mobility scenario in EAS countries, the relationship of the GHG reduction amount between biofuels implementation and EVs must be assessed. Moreover, it will also be necessary to assess whether the increase in demand for mineral resources will cause a supply-demand gap in the future. Therefore, in this chapter, the relationship between the WTW GHG reduction of biofuel implementation and mobility electrification is assessed. In addition, the potential for a supply-demand gap in the future due to increased demand for mineral resources is assessed.

1.2. Objective and Scope

The objective of this chapter is to further explore the 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 the same projection in vehicle growth in the future as that from the previous study (ERIA, 2022), but with an updated grid emission factor to assess

GHG emissions as a result of the collective efforts for EVs and biofuels in the transport sector. In this chapter, three different scenarios are considered based on the assumption of EVs and biofuels from the previous study (ERIA, 2022) and improvements in the electricity source.

The future scenarios for EVs in EAS countries contribute to the regional Sustainable Development Goals (SDGs) (Goals 7, 12, and 13). However, there is a mineral resources limitation for realising this EV environment. Therefore, in this chapter, mineral demand from the implementation of EVs (in this case, neodymium and cobalt demand) and the supply forecast from materials mining production based on United States Geological Survey (USGS) estimates are compared. In addition, forecasts from the International Energy Agency (IEA) of the materials demand for realising EVs and for other sectors are also assessed and compared to see the trendline for neodymium and cobalt demand at the global scale for not only the EV sector but also for other sectors.

1.3. Methodology

In order to analyse the energy use pattern in the transport sector and be able to predict the energy demand and the 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 2.1) (UNFCC, 2005). Inputs of travelling demand, fuel consumption, and vehicle numbers of various types into the bottom-up model can yield the estimation of energy demand, as schematically shown in Figure 2.1 (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 2.1. Differences between the Top-down and Bottom-up Approaches in the Energy Model

Top-down	Bottom-up
Uses aggregated economic data	Uses detailed data on fuels, technologies, and policies
Assesses costs/benefits through impacts on output, income, and GDP	Assesses costs/benefits of individual technologies and policies
Implicitly captures administrative, implementation, and other costs	Can explicitly include administration and programme costs
Assumes efficient markets, and no ‘efficiency gap’	Does not assume efficient markets, so overcoming market barriers can offer cost-effective energy savings
Captures intersectoral feedback and interactions	Captures interactions amongst projects and policies
Commonly used to assess the impact of carbon taxes and fiscal policies	Commonly used to assess the costs and benefits of projects and programmes
Not well suited for examining technology-specific policies	

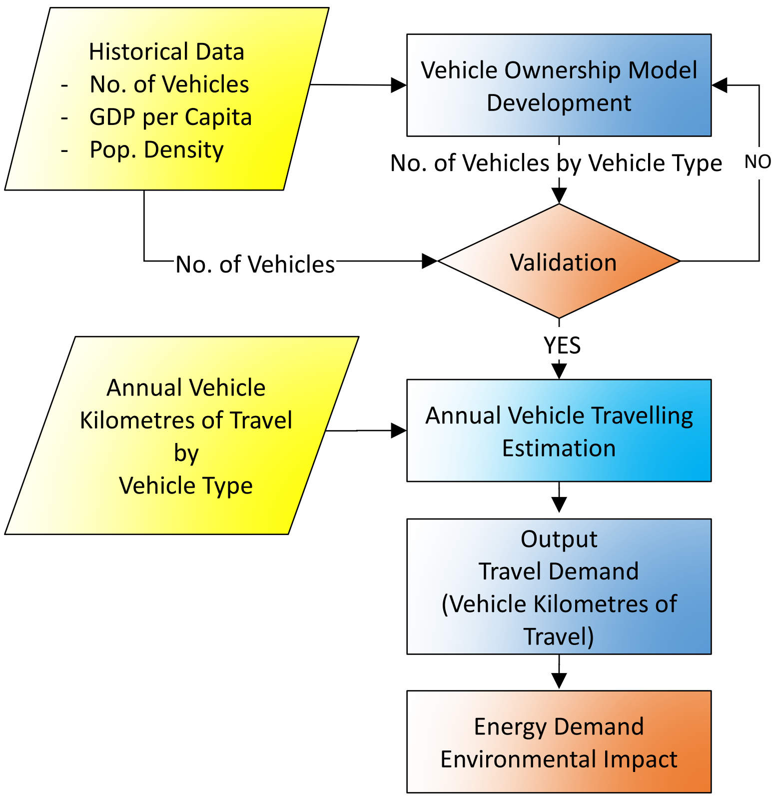
GDP = gross domestic product.
Source: UNFCC (2005).

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

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

For model calibration, the model will be benchmarked against historic data on energy consumption. For the GHG module, well-to-wheel analysis from the previous study (ERIA, 2022) will be revised for cleaner electricity generation through the grid emission factor from the available national policy, as shown in Figure 2.2 (Pongthanaisawan, 2012). With careful calibration of both energy consumption and GHG emissions, the final model with a database will be utilised to investigate various effects of energy policy.

Figure 2.1. Flow of the Bottom-up Energy Demand Model

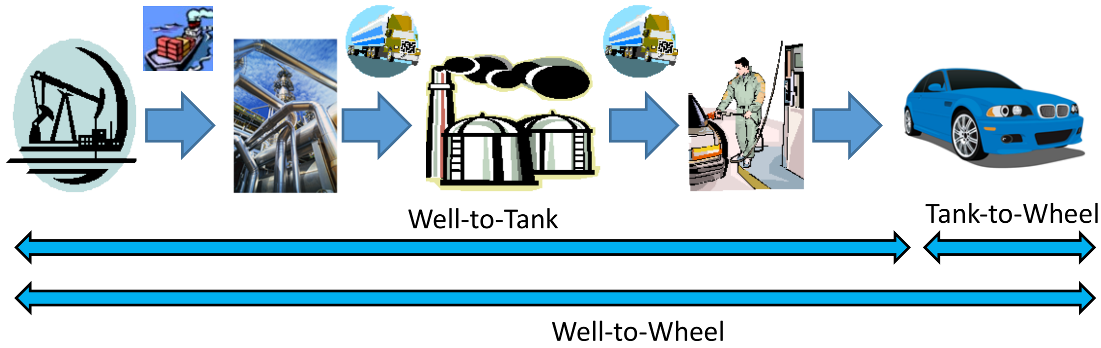


				Energy demand module			
Sector	Sub-sector	End-use	Device	Energy intensity			Energy demand
Transport sector	Transport mode	Modal split	Vehicle kilometre of travel	Type of fuel used	Fuel economy of vehicle	⇨	Scenario analysis
(vehicle)	(%)	(%)	(kilometre)	(%)	(GJ per veh-km)		(GJ or ktoe)

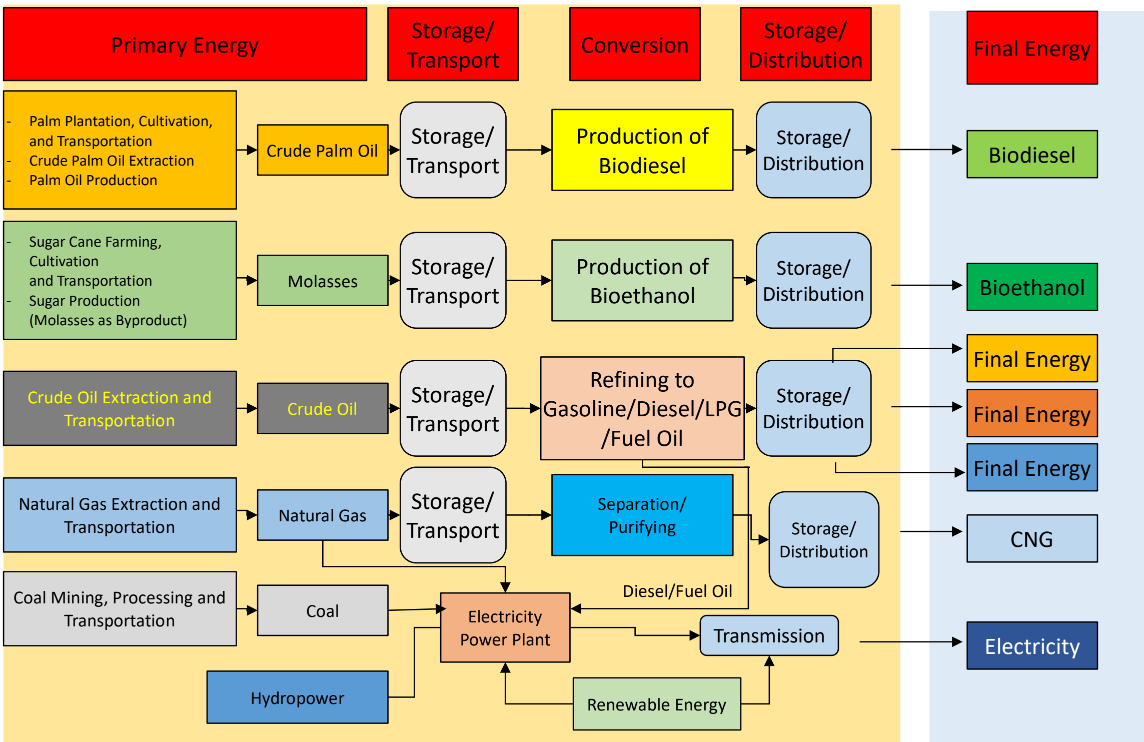
GDP = gross domestic product, GJ = gigajoule, ktoe = kilotonne of oil equivalent.
Source: LEAP (2022).

Figure 2.1. Schematic Concept of Life Cycle Inventory

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



(b) Detailed Examples of Various Transportation Fuels



CNG = compressed natural gas, LPG = liquefied petroleum gas.
Source: Pongthanaisawan (2012).

For mineral resource demand, the neodymium (Nd) and cobalt (Co) demand forecasts until 2040 for the vehicle electrification scenario in EAS countries were estimated in the second year of this ERIA project. In this chapter, ERIA's estimation results will be compared with the IEA's forecasts for Co and Nd demand used for vehicle electrification and for all applications in the world. In order to assess the amount of Co and Nd supply that will be available until 2040, mining production data for Nd and Co based on the USGS were also compared.

As explained, in the second year project report, the demand for Nd and Co was predicted by estimating the number of vehicle sales. The number of vehicles sales in EAS countries was estimated using the Vehicle Ownership Model, which can be modelled as the 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) of gross domestic product per capita and population density. Then, the model was investigated and validated by the Low Emissions Analysis Platform (LEAP) system software. The share/percentage of electric vehicle sales to whole vehicle sales was estimated by considering the input data from the working members of this ERIA report regarding vehicle electrification policy combined with the data on EV share from Bloomberg projections for EAS countries.

The demand for Nd and Co was calculated by integrating the data on the amount (contained rate) of Nd and Co in these automobiles with the number of automobiles that were sold during these projections. The contained rate of Nd per vehicle for four-wheelers and two-wheelers is based on a research paper by Yang et al. (2016). Then, Co contained per vehicle for four-wheelers and two-wheelers was estimated based on the company's original data collected by an expert's interview and the Joint Research Centre report, combined with Epic Cycle data.

Based on the report, *The Role of Critical World Energy Outlook Special Report Minerals in Clean Energy Transitions*, published by the IEA (2021), global Nd and Co demand for vehicle electrification was forecasted with two scenarios, the Sustainable Development Scenario (SDS) and the Stated Policies Scenario (STEPS). The IEA also forecasted Nd and Co demand for all usages and all sectors (not only for electric vehicles) with the same two scenarios for 2020, 2030, and 2040.

Moreover, the USGS report, *Mineral Commodity Summaries*, explains the export, import, mining production, reserves, etc. of the minerals. Based on USGS production data from 1994 to 2021, Nd and Co production until 2040 was forecasted assuming that this production (until 2021) would increase at the same rate through 2040. The demand for Nd and Co through 2040 was compared to this production.

2. Energy Demand Model

2.1. Model Setup

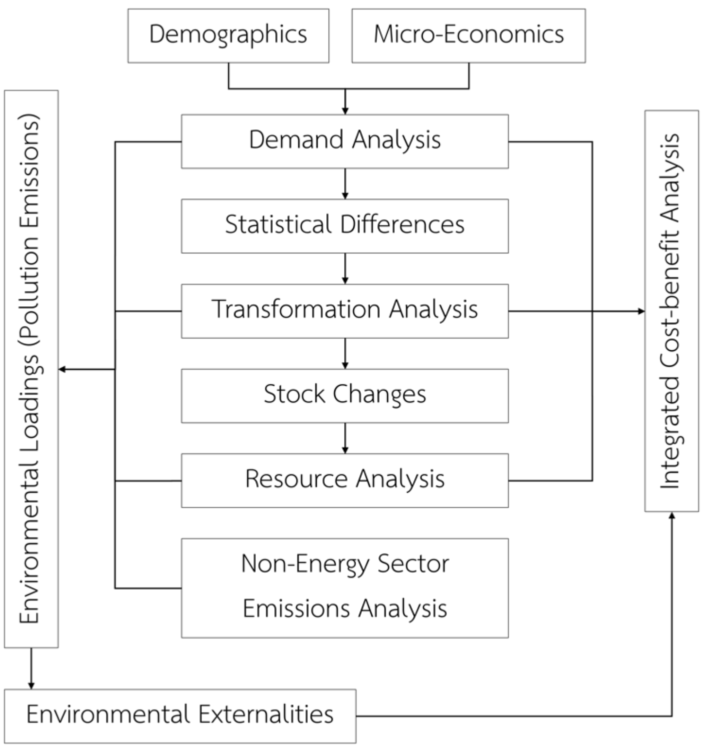
The choice for the bottom-up energy model approach in the present study is the LEAP system (LEAP, 2022), developed by the Stockholm Environment Institute. The LEAP modelling capabilities are highlighted in Table 2.2, with the calculation flows shown in Figure 2.3.

Table 2.2. 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 the energy system ✓ Non-energy sector sources and sinks

Source: LEAP (2022).

Figure 2.2. LEAP Calculation Flows



Source: LEAP (2022).

As mentioned above, 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, the Philippines, Thailand, and Viet Nam, and India from the current situation to 2040. It is noted that these three variables are not regularly updated so certain assumptions must be made from the engineering aspects, such as the type of engine (spark-ignition vs compression-ignition), engine age, and fuel ratio used (liquid with blended biofuels or gas). The projections for energy demand and CO_2 emissions of the 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 to the bottom-up approach as per the following equation. Hence, the influential energy consumed by branches of different vehicle technologies, fuels, and vehicle segments can be indicated. Besides the TTW CO_2 emissions, GHG emissions can also be analysed by multiplying the energy consumption results with the emissions factor of concordance for vehicle technologies, fuels, as well as vehicle segments.

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

where *i* is the considered vehicle (segment or technology), *j* is the type of fuel or energy used, *NV* is the number of vehicles, *FC* is fuel consumption (fuel units/km, where the 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 technologies and fuels used are simplified into gasoline vehicles (fuelled with gasohol fuel at the 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 the 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 between vehicle numbers, which are described by vehicle ownership (vehicle numbers per 1,000 people), and the household economic situation is modelled in logarithmic form with a saturation level. An example of such a 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 vehicles/1,000 population)

S = saturation level of VO (number of vehicles/1,000 population)

GDPpCap = GDP per capita (US$/person or B/person)

PopDen = population density (persons/sq. km)

a, b, and c = coefficient from curve fitting with historical data

In this study, the calculated numbers of passenger cars and motorcycles from six considered countries (Indonesia, Malaysia, the Philippines, Thailand, Viet Nam, and India) are adjusted with historical records provided to working group members. The model's calculated results are validated with historical registered records for passenger cars and motorcycles as shown in Figure 2.4. The models of vehicle numbers are shown in Table 2.3 for passenger cars and Table 2.4 for motorcycles. It is noted that GDP (in constant prices) 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 2.4. Validation of Vehicle Numbers for Five ASEAN Countries and India for (a) Passenger Cars and (b) Motorcycles

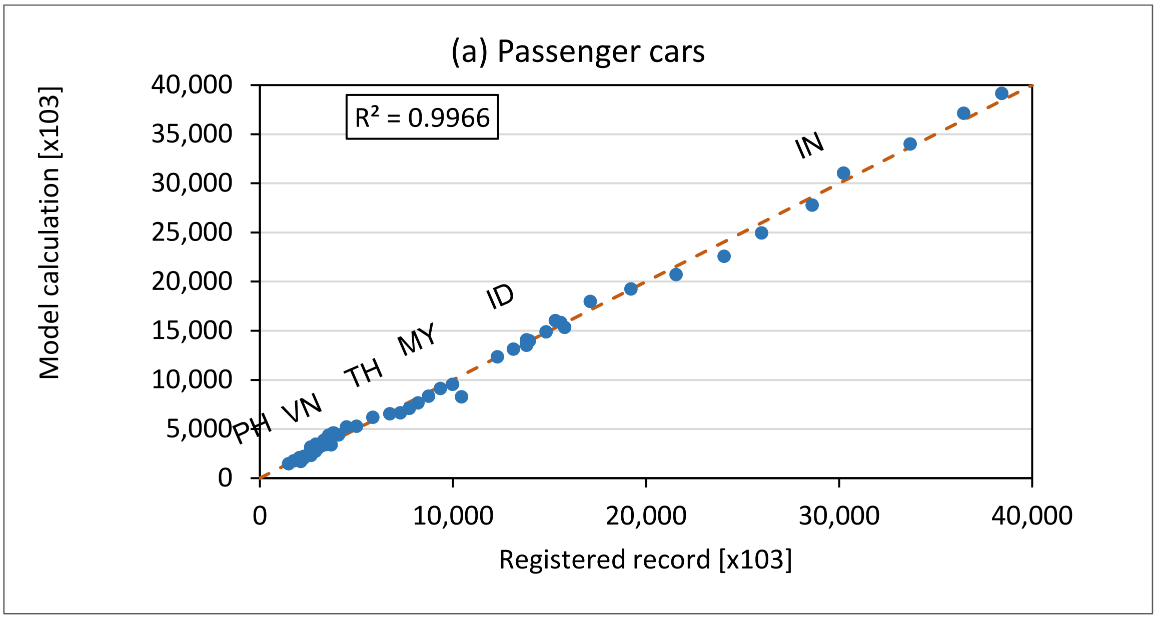
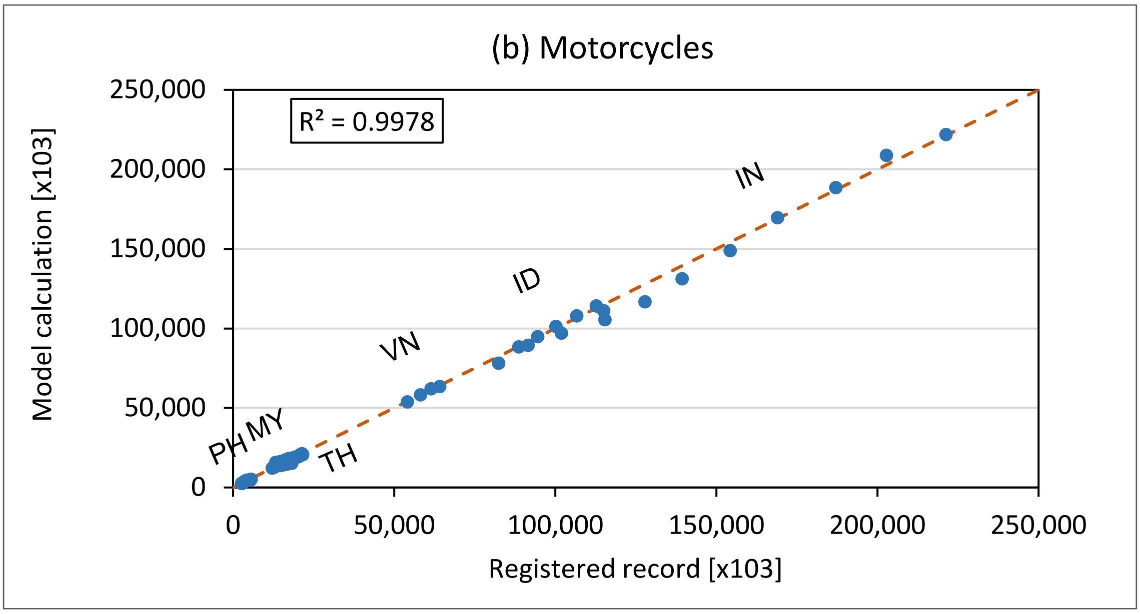


Figure 2.4. *Continued*



ID = Indonesia, IN = India, MY = Malaysia, PH = Philippines, TH = Thailand, VN = Viet Nam.
Source: ERIA (2022).

Table 2.3. Models of Passenger Car Numbers

Country	Abbr.	Vehicle ownership models (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

Note: GDP for all countries is in US dollars, except Thailand's GDP, which is in Thai baht.
Source: ERIA (2022).

The saturation levels of the S-curve logistic function are shown in the formulas, 812 for passenger cars and 600 for motorcycles, whilst Viet Nam's motorcycles have a saturation level higher than that of other countries, at 750, due to the specific situation in the country. In the vehicle stock model, new vehicles (vehicle sales) were calculated from the simplified percentage of new vehicle numbers of the total on-road vehicle numbers, which are shown in Table 2.5 for various East Asia Summit countries.

Table 2.4. 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

Note: GDP for all countries is in US dollars, except Thailand's GDP, which is in Thai baht.
Source: ERIA (2022).

Table 2.5. Percentage 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 values are calculated from the sales projections of Thailand's National EV Policy Committee and projections of vehicle ownership models (2022–2035).

2.3 Estimation of vehicle kilometres of travel

The second variable, vehicle kilometres of travel (VKT), is the distance travelled by each considered vehicle. The VKT governs 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 used where those data from member countries are not available, as shown in the note for Table 2.6.

Table 2.6. Vehicle Kilometres of Travel

	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

* Thailand's data are used where data from member countries are not available.
Source: ERIA (2022).

2.4. Estimation of Fuel Economy

The last collected variable is the fuel economy (FE) of each vehicle type. Together with VKT, the FE directly gives the total fuel or energy needed. As mentioned, 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 the type of engine (spark-ignition vs compression-ignition), engine age, and fuel ratio used (liquid with blended biofuels or gas). The vehicles in this study were therefore simplified into those with a 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 the consumption of various fuels; e.g. if gasohol E10 and gasohol 20% ethanol blend (E20) are used in similar quantities, the mean blended ratio will equal to E15). In this study, the fuel/technology of the considered vehicles is composed of:

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

Gasoline is fuelled by gasoline and ethanol fuels, diesel is fuelled by diesel and biodiesel fuels. The shares 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 is shown in Table 2.7.

Table 2.7. Assumptions of Fuel Economy

	Passenger Cars					Motorcycles	
	Gasoline	**Diesel**	**PHEVs**		**BEVs**	**Gasoline**	**eMCs**
			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

PHEV = plug-in hybrid electric vehicle, BEV = battery electric vehicle, eMC = electric motorcycle.
* Thailand's data are used where data from member countries are not available.
Note: Fuel economy is in the unit of litres/100 kilometres for gasoline and diesel, and kilowatt hours/100 kilometres for the consumed electricity of EVs (PHEVs, BEVs, and eMCs).
Source: ERIA (2022).

2.5. Tank-to-wheel Greenhouse Gas Emissions

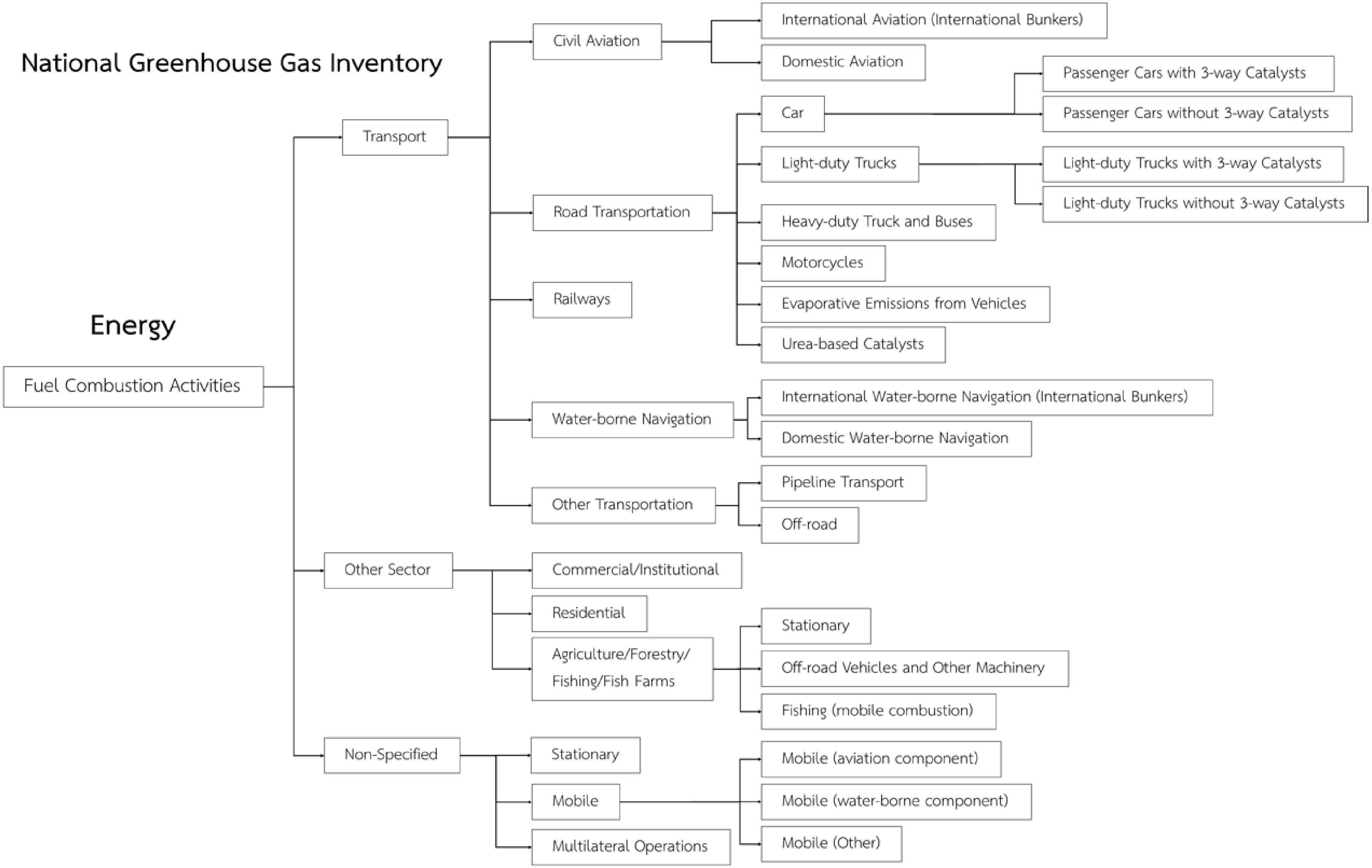
The tank-to-wheel greenhouse gas (TTW GHG) emissions are calculated according to the Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories (IPCC, 2006) in this study. For fuel combustion in road transportation, the emissions factors are selected according to the Technology and Environmental Database, as shown in Figure 2.5.

The TTW GHG emissions are defined from the fundamentals of the combustion reaction. In the combustion process, the complete combustion products are mainly CO_2 and water (H_2O). CO_2 is a major GHG emission. Emissions of methane (CH_4) and nitrous oxide (N_2O) also have major impacts on global warming. The IPCC Tier 2 scheme is selected in this study to collect TTW GHG emissions for the considered fossil fuels. The emissions levels are assumed according to the current emissions standards for new vehicles and the share of vintage vehicles in the considered region, as shown in Table 2.8.

As 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 units by multiplying by the global warming potentials (GWP) as shown in Table 2.9.

In contrast with fossil fuel combustion, biofuels are considered carbon-neutral fuels. This means that the CO_2 produced during biofuel combustion is equivalent to the CO_2 quantity absorbed in the photosynthesis process of biofuel plantation.

Figure 2.3. Activity and Source Structure in the Energy Sector



Source: IPCC (2006).

Table 2.8. Chosen Vehicle Models to Represent TTW GHG Emissions

Type of Vehicle	Chosen Vehicle Models in LEAP
Gasoline passenger car (for all gasoline combustion, including HEV and PHEV)	European cars, moderate control, gasoline
Diesel passenger car	European cars, moderate control, diesel
Gasoline motorcycle	European motorcycle > 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).

Table 2.9. Global Warming Potential of GHG Emissions from the Combustion Process

	CO_2	CH_4	N_2O
GWP (kg in CO_2 eq/kg of considered emissions)	1	25	296

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

2.6. Well-to-tank greenhouse gas emissions

To investigate the impacts of alternative technologies, which comprise carbon-neutral fuels (such as biodiesel and bio-ethanol) and electric vehicles, the WTT GHG emissions are added to fulfil the GHG emissions along the energy life cycle (fuel production and used phase). The upstream GHG emissions of electric vehicles are added in terms of the GHG emission factors of the grid electricity in various countries. This information was shared in the working group. In addition, the upstream GHG emissions of vehicles with combustion engines are collected through the fuel processes. For example, the fossil fuel processes comprise oil and gas production (oil extraction and drilling), oil and gas transportation (from the well to the refinery plant), the crude oil refinery process, commercial fuel transportation (from the refinery plant/fuel storage to the fuel retail station). The TWW emissions of the fossil fuels and biofuels used in this study are shown in Table 2.10.

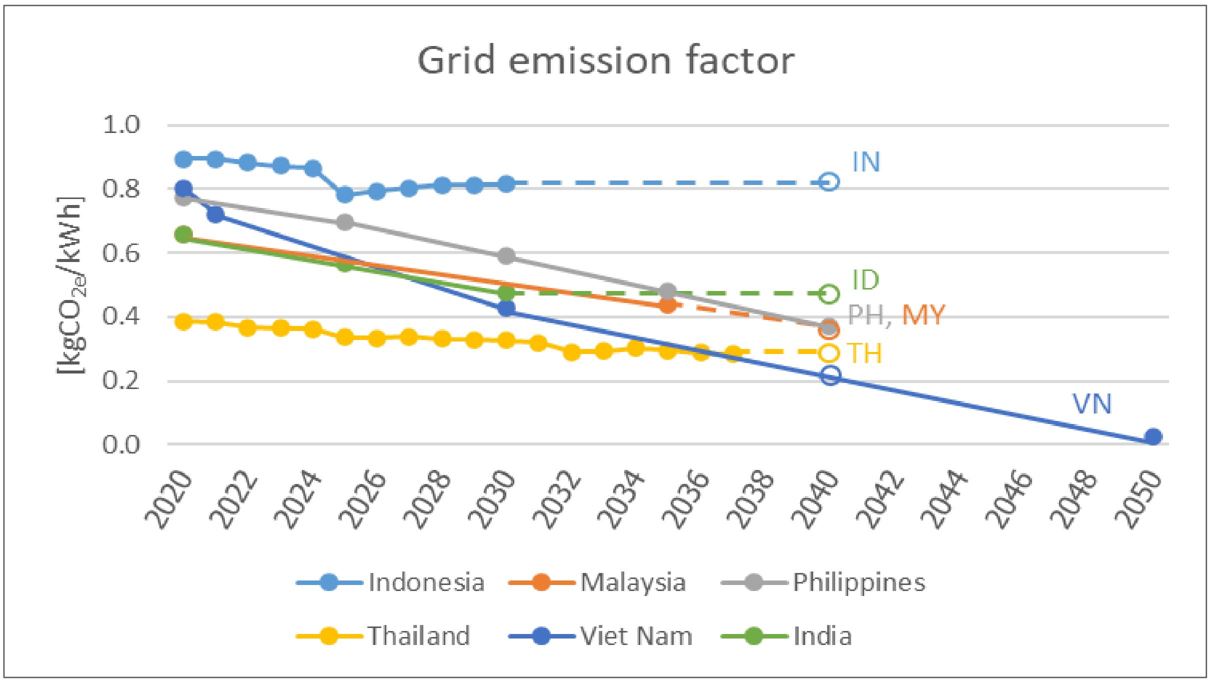
Table 2.10. Well-to-Tank Emission Factors of Fossil Fuels and Biofuels

Fuel	Well-to-Tank Emission Factor (kg CO_2/litre, kg CO_2/kg CNG)
Gasoline	0.2977
Diesel	0.3062
LPG	0.8582
CNG	0.6164
Biodiesel (FAME)	1.1780
Ethanol	0.6803

CNG = compressed natural gas, LPG = liquefied petroleum gas.
Source: TIIS, Thai National Life Cycle Inventory Database; Permpool and Gheewala (2017); Silalertruksa and Gheewala (2011)

The GHG emission factors of the grid electricity in the selected ASEAN countries and India are collected from the available policies and illustrated in Figure 2.6 with references shown in Table 2.10. The filled dots represent the grid emission factor data from the indicated policy reference with a solid line connecting each year. The unfilled dots show the projected GHG emission factors by the authors connected with dashed lines.

Figure 2.4. GHG Emission Factors of Grid Electricity in ASEAN Countries and India



ID = Indonesia, IN = India, MY = Malaysia, PH = Philippines, TH = Thailand, VN = Viet Nam.
Source: See Table 2.11.

Table 2.11. Sources of Grid Emission Factors for Selected ASEAN Countries and India

	Source
Indonesia (ID)	Indonesia's State Electricity Company (Perusahaan Listrik Negara, PLN)
Malaysia (MY)	Calculated from the Global Environment Facility shown in the GEF-7 Malaysia National Dialogue
Philippines (PH)	Philippine Energy Plan 2020–2040
Thailand (TH)	Thailand Power Development Plan 2018 (PDP2018-2037)
Viet Nam (VN)	Viet Nam's Eight National Power Development Plan (PDP8)
India (IN)	Ministry of Power, Central Electricity Authority, Government of India, *Report on Optimal Generation Mix: Version 2.0*, April 2023

Source: Philippines Department of Energy; Thailand Power Development Plan 2018 rev.1; Viet Nam's Eight National Power Development Plan (PDP8); Ministry of Power, Central Electricity Authority, Government of India.

2.7. Projection of Socioeconomic Variables

The bottom-up model was developed according to socioeconomic variables. In this study, the number of vehicles was defined using an S-curve logistic function of two socioeconomic variables, GDP and population.

2.7.1. Gross Domestic Product

The gross domestic product (GDP) information was collected at 2015 constant prices in US dollars (World Bank, 2022a) with the exception of Thailand. The data were available to the year 2020. Thailand's GDP was collected from the Bank of Thailand (Bank of Thailand, 2022) in baht at 2002 constant prices. The current GDP values and growth rates are shown in Table 2.12.

Table 2.7. Projection of Gross Domestic Product

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

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

2.7.2 Population (capita, cap)

Similar to the GDP information, the population of the considered countries was collected from the World Bank (World Bank, 2022b) with the exception of Thailand. Thailand's population data were collected from the Bank of Thailand (Bank of Thailand, 2022). The current population and growth rates are shown in Table 2.13.

Table 2.8. Population and Population Growth Rates by Country

	Current Population (millions)	Population 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. Well-to-wheel CO_2 Emissions from Biofuels/EVs in East Asia Summit Countries

In the current study, the GHG emissions are composed of both the upstream (well-to-tank) and used-phase (tank-to-wheel) processes. The impacts of GHG emissions for EVs with the improvement of electricity sources are focused on as well as the impacts of carbon-neutral fuel during the production phase. The considered scenarios are separated into three scenarios, with the assumptions for EVs and biofuels from the previous study (ERIA, 2022) shown in Table 2.14, as follows:

(1) Business-as-Usual (BAU) scenario: Focus on EV penetration without an improvement in electricity sources (electricity produced from conventional sources, i.e. coal, natural gas, or fossil fuels), shown as 'EV-NoBiofuel-NoGridImprove'.

(2) EVs with renewable electricity sources: This scenario is defined to analyse the impacts if the government invests in renewable power plants, such as solar PV and wind power, shown as 'EV-NoBiofuel-GridImprove'.

(3) Biofuel addition: As on-the-road vehicles comprise both new vehicles and on-road stock vehicles, biofuels are considered in this scenario as another option for on-road stock vehicles, which still use conventional combustion engines and will last long in the system, shown as 'EV-Biofuel-GridImprove'.

Table 2.9. Assumption for (a) Electric Vehicle Penetration and (b) Biofuel Blending in Five Selected ASEAN Countries and India

(a)		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); ERIA (2022).

Table 2.10. ***Continued***

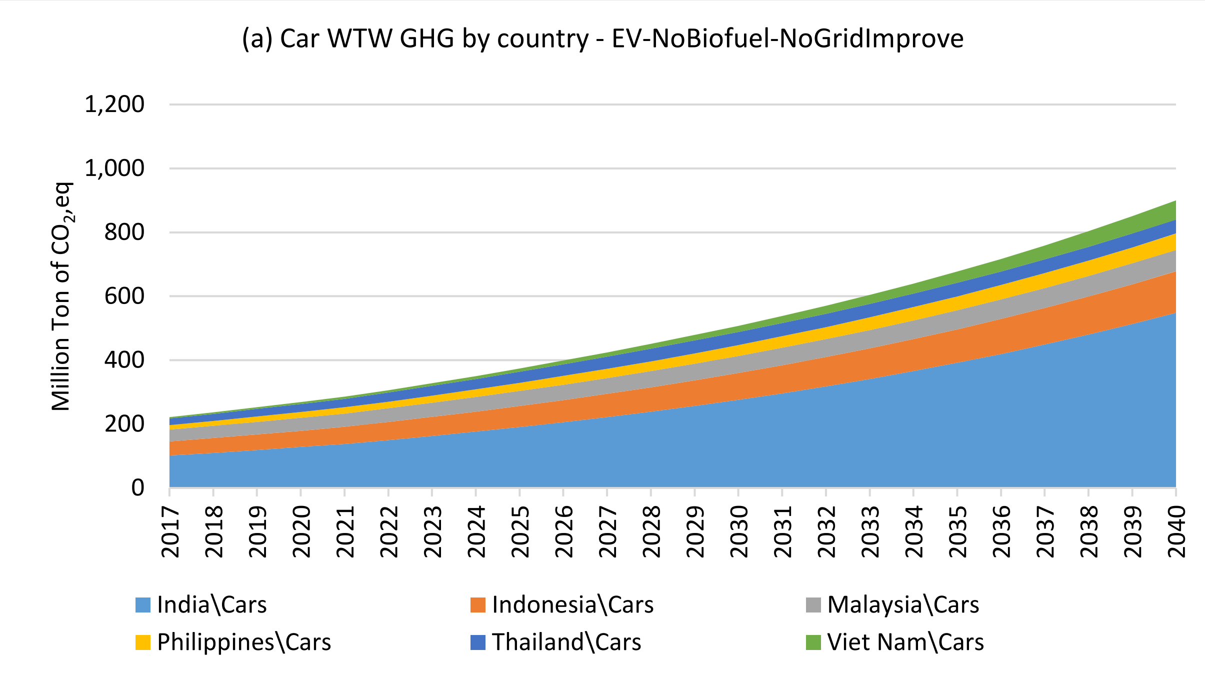
(b)		Business-as-Usual Scenario		Biofuel Scenario	
	Projection year	**Ethanol (%)**	**Biodiesel (%)**	**Ethanol (%)**	**Biodiesel (%)**
Indonesia	2022	0.0%	30.0%	0.0%	30.0%
	2024	0.0%	30.0%	0.0%	40.0%
Malaysia	2022	0.0%	10.0%	0.0%	10.0%
	2025	0.0%	10.0%	0.0%	20.0%
	2030	0.0%	10.0%	0.0%	30.0%
Philippines	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%

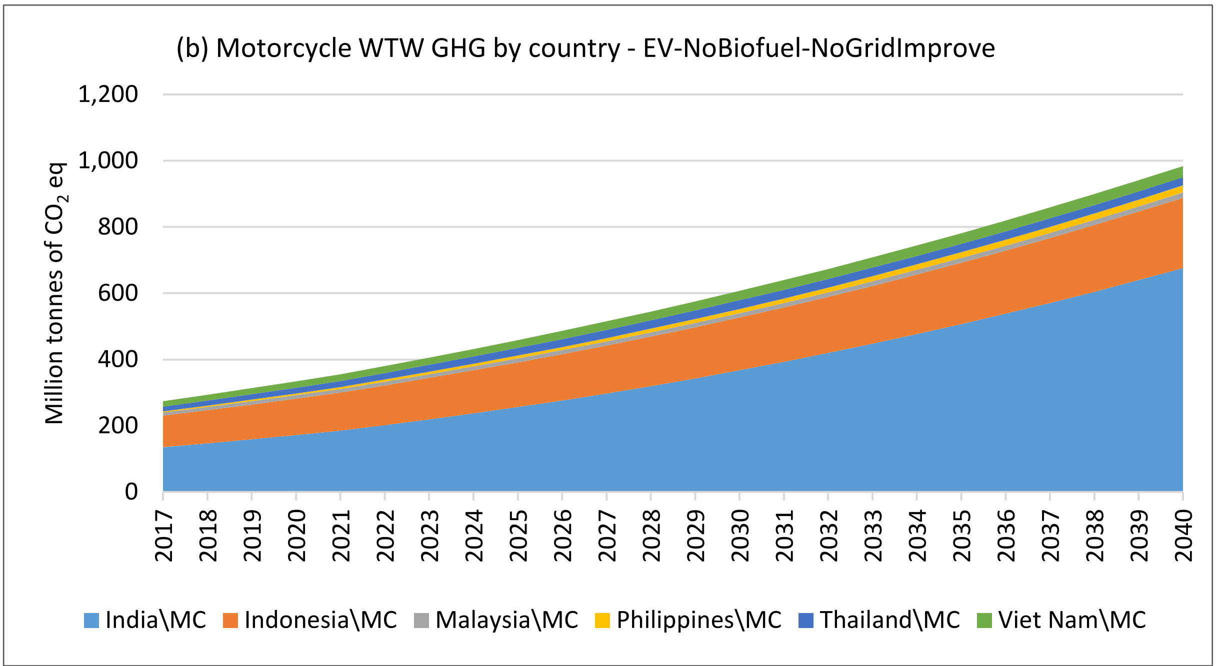
Sources: ERIA (2022).

The results for the GHG emissions calculated from these three scenarios are shown in Figure 2.7, Figure 2.8, and Figure 2.9.

To conclude the observed results of the alternative scenarios considered in this study, the projections of the well-to-wheel emissions from car and motorcycle vehicles in 5 ASEAN countries and India are compared with the baseline scenario defined as the projected scene with the current situations of EV, grid electricity emissions, and biofuel status, as shown Figure 2.10. The impact of EVs on decarbonising cars and motorcycles in 5 ASEAN countries and India is about 4.84% and 5.77%, respectively. With further improvement in grid emissions from renewable energy according to Figure 2.6, a small decarbonisation impact can be reached, 1.44% for cars and 0.76% for motorcycles, implying that the current grid emission factor target may not be enough. On the other hand, biofuel policy could help to decarbonise the transport sector further to 9.46% for cars and 10.57% for motorcycles.

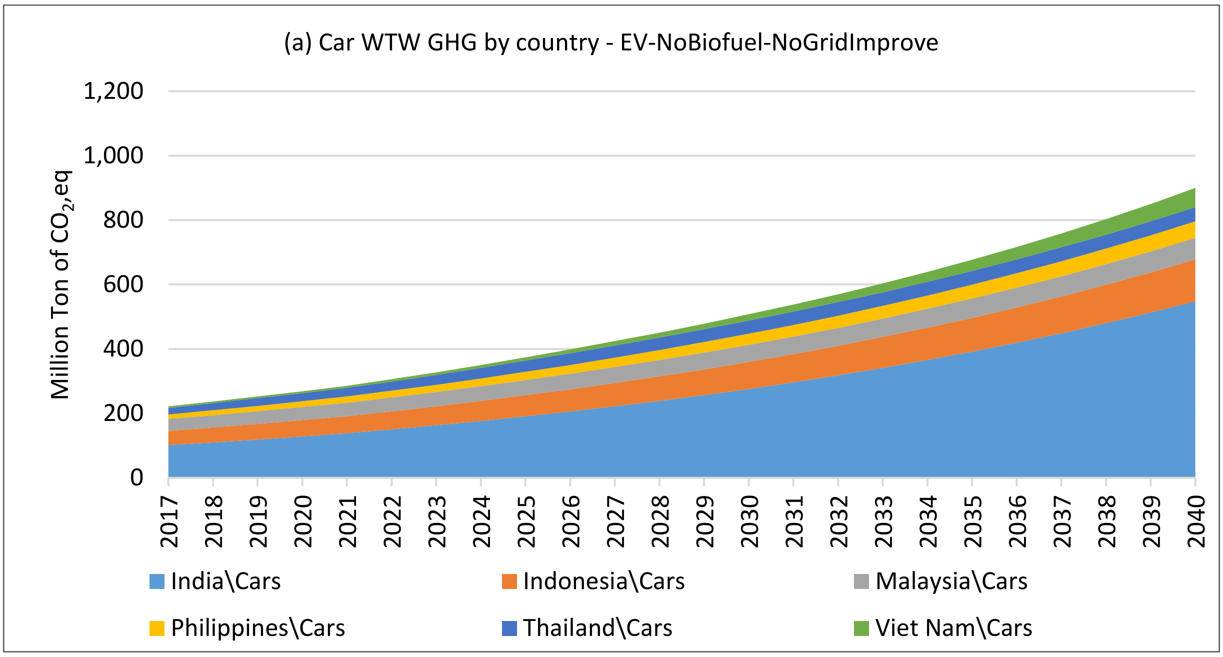
Figure 2.5. Projection of Well-to-Wheel Emissions for EV Penetration Without Improvement in Electricity Sources (a) Cars and (b) Motorcycles – 'EV-NoBiofuel-NoGridImprove'

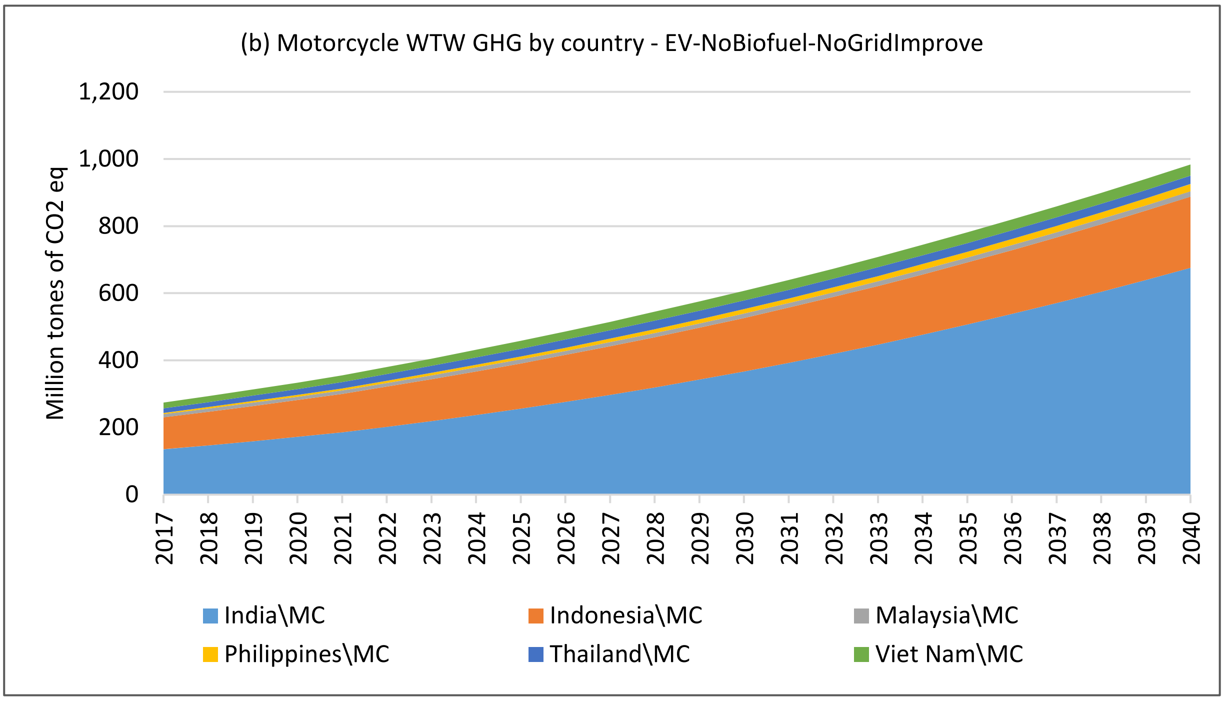




MC = motorcycles.
Source: Authors.

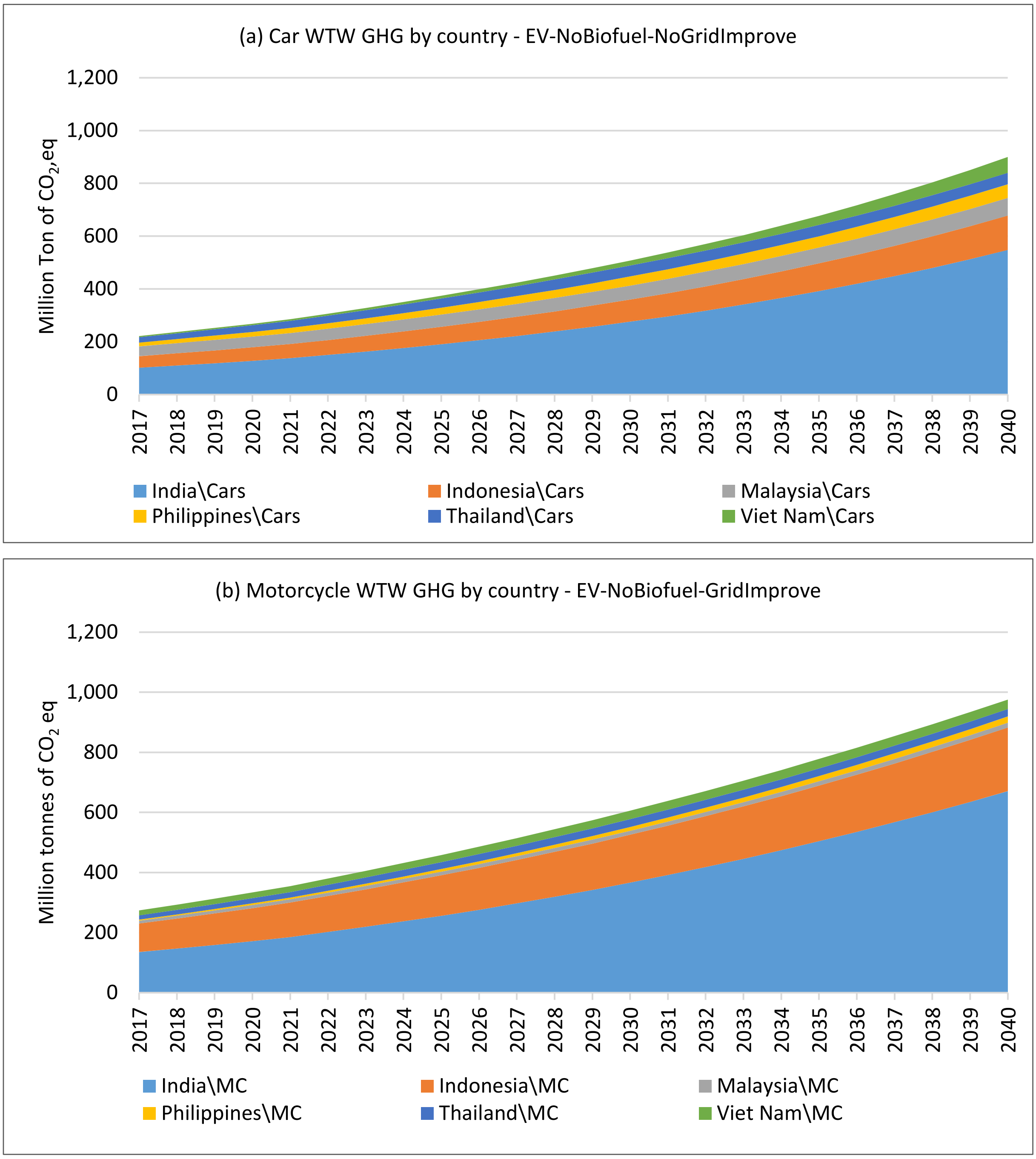
Figure 2.6. Projection of Well-to-Wheel Emissions for EV Penetration with Improvement in Electricity Sources (by Applying Renewable Electricity, e.g. solar PV, wind) (a) Cars and (b) Motorcycles – 'EV-NoBiofuel-GridImprove'





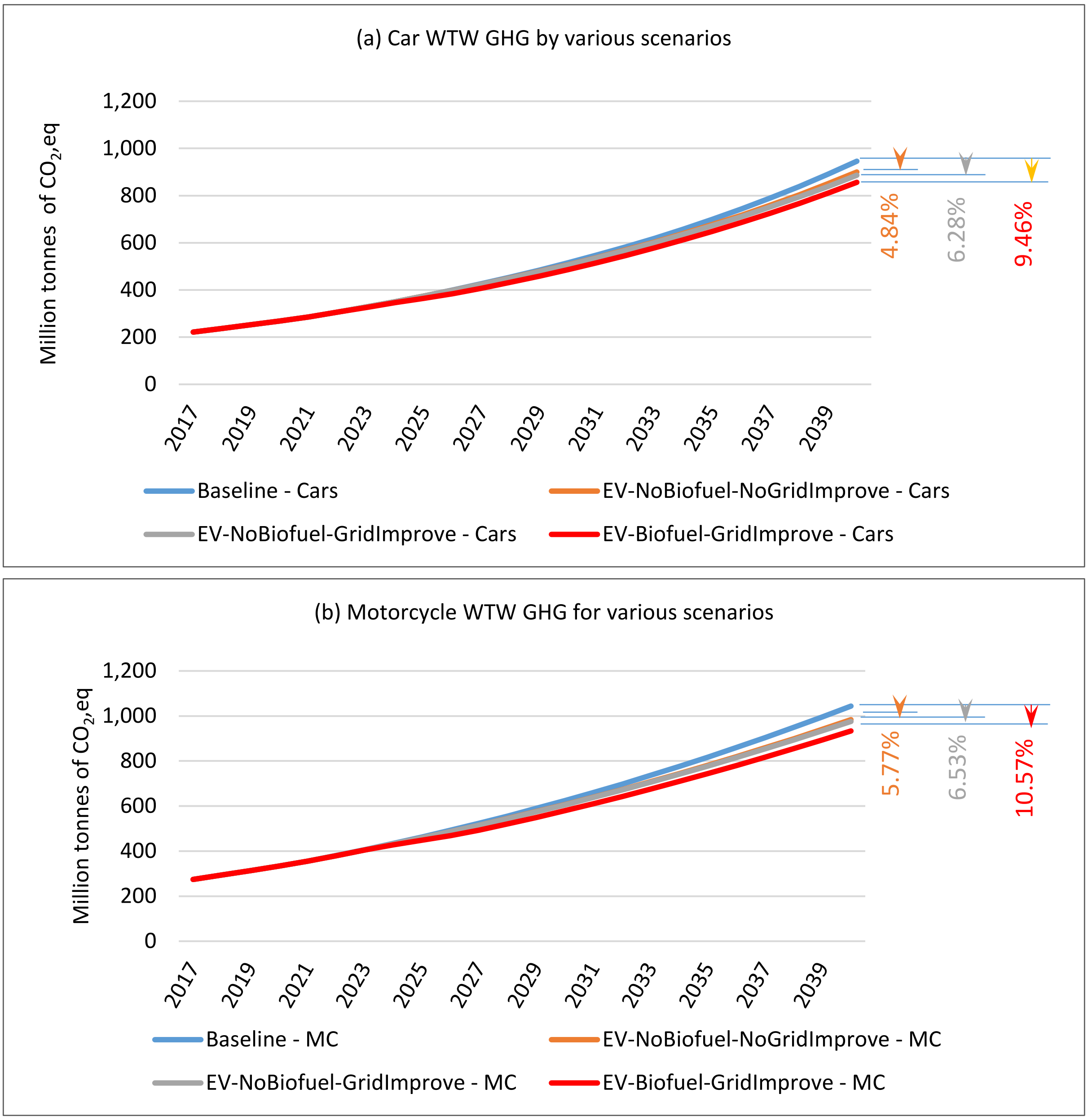
MC = motorcycles.
Source: Authors.

Figure 2.7. Projection of Well-to-Wheel Emissions When Applying Biofuel Policy for On-road Conventional Vehicles (a) Cars and (b) Motorcycles – 'EV-Biofuel-GridImprove'



MC = motorcycles.
Source: Authors.

Figure 2.8. Projection of Total Well-to-Wheel Emissions from (a) Cars and (b) Motorcycles in 5 ASEAN Countries and India



MC = motorcycles.
Source: Authors.

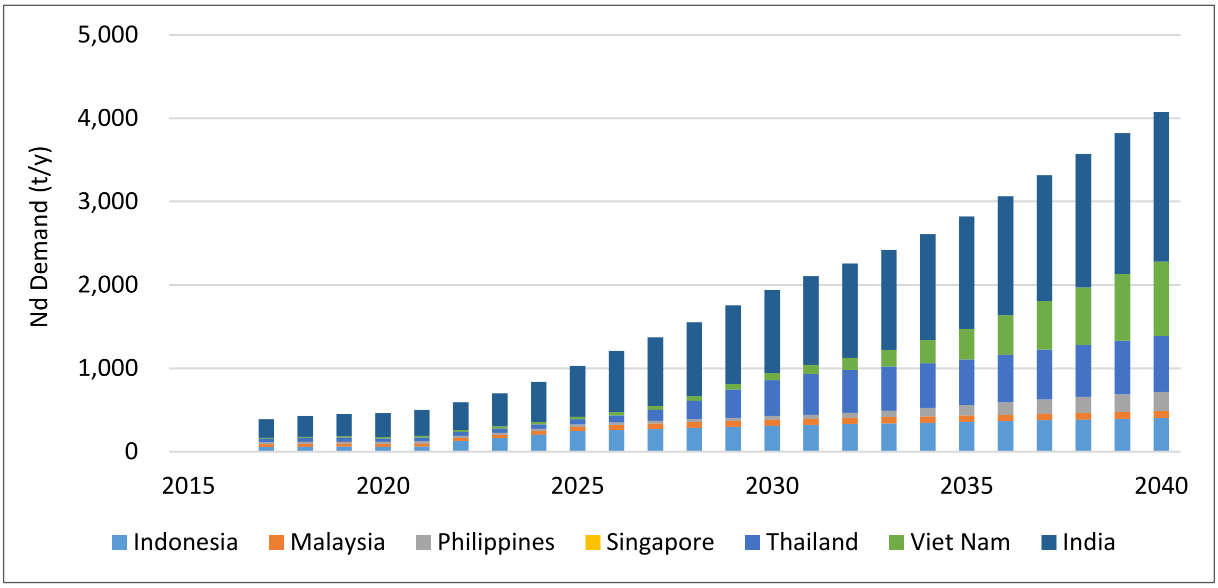
4. Mineral Resources Consumption of EVs in EAS Countries and USGS, IEA, and ERIA Project Forecasts for Neodymium and Cobalt

This section explains the results of the forecasts for demand for Nd and Co by implementing the mobility electrification of vehicles. This section also compares these results with the IEA and USGS report, which forecasted the global demand and supply of Nd and Co until 2040.

Figures 2.11 and 2.12 show the demand for Nd and Co that are used in permanent magnets and lithium-ion battery cells until 2040. Each figure shows the total demand for Nd and Co in Indonesia, Malaysia, the Philippines, Thailand, Viet Nam, and India.

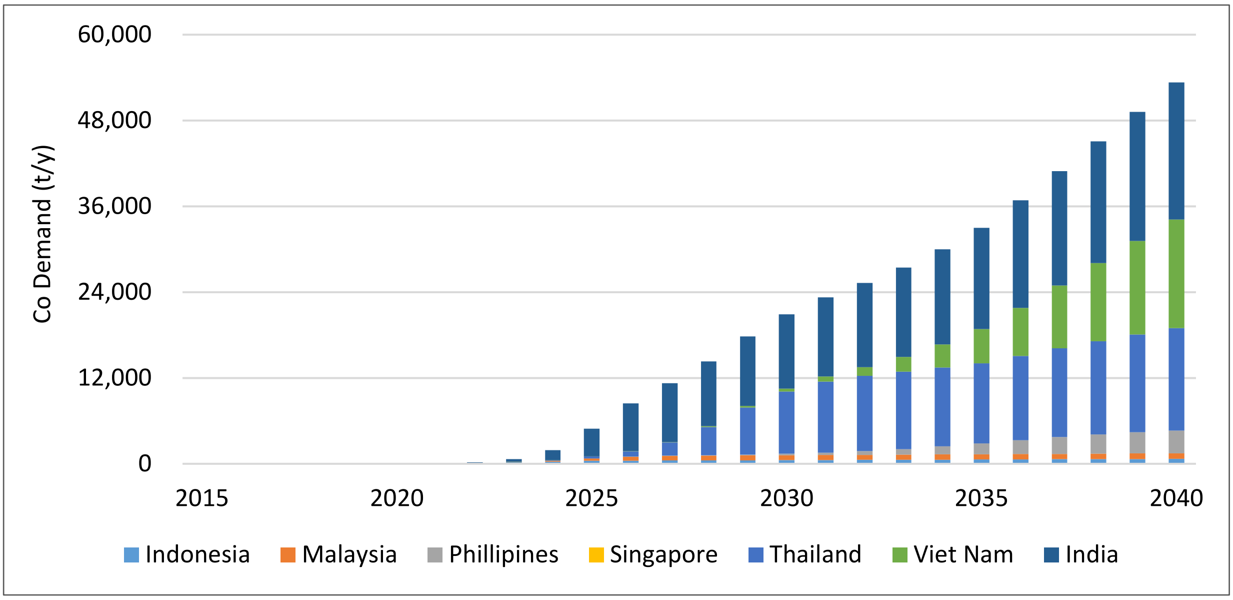
Based on Figures 2.11 and 2.12, the demand for Nd is predicted to be 4,075 t/y in 2040. India, Viet Nam, and Thailand cover 82.51% of all Nd demand in EAS countries, and India is predicted to have the largest demand for Nd in the future. Moreover, the demand for Co is predicted to be 53,32 t/y in 2040 and India, Viet Nam, and Thailand also cover 91.26% of all the demand in EAS countries.

Figure 2.11. Neodymium Demand Forecast



Nd = neodymium, t/y = tonnes/year.
Source: Authors.

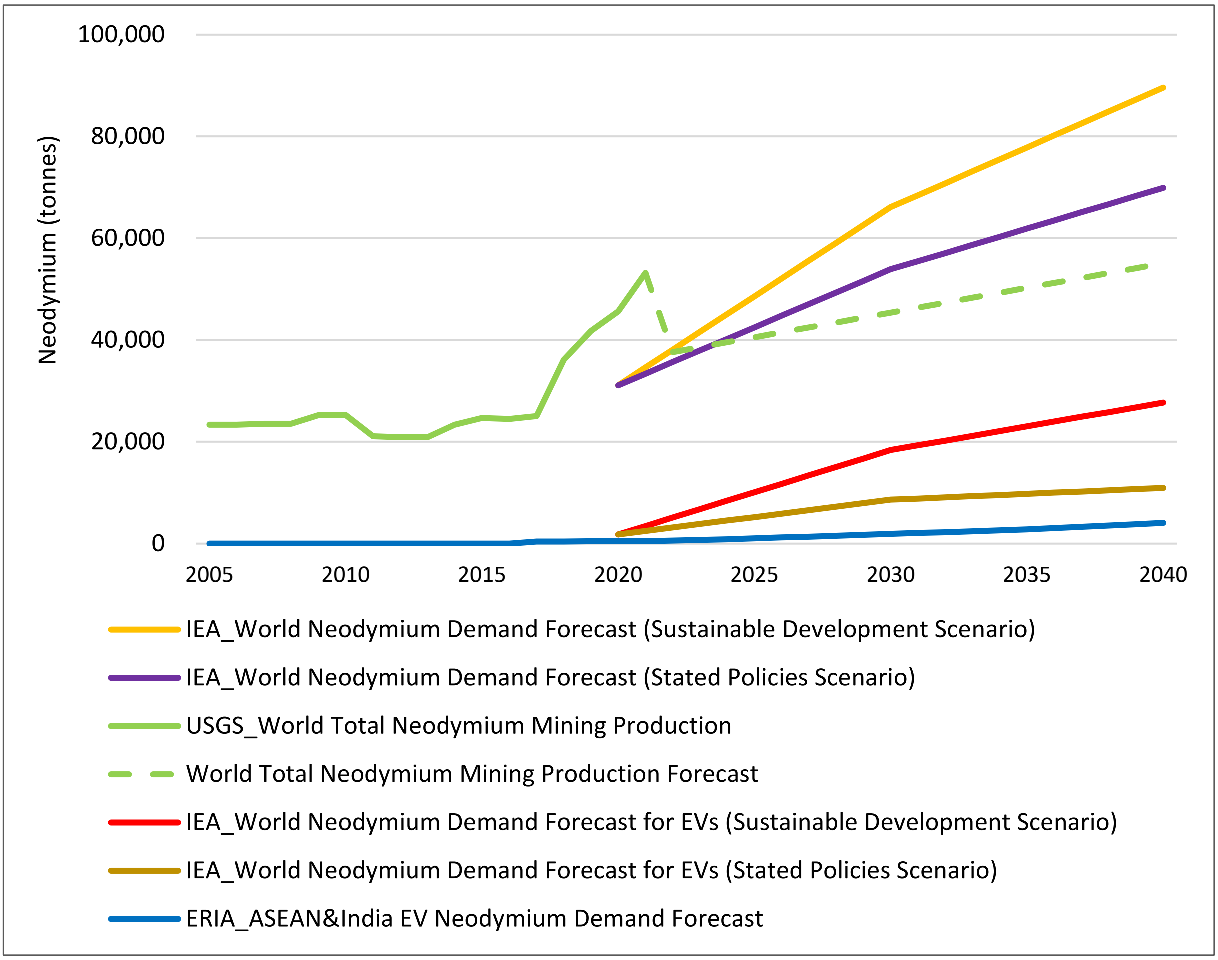
Figure 2.12. Cobalt Demand Forecast



Co = cobalt, t/y = tonnes/year.
Source: Authors.

Figure 2.13 shows the supply and demand for Nd until 2040 based on the USGS, IEA, and ERIA project. By comparing the IEA world Nd demand (of EVs) forecast of the Stated Policies Scenario (in 2040, 10.94 k-tonnes/y) and the forecast for EAS countries (4.08 k-tonnes/y), it was found that EAS countries account for about 37% of the world's total Nd demand.

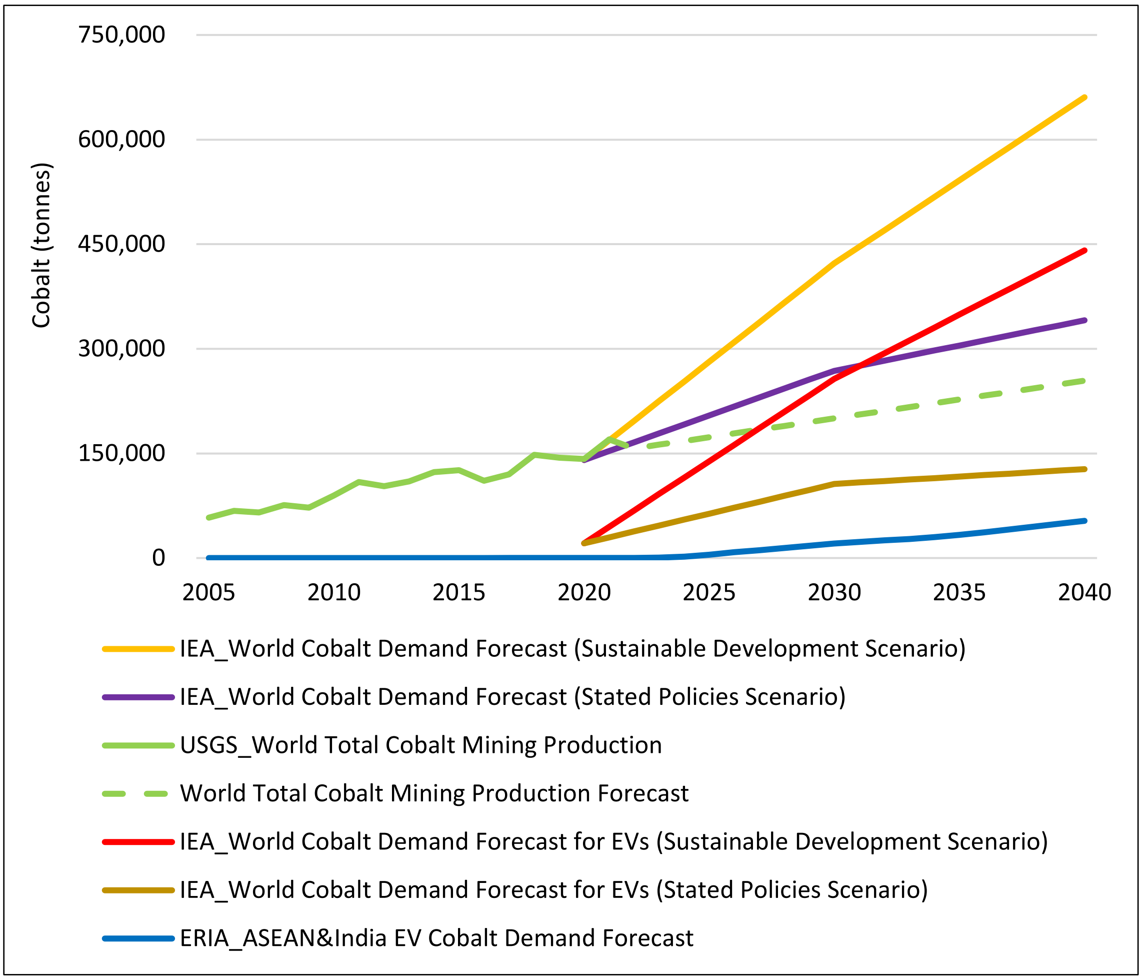
Figure 2.13. USGS, IEA, and ERIA Project Forecast for Neodymium



ERIA= Economic Research Institute for ASEAN and East Asia, IEA=International Energy Agency, USGS= United States Geological Survey.
Source: Authors.

Figure 2.14 shows the supply and demand for Co until 2040 based on the USGS, IEA, and ERIA project. By comparing the IEA world Nd demand (of EVs) forecast of the Stated Policies Scenario (in 2040, 127.4 k-tonnes/y) and the forecast for EAS countries (53.3 k-tonnes/y), it was found that EAS countries account for about 41% of the world's total Co demand.

Figure 2.14. USGS, IEA, and ERIA Project Forecast for Cobalt



ERIA= Economic Research Institute for ASEAN and East Asia, IEA=International Energy Agency, USGS= United States Geological Survey.
Source: Authors.

5. Discussion

This chapter further explores a bottom-up energy demand model for the transport sector from the previous study (ERIA, 2022), focusing on cars and motorcycles in Malaysia, the 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 EVs and biofuel forecasts.

With a relatively robust vehicle ownership model, the BAU setting for energy consumption and WTT GHG emissions can be set as a baseline for an investigation into the impacts of EVs and biofuel policy. Additional grid emission improvement by renewable energy is quantitatively assessed for a reduction in transport GHG emissions. As pointed out in the previous study (ERIA, 2022), the motorcycle segment in these six countries emits similar GHG emissions to the car segment, and the electrification effect from the current target could achieve about 5% decarbonisation in each sector. Further grid emission factor improvement from the current policy could help further decarbonise by less than 2%, implying that further consideration may be needed to improve grid emissions. On the other hand, biofuel policy could help each sector decarbonise by 10%.

This chapter also explains the result of neodymium and cobalt demand for vehicle electrification in EAS countries until 2040. This result is compared to neodymium and cobalt supply from mining production by USGS and other demand forecasts from the IEA to see the trendlines for every forecast.

The demand for Nd for vehicle electrification in EAS countries is predicted to be 4,075 t/y in 2040. By comparing the IEA world Nd demand (of EVs) forecast of the Stated Policies Scenario, it was found that EAS countries account for about 37% of the world's total Nd demand for EVs. Considering the large increase in Nd demand in Europe, the US, China, and other EV-implementing countries, EAS countries' 37% share of global demand is expected to create fierce competition with other countries.

Regarding Co, the demand for vehicle electrification in EAS countries is forecasted to be 53,324 t/y. By comparing with the IEA world Nd demand (of EVs) forecast of the Stated Policies Scenario, it was found that EAS countries account for about 41% of the world's total Co demand for EVs. Therefore, Co is also expected to face fierce competition from other countries.

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