Chapter 2

Transport Energy Demand Outlook

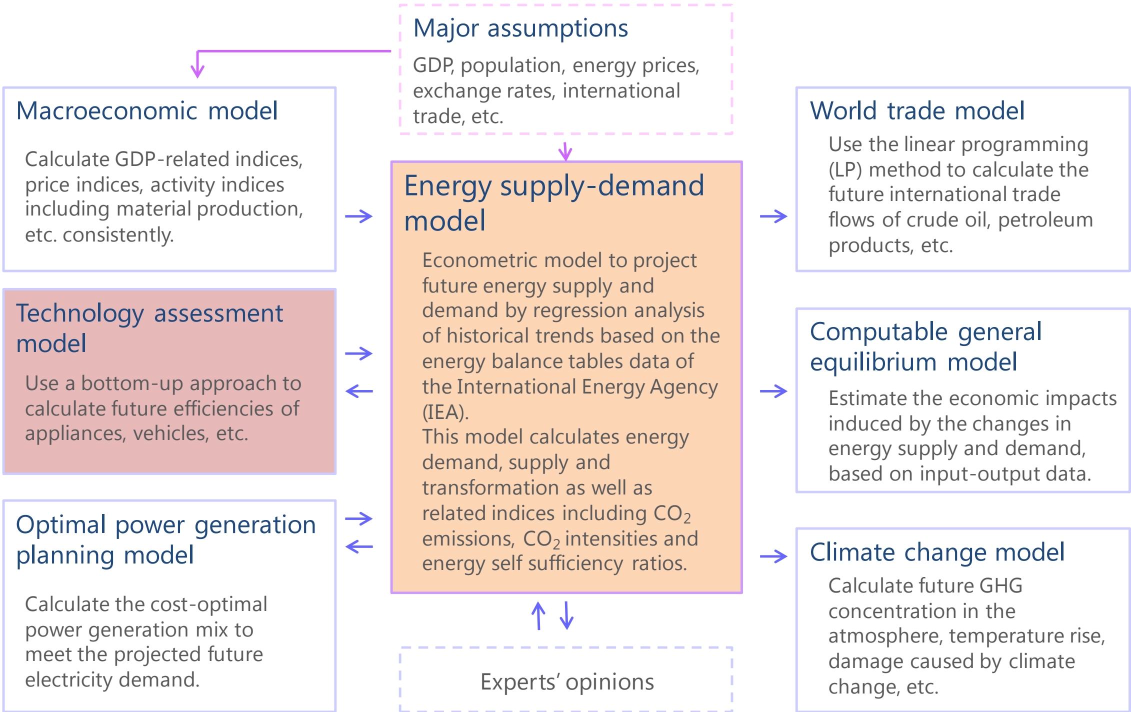
1. Introduction

1.1 Energy Analysis Model

This analysis uses the IEEJ's energy analysis model, known as the energy supply–demand model (Fig. 2.1). This model, shown at the center of a group of various models, allows the projection of future energy supply and demand through a regression analysis of historical trends. The energy demand and supply structure is based on the energy balance tables of the International Energy Agency. This model can calculate energy demand, supply, and transformation as well as related indices, including CO_2 emissions and the energy self-sufficiency rate.

The energy supply–demand model requires several assumptions such as gross domestic product (GDP), population, international energy prices, and economic activities such as material production and commercial services activity. These are fed directly into the model or provided indirectly through the macroeconomic model.

Figure 2.1: Institute of Energy Economics, Japan Energy Modelling Framework



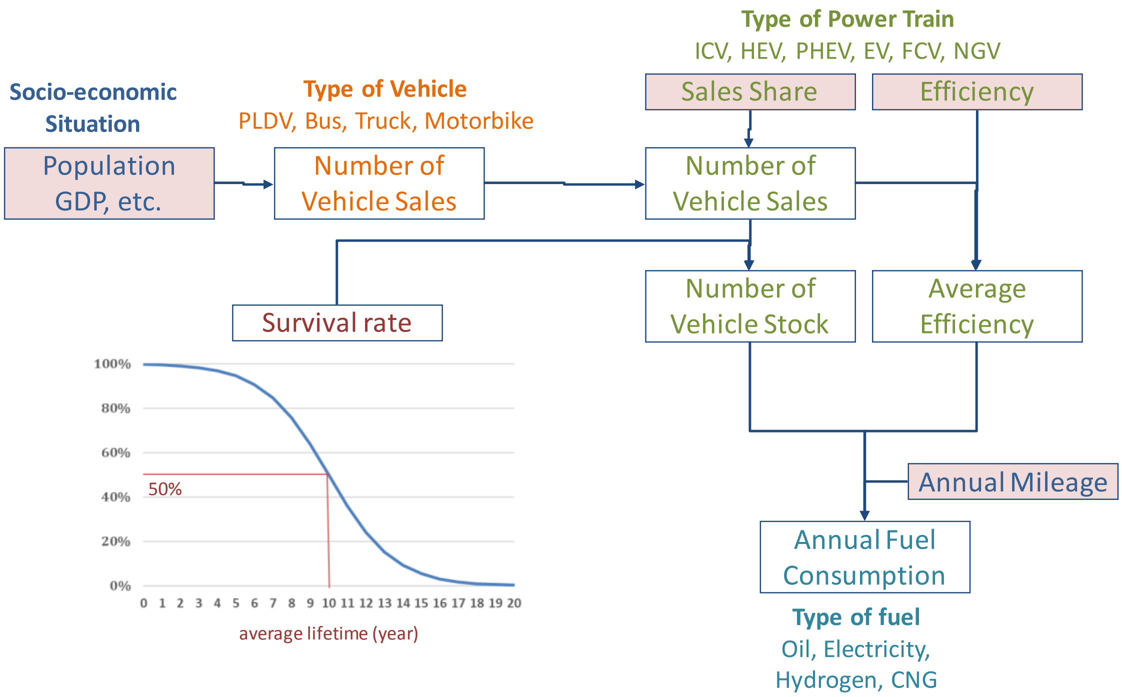
GDP = gross domestic product, GHG = greenhouse gas, CO_2 = carbon dioxide.
Source: Institute of Energy Economics, Japan.

The energy supply–demand model also requires assumptions for energy efficiency improvement with respect to household appliances and automobiles. These assumptions are calculated in the technology assessment model, which uses a bottom-up approach to calculate the future efficiencies of appliances and vehicles, amongst other items.

1.2. Technology Assessment Model for Automobiles

The technology assessment model for automobiles employs the turnover model, which deals with four vehicle types: passenger light-duty vehicles (PLDVs), buses, trucks, and motorcycles. To analyse how the powertrain mix (especially electrification) could affect fuel demand in the road sector, this model considers six types of powertrain, namely ICEVs, hybrid electric vehicles (HEVs), plug-in hybrid electric vehicles (PHEVs), EVs, FCVs, and natural gas vehicles.

Figure 2.2: Technology Assessment Model (Vehicle Turnover Model)



CNG = compressed natural gas, EV = electric vehicles, FCV = fuel-cell vehicle, GDP = gross domestic product, HEV = hybrid electric vehicle, ICEV = internal combustion engine vehicle, NGV = natural gas vehicle, PHEV = plug-in hybrid electric vehicle, PLDV = passenger light-duty vehicle.
Source: Institute of Energy Economics, Japan

After estimating numbers of future vehicle sales and shares by powertrain type (see Section 2.1.3), the model estimates numbers of future vehicle stocks by powertrain type, based on the survival rate (how many vehicles are on the road a certain number of years after being sold). This analysis uses a logistic curve to shape the survival rates and set 50% of the rate at the average lifetime. By assuming fuel efficiency by powertrain type for each year's sales (Fig. 2.2), the model can determine the average fuel efficiency on the road.

Total fuel consumption for each year can be calculated by multiplying the number of vehicle stocks, average fuel efficiency, and annual mileage. The fuel types analysed in this study are oil, electricity, hydrogen, and compressed natural gas.

1.3 Multinomial Logit Model for Sales Share

Sales shares by powertrain type are estimated using the multinomial logit model. For this model, we set utilities for using each powertrain, then calculate the ratio of the exponential function of its utility using Napier's number (e). In the model, this ratio is considered a selection probability, namely sales share.

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

i (type of powertrain) = ICEV, HEV, PHEV, EV, FCV, NGV

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

The utility is estimated based on initial cost, running cost, income level, cruising distance, and so on. When the initial and running costs are lower, the utility is higher. The utility for EVs depends on cruising distance. In this analysis, a higher income is assumed to enable the purchasing of more expensive cars.

2. Main Assumptions for the Study

2.1 Demographic Assumptions

For this study, we assumed that Indonesia would have an average annual economic growth rate of 5.0% and a population growth rate of 0.8%. GDP per capita will increase from around $4,000 to more than $10,000 (in 2010 prices) by 2040.

Table 2.1: Assumptions for Gross Domestic Product and Population

		2015	2020	2030	2040	2015/2040
GDP	bil. USD ($2010price)	988	1,276	2,124	3,329	5.0%
Population	million	258	272	295	312	0.8%
GDP per capita	USD/person	3,834	4,698	7,194	10,671	4.2%

GDP = gross domestic product.
Sources: World Development Indicators, United Nations, and Institute of Energy Economics, Japan analysis.

2.2 Automobile Assumptions

To use the automobile model, it is necessary to provide various data (such as the number of vehicles owned, number of sales, fuel consumption, and travel distance) for each type of vehicle and engine. However, although the number of vehicles owned can be obtained from the Central Bureau of Statistics (*Badan Pusat Statistik*), the other statistical data are difficult to obtain in Indonesia.

Therefore, it is necessary to estimate actual data such as fuel consumption and mileage based on a survey of the literature. Table 2.2 shows the estimated average fuel efficiency and travel mileage by vehicle type. In calibrating these averages, we considered fuel consumption (based on International Energy Agency data) in the road sector as a control total.

Table 2.2: Calibration of 2011 Levels

	Actual	Calibration		Estimation	Actual
	No. of Stock*1 (1000unit)	Average Fuel Efficiency (km/L-gsl)	Average Mileage (km/yr)	Fuel Consumption (ktoe)	Fuel Consumption*2 (ktoe)
PLDV	9,549	11.4	11,000	7,292	
Bus	2,254	5.8	20,000	6,175	
Truck	4,959	5.4	15,000	10,973	
Motorbike	68,839	30.0	4,500	8,200	
Total				32,640	32,682

km = kilometre, ktoe = kilotonne of oil equivalent, L-gsl = gasoline litre equivalent , No. = number, PLDV = passenger light-duty vehicle, yr = year.
Sources: Institute of Energy Economics, Japan analysis, Central Bureau of Statistics (Indonesia), and the International Energy Agency.

Assuming constant average mileage during the outlook period, it is expected that automobile fuel efficiency will gradually improve with technological improvement (Table 2.3). Annual improvement rates in efficiency are set based on historical trends (0.5%–0.9% for ICEVs, 0.6%–0.7% for HEVs, 0.4%–0.5% for PHEVs, and 0.2%–0.4% for EVs).

Table 2.3: Assumptions for Fuel Economy in 2017 and 2040 (km/L-gasoline eq.)

	ICV	HEV	PHEV	EV
PLDV	12.4	18.5	36.9	49.2
Bus	6.4	9.6	19.6	25.4
Truck	6.0	9.0	19.7	24.0
Motorbike	30.9	-	-	115.2

	ICV	HEV	PHEV	EV
PLDV	15.2	21.6	41.4	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

EV = electric vehicle, FCV = fuel-cell vehicle, GDP = gross domestic product, HEV = hybrid electric vehicle, ICEV = internal combustion engine vehicle, km = kilometre, L-gasoline eq. = gasoline litre equivalent, NGV = natural gas vehicle, PHEV = plug-in hybrid electric vehicle, PLDV = passenger light-duty vehicle.
Sources: WWF, International Energy Agency, and Institute of Energy Economics, Japan analysis.

Automobile sales prices are an important element of the multinomial logit model. Prices are assumed to decline gradually (rising for ICEVs) along the learning curve (Table 2.4). Learning rates for the learning curve are set as 101% for the base components and 80% for batteries. For other components of specific powertrain types, the rates are set at 95% for HEVs, 85% for PHEVs, and 85% for EVs.

Table 2.4: Assumptions for List Price in 2017 and 2040

($/unit)

	ICV	HEV	PHEV	EV
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	EV
PLDV	22,381	24,537	24,959	22,472
Bus	67,934	74,419	88,909	83,422
Truck	47,852	54,998	53,077	48,587
Motorbike	1,523	-	-	1,618

EV = electric vehicle, FCV = fuel-cell vehicle, GDP = gross domestic product, HEV = hybrid electric vehicle, ICEV = internal combustion engine vehicle, NGV = natural gas vehicle, PHEV = plug-in hybrid electric vehicle, PLDV = passenger light-duty vehicle.

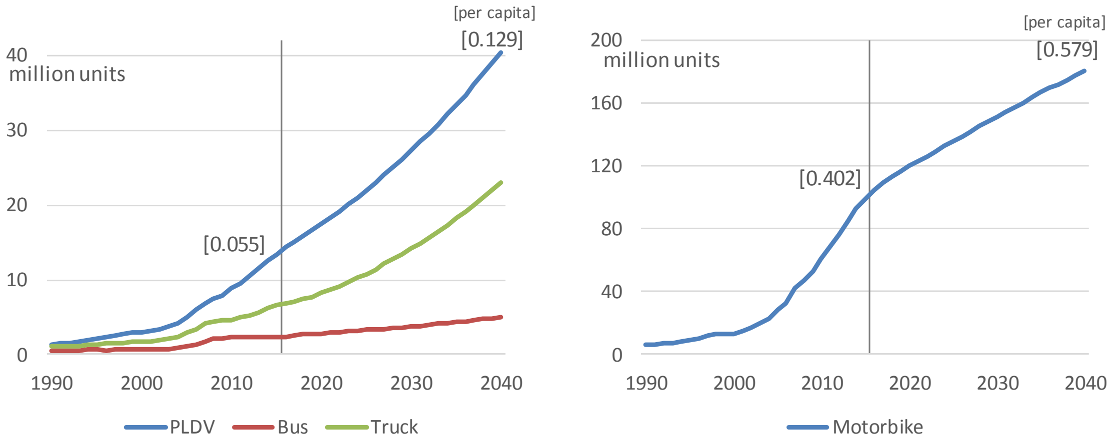
Sources: Mitsubishi Fuso, Toyota, Nissan, Hino, and Institute of Energy Economics, Japan analysis.

3. Reference Scenario

3.1. Automobile Penetration

Based on the above assumptions, the outlook for automobile vehicles is analysed in the reference scenario. In this study, it is assumed that historical trends will continue in the reference scenario without strengthening policy measures.

Figure 2.3: Outlook for Vehicle Stocks



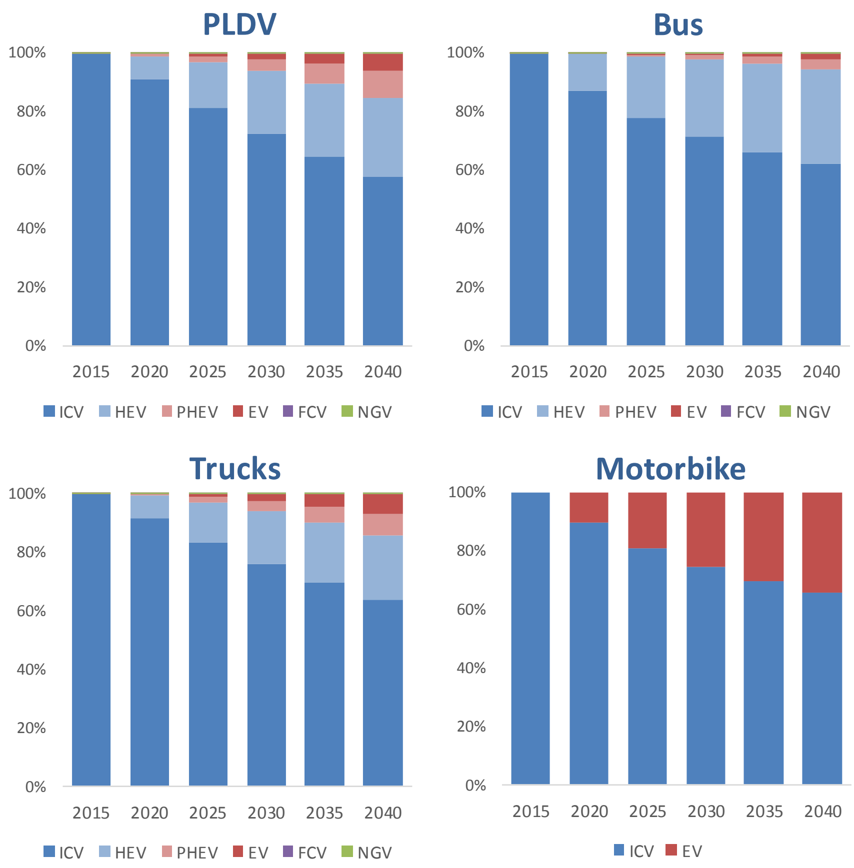
PLDV = passenger light-duty vehicle.

Sources: Central Bureau of Statistics (Indonesia) and Institute of Energy Economics, Japan analysis.

In the outlook, the number of PLDV stocks is projected to triple to more than 40 million units by 2040.[2] Per capita, this figure increases to 129 per 1,000 people (similar to the current global average). The number of freight trucks and vans increases faster than that of PLDVs (3.5 times), due to economic expansion. On the other hand, motorcycle stocks nearly double by 2040.

In terms of the mix by powertrain type, conventional ICEVs remain mainstream and the share of HEVs gradually increases in the reference scenario. The EV sales share is projected to account for only 6% of total car sales (PLDVs, buses, trucks, and motorcycle) by 2040. On the other hand, EV motorcycles will gain a more than 30% share in the motorcycle market due to the relatively small price gap between ICEVs and EVs.

Figure 2.4: Sales Share by Powertrain Type



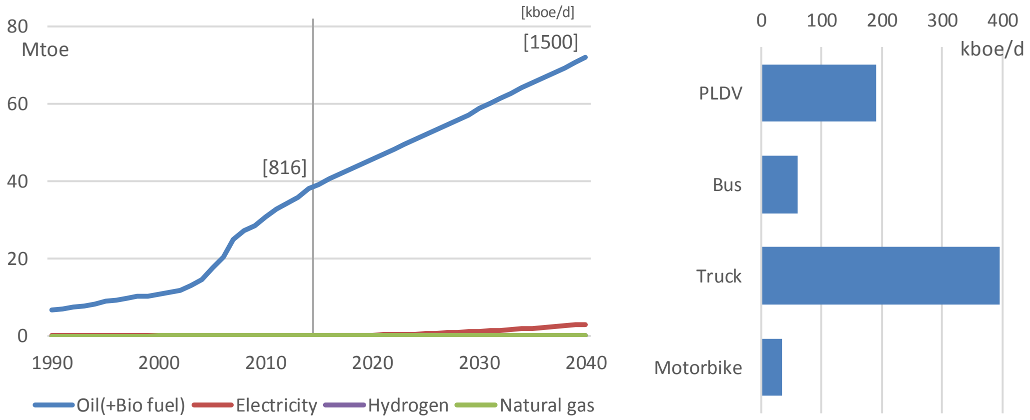
EV = electric vehicle, FCV = fuel-cell vehicle, GDP = gross domestic product, HEV = hybrid electric vehicle, ICEV = internal combustion engine vehicle, NGV = natural gas vehicle, PHEV = plug-in hybrid electric vehicle, PLDV = passenger light-duty vehicle.
Source: Institute of Energy Economics, Japan analysis.

[2] This study does not consider the effects of car-sharing, a topic that makes it challenging to estimate the future situation.

3.2. Fuel Consumption in the Road Sector

The energy demand of the road sector is calculated by multiplying the number of vehicles owned, the average fuel efficiency, and the average mileage for each vehicle type and powertrain. Fuel consumption (almost oil consumption) in the road sector almost doubles from 816 kilograms of barrel of oil equivalent per day (kboe/d) to 1,500 kboe/d by 2040 in the reference scenario. Electricity demand also increases but still accounts for a tiny portion of the road sector. Of the growth in oil demand from 2015 to 2040, around 60% comes from freight trucks and around 30% from PLDVs. This is because freight trucks are relatively less efficient and travel longer distances than PLDVs.

Figure 2.5: Demand by Fuel and Oil Growth Type in the Road Sector



kboe/d = kilograms of barrel of oil equivalent per day, Mtoe = million tonnes of oil equivalent, PLDV = passenger light-duty vehicle.
Source: International Energy Agency and Institute of Energy Economics, Japan analysis.

4. Alternative Scenario

4.1. Scenario Assumptions for Electric Vehicle Penetration

In the reference scenario the penetration of EVs is minimal. To reflect the Government of Indonesia’s target to increase the share of EVs, this study presents alternative scenarios of EV penetration. Specifically, we set the EV sales share at 35% in 2040 for a moderate EV scenario and at 100% for an advanced EV scenario (compared to 6% in the reference scenario) (Table 2.5 and Fig. 2.6).

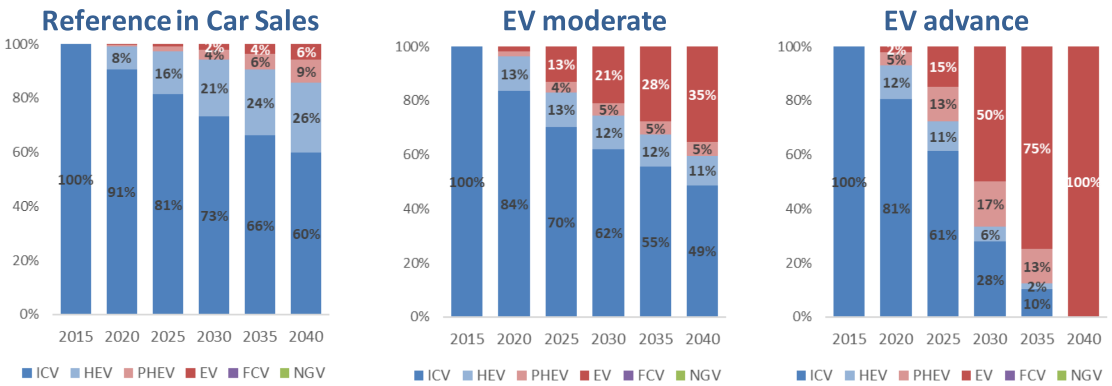
The assumed 35% share in the moderate EV scenario is based on the estimation provided by the Ministry of Energy and Mineral Resources. The 100% share in the advanced EV scenario is based on the assumption that ICEVs will be no longer sold by 2040. On the other hand, low-carbon emission vehicles are projected to account for 40% of sales in the reference scenario, which is close to the Ministry of Industry’s target of 30% by 2035.

Table 2.5: Alternative Scenarios for Vehicle Sales Mix

	EV sales share in 2040		LCEV share In 2040	
	PLDV	Motorcycle		
1) Reference	6%	34%	40%	Close to the Ministry of Industry's roadmap
2) Moderate EV	35%	36%	51%	Close to the Ministry of Energy and Mineral Resources' scenario
3) Advanced EV	100%	100%	100%	Refer to the statement by the Ministry of Energy and Mineral Resources

LCEV = low-carbon emission vehicle, PLDV = passenger light-duty vehicle.
Source: Authors.

Figure 2.6: Sales Share by Powertrain for Each Scenario

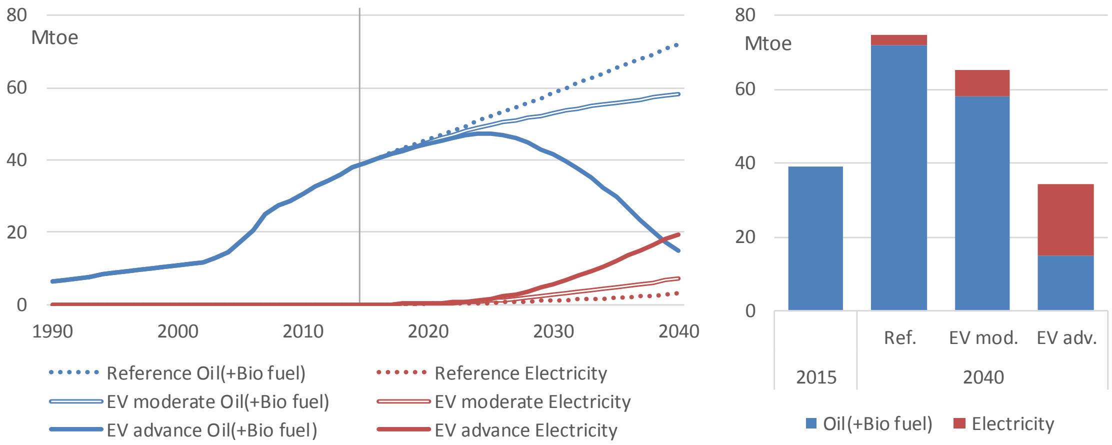


EV = electric vehicle, FCV = fuel-cell vehicle, GDP = gross domestic product, HEV = hybrid electric vehicle, ICEV = internal combustion engine vehicle, NGV = natural gas vehicle, PHEV = plug-in hybrid electric vehicle, PLDV = passenger light-duty vehicle.
Source: Institute of Energy Economics, Japan analysis.

4.2. Fuel Consumption in the Road Sector

In the moderate EV scenario, oil demand in the road sector still increases but is 20% lower in 2040 than the reference scenario projection. On the other hand, in the advanced EV scenario, oil demand peaks sometime around 2025 and declines rapidly to almost half of the current level. Electricity demand increases to the same level as the total electricity demand in 2017 (around 200 terawatt-hours [TWh]). Due to more efficient EVs, total fuel demand in 2040 will be lower than the current demand.

Figure 2.7: Fuel Demand in the Road Sector by Scenario

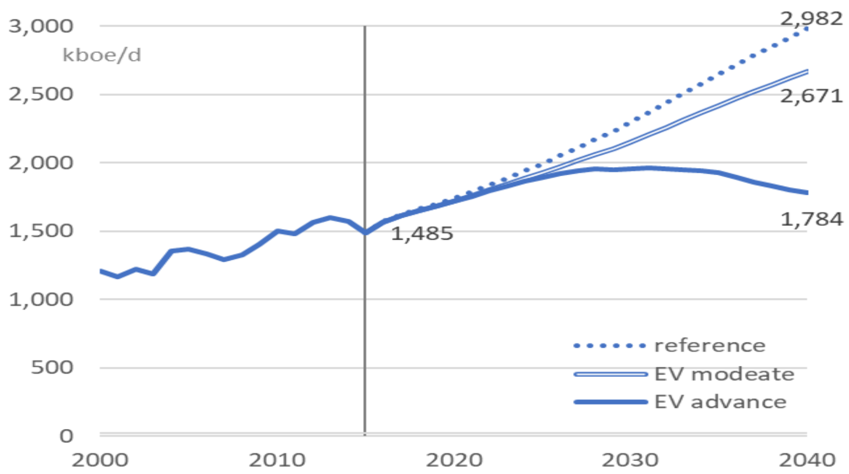


adv. = advanced, EV = electric vehicle, mod. = moderate, Mtoe = million tonnes of oil equivalent, Ref. = reference.
Source: International Energy Agency and Institute of Energy Economics, Japan analysis.

4.3. Primary Demand and Carbon Dioxide Emissions

In the reference scenario, the primary oil demand, including demand in other sectors (industry, commercial, and residential), more than doubles to around 3,000 kboe/d. In contrast, in the advanced EV scenario it would peak at around 1,800 kboe/d by 2030. However, this is still higher than the current level.

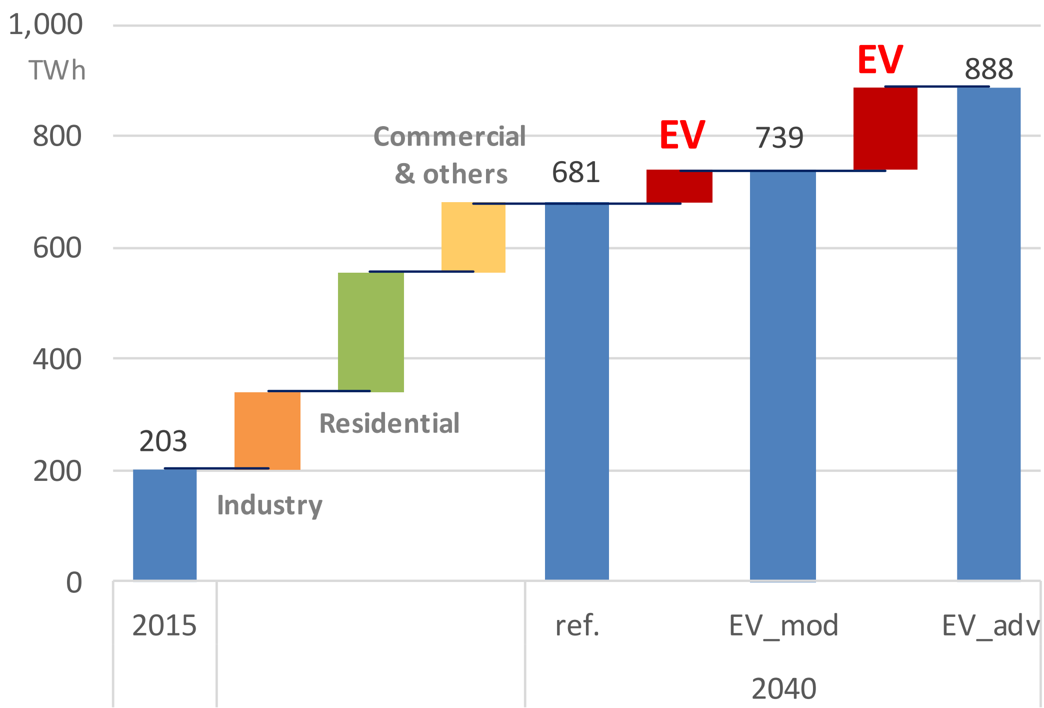
Figure 2.8: Primary Oil Demand by Scenario



EV = electric vehicle, kboe/d = kilograms of barrel of oil equivalent per day.
Sources: International Energy Agency and Institute of Energy Economics, Japan analysis.

Similarly, the electricity demand more than triples in the reference scenario from 200 TWh to 680 TWh led by the industry and the commercial sectors. The rapid penetration of EVs will increase the electricity demand further to around 900 TWh, quadruple the current level. Around 200 TWh of the additional electricity demanded by EVs requires additional power generation capacity, which is the same level as the existing capacity.

Figure 2.9: Electricity Demand by Sector and Scenario

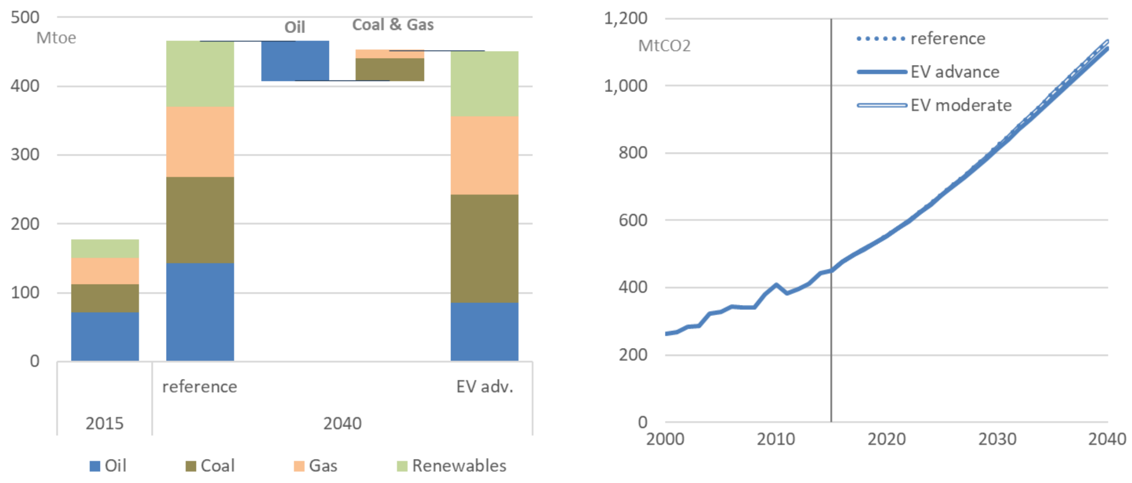


EV = electric vehicle, EV_adv = advanced EV scenario, EV_mod = moderate EV scenario.
Sources: International Energy Agency and Institute of Energy Economics, Japan analysis.

Led by fossil fuels, the total primary energy demand nearly triples in the reference scenario, meaning that CO_2 emissions also nearly triple by 2040 (Fig. 2.10).

In the advanced EV scenario, oil demand in the road sector decreases, but coal and gas in the power sector increase to meet the increased electricity demand resulting from the penetration of EVs. Coal-fired generation retains a dominant share of the power generation mix (around 60%). As a result, CO_2 emissions remain at almost the same level, only 2% lower than in the reference scenario.

Figure 2.10: Primary Energy Demand and Energy-Related Carbon Dioxide Emissions



$MtCO_2$ = metric tonnes of carbon dioxide, Mtoe = million tonnes of oil equivalent.
Note: Primary energy demand excludes traditional biomass use.
Sources: International Energy Agency and Institute of Energy Economics, Japan analysis.

5. Alternative Power Generation Mix

5.1. Scenario Assumptions for the Generation Mix

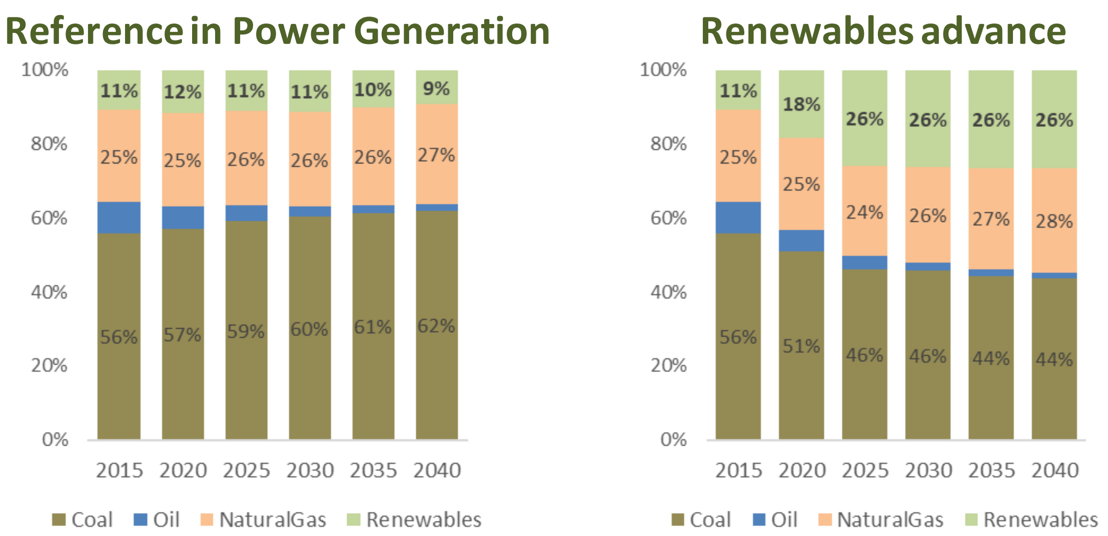
From the viewpoint of utilising EVs effectively to reduce CO_2 emissions, the power generation mix is very important. In the reference scenario, renewable power generation accounts for less than 10% of the total generation mix even in 2040; therefore, substantial penetration of EVs does not significantly impact the reduction of CO_2 emissions.

In the reference scenario, it is estimated that renewable energy (excluding traditional biomass use) will account for 9% of the power generation mix and 21% of the primary energy mix by 2040. However, the Government of Indonesia aims to increase the share of renewables to 23% of the primary energy mix by 2025. This corresponds to a 26% share in the power generation mix, according to the National Energy Council (*Dewan Energi Nasional*). In this study, we use this figure for the power generation mix in the advanced renewables scenario.

5.2 Carbon Dioxide Emissions

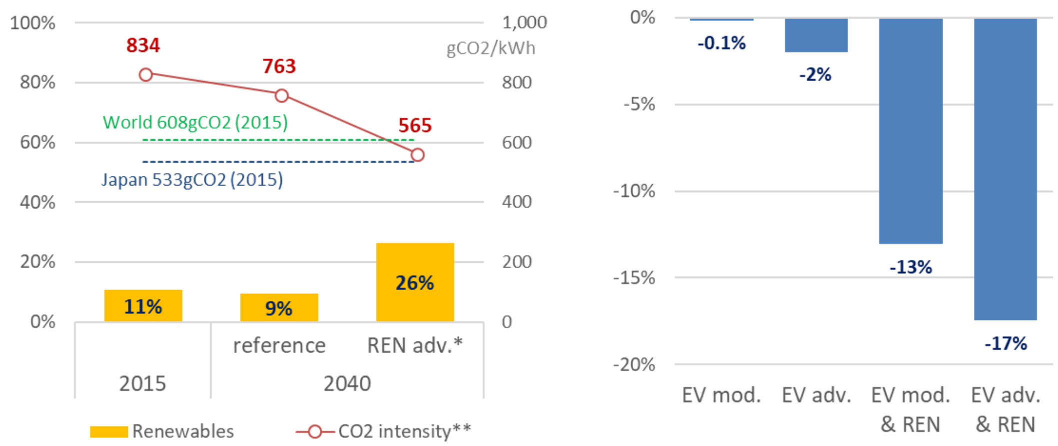
The power generation sector currently emits 834 grams (g) of CO_2 per electricity demand of 1 kilowatt-hour (kWh) (receiving-end basis), about 40% higher than the global average. In the reference scenario, CO_2 intensity decreases to 763 g in 2040 due to improvements in the efficiency of thermal power generation and transmission and distribution losses. On the other hand, in the advanced renewables scenario, the intensity drops further to 565 gCO_2/kWh, which is close to the current level in Japan (Fig. 2.12). Under this generation mix, CO_2 emissions could be reduced by 13% in the moderate EV scenario and 17% in the advanced EV scenario, compared with the reference scenario.

Figure 2.11: Power Generation Mix for Each Scenario



Sources: International Energy Agency and Institute of Energy Economics, Japan analysis. See also National Energy Council (*Dewan Energi Nasional*) (2016), *Outlook Energi Indonesia*. Jakarta.

Figure 2.12: Renewables Share and Carbon Dioxide Intensity in Power Generation in 2040 (left-side) and Carbon Dioxide Reduction from Reference in 2040 (right-side)



CO_2 = carbon dioxide, EV = electric vehicle, EV adv. = advanced EV scenario, EV mod. = moderate EV scenario, gCO_2 = grams of carbon dioxide, REN = renewables, REN adv. = advanced renewables scenario.

*Refer to Sekretariat Jenderal *Dewan Energi Nasional* (2016), 'Indonesia Energy Outlook 2016'. Jakarta.

**Receiving-end basis.

Sources: International Energy Agency and Institute of Energy Economics, Japan analysis.

6. Conclusion

According to this study, the advanced EV scenario would significantly impact oil and electricity demand. The primary oil demand would peak in 2030, compared to a continued increase in the reference scenario. On the other hand, rapid EV penetration will increase the electricity demand by around 200 TWh, matching the current level of total electricity demand in Indonesia. This means additional power generation capacity will be needed, by the same level as the existing one. In the moderate EV scenario, the impacts on electricity and oil demand will necessarily be smaller. The primary oil demand continues to increase but remains 10% lower than in the reference scenario in 2040. Additional power plants will need to provide about 30% of the existing capacity.

However, it is important to note that both scenarios produce the same results in terms of CO_2 emission reductions. This is because the decrease in emissions (from oil) in the road sector is offset by the increase in emissions (from coal and natural gas) in the power sector. Thus, EVs do not reduce CO_2 emissions significantly in the reference power generation mix, in which fossil thermal power generation accounts for around 90%.

In the advanced renewables scenario, assuming that the government meets its renewables target, the rapid penetration of EVs would lead to at most a 17% reduction in emissions from the reference scenario. To reduce CO_2 emissions, EVs need to be integrated with low-carbon electricity generation.

This study, which focused mainly on the effects on energy supply and demand, revealed that EV penetration leads to major impacts on oil and electricity demand; however, its influence on CO_2 emissions depends on the power generation mix. The results of this study might affect the planning of refineries and power generation facilities. When considering CO_2 reduction, it is also necessary to decarbonise the power generation mix, for example, through many more solar photovoltaic systems and more wind power generation. Thus, in addition to measures to promote low-carbon power generation sources (mainly renewables), incentives should be provided to promote renewable electricity sources.