Chapter 1

Integrated, Trans-boundary Energy and Electricity Markets in the BIMP Region – A Quantitative Assessment

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Chapter 1

Integrated, Trans-boundary Energy and Electricity Markets in the BIMP Region – A Quantitative Assessment

Yuhji Matsuo

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The demand for electricity is projected to expand rapidly in most countries of the Association of Southeast Asian Nations (ASEAN). In Borneo, however, current power development plans could not be regarded as efficient as far as improvement of fossil fuel-fired power-generation efficiencies and effective use of domestic hydropower resources are concerned, due mainly to its poor grid systems. In this regard, grid expansion is considered an effective way to improve the economic performance of the island's future power supply systems.

In this chapter, the authors evaluate the benefits of expanding grid interconnection lines in Borneo by carrying out simulation with the Optimal Power Generation Planning Model and the Supply Reliability Evaluation Model. Through efficient use of hydropower resources and expansion of regional interconnection lines, it is possible to reduce fossil fuel consumption, CO_2 emissions, and costs of power source development in Borneo. These can be expected to a certain extent by expanding the interconnection lines within the BIMP region alone. But even more remarkable effects may be achieved by interconnecting with large energy-consuming areas like Peninsular Malaysia and Luzon in the Philippines. However, only from a long-term perspective can such a significant cost reduction be achieved or within a time frame up to 2050. Thus, long-term plans and their steady implementation by the government as well as international financial institutions are indispensable.

1. Introduction

1.1 Study Objective

With rapid economic growth comes a continuous sharp increase in energy demand in ASEAN countries, with power demand showing a remarkable increase. The power demand in 10 ASEAN countries increased from 11.2 million tonnes of oil equivalent in 1990 to 59.2 million tonnes of oil equivalent in 2012, and is expected to increase further by 3.3 times through 2035 in the 'business as usual' case (Kimura et al, 2015). How to meet the increasing power demand has become a major issue for ASEAN countries.

The important point concerning power supply in this area is that the countries and regions with large power demand are different from those with large energy resources. For this reason, by merging these regions with international connection grid lines, it is expected that efficiency in utilising resources will be enhanced and the related cost will be reduced, thus contributing to the improvement of energy security in the entire area. Kutani et al. (2014) calculated the economic effect from transmitting electricity from the hydropower resources of Southern China, North Eastern India, Lao PDR, etc. to the large-demand regions of Thailand, Malaysia, Singapore, Indonesia, etc. through model calculation that targeted the major ASEAN countries and surrounding areas. However, since the model was calculating by country, particularly separated regions in each country were not sufficiently evaluated. Specifically, because the territories of Malaysia, Indonesia, and the Philippines are divided by water, the regions with large power demand and those with large resources differ, with no interconnection for power systems. As with international connection grids, connecting independent domestic power systems could be of great significance.

This study conducts model calculations for the island of Borneo, including the territories of Indonesia, Malaysia, and Brunei Darussalam, that have large hydropower resources or the so-called BIMP region (Brunei, Indonesia, Malaysia, and the Philippines, although it is actually often referred to as the region containing Mindanao in addition to Borneo) as well as the surrounding regions with large energy demand, and evaluates the effects of connecting their power systems.

1.2 Geographical Coverage and an Overview of Regions

1.2.1 Geographical coverage

Borneo is made up of the territories of Indonesia, Malaysia, and Brunei Darussalam. It is divided into eight regions: Sarawak and Sabah for Malaysia; West, Central, South, East, and North Kalimantan for Indonesia; and Brunei as one region.

Table 1-1 shows the regions and their respective codes used in this study.

1.2.2 Population and gross regional domestic product

The most populated region of Borneo is West Kalimantan (Kalbar), but the region with the largest gross regional domestic product (GRDP) is East Kalimantan (Kaltim).

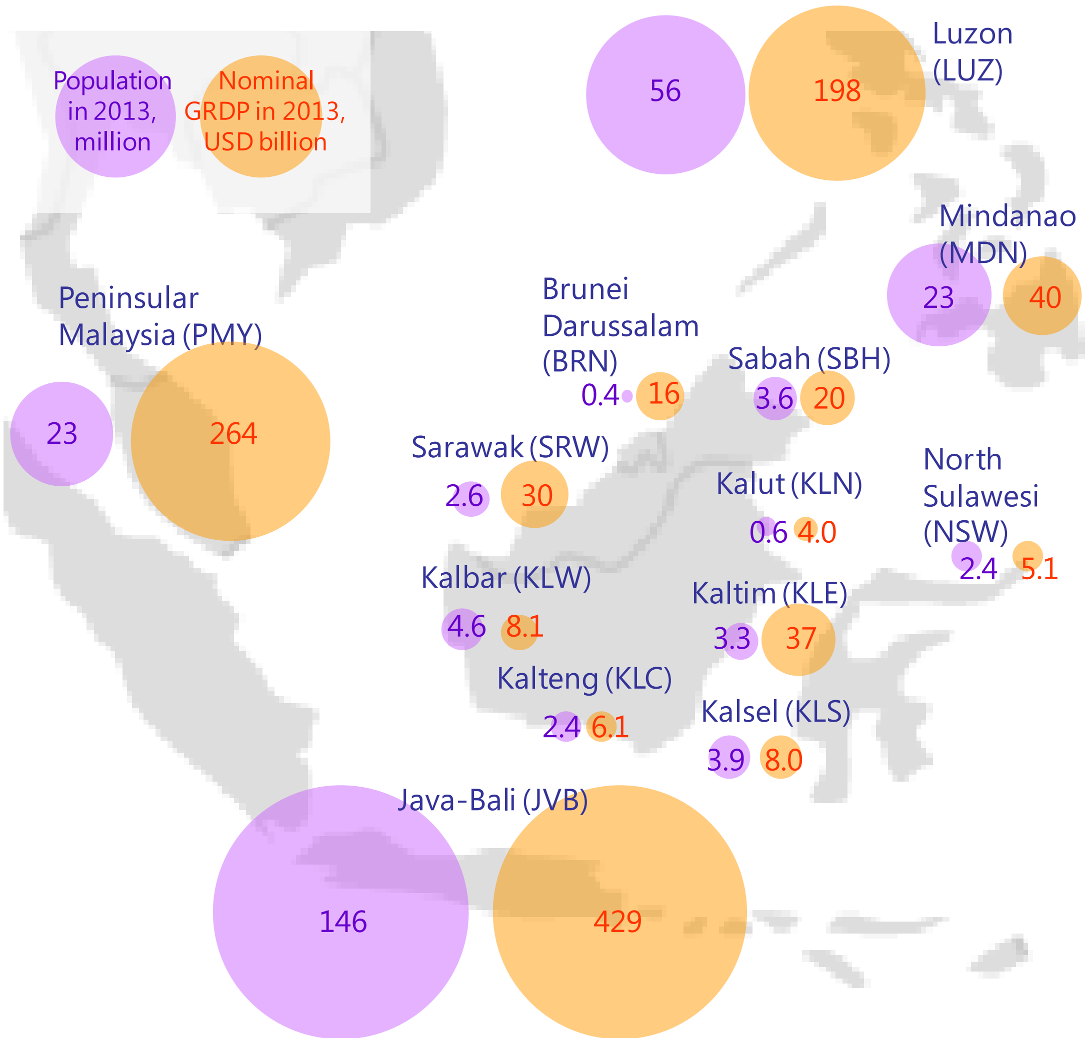
This study also covers adjacent regions with possible interconnections with Borneo: from Sarawak to the Peninsula Malaysia, from East Kalimantan to North Sulawesi, and from Sabah to Mindanao and Luzon (refer to Figure 1.2-4 for details).These regions are more populated and have larger GRDPs than Borneo.

Table 1.1-1. Classification and Codes of Borneo's Regions and Neighbour Regions

Country	Borneo Region	Code
Brunei Darussalam		BRN
Malaysia	Sarawak	SRW
	Sabah	SBH
Indonesia	West Kalimantan (Kalbar)	KLW
	Central Kalimantan (Kalteng)	KLC
	South Kalimantan (Kalsel)	KLS
	East Kalimantan (Kaltim)	KLM
	North Kalimantan (Kalut)	KLN

Country	Neighbour Region	Code
Malaysia	Peninsular Malaysia	PMY
Indonesia	Java and Bali	JVB
	North Sulawesi	NSW
Philippines	Luzon	LUZ
	Mindanao	MDN

Figure 1.1-1. Gross Regional Domestic Products and Populations of Borneo's Regions and Neighbouring Regions

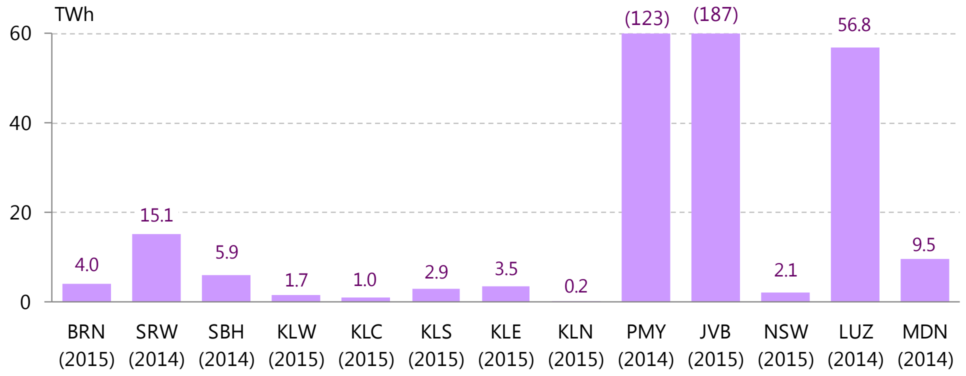


Sources: World Bank, Badan Pusat Statistik, Ministry of Energy and Mineral Resources, Department of Statistics Malaysia, Philippine Statistics Authority.

1.2.3 Power demand and the power generation mix

Power demand is linked with GRDP, demand being larger in metropolitan areas with larger GRDPs such as the Peninsular Malaysia, Java, and Luzon. Within Borneo, the combined power demand of the five states of Indonesia is not larger than that of Sabah's of Malaysia. However, compared with those of metropolitan areas, the combined power demand of the whole of Borneo is small.

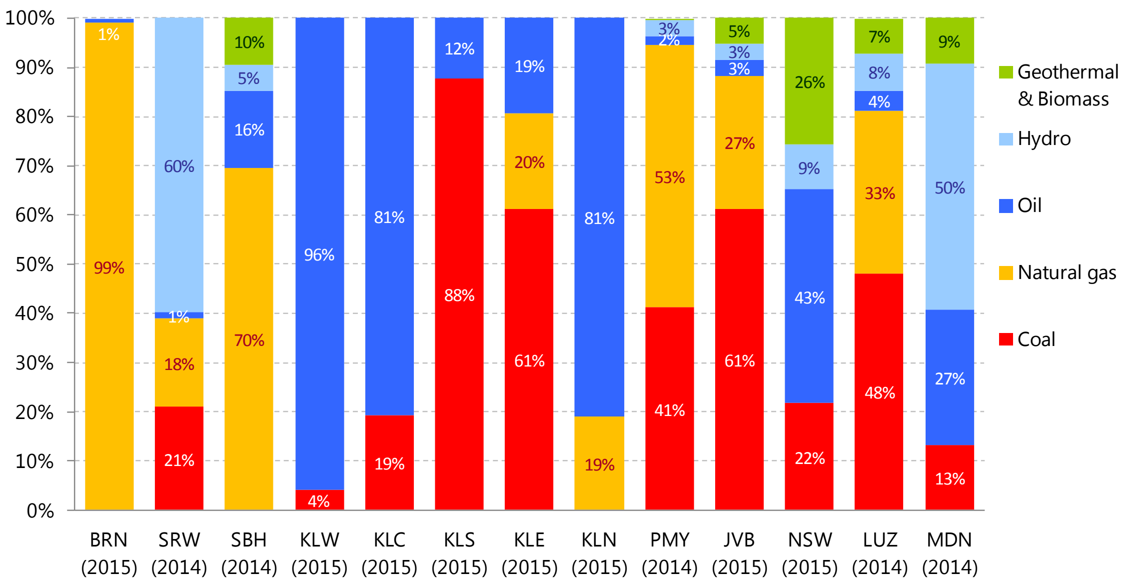
Figure 1.1-2. Power Demand of Borneo's Regions and Neighbour Regions



BRN = Brunei Darussalam, JVB = Java–Bali, KLC = Kalteng, KLE = Kaltim, KLN = Kalut, KLW = Kalbar, KLS = Kalsel, LUZ = Luzon, MDN = Mindanao, NSW = North Sulawesi, PMY = Peninsular Malaysia, SBH = Sabah, SRW = Sarawak.

Sources: Estimates from various sources.

Figure 1.1-3. Power Generation Mix of Borneo's Regions and Neighbour Regions



BRN = Brunei Darussalam, JVB = Java-Bali, KLC = Kalteng, KLE = Kaltim, KLN = Kalut, KLW = Kalbar, KLS = Kalsel, LUZ = Luzon, MDN = Mindanao, NSW = North Sulawesi, PMY = Peninsular Malaysia, SBH = Sabah, SRW = Sarawak.

Sources: Indonesia: PLN, Ministry of Energy and Mineral Resources; Malaysia: Energy Commission; Philippines: Department of Energy.

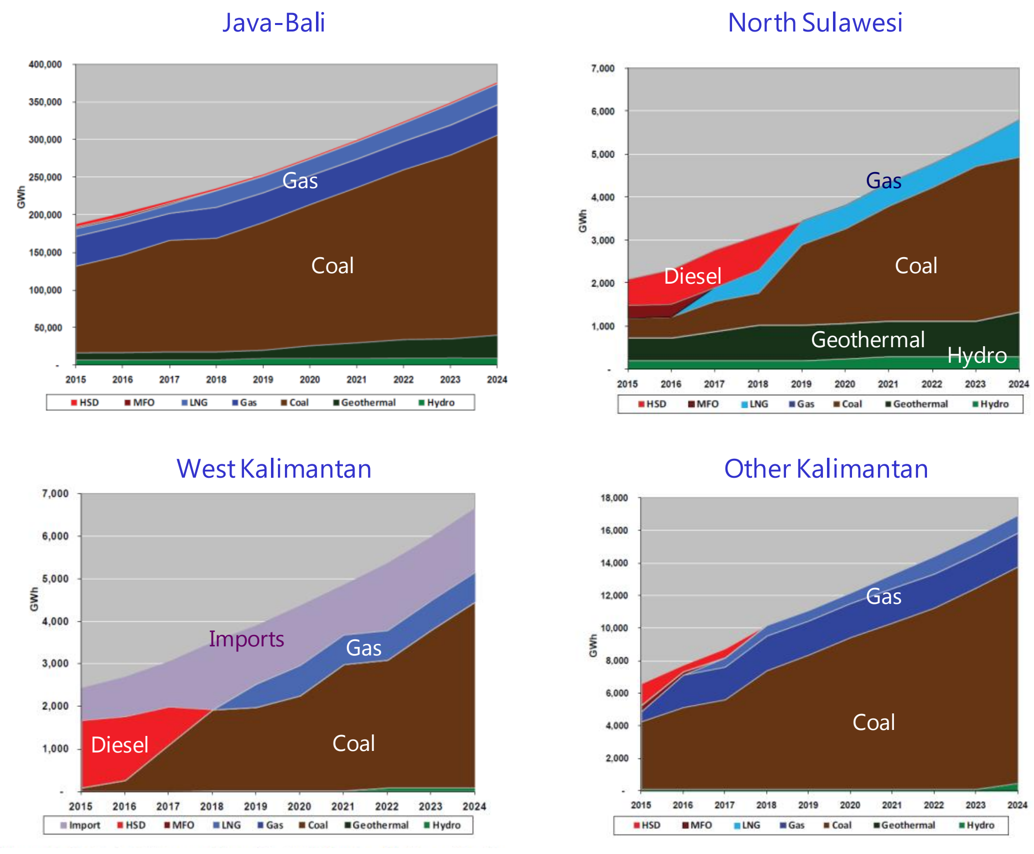
Brunei depends on natural gas for 99 percent of its power generation mix. Similarly, natural gas accounts for a large proportion of the power supply of Sabah. In Kalimantan, dependence on oil and coal is significant. In contrast to these regions that depend on fossil fuels, Sarawak and Mindanao, where energy supply is mainly based on renewable energies including geothermal and biomass, depend on hydropower for more than half of their power mix.

1.2.4 Power supply plan of each country

(a) Indonesia

The share of oil-fired thermal power is expected to decline in all states of Indonesia, which would result in higher dependence on coal-fired thermal. Dependence on fossil fuels is therefore expected to continue. The future plan by the power utility Perusahaan Listrik Negara (PLN) also assumes power import from Sarawak to West Kalimantan.

Figure 1.1-4. Power Supply Plan of Indonesia



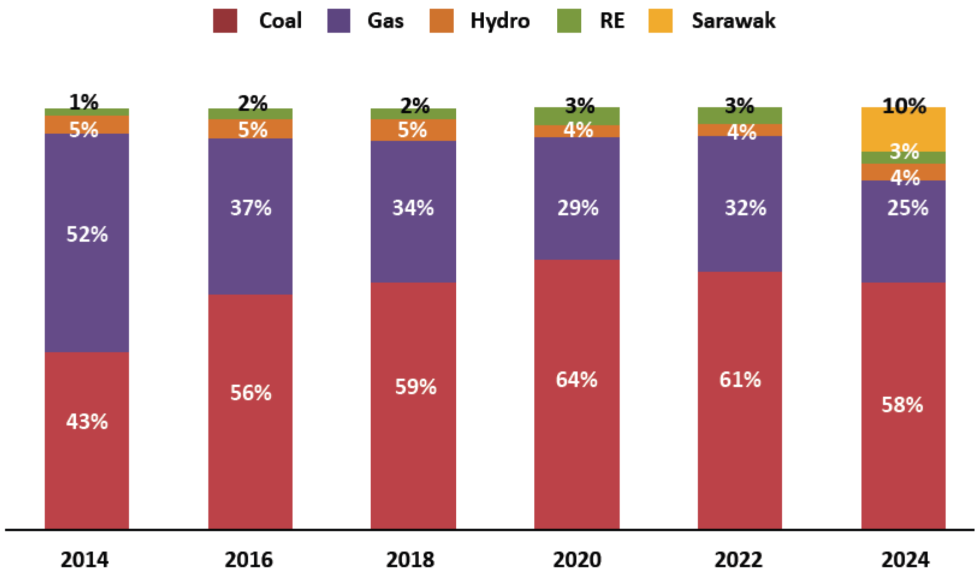
GWh = gigawatt hour, HSD = high speed diesel, LNG = liquefied natural gas, MFO = marine fuel oil.
Source: Perusahaan Listrik Negara.

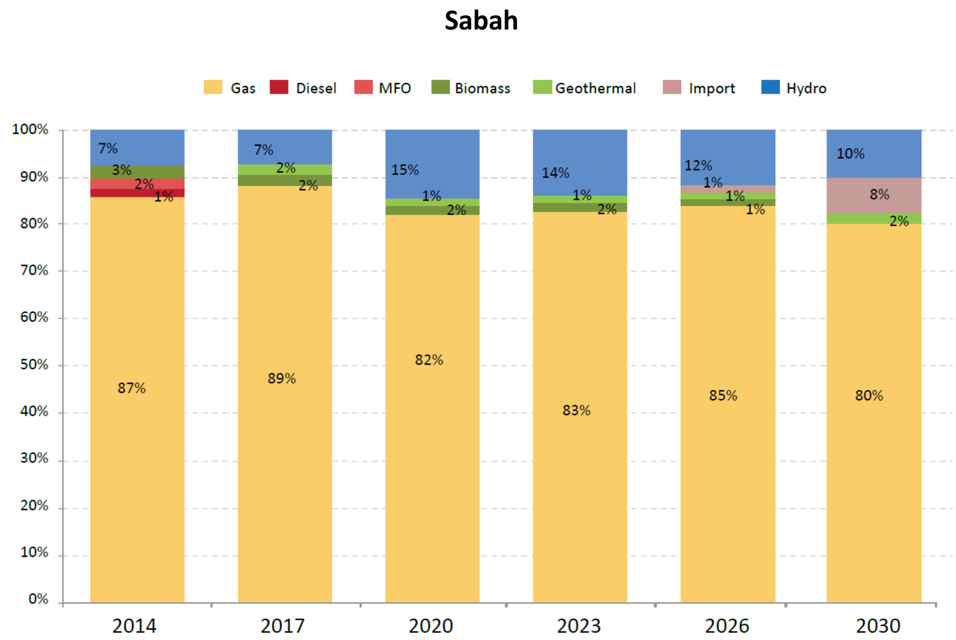
(b) Malaysia

The Energy Commission of Malaysia has been announcing its long-term power development plan for Peninsular Malaysia and Sabah. As of 2014, coal-fired and liquefied natural gas (LNG)-fired thermal power accounted for 90 percent of the power mix in Peninsular Malaysia. Future power trade from Sarawak to Peninsular Malaysia is slated to start in 2024, when the share of LNG-fired thermal power would have declined whereas dependence on coal-fired thermal power would have continued. In contrast, Sabah does not use coal-fired thermal power but depends on LNG-fired thermal power. Although power trade is to be initiated from Sarawak to Sabah in 2026, dependence on LNG-fired thermal power is forecast to remain high.

Figure 1.1-5. Power Supply Plan of Malaysia

Peninsular Malaysia



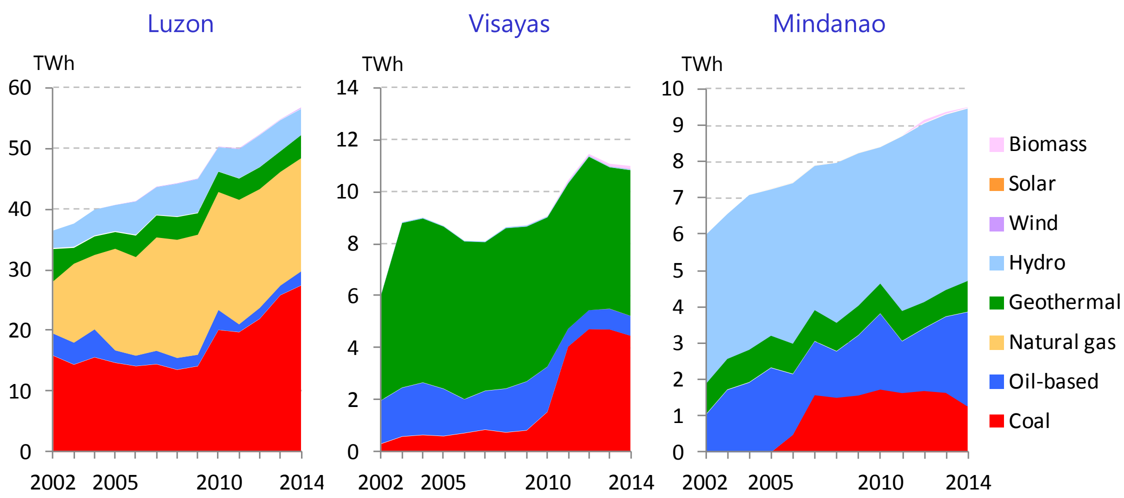


RE = renewable energy, MFO = marine fuel oil.
Source: Suruhanjaya Tenaga (Energy Commission).

(c) The Philippines

In terms of power supply, the Philippines has three large regions: Luzon, the Visayas, and Mindanao. Luzon is highly dependent on fossil fuels such as coal and LNG, while the Visayas and Mindanao are highly dependent on renewable energy sources such as geothermal and hydropower.

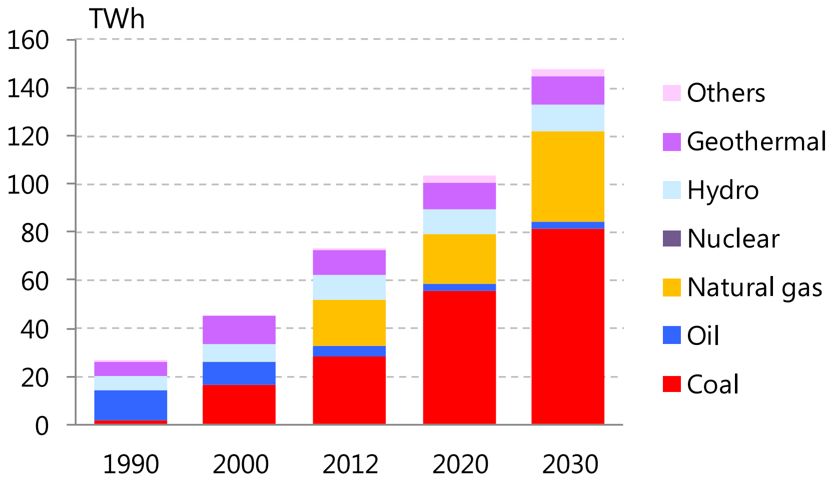
Figure 1.1-6. Trend of Power Supply in the Philippines



TWh = terawatt-hour.
Source: Department of Energy (Philippines).

As the Philippine government has not released any power development plan by source, the assumptions for this study are based on the ERIA outlook (Kimura et al., 2015) where it is assumed that the country's power demand increase in the future will be met mainly by coal and LNG-fired power generation (Figure 1.1-7).

Figure 1.1-7. Power Supply Outlook of the Philippines



TWh = terawatt.
Source: ERIA.

2. Methodology and Major Assumptions

2.1. Overview of the Model

This study uses two models similar to those used by Kutani et al. (2014).

(1) Optimal Power Generation Planning Model

The model is designed to determine an optimal electricity mix to satisfy a given electricity demand level at a minimal cost in a country or region. To assess the effects of international power grid interconnection, the model can set specific grid interconnection capacities between countries and regions and design electricity supply to meet the demand at any time.

(2) Supply Reliability Evaluation Model

An international power grid connection can be expected to improve reliability of electricity supply by allowing a country to receive electricity supply from other countries to avoid blackouts when its domestic supply is short. This means that an international power grid interconnection can allow any country in the interconnection to achieve the same loss of load expectation even at a lower supply reserve margin than in the case without such interconnection and save reserve power generation capacity. To assess this effect, this study has developed a supply reliability evaluation model using the Monte Carlo method.

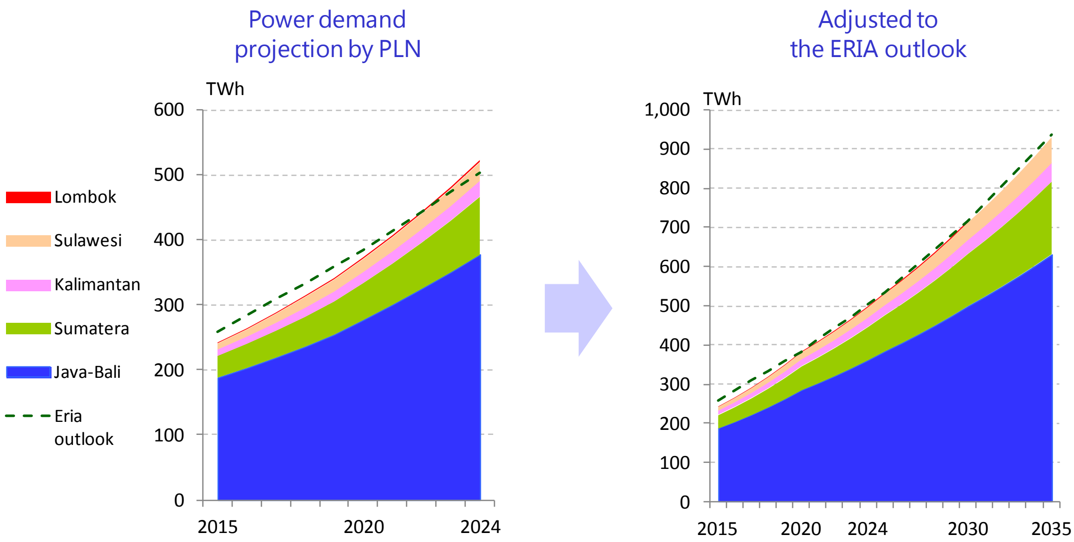
2.2 Outlook for power demand

This study refers to the ERIA outlook for the prospect of increasing power demand in Indonesia, Malaysia, Brunei, and the Philippines. As regards the projection in each region of these countries, the outlook for each country was adjusted so that the growth of the entire power demand will match that of the ERIA outlook. The details for each country are shown below.

Although the PLN's plan and the ERIA outlook both expect a future power demand increase in Indonesia, they present different growth rates: while an increase of 8.9 percent (2015–2024) is assumed in PLN's plan, the ERIA outlook presents a more modest increase of 7.5 percent (2015–2025).

In this study, the regional outlook by PLN through 2024 was corrected so that it would match that of ERIA's in terms of the demand in the entire country. The regional outlook from 2025 to 2035 was worked out by extrapolating the growth rate up to 2024.

Figure 1.2-1. Power Demand in Regions of Indonesia

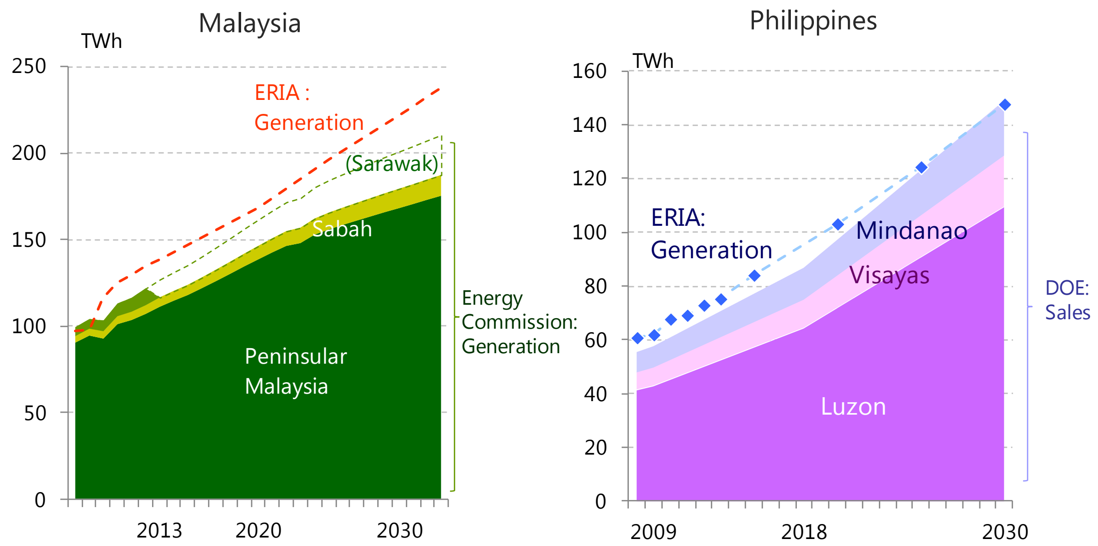


ERIA = Economic Research Institute for ASEAN and East Asia, PLN = Perusahaan Listrik Negara, TWh= terawatt-hour.
Source: Perusahaan Listrik Negara.

The growth rate of power demand in the ERIA outlook is higher in the case of Malaysia than that assumed by the Malaysian government. It is lower than that of the government's in the case of the Philippines. Figure 1.2-2 shows comparison of national projections with the ERIA outlook, where power generation for Sarawak, shown in green dotted lines, is extrapolated using power generation projections for the other two regions and the historical growth rates, as the Energy Commission publishes projections only for Sabah and Peninsular Malaysia.

In this study, corrections were made so that the growth rate of the entire nation would match that shown in the ERIA outlook for Malaysia and the Philippines. As for Brunei, the numerical values of the ERIA outlook were used.

Figure 1.2-2. Power Generation Assumptions in Malaysia and the Philippines



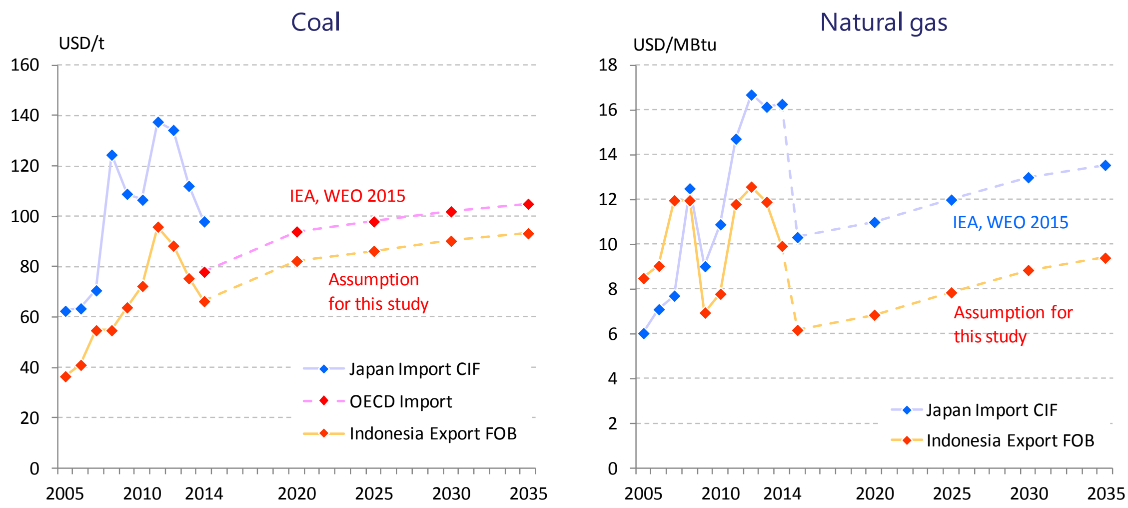
DOE = Department of Energy, ERIA = Economic Research Institute for ASEAN and East Asia. TWh = terawatt-hour.
Sources: Energy Commission, Department of Energy.

2.3 Outlook for Primary Energy Prices

If the share of hydropower increases in ASEAN countries rich in resources, domestic consumption of fossil fuels can be reduced and surplus will be available for export. From this point of view, this study uses the free-on-board export price of fossil fuels as the energy price.

The assumptions on prices were set based on the New Policies Scenario of the International Energy Agency's 'World Energy Outlook'. The export price of coal is assumed to rise from US$66/t in 2015 to US$93/t in 2035. The price of natural gas is assumed to rise from US$6.2/MMBTU in 2015 to US$9.4/MMBTU by 2035.

Figure 1.2-3. Outlook for the Prices of Coal and Natural Gas



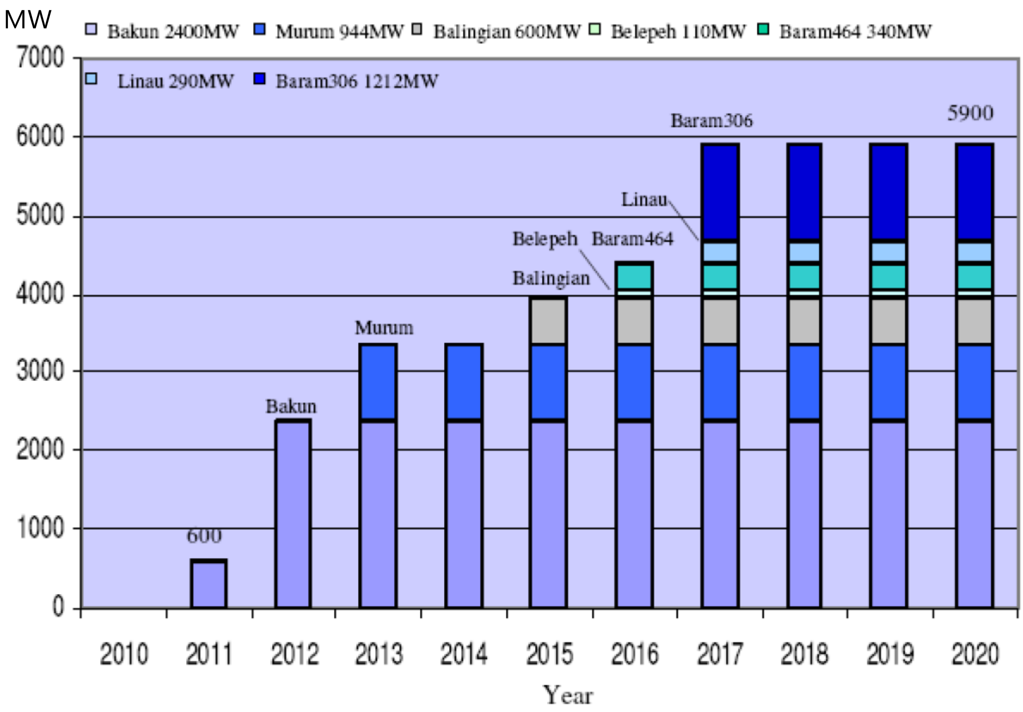
CIF = cost, insurance, and freight, FOB = free on board, IEA = International Energy Agency, MBtu = one million British thermal unit, WEO = World Energy Outlook.
Sources: Ministry of Energy and Mineral Resources, The Institute of Energy Economics Japan, International Energy Agency.

2.4 Renewable Energy Potentials

(a) Sarawak

The potential for hydropower generation in Sarawak is estimated to be 20,000 MW. In the past, only the 104-MW Batang Ai dam (started in 1985) had been used. Recent large-scale developments include the 2,400-MW Bakun dam (started in 2011) and the 904-MW Murum dam (started in 2014). At present, the 1,200-MW Baram dam is under construction and is scheduled to start operation in 2017.

Figure 1.2-4. Power Source Development Plan of Sarawak



MW = megawatt.
Source: Asian Development Bank.

(b) Sabah

The potential for 1,900 MW of hydropower and 500 MW of biomass power generation has been estimated.

(c) North Kalimantan

It has the potential for hydropower, especially along the Sesayap River, where the potential for 5,572 MW is estimated.

2.5 Expansion Plan of Regional Interconnection Lines

The expansion of regional interconnection lines is planned not only for Borneo but also in in adjacent regions not currently interconnected, except for Sarawak and West Kalimantan that have been interconnected very recently. As shown in Figure 1.2-5 and Table 1.2-1, future construction plan of interconnection lines assumes that the whole of Borneo will be interconnected by 2030. The plans also include interconnections from Borneo to Peninsula Malaysia, Java, North Sulawesi, and Luzon. The advantages of interconnection may be the following points:

(1) Effective use of the energy resources in Borneo

Large potential for hydropower exists in Borneo, especially in Sarawak and North Kalimantan, but compared with this potential, the power demand of these regions is not so large and the potential cannot be fully utilised. By interconnecting with grids out of the regions, the resources could be effectively utilised.

(2) Stabilisation of power systems

As power interchange can be achieved with other regions in an emergency, interconnection will contribute to the stabilisation of power systems. From an economic viewpoint, stabilisation of power systems will lead to a reduction in power capacity margin and equipment investment.

(3) More efficient power generation equipment

From the viewpoint of the reliability of power supply, the scale of coal-fired thermal power plants in each region is limited to within 10 percent of the entire power system. However, the power-generation efficiency of coal-fired thermal power generation plants differs in different scales, and generally, the larger the scale, the more efficient thermal efficiency will be. For this reason, by enlarging the scale through interconnection, higher efficiency technology options can be introduced.

Figure 1.2-5. Construction Plan of Inter-Borneo Interconnections

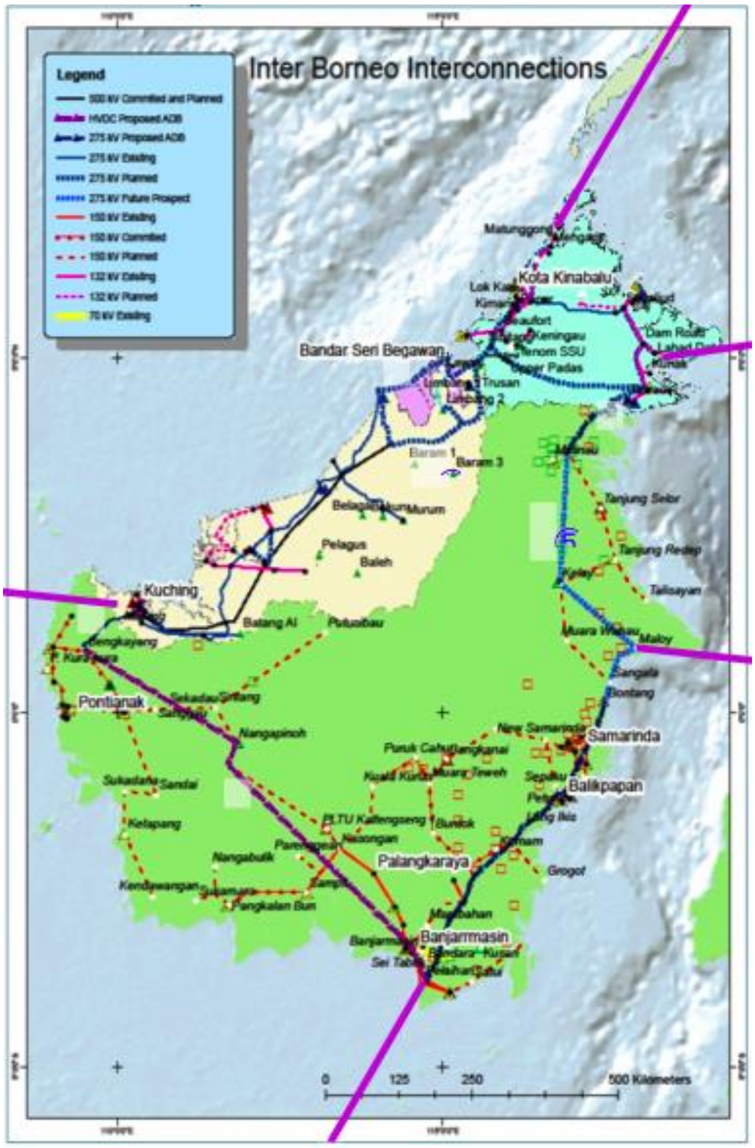


Table 1.2-1. Details of Interconnection Plans

		Year	Capacity (MW)	Length (km)	Total cost ($/kW)
(1)	Sarawak–Kalbar	2015	300	83	209
(2)	Sarawak–Brunei–Sabah	2016	300	265	363
(3)	Kalbar–Kalteng	2018	300	860	830
(4)	Kaltim–Kalut	2018	600	550	454
(5)	Kalut–Sabah	2020	600	150	132
(6)	Sarawak–P. Malaysia	2020	2,000	1,200	1,129
(7)	Kalsel–N. Sulawesi	2025	300	235	875
(8)	Sabah–Mindanao	2025	600	412	899
(9)	Kalsel–Java	2025	2,000	470	520
(10)	Sarawak–Sabah	2025	300	300	626
(11)	Sabah–Luzon	2030	2,000	950	521

km = kilometre, kW = kilowatt, MW = megawatt.

Source: Asian Development Bank.

2.6 Setting the Cases for Calculation

Using the Optimal Power Generation Planning Model and the Supply Reliability Evaluation Model, the optimal power generation mix and power exchange through 2035 were calculated. Calculations were done up to 2050 to avoid boundary effects, extrapolating the assumptions properly. However, as the introduction of renewable energies, except hydropower and nuclear power, depends mainly on policies, the introduced amount of these power sources was fixed on the basis of the values presented by ERIA and only thermal power generation (coal, natural gas, and oil) and hydropower were used as the object of analysis. Of these, the introduced amount of hydropower in Case 0 and Case 1 was fixed at the amount indicated by ERIA, while in other cases, the introduction potential was used as the potential for additional hydropower.

When the Optimal Power Generation Planning Model was used, the time interval was set at five years, with the values for 2010 as the latest historical values, and those for 2015 and subsequent years as predicted values. The discount rate was set uniformly at 5 percent so that the result of the calculation would roughly match the values presented by ERIA.

Most ASEAN countries assume large power capacity margins in power source development plans to keep to a low level the probability of blackouts. For example, in response to an increase in the power demand for the Java–Bali power system, PLN (2015) formulated a power development plan to ensure a capacity margin of 32 percent in 2024. In this study, this value was referred to and the parameters of the Supply Reliability Evaluation Model adjusted so that the loss of load expectation for the Java–Bali system would provisionally be 24 hours/year under the condition of the 32-percent power capacity margin in 2035, the target year of calculation, and were used in the calculation for all regions. The number of trials in the Supply Reliability Evaluation Model using the Monte Carlo method was set to around 140,000. As the regions with particularly small demand can receive power supply in an emergency through the interconnected line if it exists, the loss of load expectation of 24 hours/year can be achieved with a very small power capacity margin. Actually, however, for security reasons, at least a certain extent of the capacity margin would be sought even if lower loss of load expectation could be achieved with interconnections. Therefore, the minimum value of the capacity margin was set at 15 percent in this study.

Case settings are shown in Table 1.2-2.

Table 1.2-2. Case Settings

Case name	Description
Case 0	Without grid interconnection
Case 1	Grid interconnection without additional hydro potential
Case 2	Grid interconnection only in the BIMP region, with additional hydro potential
Case 3	Grid interconnection with additional hydro potential
Case 4	Grid interconnection with double capacity, with additional hydro potential

Case 0 is a BAU (Business as usual) case without considering interconnection, where each country maintains the demand-supply balance by means of domestic power generation equipment. In contrast, Case 1 makes the interconnected capacity available up to the level shown in Table 1.2-1. The current interconnection expansion plan (Table 2-1) does not assume any construction of interconnection lines between Central Kalimantan and South Kalimantan, and between South Kalimantan and East Kalimantan. However, interconnection lines are actually aimed to be constructed throughout the whole of Borneo. Therefore, it was assumed that interconnection lines would be constructed between Central Kalimantan and South Kalimantan, and, in the same manner, between South Kalimantan and East Kalimantan, and the capacities and the unit construction costs would be similar to those of the interconnection line between West Kalimantan and Central Kalimantan as shown in Table 1.2-1 (3).

In Case 2 and subsequent cases, in addition to interconnection lines, it was assumed that the potential for hydropower (Section 2-4) would be available. While interconnection lines only in the BIMP region (Borneo and Mindanao) in Case 2 were assumed, interconnection lines for Peninsular Malaysia, Java–Bali, and Luzon were likewise assumed in Case 3. In Case 4, it was assumed that the interconnection capacity would be expanded up to double that of Case 2.

Meanwhile, the maximum limit of coal-fired thermal power capacities in Brunei and Sabah was set to zero because no coal-fired thermal power had ever been introduced in these regions before, nor is there any plan for such.

Table 1.2-3. Costs of Power Generation Plants

Type	Capacity, MW	Thermal Efficiency, %	Initial Cost, US$/kW
Coal 1	< 20	25	2,000
Coal 2	20 – 100	32	2,000
Coal 3	100 – 250	35	1,500
Coal 4	250 <	40	1,500
Natural gas			870
Oil			1,340
Hydro			1,200–1,500

Kw = kilowatt, MW = megawatt.
Source: Authors.

In each of these cases, Kutani et al. (2014) and ADB (2014) were referred to for the construction costs and operation and maintenance costs of power generation plants, and assumptions were made as shown in Table 1.2-3. As mentioned, if the scale of a power system is expanded through interconnection, it will be possible to construct larger-scale and, therefore, more efficient power plants. In this study, the four types of coal-fired power generation (Table 2-3) were assumed and where it was postulated that the type of the plants would differ depending on the scale of the power system.

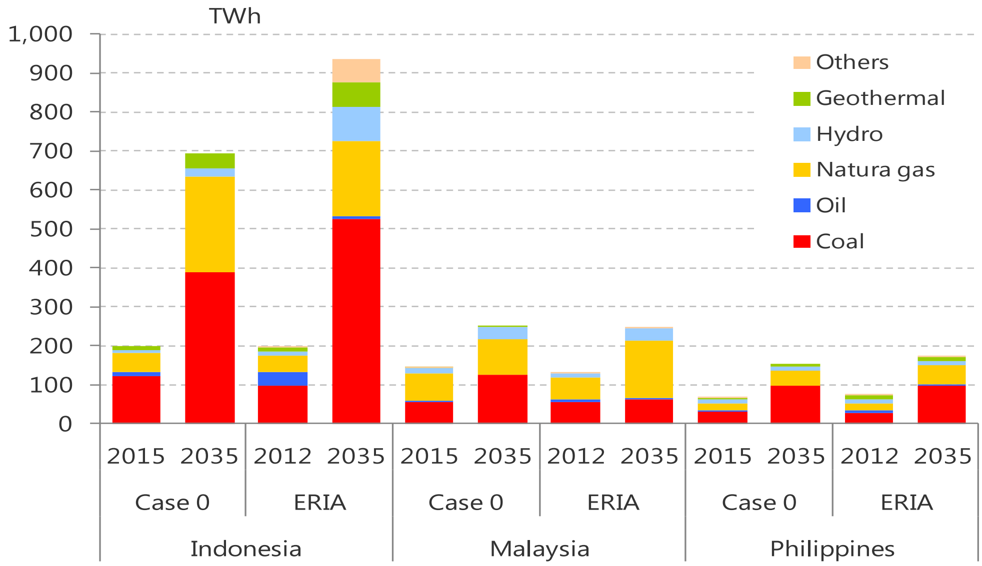
3. Results and Discussions

3.1 Composition of Power Sources in 2035

Figure 1.3-1 shows the power generation mix in Case 0 in 2035 as compared with the ERIA outlook. It should be noted that the result of Case 0 only includes Kalimantan, Java–Bali, and North Sulawesi for Indonesia, and Luzon and Mindanao for the Philippines, while the ERIA outlook includes the entire countries. Thus, in Indonesia, for example, the power generation amount for 2035 is 693 TWh, which is smaller than the 936 TWh projected by ERIA. Reflecting the fact that the share of renewables is larger in Sumatra Island, which is not included in the calculations, electricity output in Case 0 is smaller than ERIA's for hydropower, geothermal, and 'others', including biomass. In Indonesia, however, the result of Case 0 matches that of ERIA's in that thermal power generation will continue to have a large share up to 2035, and that coal-fired thermal power generation has a higher share than natural gas-fired one.

In Malaysia, on the other hand, while the share of coal-fired thermal power generation was similarly higher in the optimised calculation result for Case 0, the share of natural gas-fired in the ERIA outlook increases rapidly up to 2035. According to the Malaysia Energy Committee's outlook (Figure 1.1-5), at least until 2024, coal-fired thermal power is assumed to keep its large share in Peninsular Malaysia, accounting for the largest part of the energy consumption in Malaysia, which is nearer to the result for Case 0. In contrast, the ERIA outlook focuses more on environmental protection, which would have resulted in higher share of natural gas-fired.

Figure 1.3-1. Comparison between the ERIA Outlook and Case 0



ERIA = Economic Research Institute for ASEAN and East Asia, TWh = terawatt-hour.

Source: Authors.

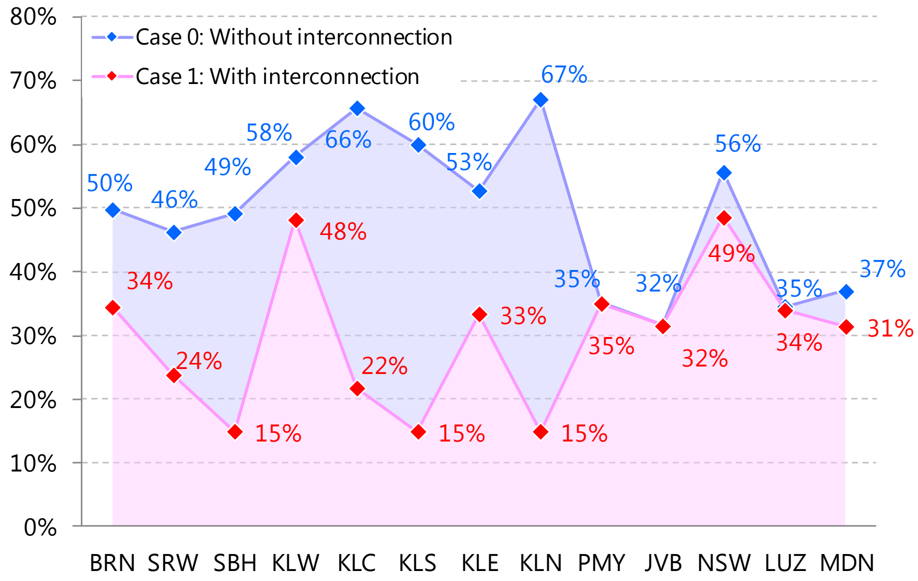
3.2 Effects on Power Capacity Margin Saving

Figure 1.3-2 shows the power capacity margin in Case 0 and Case 1. In Case 0, the parameters were adjusted so Java–Bali's margin would be 32 percent. In general, the capacity margin required to achieve the same loss of load expectation (24 hours/year) is smaller in major consuming regions such as Peninsular Malaysia and Luzon, and larger in small-demand regions such as North Kalimantan and Central Kalimantan. This is because the scale of power plants is relatively larger in comparison with the demand level in small-demand regions and, therefore, even a single trouble can easily lead to blackouts.

In contrast, in Case 1, where interconnection is assumed, the capacity margin does not really change in larger demand regions such as Java–Bali and Peninsular Malaysia, while it becomes considerably smaller in smaller demand regions. This is because when trouble occurs in a power plant of a smaller demand region, the demand can easily be met by power trade from surrounding regions. Among the states of Kalimantan, the reduction of capacity margin is small in West Kalimantan and East Kalimantan, which have a relatively large power demand. It is especially small in West Kalimantan, which is connected with the adjacent regions with small capacity interconnection lines of 0.3 GW. On the other hand, in North Kalimantan and South

Kalimantan, the capacity margin is reduced to the assumed minimum level of 15 percent.

Figure 1.3-2. Results of the Calculation of Power Capacity Margin (Case 0 and Case 1)

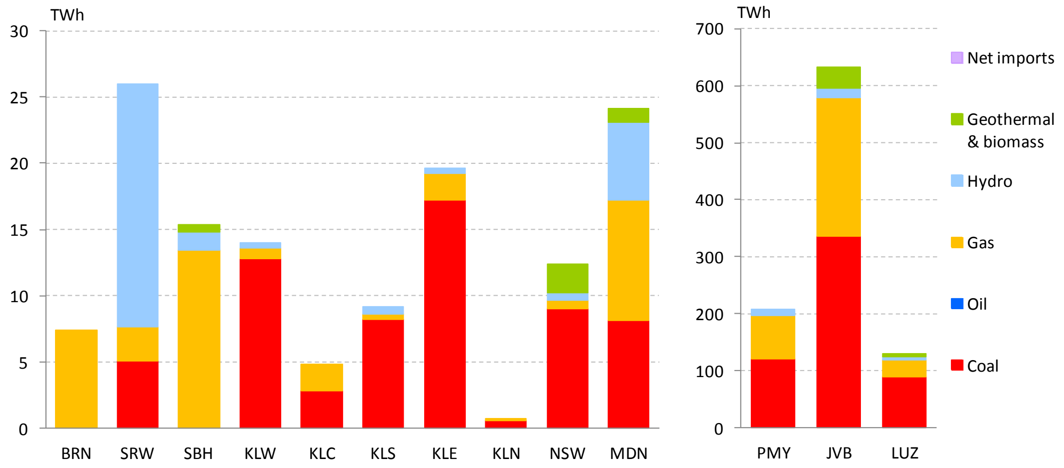


BRN = Brunei Darussalam, JVB = Java–Bali, KLC = Kalteng, KLE = Kaltim, KLN = Kalut, KLW = Kalbar, KLS = Kalsel, LUZ = Luzon, MDN = Mindanao, NSW = North Sulawesi, PMY = Peninsular Malaysia, SBH = Sabah, SRW = Sarawak.
Source: Authors.

3.3 Power Generation Mix and Trade in 2035

Figures 1.3-3 to 1.3-7 show the result of calculating the regional power generation mix in 2035. As shown in Figure 1.3-3, no trade of electricity takes place in Case 0. Coal-fired thermal power generation accounts for large shares in most regions. However, in Brunei and Sabah, where no coal-fired thermal power generation is assumed to be used, electricity is supplied mainly by natural gas-fired thermal power generation.

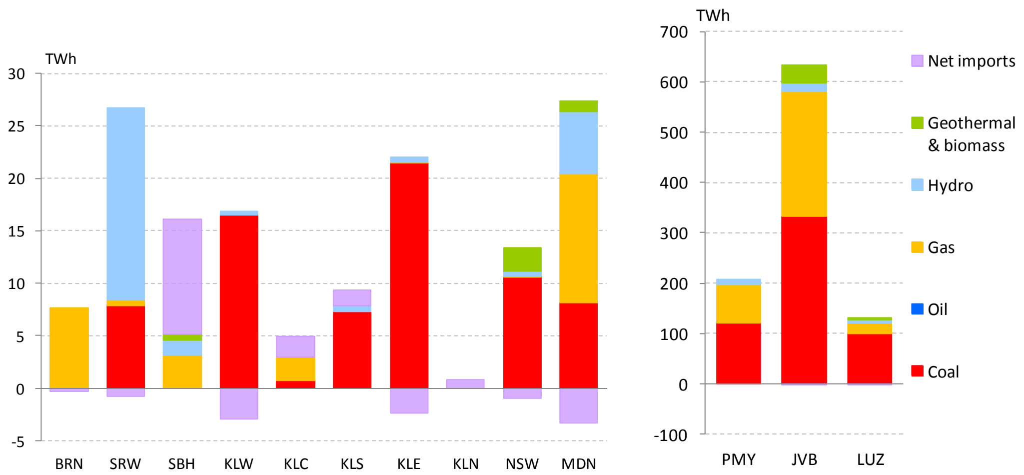
Figure 1.3-3. Power Generation Mix in 2035 (Case 0)



BRN = Brunei Darussalam, JVB = Java-Bali, KLC = Kalteng, KLE = Kaltim, KLN = Kalut, KLW = Kalbar, KLS = Kalsel, LUZ = Luzon, MDN = Mindanao, NSW = North Sulawesi, PMY = Peninsular Malaysia, SBH = Sabah, SRW = Sarawak, TWh= terawatt-hour.
Source: Authors.

Figures 1.3-4 and 1.3-5 show the power generation mix and electricity trades in 2035, assuming grid interconnection. Electricity imports from other regions become more optimal in regions such as Sabah that depend on natural gas-fired rather than coal-fired thermal power generation and regions such as North Kalimantan that depend on inefficient coal-fired thermal power generation. The region that will import the largest amount of electricity in this case is Sabah, which is assumed to be importing electricity from Luzon, Mindanao, and Sarawak.

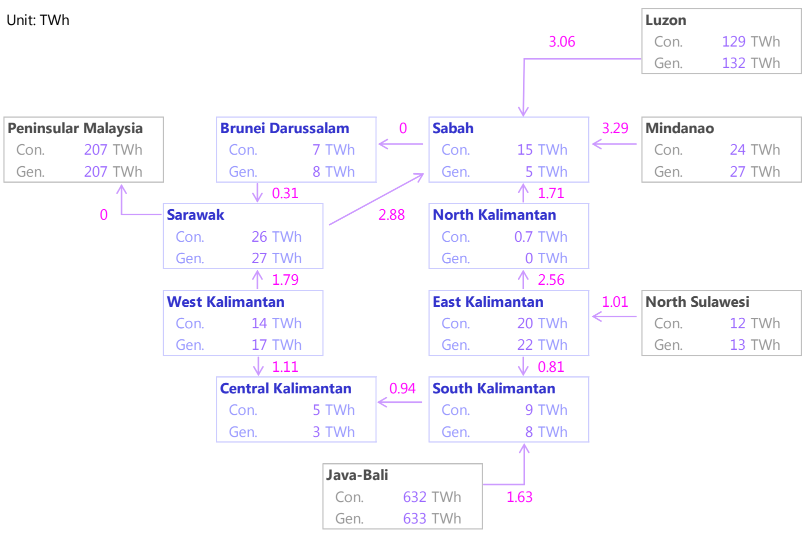
Figure 1.3-4. Power Generation Mix in 2035 (Case 1)



BRN = Brunei Darussalam, JVB = Java-Bali, KLC = Kalteng, KLE = Kaltim, KLN = Kalut, KLW = Kalbar, KLS = Kalsel, LUZ = Luzon, MDN = Mindanao, NSW = North Sulawesi, PMY = Peninsular Malaysia, SBH = Sabah, SRW = Sarawak, TWh = terawatt-hour.

Source: Authors.

Figure 1.3-5. Electricity Trade Flows in 2035 (Case 1)

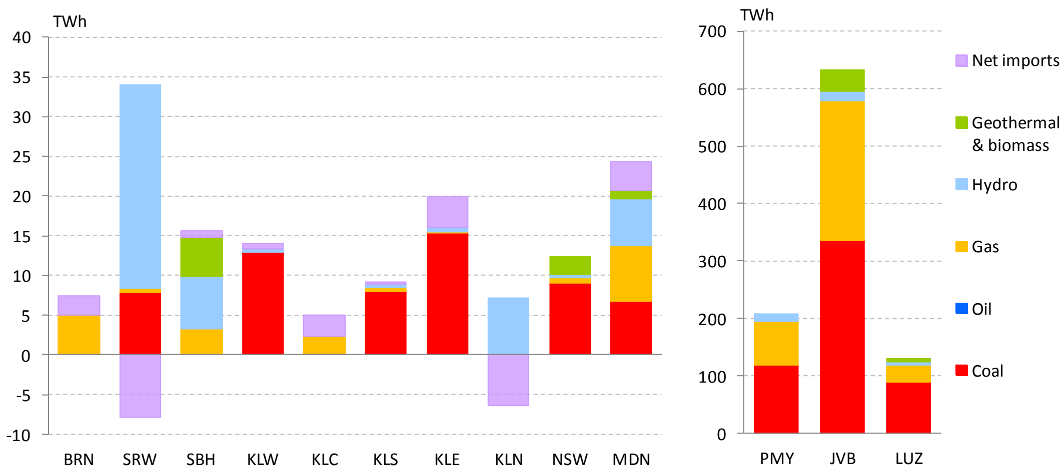


TWh = terawatt-hour.

Source: Authors.

Figures 1.3-6 and 1.3-7 show the result of Case 2, which assumes grid interconnection only in the BIMP region. In this case, electricity is imported from Sarawak and North Kalimantan, which have the potential for exporting hydropower to Brunei, East Kalimantan, and Mindanao. As Peninsular Malaysia, Java/Bali, and Luzon are not interconnected in this case, no electricity is exported to these regions.

Figure 1.3-6. Power Generation Mix in 2035 (Case 2)



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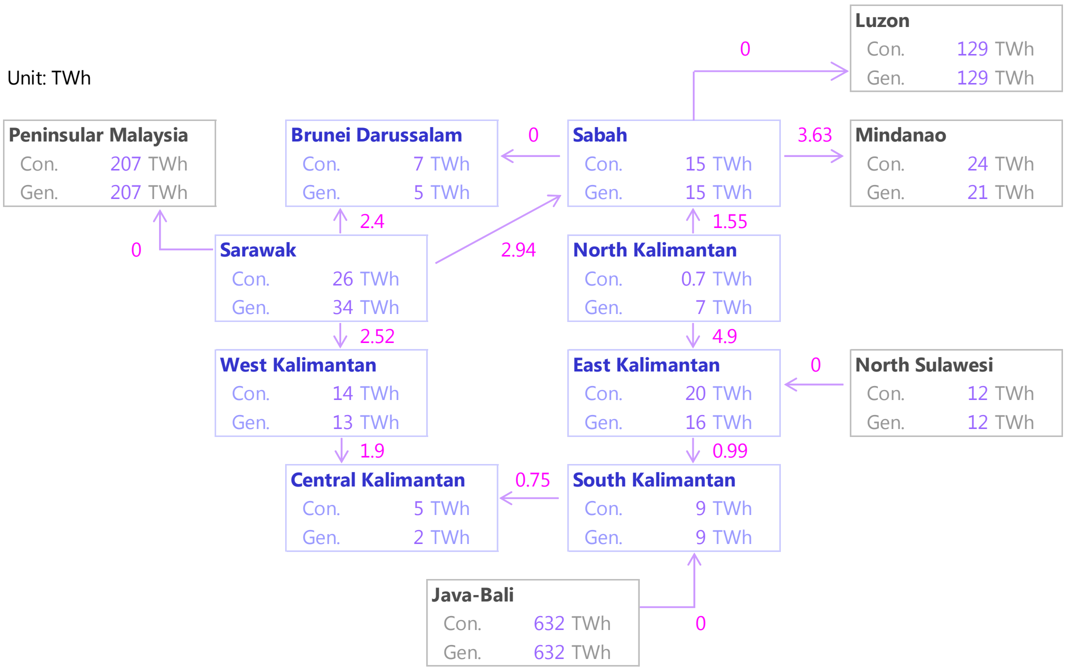
Source: Authors.

Figures 1.3-8 and 1.3-9 show the result of Case 3, which assumes grid interconnections in all regions. In this case, electricity is exported from Sarawak to Peninsular Malaysia and from Sabah to Luzon. The largest trade takes place from Sarawak to Peninsular Malaysia at 14 TWh/year. Hydropower generation in Sarawak is to be expanded from 26 TWh in Case 2 to 41 TWh in Case 3.

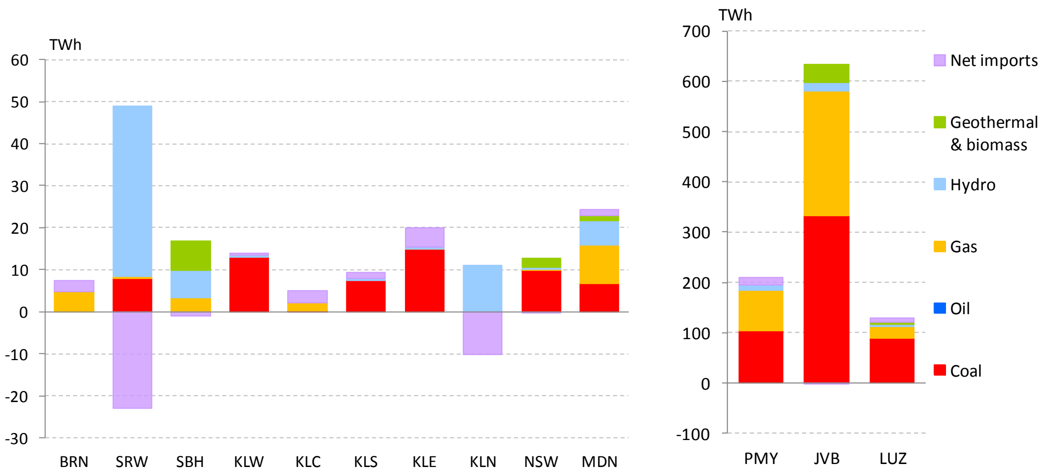
Figure 1.3-7. Electricity Trade Flows in 2035 (Case 2)



TWh = terawatt-hour.

Source: Authors.

Figure 1.3-8. Power Generation Mix in 2035 (Case 3)



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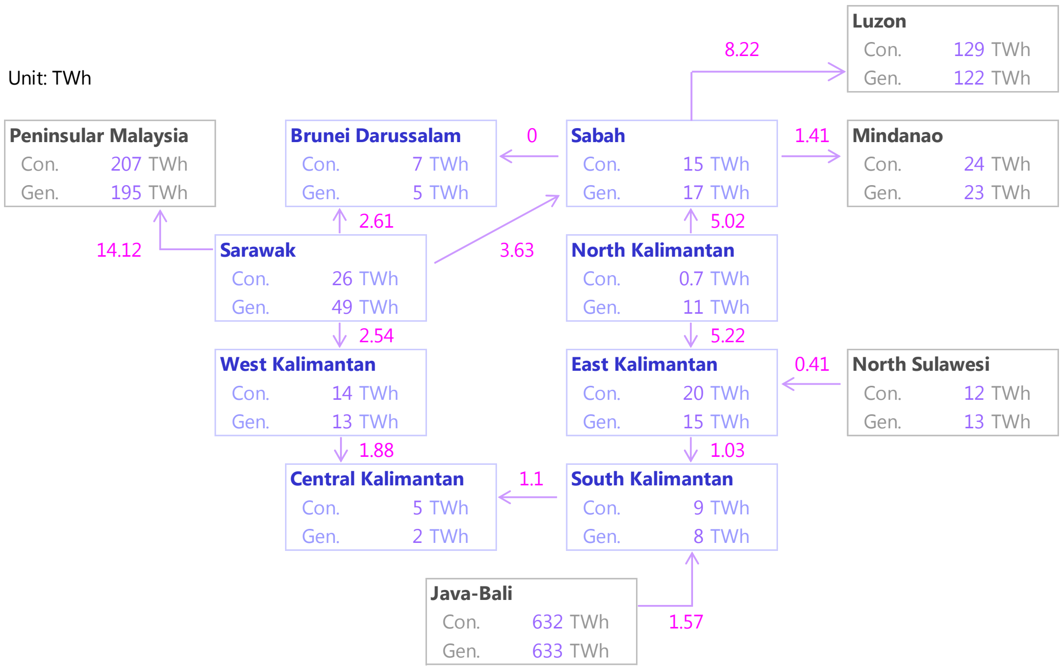
Source: Authors.

Figure 1.3-9. Electricity Trade Flows in 2035 (Case 3)

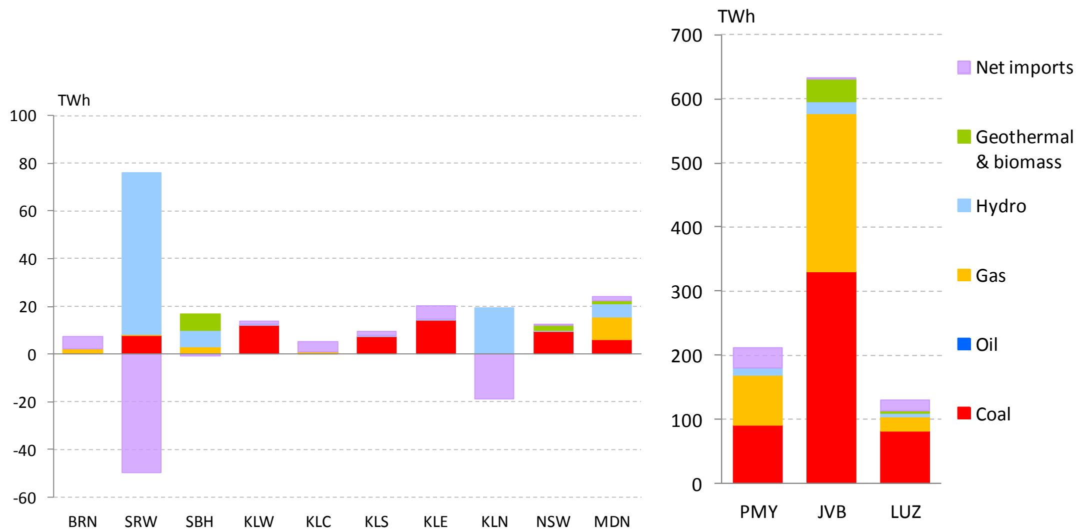


TWh = terawatt-hour.

Source: Authors.

Figures 1.3-10 and 1.3-11 show the result of Case 4, where the capacity of interconnection is set to double that for Case 3. In this case, electricity trade from Sarawak to Peninsular Malaysia is 31 TWh per year, and hydropower generation in Sarawak reaches 68 TWh. Thus, Borneo has a considerably large potential for hydropower especially in Sarawak, and could produce large benefits to enhance interconnection beyond the existing plans.

Figure 1.3-10. Power Generation Mix in 2035 (Case 4)



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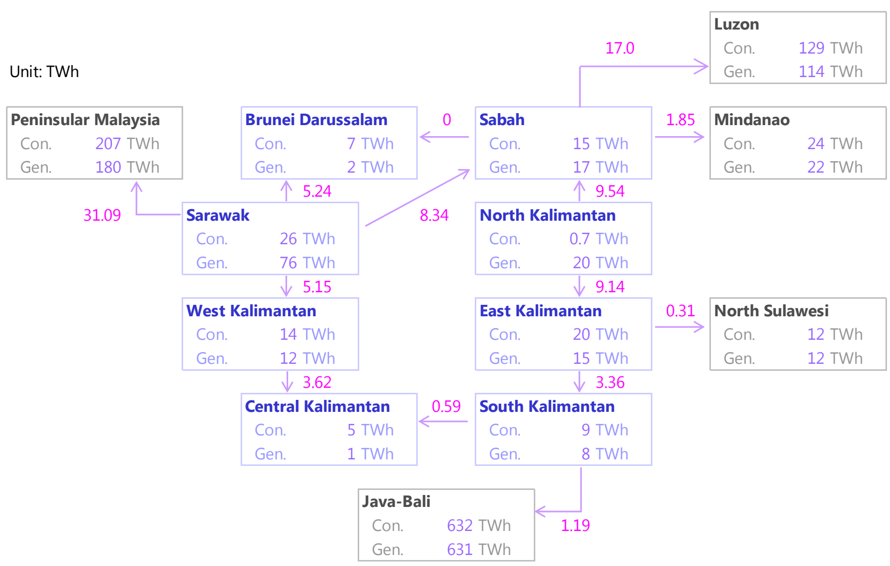
Source: Authors.

Figure 1.3-11. Electricity Trade Flows in 2035 (Case 4)

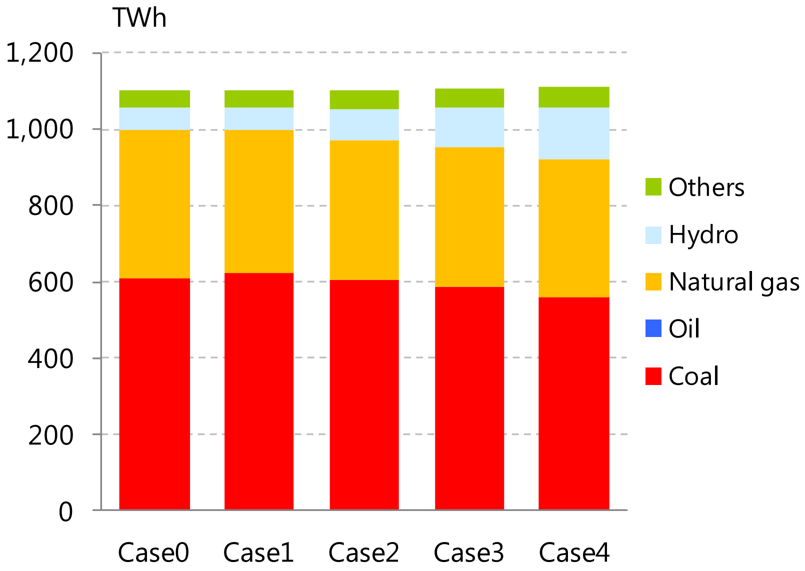


TWh = terawatt-hour.
Source: Authors.

3.4 Composition of Power Sources, CO_2 Emissions, and Cumulative Investments

Figure 1.3-12 summarises the electricity mix in 2035 in all regions for Cases 0 to 4. In Case 0, the share of oil-fired, natural gas-fired, and hydropower in the entire power supply is 55 percent, 35 percent, and 6 percent, respectively, and the total thermal power accounts for 90 percent. In contrast, in Cases 2, 3, and 4, the share of hydropower in 2035 increases up to 7 percent, 9 percent, and 12 percent, respectively. In Case 4, however, even with the share of thermal power generation as high as 83 percent, the regions still continue to depend on thermal power.

Figure 1.3-12. Power Generation Mix in 2035 (Total of All Regions)

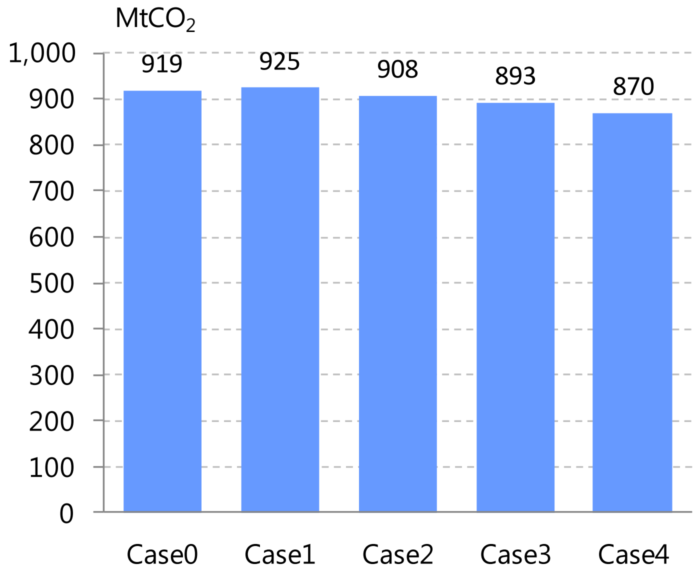


TWh = terawatt-hour.

Source: Authors.

CO_2 emissions from the power generation sector increases from 919 metric tonnes in Case 0 to 925 metric tonnes in Case 1. This is because higher cost natural gas-fired thermal power is substituted by coal-fired thermal power through grid interconnection. In Cases 2, 3, and 4, in line with the increase of hydropower, CO_2 emissions declined by 1.3 percent, 2.9 percent, and 5.3 percent, respectively, compared with those of Case 0.

Figure 1.3-13. CO_2 Emissions in 2035

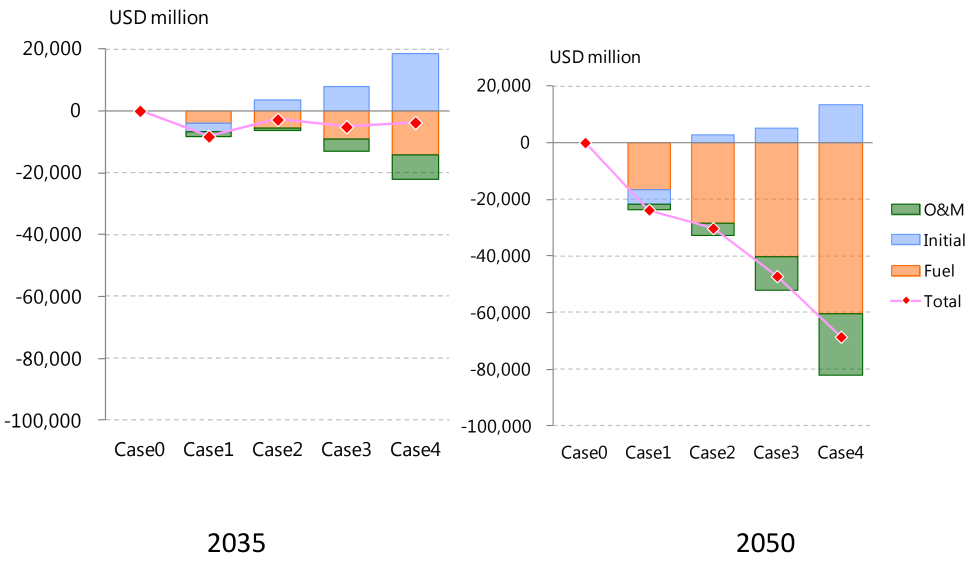


Source: Authors.

Figure 1.3-14 shows the cumulative costs up till 2035 and 2050, which include the increased investments on power generation plants and interconnection lines as the 'initial investment', the reduced fuel costs due to the decrease in thermal power generation as the 'fuel cost', and the reduced operation/maintenance costs as the 'O&M cost'.

In Case 1, the total cost is considerably reduced compared with Case 0, due to decrease in the power capacity margins. On the other hand, when we look at the time period up to 2035 in Cases 2 to 4, as the increased amount of the initial investment cannot be recovered by a decrease in fuels, the reduction in the cumulative total cost is smaller than in Case 1. From a long-term viewpoint through 2050, however, the contribution of the reduction in fossil fuels becomes larger. In particular, the reduction from Case 2 to Case 3 is larger than that from Case 1 to Case 2, which indicates that by expanding interconnection lines not only in the BIMP region but also in the surrounding demand areas, the regional hydropower resource can be utilised more efficiently and a remarkable economic effect could be expected.

Figure 1.3-14. Cumulative Costs up to 2035 and 2050



O&M = operation and maintenance.

Source: Authors.

Table 1.3-1. Cumulative Costs up to 2035 and 2050

Unit: USD million

		Case0	Case1	Case2	Case3	Case4
2030	Decrease in fuel costs	0	3,829	5,495	9,043	14,078
	Decrease in O&M costs	0	1,468	899	3,979	7,985
	Increase in initial costs	0	-2,983	3,599	7,889	18,303
	Total benefits	0	8,280	2,795	5,134	3,760
2050	Decrease in fuel costs	0	16,496	28,326	40,142	60,403
	Decrease in O&M costs	0	1,999	4,390	12,137	21,555
	Increase in initial costs	0	-5,283	2,513	5,129	13,386
	Total benefits	0	23,778	30,203	47,150	68,572

O&M = operation and maintenance.

Source: Authors.

4. Conclusions and the Way Forward

In this study, the benefits of expanding grid interconnection lines in the south ASEAN region and the BIMP region was evaluated by carrying out a simulation with the Optimal Power Generation Planning Model and the Supply Reliability Evaluation Model on the basis of the current expansion plan of grid interconnection. Through the efficient use of the hydropower resources present in Borneo with the expansion of regional interconnection lines, it is possible to reduce fossil fuel consumption, CO_2 emissions, and the costs of power source development. These effects can be expected to a certain extent by expanding the interconnection lines within the BIMP region alone. But even more remarkable effects may be expected by further interconnecting with the large energy-consuming areas like Peninsular Malaysia and Luzon. However, any significant cost reduction can be achieved only from a long-term point of view and within a time frame up to 2050. For this reason, long-term plans by the government of host country and international financial institutions and their steady implementation are indispensable.

The expected effects of interconnection estimated in this study are: efficient use of hydropower resources, reduction of power capacity margin through power interchange in an emergency, and enhancement of coal-fired thermal power generation efficiency by expanding the grids. Evaluating these effects will be relevant when assuming mainly a considerable expansion of hydropower and biomass among renewable energy sources. It must also be noted, however, that the cost of solar power generation has been decreasing recently and its use is aimed to be significantly increased in ASEAN countries in the future. Generally speaking, although there is a limit to increased use of solar power generation that cannot control the output, the contribution of power interchange through interconnection could go over the limit. Further examination of this effect is planned in the future.

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