# Study on ASEAN Power Grid

# Final Report

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Japan International Cooperation Agency (JICA)

The Institute of Energy Economics, Japan (IEEJ)


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# Contents

Abbribiations

| | |
|---|---|
| ASEAN | Association of Southeast Asian Nations |
| AIMS | ASEAN Interconnection Masterplan Study |
| AMEM | ASEAN Ministers on Energy Meeting |
| APAEC | ASEAN Plan of Action for Energy Cooperation |
| APG | ASEAN Power Grid |
| RE | Renewable Energy |
| F/S | Feasibility Study |
| CN | Carbon Neutrality |
| DPs | Development Partners |
| HVDC | High-voltage Direct Current |
| HVAC | High-voltage Alternating Current |
| FIRR | Financial Internal Rate of Return |
| COD | Commercial Operation Date |
| AMS | ASEAN Member States |
| COP | Conference of the Parties |
| EV | Electric Vehicle |
| PDP | Power Development Plan |
| BAU | Business as Usual |
| FOLU | Forestry and Other Land Use |
| NDC | Nationally Determined Contribution |
| LPG | Liquefied Petroleum Gas |
| AP | Alternative Policy |
| SAIDI | System Average Interruption Duration Index |
| SAIFI | System Average Interruption Frequency Index |
| IPP | Independent Power Producer |

# Summary

1. Background and Objective

The ASEAN region is struggling to balance the need to meet growing electricity demand with the need to decarbonize. Under these circumstances, the region's unevenly distributed hydro and wind power potential must be maximized to meet the region's energy security and climate goals. In order to connect the unevenly distributed renewable energy to large demand areas, it is necessary to develop and strengthen electricity grids. Meantime, the ASEAN Energy Centre (hereinafter referred to as "ACE"), which formulates energy strategies in collaboration with relevant ministries and agencies of ASEAN member states and the ASEAN Secretariat, has updated the ASEAN Interconnection Masterplan Study (AIMS) III in 2022, which conducted technical studies on power interconnection. In light of this situation, this project will conduct a basic information collection and confirmation study on the ASEAN Power Grid Programme to examine support approach to the programme. The survey will target 10 ASEAN member countries and 18 power line projects identified by ASEAN.

2. Status of ASEAN Interconnection Lines

The first discussion on cross-border energy trade within the ASEAN region took place during the “Conference on the ASEAN Energy Cooperation Agreement” held in Manila in 1986 and emphasized the importance of cooperation between ASEAN member countries to develop energy resources and improve ASEAN's economic integration.

At the 2nd ASEAN Informal Summit in 1997, the “ASEAN Vision 2020” was adopted, and the first action plan for its realization was adopted at the 6th ASEAN Official Summit in 1998 as the “Hanoi Plan of Action” (a six-year plan from 1999 to 2004). Among these, it was also stated that an electricity interconnection system within ASEAN would be established through the ASEAN Power Grid (hereafter, APG). This was the first time that the APG was clearly stated.

At the 17th ASEAN Ministers on Energy Meeting (AMEM) held in 1999, it was decided to accelerate the implementation of the energy action plan based on the “Hanoi Plan of Action”, and the ASEAN Plan of Action for Energy Cooperation (APAEC) (1999-2004), in which all 10 Southeast Asian countries participated as a region for the first time, was adopted. Subsequently, the APAEC was adopted for the periods 2004-2009, 2010-2015, 2016-2025 Phase I (2016-2020). The ultimate goal of these plans was to formulate a “Master Plan for Interconnection” to achieve the goals outlined in the ASEAN Vision 2020.

The APAEC Phase II (2021-2025), adopted at the 38th AMEM in 2020, sets ambitious goals and initiatives to improve sustainability and supports the United Nations Sustainable Development Goals (SDGs)7. The theme has been maintained from Phase I (2016-2020), “Enhancing energy connectivity and market integration in ASEAN to achieve energy security, accessibility, affordability and sustainability for all” and the sub-theme "Accelerating Energy Transition and Strengthening Energy Resilience through Greater Innovation and Cooperation" has been added.

The ASEAN Interconnection Masterplan Study (AIMS) is a study of an interconnection masterplan for the APG and was first proposed at the 17th AMEM held in Bangkok, Thailand in 1999. At the 21st AMEM held in Langkawi, Malaysia in 2003, the final report of AIMS (AIMS-I) was agreed upon as a guideline for the implementation of power interconnection projects. Due to the rapid development of ASEAN, a second survey, AIMS-II, was required and was conducted in 2010. The main objective of AIMS II was to promote a more efficient, economical and safe power system through the coordinated development of the power grids of each country in the region as a whole, by planning the APG through the interconnection of AMS.

The strategy formulated based on these studies was to first encourage participation between two countries across national borders, then gradually expand to a sub-regional basis (north, south, east), and finally move to a fully integrated APG system. The AIMS-III project was designed to explore the feasibility of multilateral power trading in the ASEAN region, with the aim of strengthening the resilience and modernization of power grids, achieving affordable and resilient power supply, and increasing the share of renewable energy (RE) in power grids to 23% by 2025. This was also a concrete response to the request made at the 35th AMEM in 2017. AIMS-III is composed of three phases, and the first two phases of AIMS-III will develop plans for cross-border transmission infrastructure necessary to support multilateral power trade among ASEAN member states (AMS) and renewable energy (RE) integration in the APG, while Phase 3 will further develop minimum requirements, regulatory frameworks, grid codes and technical standards for multilateral market development.

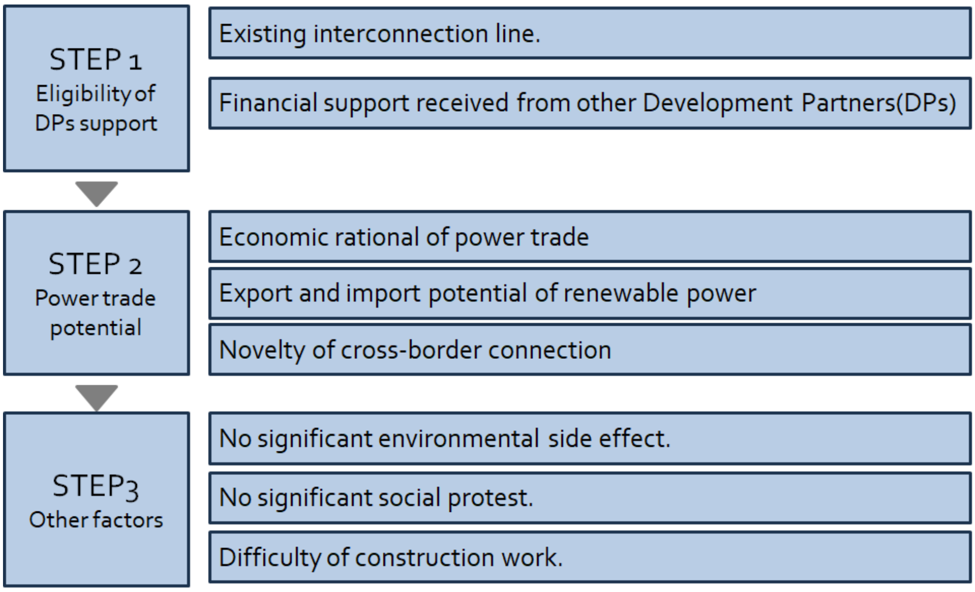
3. Assessment of Cross Border Interconnection Projects with high development priority and Financial Analysis

ASEAN member states (AMS) have set ambitious targets for carbon neutrality (CN). Meanwhile, the region is experiencing robust electricity demand, much of which is being met by fossil power generation. To achieve CN, the region needs to maximize its renewable energy potentials. To this end, cross-border power lines, the ASEAN Power Grid (APG), need to be strengthened to connect the untaped renewable energy resources to demand center. Under these circumstances, this study aims to examine possible approaches by the Development Partners, including JICA, to support the APG, thereby CN targets of the region and high development priority interconnection lines are selected.

(1) Assessment of Cross Border Interconnection Projects with high development priority.

This study selected high development priority interconnection lines from the 18 projects proposed in AIMS III that would be most meaningful for Development partner(DPs) support, including JICA.. In selecting the high development priority lines, this study set evaluation criteria and evaluated them in a step-by-step process

- Step 1, Step 2, and Step 3. This study aimed to evaluate the projects fairly based on publicly available information, rather than considering individual circumstances.




Source: JICA Study Team

**Figure 1 Assessment n Criteria**

The evaluation results for Steps 1 to 3 are shown in Table 1. The top development priority is the No. 7) Sarawak-Brunei route. The main reasons are that Brunei has very low renewable energy potential compared to its peak demand, and Brunei's electricity generation costs are much higher than Sarawak's, making this an attractive opportunity. Additionally, this would be the first interconnection between the two, giving it high novelty. In Step 3, the environmental and social impacts of the lines were not found to be significant issues. The construction complexity of building an overhead transmission line across Borneo was also not considered a major concern. The second development priority is the No. 16) Singapore-Sumatra, Singapore-Batam lines. This is because Indonesia has very high renewable energy potential for export, while Singapore has low domestic renewable resources and high import needs. As with the Sarawak-Brunei line, this would be the first interconnection between the countries, giving it high novelty. However, the Step 3 evaluation found that the subsea cable routing through the Malacca and Singapore Straits would pose significant construction challenges, offsetting the other positive factors. The third development priority is the No. 6) Philippines (Palawan)-Sabah line. This is driven by the Philippines' low renewable potential relative to its peak demand, creating high import needs, as well as the novelty of the first interconnection. But the Step 3 analysis flagged the challenges of the long subsea cable required between Sabah and Palawan.

**Table 1 Results of the High Development Priority Lines:**

| | Countries | Income Class | STEP1 | | STEP2 | | | | | STEP3 | | | Priority |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| # | | | Existing | DPs | Econo. | RE exp. | RE imp. | Nov. | Total | Env. | Social | Const. | |
| 1 | Peninsula Malaysia- Singapore | Upper Middle and Uppermost-Middle | No | No | 2 | 2 | 3 | 2 | 9 | + | + | - | |
| 2 | Thailand - Peninsula Malaysia (Su Ngai Kolok - Rantau Panjang) | Upper Middle and Uppermost-Middle | No | No | 1 | 2 | 1 | 1 | 5 | + | + | + | |
| | Thailand - Peninsula Malaysia (Khlong Ngae - Gurun 2nd Phase) | Upper Middle and Uppermost-Middle | No | No | 1 | 2 | 1 | 1 | 5 | + | + | + | |
| 3 | Internal Malaysia (Sarawak - Peninsula Malaysia) | Upper Middle and Uppermost-Middle | No | No | 2 | 1 | 3 | 3 | 9 | + | + | - | |
| 4 | Peninsula Malaysia - Sumatra | Upper Middle and Uppermost-Middle | No | Yes | 1 | 2 | 1 | 3 | 7 | + | + | - | |
| 5 | Sarawak - Kalimantan | Upper Middle and Uppermost-Middle | Yes | No | | | | | | | | | |
| 6 | Philippines - Sabah (Malaysia) | Lower-Middle – Upper Middle and Uppermost-Middle | No | No | 2 | 2 | 3 | 3 | 10 | + | + | - | 3rd |
| 7 | Sarawak (Malaysia) - Brunei Darussalam | Upper Middle and Uppermost-Middle | No | No | 3 | 2 | 3 | 3 | 11 | + | + | + | 1st |
| 8 | Sarawak (Malaysia) - Sabah (Malaysia) | Upper Middle and Uppermost-Middle | Yes | No | | | | | | | | | |
| 9 | Thailand - Lao PDR | Upper Middle and Uppermost-Middle - Lower-Middle | No | No | 2 | 2 | 1 | 1 | 6 | + | + | + | |
| 10 | Lao PDR - Vietnam (Nam Ou - Dien Bien) | LDC or Low - Lower-Middle | No | No | 2 | 2 | 2 | 1 | 7 | + | + | + | |
| | Lao PDR - Vietnam (Luang Prabang - Nho Quan) | LDC or Low - Lower-Middle | No | No | 2 | 2 | 2 | 1 | 7 | + | + | + | |
| 11 | Thailand - Myanmar | Upper Middle and Uppermost-Middle -LDC or Low | Yes | No | | | | | | | | | |
| 12 | Vietnam – Cambodia | Lower-Middle- LDC or Low | No | No | 1 | 3 | 2 | 2 | 8 | + | + | + | |
| 13 | Lao PDR – Cambodia (Ban Hat - Kampong Sralao) | LDC or Low | No | No | 2 | 2 | 2 | 2 | 8 | + | + | + | |
| | Lao PDR - Cambodia (Ban Hat - Preah Vihear ) | LDC or Low | No | No | 2 | 2 | 2 | 2 | 8 | - | + | - | |
| 14 | Thailand – Cambodia | Upper Middle and Uppermost-Middle - LDC or Low | No | No | 1 | 3 | 1 | 2 | 7 | + | + | - | |
| 15 | East Sabah (Malaysia) - North Kalimantan (Indonesia) | Upper Middle and Uppermost-Middle | No | Yes | 1 | 2 | 1 | 3 | 7 | + | + | - | |
| 16 | Singapore - Indonesia (Singapore- Sumatra) | Upper Middle and Uppermost-Middle | No | No | 2 | 3 | 3 | 3 | 11 | + | + | - | 2nd |
| | Singapore - Indonesia (Singapore – Batam) | Upper Middle and Uppermost-Middle | No | No | 2 | 3 | 3 | 3 | 11 | + | + | - | 2nd |
| 17 | Lao PDR - Myanmar | LDC or Low | Yes | No | | | | | | | | | |
| 18 | Internal Indonesia (Kalimantan-Java) | Upper Middle and Uppermost-Middle | No | No | 1 | 2 | 2 | 3 | 8 | + | + | - | |
| | Internal Indonesia (Sumatra-Java) | Upper Middle and Uppermost-Middle | No | No | 2 | 2 | 2 | 3 | 9 | + | + | - | |

Source: JICA Study Team

## (2) Assumptions of Financial Analysis

Based on these evaluations, financial analysis will proceed for thehigh development priority lines: No. 7) Sarawak-Brunei, No. 16) Singapore-Sumatra/Batam, and No. 6) Philippines-Sabah. The assumptions for the priority routes are as shown in Table 2. All transmission lines are double-circuit lines due to avoid the risk of accidents.

**Table 2 Assumptions for High Development Priority Routes**

| | Voltage (kV) x Circuits | AC/DC | Line Capacity (MW) | Line Length (km) | |
|---|---|---|---|---|---|
| | | | | Overhead | Submarine |
| Sabah to Palawan | 275 x 2 | HVDC | 196 | 60 | 170 |
| Sarawak to Brunei | 275 x 2 | HVAC | 600 | 45 | 0 |
| Sumatra to Singapore | 250 x 2 | HVDC | 1,600 | 0 | 100 |
| Batam to Singapore | 250 x 2 | HVDC | 1,600 | 10 | 20 |

Source: Assumption by Study Team based on various materials

Other assumptions are as follows.

1) Income for Financial Internal Rate of Return (FIRR)

The amount of power trade was determined to be 40% of the line capacity considering transient stability, voltage stability, frequency abnormalities, and so on.

The transmission and distribution charges obtained from grid interconnection (annual trade volume kWh/year x transmission and distribution charges US$/kWh) is the income of FIRR.

2) Construction Costs

The construction costs were assumed based on a report from the European Union Agency for the Cooperation of Energy Regulators (ACER) as shown in Table 3.

**Table 3 Assumptions of Construction Costs**

| Facility | Unit | Unit cost |
|---|---|---|
| Overhead line (250-300kV x 2) | 1,000 US$/km | 607.2 |
| Submarine line (250-300kV x 2) | 1,000 US$/km | 2,437.6 |
| HVDC converter | 1,000 US$/MW | 165.0 |

Source: www.acer.europa.eu/sites/default/files/documents/Publications_annex/ACER_UIC_indicators_table.pdf (reference date: 2025-03-11)

3) O&M Cost

Since the transmission line has no rotating parts, the annual O&M costs are assumed to be 1% of the construction cost. This figure (1%) is not significantly different from the figure used by power companies.

4) Project Lifetime

Project lifetime was set at 25 years according to JICA guideline. Although unrealistic, the construction period was set at one year.

5) Target of IRR

Because transmission lines are public infrastructure, they do not require a high rate of return compared to private businesses. For this reason, the target of IRR for the interconnection projects was set at 6%.

(3) Results of Financial Analysis

Generally, financial analysis reveals the following three points: 1) profitability, 2) payback period, and 3) decision-making on project implementation. In addition, sensitivity analysis reveals the parameters that affect the IRR. In this financial analysis, the transmission and distribution charges to achieve an IRR of 6% was calculated. The transmission and distribution charge to achieve an IRR of 6% is cheapest for Sarawak to Brunei, which does not have an AC/DC converter and has a relatively short transmission line, at US$0.0011/kWh, followed by Batam to Singapore, which has an AC/DC converter, a short transmission line, and a large amount of power trade, at US$0.005/kWh. The transmission and distribution charge for Sabah to Palawan with long transmission line and small power trade is high at US$0.0621/kWh. Generally, it is said that transmission and distribution charges are around 30% of electricity tariff. Electricity tariff in ASEAN countries are around US$0.1/kWh, so transmission and distribution charges will be around US$0.03/kWh. Therefore, it is clear that the transmission and distribution charge from Sabah to Palawan is high.

**Table 4 Results of FIRR**

| | Sabah to Palawan | Sarawak to Brunei | Sumatra to Singapore | Batam to Singapore |
|---|---|---|---|---|
| Line capacity (MW) | 196 | 600 | 1,600 | 1,600 |
| Line Length (km) | 230 | 45 | 100 | 30 |
| Annual trade (GWh/year) | 687 | 2,102 | 5,606 | 5,606 |
| Transmission and distribution charge (US$/kWh) | 0.0621 | 0.0011 | 0.0080 | 0.0050 |

4. Considerations and Recommendations for Financial Assistance

This study has identified that, among the 18 projects proposed in AIMS III, the routes with the high development priority for the Development Partners, including JICA are "Sarawak - Brunei," "Singapore - Indonesia," and "Philippines - Sabah." Based on these results, and considering the possibility that the Development Partners may explore financial assistance, this study summarizes the considerations and recommendations for the formation of ODA loans (or private sector investment finance) projects. However, the summarized results are preliminary and do not necessarily lead to the formation of ODA loan (or private sector investment finance) projects based on this study.

(1) Sarawak - Brunei

The considerations and recommendations for the Sarawak - Brunei route are as follows:

**Table 5 Considerations and Recommendations for the Sarawak - Brunei Route**

| Considerations | Recommendations |
|---|---|
| A feasibility study (F/S) is currently being conducted for the Sarawak (Malaysia) - Brunei route. | The feasibility study (F/S) is assumed to be funded by utilities (such as Sarawak Energy) and/or the Brunei government, and the financier has not yet been determined. Generally, for cross-border projects, utilities first conduct the F/S, the government makes a decision, and then ACE evaluates whether the route qualifies as an APG project. If it qualifies as an APG project, ACE also assists with various adjustments. Therefore, if development partner seriously considers providing financial assistance for this route, it is recommended to consult with ACE and coordinate with the target country governments and utilities while receiving advice from ACE. |
| It seems that the COD for the Sarawak (Malaysia) - Brunei route has been postponed from 2021 to 2028. What were the reasons behind this delay?<br>, | The postponement of the COD for international interconnection lines is not limited to the Sarawak (Malaysia) - Brunei route; delays have occurred on many routes. Many countries often experience project delays as they consider the benefits and cost burdens. Therefore, the role of ACE in mediating and ensuring project progress with the mandate of the respective governments becomes crucial. For JICA, utilizing ACE holds significant value. |

(2) Singapore-Indonesia

The following are the considerations and recommendations for the Singapore-Indonesia route:

**Table 6 Considerations and Recommendations for the Singapore – Indonesia Route**

| Considerations | Recommendations |
|---|---|
| It may be difficult or time-consuming to secure land for renewable energy on Batam Island. | In February 2025, a floating solar panel system manufacturing plant began operations to supply solar power from Batam Island to Singapore. One of the reasons for the adoption of floating solar PV in Indonesia, despite delays in large-scale solar PV projects, is the high cost of securing land for renewable energy and the need to avoid issues related to relocating local residents. These land issues in Indonesia contribute to the preference for floating solar PV solutions. When constructing the Singapore-Batam route, it will be necessary to address the land issues on Batam Island as a renewable power generation site. |

| | |
|---|---|
| Are there any considerations to keep in mind when starting the feasibility study (F/S)? | Generally, for cross-border projects, the utility first conducts the feasibility study (F/S), followed by the government's decision-making. Subsequently, ACE evaluates whether the route qualifies as an APG project. If it qualifies, ACE also assists with various coordination efforts on the route. Therefore, if JICA is to seriously consider financial assistance for this route, it is recommended to consult with ACE and coordinate with the target country's government and utilities while receiving advice from ACE. |
| How difficult is it to lay a subsea cable for the Singapore-Sumatra route? | Although the subsea cable for the Singapore-Sumatra route is planned to be less than 100 km in length, the difficulty level will remain unclear even for ACE until a detailed feasibility study (F/S) is conducted. Additionally, there is a movement to create guidelines at the ASEAN level for subsea cables (power, communication, etc.). It is necessary to consider how much these guidelines will contribute to the smooth installation process and, conversely, how much they will impact installation costs. |

(3) Philippines-Sabah (Malaysia)

The following are the considerations and recommendations for the Philippines-Sabah route:

**Table 7 Considerations and Recommendations for the Philippines – Sabah Route**

| Considerations | Recommendations |
|---|---|
| There are discussions in the Philippines regarding energy security, as 40% of the shares of the National Grid Corporation of the Philippines (NGCP) are owned by China's State Grid Corp. | During the process of electricity market reform, which was initiated due to the excessive debt problem of the former state-owned power company in the Philippines, Chinese capital entered NGCP. However, there are some voices of opposition within Philippine public opinion. Therefore, when constructing international interconnection lines, including NGCP, it is necessary to pay close attention to public opinion in both the Philippines and Malaysia. |
| The grid frequency in the Philippines is 60Hz, which is different from other countries. | To build new transmission infrastructure between the Philippines and Malaysia, it is first necessary to enhance interconnectivity at the bilateral level. However, the Philippines has a grid frequency of 60Hz, which is different from Malaysia and other AMS, making the connection a potentially complex challenge. Therefore, it is necessary to overcome this technical challenge for the Philippines-Sabah route. |

| | |
|---|---|
| Are there any considerations to keep in mind when starting the feasibility study (F/S)? | Generally, for cross-border projects, the utility first conducts the feasibility study (F/S), followed by the government's decision-making. Subsequently, ACE evaluates whether the route qualifies as an APG project. If it qualifies, ACE also assists with various coordination efforts on the route. Therefore, if JICA is to seriously consider financial assistance for this route, it is recommended to consult with ACE and coordinate with the target country's government and utilities while receiving advice from ACE. |
| How difficult is it to lay a subsea cable for the Philippines-Sabah route? | Although the subsea cable for the Philippines-Sabah route is planned to be over 200 km in length, the difficulty level will remain unclear even for ACE until a detailed feasibility study (F/S) is conducted. Additionally, there is a movement to create guidelines at the ASEAN level for subsea cables (power, communication, etc.).[42] It is necessary to consider how much these guidelines will contribute to the smooth installation process and, conversely, how much they will impact installation costs. |

It has been identified that there are multiple considerations when advancing financial assistance for any of the three high-development priority routes. If development partner proceeds to the financing, it is necessary to address the risks arising from above considerations and from considerations that may emerge during future detailed feasibility studies (F/S). On the other hand, some routes already show political commitment; therefore, it is crucial to proceed with a sense of urgency in cooperation with AMS governments, utilities, and ACE.

## Background and Objectives

The Paris Agreement was adopted at the 21st Conference of the Parties to the United Nations Framework Convention on Climate Change (COP21) in December 2015 as an international framework for reducing greenhouse gas emissions after 2020. The Agreement aims to limit global warming to 1.5°C, well below the 2°C level of the pre-industrial era. ASEAN countries have also set ambitious climate targets as part of the global community.

Electricity demand in the ASEAN region is growing steadily on the back of economic recovery since the Corona virus pandemic, increasing by 4.25% in 2022 compared to 2021 (ASEAN Centre for Energy, 2023). As of 2022, the installed power generation capacity in the ASEAN region was 310 GW, with coal-fired (106 GW) and gas-fired (90 GW) power plants accounting for the majority, indicating that fossil generation is a mainstay of power supply. In addition, 30 GW of new power capacity has been added in the region between 2021 and 2022, more than 60% of which were based on fossil fuels. This suggests that the region is struggling to balance the need to meet growing electricity demand with the need to decarbonize.

Under these circumstances, the region's unevenly distributed hydro and wind power potential must be maximized to meet the region's energy security and climate goals. In order to connect the unevenly distributed renewable energy to large demand areas, it is necessary to develop and strengthen electricity grids.

Meantime, the ASEAN Energy Centre (hereinafter referred to as "ACE"), which formulates energy strategies in collaboration with relevant ministries and agencies of ASEAN member states and the ASEAN Secretariat, has updated the ASEAN Interconnection Masterplan Study (AIMS) III in 2022, which conducted technical studies on power interconnection.

In light of this situation, this project will conduct a basic information collection and confirmation study on the ASEAN Power Grid Programme to examine support approach to the programme.

The survey will target 10 ASEAN member countries and 18 power line projects identified by ASEAN. In addition, potential technical cooperation programmes for the ACE will be explored.

# Chapter 1 Energy Supply and Demand in ASEAN

1.1 Brunei

1.1.1 Policies for the Energy and Electricity Sector

(1) Climate Change Targets

Brunei has submitted to the UN its commitment to reduce greenhouse gas emissions by 20% by 2030 compared to BAU. Although no clear long-term goal has been set, Brunei announced at COP26 in 2021 that, as ASEAN chair, it will further reduce GHG emissions by 2050, mainly through energy transition and forest conservation, thus demonstrating its ambition to achieve net-zero emissions in the future.

(2) Energy and Electricity Policy

In Brunei, the Brunei Climate Change Secretariat (BCCS) was established in 2018, and "The Brunei Darussalam National Climate Change Policy (BNCCP)" was formulated in 2020.

The BNCCP consists of 10 strategies with a target year of 2035. The goals of the BNCCP include the promotion of EV sales, forest plantations, and the introduction of renewable energy.

**Table 1.1.1 Ten Strategies in the BNCCP**

| No. | Title. | Main contents |
|---|---|---|
| 1 | Industrial Emissions | Do not routinely flare and operate as rationally as possible to reduce overall emissions in the industrial sector. |
| 2 | Forest Cover | Plant 500,000 trees to ensure a carbon sink.<br>Consider an additional 400,000 tree plantations.. |
| 3 | Electric Vehicles | Increase the share of EV in the car sales to 60%. This includes lowering the price of EVs through taxation and developing recharging points. |
| 4 | Renewable Energy | Increase the share of renewable energy, mainly solar, to at least 30%. |
| 5 | Power Management | Reduce greenhouse gas emissions from the power generation sector by 10% compared to the BAU through improving energy efficiency in power generation. |
| 6 | Carbon Pricing | Implement a carbon pricing system for all industrial facilities by 2025. |
| 7 | Waste Management | Reduce methane gas emissions primarily by reducing waste emissions per capita to 1 kg per day, |
| 8 | Climate Resilience & Adaptation | Strengthen Brunei's resilience and adaptability to climate change risks such as flooding, forest fires, strong winds, and land subsidence. |
| 9 | Carbon Inventory | Mandate all facilities that emit or absorb greenhouse gases to report greenhouse gas emission data |

| 10 | Awareness & Education | Raise public awareness on climate change and adaptation policies, thus promote education. |
|---|---|---|

Source: BCCS, Brunei Darussalam National Climate Change Policy.

### 1.1.2 Current and Projected Energy and Electricity Supply and Demand

#### (1) Current Energy Supply and Demand

##### 1) Domestic energy production

Brunei produces an oil and natural gas with an extremely high energy self-sufficiency rate of 278% in 2022, while its production has been declining in recent years. Regarding renewable energy, as the country is close to the equator, Brunei has huge potential for solar power generation.

**Table 1.1.2 Domestic Energy Production in Brunei (Unit：ktoe)**

| | Coal | Crude Oil | Natural Gas | Nuclear | Hydro | Renewable Energy | Total |
|---|---|---|---|---|---|---|---|
| 1990 | 0 | 7,697 | 7,945 | 0 | 0 | 2 | 15,644 |
| 1995 | 0 | 8,891 | 9,353 | 0 | 0 | 0 | 18,244 |
| 2000 | 0 | 10,221 | 9,466 | 0 | 0 | 0 | 19,687 |
| 2005 | 0 | 11,063 | 10,000 | 0 | 0 | 0 | 21,063 |
| 2010 | 0 | 8,307 | 10,269 | 0 | 0 | 0 | 18,576 |
| 2015 | 0 | 6,695 | 9,414 | 0 | 0 | 0 | 16,109 |
| 2020 | 0 | 5,550 | 8,911 | 0 | 0 | 0 | 14,460 |
| 2022 | 0 | 4,615 | 7,468 | 0 | 0 | 0 | 12,084 |

Source: IEA, World Energy Balances 2024_07.

##### 2) Primary energy supply

Although natural gas has accounted for a large share of primary energy supply in Brunei, the share of crude oil and coal has increased in recent years. The share of natural gas in total primary energy supply decreased from 83% in 2010 to 58% in 2022.

**Table 1.1.3 Primary Energy Supply in Brunei (Unit：ktoe)**

| | Coal | Crude Oil | Petroleum Products | Natural Gas | Nuclear | Hydro | Renewable Energy | Electric Power | Total |
|---|---|---|---|---|---|---|---|---|---|
| 1990 | 0 | 115 | -67 | 1,676 | 0 | 0 | 2 | 0 | 1,727 |
| 1995 | 0 | 336 | -100 | 2,011 | 0 | 0 | 0 | 0 | 2,248 |
| 2000 | 0 | 642 | -108 | 1,850 | 0 | 0 | 0 | 0 | 2,385 |
| 2005 | 0 | 531 | -151 | 1,838 | 0 | 0 | 0 | 0 | 2,218 |
| 2010 | 0 | 617 | -54 | 2,677 | 0 | 0 | 0 | 0 | 3,241 |
| 2015 | 0 | 435 | 146 | 2,137 | 0 | 0 | 0 | 0 | 2,718 |
| 2020 | 691 | 8,630 | -7,550 | 2,329 | 0 | 0 | 0 | 0 | 4,101 |
| 2022 | 681 | 8,810 | -7,665 | 2,507 | 0 | 0 | 0 | 0 | 4,343 |

Source: IEA, World Energy Balances 2024_07.

3) Final energy consumption

Final energy consumption in Brunei was 22% in 2022 with 22% from Industry, 28% from transportation, 11% from commercial, 11% from residentials, and 29% from non-energy uses. Compared to 2000, energy consumption in industry and residentials has seen significant growth, while the increase in transportation and commercial use has been more limited.

**Table 1.1.4 Final Energy Consumption in Brunei (Unit：ktoe)**

| | Industry | Transportation | Commercial | Agricultural, Forestry and Fisheries | Residential | Other | Non-Energy use | Total |
|---|---|---|---|---|---|---|---|---|
| 1990 | 61 | 188 | 38 | 0 | 45 | 2 | 17 | 351 |
| 1995 | 90 | 263 | 86 | 0 | 61 | 0 | 32 | 532 |
| 2000 | 70 | 274 | 141 | 0 | 67 | 0 | 22 | 575 |
| 2005 | 50 | 320 | 181 | 0 | 53 | 0 | 24 | 629 |
| 2010 | 164 | 395 | 134 | 0 | 142 | 0 | 477 | 1,312 |
| 2015 | 151 | 457 | 158 | 0 | 152 | 12 | 367 | 1,297 |
| 2020 | 237 | 406 | 170 | 0 | 157 | 16 | 524 | 1,511 |
| 2022 | 312 | 407 | 152 | 0 | 153 | 0 | 414 | 1,438 |

Source: IEA, World Energy Balances 2024_07.

(2) Current Electricity Supply and Demand

1) Electricity generation

The total electricity generation in Brunei was 5.6 TWh in 20212, with 21.6% from coal, 0.8% from oil, 77.5% from gas-fired, and 0.1% from solar. Coal has not been used to generate electricity since 1971, when the statistics begun, but it has been introduced since 2019 to compensate for the recent increase in electricity demand.

**Table 1.1.5 Electricity Generation in Brunei (Unit: GWh)**

| | Coal | Petroleum | Gas | Solar | Total |
|---|---|---|---|---|---|
| 2000 | 0 | 23 | 2,520 | 0 | 2,543 |
| 2005 | 0 | 29 | 3,235 | 0 | 3,264 |
| 2010 | 0 | 38 | 3,754 | 0 | 3,792 |
| 2015 | 0 | 42 | 4,156 | 2 | 4,200 |
| 2020 | 1,226 | 40 | 4,469 | 2 | 5,737 |
| 2022 | 1,208 | 46 | 4,344 | 5 | 5,6603 |

Source: IEA, World Energy Balances 2024_07.

2) Exported, imported and lost electricity, etc.

Brunei currently does not have an international interconnection line, and therefore electricity import and export are not implemented.

**Table 1.1.6 Exported, Imported and Lost Electricity, etc. in Brunei (Unit: GWh)**

| | Electricity Generation | Imported Electricity | Exported Electricity | Transmission and distribution losses (etc.) | Domestic Electricity Consumption |
|---|---|---|---|---|---|
| 2000 | 2,543 | 0 | 0 | 88 | 2,455 |
| 2005 | 3,264 | 0 | 0 | 627 | 2,637 |
| 2010 | 3,792 | 0 | 0 | 878 | 2,914 |
| 2015 | 4,200 | 0 | 0 | 809 | 3,391 |
| 2020 | 5,737 | 0 | 0 | 1,005 | 4,732 |
| 2022 | 5,603 | 0 | 0 | 1,050 | 4,553 |

Source: IEA, World Energy Balances 2024_07.

3) Electricity consumption

The electricity consumption in Brunei was about 4.5 TWh in 2022, with 39% used for commercial and public purposes, 30% for industrial use, and 31% for residential use. Compared to 2010, commercial/public and residential consumption has increased around 10% to 20%, while industrial consumption has risen significantly by around 7.7 times.

**Table 1.1.7 Electricity Consumption in Brunei (Unit: GWh)**

| | Commercial & Public | Industry | Residential | Total |
|---|---|---|---|---|
| 2000 | 1,642 | 290 | 523 | 2,455 |
| 2005 | 2,110 | 133 | 394 | 2,637 |
| 2010 | 1,553 | 180 | 1,181 | 2,914 |
| 2015 | 1,834 | 189 | 1,368 | 3,391 |
| 2020 | 1,973 | 1,356 | 1,403 | 4,732 |
| 2022 | 1,765 | 1,380 | 1,408 | 4,553 |

Source: IEA, World Energy Balances 2024_07.

(3) Renewable Energy Potential

Due to its small land area, Brunei's renewable energy potential is limited. The total renewable energy potential is 2.0 GW, with 1.9 GW from solar PV and 0.1 GW from hydropower. This is the second smallest among ASEAN countries, next to Singapore.

**Table 1.1.8 Renewable Energy Potential in Brunei (Unit: GW)**

| Solar PV | Onshore wind | Offshore wind | Biomass | Hydro | Geothermal | Total |
|---|---|---|---|---|---|---|
| 1.9 | - | - | - | 0.1 | - | 2.0 |

Source: IRENA & ACE; Renewable Energy Outlook for ASEAN, (2022).

(4) Energy Demand Forecasts

Public data on Brunei's energy demand has not been released.

(5) Electricity Demand Forecasts

In its 2013 Energy White Paper, the Bruneian government forecasts that domestic electricity demand will increase at an annual rate of 4%, reaching 9.54 billion kWh by 2035. Since then, no official electricity demand projections have been released.

1.1.3 Actual Situation of Electricity Import/Export

Currently there is no interconnection line and no import/export of electricity is recorded in Brunei.

1.1.4 Power Supply Development Plan, National Grid Development Plan

(1) Power Generation Facilities

As of 2021, according to UN data, thermal power accounted for 99.6% of the total power generation capacity in Brunei with 79% publicly owned and 20.6% privately owned. In addition, solar power has been introduced in recent years. Official data on power generation facilities has not been publicly released.

**Table 1.1.9 Power Generation Plants in Brunei (Unit: MW)**

| | Steam Power (Public) | Steam Power (Private) | Steam Power (Total) | Solar (Public) | Solar (Private) | Solar (Total) | Total |
|---|---|---|---|---|---|---|---|
| 2000 | 705 | 65 | 770 | 0 | 0 | 0 | 770 |
| 2005 | 691 | 68 | 759 | 0 | 0 | 0 | 759 |
| 2010 | 715 | 70 | 785 | 0 | 0 | 0 | 785 |
| 2015 | 708 | 110 | 818 | 1 | 0 | 1 | 819 |
| 2020 | 892 | 234 | 1,126 | 1 | 0 | 1 | 1,127 |
| 2022 | 899 | 234 | 1,133 | 1 | 4 | 5 | 1,138 |

Source: UN Data

(2) Power Generation Facility Plan

In Brunei, no medium to long-term power generation capacity plan has been announced. On the other hand, according to ERIA, Brunei has set a goal for renewable energy to account for at least 30% of the installed power generation capacity by 2035 with a focus on solar power.

(3) Cost of Electricity

According to the AIMSIII Phase I Update report, Brunei's electricity generation cost in 2020 was 15.1 cents per kWh.

(4) Domestic Transmission System

Public data on Brunei's domestic transmission system has not been released.

(5) Domestic grid development plans

Public data on Brunei's domestic grid development plans has not been released.

(6) Supply Reliability

Public data on Brunei's supply reliability has not been released.

### 1.1.5 Status of Existing International Interconnection Lines

The ASEAN Interconnection Masterplan Study (AIMS) III Phase 1 & 2 Update, published in August 2023, outlines the status of cross-border interconnections as of 2022, as well as projections for interconnection development under three scenarios for 2025 and 2040: the Updated Power Development Plan (Updated PDP), the ASEAN Renewable Energy Target Case (ASEAN RE Target), and the High Renewable Energy Target (High RE Target). For Brunei, the outlook for cross-border interconnections is presented as follows.

**Table 1.1.10 Status and Outlook of Cross-Border Interconnections in Brunei (MW)**

| AIMS No. | International interconnection line (country-to-country) | APG Status | Updated PDP | | ASEAN RE Target | | High RE Target | |
|---|---|---|---|---|---|---|---|---|
| | | 2022 | 2025 | 2040 | 2025 | 2040 | 2025 | 2040 |
| 8 | Sarawak - Brunei | - | 100 | 150 | 62 | 100 | 540 | 643 |

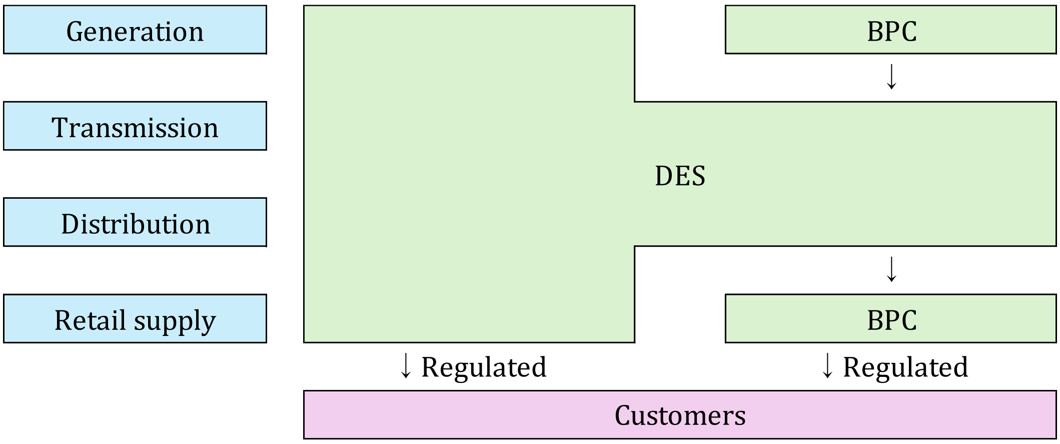
Source: ACE, (2023), Findings of ASEAN Interconnection Masterplan Study (AIMS) III Phase 1 & 2 Update.

### 1.1.6 Trends in Electricity and International Electricity Markets

(1) Electric Utility System

In Brunei, the Department of Electrical Services (DES) under the Department of Energy (DOE) operates a vertically integrated electricity business from generation to retail.

Berakas Power Company (BPC), a government-owned company, is also engaged in power generation, transmission, distribution, and retail business, supplying about 40% of Brunei's electricity demands. In addition, there are IPPs whose main purpose is to generate their own power.




Source: Compiled by JICA Team

**Figure 1.1.1 Electric Utility System in Brunei**

(2) Electric Utility Regulations

In Brunei, DES, a division of the DOE established in 2022 under the Prime Minister's Office (PMO), operates a vertically integrated electricity business from generation to retail, and regulates and supervises the electricity business. As for the legal system, the "Electricity Act" regulates the electric utility business and requires a license to operate in this field.

(3) Major Electric Utility

As already mentioned, DES and BPC are the major electric utilities in Brunei. DES has been supplying electricity as an agency directly under the Prime Minister's Office before Brunei's independence. As a result of several reorganizations, it is now a division of the DOE.

BPC is a government-owned company established in 1998 and is a wholly owned subsidiary of Darussalam Assets, another government-owned company. BPC provides electricity in areas covering approximately 40% of Brunei's electricity demands, including strategically important areas within the Muara District.

(4) Electricity Trading Environment with Foreign Operators and Domestic Market

As stated in section 1.1.3, there are currently no interconnections with other countries, and there is no record of electricity imports or exports.

## 1.2 Cambodia

### 1.2.1 Policies for the Energy and Electricity Sector

#### (1) Climate Change Targets

According to BAU scenario, Cambodia is expected to emit greenhouse to reach 154.9 million tCO2e in 2030. These emissions are covered by 49.2% from the forestry and other land use (FOLU) sector, 22.2% from energy sector, 17.5% from agriculture sector, and 9.0% from industrial sector.

The Nationally Determined Contribution (NDC) conditionally aims to reduce emissions by 64.6 million tCO2e per year by 2030, representing a 41.7% reduction compared to the BAU scenario. Under the NDC, the FOLU sector accounts for 59.1% of emissions, the energy sector 21.3%, the agricultural sector 9.6%, and the industrial sector 9.1%.

**Table 1.2.1 NDC Scenarios in Cambodia (2030)**

| department | Percentage of emissions by sector (%) | GHG emissions (MtCO2e) |
|---|---|---|
| Forestry and other land uses | 59.1 | 38.1 |
| Energy | 21.3 | 13.7 |
| Agriculture | 9.6 | 6.2 |
| Industry | 9.1 | 5.9 |
| Waste | 0.9 | 0.6 |
| Total Amount | 100 | 64.6 |

Source: KOC, Cambodia's Updated Nationally Determined Contribution.

#### (2) Energy and Electricity Policy

The Basic Energy Plan calls for contributions to two points.

1. Savings in conventional energy consumption, such as oil and electricity.
2. Utilization of domestic energy sources such as hydropower and biomass.

Cambodia's demand for gasoline, diesel fuel, and liquefied petroleum gas (LPG) has been growing rapidly, and the country has relied on imports for most of this demand. In addition, according to the Energy Consumption Outlook, demand for these petroleum products will continue to increase until 2040. The following measures are recommended in response to this outlook.

- Transition the conventional transportation, which primarily use petroleum products, to high-efficiency vehicles.
- Stockpile adequate quantities of petroleum products for commercial use.

- Reduce gasoline imports by adopting biofuels (especially bioethanol).
- Strengthen the petroleum supply chain by operating under appropriate petroleum policies and regulations.

According to the Energy Consumption Outlook, electricity demand is expected to increase 7.5 times between 2015 and 2040. In light of this situation, the following measures are recommended.

- The power generation mix in 2030 will consist of 35% coal, 55% hydropower, and 10% biomass and solar power.
- Improve transmission and distribution losses (from 13% in 2016 to 8% in 2030) and increase residential electrification from approximately 70% in 2019 to 95% in 2030.

Additionally, it is recommended to reform the electricity pricing system by introducing a Time of Use Pricing system. This would help balance electricity demand and reduce price differences between urban and rural areas.

1.2.2 Current and Projected Energy and Electricity Supply and Demand

(1) Current Energy Supply and Demand

1) Domestic energy production

In 2000, renewable energy was produced domestically with the energy self-sufficiency rate at 80%. Despite the increase in renewable energy production, the domestic primary energy supply has increased even more, reducing the self-sufficiency rate to 40% in 2022.

Although coal has been produced since 2017, its self-sufficient rate was at only 1% in 2022, relying heavily on imports from overseas.

**Table 1.2.2 Domestic Energy Production in Cambodia (Unit: ktoe)**

| | Coal | Crude Oil | Natural Gas | Nuclear | Hydro | Renewable Energy | Total |
|---|---|---|---|---|---|---|---|
| 1995 | 0 | 0 | 0 | 0 | 0 | 2,317 | 2,317 |
| 2000 | 0 | 0 | 0 | 0 | 0 | 2,710 | 2,710 |
| 2005 | 0 | 0 | 0 | 0 | 4 | 2,902 | 2,906 |
| 2010 | 0 | 0 | 0 | 0 | 3 | 2,969 | 2,972 |
| 2015 | 0 | 0 | 0 | 0 | 176 | 3,238 | 3,415 |
| 2020 | 26 | 0 | 0 | 0 | 350 | 3,478 | 3,854 |
| 2022 | 7 | 0 | 0 | 0 | 529 | 2,946 | 3,483 |

Source: IEA, World Energy Balances 2024_07.

2) Primary energy supply

Primary energy supply is also increasing in line with the increase in final energy consumption. In particular, the growth rate of primary energy supply of petroleum products is relatively high, increasing 4.8 times in 2022 compared to 2000.

Additionally, the share of coal in annual energy consumption rose from 0% in 2000 to 16% in 2022, indicating an increase of 16 percentage points.

**Table 1.2.3 Primary Energy Supply in Cambodia (Unit: ktoe)**

| | Coal | Crude Oil | Petroleum Products | Natural Gas | Nuclear | Hydro | Renewable Energy | Electric | Total |
|---|---|---|---|---|---|---|---|---|---|
| 1995 | 0 | 0 | 511 | 0 | 0 | 0 | 2,317 | 0 | 2,829 |
| 2000 | 0 | 0 | 694 | 0 | 0 | 0 | 2,710 | 0 | 3,404 |
| 2005 | 0 | 0 | 941 | 0 | 0 | 4 | 2,902 | 2 | 3,849 |
| 2010 | 24 | 0 | 1,558 | 0 | 0 | 3 | 2,969 | 133 | 4,687 |
| 2015 | 558 | 0 | 1,912 | 0 | 0 | 176 | 3,238 | 133 | 6,018 |
| 2020 | 1,106 | 11 | 3,258 | 0 | 0 | 350 | 3,478 | 328 | 8,532 |
| 2022 | 1,378 | 11 | 3,351 | 0 | 0 | 529 | 2,946 | 413 | 8,629 |

Source: IEA, World Energy Balances 2024_07.

3) Final energy consumption

Industry final energy consumption accounted for 32% of the total, transportation energy consumption 30%, residential energy consumption 27%, commercial energy consumption 6%, and agricultural, forestry and fisheries energy consumption 3%. Compared to 2000, energy consumption in the transportation sector increased by 16%, with rising fuel consumption in vehicles. On the other hand, residential energy consumption decreased by 38% compared to 2000, possibly due to an increase in the share of transportation and industrial energy consumption.

**Table 1.2.4 Final Energy Consumption in Cambodia (Unit: ktoe)**

| | Industry | Transportation | Commercial | Agricultural, Forestry and Fisheries | Residential | Other | Non-energy use | Total |
|---|---|---|---|---|---|---|---|---|
| 1995 | 438 | 382 | 3 | 0 | 1,712 | 1 | 7 | 2,543 |
| 2000 | 608 | 433 | 9 | 0 | 1,959 | 3 | 12 | 3,024 |
| 2005 | 695 | 492 | 20 | 0 | 2,113 | 4 | 12 | 3,336 |
| 2010 | 902 | 980 | 123 | 0 | 2,144 | 15 | 14 | 4,178 |
| 2015 | 1,118 | 1,354 | 332 | 0 | 2,208 | 182 | 46 | 5,242 |
| 2020 | 1,702 | 2,219 | 437 | 0 | 2,559 | 118 | 96 | 7,130 |
| 2022 | 2,428 | 2,253 | 457 | 222 | 2,026 | 0 | 190 | 7,576 |

Source: IEA, World Energy Balances 2024_07.

(2) Current Electricity Supply and Demand

1) Electricity generation

The electricity generation was 13.6TWh in 2023 with 57% coming from coal-fired power, 0.4% from oil-fired power, 35% from hydroelectric power, and 6% from renewable energy. Compared to 2010, coal-fired power generation has increased 244 times and hydro power generation has increased 151 times. On the other hand, oil-fired power generation has decreased by 94%.

**Table 1.2.5 Electricity Generation in Cambodia (Unit: GWh)**

| | Coal | Petroleum | Hydro | Solar | Biomass | Total |
|---|---|---|---|---|---|---|
| 2000 | - | 447 | 30 | - | - | 477 |
| 2005 | - | 836 | 44 | - | 0 | 880 |
| 2010 | 32 | 899 | 32 | - | 6 | 969 |
| 2015 | 2,128 | 164 | 2,160 | - | 38 | 4,490 |
| 2019 | 3,734 | 732 | 4,025 | 93 | 91 | 8,675 |
| 2023 | 7,823 | 54 | 4,840 | 823 | 75 | 13,614 |

Source: MME, Cambodia Energy Statistics 2000-2019. and EAC, Annual Report on Power Sector for Year 2023.

2) Exported, imported and lost electricity, etc.

In 202, the total imported electricity was about 3.3 TWh. Imported electricity accounted for 20% of the total available supply. The imported electricity has increased 76 times compared to 2000.

**Table 1.2.6 Exported Imported and Lost Electricity, etc. (GWh)**

| | Electricity Generation | Imported Electricity | Exported Electricity | Availability | Domestic Electricity Consumption | (Reference) Transmission and Distribution Loss Ratio |
|---|---|---|---|---|---|---|
| 2000 | 477 | 44 | 0 | 521 | 449 | 13.82% |
| 2005 | 880 | 81 | 0 | 961 | 857 | 10.73% |
| 2010 | 969 | 1,541 | 0 | 2,510 | 2,251 | 10.28% |
| 2015 | 4,490 | 1,526 | 0 | 6,016 | 5,198 | 13.58% |
| 2019 | 8,675 | 3,063 | 0 | 11,738 | 10,191 | 13.18% |
| 2023 | 13,614 | 3,373 | 0 | 16,987 | 15,251 | 10.22% |

Source: MME, Cambodia Energy Statistics 2000-2019. and EAC, Annual Report on Power Sector for Year 2023.

3) Electricity consumption

The electricity Consumption was 10 TWh in 2019, with industrial, commercial and residential consumption each accounting for 33%. Compared to 2005, industrial consumption has increased 23 times, while commercial and residential consumption has increased 9 times.

**Table 1.2.7 Electricity Consumption in Cambodia (Unit: GWh)**

| | Industry | Commercial | Residential | Total |
|---|---|---|---|---|
| 2000 | 26 | 186 | 237 | 449 |
| 2005 | 144 | 348 | 366 | 858 |
| 2010 | 490 | 893 | 869 | 2,252 |
| 2015 | 1,141 | 2,530 | 1,527 | 5,198 |
| 2019 | 3,383 | 3,408 | 3,400 | 10,191 |

Source: MME, based on Cambodia Energy Statistics 2000-2019.

(3) Renewable Energy Potential

Cambodia's land area is the third smallest among ASEAN countries, after Singapore and Brunei; however, due to its high solar irradiance, it has a significant solar PV potential of 1,597.0 GW. The total renewable energy potential is the third largest, following Indonesia, and Thailand(except Myanmar). Additionally, Cambodia has an offshore wind power potential of 88.8 GW, which is the third largest after Indonesia and Vietnam.

**Table 1.2.8 Renewable Energy Potential in Cambodia (Unit: GW)**

| Solar PV | Onshore wind | Offshore wind | Biomass | Hydro | Geothermal | Total |
|---|---|---|---|---|---|---|
| 1,597.0 | 2.5 | 88.8 | - | 10.0 | - | 1,698.3 |

Source: IRENA & ACE; Renewable Energy Outlook for ASEAN, (2022).

(4) Energy Demand Forecasts

Cambodia has developed two supply and demand scenarios. Under the BAU scenario, primary energy supply is projected to increase to about 13 Mtoe, an average annual increase of about 4%. Fossil fuels are expected to remain dominant in 2030, accounting for nearly 60% of total energy consumption. The increase in coal consumption is due to an increase in electricity generation, while the increase in oil consumption is due to an increase in cars and motorcycles.

Primary energy supply in the Alternative Policy (AP) scenario increases to about 10 Mtoe, with non-fossil fuels accounting for 52% of supply in 2030. In particular, hydro power is expected to increase by 2.7 times and renewable energy by 6 times.

**Table 1.2.9 Energy Supply and Demand Forecasts for Cambodia (Unit：Mtoe, as of 2019)**

<BAU Scenario>

| | Coal | Petroleum Products | Hydro | Biomass | Renewable Energy | Electric Power | total |
|---|---|---|---|---|---|---|---|
| 2020 | 2.25 | 2.83 | 0.33 | 4.41 | 0.01 | 0.01 | 9.84 |
| 2025 | 2.82 | 3.26 | 0.35 | 4.55 | 0.03 | 0.00 | 11.01 |
| 2030 | 3.81 | 3.78 | 0.38 | 4.66 | 0.03 | 0.01 | 12.67 |

<AP Scenario>

| | Coal | Petroleum Products | Hydro Power | Biomass | Renewable Energy | Electric Power | Total |
|---|---|---|---|---|---|---|---|
| 2020 | 1.73 | 2.56 | 0.34 | 4.24 | 0.01 | 0.19 | 9.07 |
| 2025 | 1.93 | 2.96 | 0.69 | 4.34 | 0.04 | 0.02 | 9.98 |
| 2030 | 1.70 | 3.28 | 0.95 | 4.46 | 0.06 | 0.00 | 10.45 |

Source: Based on MME, Cambodia Basic Energy Plan_2019.

(5) Electricity Demand Forecasts

The "Power Development Master Plan (PDP) 2022-2040" formulated in September 2022 includes forecasts for electricity supply and demand until 2040. In 2040, domestic power consumption is expected to reach approximately 54 TWh. This is expected to increase by 4.4 times compared to 2020.

**Table 1.2.10 Electricity Supply and Demand Forecasts in Cambodia**

| | Domestic Power Consumption (GWh) | From 2020 Rate of increase |
|---|---|---|
| 2020 | 12,290 | - |
| 2025 | 22,108 | 79.89% |
| 2030 | 30,080 | 144.75% |
| 2035 | 41,579 | 238.32% |
| 2040 | 54,597 | 344.24% |

Source: MME, Power Development Masterplan 2022-2040.

1.2.3 Actual Situation of Electricity Import/Export

Cambodia imports electricity from neighboring countries such as Thailand, Vietnam, and Laos. During the dry season, the amount of water for hydropower generation decreases, leading to a need for electricity imports. In addition, despite stable economic growth, the country continues to import electricity from neighboring countries because of a significant shortage of electricity due to a lack of investment in the power sector.

**Table 1.2.11 Electricity Imports in Cambodia (Unit: GWh)**

| | Thailand | Vietnam | Laos | Total |
|---|---|---|---|---|
| 2005 | 56.84 | 25.41 | 0.00 | 82.25 |
| 2010 | 385.28 | 1,155.41 | 5.75 | 1,546.44 |
| 2015 | 307.39 | 1,200.39 | 18.31 | 1,526.09 |
| 2020 | 809.78 | 1,247.02 | 1,762.84 | 3,819.64 |
| 2023 | 132.22 | 682.29 | 2,558.68 | 3,373.19 |

Source: EAC, Annual Report on the Power Sector.

1.2.4 Power Supply Development Plan, National Grid Development Plan

(1) Power Generation Plants

In 2023, Cambodia's installed capacity was 3.8 GW with 36% from coal-fired, 34% from hydropower, 16% from oil-fired, and 11% from solar PV. Compared to 2010, coal-fired capacity has increased 108 times and hydropower capacity has increased 102 times.

**Table 1.2.12 Power Generation Plants in Cambodia (Unit: MW)**

| | Coal | Petroleum | Hydro Power | Solar | Biomass | Total |
|---|---|---|---|---|---|---|
| 2005 | - | 218 | 13 | - | 0 | 231 |
| 2010 | 13 | 328 | 13 | - | 6 | 360 |
| 2015 | 403 | 305 | 930 | - | 20 | 1,657 |
| 2020 | 675 | 659 | 1,330 | 297 | 31 | 2,991 |
| 2023 | 1,410 | 646 | 1,332 | 437 | 49 | 3,874 |

Source: EAC, Annual Report on the Power Sector.

(2) Power Generation Facility Plan

The planned power generation capacity is 10 GW in 2040, which is 2.6 times higher than in 2023 (3.8GW) . Of this, solar power and hydro power will account for 31% and 29%, respectively, bringing the share of renewable energy sources to 60%. In particular, solar power is expected to increase 7 times compared to 2023.

**Table 1.2.13 Planned Electricity Generation Facilities in Cambodia (Unit: MW, as of Sep. 2022)**

| | Coal | Petroleum | Natural Gas | Hydro | Solar | Biomass | Total |
|---|---|---|---|---|---|---|---|
| 2025 | 2,266 | 643 | 0 | 1,328 | 705 | 51 | 4,993 |
| 2030 | 2,266 | 643 | 0 | 1,558 | 1,005 | 101 | 5,573 |
| 2035 | 2,266 | 643 | 0 | 2,255 | 1,305 | 151 | 6,620 |
| 2040 | 2,266 | 643 | 900 | 2,973 | 3,155 | 201 | 10,138 |

Source: MME, Power Development Masterplan 2022-2040.

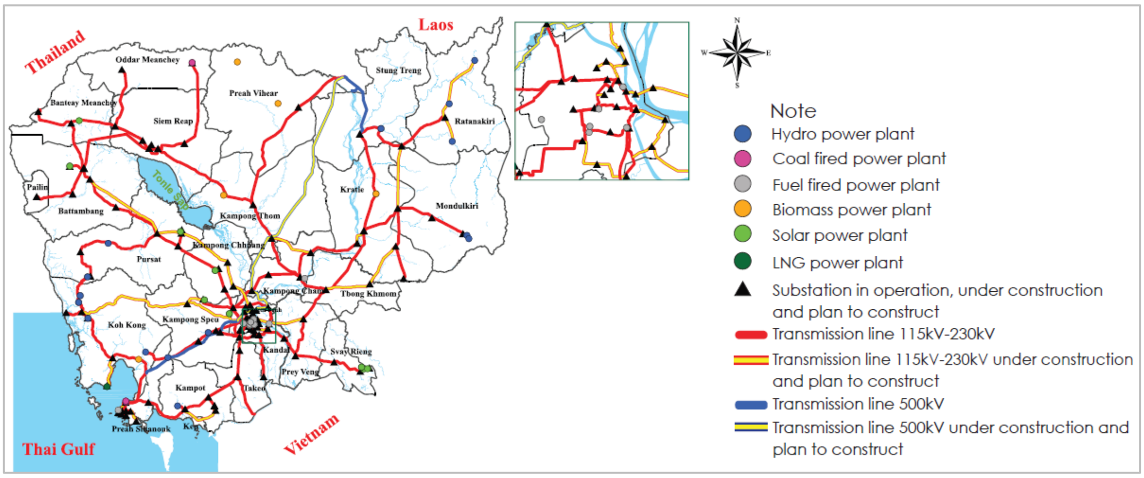
(3) Cost of Electricity

According to the AIMSIII Phase I Update report, Cambodia's electricity generation cost in 2020 was 4.2 cents per kWh.

(4) Domestic Transmission System

Prior to 2010, Cambodia had two independent high-voltage grids, one covering the provinces of Phnom Penh, Kadal, and Takeo in the southeast of the country and connected to the Vietnamese grid; the second, covering the provinces of Battambang, Banteay Meanchey, and Siem Reap provinces in the northwestern part of the country and was connected to the Thai grid.

In 2015, these two high-voltage grids were connected to the adjacent state grids, evolving into a countrywide grid by 2021. Today, 500 kV, 230 kV, and 115 kV transmission lines have been installed in various regions of the country.




Nite: Including construction and under planning.

Source: EAC, Salient Feature of the Power Sector for 2024.

**Figure 1.2.1 Cambodia domestic power transmission system diagram (as of 2024)**

(5) Domestic Grid Development Plans

In Cambodia's PDP, a transmission development plan through 2040 has been developed. Based on this development plan, a total of US$1.796 billion is required for the expansion of the transmission and distribution network from 2022 to 2040.

The development of this transmission and distribution network has three main objectives.

1. Develop a power transmission and distribution network so that all domestic power sources can be integrated into a single grid.
2. Control power supply based on time and season to meet power demand.
3. Transmits electricity through substations to cities, states, and other areas to deliver electricity to all customers.

The following table is to describe the development plan through 2029.

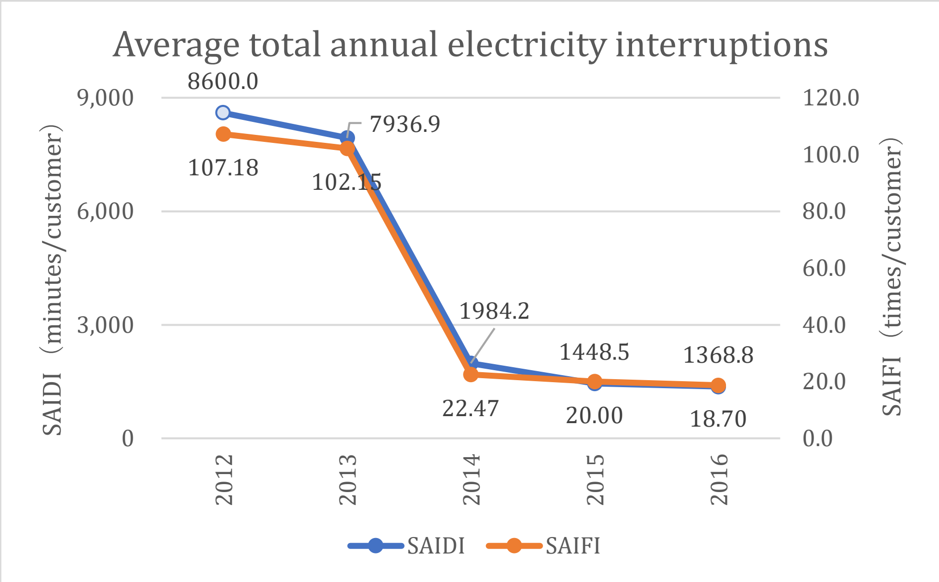
**Table 1.2.14 Cambodia's National Grid Development Plan to 2029 (as of 2024)**

| No. | Project Name | Voltage (kV) | Distance (km) |
|---|---|---|---|
| 1 | Kph Kong - Bek Chan Grid | 230 | 204.00 |
| 2 | Bek Chan Grid - Khsach Kandal Substation | 500 | 45.00 |
| 3 | East Phnom Penh - Laos Border Grid Substation | 500 | 300.00 |
| 4 | Lvea Em Grid Substation - Svay Antor Substation | 230 | 40.00 |
| 5 | Steung Trang - Baray Grid | 115 | 55.00 |
| 6 | Kampong Tralach Grid Substation - Kampong Chhnang 2nd Substation | 230 | 29.00 |
| 7 | Kampong Chhnang Grid Substation - Kampong Chhnang 2nd Substation | 230 | 15.00 |
| 8 | Kampong Chhnang 2nd Substation - New Krokor Substation | 230 | 65.00 |
| 9 | New Krokor Grid Substation - Pursat Substation | 230 | 29.00 |
| 10 | Pursat Grid Substation - Sang Ke Substation | 230 | 102.00 |
| 11 | Kampong Tralach Grid Substation - Mukkampoul Substation | 230 | 31.30 |
| 12 | Prek Prasob Grid Substation - Kratie Substation | 115 | 13.00 |
| 13 | Grid Between Stung Treng and Ratanakiri - Chong Phlas Substation | 230 | 72.00 |
| 14 | Phnom Prech - Memut - Suong Grid Substation | 230 | 108.00 |
| 15 | Ratanakiri Grid Substation - Prek La'ang Hydropower Plant | 230 | 77.00 |
| 16 | Ratanakiri Grid Substation - Sre Pok 3A Hydropower Plant | 230 | 26.00 |
| 17 | Ratanakiri Grid Substation - Sre Pok 4 Hydropower Plant - Sre Pok 3A Hydropower Plant | 230 | 100.00 |

Source: EAC, Salient Feature of the Power Sector for 2024.

(6) Supply Reliability

Supply reliability in Cambodia has improved since 2012 due to an increased generation capacity. The average duration of outages (SAIDI) improved 1,984.2 minutes/customer in 2014 to 1,368.8 minutes/customer in 2015. The average number of outages (SAIFI) improved from 22.47 times/customer to 18.7 times/customer.




Source: MME, Cambodia Basic Energy Plan_2019.

**Figure 1.2.2 Supply Reliability in Cambodia**

1.2.5 Status of Existing International Interconnection Lines

As for the international interconnection line with Thailand, a 115 kV transmission line was established in 2007 from the Aranya Prathet substation in Thailand to three areas in Cambodia: Banteay Meanchey, Battambang, and Siem Reap. In addition, under an agreement with Trat Province (Thailand), a 22 kV transmission line has been installed to connect Koh Kong Province and Poi Pet in Cambodia.

As for the international interconnection line with Vietnam, Électricité du Cambodge (EDC) began importing electricity from Vietnam via a 330 kV transmission line in March 2009 to supply power to Phnom Den, Takeo Province, and Phnom Penh. Since 2002, EDC has also imported electricity from PC2 (Vietnam) to supply Kampong Cham Province, Svay Rieng Province, Kampot Province, Kandal Province, Kratie Province, Mondulkiri Kampong Cham Province, Svay Rieng Province, Kampot Province, Kandal Province, Kratie Province, Mondulkiri Province and Svay Rieng Province.

As for the international interconnection lines with Laos, a 22 kV transmission line to Stung Treng (Cambodia) was established in 2010. In 2015, a new interconnection line was installed from Ban Hat Substation (Laos) to Preah Vihear Province in Cambodia.

The ASEAN Interconnection Masterplan Study (AIMS) III Phase 1 & 2 Update, published in August 2023, outlines the status of cross-border interconnections as of 2022, as well as projections for interconnection development under three scenarios for 2025 and 2040: the Updated Power Development Plan (Updated PDP), the ASEAN Renewable Energy Target Case (ASEAN RE Target), and the High Renewable Energy Target (High RE Target). For Cambodia, the outlook for cross-border interconnections is presented as follows.

**Table 1.2.15 Status and Outlook of Cross-Border Interconnections in Cambodia (MW)**

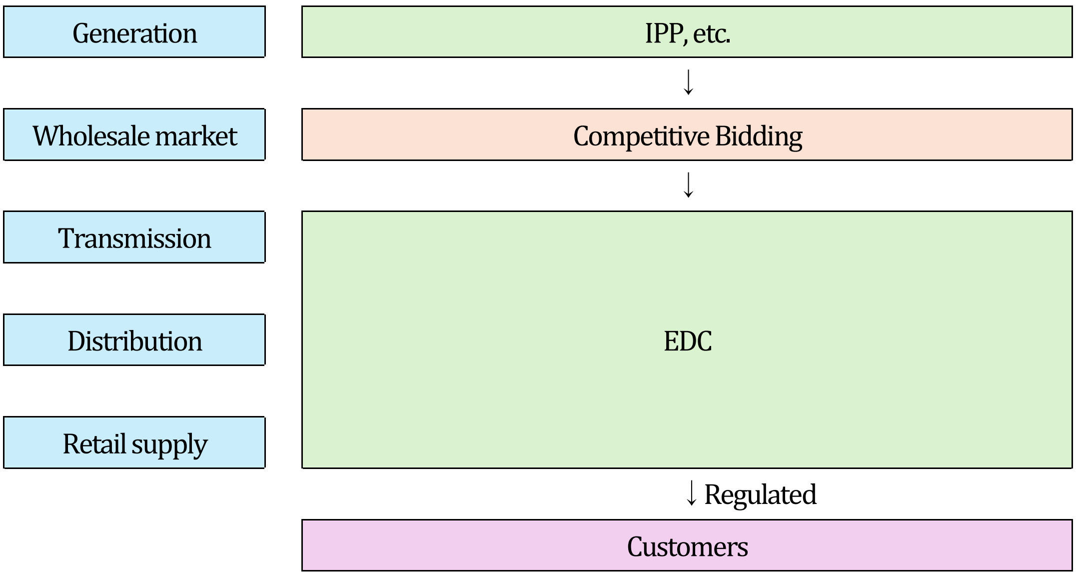
| AIMS No. | International interconnection line (country-to-country) | Proposed ASEAN Interconnection Projects from the AIMS III study (by the Year) | | | | | |
|---|---|---|---|---|---|---|---|
| | | Base Case (Existing PDP) | | Optimum Case | | ASEAN RE Target Case | |
| | | 2025 | 2040 | 2025 | 2040 | 2025 | 2040 |
| 12 | Vietnam - Cambodia | 200 | 200 | 329 | 1,312 | 328 | 1,353 |
| 13 | Lao PDR - Cambodia | 300 | 300 | 300 | 579 | 306 | 625 |
| 14 | Thailand - Cambodia | 230 | 230 | 351 | 1,370 | 351 | 1,315 |

Source: ACE, (2023), Findings of ASEAN Interconnection Masterplan Study (AIMS) III Phase 1 & 2 Update.

### 1.2.6 Trends in Electricity and International Electricity Markets

#### (1) Electric Utility System

In Cambodia, EDCs and independent power producers (IPPs) generate electricity, and EDCs are generally responsible for transmission and distribution. IPP sells the electricity to EDCs and EDCs are responsible for most retail supply to consumers. For these reasons, the retail electricity market has not been deregulated and under regulatory control. To provide electricity services, operators are required to obtain a license issued by the Electricity Authority of Cambodia (EAC) in accordance with the “Electricity Law (enacted in February 2001)”. Some private operators hold licenses for power distribution and retail business, but the number of issued licenses are limited.




Source: Compiled by JICA Team

**Figure 1.2.3 Electricity Business Structure in Cambodia**

(2) Electric Utility Regulations

The Electricity Law of Cambodia defines the roles of the Ministry of Mines and Energy (MME) and the EAC as follows, respectively

- MME: Development and management of national policies, strategies and plans in the power sector.
- EAC: Guarantee of efficiency, quality, sustainability, and transparency in the provision of electricity services and use of electricity.

The MME decides a direction for Cambodia's power sector and also sets technical standards in the power sector. The EAC monitors and guides both suppliers and customers in the power sector by issuing rules and regulations in line with the policies, guidelines, and technical standards set by the MME. The specific roles of the EAC are

A) Issue, modify, suspend, revoke, or deny licenses for electric service.
B) Approve power service rates and fees, terms and conditions.
C) Develop regulations and standards for license holders' investment plans.
D) Critique the financial activities and organizational structure of the license holder.
E) Approve the license holder's performance standards.
F) Evaluate and resolve consumer complaints and contract disputes with license holders and license violations.
G) Approve uniform accounting rules for all license holders.
H) Prepare and publish a report on the power and related information received from the license holder.
I) Defines the fees applicable to license holders.
J) Establish procedures for public disclosure to the public.
K) Issue appropriate temporary and permanent orders for electric power services in accordance with the stipulated regulations and other rules.
L) Impose fines and suspend power supply or licenses to operators who violate the standards set by the Electricity Law and the EAC.
M) Require electricity service providers and consumers to comply with national energy security, economic, environmental, and other national policy regulations.
N) Assume any other role incidental or consequential to the above duties.
O) Establish terms and conditions of employment for officers or employees, including EAC professionals/consultants.

(3) Major Electric Utility

Prior to October 1958, electricity in Cambodia was provided by three private operators: the Water and Electricity Company (CEE: Compagnie des Eaux et Electricité), the Union d'Electricité d'Indochine (UNEDI: Union d'Electricité d' Indochine), and the French-Cambodian Electricity Company (CFKE: Compagnie Franco-Khmère d'Electricité). After mergers and transfers, EDC was reorganized under the jurisdiction of MME in 1993, and in March 1996, ED became a state-owned limited company that generates, transmits, and distributes electricity throughout Cambodia.

The "Electricity Law" enacted in February 2001 liberalized the power generation and distribution business, resulting in a rapid increase in IPPs. For example, IPP generated 13,332 GWh (97.9%) of the total 13,614 GWh in 2023.

(4) Electricity Trading Environment with Foreign Operators and Domestic Market

As mentioned above, Cambodia imports electricity from Thailand, Vietnam, and Laos. Among them, in Vietnam, MME has concluded a power trading agreement with the Ministry of Industry of Vietnam. Based on this agreement, EDC has concluded a power purchase agreement with Vietnam Electricity (EVN).

Some private companies have obtained the right from MME to purchase electricity from the Provincial Electricity Authority (PEA) of Thailand. 22kV imported electricity costs are based on PEA's Time of Use (TOU) rates and vary depending on usage conditions. The cost of electricity imported by EDC at 115 kV has different tariff structure than the electricity cost mentioned above.

1.3 Indonesia

1.3.1 Policies for the Energy and Electricity Sector

(1) Climate Change Targets

In 2021, Indonesia announced its long-term goal of achieving carbon neutrality by 2060. In the medium term, the country set targets in its enhanced NDC submitted in 2022 to reduce greenhouse gas emissions by 31.89% without international support and by 43.2% with international support by 2030.

(2) Energy and Electricity Policy

Indonesia's basic policy in the energy sector is first defined by the National Energy Policy (KEN: Kebijakan Energi Nasional). Based on KEN, the Ministry of Energy and Mineral Resources (MEMR) then develops the National Electricity General Plan (RUKN) for the power sector. The latest RUKN2024, published in November 2024, outlines the country's power demand and supply projections, as well as the development plan for the national power supply system, all in line with Indonesia's goal of achieving carbon neutrality by 2060. The key points are as follows:

1. Electricity demand in Indonesia is projected to increase from around 482 TWh in 2024 to around 1,813 TWh by 2060. The demand in 2060 consists of 28% residential, 13% commercial, 5% public, 43% industrial, and 11% electric vehicles.
2. The total installed capacity in 2060 is estimated to be around 443 GW, with 41.6% being variable renewable energy (VRE) sources, including 34 GW of storage, and 58.4% being dispatchable non-VRE generation.
3. Electricity generation in 2060 is expected to reach around 1,947 TWh, with 73.6% coming from new and renewable energy sources (24.1% new energy, 49.5% renewable energy), and 26.4% from fossil fuels with carbon capture and storage (CCS).
4. The government plans to accelerate the construction of wind and solar power, as well as develop large-scale geothermal and hydropower projects.
5. The government plans to promote the specific projects include a hydropower plant in Papua, a solar power plant in East Nusa Tenggara, a nuclear power plant in West Kalimantan, and the production of green hydrogen.
6. Existing coal-fired power plants will be retrofitted to use 100% green ammonia or biomass co-firing with CCS, while gas turbines will be converted to use 100% green hydrogen or gas with CCS.
7. The construction of new coal-fired power plants will be restricted.
8. The electricity transmission network will be expanded, with the following interconnection plans:
    a. Within-island interconnections:
        1) Sumatra,
        2) Sulawesi
        3) Kalimantan
        4) Papua
    b. Inter - island interconnections:
        1) Sumatra-Batam by 2028
        2) Java-Bali by 2029
        3) Sumatra-Java by 2031
        4) Bali-Lombok-Sumbawa by 2035
        5) Java-Kalimantan by 2040
        6) Sumbawa-Flores, Kalimantan-Sulawesi by 2041
        7) Sumba-Sumbawa-Sulawesi by 2045

Based on the RUKN (Electricity Supply Business Plan), the state-owned electricity company of Indonesia (PLN: Perushaan Listrik Negara) has developed a 10-year detailed Electricity Supply Business Plan (RUPTL: Rencana Usaha Penyediaan Tenaga Listrk). The latest version as of March 2025 is the RUPTL 2021-2030, which was published in 2021. The key points are as follows:

1. The average electricity demand growth rate is projected to be 4.9% over the next 10 years until 2030.
2. The share of renewable energy in the energy mix is targeted to be increased to 24.8% by 2030.
3. A total of 40.6 GW of new power generation capacity will be added by 2030, with 20.9 GW (around 51.6%) coming from renewable energy sources.
4. 47,700 km of new transmission lines will be constructed between 2021 and 2030.
5. Private sector participation in new power generation projects is encouraged. Around 64.8% of new power generation projects will be developed by the private sector, with 56.3% of those being in the renewable energy sector.

### 1.3.2 Current and Projected Energy and Electricity Supply and Demand

#### (1) Current Energy Supply and Demand

##### 1) Domestic energy production

Indonesia has abundant domestic production of coal, crude oil, and natural gas, with an energy self-sufficiency rate of 187% in 2022. As primary energy supplies have increased in recent years, the energy self-sufficiency rate has declined by about 24 percentage points from 211% in 2015 to 2022, but the country still has a high self-sufficiency rate. As of 2022, the self-sufficiency rate for coal was 357%, oil 66%, and gas is 150%, meaning that the country has abundant resources especially coal and natural gas.

**Table 1.3.1 Domestic Energy Production in Indonesia (Unit: ktoe)**

| | Coal | Crude Oil | Natural Gas | Nuclear | Hydro | Renewable Energy | Total |
|---|---|---|---|---|---|---|---|
| 1990 | 5,847 | 74,590 | 42,136 | 0 | 491 | 31,529 | 154,592 |
| 1995 | 23,893 | 81,838 | 57,146 | 0 | 647 | 35,052 | 198,576 |
| 2000 | 45,455 | 71,596 | 61,164 | 0 | 861 | 29,332 | 208,408 |
| 2005 | 98,231 | 53,445 | 65,580 | 0 | 922 | 29,757 | 247,935 |
| 2010 | 186,314 | 48,443 | 74,807 | 0 | 1,501 | 33,518 | 344,583 |
| 2015 | 243,710 | 40,444 | 65,488 | 0 | 1,182 | 31,893 | 382,716 |
| 2020 | 296,709 | 36,261 | 51,194 | 0 | 2,092 | 50,848 | 437,103 |
| 2022 | 356,156 | 31,577 | 49,630 | 0 | 2,347 | 58,514 | 498,223 |

Source: IEA, World Energy Balances 2024_04.

2) Primary energy supply

In Indonesia, primary energy supply is also increasing in line with the increase in final energy consumption. In particular, the growth rate of coal is outstandingly high, increasing 8.3 times in 2022 compared to 2000, and 3.1 times compared to 2010.

**Table 1.3.2 Primary Energy Supply in Indonesia (Unit ktoe)**

| | Coal | Crude Oil | Petroleum Products | Natural Gas | Nuclear | Hydro | Renewable Energy | Electric Power | Total |
|---|---|---|---|---|---|---|---|---|---|
| 1990 | 3,549 | 42,262 | -8,916 | 15,818 | 0 | 491 | 31,479 | 0 | 84,682 |
| 1995 | 6,330 | 51,094 | -3,473 | 25,342 | 0 | 647 | 34,947 | 0 | 114,887 |
| 2000 | 12,009 | 54,205 | 3,661 | 26,565 | 0 | 861 | 29,274 | 0 | 126,575 |
| 2005 | 22,127 | 50,278 | 14,904 | 29,273 | 0 | 922 | 29,637 | 0 | 147,141 |
| 2010 | 31,839 | 52,293 | 15,098 | 38,823 | 0 | 1,501 | 32,928 | 0 | 172,483 |
| 2015 | 39,691 | 49,949 | 21,299 | 37,865 | 0 | 1,182 | 31,290 | 1 | 181,277 |
| 2020 | 68,333 | 49,273 | 18,328 | 34,101 | 0 | 2,092 | 50,435 | 134 | 222,694 |
| 2022 | 99,836 | 48,177 | 25,189 | 33,102 | 0 | 2,347 | 57,784 | 69 | 266,503 |

Source: IEA, World Energy Balances 2024_04.

3) Final energy consumption

In Indonesia, industrial final energy consumption accounts for 46% of total energy consumption, transportation 32%, residential 13%, and non-energy use 4%. Compared to final energy consumption in 2010, industrial consumption increased 64%, transportation increased 87%, and commercial increased by 63%. On the other hand, energy consumption in agriculture, forestry, and fisheries declined by 54% compared to 2010, possibly due to a decrease in the share of primary industries as industrialization progressed.

**Table 1.3.3 Final Energy Consumption in Indonesia (in ktoe)**

| | Industry | Transportation | Commercial | Agricultural, Forestry and Fisheries | Residential | Other | Non-energy use | Total |
|---|---|---|---|---|---|---|---|---|
| 1990 | 17,440 | 10,712 | 797 | 991 | 19,499 | 246 | 7,355 | 57,041 |
| 1995 | 25,380 | 16,374 | 1,706 | 1,551 | 20,956 | 327 | 7,392 | 73,686 |
| 2000 | 30,032 | 20,845 | 2,887 | 2,880 | 23,634 | 950 | 9,807 | 91,035 |
| 2005 | 35,392 | 23,419 | 3,670 | 3,013 | 23,465 | 705 | 10,950 | 100,615 |
| 2010 | 49,082 | 30,143 | 4,264 | 2,125 | 20,553 | 531 | 10,146 | 116,846 |
| 2015 | 45,452 | 44,796 | 5,497 | 2,232 | 20,628 | 229 | 7,086 | 125,919 |
| 2020 | 55,840 | 48,104 | 6,037 | 930 | 22,585 | 410 | 7,856 | 141,762 |
| 2022 | 80,624 | 56,438 | 6,935 | 983 | 22,521 | 655 | 6,546 | 174,702 |

Source: IEA, World Energy Balances 2024_04.

(2) Current Electricity Supply and Demand

1) Electricity generation

In Indonesia, the total electricity generation was 350.6 TWh in 2023 with 62% caming from coal-fired power, 1% from natural gas, 17% from gas turbines and other sources, 2% from diesel, 7% from hydroelectric power, and 12% from renewable energy. Compared to 2000, coal-fired power generation has increased 6.4 times, while oil and gas power generation has decreased. The renewable energy generation has also increased significantly, 8.3 times compared to 2000, mostly due to the growth in geothermal and biomass power generation.

**Table 1.3.4 Electricity Generation in Indonesia (Unit: GWh)**

| | Coal | Petroleum | Natural Gas | Gas turbines, etc. | Diesel | Hydro | Renewable Energy | Total |
|---|---|---|---|---|---|---|---|---|
| 2000 | 34,002 | 6,055 | 3,598 | 28,331 | 6,449 | 10,016 | 4,875 | 93,326 |
| 2005 | 51,793 | 8,180 | 838 | 40,250 | 8,959 | 10,725 | 6,626 | 127,371 |
| 2010 | 68,477 | 6,712 | 1,108 | 54,282 | 12,295 | 17,456 | 9,457 | 169,787 |
| 2015 | 124,657 | 11,419 | 260 | 53,876 | 19,492 | 13,741 | 10,537 | 233,982 |
| 2020 | 180,880 | 34 | 1,432 | 49,844 | 6,730 | 24,325 | 28,580 | 291,825 |
| 2023 | 217,819 | 76 | 1,852 | 59,154 | 6,482 | 24,590 | 40,635 | 350,608 |

Note1: Coal includes mixed combustion.

Note2: Gas turbine and others include gas combined and gas engine.

Note3: Renewable energy includes geothermal, wind, solar, biomass, biogas, and waste power generation.

Source: MEMR, Handbook of Energy & Economic Statistics of Indonesia 2012,2023

2) Exported, imported and lost electricity etc.

As of 2023, the total imported electricity was about 0.9 TWh, but no exports were implemented. Compared to 2010, the total electricity supply has increased by 90% while the imported electricity has increased by 446 times.

**Table 1.3.5 Imported and Exported Electricity, Transmission and Distribution Losses in Indonesia (Unit: GWh)**

| | Electricity Generation | Imported Electricity | Exported Electricity | Power Supply | Transmission and Distribution Losses, etc. | Domestic Electricity Consumption |
|---|---|---|---|---|---|---|
| 2010 | 169,787 | 2 | 0 | 169,789 | 22,491 | 147,298 |
| 2015 | 233,982 | 13 | 0 | 233,995 | 31,150 | 202,845 |
| 2020 | 274,851 | 1,553 | 0 | 276,404 | 15,842 | 260,562 |
| 2023 | 323,320 | 893 | 0 | 324,213 | 8,488 | 315,725 |

Source: MEMR, Handbook of energy and economic statistics Indonesia 2020,2023

3) Electricity consumption

The electricity Consumption was 316TWh in 2023 with 37 accounting for industrial consumption 395 for residential consumption, 24% for commercial consumption, and 0.1% for transportation consumption. Compared to 2010, industrial consumption was 2.2 times higher, residential consumption was 2.0 times higher, commercial consumption was 2.1 times higher, and transportation consumption was 4.3 times higher.

**Table 1.3.6 Electricity Consumption in Indonesia (Unit: GWh)**

| | Industry | Residential | Commercial | Transportation | Total |
|---|---|---|---|---|---|
| 2000 | 34,013 | 30,563 | 14,588 | 44 | 79,208 |
| 2005 | 42,448 | 41,184 | 23,400 | 55 | 107,087 |
| 2010 | 50,985 | 59,825 | 36,399 | 89 | 147,298 |
| 2015 | 64,079 | 88,682 | 49,879 | 205 | 202,845 |
| 2020 | 89,133 | 112,235 | 58,902 | 292 | 260,562 |
| 2023 | 115,341 | 122,824 | 77,176 | 384 | 315,725 |

Source: MEMR, Handbook of Energy & Economic Statistics of Indonesia 2010, 2012, 2023)

(3) Renewable Energy Potential

Indonesia has the largest land area among ASEAN countries; however, as an archipelago with extensive forest areas, its total renewable energy potential is 3,674.0 GW, making it the largest except Myanmar. Indonesia has the largest potential among ASEAN countries for offshore wind power (589.0 GW), biomass power (43.3 GW), hydropower (94.6 GW), and geothermal power (29.5 GW).

**Table 1.3.7 Renewable Energy Potential in Indonesia (Unit: GW)**

| Solar PV | Onshore wind | Offshore wind | Biomass | Hydro | Geothermal | Total |
|---|---|---|---|---|---|---|
| 2,898.0 | 19.6 | 589.0 | 43.3 | 94.6 | 29.5 | 3,674.0 |

Source: IRENA & ACE; Renewable Energy Outlook for ASEAN, (2022).

(4) Energy Demand Forecasts

Official data on power generation facilities in Indonesia has not been publicly released

(5) Electricity Demand Forecasts

The RUPTL 2021-2030 plan includes two scenarios for electricity demand projections up to 2030. The "realistic" scenario assumes that economic activity and electricity demand will take time to recover from the impact of the COVID-19 pandemic. The "optimistic" scenario assumes a faster recovery. In the optimistic scenario, electricity demand is projected to increase from 256 TWh in 2021 to 409 TWh by 2030. In the realistic scenario, demand is projected to increase from 253 TWh in 2021 to 390 TWh by 2030.

**Table 1.3.8 Projected Electricity Demand in 2030 (Unit: TWh)**

| | 2021 | 2025 | 2030 |
|---|---|---|---|
| Optimistic Scenario | 256 | 322 | 409 |
| Realistic Scenario | 253 | 311 | 390 |

Source: PLN, RUPTL 2021-30

1.3.3 Actual Situation of Electricity Import/Export

As of March 2025, Indonesia's interconnections with other countries exist only between Indonesia and Malaysia. In 2016, an interconnection line was commissioned connecting West Kalimantan province in Indonesia and Sarawak state in Malaysia. This has enabled electricity trading between Indonesia's PLN and Malaysia's Sarawak Energy Berhad (SEB). The volume of electricity imported from Malaysia has increased from 693 GWh in 2016 to 1,553 GWh in 2020, but has since decreased to 893 GWh as of 2023.

**Table 1.3.9 Electricity Imports in Indonesia (Unit: GWh)**

| | Malaysia |
|---|---|
| 2010 | 2.2 |
| 2015 | 12.75 |
| 2016 | 692.7 |
| 2020 | 1553.00 |
| 2023 | 892.91 |

Source: MEMR, Handbook of energy and economic statistics Indonesia 2020,2023

### 1.3.4 Power Supply Development Plan, National Grid Development Plan

#### (1) Power Generation Facilities

In Indonesia, the installed capacity was 91 GW in 2023 with 55% from steam, 5% from diesel, 18% from combined cycle, 8% from gas, 7% from hydropower, and renewable energy. Compared to 2000, steam power has increased by 4.6 times, while diesel power has decreased by 59%. There has also been a remarkable increase in renewable energy generation, increasing12.8 times compared to 2000, and 5.6 times compared to 2010.

**Table 1.3.10 Power Generation Plants in Indonesia (Unit: MW)**

| | Steam Power | Diesel | Combined Cycle | Gas | Hydro | Renewable Energy | Total |
|---|---|---|---|---|---|---|---|
| 2000 | 10,672 | 11,223 | 6,863 | 3,805 | 4,199 | 525 | 37,287 |
| 2005 | 9,750 | 3,042 | 6,566 | 3,199 | 3,224 | 820 | 26,601 |
| 2010 | 12,982 | 4,570 | 7,590 | 3,914 | 3,734 | 1,193 | 33,983 |
| 2015 | 26,448 | 3,824 | 10,293 | 5,597 | 5,307 | 3,218 | 54,688 |
| 2020 | 36,668 | 4,867 | 12,236 | 8,526 | 6,121 | 4,333 | 72,751 |
| 2023 | 49,756 | 4,638 | 16,066 | 7,393 | 6,570 | 6,743 | 91,166 |

Note: Including off-grid

Source: Handbook of energy and economic statistics Indonesia 2012,2023.

#### (2) Power Generation Facility Plan

According to RUPTL 2021–2030, Indonesia's installed capacity is expected to reach 99.2 GW by 2030. The projected energy mix is as follows: Coal-fired power: 45.1%, Gas/oil/diesel: 25.8%, Hydropower: 15.7%, Geothermal: 5.8%, Other renewables: 4.7%, Solar power: 2.8%. Additionally, newly installed power sources will account for 40% of total capacity by 2030.

**Table 1.3.11 Power Generation Capacity Plan in Indonesia (Unit: MW)**

| | Classification | Coal | Gas/Oil /Disel | Hydro | Geothermal | Solar | Other Renewable | 計 |
|---|---|---|---|---|---|---|---|---|
| 2030 | New+ Existing | 44,726 | 25,613 | 15,565 | 5,798 | 4,680 | 2,827 | 99,209 |
| 2030 | Existing | 13,819 | 5,833 | 10,391 | 3,355 | 4,680 | 2,497 | 40,575 |

Source: PLN, RUPTL 2021-30

(3) Cost of Electricity

According to the AIMSIII Phase I Update report, the electricity generation cost in 2020 for Indonesia's Java region was 4.6 cents per kWh, for the Sumatra region it was 3.3 cents per kWh, and for the Kalimantan region it was 5.2 cents per kWh.

(4) Domestic Transmission System

Indonesia's power grid operates independently across different islands, including Java-Bali, Sumatra, Kalimantan, and Sulawesi. Within Sulawesi, the grid is divided into eastern and western regions, while in Kalimantan, it is split between the north and south. On Java Island, the main transmission network consists of two 500 kV transmission lines running along both the southern and northern coastal routes, connecting the eastern and western parts of the island. The voltage levels in the system are 500 kV, 275 kV, 150 kV, 70 kV, and 25 kV. Additionally, between 2020 and 2023, the transmission network was expanded by 26,357 km.

**Table 1.3.12 Transmission Facilities in Indonesia (as of 2023: Unit: km)**

| Length (km) | 25kV | 70kV | 150kV | 275kV | 500kV | total |
|---|---|---|---|---|---|---|
| Java, Bali | 97 | 2,996 | 17,031 | - | 6,794 | 26,919 |
| Sumatra | - | 671 | 17,557 | 4,240 | 400 | 22,869 |
| Kalimantan | - | 217 | 16,707 | 325 | - | 17,249 |
| Sulawesi Nusa Tenggara | 5 | 2,462 | 17,521 | 7 | - | 19,994 |
| Maluku Papua | - | 400 | 260 | - | - | 660 |
| total amount | 101 | 6,747 | 69,076 | 4,573 | 7,194 | 87,691 |

Source: PLN, STATISTIK PLN2023

**Table 1.3.13 Transmission Line Extension in Indonesia (Unit: km)**

| Year | 25kV | 70kV | 150kV | 275kV | 500kV | Total |
|---|---|---|---|---|---|---|
| 2020 | 101 | 5,656 | 46,680 | 3,648 | 5,250 | 61,334 |
| 2021 | 101 | 5,632 | 48,536 | 3,648 | 6,445 | 64,362 |
| 2022 | 101 | 5,910 | 51,396 | 3,828 | 6,971 | 68,206 |
| 2023 | 101 | 6,747 | 69,076 | 4,573 | 7,194 | 87,691 |

Source: PLN, STATISTIK PLN 2020-23

(5) Domestic Grid Development Plans

To accommodate growing electricity demand, Indonesia plans to expand its transmission network by 47,723 km between 2021 and 2030. Ongoing projects include the interconnection between Sumatra's power grid and surrounding island grids to supply affordable electricity from Sumatra to meet the increasing demand in these island regions. Additionally, to reduce power supply costs for Muna and Buton Islands, there is an ongoing project to first interconnect Muna and Buton, and then further connect them to Southeast Sulawesi's power grid.

**Table 1.3.14 Transmission Line Expansion Plan in Indonesia (2030)**

| Voltage | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 500kV | 2,211 | 552 | 440 | 28 | 1537 | 201 | 321 | 1268 | 207 | 1020 | 7,485 |
| 275kV | 676 | 236 | 1,867 | 275 | 280 | 40 | 1,010 | 0 | 0 | 0 | 4,384 |
| 150kV | 4,520 | 6,249 | 7,114 | 4,152 | 3,708 | 1,426 | 2,102 | 2,433 | 1,858 | 950 | 34,512 |
| 70kV | 284 | 253 | 0 | 0 | 132 | 241 | 10 | 0 | 52 | 70 | 1,042 |
| plan | 7,691 | 7,290 | 9,421 | 4,455 | 5,657 | 1,908 | 3,443 | 3,701 | 2,117 | 2,040 | 47,723 |

Source: PLN, RUPTL 2021-2030

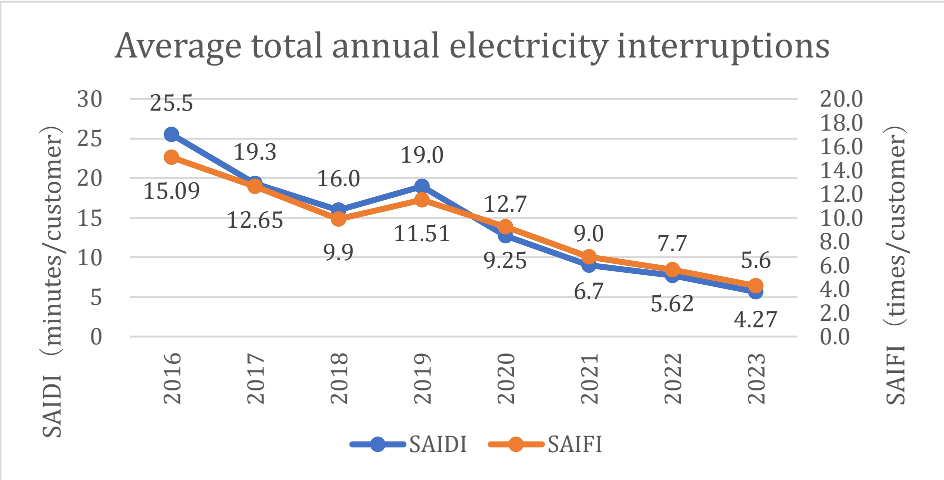
**Table 1.3.15 Major Domestic Grid Development Plans (as of 2021)**

| No. | Connected area | | Voltage (kV) | Opening year |
|---|---|---|---|---|
| 1 | Sumatra Island | Bangka Island | 150kV | 2022 |
| 2 | Sumatra Island | Bengkalis Island | 150kV | 2022 |
| 3 | Sumatra Island | Tebing Tinggi Island | 150kV | 2023 |
| 4 | Tebing Tingg Island | Karim Besar Island | 150kV | 2025 |
| 5 | Muna Island | Buton Island | 150kV | 2022 |
| 6 | Sulawesi Island | Muna Island | 150kV | 2026 |

Source: PLN, RUPTL 2021-2030

(6) Supply Reliability

Supply reliability in Indonesia has improved over the years. The average outage duration (SAIDI) decreased 25.5 minutes/customer in 2016 to 4.27/customer in 2023.The average number of outages (SAIFI) improved from 15.09/customer in 2016 to 5.64 minutes/customer in 2023.




Source: PLN, STATISTIK PLN 2016-2023

**Figure 1.3.1 Supply Reliability in Indonesia**

1.3.5 Status of Existing International Interconnection Lines

As mentioned earlier, Indonesia's power grid is only interconnected with that of Malaysia. In 2016, a 275 kV international interconnection transmission line was commissioned, linking West Kalimantan in Indonesia with Sarawak in Malaysia. Electricity trading is conducted between PLN (Indonesia's state-owned electricity company) and Sarawak Energy (SEB), the electricity provider in Sarawak.

The ASEAN Interconnection Masterplan Study (AIMS) III Phase 1 & 2 Update, published in August 2023, outlines the status of cross-border interconnections as of 2022, as well as projections for interconnection development under three scenarios for 2025 and 2040: the Updated Power Development Plan (Updated PDP), the ASEAN Renewable Energy Target Case (ASEAN RE Target), and the High Renewable Energy Target (High RE Target). For Indonesia, the outlook for cross-border interconnections is presented as follows.

Table 1.3.16 Status and Outlook of Cross-Border Interconnections in Indonesia (MW)

| AIMS No. | International interconnection line (country-to-country) | APG Status | Updated PDP | | ASEAN RE Target | | High RE Target | |
|---|---|---|---|---|---|---|---|---|
| | | 2022 | 2025 | 2040 | 2025 | 2040 | 2025 | 2040 |
| 4 | P. Malaysia - Sumatra | - | - | 2,000 | 1,067 | 2,130 | 10,000 | 10,000 |
| 5 | Batam - Singapore | - | - | - | - | - | - | - |
| 6 | Sarawak - Kalimantan | 230 | 230 | 830 | 230 | 777 | 230 | 769 |
| 15 | Sabah - Kalimantan | - | - | 200 | 158 | 174 | 1,126 | 4,319 |
| 16 | Sumatra - Singapore | - | - | 1,200 | 843 | 1,133 | 8,599 | 10,000 |
| 18 | Internal Indonesia | | | | | | | |
| | Java - Kalimantan | - | - | - | 9 | 435 | 477 | 477 |
| | Sumatra - Java | - | - | 6,200 | 7,943 | 10,000 | 7,961 | 10,000 |

Source: ACE, (2023), Findings of ASEAN Interconnection Masterplan Study (AIMS) III Phase 1 & 2 Update.

### 1.3.6 Trends in Electricity and International Electricity Markets

#### (1) Electric Utility System

In Indonesia, the power generation sector is managed by the state-owned electricity company, PLN, and Independent Power Producers (IPPs). The entry of IPPs began in 1992, as the rapidly increasing electricity demand became difficult for PLN to handle alone. While PLN primarily oversees the transmission, distribution, and retail sectors, in regions not interconnected with PLN's power grid, off-grid electricity is supplied and sold by village cooperatives (KUD: Kooperasi Unit Desa).

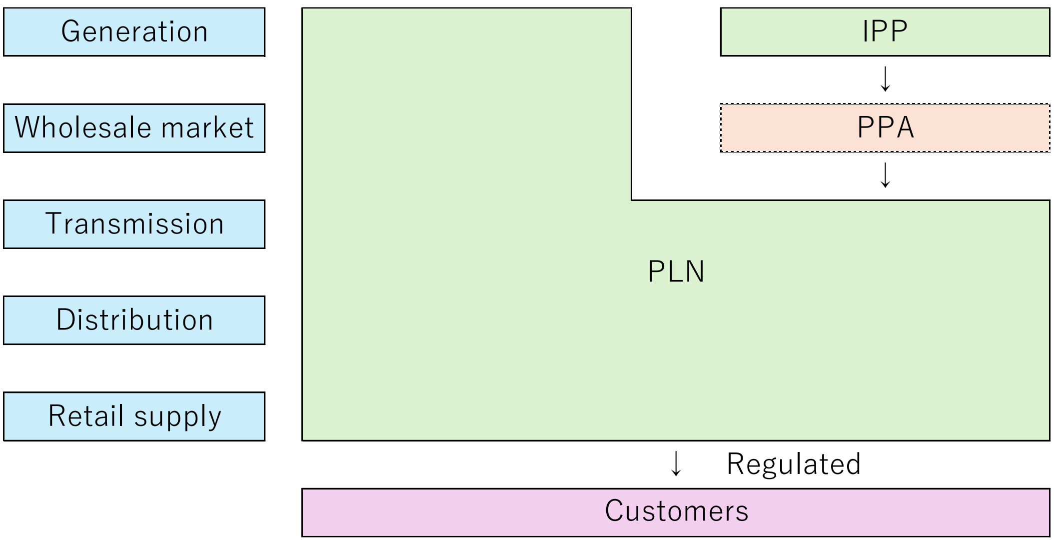



**Figure 1.3.2 Electricity Business Structure in Indonesia**

Source: Compiled by JICA Team

(2) Electric Utility Regulations

In Indonesia, the Ministry of Energy and Mineral Resources (MEMR: Ministry of Energy and Mineral Resources) is responsible for formulating electricity policy as well as regulating and supervising PLN and other related companies. The Ministry of Energy and Mineral Resources consists of four directorates (Directorate General of Electricity, Directorate General of Oil and Gas, Directorate General of Minerals and Coal, and Directorate General of New Energy, Renewable Energy, and Energy Conservation) and three agencies (Directorate General of Mineral Resources Education, Mineral Resources Research and Development Agency, and Geological Agency). In Indonesia, the Directorate General of Electricity regulates and supervises the electric power sector.

(3) Major Electric Utility

PLN is 100% owned by the government and is responsible for the supply of electricity in Indonesia through an integrated system of generation, transmission, distribution, and retail. The business operations are divided into three regions: (1) Sumatra, Kalimantan; (2) Java, Madura, and Bali; and (3) Sulawesi, Maluku, Papua, and Tenggara.

In the power generation sector, the entry of IPP businesses began in 1992, as it became difficult for PLN alone to meet the rapidly growing electricity demand in the late 1990s. In the power transmission and distribution and retail sectors, off-grid village cooperatives (KUDs) have been supplying and selling electricity in areas not linked to the PLN power system.

(4) Electricity Trading Environment with Foreign Operators and Domestic Market

As mentioned earlier, Indonesia engages in electricity trading only with Sarawak in Malaysia, and its electricity trade with foreign markets is considered limited.

## 1.4 Laos

### 1.4.1 Policies for the Energy and Electricity Sector

(1) Climate Change Targets

Laos has submitted its Nationally Determined Contribution (NDC) to the United Nations in 2021, outlining its plans to address greenhouse gas emissions. Laos has pledged to unconditionally reduce its greenhouse gas emissions by 60% by 2030. Additionally, Laos has set a conditional target of achieving net-zero emissions by 2050, provided that it receives support from developed countries..

(2) Energy and Electricity Policy

According to the National Power Development Strategy, 2022–2030 and the Ninth Five-Year Energy and Mines Development Plan 5, 2021–2025, the Ministry of Energy and Mines has set the following goals for the power sector:

1. Increase power supply efficiency by 75 % for hydropower, 14 % for thermal power plants, and 11 % for renewable energy; and meet the domestic demand and export target.
2. Develop transmission lines for domestic power supply and for export.
3. Improve distribution and services.
4. Expand the electrification rate to 98 % in rural areas by 2025.
5. Promote green energy usage in the transport sector by increasing the number of electric vehicles to 15 % of all cars in the country by 2025.
6. Promote energy savings and conservation by reducing energy consumption by 10 % by 2030

1.4.2 Current and Projected Energy and Electricity Supply and Demand

(1) Current Energy Supply and Demand

1) Domestic energy production

Laos has abundant domestic coal production, with an energy self-sufficiency rate of 149% in 2022. As of 2000, domestic energy production came from 78% renewable energy (biomass) and 18% from hydropower. However, with the start of operations at Hongsa Power Plant in 2015, coal production increased dramatically. As a result, in 2022, domestic energy production consisted of 47% coal, 36% hydropower, and 17% renewable energy (mainly biomass). In addition, in 2022, the energy self-sufficiency rate increased by 49 percentage points compared to 2000.

**Table 1.4.1 Domestic Energy Production in Laos (Unit：ktoe)**

| | Coal | Crude Oil | Natural Gas | Nuclear | Hydro | Renewable Energy | Total |
|---|---|---|---|---|---|---|---|
| 2000 | 58 | 0 | 0 | 0 | 296 | 1,260 | 1,614 |
| 2005 | 104 | 0 | 0 | 0 | 302 | 1,418 | 1,824 |
| 2010 | 247 | 0 | 0 | 0 | 726 | 1,670 | 2,643 |
| 2015 | 1,153 | 0 | 0 | 0 | 1,207 | 1,619 | 3,979 |
| 2020 | 3,497 | 0 | 0 | 0 | 2,452 | 1,603 | 7,551 |
| 2022 | 4,295 | 0 | 0 | 0 | 3,331 | 1,578 | 9,203 |

Source: IEA, World Energy Balances 2024_07.

2) Primary energy supply

In Laos, primary energy supply is also increasing in line with increasing final energy consumption. In particular, the increase in coal as primary energy supply is 412 times higher in 2022 than in 2000, following the start of operation at the Hongsa power plant. The growth rate of hydropower as a primary energy supply is about 11 times higher than in 2000.

**Table 1.4.2 Primary Energy Supply in Laos (Unit:ktoe)**

| | Coal | Crude Oil | Petroleum Products | Natural Gas | Nuclear | Hydro | Renewable Energy | Electric Power | Total |
|---|---|---|---|---|---|---|---|---|---|
| 2000 | 9 | 0 | 272 | 0 | 0 | 296 | 1,260 | -225 | 1,612 |
| 2005 | 31 | 0 | 344 | 0 | 0 | 302 | 1,418 | -187 | 1,907 |
| 2010 | 145 | 0 | 621 | 0 | 0 | 726 | 1,670 | -467 | 2,694 |
| 2015 | 1,153 | 0 | 935 | 0 | 0 | 1,207 | 1,619 | -817 | 4,097 |
| 2020 | 2,983 | 0 | 870 | 0 | 0 | 2,452 | 1,603 | -2,525 | 5,381 |
| 2022 | 3,708 | 0 | 907 | 0 | 0 | 3,331 | 1,578 | -3,361 | 6,161 |

Source: IEA, World Energy Balances 2024_07.

3) Final energy consumption

In Laos, industrial final energy consumption accounted for 28% of total energy consumption in 2022, with 24% accounting for transportation, 11% for commercial consumption , and 36% for residential consumption. Compared to 2010, industrial energy consumption increased by 179% in line with industrialization. In contrast, residential energy consumption increased by only 1% compared to 2010, suggesting that energy conservation and other measures may be having an effect.

**Table 1.4.3 Final Energy Consumption in Laos (Unit:ktoe)**

| | Industry | Transportation | Commercial | Agricultural, Forestry and Fisheries | Residential | Other | Non-energy use | Total |
|---|---|---|---|---|---|---|---|---|
| 2000 | 83 | 255 | 211 | 3 | 960 | 0 | 0 | 1,511 |
| 2005 | 111 | 330 | 242 | 3 | 1,093 | 0 | 0 | 1,779 |
| 2010 | 359 | 498 | 332 | 4 | 1,270 | 0 | 1 | 2,465 |
| 2015 | 631 | 769 | 351 | 3 | 1,254 | 0 | 3 | 3,011 |
| 2020 | 589 | 799 | 385 | 11 | 1,284 | 0 | 1 | 3,070 |
| 2022 | 1,000 | 843 | 406 | 10 | 1,285 | 0 | 1 | 3,544 |

Source: IEA, World Energy Balances 2024_07.

(2) Current Electricity Supply and Demand

1) Electricity generation

In 2021, Laos generated 56 TWh of electricity with 21.8% from coal-fired, 76.8% from hydropower, 1.3% from biofuels, and 0.2% from solar PV.

**Table 1.4.4 Electricity Generation in Laos (Unit: GWh)**

| | Coal | Other Fossil Fuels | Hydro | Biofuel | Solar | Total |
|---|---|---|---|---|---|---|
| 2021 | 12,200 | 0 | 43,083 | 703 | 95 | 56,081 |

Source: MEM, Country Update- Lao PDR.

2) Exported imported and lost electricity, etc.

In Laos, the imported electricity in 2018 was approximately 0.3 TWh, while the exported electricity was around 2.6 TWh. This means that exports accounted for about 80% of the country's total power generation. However, official electricity statistics for Laos have not been published in recent years, making it difficult to obtain accurate data.

**Table 1.4.5 Exported and Imported Electricity in Laos(Unit: GWh)**

| | Electricity Generation | Imported Electricity | Exported Electricity | Power Supply |
|---|---|---|---|---|
| 2016 | 2,642 | 787 | 1,538 | 1,891 |
| 2017 | 2,849 | 431 | 1,837 | 1,442 |
| 2018 | 3,182 | 301 | 2,630 | 852 |

Source: EDL, Annual Report 2018

3) Electricity consumption

The electricity consumption was 7.8 TWh in 2021 with 56% coming from industrial consumption, 30% from residential consumption, 9% from commercial consumption, and 4% from government consumption. Compared to 2010, industrial consumption increased by 8.8 times and residential consumption by 2.45 times, while commercial consumption only increased by 1.3 times.

**Table 1.4.6 Electricity Consumption in Laos (Unit: GWh)**

| | Industry | Residential | Trade | Government | Others | Total |
|---|---|---|---|---|---|---|
| 2010 | 495 | 942 | 584 | 145 | 60 | 2,228 |
| 2014 | 1,562 | 1,425 | 531 | 205 | 68 | 3,791 |
| 2021 | 4,333 | 2,310 | 731 | 280 | 124 | 7,779 |

Source: EDL-Gen, Opportunity Day Presentation 19 May 2022

(3) Renewable Energy Potential

Lao PDR has the seventh largest land area among ASEAN countries; however, due to its high solar irradiance, it has a relatively large solar PV potential of 983.0 GW. The total renewable energy potential is 1,022.2 GW, making it the sixth largest among ASEAN countries.

**Table 1.4.7 Renewable Energy Potential in Laos (Unit: GW)**

| Solar PV | Onshore wind | Offshore wind | Biomass | Hydro | Geothermal | Total |
|---|---|---|---|---|---|---|
| 983.0 | 11.9 | - | 1.2 | 26.0 | 0.1 | 1,022.2 |

Source: IRENA & ACE; Renewable Energy Outlook for ASEAN, (2022).

(4) Energy demand Forecasts

Public data on Laos's energy demand forecasts has not been released.

(5) Electricity demand Forecasts

The "National Power Development Strategy 2021-2023" developed by the Ministry of Energy and Mines (MEM) forecasts the country's domestic power demand up to 2030. The power demand projection includes three scenarios: a Business-as-Usual (BAU) case, an Electric Vehicle (EV) adoption case, and an Industrial (IN) demand growth case.The EV+IN case forecasts that power demand will increase from 1,406 MW in 2021 to 3,188 MW by 2030, approximately a 2.3-fold increase.

**Table 1.4.8 Power Demand Forecast in Laos (Unit: GW)**

| Year | BAU | EV | IN | EV+IN |
|---|---|---|---|---|
| 2021 | 1,380 | 1,396 | 1,403 | 1,406 |
| 2025 | 1,902 | 2,012 | 2,030 | 2,134 |
| 2030 | 2,541 | 2,760 | 2,965 | 3,188 |

Source: MEM, Country Update-Lao PDR

1.4.3 Actual Situation of Electricity Import/Export

Laos imports electricity from Thailand, Vietnam, and China in areas where the power grid is underdeveloped. The government has so far positioned electricity as an important export good, and has been promoting power source development, mainly hydropower generation. Most of the electricity generated is exported to neighboring countries such as Thailand, Cambodia, and Myanmar. In recent years, Laos has ended its exports to Malaysia, with Thailand and Vietnam appearing to be the primary export destinations.

**Table 1.4.9 Electricity Imports from Laos (Unit: GWh)**

| | Thailand | Vietnam | China | total |
|---|---|---|---|---|
| 2018 | 261 | 26 | 14 | 301 |

Source: Japan Electric Power Information Center, Inc. (JEPIC), Electricity in Overseas Countries, Lao People's Democratic Republic (2023))

**Table 1.4.10 Electricity Exports from Laos (Unit: GWh)**

| | Thailand | Cambodia | Myanmar | Malaysia | total |
|---|---|---|---|---|---|
| 2018 | 2,550 | 60 | 1 | 20 | 2,631 |

Source: Japan Electric Power Information Center, Inc. (JEPIC), Electricity in Overseas Countries, Lao People's Democratic Republic (2023)

1.4.4 Power Supply Development Plan, National Grid Development Plan

(1) Power Generation Facilities

In 2021, Laos had a total power generation capacity of approximately 11 GW, with hydropower accounting for 81%, coal for 17%, biomass for 1%, and solar for 0.5%. Of this, EDL-Generation, a subsidiary of Electricité du Laos (EDL), owned 1.7 GW (15%), while independent power producers (IPPs) owned 9.3 GW (85%), highlighting the significant dominance of IPPs in the country's power generation sector.

**Table 1.4.11 Power Generation Plants in Laos (Unit: MW)**

| | Hydro | Coal | Biomass | Solar | Total |
|---|---|---|---|---|---|
| 2021 | 8,910 | 1,878 | 112 | 56 | 10,956 |

Source: EDL-Gen, Opportunity Day Presentation 19 May 2022

**Table 1.4.12 Share of Owners of Power Generation Plants in Laos (Unit : MW)**

| | EDL-Gen | IPP | Total |
|---|---|---|---|
| 2021 | 1,683 | 9,273 | 10,956 |

Source: EDL-Gen, Opportunity Day Presentation 19 May 2022

In 2021, EDL-Generation had a total power generation capacity of approximately 1.7 GW, with 42% coming from its own facilities and 58% from equity investments in IPPs. Among investments in IPPs, the Electricity Generating Authority of Thailand (EGAT) accounted for 42%, EDL's power generation division for 13%, and Électricité du Cambodge (EDC) for 3%.

**Table 1.4.13 Share of power generation plants owned by EDL-Gen and its investments in IPPs (Unit: MW)**

| | EDL-Gen | IPPs | | | Total |
|---|---|---|---|---|---|
| | | EGAT | EDL (Power Generation division) | EDC(Cambodia) | |
| 2021 | 699 | 705 | 227 | 52 | 1,683 |

Source: EDL-Gen, Opportunity Day Presentation 19 May 2022

(2) Power Generation Facility Plan

The overall electricity generation capacity plan for Laos has not been publicly disclosed. However, EDL-Generation, the state-owned power company, plans to expand its generation capacity from 2021 to 2030 by around 2,452 MW. The total electricity generation capacity in Laos is expected to increase by approximately 46% between 2021 and 2030. Of this, the capacity of EDL-Generation is projected to grow by 39%, while the capacity of independent power producers (IPPs) is expected to increase by 50%.

**Table 1.4.14 Planned Generation Plants in EDL-Generation (Unit: MW)**

| | EDL-Gen | IPPs |
|---|---|---|
| 2021 | 699 | 984 |
| 2030 | 974 | 1,478 |

Source: EDL-Gen, Opportunity Day Presentation 19 May 2022

(3) Cost of Electricity

According to the AIMSIII Phase I Update report, Lao PDR's electricity generation cost in 2020 was 0.1 cents per kWh.

(4) Domestic Transmission System

In Laos, there are 230kV, 115kV, and 22kV transmission lines installed.

**Table 1.4.15 Transmission and Substation Plants in Laos (Unit: km)**

| Voltage | Substation | Length (cct-Km) |
|---|---|---|
| 230/115/22kV | 14 | 2,726 |
| 115kV/22kV | 67 | 8,133 |
| Total | 81 | 10,859 |

Source: MEM, Country Update-Lao PDR

Note: The green lines represent power transmission lines that are used exclusively for exports, while the orange lines represent the domestic power grid.

Source: ERIA, A Resilient Power System and Power Market in Lao PDR

**Figure 1.4.1 Domestic Transmission System Diagram in Laos (as of 2018)**

(5) Domestic Grid Development Plans

Public data on Laos's domestic grid development plans has not been released.

(6) Supply Reliability

Public data on Laos's supply reliability has not been released.

1.4.5 Status of Existing International Interconnection Lines

The ASEAN Interconnection Masterplan Study (AIMS) III Phase 1 & 2 Update, published in August 2023, outlines the status of cross-border interconnections as of 2022, as well as projections for interconnection development under three scenarios for 2025 and 2040: the Updated Power Development Plan (Updated PDP), the ASEAN Renewable Energy Target Case (ASEAN RE Target), and the High Renewable Energy Target (High RE Target). For Laos, the outlook for cross-border interconnections is presented as follows.

**Table 1.4.16 Status and Outlook of Cross-Border Interconnections in Laos (MW)**

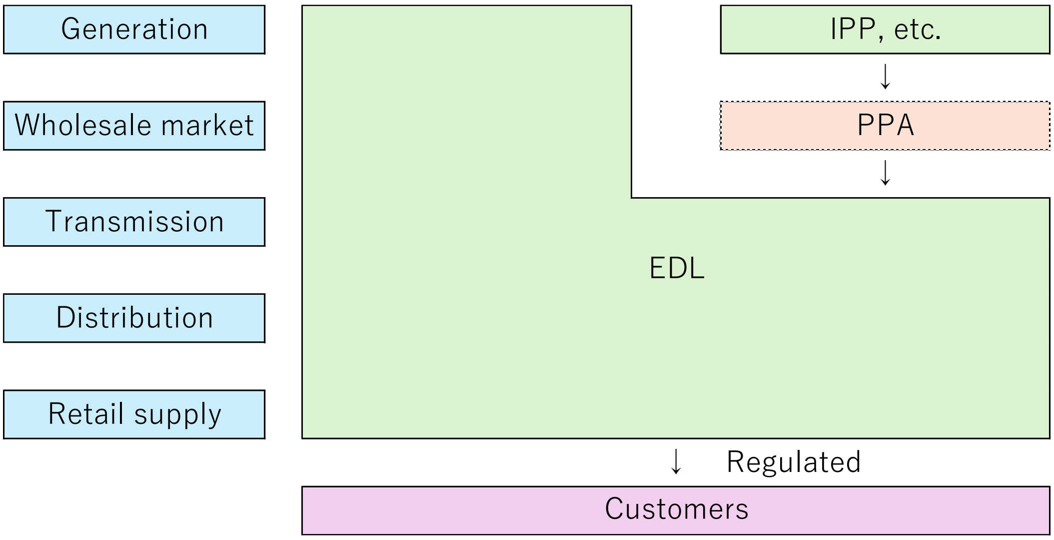
| AIMS No. | International interconnection line (country-to-country) | APG Status 2022 | Updated PDP | | ASEAN RE Target | | High RE Target | |
|---|---|---|---|---|---|---|---|---|
| | | | 2025 | 2040 | 2025 | 2040 | 2025 | 2040 |
| 9 | Thailand - Lao PDR | 700 | 900 | 1,300 | 700 | 700 | 5,298 | 5,630 |
| 10 | Lao PDR – Vietnam | 570 | 570 | 620 | 307 | 625 | 1,342 | 10,200 |
| 13 | Lao PDR - Cambodia | 200 | 300 | 500 | 306 | 625 | 300 | 820 |
| 17 | Lao PDR - Myanmar | - | 300 | 350 | 306 | 624 | 758 | 4,606 |

Source: ACE, (2023), Findings of ASEAN Interconnection Masterplan Study (AIMS) III Phase 1 & 2 Update.

1.4.6 Trends in Electricity and International Electricity Markets

(1) Electric Utility System

In Laos, the Électricité du Laos (EDL) is responsible for all aspects of power generation, transmission, and distribution, as well as retail. In 2010, EDL spin off its power generation division with a capacity of 5 MW or more, and establish a subsidiary, EDL-Generation. IPPs have also entered the power generation sector, which can be broadly classified into domestic supply and export. In areas not covered by the power grid, electricity is supplied by small hydropower and off-grid sources under the Provincial Department of Energy and Mines (PDEM).




Note: Electricity generation is primarily undertaken by EDL-Gen, whereas high-voltage transmission ( above 230 kV) is managed by EDL-T.

Source : Compiled by JICA Team

**Figure 1.4.2 Electric Utility System in Laos**

(2) Electric Utility Regulations

In Laos, the Ministry of Energy and Mines (MEM: Ministry of Energy and Mines) is responsible for energy policy and the energy and mining sector.

MEM has several important divisions, including the Department of Energy Policy and Planning (DEPP), which is in charge of energy policy and planning: the Department of Energy Management (DEM), which drafts energy laws, regulations, technical and safety standards, etc.; and the Department of Energy Business (DEB), which is in charge of private investment in the power generation sector.

In addition to the MEM, Other key agencies include the Ministry of Planning and Investment, which is responsible for regulating foreign investment in Laos and oversees contracts with IPPs, and the Ministry of Natural Resources and Environment (MONRE), which is responsible for formulating and implementing policies related to the environment, land, and natural resource management.

Electricity sector in Laos is regulated by the Law on Electricity in 1997. Since its enactment, the law has been revised in 2008, 2011, and 2017. The latest revision in 2017 includes new provisions for power generation development and the promotion of renewable energy.

(3) Major Electric Utilities

EDL (Electricite du Laos) was established in 1961. EDL had a monopoly in domestic power generation, but saw a shift in 2005 with the establishment of Lao Holding State Enterprise (LHSE). The entity invests in IPP companies and supplies electricity for export to the entity such as Electricity Generating Authority of Thailand (EGAT). In 2010, power generation division in EDL with a capacity of more than 5 MW was spun off to form a subsidiary, EDL-Generation.

In 2020, facing increasing fiscal challenges, EDL spun off its high-voltage transmission division and formed a joint venture with China Southern Power Grid. The resulting company, Electricite Du Laos Transmission Company Ltd. (EDL-T), is owned 90% by China Southern Power Grid and 10% by the Government of Laos.

(4) Electricity trading environment with foreign operators and domestic market

In regions of Laos where the transmission network remains underdeveloped, electricity is imported from neighboring countries such as Thailand, Vietnam, and China. Conversely, in recent years, the primary destinations for Lao electricity exports have included Thailand and Vietnam.

## 1.5 Malaysia

### 1.5.1 Policies for the Energy and Electricity Sector

(1) Climate Change Targets

Malaysia has committed to achieving carbon neutrality as a long-term goal for reducing greenhouse gas emission. The country has also submitted a medium-term goal to the United Nations to reduce its carbon intensity per unit of GDP by 45% from 2005 levels by 2030.

(2) Energy and Electricity Policy

In 2022, Malaysia announced the National Energy Policy, 2022-2040 (National Energy Policy, 2022-2040), outlining the Malaysian government's policy for the future energy transition. Subsequently in 2023, Malaysia released the "National Energy Transition Roadmap (NETR), which builds on the National Energy Policy by setting out specific targets and more specific actions for achieving carbon neutrality by 2050.

**Table 1.5.1 Major Targets of Efforts in NETR by 2050**

| Category | Target year | Contents |
|---|---|---|
| Energy Efficiency | 2040 | Achieve 21% energy savings compared to BAU (Business-as-Usual), 15% reduction for residential and 22% reduction for industrial/commercial use. |
| | 2050 | Achieve 22% energy savings compared to BAU, 20% reduction for residential use and 23% reduction for industrial/commercial use. |
| Renewable Energy | 2050 | Ensure that 70% of installed capacity coms from renewable energy.<br>Do not construct any new coal power plants |
| Hydrogen | 2050 | Completely eliminate the use of gray hydrogen as a raw material<br>Produce 2.5 Mtpa of green hydrogen using renewable energy sources such as hydropower and solar power. |
| Bioenergy | 2050 | Increase biofuel refining capacity to 3.5 billion liters<br>Increase installed capacity of biomass and biogas power to 1.4 GW |
| Green Mobility | 2030 | <Land transportation (heavy-duty vehicles)<br>Maintain target of increasing rail freight utilization to 5<br>Maintain biodiesel blending target at B30 (30%) |
| | 2050 | <Land transportation (passenger car)<br>Increase public transportation use to 60%.<br>Increase the penetration rate of EVs (including hybrids) to 80%<br>Increase the penetration rate of electric motorcycles to 80%<br>Strengthen EV manufacturing capacity in Malaysia and increase the local EV (including hybrid vehicles) manufacturing ratio to 90%.<br>Continue to improve fuel efficiency<br><Land transportation (heavy-duty vehicles)<br>Adopt new regional benchmarks for fuel efficiency.<br>Ensure that 5% of large vehicles use hydrogen.<br><Aviation><br>Achieve net-zero carbon emissions in international aviation (in line with ICAO's goals).<br>Mandate up to 47% blending of sustainable aviation fuel (SAF).<br><Shipping><br>Increase the share of low-carbon fuels in marine transportation to 40% |
| Carbon Capture, Utilization and Storage | 2030 | Develop three CCUS hubs: two in the Peninsula and one in Sarawak<br>Increase the total storage capacity up to 15Mtpa |
| | 2050 | Develop three carbon capture hubs<br>Increase the total storage capacity up to 40-80Mtpa |

Source: MOE, "National Energy Transition Roadmap."

### 1.5.2 Current and Projected Energy and Electricity Supply and Demand

#### (1) Current Energy Supply and Demand

##### 1) Domestic energy production

Malaysia is one of the world's leading producers of crude oil and natural gas. The country is the world's fifth largest exporter of natural gas as of 2023. Malaysia is also highly self-sufficient in energy, with an energy self-sufficiency rate of 97% in 2022. In Malaysia, crude oil production has been declining in recent years, while natural gas production has been slightly increasing. The Malaysian government has been promoting the introduction of renewable energy, and as a result, energy production from renewable energy has increased significantly in recent years.

**Table 1.5.2 Domestic Energy Production in Malaysia (Unit ktoe)**

| | Coal | Crude Oil | Natural Gas | Nuclear | Hydro | Renewable Energy | Total |
|---|---|---|---|---|---|---|---|
| 1990 | 70 | 30,629 | 15,487 | 0 | 343 | 1,208 | 47,737 |
| 1995 | 85 | 36,938 | 24,618 | 0 | 535 | 1,253 | 63,428 |
| 2000 | 242 | 32,280 | 42,560 | 0 | 599 | 1,267 | 76,948 |
| 2005 | 497 | 37,410 | 55,370 | 0 | 446 | 1,107 | 94,830 |
| 2010 | 1,511 | 34,404 | 51,009 | 0 | 556 | 912 | 88,392 |
| 2015 | 1,613 | 33,566 | 57,843 | 0 | 1,197 | 998 | 95,219 |
| 2020 | 1,878 | 28,732 | 55,471 | 0 | 2,347 | 1,537 | 89,964 |
| 2022 | 2,050 | 25,834 | 64,454 | 0 | 2,674 | 1,596 | 96,607 |

Source: IEA, "World Energy Balances 2024_07."

2) Primary energy supply

In Malaysia, natural gas accounted for the largest share of primary energy supply in 2022 at 47%. In addition, coal supply has increased significantly since the 2000s..The share of coal in the total primary energy supply rose from 5% in 2000 to 24% in 2022. Since 2015, the primary energy supply from hydropower generation has also increased significantly.

**Table 1.5.3 Primary Energy Supply in Malaysia (Unit ktoe)**

| | Coal | Crude Oil | Petroleu m Products | Natural Gas | Nuclear | Hydro | Renewab le Energy | Electric power | Total |
|---|---|---|---|---|---|---|---|---|---|
| 1990 | 1,355 | 10,025 | 1,452 | 6,801 | 0 | 343 | 1,230 | -5 | 21,201 |
| 1995 | 1,613 | 19,324 | -1,120 | 12,354 | 0 | 535 | 1,237 | -2 | 33,941 |
| 2000 | 2,308 | 22,581 | -3,179 | 24,729 | 0 | 599 | 1,250 | 0 | 48,287 |
| 2005 | 6,888 | 26,705 | -1,810 | 31,870 | 0 | 446 | 1,074 | -192 | 64,982 |
| 2010 | 14,601 | 24,924 | 407 | 31,195 | 0 | 556 | 817 | -13 | 72,487 |
| 2015 | 17,517 | 25,953 | 1,647 | 37,538 | 0 | 1,197 | 690 | 1 | 84,545 |
| 2020 | 24,820 | 25,145 | 1,809 | 36,594 | 0 | 2,347 | 1,405 | -134 | 91,986 |
| 2022 | 23,539 | 23,122 | 1,997 | 4,6844 | 0 | 2,674 | 1,419 | -119 | 99,475 |

Source: IEA, "World Energy Balances 2024_07."

3) Final energy consumption

In Malaysia, industrial final energy consumption accounted for 33% of total energy consumption in 2022, transportation energy consumption 32%, commercial energy consumption 8%, residential energy consumption 7%, and non-energy use 19%. Compared to 2010, overall energy consumption has increased by 42%, with residential energy consumption increasing by 51% and non-energy use increasing by approximately 3 times, while commercial energy consumption has only increased by 5%.

**Table 1.5.4 Final Energy Consumption in Malaysia (Unit: ktoe)**

| | Industry | Transportation | Commercial | Agricultural, Forestry and Fisheries | Residential | Other | Non-energy use | Total |
|---|---|---|---|---|---|---|---|---|
| 1990 | 5,549 | 4,882 | 791 | 0 | 1,331 | 0 | 838 | 13,391 |
| 1995 | 8,627 | 6,899 | 1,323 | 446 | 1,642 | 0 | 2,994 | 21,931 |
| 2000 | 11,732 | 10,811 | 2,214 | 104 | 1,984 | 0 | 2,250 | 29,095 |
| 2005 | 15,948 | 13,685 | 2,951 | 101 | 2,432 | 0 | 2,174 | 37,291 |
| 2010 | 14,924 | 14,927 | 4,296 | 1,073 | 2,824 | 0 | 3,696 | 41,741 |
| 2015 | 15,120 | 21,031 | 4,468 | 910 | 3,147 | 0 | 5,928 | 50,604 |
| 2020 | 17,448 | 17,733 | 4,038 | 867 | 4,085 | 0 | 11,805 | 55,976 |
| 2022 | 19,491 | 18,961 | 4,505 | 1,117 | 4,257 | 0 | 11,444 | 59,476 |

Source: IEA, "World Energy Balances 2024_07."

(2) Current Electricity Supply and Demand

1) Electricity generation

In Malysia, the total electricity generation was 187 TWh in 2022, with 47% coming from coal, 1% from oil, 34% from gas-fired power, 17% from hydroelectric power, and 2% from renewable energy. Compared to 2010, oil-fired power generation and gas-fired power generation decreased by 72% and 9%, respectively, while coal-fired power generation increased by approximately 2.0 times, hydro power generation by approximately 3.8 times, and renewable energy generation by approximately 2.4 times, indicating that the amount of renewable energy generation has increased in recent years.

**Table 1.5.5 Electricity Generation in Malaysia (Unit: GWh)**

| | Coal | Petroleum | Gas | Hydro | Renewable energy | Total |
|---|---|---|---|---|---|---|
| 2000 | 7,691 | 3,600 | 50,998 | 6,966 | 0 | 69,255 |
| 2005 | 19,991 | 2,203 | 55,287 | 5,191 | 1 | 82,673 |
| 2010 | 42,839 | 3,670 | 70,795 | 6,472 | 1,010 | 124,786 |
| 2015 | 63,474 | 1,739 | 69,962 | 13,924 | 1,024 | 150,123 |
| 2020 | 88,988 | 903 | 53,676 | 27,295 | 3,270 | 174,132 |
| 2022 | 87,584 | 1,013 | 64,180 | 31,101 | 3,420 | 187,299 |

Source: IEA, "World Energy Balances 2023_07."

2) Exported, imported and lost electricity, etc.

In Malaysia, the electricity imports in 2022 were 31 GWh, while exports were 1,416 GWh, exceeding the amounts of imports.

**Table 1.5.6 Exported, imported and lost electricity, etc.in Malaysia (Unit: GWh)**

| | Electricity Generation | Imported Electricity | Export Electricity | Power Supply | Transmission and distribution losses (etc.) | Domestic Electricity Consumption |
|---|---|---|---|---|---|---|
| 2000 | 69,255 | 1 | 0 | 69,256 | 8,051 | 61,205 |
| 2005 | 82,673 | 2 | 2233 | 80,442 | -313 | 80,755 |
| 2010 | 124,786 | 0 | 151 | 124,635 | 13,782 | 110,853 |
| 2015 | 150,123 | 13 | 3 | 150,133 | 17,581 | 132,552 |
| 2020 | 174,132 | 18 | 1572 | 172,579 | 20,448 | 152,131 |
| 2022 | 187,299 | 31 | 1416 | 185,914 | 21,687 | 164,228 |

Source: IEA, "World Energy Balances 2023_07."

3) Electricity consumption

The electricity consumption was 164 TWh in 2022, 49% coming from industrial consumption, 28% commercial and public consumption, 23% residential consumption, and 1% other consumption. Compared to 2010, industrial consumption increased by 52%, commercial and public consumption by 32%, and other consumption by 64%, residential consumption increased by 64%.

**Table 1.5.7 Electricity Consumption in Malaysia (Unit: GWh)**

| | Industry | Commercial & Public | Residential | Other | Total |
|---|---|---|---|---|---|
| 2000 | 32,622 | 17,193 | 11,339 | 51 | 61,205 |
| 2005 | 39,204 | 25,264 | 16,224 | 63 | 80,755 |
| 2010 | 52,715 | 35,123 | 22,527 | 488 | 110,853 |
| 2015 | 60,473 | 42,604 | 28,738 | 737 | 132,552 |
| 2020 | 74,245 | 40,478 | 36,330 | 1,078 | 152,131 |
| 2022 | 80,144 | 46,421 | 36,906 | 756 | 164,228 |

Source: IEA, "World Energy Balances 2024_07."

(3) Renewable Energy Potential

Malaysia has the fifth largest land area among ASEAN countries; however, with approximately 59% of its land covered by forests, suitable areas for solar power generation are limited. Consequently, its total renewable energy potential is 423.5 GW, making it the seventh largest among ASEAN countries.

**Table 1.5.8 Renewable Energy Potential in Malaysia (Unit: GW)**

| Solar PV | Onshore wind | Offshore wind | Biomass | Hydro | Geothermal | Total |
|---|---|---|---|---|---|---|
| 337.0 | - | 53.3 | 4.2 | 29.0 | - | 423.5 |

Source: IRENA & ACE; Renewable Energy Outlook for ASEAN, (2022).

(4) Energy Demand Forecasts

In Malaysia, the National Energy Transition Roadmap (NETR), published in 2023, forecasts primary energy supply through 2050. Under the forecasts, supply from renewable energy sources is expected to increase significantly, while coal will be phased out. In addition, the share of natural gas is assumed to account for 56% of total primary energy supply in 2050, an even larger share than the current level.

**Table 1.5.9 Primary Energy Supply Forecasts for Malaysia (Unit: ktoe, as of August 2023)**

| | Renewable energy (for hydrogen production) | Renewable Energy | Coal | Natural gas | Petroleum | Total |
|---|---|---|---|---|---|---|
| 2023 | 0 | 4,000 | 18,000 | 41,000 | 33,000 | 95,000 |
| 2040 | 0 | 20,000 | 20,000 | 46,000 | 31,000 | 117,000 |
| 2050 | 5,000 | 18,000 | 1000 | 57,000 | 21,000 | 102,000 |

Source: Ministry of Economy, "National Energy Transition Roadmap.")

Note: Rounding may result in discrepancies in the total values.

(5) Electricity Demand Forecasts

Public data on Malaysia 's Electricity Demand Forecasts has not been released.

1.5.3 Actual Situation of Electricity Imports and Exports

In Malaysia, as of 2021, electricity imports have only taken place in the Peninsula (Thailand and Singapore) and there are no electricity imports from Sarawak State (Indonesia).

Electricity exports were substantial in the peninsula until around 2008, but it has been declining since 2009.In contrast, large-scale electricity exports have continued to take place via the interconnection line with Indonesia in Sarawak province since its opening in 2016.

**Table 1.5.10 Electricity Imports in Malaysia (Unit: GWh)**

| Junction | Peninsula | Sarawak Province | Total |
|---|---|---|---|
| Access Point | Thailand and Singapore | Indonesia | |
| 2000 | 13 | 0 | 13 |
| 2005 | 1 | 0 | 1 |
| 2010 | 0 | 0 | 0 |
| 2015 | 13 | 0 | 13 |
| 2020 | 18 | 0 | 18 |
| 2021 | 34 | 0 | 34 |

Note: The inconsistency in the numbers between the EC information and the IEA "World Energy Balances 2024_07" is likely due to differences in the compilation methods.

Source: EC, "Malaysia Energy Statistics Handbook.", "Electricity Supply Industry in Malaysia Performance and Statistical Information.", "Electricity Supply Industry in Malaysia.

**Table 1.5.11 Export of Electricity in Malaysia (Unit: GWh)**

| Junction | Peninsula | Sarawak Province | Total |
|---|---|---|---|
| Access Point | Thailand and Singapore | Indonesia | |
| 2000 | 7 | 0 | 7 |
| 2005 | 1,694 | 0 | 1,701 |
| 2010 | 88 | 0 | 1,782 |
| 2015 | 3 | 0 | 91 |
| 2020 | 3 | 1,568 | 1,574 |
| 2021 | 1 | 973 | 2,545 |

Note: The inconsistency in the numbers between the EC information and the IEA "World Energy Balances 2024_07" is likely due to differences in the compilation methods.

Source: EC, "Malaysia Energy Statistics Handbook.", " Electricity Supply Industry in Malaysia Performance and ", "Electricity Supply Industry in Malaysia.

### 1.5.4 Power Supply Development Plan, National Grid Development Plan

#### (1) Power Generation Plants

In Malaysia, the installed power generation capacity was 37 GW in 2021 with 35% coming from coal, 40% from gas, 1% from oil, 17% from hydro, 1% from biomass, and 5% from solar. In recent years, the installed capacity of coal-fired, hydro power, and solar power has increased significantly. As of now, government-owned companies such as Tenaga Nasional Berhad (TNB), Sabah Electricity Sdn. Bhd (SESB), and Sarawak Energy Berhad (SEB) collectively own about 28% of the total power generation capacity. The majority of the generation capacity is owned by independent power producers (IPPs) However, IPPs are mostly located in the Peninsula and Sabah. In contrast, since there are no IPPs in Sarawak as of 2021, SEB owns 92% of the total power generation capacity in the state.

**Table 1.5.12 Power Generation Plants in Malaysia (Unit: MW) and Ownership Percentage of Power Generation Plants**

| | Coal | Gas | Petroleum | Hydro | Biomass | Solar | Other | Total |
|---|---|---|---|---|---|---|---|---|
| 2010 | 7,650 | 13,852 | 702 | 2,107 | 50 | 0 | 0 | 24,361 |
| 2015 | 8,546 | 13,506 | 1,467 | 5,716 | 863 | 226 | 116 | 30,439 |
| 2020 | 13,284 | 13,058 | 533 | 6,188 | 413 | 1,419 | 142 | 35,037 |
| 2021 | 13,284 | 14,995 | 448 | 6,217 | 412 | 1,700 | 368 | 37,422 |
| | TNB | SESB | SEB | IPP | Other | Total | | |
| 2010 | 29% | 2% (of the total) | 2% (of the total) | 67%. | 0 | 100%. | | |
| 2015 | 21%. | 1 | 8% | 59%. | 11%. | 100%. | | |
| 2020 | 13%. | 1 | 15%. | 61%. | 10% (%) | 100%. | | |
| 2021 | 12% | 1% | 15% | 61% | 11% | 100% | | |

Source: EC, "National Energy Report.

(2) Power Generation Facility Plan

In Malaysia, National Energy Transition Roadmap (NETR) formulated in 2023 includes plans for power generation capacity up to 2050. The total installed capacity is projected to reach 97 GW in 2050, consisting of 58% solar, 11% hydro, 1% biomass, 0% oil, 29% gas, and 0% coal, gas, 29% oil, and 0% coal.

**Table 1.5.13 Planned Power Generation Plants in Malaysia (Unit: MW, as of August 2023)**

| | Solar | Hydro | Biomass | Petroleum | Gas | Coal | Total |
|---|---|---|---|---|---|---|---|
| 2022 | 5,520 | 6,440 | 460 | 1,380 | 19,320 | 13,340 | 46,000 |
| 2030 | 6,860 | 7,840 | 490 | 980 | 21,070 | 11,270 | 49,000 |
| 2035 | 14,000 | 8,400 | 560 | 1,120 | 25,760 | 6,160 | 56,000 |
| 2040 | 26,520 | 8,160 | 680 | 1,360 | 25,840 | 6,120 | 68,000 |
| 2045 | 42,640 | 9,020 | 820 | 0 | 29,520 | 820 | 82,000 |
| 2050 | 56,260 | 10,670 | 970 | 0 | 28,130 | 0 | 97,000 |

Note: The capacity for each type of energy source is estimated based on the total installed capacity and the projected energy mix. Due to rounding and other factors, the sum of these capacities may not match the total installed capacity exactly.

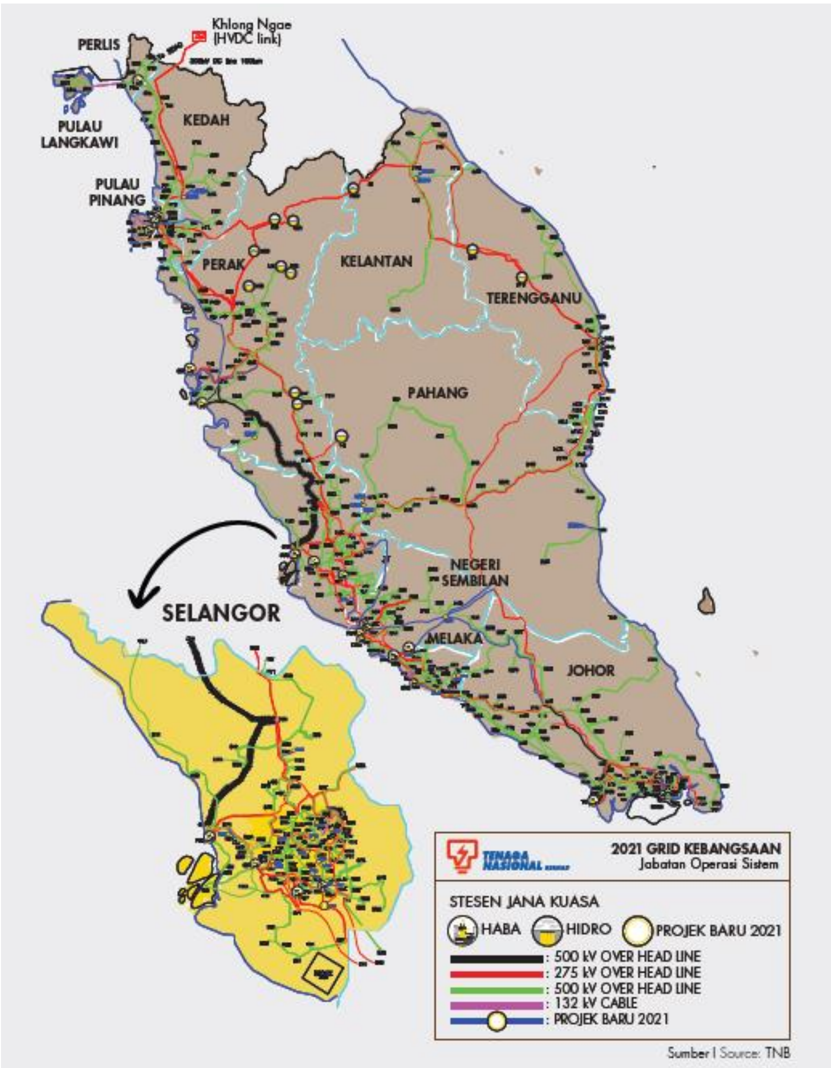
Source: Ministry of Economy, "National Energy Transition Roadmap.")

(3) Cost of Electricity

According to the AIMSIII Phase I Update report, the electricity generation cost in 2020 for Malaysia's Peninsular region was 3.6 cents per kWh, for the Sabah region it was 6.8 cents per kWh, and for the Sarawak region it was 1.8 cents per kWh.

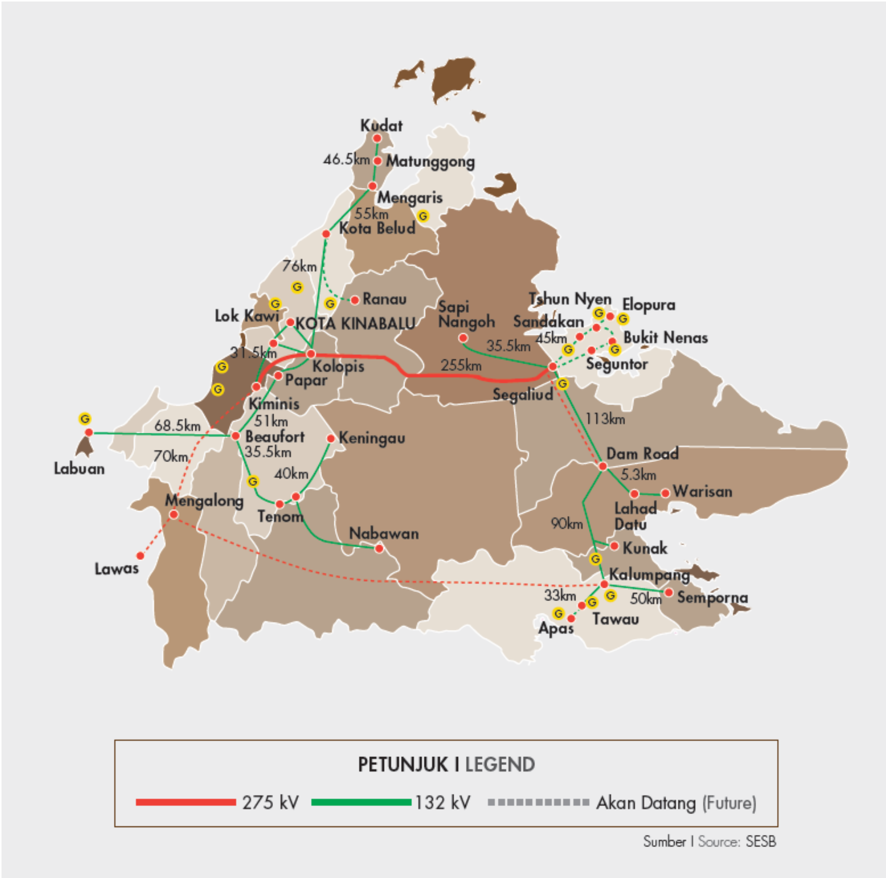
(4) Domestic Transmission System

Malaysia's power transmission system is constructed and operated in the Peninsular, Sabah, and Sarawak states, respectively. For example, Sabah does not have 500kV transmission lines, resulting in independent operations across these regions.



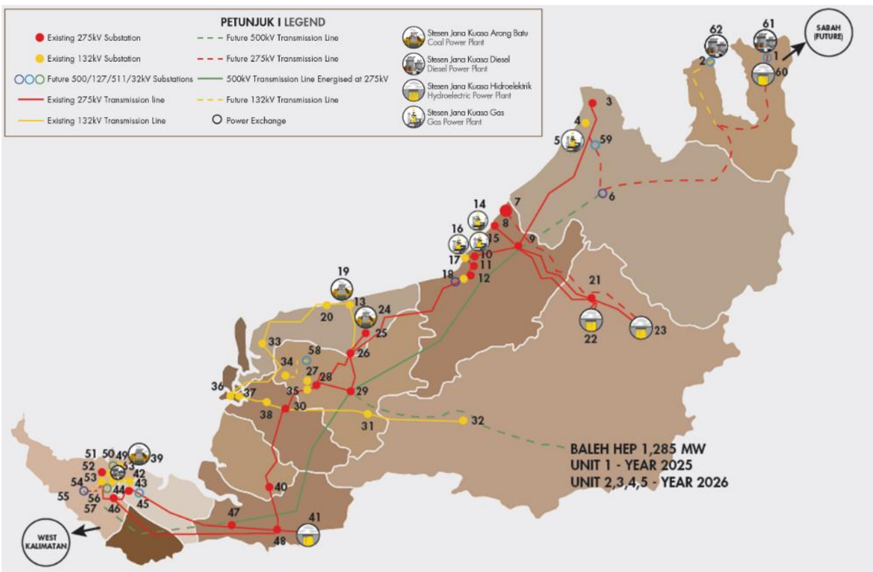

Source: EC, " Performance & Statistical Information on the Malaysian Electricity Supply Industry 2021"

**Figure 1.5.1 Domestic Transmission System Diagram in Peninsula**




Source:EC," Performance & Statistical Information on the Malaysian Electricity Supply Industry 2021"

**Figure 1.5.2 Domestic Transmission System Diagram in Sabah State**




Source: EC," Performance & Statistical Information on the Malaysian Electricity Supply Industry 2021"

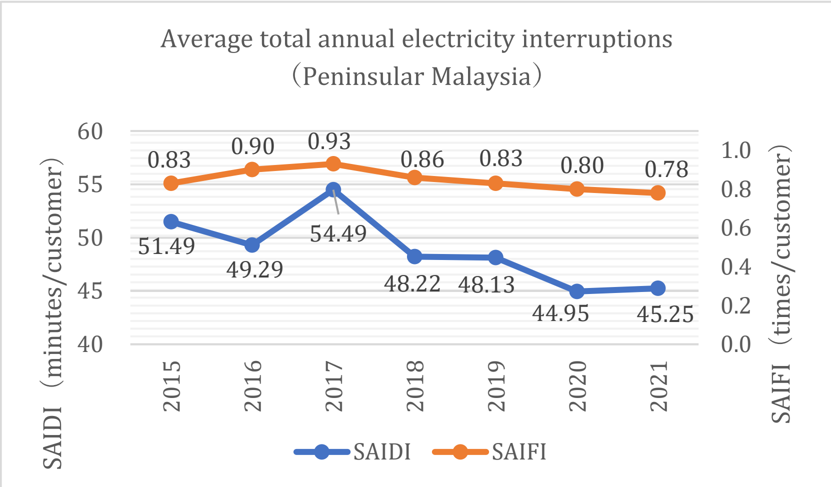
**Figure 1.5.3 Domestic Transmission System Diagram in Sarawak State**

(5) Domestic Grid Development Plans

Public data on Malaysia 's domestic grid development plans has not been released.

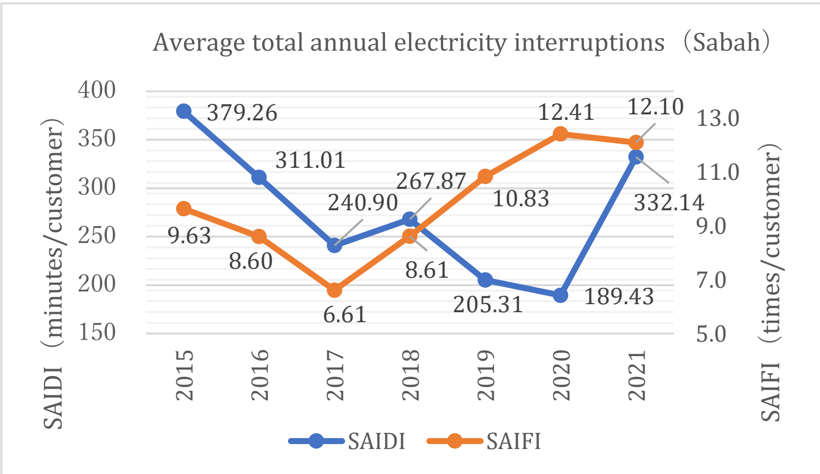
(6) Supply Reliability

Supply reliability in Malaysia varies widely by region. The highest reliability is founded in the Peninsula region. Sarawak has the next highest supply reliability, while Sabah has the lowest reliability.



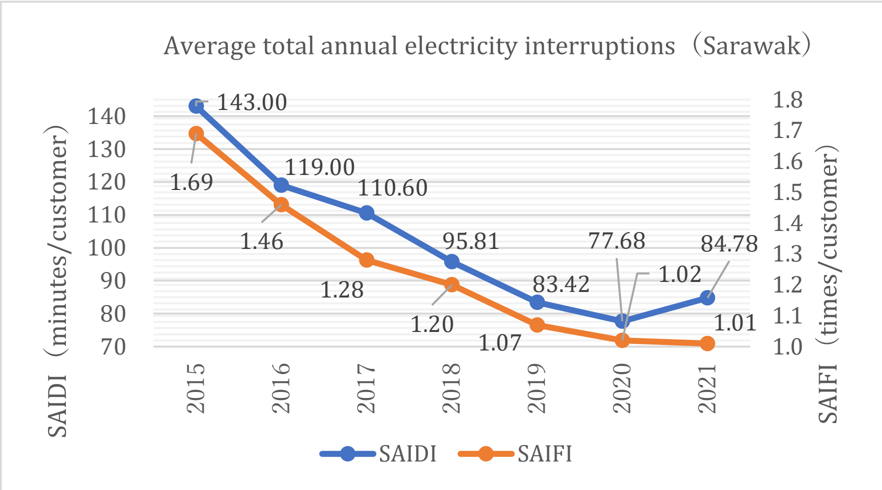

Source: EC, "Malaysia Energy Statistics Handbook 2022."

**Figure 1.5.4 Supply Reliability in Peninsula**




Source: EC, "Malaysia Energy Statistics Handbook 2022."

**Figure 1.5.5 Supply Reliability in Sabah State**




Source: EC, "Malaysia Energy Statistics Handbook 2022."

**Figure 1.5.6 Supply Reliability in Sarawak State**

1.5.5 Status of Existing International Interconnection Lines

The ASEAN Interconnection Masterplan Study (AIMS) III Phase 1 & 2 Update, published in August 2023, outlines the status of cross-border interconnections as of 2022, as well as projections for interconnection development under three scenarios for 2025 and 2040: the Updated Power Development Plan (Updated PDP), the ASEAN Renewable Energy Target Case (ASEAN RE Target), and the High Renewable Energy Target (High RE Target). For Malaysia, the outlook for cross-border interconnections is presented as follows.

**Table 1.5.14 Status and Outlook of Cross-Border Interconnections in Malaysia (MW)**

| AIMS No. | International interconnection line (country-to-country) | APG Status | Updated PDP | | ASEAN RE Target | | High RE Target | |
|---|---|---|---|---|---|---|---|---|
| | | 2022 | 2025 | 2040 | 2025 | 2040 | 2025 | 2040 |
| 1 | P. Malaysia - Singapore | 525 | 1,050 | 1,050 | 1,050 | 1,050 | 1,705 | 3,154 |
| 2 | Thailand - P. Malaysia | 300 | 300 | 350 | 300 | 1,043 | 9,937 | 10,300 |
| 3 | P. Malaysia - Sarawak | - | - | - | 64 | 695 | - | 3,152 |
| 4 | P. Malaysia - Sumatra | - | - | 2000 | 1,067 | 2,130 | 10,000 | 10,000 |
| 6 | Sarawak - Kalimantan | 230 | 230 | 830 | 230 | 777 | 230 | 76 |
| 7 | Philippines - Sabah | - | - | 200 | 147 | 196 | 639 | 6,086 |
| 8 | Sarawak - Sabah – Brunei | | | | | | | |
| | Sarawak - Brunei | - | 100 | 100 | 62 | 100 | 540 | 643 |
| | Sabah - Sarawak | 50 | 100 | 150 | 156 | 177 | 978 | 2,819 |
| 15 | Sabah - Kalimantan | - | - | 200 | 158 | 174 | 1,126 | 4,319 |

Source: ACE, (2023), Findings of ASEAN Interconnection Masterplan Study (AIMS) III Phase 1 & 2 Update.

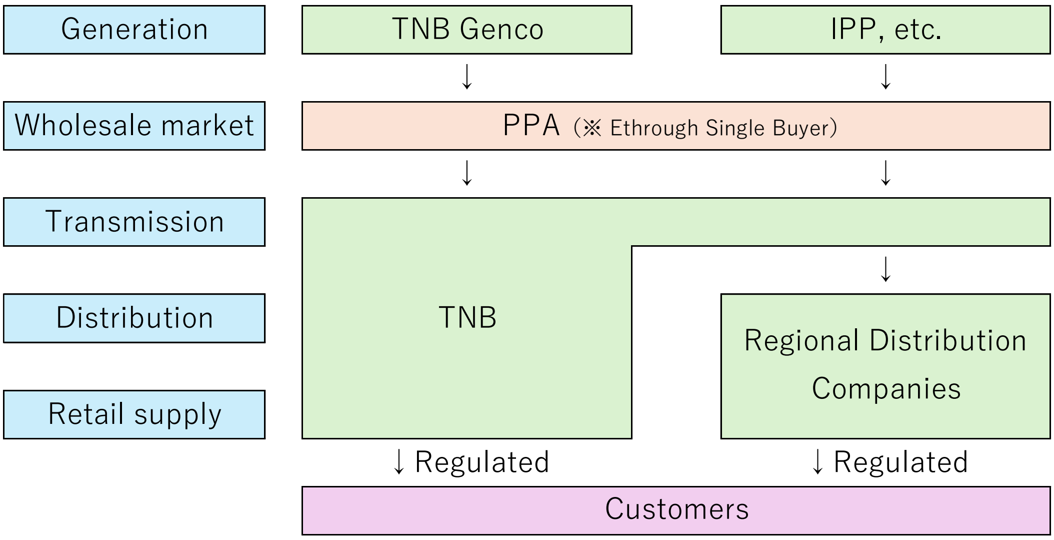
### 1.5.6 Trends in Electricity and International Electricity Markets

#### (1) Electric Utility System

In Malaysia, TNB, SESB, and SEB provide electricity to the peninsula, Sabah, and Sarawak, respectively, under a vertically integrated system. In the power generation business, many IPPs and other companies have entered the market, sharing power to vertically integrated companies in each region through PPAs. In the power generation and retail business, some regional distribution companies operate on a regional basis.

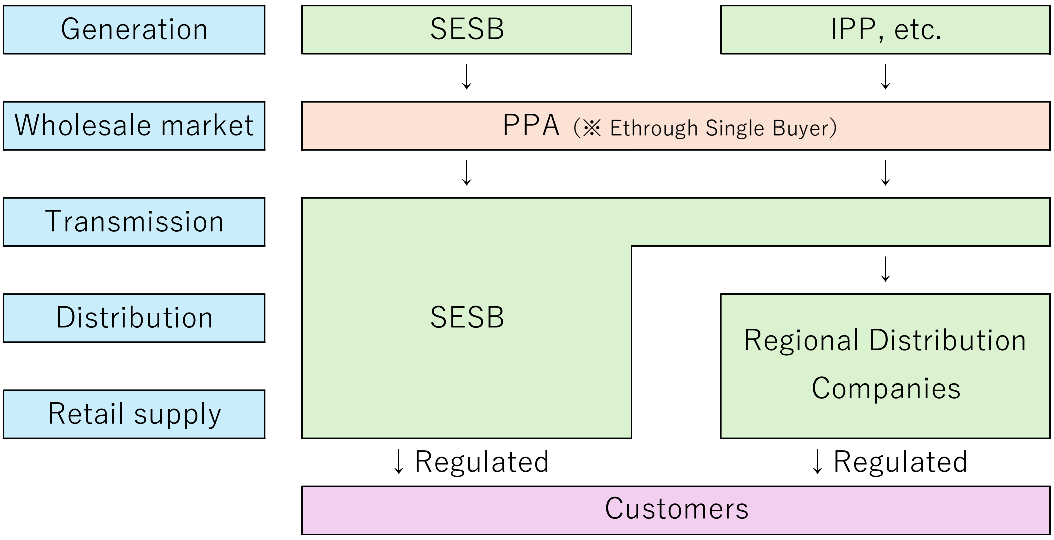
Regarding electricity wholesale, in all regions, a Single Buyer (SB) within each region's vertically integrated utility acts as the sole purchaser of electricity. The SB enters into Power Purchase Agreements (PPAs) with Independent Power Producers (IPPs) and other generators, requesting electricity generation in order of lowest marginal cost, thereby minimizing the overall electricity supply cost.

Further liberalization of the electricity industry is planned in the second phase of Malaysia's electricity reform (MESI 2.0: Malaysian Electricity Supply Industry 2.0 reform), which was launched in 2019. However, it has been announced that the reform will be reviewed in 2020 due to financial concerns, and no details have been released regarding the status of the review since then. In addition to the liberalization of electricity retailing, MESI 2.0 includes provisions for the liberalization of power generation fuel procurement and the establishment of electricity and capacity markets.



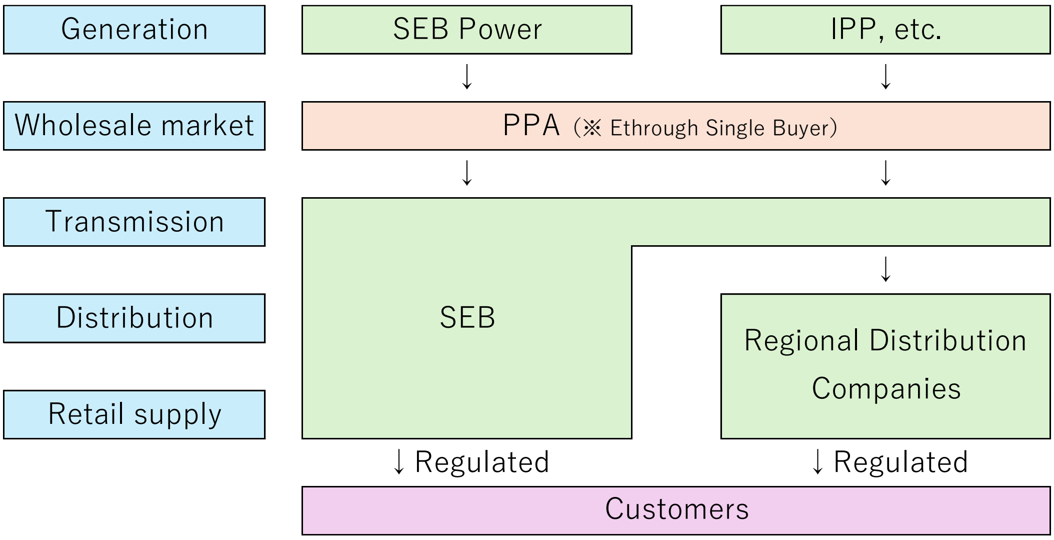

Source: Compiled by JICA Team

**Figure 1.5.7 Electric Utility System in Peninsula**




Source: Compiled by JICA Team

**Figure 1.5.8 Electric Utility System in Sabah State**




Source: Compiled by JICA Team

**Figure 1.5.9 Electric Utility System in Sarawak State**

(2) Electric Utility Regulations

In Malaysia, the Ministry of Economy is responsible for formulating overall socioeconomic policies, including energy such as electricity and gas. In Malaysia, the regulatory bodies for energy, including electricity and gas supply, are as follows: the Energy Commission (EC) oversees the Peninsula region, while Sabah has the Energy Commission of Sabah (ECoS). In Sarawak, electricity regulation is managed by the Electricity Supply Division (ESD) under the Ministry of Utility and Telecommunication (MUT).

(3) Major Electric Utility

Tenaga Nasional Berhad (TNB) is vertically integrated in the supply of electricity in the peninsula and was established in 1990 when the National Electricity Board of the States of Malaya (NEB) was privatized. In addition to Malaysia, TNB has operations in the United Kingdom, Kuwait, Turkey, Saudi Arabia, and India.

Sabah Electricity Sdn. Bhd (SESB) is a vertically integrated electricity provider in Sabah and is a government-owned company established when the Sabah Electricity Board was privatized in 1998. TNB owns 83% and the Sabah State Government owns the rest, making it a subsidiary of TNB.

Sarawak Energy Berhad (SEB) is a vertically integrated power supply company in the state of Sarawak. Berhad is a government-affiliated company wholly owned by the Sarawak State Government, formerly known as Sarawak Electricity Supply Corporation (SESCO).

In the IPP sector, Malakoff Corporation Berhad is the largest, with 5,930 MW of thermal capacity and 159 MW of renewable energy capacity as of March 2025.

(4) Electricity Trading environment with Foreign Operators and Domestic Market

For electricity exports from the peninsula, regulations are outlined in the "Guide for CBES" (Cross-Border Electricity Sales) issued by the Energy Commission (EC). The regulations vary depending on whether the electricity being sold is derived from renewable energy sources.

The sale of electricity from Malaysia to Singapore from non-renewable energy sources is conducted through TNB using existing international interconnection lines with a capacity less than 100 MW. On the other hand, for the sale of electricity from Malaysia to Thailand derived from non-renewable energy sources, PPD (Power Plant Developer) is required to develop and construct a dedicated international interconnection line. It is prohibited from using existing international interconnection lines for the sale of electricity to other countries. In addition, it is prohibited to connect power plants and interconnection facilities to the Malaysian grid.

The sale of electricity derived from renewable energy sources to Singapore and Thailand will be conducted through SB using the existing international interconnection lines. SB is responsible for all aspects, including implementation of the bidding process and settlement. For transmission capacity, Singapore has a maximum limit of 300 MW, while the capacity to Thailand will vary depending on supply conditions.

## 1.6 Philippines

### 1.6.1 Policies for the Energy and Power Sector

#### (1) Climate Change Targets

Despite accounting for only 0.4% of global greenhouse gas emissions, the Philippines is one of the most vulnerable countries to the effects of climate change. Between 2011 and 2021, the Philippines suffered about approximately US$119 billion in damages (as of August 2024) due to tropical cyclones. As a result, without appropriate measure, climate change could exacerbate poverty and inequality in the country.

In the Nationally Determined Contribution (NDC) submitted to the United Nations Framework Convention on Climate Change (UNFCCC) in 2021, the country has committed to reduce 75% of its projected greenhouse gas emissions compared to the BAU. Of this reduction target, 2.71% is unconditional while 72.29% depends on support from developed countries to achieve reductions in the industrial, agricultural, waste, transportation, and energy sectors.

#### (2) Energy and Electricity Policy

In the Philippines, the "Climate Change Act" was passed in 2009 and the "National Climate Change Action Plan (NCCAP) 2011-2028" was formulated in 2011. The NCCAP outlines the following four objectives to cope with climate change: (1) to promote energy efficiency and energy conservation nationwide, (2) to strengthen the development of sustainable and renewable energy, (3) to promote and introduce environmentally friendly transportation, and (4) to rebuild and improve the energy system infrastructure.

In addition, the Department of Energy (DOE) formulated the Philippine Energy Plan (PEP) 2023-2050 in June 2024, which has the following three goals

1. Facilitate access to affordable energy prices
   - A) Achieve 100% residential electrification rate by 2028
   - B) Interconnect the off-grid areas to the national grid
   - C) Introduce the Distributed Energy Systems (DES) in off-grid areas, etc.
2. Ensure reliable and resilient energy supply
   - A) Ensure resilience and safety of energy infrastructure
   - B) Improve energy self-sufficiency
   - C) Increase LNG fuel to complement renewable energy, etc.
3. Transition to clean and sustainable energy resources
   - A) Increase the share of renewable energy in the power generation mix to 35.0% by 2030 and 50.0% by 2040

B) Enhance the port infrastructure to support offshore wind power projects

C) Pursuit alternative fuels and emerging technologies: electric vehicles (EVs), hydrogen and its derivatives, energy storage systems (ESS), etc.

1.6.2 Current and Projected Energy and Electricity Supply and Demand

(1) Current Energy Supply and Demand

1) Domestic energy production

In the Philippines, natural gas production from the Malampaya gas field began in 2002, alongside the production of coal and crude oil. In 2022, energy production reached 31,651 ktoe, which is about 1.9 times higher than in 1990. On the other hand, the energy self-sufficiency ratio declined from 62% in 1990 to 52% in 2022. Specifically, the self-sufficiency rate was 40% for coal, 6% for crude oil, and 100% for natural gas with coal and crude oil dependent on imports. The breakdown of renewable energy, geothermal accounts for approximately 50% and biomass accounts for approximately 45%.

**Table 1.6.1 Domestic Energy Production in the Philippines (Unit: ktoe)**

| | Coal | Crude oil | Natural gas | Nuclear | Hydro | Renewable energy | Total |
|---|---|---|---|---|---|---|---|
| 1990 | 625 | 232 | 0 | 0 | 521 | 15,153 | 16,531 |
| 1995 | 643 | 128 | 4 | 0 | 536 | 13,761 | 15,071 |
| 2000 | 645 | 56 | 9 | 0 | 671 | 17,604 | 18,984 |
| 2005 | 1,521 | 783 | 2,701 | 0 | 721 | 15,693 | 21,419 |
| 2010 | 3,510 | 975 | 3,051 | 0 | 671 | 17,106 | 25,313 |
| 2015 | 3,894 | 761 | 2,875 | 0 | 745 | 19,468 | 27,744 |
| 2020 | 6,836 | 498 | 3,313 | 0 | 618 | 19,951 | 31,217 |
| 2022 | 7,631 | 390 | 2,632 | 0 | 867 | 20,130 | 31,651 |

Source: IEA, World Energy Balances 2024_07.

2) Primary energy supply

Primary energy supply is increasing as final energy consumption increases. Compared to 2000, before domestic production began in 2002, natural gas increased 292 times in 2022. Petroleum products were the next highest increasing source, increasing 25 times in 2022 compared to 2000. As with domestic energy production, geothermal and biomass account for the majority of renewable energy.

**Table 1.6.2 Primary Energy Supply in the Philippines (Unit: ktoe)**

| | Coal | Crude Oil | Petroleum Products | Natural Gas | Nuclear | Hydro | Renewable Energy | Electric power | Total |
|---|---|---|---|---|---|---|---|---|---|
| 1990 | 1,256 | 10,090 | -368 | 0 | 0 | 521 | 15,153 | 0 | 26,652 |
| 1995 | 1,645 | 15,875 | 593 | 4 | 0 | 536 | 13,761 | 0 | 32,415 |
| 2000 | 4,625 | 15,361 | 540 | 9 | 0 | 671 | 17,604 | 0 | 38,810 |
| 2005 | 5,317 | 10,629 | 3,178 | 2,701 | 0 | 721 | 15,694 | 0 | 38,240 |
| 2010 | 7,030 | 8,886 | 4,714 | 3,051 | 0 | 671 | 17,213 | 0 | 41,566 |
| 2015 | 11,615 | 10,431 | 7,248 | 2,875 | 0 | 745 | 19,643 | 0 | 52,559 |
| 2020 | 17,336 | 4,737 | 11,715 | 3,313 | 0 | 618 | 20,145 | 0 | 57,865 |
| 2022 | 19,075 | 6,342 | 13,508 | 2,632 | 0 | 867 | 20,346 | 0 | 62,771 |

Source: IEA, World Energy Balances 2024_07.

3) Final energy consumption

In 2022, industrial final energy consumption accounted for 20% of total energy consumption, transportation energy consumption 35%, commercial energy consumption 12%, and residential energy consumption 29%. Compared to 2000, commercial energy consumption has increased by approximately 2.7 times, and the increases in petroleum products in the primary energy supply can be attributed to this increase in commercial energy consumption.

**Table 1.6.3 Final Energy Consumption in the Philippines (Unit: ktoe)**

| | Industry | Transportation | Commercial | Agricultural, Forestry and Fisheries | Residential | Other | Non-Energy use | Total |
|---|---|---|---|---|---|---|---|---|
| 1990 | 4,147 | 4,527 | 804 | 333 | 8,835 | 0 | 399 | 19,045 |
| 1995 | 4,991 | 6,973 | 1,011 | 390 | 8,354 | 0 | 423 | 22,142 |
| 2000 | 4,558 | 8,304 | 1,660 | 361 | 7,894 | 0 | 413 | 23,191 |
| 2005 | 4,978 | 8,284 | 1,880 | 370 | 7,021 | 0 | 202 | 22,734 |
| 2010 | 5,948 | 8,044 | 2,664 | 348 | 7,878 | 0 | 220 | 25,101 |
| 2015 | 6,751 | 10,591 | 3,369 | 400 | 8,730 | 0 | 1,180 | 31,021 |
| 2020 | 6,180 | 9,873 | 4,606 | 440 | 10,028 | 0 | 1,298 | 32,425 |
| 2022 | 7,067 | 12,375 | 4,447 | 379 | 10,310 | 0 | 1,290 | 35,869 |

Source: IEA, World Energy Balances 2024_07.

(2) Current Electricity Supply and Demand

1) Electricity generation

The total electricity generation was approximately 118 TWh in 2023 with 62% from coal-fired, 14% from gas-fired, 9% from hydro and geothermal, and 4% from other renewable energies. Compared to

2000, the coal-fired power generation has quadrupled, while oil-fired power generation has decreased. In recent years, hydro and solar generation have been remarkably increasing.

**Table 1.6.4 Electricity Generation in the Philippines (Unit: GWh)**

| | Coal | Petroleum | Natural Gas | Geothermal | Hydro | Solar | Wind | Biomass | Total |
|---|---|---|---|---|---|---|---|---|---|
| 2000 | 16,663 | 9,185 | 17 | 11,626 | 7,799 | 0 | 0 | 0 | 45,290 |
| 2005 | 15,257 | 6,141 | 16,861 | 9,902 | 8,387 | 2 | 17 | 0 | 56,568 |
| 2010 | 23,301 | 7,101 | 19,518 | 9,929 | 7,803 | 1 | 62 | 27 | 67,743 |
| 2015 | 36,686 | 5,886 | 18,878 | 11,044 | 8,665 | 139 | 748 | 367 | 82,413 |
| 2020 | 58,176 | 2,474 | 19,497 | 10,757 | 7,192 | 1,373 | 1,026 | 1,261 | 101,756 |
| 2023 | 73,754 | 1,304 | 16,668 | 10,730 | 10,287 | 2,544 | 1,308 | 1,409 | 118,004 |

Source: DOE, Power Capacity and Generation. and 2023 POWER STATISTICS.

2) Exported, imported and lost electricity, etc.

The proportion of electricity lost relative to total generation was 14% in 2000 and 10% in 2023, indicating a reduction in transmission losses.

**Table 1.6.5 Exported, imported and lost electricity (Unit: GWh)**

| | Electricity Generation | Imported Electricity | Exported Electricity | Transmission and Distribution loss | Domestic Electricity Consumption |
|---|---|---|---|---|---|
| 2000 | 45,290 | 0 | 0 | 6,345 | 38,944 |
| 2005 | 56,568 | 0 | 0 | 6,817 | 49,749 |
| 2010 | 67,743 | 0 | 0 | 7,800 | 59,943 |
| 2015 | 82,413 | 0 | 0 | 7,481 | 74,932 |
| 2020 | 101,756 | 0 | 0 | 9,742 | 92,014 |
| 2023 | 118,004 | 0 | 0 | 11,793 | 106,211 |

Source: DOE, Power Capacity and Generation. and DOE, Power Consumption Table.

3) Electricity consumption

The total electricity consumption was approximately 106 TWh in 2023 with 28% from industrial consumption, 25% from service consumption, and 35% from residential consumption. Compared to 2010, residential consumption increased by 96%, service consumption by 61% and industrial consumption by 58%.

**Table 1.6.6 Electricity Consumption in the Philippines (Unit: GWh)**

| | Industry | Service | Residential | Own-use | Other | Total |
|---|---|---|---|---|---|---|
| 2000 | 13,191 | 9,512 | 12,894 | 2,390 | 957 | 38,944 |
| 2005 | 15,705 | 12,245 | 16,031 | 4,591 | 1,177 | 49,749 |
| 2010 | 18,576 | 16,261 | 18,833 | 4,677 | 1,596 | 59,943 |
| 2015 | 22,514 | 20,085 | 22,747 | 7,124 | 2,462 | 74,932 |
| 2020 | 25,566 | 20,727 | 34,292 | 8,771 | 2,658 | 92,014 |
| 2023 | 29,493 | 26,236 | 36,968 | 10,403 | 3,112 | 106,211 |

Source: DOE, 2023 POWER STATISTICS.

(3) Renewable Energy Potential

The Philippines has the sixth largest land area among ASEAN countries; however, as an archipelago, it has limited suitable areas for solar PV. Consequently, its total renewable energy potential is 210.1 GW, making it the third smallest after Singapore and Brunei. Nevertheless, its offshore wind power potential is 69.4 GW, which is the fourth largest after Indonesia, Vietnam, and Cambodia.

**Table 1.6.7 Renewable Energy Potential in the Philippines (Unit: GW)**

| Solar PV | Onshore wind | Offshore wind | Biomass | Hydro | Geothermal | Total |
|---|---|---|---|---|---|---|
| 122.5 | 3.5 | 69.4 | 0.2 | 10.5 | 4.0 | 210.1 |

Source: IRENA & ACE; Renewable Energy Outlook for ASEAN, (2022).

(4) Energy Demand Forecasts

The primary energy supply is assumed to increase 2.3 times in 2050 compared to 2022. Of this increase, natural gas will increase by 9.5 times, hydropower by 4.2 times, and solar power by 39.6 times.

**Table 1.6.8 Primary Energy Supply Forecasts for the Philippines (Unit: Mtoe)**

| | Coal | Petroleum | Natural gas | Geothermal | Hydro | Solar | Wind | Biomass | Total |
|---|---|---|---|---|---|---|---|---|---|
| 2022 | 19.08 | 19.83 | 2.61 | 8.96 | 2.51 | 0.16 | 0.09 | 8.32 | 61.56 |
| 2030 | 22.63 | 25.58 | 4.92 | 12.36 | 2.70 | 1.54 | 1.34 | 8.61 | 79.68 |
| 2040 | 22.43 | 34.50 | 10.83 | 16.23 | 6.65 | 4.30 | 4.21 | 8.50 | 107.65 |
| 2050 | 22.28 | 43.50 | 24.82 | 18.30 | 10.59 | 6.34 | 7.98 | 6.69 | 140.50 |

Source: DOE, Philippine Energy Plan 2023-2050.

(5) Electricity Demand Forecasts

As set out in the PEP 2023-2050, an ambitious target was adopted to increase the domestic renewable energy supply ratio from 35% by 2030 and 50% by 2040. The share of renewable energy is not expected to increase after 2040, while the share of coal-fired power generation LNG-fired power generation is expected to increase.

**Table 1.6.9 Forecasts of Electricity Supply and Demand in the Philippines**

**(Unit: [Upper] GWh [lower] %)**

| | Coal | Petroleum | Natural Gas | Renewable Energy | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Geothermal | Hydro | Wind | Solar | Biomass | |
| 2022 | 66,430 | 2,520 | 17,880 | 24,670 | 10,420 | 10,080 | 1,030 | 1,820 | 1,320 | 111,500 |
| | 59.6 | 2.3 | 16.0 | 22.1 | 9.3 | 9.0 | 0.9 | 1.6 | 1.2 | 100.0 |
| 2030 | 78,180 | 1,070 | 31,480 | 59,620 | 14,380 | 10,530 | 15,630 | 17,960 | 1,120 | 170,350 |
| | 45.9 | 0.6 | 18.5 | 35.0 | 8.4 | 6.2 | 9.2 | 10.5 | 0.7 | 100.0 |
| 2040 | 71,170 | 1,060 | 69,260 | 144,820 | 18,880 | 25,950 | 49,000 | 49,990 | 1,000 | 286,310 |
| | 24.9 | 0.4 | 24.2 | 50.6 | 6.6 | 9.1 | 17.1 | 17.5 | 0.3 | 100.0 |
| 2050 | 63,770 | 1,060 | 158,760 | 230,230 | 21,290 | 41,300 | 92,760 | 73,720 | 1,160 | 453,820 |
| | 14.1 | 0.2 | 35.0 | 50.7 | 4.7 | 9.1 | 20.4 | 16.2 | 0.3 | 100.0 |

Source: DOE, Philippine Energy Plan 2023-2050

### 1.6.3 Actual Situation of Electricity Import/Export

Although an interconnection with the Malaysian state of Sabah is planned, no interconnection with outside countries has yet been implemented. Therefore, there is currently no record of electricity import/export.

### 1.6.4 Power Supply Development Plan, National Grid Development Plan

#### (1) Power Generation Plants

In 2023, the installed power generation capacity was 28 GW with 43.9% from coal-fired, 13.2% from oil-fired, and 13.4% from hydro.

Compared to 2005, the installed capacity other than geothermal has been increasing.

**Table 1.6.10 Power Generation Plants in the Philippines (Unit: MW)**

| | Coal | Petroleum | Natural Gas | Geothermal | Hydro | Solar | Wind | Biomass | Total |
|---|---|---|---|---|---|---|---|---|---|
| 2005 | 3,967 | 3,663 | 2,763 | 1,978 | 3,222 | 1 | 25 | 0 | 15,619 |
| 2010 | 4,867 | 3,193 | 2,861 | 1,966 | 3,400 | 1 | 33 | 38 | 16,359 |
| 2015 | 5,963 | 3,610 | 2,862 | 1,917 | 3,600 | 165 | 427 | 221 | 18,765 |
| 2020 | 10,944 | 4,237 | 3,453 | 1,928 | 3,779 | 1,019 | 443 | 447 | 26,250 |
| 2023 | 12,406 | 3,737 | 3,732 | 1,952 | 3,799 | 1,653 | 427 | 585 | 28,291 |

Source: DOE, Summary of 2023 Power Statistics

(2) Power Generation Facility Plan

Compared to 2022, the Philippines plans to expand its power generation capacity to 150 GW by 2050, which increases 5.3 times the capacity.

The share of coal-fired power, which accounted for 44% in 2022, is expected to decrease to 9.8% by 2050. In contrast, solar power, which accounted for 5.4% in 2022, is planned to increase to 37.4% by 2050.

**Table 1.6.11 Planned Electricity Generation Plants in the Philippines (Unit: MW)**

| | Coal | Petro-leum | Natural gas | Geo-thermal | Hydro | Solar | Wind | Bio-mass | Total |
|---|---|---|---|---|---|---|---|---|---|
| 2022(Existing) | 12,428 | 3,834 | 3,732 | 1,952 | 3,745 | 1,530 | 427 | 611 | 28,259 |
| 2023-2028 (Newly constructed) | 2,305 | 20 | 2,413 | 425 | 295 | 9,328 | 3,700 | 42 | 18,528 |
| 2029-2050 (Newly constructed) | 0 | 0 | 19,468 | 930 | 9,970 | 45,620 | 28,142 | 50 | 104,180 |
| 2050 (Existing+Newly constructed) | 14,733 | 3,854 | 25,613 | 3,307 | 14,010 | 56,478 | 32,269 | 703 | 150,967 |

Source: DOE, Philippine Energy Plan 2023-2050

(3) Cost of Electricity

According to the AIMSIII Phase I Update report, the electricity generation cost in 2020 for the Philippines was 2.8 cents per kWh.

(4) Domestic Transmission System

The Philippines is divided into three main interconnected areas, namely Luzon, Visayas, and Mindanao.

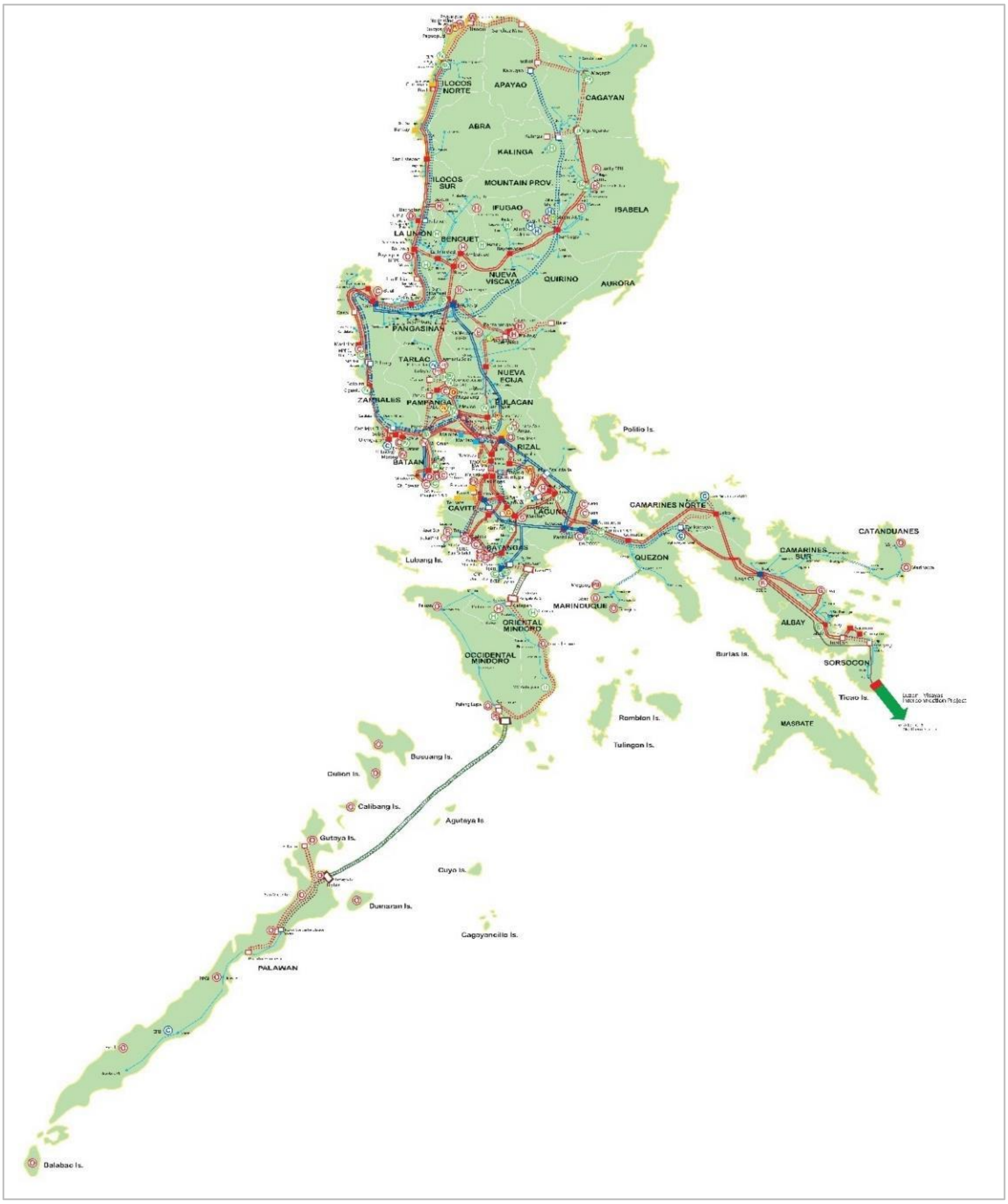
In December 2022, the total capacity of substations managed by the National Grid Corporation of the Philippines (NGCP) reached 48,800.5 MVA, and the total length of transmission lines reached 21,027 ckt-km.

**Table 1.6.12 Domestic Transmission System in the Philippines (as of 2022)**

| Area | Substation capacity (MVA) | Total length of transmission lines |
|---|---|---|
| Luzon area | 35,641.0 | 9,631.9 |
| Visayas area | 5,848.5 | 5,393.5 |
| Mindanao area | 7,311.0 | 6,001.6 |
| Total | 48,800.5 | 21,027.0 |

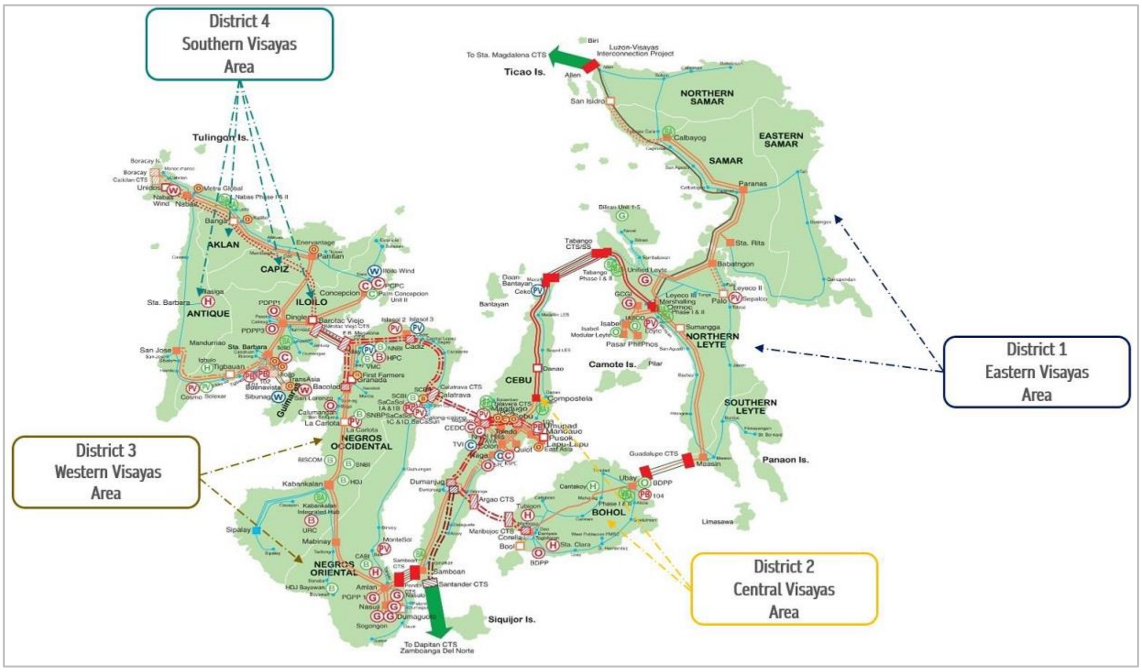
Source: DOE, Power Development Plan 2023-2050.

<Luzon area>

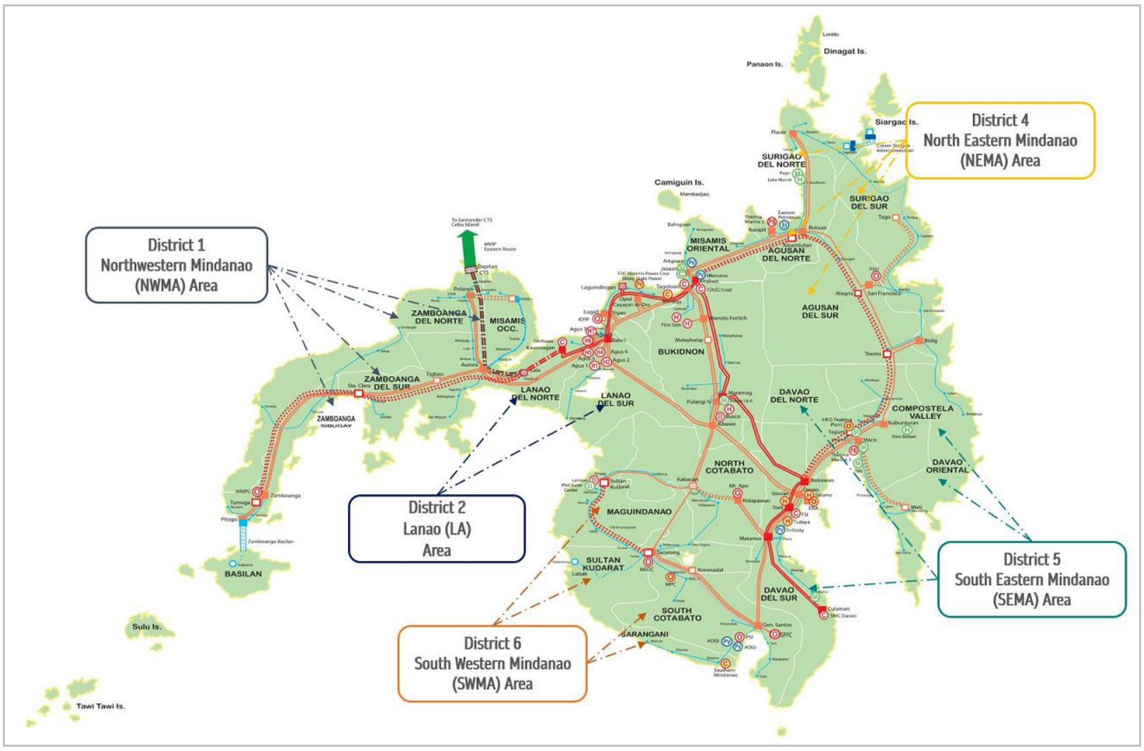


ILOCOS NORTE
APAYAO
CAGAYAN
ABRA
KALINGA
ILOCOS SUR
MOUNTAIN PROV.
IFUGAO
ISABELA
LA UNION
BENGUET
NUEVA VISCAYA
QUIRINO
AURORA
PANGASINAN
TARLAC
NUEVA ECIJA
ZAMBALES
PAMPANGA
BULACAN
Polillo Is.
RIZAL
BATAAN
CAVITE
LAGUNA
CAMARINES NORTE
BATANGAS
QUEZON
CATANDUANES
CAMARINES SUR
Lubang Is.
MARINDUQUE
ALBAY
ORIENTAL MINDORO
OCCIDENTAL MINDORO
Burias Is.
SORSOGON
Ticao Is.
Romblon Is.
MASBATE
Tulingon Is.
Busuang Is.
Calibang Is.
Agutaya Is.
Gutaya Is.
Cuyo Is.
Dumaran Is.
Cagayancillo Is.
PALAWAN
Dalabac Is.

<Visayas area>




<Mindanao area>




Source: NGCP, Transmission Development Plan 2023-2040.

**Figure 1.6.1 Domestic Transmission System Diagram in the Philippines**

(5) Domestic Grid Development Plans

The Power-Development-Plan (PDP)-2020-2040, which was formulated in 2021, includes a domestic grid development plan. The roadmap includes three main points.

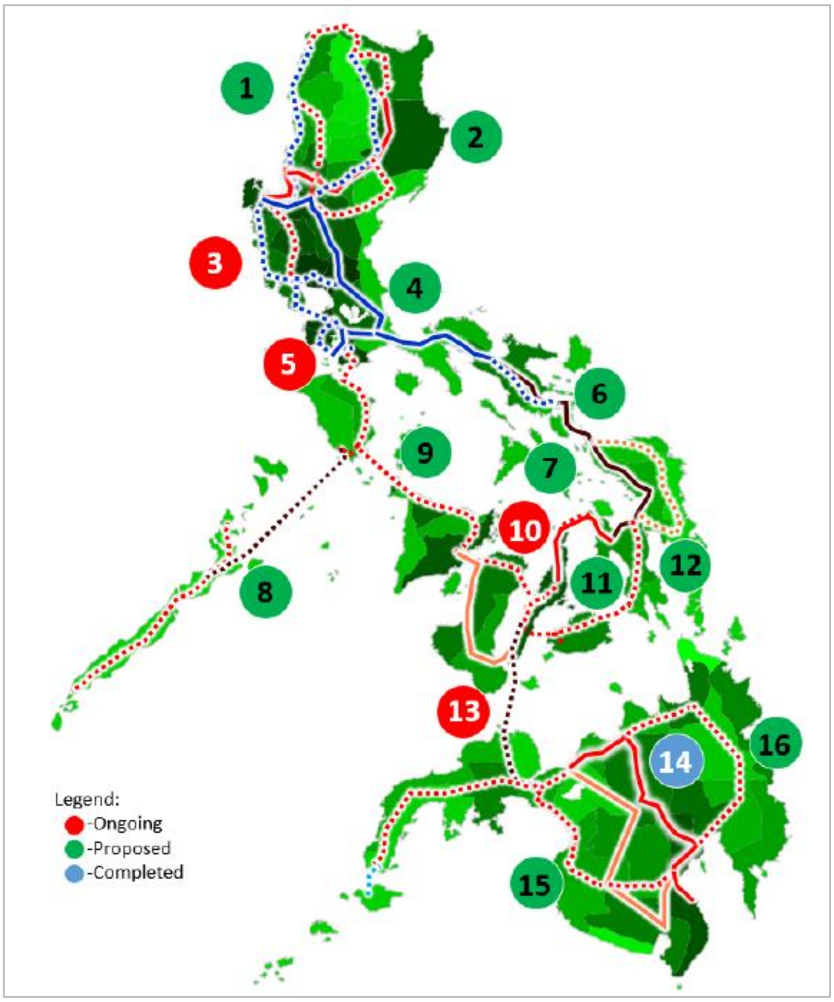
1. Improve reliability and resilience of the main grid
2. Interconnect between Luzon, Visayas and Mindanao areas
3. Interconnect between off-grid areas and the main grid

The Transmission Development Plan (TDP) 2023-2040, which was formulated in 2023, includes a representative domestic grid development plan, but please refer to the document for details.

**Table 1.6.13 Domestic Grid Plan in the Philippines (as of 2023)**

| No | Connection area/point | | | Voltage (KV) | Operation Start Status and Schedule |
|---|---|---|---|---|---|
| | Location 1 | Location 2 | Location 3 | | |
| 1 | Bolo. | Laoag | - | 500 | 2034 |
| 2 | Nagsaag | Kabugao | - | 500 | 2031-2035 |
| 3 | Western Luzon | - | - | 500 | 2025 |
| 4 | Metro Manila | - | - | 500 | 2034 |
| 5 | Batangas | Mindoro | - | 230 | 2027 |
| 6 | Luzon | Visayas | - | 350 | 2032 |
| 7 | Luzon | Visayas | - | 230 | 2036-2040 |
| 8 | Palawan | Mindoro | - | 350 | 2033 |
| 9 | Mindoro | Panay | - | 230 | 2036-2040 |
| 10 | Cebu | Negros | Panay | 230 | 2023 |
| 11 | Metro Cebu | - | - | 230 | 2023-2040 |
| 12 | Cebu | Bohol | Leyte | 230 | 2024-2035 |
| 13 | Mindanao | Visayas | - | 350 | 2023 |
| 14 | Mindanao | - | - | 230 | Operation has been started |
| 15 | Southwestern Mindanao | - | - | 230 | 2035 |
| 16 | eastern Mindanao | - | - | 230 | 2032 |

Source: NGCP, Transmission Development Plan 2023-2040.

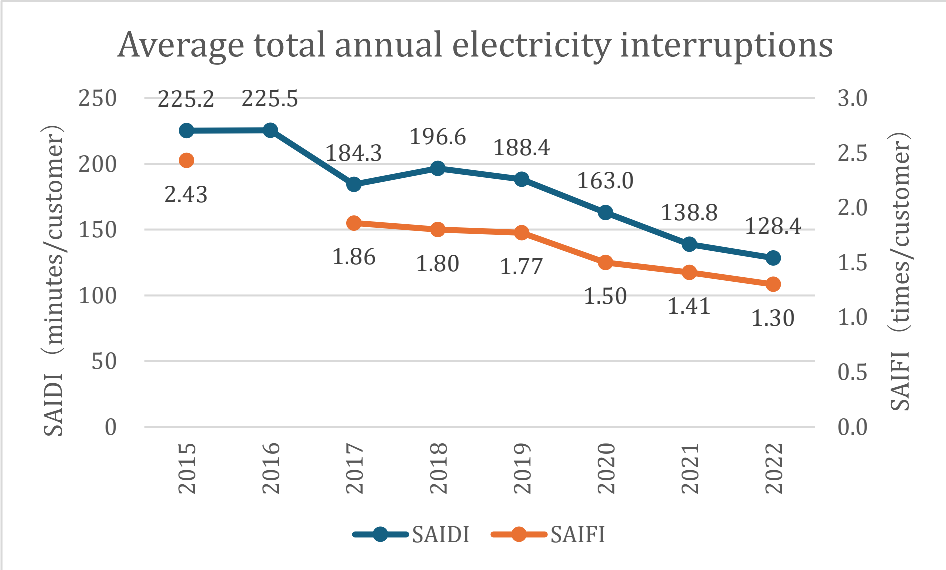



Source: NGCP, Transmission Development Plan 2023-2040.

**Figure 1.6.2 Domestic Grid Plan in the Philippines (as of 2023)**

(6) Supply Reliability

According to Manila Electric Company (Meralco), the largest distribution utility in the Philippines, supply reliability in its service area has improved over the years. The average duration of outages (SAIDI) was improved from 225.2 minutes per customer in 2015 to 128.4 minutes/customer in 2022. The average number of outages (SAIFI) was improved from 2.43 times per customer in 2015 to 1.30 times/customer in 2022.




Source: Meralco, Annual Report 2019. and Annual and Sustainability Report 2022

**Figure 1.6.3 Supply Reliability in the Philippines**

### 1.6.5 Status of Existing International Interconnection Lines

The Brunei Darussalam-Indonesia-Malaysia-Philippines East ASEAN Growth Area(BIMP-EAGA), has conducted several feasibility studies (F/S) for a Borneo-Mindanao interconnection to address the power supply shortage in the Mindanao area. The Asian Development Bank (ADB) also conducted a similar study on the Palawan-Sabah interconnection to import cheap electricity from Sabah, Malaysia to Palawan, Philippines.

The ASEAN Interconnection Masterplan Study (AIMS) III Phase 1 & 2 Update, published in August 2023, outlines the status of cross-border interconnections as of 2022, as well as projections for interconnection development under three scenarios for 2025 and 2040: the Updated Power Development Plan (Updated PDP), the ASEAN Renewable Energy Target Case (ASEAN RE Target), and the High Renewable Energy Target (High RE Target). For Philippines, the outlook for cross-border interconnections is presented as follows.

**Table 1.6.14 Status and Outlook of Cross-Border Interconnections in Philippines (MW)**

| AIMS No | International interconnection line (country-to-country) | APG Status 2022 | Updated PDP | | ASEAN RE Target | | High RE Target | |
|---|---|---|---|---|---|---|---|---|
| | | | 2025 | 2040 | 2025 | 2040 | 2025 | 2040 |
| 7 | Philippines - Sabah | - | - | 200 | 147 | 196 | 639 | 6,086 |

Source: ACE, (2023), Findings of ASEAN Interconnection Masterplan Study (AIMS) III Phase 1 & 2 Update.

1.6.6 Trends in Electricity and International Electricity Markets

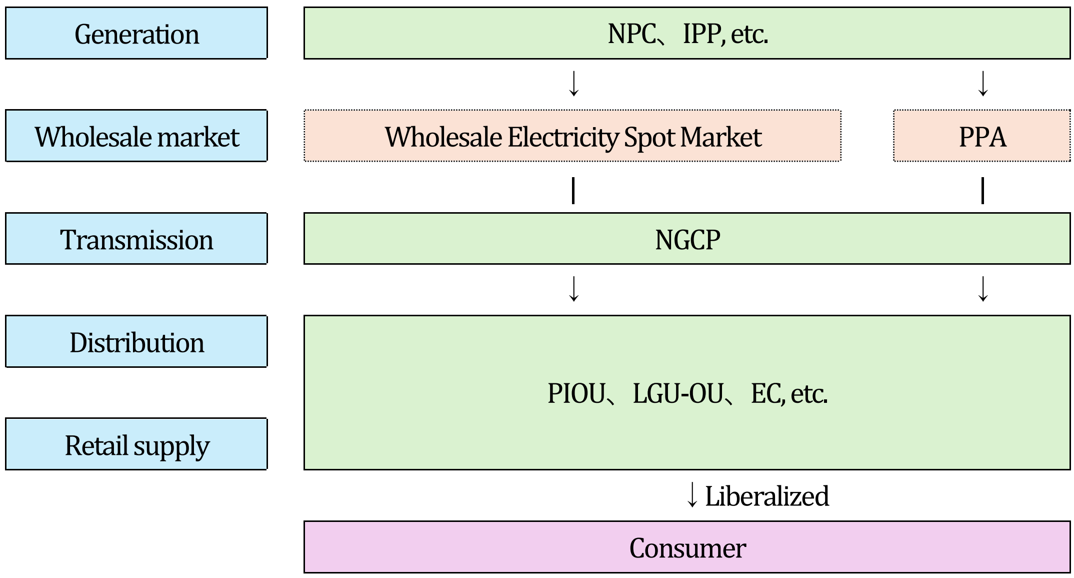
(1) Electric Utility System

In June 2001, the Electric Power Industry Reform Act (EPIRA) was enacted. With the implementation of EPRIA, the state-owned electric power company were privatized and separated into power generation, transmission, and distribution/retail business.

The power generation business has been monopolized by the National Power Corporation (NPC) but since the entry of independent power producers (IPPs), the power generation business has been liberalized.

In the power transmission business, the National Transmission Corporation (TRANSCO) was established under EPIRA. TRANSCO was responsible for the management and operation of the national power grid since March 2003, but the company was required to be privatized through divestiture or outsourcing under EPRIA. Following bidding process held in December 2007, TRANSCO's business rights were handed over to NGCP in January 2009. However, all transmission assets remain under the ownership of TRANSCO.

In the distribution and retail (DU) business, there are private investor-owned utilities (PIOUs), local government units (LGUs), and electric cooperatives (EC). DUs procure electricity from power generators through the Wholesale Electricity Spot Market (WESM) or through bilateral transactions.




Source: Compiled by JICA Team

**Figure 1.6.4 Electric Utility System in the Philippines**

(2) Electric Utility Regulations

The DOE is responsible for the overall energy policy. Its primary role is to formulate, implement, and manage all plans in the energy sector, and to promote the exploration, development, and utilization of energy resources and energy conservation.

The National Electrification Administration (NEA), under the supervision of the DOE, is promoting the rural electrification program, providing funds for rural electrification and construction of power facilities. The Energy Regulatory Commission (ERC) monitors the electricity market, regulates electricity tariffs, and issue businesses licenses as well as regulates gas prices.

The Department of Environment and Natural Resources (DENR) is tasked with determining policies on the environment and natural resources and balancing development activities with environmental management in order to achieve sustainable development.

(3) Major Electric Utility

Among power producers, NPC is mandated to supply electricity to non-electrified and off-grid areas in the country and operates a generation facility called Small Power Utilities Group (SPUG). In addition, the company is required to efficiently manage the remaining government-owned power assets. San Miguel, Aboitiz, and First Gen are the top three IPPs in terms of power generation market share.

As of March 2025, there are 152 distribution and retail operators, which are listed on the DOE website. Of these, the following list shows the operator with the largest electricity supply (MWh) in 2022.

**Table 1.6.15 the largest electricity suppliers (MWh) in Philippines as of 2022.**

| Area | Company Name | Classification. | Electricity supply (MWh) | Share (%) | Entire region (MWh) |
|---|---|---|---|---|---|
| Luzon Area | MERALCO | PIOU | 32,065,029 | 66.8% | 47,992,121 |
| Visayas Region | VECO | PIOU | 2,104,421 | 23.7% | 8,868,396 |
| Mindanao Region | DLPC | PIOU | 2,682,856 | 20.3% | 13,247,497 |

Source: DOE, DISTRIBUTION DEVELOPMENT PLAN 2023-2032.

(4) Electricity Trading Environment with Foreign Operators and Domestic Market

As stated in "1.6.3. Actual status of electricity import/export", there are currently no interconnection and electricity trade with other countries conducted.

## 1.7 Singapore

### 1.7.1 Policies for the Energy and Power Sector

(1) Climate Change Targets

Singapore has committed to achieving carbon neutrality as a long-term goal for reducing greenhouse gas emission. In 2020, Singapore announced its medium-term goal to cap its emissions at 65 million tons of CO2 equivalent around 2030, a 36% reduction from 2005 levels. However, in 2022, Singapore revised its plan and set a new target to reduce 2030 emissions to approximately 60 million tons of CO2 equivalent by peaking emissions earlier.

(2) Energy and Electricity Policy

In Singapore, the "Singapore Green Plan 2030" was formulated in 2021, setting medium-term and specific action to achieve carbon neutrality by 2050. The Singapore Green Plan 2030 has five pillars: (1) City in Nature, (2) Energy Reset, (3) Sustainable Living, (4) Green Economy, and (5) Resilient Future, with specific action for each pillar as shown in the table below.

Regarding electricity policy, given Singapore's limited renewable energy generation potential, the government has set a medium-term to expand imports of renewable energy electricity from neighboring countries. The government aims to import up to 4 GW of renewable energy electricity by 2035, covering about 30% of Singapore's electricity supply. In addition to this goal, the government set the long-term goal by 2050 based on three scenarios (details are provided in Section 1.8.4.2, "Power Generation Facility Plan").

**Table 1.7.1 Action Goals in the Singapore Green Plan 2030**

| Category | Target Year | Contents |
|---|---|---|
| City in Nature | 2026 | Develop new parks with more than 130 ha and improve the existing parks |
| | 2030 | Double the annual tree-planting rate, plant more than 1 million trees<br>Increase park area by 50% compared to 2020<br>All residentials will be within a 10-minute walk from the park |
| | 2035 | Increase green space by 1,000 ha |
| Energy Reset | 2025 | Peak solar power generation capacity to 1.5 GW<br>Install 200 MWh of energy storage (achieved by 2022)<br>Reduce energy consumption in the seawater desalination process to less than 2 kWh/m3<br>Build 100% energy self-sufficient waste and used water treatment facility (Tuas Nexus)<br>Suspend new registration of diesel vehicles<br>Install EV chargers in all parking lots developed by the Housing Development Board (HDB) |

| | | |
|---|---|---|
| | | Electrify New light vehicles, forklifts, and tractors at Changi Airport |
| | 2030 | Increase the peak generation capacity of solar to more than 2 GW<br>Develop highest level of power generation technology to reduce CO2<br>Green 80% of buildings (based on total floor area)<br>Increase the share of high energy efficient building in new building to 80%<br>Improve energy efficiency in best-in-class green buildings by 80% compared to 2005 levels<br>Reduce energy consumption in existing HDB towns by 15%.<br>Unify new car registrations with cleaner energy models.<br>Deploy 60,000 EV charging points nationwide<br>Ensure all new port vessels in port waters are either electric or B100 biofuel capable |
| | 2040 | All vehicles run on cleaner energy<br>All airport vehicles at Changi Airport run on cleaner energy |
| Sustainable Living | 2026 | Reduce 20% in landfill disposal per person per day |
| | 2030 | Reduce residential water consumption to 130 liters per person per day<br>Reduce landfill disposal by 30% per day per day<br>Increase the modal share at peak hour by 75%<br>Electrify half of all public buses.<br>Expand rail network to 360 km by early 2030s<br>Expand bicycle road network to approximately 1,300 km<br>Reduce net carbon emissions from the school sector by two-thirds<br>Make more than 20% of schools carbon neutral |
| | 2040 | Replace existing diesel buses with cleaner energy buses<br>Increase the modal share at peak hour by 80%<br>Public transportation, active transportation (e.g., walking and bicycling), and shared transportation should account for nine-tenths of all trips during peak hours. |
| Green Economy | 2030 | Make Jurong Island a sustainable energy and chemical park<br>Make Singapore a sustainable tourist destination<br>Make Singapore a major hub for green finance and services<br>Make Singapore the carbon service hub of Asia<br>Make Singapore a regional center for developing new sustainable solutions<br>Develop a strong group of companies from local businesses and seize opportunities for sustainability |
| Resilient Future | 2030 | Complete the coastal protection plan for the east and northwest coasts of the city and Jurong Island.<br>Strengthen the capacity of Singapore's agriculture and food industry to locally and sustainably produce 30% of Singapore's food needs. |

Source: Singapore government website.

1.7.2 Current and Projected Energy and Electricity Supply and Demand

(1) Current Energy Supply and Demand

1) Domestic energy production

Singapore has few domestic energy resources and relies on imports from abroad for almost its entire energy supply. Its energy self-sufficiency rate was at 2% in 2022. In recent years, Singapore has been increasing the amount of renewable energy such as solar and biomass, but it has yet to significantly improve the energy self-sufficiency rate.

**Table 1.7.2 Domestic Energy Production in Singapore (Unit: ktoe)**

| | Coal | Crude oil | Natural gas | Nuclear | Hydro | Renewable energy | Total |
|---|---|---|---|---|---|---|---|
| 1990 | 0 | 0 | 0 | 0 | 0 | 70 | 70 |
| 1995 | 0 | 0 | 0 | 0 | 0 | 202 | 202 |
| 2000 | 0 | 0 | 0 | 0 | 0 | 202 | 202 |
| 2005 | 0 | 0 | 0 | 0 | 0 | 394 | 394 |
| 2010 | 0 | 0 | 0 | 0 | 0 | 587 | 588 |
| 2015 | 0 | 0 | 0 | 0 | 0 | 621 | 621 |
| 2020 | 0 | 0 | 0 | 0 | 0 | 601 | 601 |
| 2022 | 0 | 0 | 0 | 0 | 0 | 690 | 690 |

Source: IEA, "World Energy Balances 2024_04

2) Primary energy supply

In Singapore, crude oil accounted for a large share of primary energy supply but natural gas has been increasing since the 2000s. In 2000, natural gas accounted for 6% of the total primary energy supply, but in 2005 it has risen to 24%, and has remained at around 25% since then.

**Table 1.7.3 Primary Energy Supply in Singapore (Unit: ktoe)**

| | Coal | Crude oil | Petroleum Products | Natural Gas | Nuclear | Hydro | Renewable Energy | Electric power | Total |
|---|---|---|---|---|---|---|---|---|---|
| 1990 | 21 | 41,678 | -30,243 | 0 | 0 | 0 | 70 | 0 | 11,526 |
| 1995 | 11 | 52,526 | -35,161 | 1,266 | 0 | 0 | 202 | 0 | 18,845 |
| 2000 | 0 | 42,668 | -25,321 | 1,119 | 0 | 0 | 202 | 0 | 18,669 |
| 2005 | 3 | 59,610 | -44,009 | 5,014 | 0 | 0 | 394 | 0 | 21,012 |
| 2010 | 7 | 45,530 | -28,438 | 6,493 | 0 | 0 | 587 | 0 | 24,180 |
| 2015 | 406 | 49,237 | -26,592 | 8,545 | 0 | 0 | 684 | 0 | 32,281 |
| 2020 | 433 | 46,522 | -22,549 | 9,227 | 0 | 0 | 671 | 0 | 34,305 |
| 2022 | 416 | 49,038 | -22,340 | 9,488 | 0 | 0 | 774 | 0 | 37,376 |

Source: IEA, "World Energy Balances 2024_04

3) Final energy consumption

In Singapore, industrial final energy consumption accounted for 38% of total energy consumption in 2022, transportation energy consumption 12%, commercial energy consumption 12%, residential energy consumption 4%, and non-energy use 33%. Compared to 2010, energy consumption increased in the industrial, commercial, and residential sectors. On the other hand, energy consumption in transportation has decreased by 7% compared to 2010. In addition to the development of public transport and improved fuel efficiency of vehicles, various policies aimed at limiting the number of vehicles on the road in the country, such as the Certificate of Entitlement (COE) required for vehicle purchase are thought to have contributed to this.

**Table 1.7.4 Final Energy Consumption in Singapore (Unit: ktoe)**

| | Industry | Transportation | Commercial | Agricultural, forestry and fisheries | Residential | Other | Non-energy use | Total |
|---|---|---|---|---|---|---|---|---|
| 1990 | 605 | 1,358 | 819 | 1 | 279 | 32 | 1,913 | 5,007 |
| 1995 | 748 | 1,882 | 781 | 2 | 370 | 42 | 2,234 | 6,060 |
| 2000 | 2,179 | 1,753 | 957 | 3 | 624 | 66 | 2,724 | 8,306 |
| 2005 | 3,235 | 1,955 | 1,223 | 0 | 607 | 114 | 6,325 | 13,460 |
| 2010 | 5,110 | 2,425 | 1,577 | 0 | 651 | 34 | 5,476 | 15,273 |
| 2015 | 6,474 | 2,593 | 1,773 | 0 | 702 | 26 | 7,243 | 18,810 |
| 2020 | 6,452 | 2,287 | 1,858 | 0 | 801 | 22 | 5,783 | 17,202 |
| 2022 | 7,049 | 2,247 | 2,157 | 0 | 765 | 19 | 6,150 | 18,388 |

Source: IEA, World Energy Balances 2024_04

(2) Current Electricity Supply and Demand

(1) Electricity generation

The total electricity generation was 55TWh in 2023 with 1% coming from coal, 0.4% from oil, 95% from gas-fired power, and 4% from other sources. Compared to 2010, oil-fired power generation has decreased sharply by 98%, while gas-fired power generation has increased by 50%. Solar power has also been increasing in recent years.

**Table 1.7.5 Electricity Generation in Singapore (Unit: GWh)**

| | Coal | Petroleum | Gas | Other | Total |
|---|---|---|---|---|---|
| 2005 | 0 | 8,827 | 28,430 | 955 | 38,213 |
| 2010 | 0 | 9,164 | 35,023 | 1,180 | 45,367 |
| 2015 | 603 | 352 | 47,909 | 1,458 | 50,272 |
| 2020 | 531 | 212 | 50,843 | 1,486 | 53,072 |
| 2023 | 557 | 223 | 52,624 | 2,395 | 55,687 |

Note: The electricity generation from each energy source is roughly calculated based on the total generation capacity and the generation mix percentages provided in the statistics. Due to rounding, the sum of the generation values for each energy source may not match the total generation capacity shown in the far-right column."

Source: Energy Market Authority of Singapore, "Singapore Energy Statistics 2024.

2) Exported imported and lost electricity etc.

No import or export of electricity has taken place in Singapore as of 2023.

**Table 1.7.6 Exported imported and lost electricity in Singapore, etc. (Unit: GWh)**

| | Electricity Generation | Imported Electricity | Exported Electricity | Transmission and distribution losses (etc.) | Domestic Electricity Consumption |
|---|---|---|---|---|---|
| 2005 | 38,213 | 0 | 0 | 2,724 | 35,489 |
| 2010 | 45,367 | 0 | 0 | 3,115 | 42,252 |
| 2015 | 50,272 | 0 | 0 | 2,758 | 47,514 |
| 2020 | 53,072 | 0 | 0 | 2,292 | 50,780 |
| 2023 | 55,687 | 0 | 0 | 802 | 54,885 |

Source: Energy Market Authority of Singapore, "Singapore Energy Statistics 2024.

3) Electricity consumption

The electricity consumption was approximately 55 TWh in 2023 with 40% from industrial, 40% from commercial, 14% from residential and 5% from transport. Compared to 2010, electricity consumption in Singapore has been increasing as a whole, with industrial consumption by 25%, commercial consumption by 44%, residential consumption by 21%, and transportation consumption by 44%.

**Table 1.7.7 Electricity Consumption in Singapore (Unit: GWh)**

| | Industry | Commercial | Residential | Transportation | Other | Total |
|---|---|---|---|---|---|---|
| 2005 | 14,509 | 13,076 | 6,093 | 1,200 | 612 | 35,489 |
| 2010 | 17,665 | 15,319 | 6,636 | 2,107 | 525 | 42,252 |
| 2015 | 20,088 | 17,481 | 7,221 | 2,445 | 279 | 47,514 |
| 2020 | 20,979 | 18,518 | 8,245 | 2,809 | 229 | 50,780 |
| 2023 | 22,103 | 22,093 | 8,003 | 3,030 | 158 | 55,387 |

Source: Energy Market Authority of Singapore, "Singapore Energy Statistics 2024.

(3) Renewable Energy Potential

Singapore has the smallest land area among ASEAN countries, and consequently, its renewable energy potential is also the smallest, with 0.3 GW from solar PV and 0.1 GW from onshore wind power, totaling 0.4 GW.

**Table 1.7.8 Renewable Energy Potential in Singapore (Unit: GW)**

| Solar PV | Onshore wind | Offshore wind | Biomass | Hydro | Geothermal | Total |
|---|---|---|---|---|---|---|
| 0.3 | 0.1 | - | - | - | - | 0.4 |

Source: IRENA & ACE; Renewable Energy Outlook for ASEAN, (2022).

(4) Energy Demand Forecasts

Public data on Brunei's energy demand has not been released.

(5) Electricity Demand Forecasts

Singapore's annual electricity demand and peak demand are expected to grow at an average annual growth rate of 2.8% to 3.2% from 2022 to 2032, and is expected to continue to increase steadily due to economic growth, digitalization, and electrification.

**Table 1.7.9 Assumed Electricity Demand in Singapore to 2032 (as of November 2021)**

| | Annual Electricity demand (GWh) | Annual peak demand (MW) |
|---|---|---|
| 2022 | 56,200 - 67,200 | 7,700 - 8,100 |
| 2025 | 64,000 - 67,200 | 8,800 - 9,300 |
| 2030 | 71,300 - 76,400 | 9,800 - 10,600 |
| 2032 | 74,000 - 79,500 | 10,100 - 11,000 |

Source: Energy Market Authority of Singapore, "Singapore Electricity Market Outlook 2021.

1.7.3 Actual Situation of Electricity Import/Export

There has been no electricity imports and exports to Singapore between 2005 and 2022, for which statistics are currently available. However, the Singaporean government has announced a goal to import up to 4 GW of renewable energy by 2035, which would provide approximately 30% of Singapore's electricity supply. To achieve this, technical and regulatory framework for future large-scale electricity imports is currently under consideration. As of now, Singapore has interconnection lines with Malaysia only.

1.7.4 Power Supply Development Plan, National Grid Development Plan

(1) Power Generation Plants

In Singapore, the installed generation capacity was 12 GW in 2024, with gas-fired power generation accounting for more than 80% of the total generation capacity.

**Table 1.7.10 Power Generation Plants in Singapore (Unit: MW)**

| | Gas (CCGT) | Gas (OCGT) | Coal, Petroleum | Solar | Waste Power Generation | Storage Battery | Total |
|---|---|---|---|---|---|---|---|
| 2005 | 4,534 | 287 | 4,640 | 0 | 306 | 0 | 9,767 |
| 2010 | 6,154 | 370 | 3,148 | 3 | 257 | 0 | 9,931 |
| 2015 | 10,356 | 180 | 2,557 | 46 | 257 | 0 | 13,395 |
| 2020 | 10,491 | 180 | 764 | 331 | 257 | 0 | 12,022 |
| 2024 | 10,530 | 180 | 14 | 1,038 | 345 | 200 | 12,306 |

Source: Energy Market Authority of Singapore, "Singapore Energy Statistics 2024.

(2) Power Generation Facility Plan

Singapore expects that it will need additional generation capacity in 2028 due to increased peak power demand, and has implemented a plan to develop 600 MW of gas-fired capacity by the end of 2027. The following is the status of the power generation facility plan for 2028 and beyond but only the power generation mix has been considered.

In 2035, power generation mix in Singapore is expected to consist of 50% natural gas and 30% renewable energy imports, with the remaining 20% from solar power, hydrogen, biomass, and other sources.

In 2050, power generation mix in Singapore is considered based on the following three scenarios

1. Clean Energy Renaissance

   In this scenario, clean energy technology advances and global coordination will continue over the next 30 years, and Singapore will steadily decarbonize by diversifying its electricity supply mix through electricity imports and the development of hydrogen and geothermal power generation, while maintaining the stability and reliability of its electricity system through the widespread use of distributed energy resources (DER). This scenario is a good example of how Singapore can make progress in decarbonizing its electricity system. Of the total electricity supply sources, 40% will come from hydrogen and 40% from renewable electricity imports, with the remaining 20% from solar and geothermal.
2. Climate Action Bloc

   This scenario assumes that progress in clean energy technologies will be slow, but that countries will unite to combat climate change, and that electricity imports will be the main source of electricity supply in 2050. Of the total electricity supply, 60% will come from renewable electricity imports, 10% from hydrogen, and the remaining 30% from natural gas, solar, and geothermal, mainly offset by carbon credits.

3. Emergent Technology Trailblazer
   This scenario assumes that hydrogen will be the main source of electricity supply in 2050 as a result of Singapore's aggressive investment in new technologies and accelerated development of hydrogen technology, despite the difficulties in trading international electricity and carbon credits due to increasing geopolitical divisions and global nationalism. Of the total electricity supply, 50% will come from hydrogen, less than 25% from renewable electricity imports and the remaining from solar, nuclear, and geothermal power.

**Table 1.7.11 Assumed Power Supply Structure in Singapore by 2050 (as of January 2024)**

| | Coal | Petroleum | Natural gas | Solar, Biomass | Total |
|---|---|---|---|---|---|
| 2023 (Actual) | 0.9% | 0.3% | 94.3% | 4.4% | 100%. |
| | Natural gas | Renewable energy Electricity imports | Other | Total | |
| Year 2035 | 50% | 30% | 20%. | 100% | |
| | hydrogen | Renewable energy Electricity imports | Other | Total | |
| 2050 (Clean Energy Renaissance) | 40% | 40% | 20%. | 100% | |
| 2050 (Climate Action Bloc) | 10% | 60% of the time | 30 | Total | |
| 2050 (Emergent Technology Trailblazer) | More than 50% | Less than 25% | Less than 25% | 100% | |

Source: Energy Market Authority of Singapore, "Energy 2050 Committee Report.")

(3) Cost of Electricity

According to the AIMSIII Phase I Update report, Singapore's electricity generation cost in 2020 was 8.8 cents per kWh.

(4) Domestic Transmission System

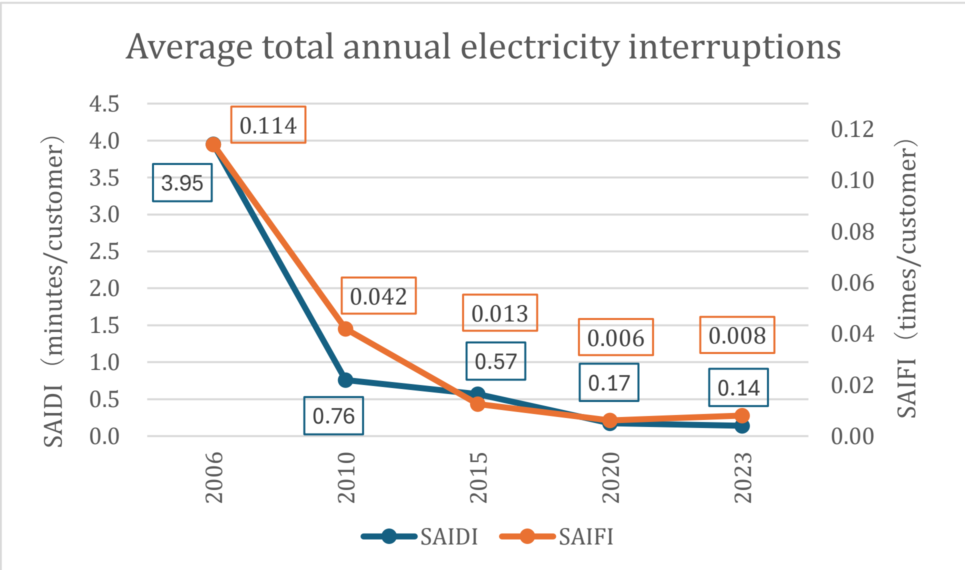
All domestic transmission systems are managed by the SP Group and consist of 400kV, 230kV, and 66kV.

(5) Domestic Grid Development Plans

Public data on Singapore's energy demand has not been released.

(6) Supply Reliability

In Singapore, the supply reliability is among the highest in the world, with the average outage duration (SAIDI) was 0.14 minutes/customer and the average number of outages (SAIFI) was 0.008/customer in 2023.




Source: Energy Market Authority of Singapore, System Average Interruption Duration Index (SAIDI) & System Average Interruption Frequency Index (SAIFI)

**Figure 1.7.1 Supply Confidence in Singapore**

1.7.5 Status of Existing International Interconnection Lines

In Singapore, the existing international interconnection line is only interconnected to Malaysia with a capacity of 1 GW. The Singapore-Malaysia international interconnection line was built in 1983, and in 2022 it was upgraded to nearly double its transmission capacity.

In June 2022, as part of the Laos-Thailand-Malaysia-Singapore Power Integration Project (LTMS-PIP: Lao PDR-Thailand-Malaysia-Singapore Power Integration Project), up to 100 MW of hydro from Laos was experimentally imported to Singapore via Thailand and Malaysia through the existing interconnection line. In addition, a pilot program has begun in 2024, which will involve importing 100 MW of electricity from Malaysia to Singapore over two years through the same interconnection

**Table 1.7.12 Existing International Interconnection lines in Singapore (as of June 2024)**

| Connection area/point | Voltage (kV) | Transmission capacity (MW) | Start of operation |
|---|---|---|---|
| Singapore - Malaysia | Unknown<br>(230KV or 400kV) | 1,000 | 1983 |

Source: Singapore government website

In 2023, the Energy Market Authority of Singapore (EMA) has approved a project to import 1 GW of electricity from Cambodia, 2 GW from Indonesia, and 1.2 GW from Vietnam, in addition, 1.4GW from Indonesia and 1.75GW from Australia in 2024 These projects involve laying submarine interconnection lines from each country to Singapore, and importing low-carbonenergy through these interconnection lines. Singapore aims to import around 6GW of low-carbon electricity by 2035.

**Table 1.7.13 International Interconnection Line Development Plan in Singapore (as of March 2025)**

| Connected area | Transmission capacity (MW) | Year of one's fortune (fortune-telling) | Situation |
|---|---|---|---|
| Singapore ～ Cambodia | 1,000 | Unknown at this time | in planning |
| Singapore ～ Indonesia | 3,400 | 2028 | in planning |
| Singapore ～ Vietnam | 1,200 | Unknown at this time | in planning |
| Singapore ～ Australia | 1,750 | Be after 2035 | in planning |

Source: EMA's website

The ASEAN Interconnection Masterplan Study (AIMS) III Phase 1 & 2 Update, published in August 2023, outlines the status of cross-border interconnections as of 2022, as well as projections for interconnection development under three scenarios for 2025 and 2040: the Updated Power Development Plan (Updated PDP), the ASEAN Renewable Energy Target Case (ASEAN RE Target), and the High Renewable Energy Target (High RE Target). For Singapore, the outlook for cross-border interconnections is presented as follows.

**Table 1.7.14 Status and Outlook of Cross-Border Interconnections in Singapore (MW)**

| AIMS No | International interconnection line (country-to-country) | APG Status | Updated PDP | | ASEAN RE Target | | High RE Target | |
|---|---|---|---|---|---|---|---|---|
| | | 2022 | 2025 | 2040 | 2025 | 2040 | 2025 | 2040 |
| 1 | P. Malaysia - Singapore | 525 | 1,050 | 1,050 | 1,050 | 1,050 | 1,705 | 3,154 |
| 5 | Batam - Singapore | - | - | - | - | - | - | - |
| 16 | Sumatra - Singapore | - | - | 1,200 | 843 | 1,133 | 8,599 | 10,000 |

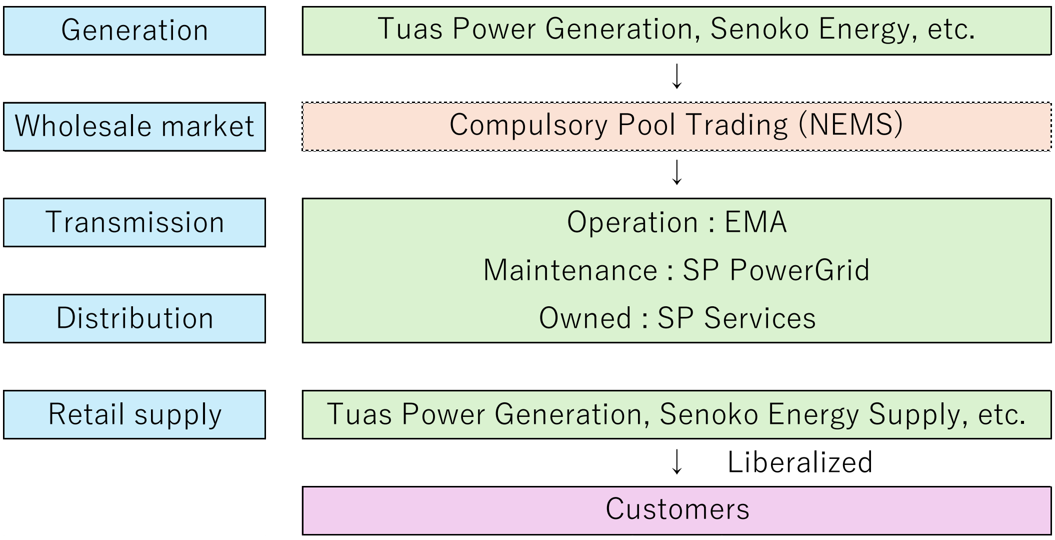
Source: ACE, (2023), Findings of ASEAN Interconnection Masterplan Study (AIMS) III Phase 1 & 2 Update.

### 1.7.6 Trends in Electricity and International Electricity Markets

#### (1) Electric Utility System

In Singapore, the electricity business, which had been state-run for many years, has been gradually restructured and liberalized since 1995. To operate in the electricity sector, a license from EMA is required. However, in the transmission and distribution sector, only Singapore Power (SP) Group, a wholly owned subsidiary of Temasek Holdings, a government-affiliated investment company, holds a license. SP Power Assets owns the transmission and distribution assets, SP PowerGrid maintains and operates the transmission and distribution facilities, and SP Services provides meter reading and final security of supply to customers. Grid operations are carried out by EMA.

The power generation and retail sectors have been liberalized, and as of June 2024, 19 power generation and 17 retail licenses have been registered. All electricity generated by power companies is traded on the National Electricity Market of Singapore (NEMS) on a half-hourly basis. The Energy Market Company (EMC) is the sole operator and manager of the wholesale market. The minimum requirement for a power generation company is to own at least one generator with more than 10 MW, while a company that owns only a generator between 1 MW and 10 MW is classified as a wholesale company. Entities that provide ancillary services to the grid through load shedding or supply generated electricity to non-residential customers on the same premises are also required to obtain a wholesale company license.




Source: Compiled by JICA Team

**Figure 1.7.2 Electric Utility System in Singapore**

(2) Electric Utility Regulations

In Singapore, the Energy Division of the Ministry of Trade and Industry (MTI) is responsible for formulating energy policy, including electricity policy. Under MTI, the energy market authority (EMA) serves as the regulator for the electricity, gas, and district cooling markets. Under the EMA, grid operations, grid development plans, and liberalization of the electricity and gas market in generation and retail sector has been implemented.

(3) Major Electric Utility

In Singapore, the major electric utilities are Singapore Power (SP) Group, Senoko Energy, YTL PowerSeraya, and Tuas Power, which were established following the restructuring of the electric power business since 1995. The SP Group operates in the transmission and distribution sector as a regulated business, and as of 2022, Tuas Power Generation, Senoko Energy, and YTL PowerSeraya will account for about 50% of the total in the power generation sector, while in the retail sector, SP Services (regulated rates), Tuas Power Supply, Seraya Energy, and Senoko Energy Supply accounts for about 70% of the total market share.

Singapore Power is a wholly owned subsidiary of Temasek Holdings, a government-owned investment company.

Senoko Energy was originally established as the power generation arm of Singapore's Public Utilities Board (PUB), but was sold to Singapore Power in 1995, and in 2001, it became a direct subsidiary of Temasek Holdings. In 2008. The company privatized after being sold to a consortium led by Marubeni Corporation including Engie, Kansai Electric Power Company, Kyushu Electric Power Company, and Japan Bank for International Cooperation (JBIC) as members.

YTL PowerSeraya was initially established as part of Singapore Power, but was privatized in 2001 when it became a direct subsidiary of Temasek Holdings and was sold to Malaysia's YTL Power International Berhad in 2009.

Tuas Power was initially established as a direct subsidiary of Temasek Holdings and was privatized in 2008 when it was sold to Sino Sing Power, a wholly owned subsidiary of China Huaneng Group.

(4) Electricity Trading Environment with Foreign Operators and Domestic Market

For importing electricity into Singapore, the requirements are outlined in the Guide to Electricity Imports published by the EMA. Due to the limited capacity of international interconnection lines, the EMA issued a public call for proposals. Only those companies selected by the EMA are authorized to import electricity.

Authorized electricity importers are granted a license by the EMA and required to participate in the Singapore National Electricity Market (NEMS). They are required to follow the market rules such as participating in 30-minute trading intervals.

## 1.8 Thailand

### 1.8.1 Policies for the Energy and Power Sector

#### (1) Climate Change Targets

Thailand has committed to achieving carbon neutrality by 2050 and aim to reach net zero greenhouse gas emissions by 2065. Thailand also submitted a medium-term target to UN to reduce greenhouse gas emissions by 40% in 2030 compared to BAU, subject to certain condition. This condition depends on receiving support in financial, technological, and capacity-building from developed countries.

#### (2) Energy and Electricity Policy

Thailand has formulated the "National Energy Plan (NEP)" to outline policy directions for the gradual transition to clean energy and the reduction of greenhouse gas emissions. In June 2024, the draft of the next "National Energy Plan" was released for public comment. The "National Energy Plan" includes the "Power Development Plan (PDP)," the "Alternative Energy Development Plan (AEDP)," and others. While final details may be subject to change, the key contents of these plans are as follows:

The draft "PDP 2024" presents a strategic plan for power development in Thailand from 2024 to 2037. It aims to ensure a stable, cost-effective, and sustainable power supply while addressing the increasing domestic energy demand and adapting to the global trend of decarbonization and the expansion of renewable energy utilization.

According to "PDP 2024," peak electricity demand is projected to reach 56,133 MW by 2037, with an additional 77,407 MW of capacity planned. Currently, the existing capacity stands at 53,868 MW, with 18,884 MW scheduled for decommissioning. As a result, the total supply capacity is expected to reach 112,391 MW by 2037. The breakdown of the additional 77,407 MW capacity is as follows:

1. New power generation plants (47,251 MW),
2. Energy storage plants (12,957 MW), and
3. Power generation from existing contracts (17,199 MW).

Among the new power generation plants, renewable energy accounts for 34,851 MW, combined cycle power plants for 6,300 MW, nuclear power (small modular reactors) for 600 MW, imported electricity from neighboring countries for 3,500 MW, and other sources (demand response and vehicle-to-grid) for 2,000 MW.

As for energy storage, pumped storage power is set at 2,472 MW, while battery energy storage systems (BESS) will account for 10,485 MW.

"PDP 2024" is based on the principles of stability, economic efficiency, and sustainability in power supply.

- Regarding stability, it aims to secure a stable and reliable power supply that can meet electricity demand at all times, while also addressing the intermittency of renewable energy.
- For economic efficiency, it focuses on stabilizing and rationalizing electricity prices while efficiently utilizing existing infrastructure such as gas pipelines and terminals.
- In terms of sustainability, it aims to increase the share of renewable energy, improve energy efficiency, and achieve $CO_2$ reduction targets.

The draft "AEDP 2024" sets specific targets and measures to increase the share of renewable energy in Thailand's energy mix, reduce greenhouse gas emissions, and achieve long-term sustainability.

"AEDP 2024" outlines the following renewable energy targets:

1. Renewable energy power capacity,
2. Thermal energy production, and
3. Biofuels.

The target for renewable energy power capacity is to increase it to 73,286 MW by 2037. The breakdown includes:

- Solar power (including ground-mounted and floating solar) at 38,974 MW,
- Wind power at 9,379 MW,
- Biomass power at 5,490 MW, and
- Hydropower at 2,918 MW.

The target for thermal energy production is to increase it to 17,061 ktoe by 2037, with biomass accounting for 15,551 ktoe, while the remainder consists of biogas, waste-to-energy, and solar thermal energy.

The target for biofuels is to reach 1,621 ktoe by 2037, including:

- Biodiesel at 775 ktoe,
- Ethanol at 289 ktoe, and
- Sustainable Aviation Fuel (SAF) at 553 ktoe.

"AEDP 2024" aims to achieve a reduction of at least 75 $MtCO_2e$ in $CO_2$ emissions by 2037 compared to current levels, aligning with Thailand's long-term carbon neutrality goals.

To achieve these targets, "AEDP 2024" incorporates several measures, including:

1. Environmentally friendly financial support (investment incentives and utilization of green finance),

2. Improvements to the renewable energy purchase price system,
3. Support for the development of energy storage systems,
4. Investments in strengthening transmission networks and infrastructure, and
5. Promotion of research and development (R&D) in renewable energy technologies.

1.8.2 Current and Projected Energy and Electricity Supply and Demand

(1) Current Energy Supply and Demand

1) Domestic energy production

Thailand produced coal, crude oil, and natural gas domestically with an energy self-sufficiency rate at 45% in 2022. However, as primary energy supply increased, the country became more dependent on imports from overseas. The energy self-sufficiency rate decreased about 16 percentage points compared to 2000. In 2022, the self-sufficiency rates ware 19% for coal 22% crude oil, and 57% for natural gas with coal and crude oil in particular dependent on imports. Domestic natural gas production conducted in Erawan, Bongkot, and Pailin, all of which are offshore gas fields located in Taiwan.

**Table 1.8.1 Domestic Energy Production in Thailand (Unit: ktoe)**

| | Coal | Crude oil | Natural gas | Nuclear | Hydro | Renewable Energy | Total |
|---|---|---|---|---|---|---|---|
| 1990 | 3,602 | 2,863 | 4,994 | 0 | 428 | 14,922 | 26,810 |
| 1995 | 5,344 | 4,327 | 8,714 | 0 | 577 | 14,236 | 33,198 |
| 2000 | 5,135 | 8,065 | 15,639 | 0 | 518 | 14,598 | 43,955 |
| 2005 | 6,055 | 12,976 | 18,504 | 0 | 499 | 17,163 | 55,197 |
| 2010 | 5,320 | 17,490 | 24,728 | 0 | 478 | 22,578 | 70,593 |
| 2015 | 3,858 | 19,701 | 25,794 | 0 | 333 | 25,454 | 75,140 |
| 2020 | 3,282 | 17,062 | 20,366 | 0 | 402 | 23,652 | 64,764 |
| 2022 | 3,379 | 13,215 | 17,489 | 0 | 584 | 23,637 | 58,304 |

Source: IEA, World Energy Balances 2024_04.

2) Primary energy supply

In Thailand, primary energy supply is also increasing as final energy consumption increases. In particular, primary energy supply from coal has grown relatively high with increasing 2.3 times from 2000 to 2022. However, compared to 2010, the growth rate has moderated to about 7%.

**Table 1.8.2 Primary Energy Supply in Thailand (Unit: ktoe)**

| | Coal | Crude Oil | Petroleum Products | Natural Gas | Nuclear | Hydro | Renewable Energy | Electric Power | Total |
|---|---|---|---|---|---|---|---|---|---|
| 1990 | 3,819 | 12,682 | 5,498 | 4,994 | 0 | 428 | 14,920 | 53 | 42,395 |
| 1995 | 6,883 | 26,067 | 5,648 | 8,714 | 0 | 577 | 14,245 | 53 | 62,188 |
| 2000 | 7,673 | 39,858 | -7,617 | 17,368 | 0 | 518 | 14,612 | 238 | 72,651 |
| 2005 | 11,503 | 52,670 | -8,529 | 25,930 | 0 | 499 | 17,186 | 325 | 99,583 |
| 2010 | 16,362 | 58,643 | -13,693 | 32,965 | 0 | 478 | 22,619 | 488 | 117,862 |
| 2015 | 16,863 | 69,357 | -15,304 | 37,751 | 0 | 333 | 25,515 | 1,044 | 135,560 |
| 2020 | 17,099 | 63,218 | -8,021 | 33,252 | 0 | 402 | 23,719 | 2,316 | 131,984 |
| 2022 | 17,503 | 60,359 | -5,149 | 30,541 | 0 | 584 | 23,659 | 2,873 | 130,370 |

Source: IEA, World Energy Balances 2024_04.

3) Final energy consumption

In Thailand, industrial final energy consumption accounted for 33% of total energy consumption, transportation energy consumption 29%, residential energy consumption 9%, and non-energy use 22%. On the other hand, residential energy consumption decreased by 24% compared to 2010, possibly due to energy conservation and other factors.

**Table 1.8.3 Final Energy Consumption in Thailand (Unit: ktoe)**

| | Industry | Transportation | Commercial | Agricultural, Forestry and Fisheries | Residential | Other | Non-energy use | Total |
|---|---|---|---|---|---|---|---|---|
| 1990 | 8,678 | 9,229 | 1,401 | 1,820 | 7,589 | 21 | 429 | 29,168 |
| 1995 | 15,939 | 15,670 | 2,533 | 1,587 | 7,131 | 53 | 1,774 | 44,688 |
| 2000 | 16,744 | 14,968 | 3,091 | 2,817 | 7,667 | 42 | 5,753 | 51,082 |
| 2005 | 23,422 | 18,537 | 3,828 | 3,239 | 9,199 | 49 | 12,251 | 70,524 |
| 2010 | 26,493 | 19,426 | 5,604 | 3,472 | 11,286 | 68 | 18,085 | 84,433 |
| 2015 | 32,161 | 22,742 | 4,469 | 3,930 | 11,553 | 562 | 22,643 | 98,059 |
| 2020 | 30,827 | 26,604 | 4,580 | 2,341 | 8,875 | 641 | 22,924 | 96,792 |
| 2022 | 31,535 | 27,777 | 4,781 | 2,173 | 8,592 | 713 | 21,217 | 96,788 |

Source: IEA, World Energy Balances 2024_04.

(2) Current Electricity Supply and Demand

1) Electricity generation

In Thailand, the total electricity generation was 190 TWh in 2023, with 16% coming from coal-fired, 68% from gas-fired, 3% from hydropower, and 12% from renewable energy. Compared to 2000, coal-fired has increased by 67%, while oil-fired has declined sharply. Gas-fired has also increased markedly, with 2.2 times increase compared to 2000. In recent years, the electricity generation from renewable energy has increased rapidly.

**Table 1.8.4 Electricity Generated in Thailand (Unit: GWh)**

| | Coal | Petroleum | Gas | Nuclear | Hydro | Renewable energy | Total |
|---|---|---|---|---|---|---|---|
| 2000 | 18,197 | 9,751 | 61,095 | 0 | 5,891 | 495 | 95,430 |
| 2005 | 20,614 | 7,908 | 94,468 | 0 | 5,671 | 1,765 | 130,427 |
| 2010 | 29,764 | 619 | 118,438 | 0 | 5,347 | 3,407 | 157,577 |
| 2015 | 34,582 | 923 | 128,525 | 0 | 3,761 | 10,041 | 177,835 |
| 2020 | 36,823 | 722 | 113,859 | 0 | 4,540 | 20,529 | 176,477 |
| 2023 | 30,433 | 888 | 129,402 | 0 | 6,588 | 23,179 | 190,495 |

Source: EPPO, Energy Statistics in Thailand

2) Exported, imported and lost electricity, etc.

In Thailand, the total imported electricity was about 33 TWh, and the total exported electricity was about 2 TWh in 2023, with imported electricity accounting for 15% of the total electricity supply. The imported electricity has increased by 4.5 times compared to 2010.

**Table 1.8.5 Exported, imported and lost electricity, etc. in Thailand (Unit: GWh)**

| | Electricity Generation | Imported Electricity | Exported Electricity | Power supply | Transmission and Distribution Losses, etc. | Domestic Electricity Consumption |
|---|---|---|---|---|---|---|
| 2005 | 130,426 | 4,372 | 501 | 134,297 | 13,057 | 121,240 |
| 2010 | 157,575 | 7,254 | 1,314 | 163,515 | 14,214 | 149,301 |
| 2015 | 177,832 | 14,414 | 2,267 | 189,980 | 15,147 | 174,833 |
| 2020 | 176,473 | 29,551 | 2,618 | 203,406 | 16,359 | 187,046 |
| 2023 | 190,490 | 32,805 | 2,256 | 221,038 | 17,116 | 203,923 |

Source: EPPO, Energy Statistics in Thailand

3) Electricity consumption

In Thailand, the electricity consumption was about 204 TWh in 2023 with 42% from industrial consumption, 25% from commercial consumption, and 28% from residential consumption. Compared to 2010, commercial consumption has increased 2.2 times and residential consumption has increased 2.3 times, but industrial consumption has only increased by around 32%.

**Table 1.8.6 Electricity Consumption in Thailand (Unit: GWh)**

| | Industry | Commercial | Agricultural, Forestry and Fisheries | Residential | Other | Total |
|---|---|---|---|---|---|---|
| 2005 | 65,365 | 23,145 | 249 | 25,482 | 6,998 | 121,240 |
| 2010 | 75,433 | 29,958 | 335 | 33,214 | 10,361 | 149,301 |
| 2015 | 83,984 | 42,466 | 387 | 41,286 | 6,711 | 174,833 |
| 2020 | 82,158 | 43,950 | 417 | 52,860 | 7,661 | 187,046 |
| 2023 | 86,274 | 49,962 | 484 | 57,726 | 9,476 | 203,923 |

Source: EPPO, Energy Statistics in Thailand.

(3) Renewable Energy Potential

Thailand has the third largest land area among ASEAN countries, and its total renewable energy potential is also the second largest, following Indonesia(except Myanmar). Due to its high solar irradiance, Thailand has a solar PV potential of 3,509.0 GW, which is the largest among ASEAN countries except Myanmar. Additionally, its onshore wind power potential (32.4 GW) is the largest among ASEAN countries.

**Table 1.8.7 Renewable Energy Potential in Thailand (Unit: GW)**

| Solar PV | Onshore wind | Offshore wind | Biomass | Hydro | Geothermal | Total |
|---|---|---|---|---|---|---|
| 3,509.0 | 32.4 | 29.6 | 18.0 | 15.0 | - | 3,604.0 |

Source: IRENA & ACE; Renewable Energy Outlook for ASEAN, (2022).

(4) Energy Demand Forecasts

Public data on Thailand 's energy demand has not been released.

(5) Electricity Demand Forecasts

In Thailand, the "Power Development Plan (PDP) 2018" formulated in October 2020 includes forecasts for electricity supply and demand until 2037, etc. In 2037, the total electricity generation (without considering energy conservation and electricity imports) will reach 367 TWh. Of this generation, Coal-fired is expected to decrease by only 4% between 2020 and 2037, while gas-fired is expected to increase by 59%. In addition, maximum electricity demand will increase to about 62 GW by 66% between 2020 and 2037. Electricity consumption is expected to reach 431 TWh by 67% between 2020 and 2037.

**Table 1.8.8 Forecasts of Electricity Supply and Demand in Thailand**

| | Electricity generation . (GWh) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Coal | Petroleum | Gas | Hydro | Renewable Energy | Energy Conservation | Electricity Imports | Total |
| 2020 | 47,804 | 186 | 123,636 | 28,512 | 19,677 | | 132 | 219,946 |
| 2025 | 36,357 | 101 | 168,940 | 27,810 | 27,762 | | 131 | 261,100 |
| 2030 | 43,225 | 101 | 186,904 | 33,233 | 39,545 | | 131 | 303,138 |
| 2035 | 48,510 | 101 | 185,941 | 39,143 | 61,971 | 12,505 | 131 | 348,302 |
| 2037 | 46,087 | 101 | 196,062 | 38,308 | 66,270 | 20,499 | 131 | 367,458 |

| | Power Generation Capacity (MW) | Maximum power Demand (MW) | Energy consumption (GWh) |
|---|---|---|---|
| 2020 | 51,393 | 37,437 | 258,549 |
| 2025 | 54,026 | 44,396 | 306,774 |
| 2030 | 62,554 | 51,341 | 355,789 |
| 2035 | 73,984 | 58,803 | 408,281 |
| 2037 | 77,211 | 61,965 | 430,693 |

Source: EPPO, Power Development Plan 2018.

1.8.3 Actual Situation of Electricity Import/Export

Thailand imports electricity mainly from Laos. This is due to the recent development of power sources by IPPs in Laos, and the power generated by these IPPs is procured by EGAT under the PPA. While the Thai government aims to reduce its reliance on imported electricity, domestic power development is challenging, leading to continued dependence on electricity imports from other countries.

**Table 1.8.9 EGAT Electricity Imports (Unit: GWh)**

| | Laos | Malaysia | Total |
|---|---|---|---|
| 2005 | N.A. | N.A. | 4,375 |
| 2010 | 6,938 | 269 | 7,208 |
| 2015 | 14,288 | 138 | 14,427 |
| 2020 | 33,230 | 127 | 33,356 |
| 2022 | 35,383 | 89 | 35,472 |

Note: Data cited from EGAT's Annual Report, which specifies the country names

Source: EGAT, Annual Report.

1.8.4 Power Supply Development Plan, National Grid Development Plan

(1) Power Generation Plants

In Thailand, the installed generation capacity was 43 GW in 2023 with EGAT accounting for 39% of the total, IPPs for 39%, and Small Power Producers (SPPs) for 21% (excluding very small power producers). The installed capacity in EGAT was about 17 GW with 39% from thermal and 18% from hydropower. Regarding the ownership share of power generation plants, EGAT holds 39%, IPPs holds 39& and SPPs holds 21%. EGAT's share of ownership of generation plants has declined from 61% in 2005 to 39%.

**Table 1.8.10 Power Generation Plants in Thailand (Unit: MW)**

| | EGAT | IPP | SPP | Total | | | |
|---|---|---|---|---|---|---|---|
| 2005 | 15,795 | 8,000 | 2,016 | 25,811 | | | |
| 2010 | 14,998 | 12,152 | 2,182 | 29,332 | | | |
| 2015 | 15,518 | 14,767 | 5,144 | 35,429 | | | |
| 2020 | 16,037 | 14,249 | 9,474 | 39,760 | | | |
| 2022 | 16,920 | 16,749 | 9,195 | 42,864 | | | |
| | EGAT | | | | | | |
| | Thermal | Diesel | CCGT | Hydro | Renewable Energy | Other | Total |
| 2005 | - | - | - | - | - | - | 15,795 |
| 2010 | 4,699 | 4 | 6,866 | 3,424 | 5 | - | 14,998 |
| 2015 | 3,647 | 30 | 8,382 | 3,448 | 40 | - | 15,518 |
| 2020 | 3,687 | 30 | 8,262 | 2,972 | 86 | 1,000 | 16,037 |
| 2022 | 3,687 | 30 | 9,086 | 2,986 | 131 | 1,000 | 16,920 |

Note: Excluding Very Small Power Producers (VSPP).

Source: EGAT, "EGAT Annual Report", EPPO, "Energy Statistics in Thailand.

(2) Power Generation Facility Plan

In Thailand, Power Development Plan (PDP) 2018, formulated in October 2020, includes plans for power generation plants through 2037. In 2037, maximum power demand is expected to reach 62 GW and generation capacity will be 77 GW. Maximum demand is expected to increase by 66% and generation capacity by 50% between 2020 and 2037.

**Table 1.8.11 Planned Power Generation Plants in Thailand (Unit: MW)**

| | Maximum Power Demand | Power Generation Capacity |
|---|---|---|
| 2020 | 37,437 | 51,393 |
| 2025 | 44,396 | 54,026 |
| 2030 | 51,341 | 62,554 |
| 2035 | 58,803 | 73,984 |
| 2037 | 61,965 | 77,211 |

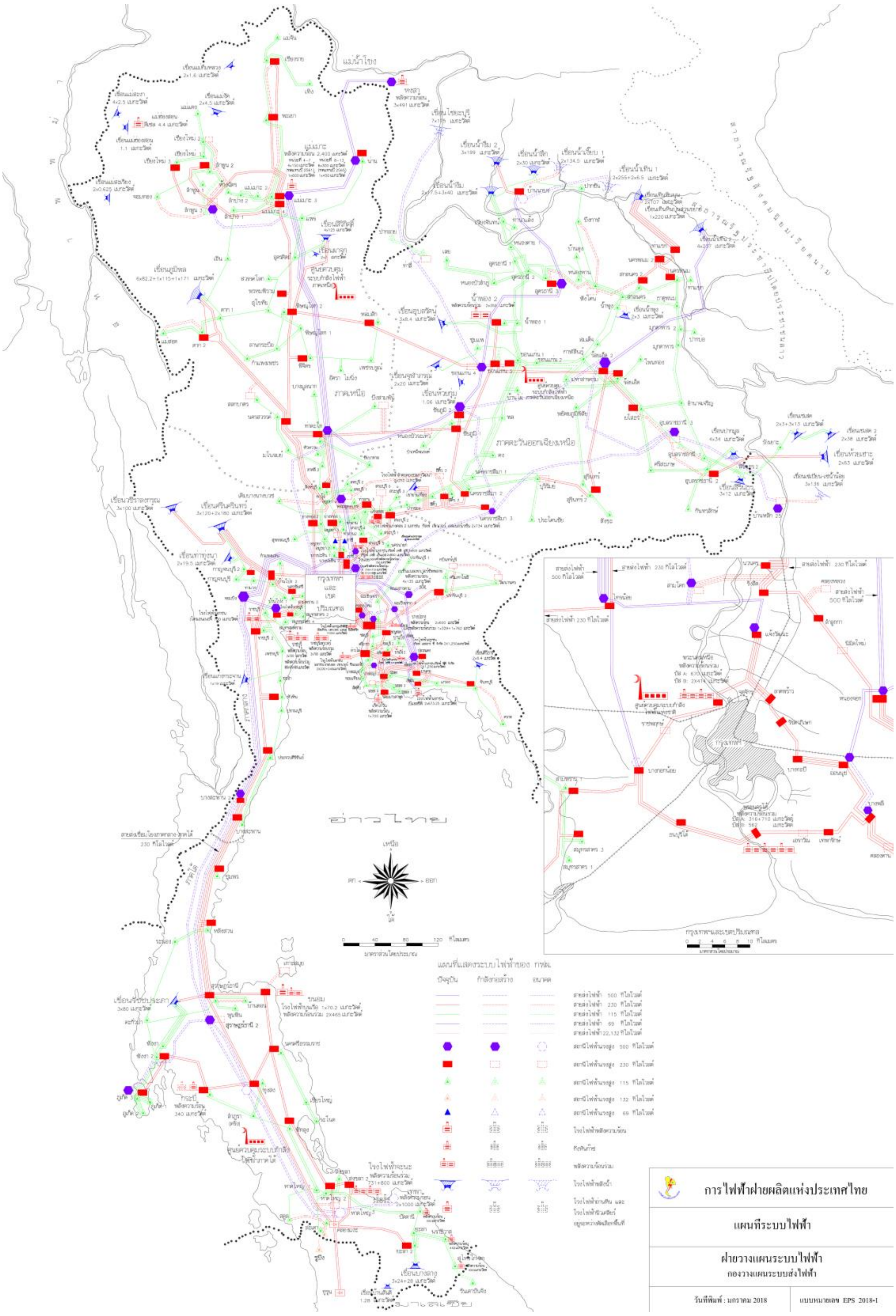
Source: EPPO, Power Development Plan 2018.

(3) Cost of Electricity [Metrological Analysis II

According to the AIMSIII Phase I Update report, Thailand's electricity generation cost in 2020 was 4.8 cents per kWh.

(4) Domestic Transmission System

In Thailand, 500 kV and 230 kV transmission lines have been constructed as bulk systems, 115 kV and 69 kV lines have been installed as local systems. 500 kV lines are used to transmit power from the Mae Moh coal-fired power plant in the north and major thermal power plants in the central region to the south and the capital region. The 230 kV line constitutes the outer ring of the Bangkok metropolitan area and connects the main power plants and substations, as well as the interconnecting substation with Malaysia.




Source: EPPO, Power Development Plan 2018.

**Figure 1.8.1 Domestic Transmission System Diagram in Thailand (as of 2018)**

(5) Domestic Grid Development Plans

In Thailand, the Power Development Plan (PDP) 2018, formulated in October 2020, includes a domestic grid development plan for 2018 and beyond. Although it does not describe specific domestic grid development plans, it lists nationwide grid expansion projects, renewal of the aging transmission system, and enhancement of the transmission system to strengthen power stability.

**Table 1.8.12 Domestic Grid Plan in Thailand (2018-2037)**

| | Project | Start of Operation |
|---|---|---|
| Under construction | | |
| 1 | Electricity transmission system expansion project in Bangkok and surrounding areas | Phase 3: 2021 |
| 2 | Electricity transmission system expansion project | 2023 |
| 3 | Project to improve the electrical transmission system in the eastern region to enhance Stable electrical system | 2021 |
| 4 | Project to improve the electrical transmission system in the western and southern regions to enhance the stability of the electrical system | 2021 |
| 5 | Project to improve and expand the electrical transmission system that has deteriorated over time, Phase 1: High Voltage Power Station | 2021 |
| 6 | Project to improve and expand the electrical transmission system that has deteriorated over time | 2023 |
| 7 | Project to improve and expand electrical transmission systems that have deteriorated over time | 2022 |
| 8 | Electricity transmission system project to purchase electricity from large private power producers (IPP 2007) | |
| 9 | Project to expand the main electricity transmission system to support small private power producers using the Cogeneration system in accordance with the The Project to expand the main electricity transmission system to support small private power producers using the Cogeneration system in accordance with the electricity purchase regulations of 2010 | 2019 |
| 12 | Project to improve the electrical transmission system in the northeastern region. Lower Northern, Central and Bangkok to enhance the stability of the Lower Northern, Central and Bangkok to enhance the stability of the electrical system | Phase 1: 2021<br>Phase 2: 2021<br>Phase3: N/A |
| 13 | Project to improve the electrical transmission system in the lower southern region to enhance Stable electrical system | Phase 1: 2021<br>Phase 2: N/A |
| 14 | Project to improve the electrical transmission system in the upper northern region to enhance Stable electrical system | 2023 |
| 15 | Electricity transmission system project for purchasing electricity from major private power producers | Phase 3: 2022 |
| 16 | Smart Grid Development Pilot Project in Mae Hong Son Province | 2020 |
| 17 | Project to improve/solve electrical system problems by installing a storage system Energy in Chaiyaphum and Lopburi provinces to support the impact of Energy in Chaiyaphum and Lopburi provinces To support the impact of renewable energy | 2020 |
| Under planning | | |
| 1 | Electricity transmission system development project to support special economic zones | Phase 1: 2024<br>Phase 2: 2024 |
| 2 | Project to develop an undersea cable system to Koh Samui District, Surat Thani Province, to enhance the stability of the electrical system | 2027 |

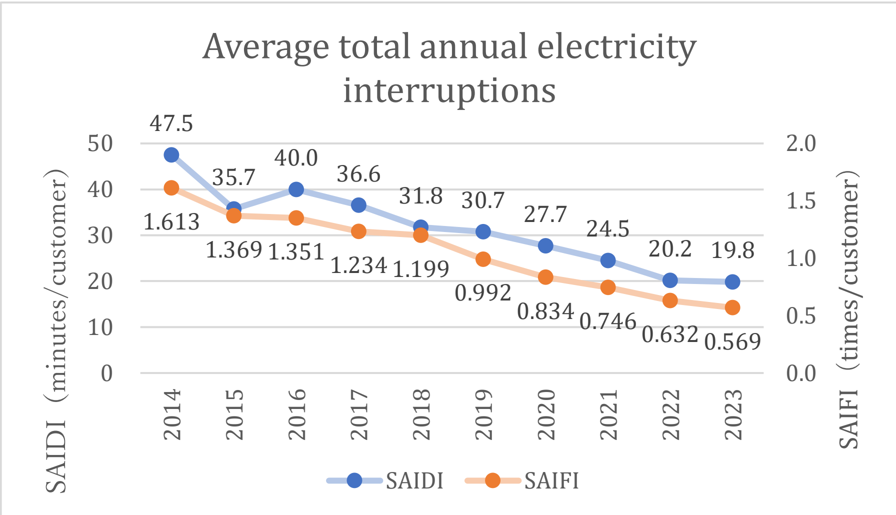
| | | |
|---|---|---|
| 3 | Project to expand the electricity transmission system in Bangkok and surrounding areas | 2022～ |
| 4 | Project to expand the electrical transmission system | 2024~. |
| 5 | Electricity transmission system project to support the project to increase water costs for Bhumibol Dam | 2027 |
| 6 | Electrical network system connection project to support the economic corridor route. | - |
| 7 | Project to improve and expand the electrical transmission system that has deteriorated over time | 2024~. |
| 8 | Electricity transmission system project to connect new power plants within the country | 2018~ |
| 11 | Electrical system development project according to the electrical network system development master plan. | - |

Note : The number on the left corresponds to the project number listed in the source.

Source: EPPO, Power Development Plan 2018.

(6) Supply Reliability

Supply reliability in the Metropolitan Electricity Authority of Thailand (MEA) supply area has been improving year by year. The average outage duration (SAIDI) was improved from 47.5 minutes/customer in 2014 to 19.8 minutes/customer. The average number of outages (SAIFI) was improved from 1.613 times /customer in 2014 to 0.569 times/customer.




Source: https://www.mea.or.th/en/statistics/reliability-indices

**Figure 1.8.2 Supply Reliability in Thailand (MEA Supply Area)**

1.8.5 Status of Existing International Interconnection Lines

For international interconnection line with Malaysia, there are ± 300 kV DC transmission line (approximately 110 km from the Khong Crossing Conversion Station on the Thailand to the Guran Crossing Conversion Station on the Malaysian side) and a 132 kV AC transmission line have been installed.

The international interconnection lines with Laos include a 500 kV transmission line, a 230 kV transmission line, and a 115 kV transmission line. The international interconnection line with Cambodia is a 115 kV transmission line.

In Thailand, the Electricity Development Plan (PDP) 2018, formulated in October 2020, includes plans for domestic grid development after 2018. Although no specific projects are mentioned for other international interconnection lines, the projecting of international interconnection lines is mentioned.

**Table 1.8.13 International Interconnection Line Development Plan in Thailand (2018-2037)**

| | Project | Start of Operation |
|---|---|---|
| Under construction | | |
| 10 | Project to develop the electricity transmission system in the provinces of Ubon Ratchathani, Yasothon and Anatcharoen to purchase electricity from Projects in the Lao PDR | 2018 |
| 11 | Electricity transmission system development project in Loei, Nong Bua Laphu and Khon Kaen provinces to purchase electricity from projects in Lao PDR | 2018 |
| Under planning | | |
| 9 | Electricity transmission system project to purchase electricity from power plants in neighboring countries | 2027～ |
| 10 | System-to-system international electricity transmission linkage project | 2019～ |

Note: The number on the left corresponds to the project number listed in the source.

Source: EPPO, Power Development Plan 2018.

The ASEAN Interconnection Masterplan Study (AIMS) III Phase 1 & 2 Update, published in August 2023, outlines the status of cross-border interconnections as of 2022, as well as projections for interconnection development under three scenarios for 2025 and 2040: the Updated Power Development Plan (Updated PDP), the ASEAN Renewable Energy Target Case (ASEAN RE Target), and the High Renewable Energy Target (High RE Target). For Thailand, the outlook for cross-border interconnections is presented as follows.

**Table 1.8.14 Status and Outlook of Cross-Border Interconnections in Thailand (MW)**

| AIMS No | International interconnection line (country-to-country) | APG Status | Updated PDP | | ASEAN RE Target | | High RE Target | |
|---|---|---|---|---|---|---|---|---|
| | | 2022 | 2025 | 2040 | 2025 | 2040 | 2025 | 2040 |
| 2 | Thailand - P. Malaysia | 300 | 300 | 350 | 300 | 1,043 | 9,937 | 10,300 |
| 9 | Thailand - Lao PDR | 700 | 900 | 1,300 | 700 | 700 | 5,298 | 5,630 |
| 11 | Thailand - Myanmar | - | - | 1,250 | 919 | 1,262 | 949 | 1,310 |
| 14 | Thailand – Cambodia | 230 | 200 | 1,000 | 351 | 1,315 | 7,953 | 10,120 |

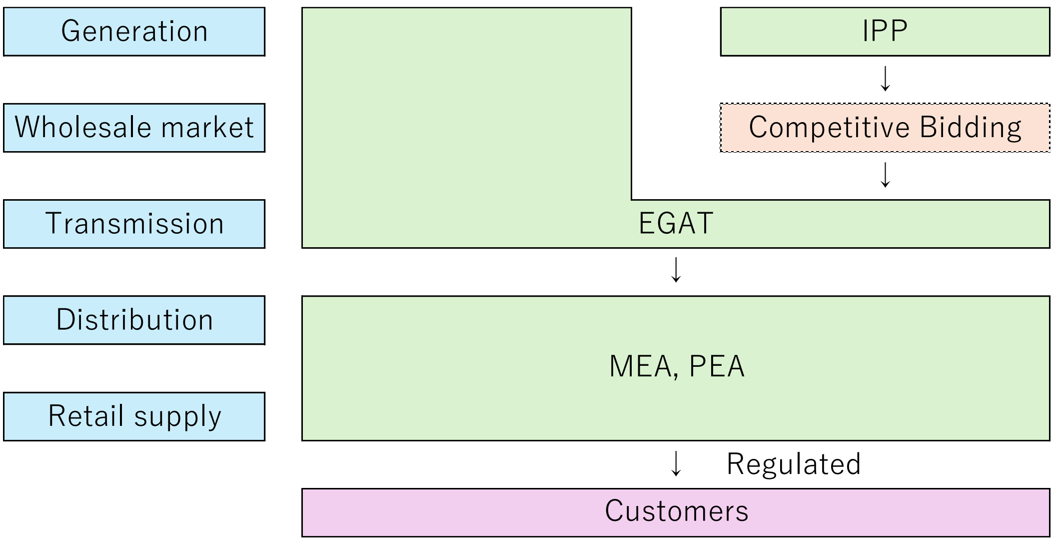
Source: ACE, (2023), Findings of ASEAN Interconnection Masterplan Study (AIMS) III Phase 1 & 2 Update.

1.8.6 Trends in Electricity and International Electricity Markets

(1) Electric Utility System

In Thailand, traditionally, the Electricity Generating Authority of Thailand (EGAT) generates and transmits electricity, while the Metropolitan Electricity Authority (MEA) and Provincial Electricity Authority (PEA) distribute electricity. Later, with the liberalization of entry into the power generation sector in 1992, independent power producers (IPPs) and small power producers (SPPs) with a capacity with less than 90 MW entered the power generation business. In addition, in order to promote the use of renewable energy, Very Small Power Producers (VSPP) with a capacity less than 10 MW are allowed to sell power directly to MEAs and PEAs.

In Thailand, the Energy Regulatory Commission (ERC) issues generation licenses, transmission system licenses, distribution system licenses, retail supply licenses, and electricity supply directives.




Source: Compiled by JICA Team

**Figure 1.8.3 Electricity Business Structure in Thailand**

(2) Electric Utility Regulations

In Thailand, the Ministry of Energy (MOE: Ministry of Energy) is in charge of formulating electricity policy and overseeing the Electricity Generating Authority of Thailand (EGAT). The MOE has important divisions such as the Energy Policy and Planning Office (EPPO), which handles energy policy and planning, and the Department of Alternative Energy Development and Efficiency (DEDE), which focus on energy efficiency and conservation and the promotion of alternative energy

On the other hand, the Ministry of the Interior (MOI) oversees the Metropolitan Electricity Authority (MEA) and the Provincial Electricity Authority (PEA), which conduct distribution business.

Apart from the Ministry of Energy, other electricity regulatory agencies include the National Energy Policy Council (NEPC), which formulates energy policy, and the Ministry of Science and Technology (MOST), which regulates nuclear power projects.

As an independent regulatory agency, the Energy Regulatory Commission (ERC) was established under the Energy Industry Act of 2007, and responsible for regulating the electricity sector including licensing and tariff regulation.

(3) Major Electric Utility

The Electricity Generating Authority of Thailand (EGAT) was established in 1969 through the merger of the Yanhee Electricity Authority (YEA), the Lignite Authority (LA), and the North-East Electricity Authority (NEEA). EGAT has monopolized the domestic power generation business, but with the entry of IPPs and SPPs following the liberalization of the power generation sector in 1992, its share of ownership of domestic power generation facilities has been declining year by year. In addition to its power generation business, EGAT procures electricity from IPPs, SPPs, and overseas operators, and supplies it wholesale to electricity distribution companies (MEA and PEA). EGAT also owns and operates power transmission and substation facilities.

The Metropolitan Electricity Distribution Authority (MEA) was formed in 1958 by the merger of Bangkok Electricity Authority and Royal Samsen Electricity Division.

The Provincial Electricity Authority (PEA) was established in 1960 to promote rural electrification. Its operating area covers more than 90% of the total area of Thailand.

(4) Electricity trading environment with foreign operators and domestic market

Thailand exports electricity to neighboring Cambodia, Laos, and Malaysia and imports electricity from Laos and Malaysia, with the majority of its electricity imports coming from Laos, with 95% (5,935 MW) of its contracted import capacity coming from Laos. The purchase of electricity from Laos is based on a Memorandum of Understanding (MoU) on power cooperation signed between the governments of the two countries, and the current MoU, signed in 2016, calls for Thailand to purchase 9,000 MW of electricity from Laos. Thailand had also signed an MoU to procure power from Myanmar, but it expired in 2010. Re-signing of the MoU has been considered, but its realization has been delayed due to political instability in Myanmar.

## 1.9 Vietnam

### 1.9.1 Policies for the Energy and Power Sector

#### (1) Climate Change Targets

Vietnam has committed to achieving carbon neutrality by 2050as a long-term goal for reducing greenhouse gas emission. Vietnam also submitted a medium-term goal to the UN to reduce GHG emissions by 43.5% by 2030 compared to BAU, subject to conditions. This condition is based on financial, technological, and capacity-building support from developed countries.

#### (2) Energy and Electricity Policy

In May 2023, the Vietnamese government approved the "8th National Power Development Plan (PDP8)," and in April 2024, the Deputy Prime Minister approved the implementation plan for PDP8. The delay of approximately two and a half years from the original schedule was due to the phase-out of coal-fired power generation and the consideration of alternative energy sources for domestic natural gas. PDP8 covers the period from 2021 to 2030 but also outlines some targets for 2050.

One of the major goals of PDP8 is to increase the installed power generation capacity by seven to nine times compared to 2020 by 2050, in line with economic growth. Additionally, it aims to phase out coal-fired power plants and raise the share of renewable energy sources (solar, wind, and biomass) in the total power generation capacity to 28.6% by 2030 and approximately 70% by 2050. Furthermore, 13 new gas-fired power generation projects (totaling 22.5 GW) will be developed, and gas-fired power capacity is expected to reach 37.3 GW by 2030.

The overall goals of PDP8 include:

- Ensuring national energy security for socioeconomic development, industrialization, and modernization.
- Modernizing power generation, building a smart power grid, managing an advanced power system for a green transition, reducing emissions, and coordinating with science and technology development to achieve a fair and successful energy transition.
- Establishing an energy industry ecosystem based on renewable and new energy sources.

Specific targets are as follows:

- The total electricity supply, including domestic generation and imports, will increase to approximately 378.3 TWh by 2025, 567 TWh by 2030, and 1,224.3–1,378.7 TWh by 2050.
- The maximum electricity demand will increase to approximately 59,318 MW by 2025, 90,512 MW by 2030, and 185,187–208,555 MW by 2050.

- By 2030, 50% of commercial buildings and 50% of residential buildings will use rooftop solar power for self-consumption (not for sale to the domestic electricity system).
- Greenhouse gas emissions from power generation will be limited to approximately 204–254 million metric tons (MT) by 2030 and 27–31 million MT by 2050. If international partners fully implement JETP commitments, peak emissions will be capped at 170 million MT by 2030.
- Renewable energy power plants will be constructed for electricity exports, with electricity export capacity increasing to approximately 5–10 GW by 2030.

PDP8 also aims to improve the efficiency of the electricity market. Specific measures include reforming the power sector according to the approved roadmap toward a competitive electricity market, enhancing the efficiency of state-owned power enterprises, adopting advanced management models and practices, improving international credit ratings, and ensuring operational transparency.

However, PDP8 faces significant challenges. Delays in LNG projects, uncertainties in domestic gas resources, and slow progress in renewable energy investments pose risks to energy security and carbon neutrality targets including the construction of new nuclear power plants. To address these issues, the Ministry of Industry and Trade (MoIT) is consulting experts and revising PDP8. The revisions are driven by concerns about energy security, project delays, and the transition to clean energy. As a result, the government approved a decision in December 2024 to adjust PDP8, and the revised plan was submitted in February 2025.

Vietnam's existing Electricity Law, enacted in 2004 and amended four times (in 2012, 2018, 2022, and 2023), has not fully addressed key issues in the electricity industry. One major concern is that electricity procurement costs are not adequately reflected in retail prices, causing financial losses for electricity businesses. Additionally, the current Electricity Law is deemed insufficient to support the implementation of PDP8, which aims to shift Vietnam's energy structure from fossil fuels to renewable sources. PDP8 envisions solar and wind power accounting for more than 60% of total installed capacity by 2050. Currently, wind and solar power make up about 30% of Vietnam's power generation capacity, but experts emphasize the need for more transparent regulations on bidding and auctions, as well as clear responsibilities for investors to meet PDP8 goals.

The "Electricity Law 2024," adopted in November 2024 and set to take effect in February 2025, introduces key provisions:

- Gradual elimination of cross-subsidies in retail electricity pricing.
- Introduction of long-term minimum contract quantities for large-scale projects such as offshore wind and LNG power plants to enhance power supply stability and cash flow predictability.
- Allowing projects utilizing Direct Power Purchase Agreements (DPPA) to bypass the bidding process, fostering a favorable environment for renewable energy generation using synthetic DPPA.

- Offshore wind power projects will be allowed to enter direct contracts (nominated bidding) and facilitate equity transfers of offshore wind power projects.

Furthermore, in Vietnam, the "Revised 8th National Power Development Plan (PDP8 revision)" was formulated in April 2025, reflecting updates to the original PDP8. The revision was driven by adjustments to projected electricity demand in line with upgraded economic growth targets, as well as modifications to the power generation mix. For example, regarding installed power generation capacity by 2030, the original PDP8 set the target at 145.5 GW, whereas the PDP8 revision raises it to a range between 197.7 GW (minimum scenario) and 268.2 GW (maximum scenario). In particular, the target for renewable energy (excluding large-scale hydropower) was increased from 45.7 GW in PDP8 to between 93.9 GW (minimum scenario) and 155.7 GW (maximum scenario) in the PDP8 revision.

### 1.9.2 Current and Projected Energy and Electricity Supply and Demand

#### (1) Current Energy Supply and Demand

##### 1) Domestic energy production

Vietnam produced coal, crude oil, and natural gas domestically with self-sufficiency rate at 65% in 2022. However, as primary energy supplies increased, the country became increasingly dependent on imports from outside the country. In 2022, the energy self-sufficiency rate decreased by 74 percentage points compared to 2000. The self-sufficiency rates were 61% for coal, 56% crude oil, and 100% for natural gas. In particular, coal and crude oil depends on imports from overseas. Crude oil is produced domestically at the Bach Ho and Su Tu Den oil fields in southern Vietnam.

**Table 1.9.1 Domestic Energy Production in Vietnam (Unit: ktoe)**

| | Coal | Crude oil | Natural gas | Nuclear | Hydro | Renewable energy | Total |
|---|---|---|---|---|---|---|---|
| 1990 | 2,597 | 2,750 | 3 | 0 | 462 | 12,471 | 18,282 |
| 1995 | 4,676 | 7,790 | 186 | 0 | 910 | 12,872 | 26,434 |
| 2000 | 6,501 | 16,860 | 1,120 | 0 | 1,251 | 14,190 | 39,922 |
| 2005 | 19,003 | 19,319 | 5,988 | 0 | 1,457 | 14,794 | 60,560 |
| 2010 | 25,108 | 15,589 | 8,124 | 0 | 2,369 | 14,714 | 65,904 |
| 2015 | 22,337 | 17,478 | 7,899 | 0 | 4,826 | 8,550 | 61,089 |
| 2020 | 24,290 | 9,358 | 7,399 | 0 | 6,268 | 8,497 | 55,812 |
| 2022 | 27,919 | 9,509 | 7,629 | 0 | 8,248 | 12,731 | 66,037 |

Source: IEA, World Energy Balances 2024 July.

2) Primary energy supply

In Vietnam, primary energy supply is increasing in line with the increase in final energy consumption. In particular, the growth rate of primary energy supply of coal and natural gas is relatively high. Compared to 2000, coal increased by about 10 times and natural gas by about 7 times in 2022. Compared to 2010, coal has been increased by about 3 times while natural gas decreased by 6%.

**Table 1.9.2 Primary Energy Supply in Vietnam (Unit: ktoe)**

| | Coal | Crude oil | Petroleum Products | Natural Gas | Nuclear | Hydro | Renewable Energy | Electric power | Total |
|---|---|---|---|---|---|---|---|---|---|
| 1990 | 2,223 | 0 | 2,711 | 3 | 0 | 462 | 12,471 | 0 | 17,868 |
| 1995 | 3,325 | 0 | 4,594 | 186 | 0 | 910 | 12,872 | 0 | 21,888 |
| 2000 | 4,372 | 296 | 7,510 | 1,120 | 0 | 1,251 | 14,190 | 0 | 28,739 |
| 2005 | 8,262 | 466 | 11,590 | 4,692 | 0 | 1,457 | 14,794 | 33 | 41,294 |
| 2010 | 14,651 | 6,599 | 11,748 | 8,124 | 0 | 2,369 | 14,714 | 399 | 58,604 |
| 2015 | 24,406 | 7,349 | 9,992 | 7,899 | 0 | 4,826 | 8,513 | 84 | 63,068 |
| 2020 | 50,777 | 16,452 | 7,797 | 7,399 | 0 | 6,268 | 8,403 | 130 | 97,225 |
| 2022 | 45,943 | 17,128 | 10,217 | 7,629 | 0 | 8,248 | 12,614 | 200 | 101,979 |

Source: IEA, World Energy Balances 2024 July.

3) Final energy consumption

In Vietnam, industrial final energy consumption accounted for 53% of the total, transportation energy consumption 20%, residential energy consumption 14%, and non-energy use 4% in 2022. Compared to 2010, industrial energy consumption has increased 2.2 times. On the other hand, residential energy consumption decreased by 37% compared to 2010, possibly due to energy conservation and other measures.

**Table 1.9.3 Final Energy Consumption in Vietnam (Unit: ktoe)**

| | Industry | Transportation | Commercial | Agricultural, forestry and fisheries | Residential | Other | Non-energy use | Total |
|---|---|---|---|---|---|---|---|---|
| 1990 | 4,538 | 1,380 | 334 | 249 | 9,412 | 0 | 28 | 15,941 |
| 1995 | 6,015 | 2,407 | 659 | 375 | 10,130 | 0 | 246 | 19,832 |
| 2000 | 7,862 | 3,499 | 1,095 | 421 | 11,940 | 0 | 132 | 24,949 |
| 2005 | 11,498 | 6,409 | 1,568 | 614 | 14,193 | 0 | 799 | 35,081 |
| 2010 | 17,421 | 10,321 | 1,754 | 612 | 15,990 | 0 | 2,260 | 48,359 |
| 2015 | 18,613 | 11,062 | 1,663 | 2,214 | 11,210 | 0 | 2,017 | 46,780 |
| 2020 | 37,330 | 12,273 | 2,426 | 3,242 | 10,281 | 0 | 2,499 | 68,049 |
| 2022 | 38,323 | 14,690 | 2,941 | 3,589 | 10,060 | 0 | 3,013 | 72,617 |

Source: IEA, World Energy Balances 2024 July.

(2) Current Electricity Supply and Demand

1) Electricity generation

The total electricity generation was 267TWh in 2023 with 45% coming from coal-fired power, 10% from gas-fired power, 31% from hydroelectric power, and 14% from renewable energy. Compared to 2010, coal-fired power generation has increased by 511%, while oil- and gas-fired power generation has decreased. In recent years, the power generation from renewable energy sources has increased rapidly.

**Table 1.9.4 Electricity Generated in Vietnam (Unit: GWh)**

| | Coal | Petroleum | Gas | Nuclear | Hydro | Renewable energy | Total |
|---|---|---|---|---|---|---|---|
| 2000 | 3,135 | 4,519 | 4,356 | 0 | 14,551 | 0 | 26,561 |
| 2005 | 12,175 | 2,167 | 22,319 | 0 | 16,945 | 50 | 53,656 |
| 2010 | 19,690 | 3,410 | 44,148 | 0 | 27,550 | 105 | 94,903 |
| 2015 | 56,469 | 992 | 48,148 | 0 | 56,123 | 179 | 161,911 |
| 2020 | 119,147 | 1,063 | 34,802 | 0 | 72,892 | 12,217 | 240,121 |
| 2023 | 120,351 | 459 | 26,784 | 0 | 81,614 | 38,375 | 267,583 |

Note: Data for 2000-2010 are from IEA Energy Balance; data for 2023 are from EVN.

Source: EVN Annual Report 2022-23, based on IEA, World Energy Balances 2023 July.

2) Exported imported and lost electricity.

In 2023, Vietnam imported about 4.1 TWh of electricity and export about 0.7 TWh of electricity, with imports accounting for about 1.5% of the total electricity supply.

**Table 1.9.5 Exported imported and lost electricity in Vietnam (Unit: GWh)**

| | Electricity Generation | Imported Electricity | Exported Electricity | Power supply | Ttransmission and Distribution losses, etc. | Domestic Electricity Consumption |
|---|---|---|---|---|---|---|
| 2023 | 267,583 | 4,097 | 739 | 270,941 | 17,409 | 253,532 |

Source: EVN Annual Report 2022-23.

3) Electricity consumption

The electricity Consumption in Vietnam was about 253 TWh in 2023 with industrial consumption accounting for 51%, commercial consumption for 5%, and residential consumption for 36%. Compared to 2010, industrial consumption has increased 2.9 times, commercial consumption has increased 3.5 times, and residential consumption has increased 2.8 times.

**Table 1.9.6 Electricity Consumption in Vietnam (Unit: GWh)**

| | Industry | Commercial | Agricultural, Forestry and Fisheries | Residential | Other | Total |
|---|---|---|---|---|---|---|
| 2005 | N.A. | N.A. | N.A. | N.A. | N.A. | N.A. |
| 2010 | 44,668 | 3,896 | 947 | 31,971 | 4,187 | 85,669 |
| 2015 | 77,189 | 7,548 | 2,327 | 50,377 | 6,242 | 143,682 |
| 2020 | N.A. | N.A. | N.A. | N.A. | N.A. | N.A. |
| 2023 | 129,223 | 13,543 | 9,135 | 90,736 | 10,761 | 253,532 |

Source: EVN Annual Report 2022-23

(3) Renewable Energy Potential

Vietnam has the fourth largest land area among ASEAN countries, and its total renewable energy potential is the fifth largest. Particularly, its offshore wind power potential is 322.1 GW, which is the second largest after Indonesia.

**Table 1.9.7 Renewable Energy Potential in Vietnam (Unit: GW)**

| Solar PV | Onshore wind | Offshore wind | Biomass | Hydro | Geothermal | Total |
|---|---|---|---|---|---|---|
| 844.0 | 31.1 | 322.1 | 8.6 | 35.0 | 0.3 | 1,241.1 |

Source: IRENA & ACE; Renewable Energy Outlook for ASEAN, (2022).

(4) Energy demand Forecasts

Public data on Vietnam 's energy demand forecasts has not been released.

(5) Electricity demand Forecasts

Public data on Vietnam 's electricity demand forecasts has not been released.

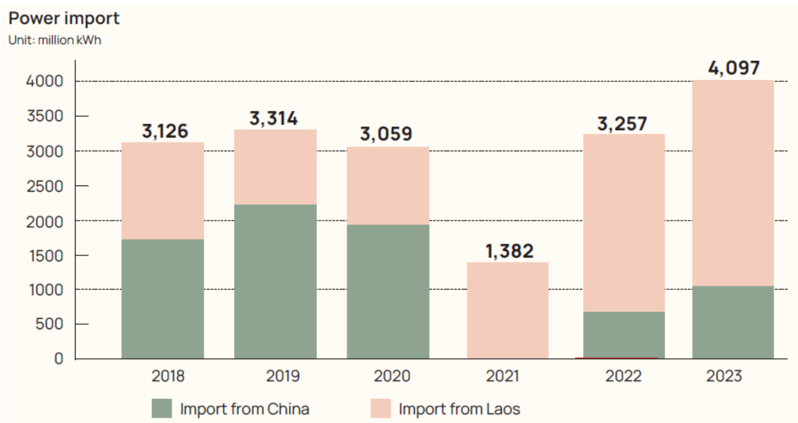
1.9.3 Actual Situation of Electricity Import/Export

In 2023, Vietnam imported about 4.1 TWh of electricity and export about 0.7 TWh, with imports accounting for about 1.5% of the total electricity supply. Vietnam imports electricity from China and Laos, with the share of electricity imports from Laos increasing in recent years. On the other hand, Vietnam exports electricity to Laos and Cambodia, but mostly to Cambodia.

**Table 1.9.8 Electricity Import/Export in Vietnam (Unit: GWh)**

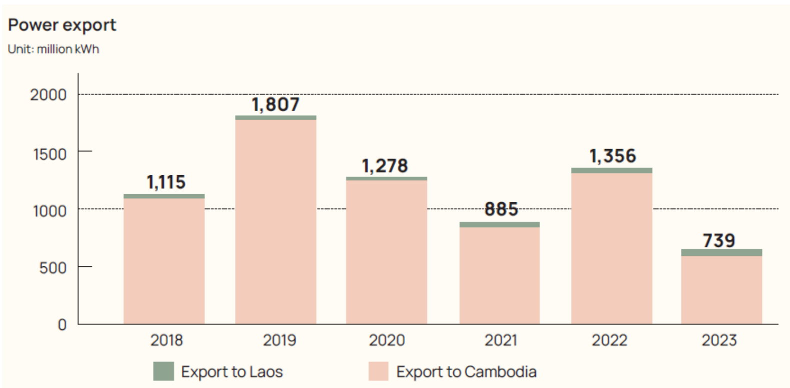
| | Electricity Imports | Electricity Export | Net Electricity Import and Export |
|---|---|---|---|
| 2018 | 3,126 | 1,115 | 2,011 |
| 2019 | 3,314 | 1,807 | 1,507 |
| 2020 | 3,059 | 1,278 | 1,781 |
| 2021 | 1,382 | 885 | 497 |
| 2022 | 3,257 | 1,356 | 1,901 |
| 2023 | 4,097 | 739 | 3,358 |

Source: EVN Annual Report 2022-23




Source: EVN Annual Report 2022-23

**Figure 1.9.1 Electricity imports by country (unit: GWh) in Vietnam**




Source: EVN Annual Report 2022-23

**Figure 1.9.2 Vietnam's Electricity Exports by Country (Unit: GWh)**

1.9.4 Power Supply Development Plan, National Grid Development Plan

(1) Power Generation Plants

In 2023, the installed power generation capacity in Vietnam was 80 GW with 15% coming from Vietnam Electricity (EVN), 22% from the three GENCOs that have been systematically spun off from EVN, and 62% from independent power producers (IPPs) and others. Of the total power generation capacity in Vietnam, coal-fired power accounted for 34%, oil-fired power 1%, gas-fired power 9%, hydro 29%, and renewable energy 27%.

**Table 1.9.9 Power Generation Plants in Vietnam (Unit: MW)**

| | Coal-Fired Thermal | Oil-fired Thermal | Gas-Fired | Hydro | Renewable energy | Other | Total |
|---|---|---|---|---|---|---|---|
| 2015 | 12,903 | 875 | 7,998 | 14,636 | 2,141 | 0 | 38,553 |
| 2020 | 21,554 | - | 8,858 | 20,774 | 17,539 | 0 | 68,725 |
| 2023 | 26,756 | 1,126 | 7,152 | 22,872 | 21,664 | 165 | 79,735 |

| | EVN | GENCO1 | GENCO2 | GENCO3 | EVNCPC | Other | Total |
|---|---|---|---|---|---|---|---|
| 2015 | 7,722 | 5,144 | 4,337 | 6,377 | | 14,973 | 38,553 |
| 2020 | 11,883 | 6,979 | 4,421 | 6,230 | | 39,212 | 68,725 |
| 2023 | 11,974 | 7,014 | 4,421 | 6,450 | 43 | 49,834 | 79,736 |

Source: EVN Annual Report 2022-23

(2) Power Generation Facility Plan

In Vietnam, the 8th National Basic Plan for Electricity Development (PDP8), formulated in May 2023, includes the power generation mix in 2030 and 2050, etc. In 2030, the maximum electricity demand is expected to reach about 96 GW and power generation capacity about 146 GW.

**Table 1.9.10 Power Generation Facility Plan in Vietnam**

| | Installed capacity (GW) | | | | Power Generation Mix (%) | | | |
|---|---|---|---|---|---|---|---|---|
| | Year 2020 | Year 2030 | 2050 (lower limit) | 2050 (upper limit) | Year 2020 | Year 2030 | 2050 (lower limit) | 2050 (upper limit) |
| Coal-Fired Thermal | 21.5 | 30.1 | 0.0 | 0.0 | 31.0% | 20.0% | 0.0% | 0.0% |
| Change of fuel type from coal to biomass ammonia | 0.0 | 0.0 | 25.6 | 32.4 | 0.0% | 0.0% | 5.2% | 5.7 |
| Domestic Natural Gas-Fired | 8.9 | 14.9 | 0.0 | 0.0 | 12.8% | 9.9% | 0.0% | 0.0% |
| LNG-fired Thermal | 0.0 | 22.4 | 7.9 | 7.9 | 0.0% | 14.9% | 1.6% | 1.4% |
| Hydrogen Mixed firing | 0.0 | 0.0 | 27.9 | 36.9 | 0.0% | 0.0% | 5.7% | 6.4% |
| Renewable Energy | 17.5 | 45.7 | 335.3 | 409.4 | 25.3% | 30.4% | 68.4% | 71.4% |
| Onshore Wind | 0.5 | 21.9 | 60.1 | 77.1 | 0.7% | 14.5% | 12.2% | 13.4% |
| Offshore Wind | 16.6 | 6.0 | 70.0 | 91.5 | 24.0% | 4.0% | 14.3% | 16.0% |
| Solar | 0.4 | 12.8 | 168.6 | 189.3 | 0.6% | 8.5% | 34.4% | 33.0% |
| Biomass | 0.0 | 2.3 | 6.0 | 6.0 | 0.0% | 1.5% | 1.2% | 1.0% |
| Energy Storage | 0.0 | 0.3 | 30.7 | 45.6 | 0.0% | 0.2% | 6.2% | 7.9% |
| Pump Storage | 0.0 | 2.4 | 0.0 | 0.0 | 0.0% | 1.6% | 0.0% | 0.0% |
| Hydro | 20.8 | 29.3 | 36.0 | 36.0 | 30.0% | 19.5% | 7.3% | 6.3% |
| Other | 0.0 | 3.0 | 46.7 | 39.4 | 0.0% | 2.0% | 9.5% | 6.9% |
| Total generation capacity | 68.7 | 145.5 | 479.5 | 562.1 | 99.1% | 96.7% | 97.7% | 98.1% |
| Import Capacity | 0.6 | 5.0 | 11.0 | 11.0 | 0.9% | 3.3% | 2.3% | 1.9% |
| Total supply capacity | 69.3 | 150.5 | 490.5 | 573.1 | 100.0% | 100.0% | 100.0% | 100.0% |
| Peak Demand | 45.6 | 96.0 | 194.0 | 217.0 | - | - | - | - |

Source: Socialist Republic of Viet Nam (2023), Decision approving National Power Development Plan 8.

(3) Cost of Electricity

According to the AIMSIII Phase I Update report, Vietnam's electricity generation cost in 2020 was 3.0 cents per kWh.

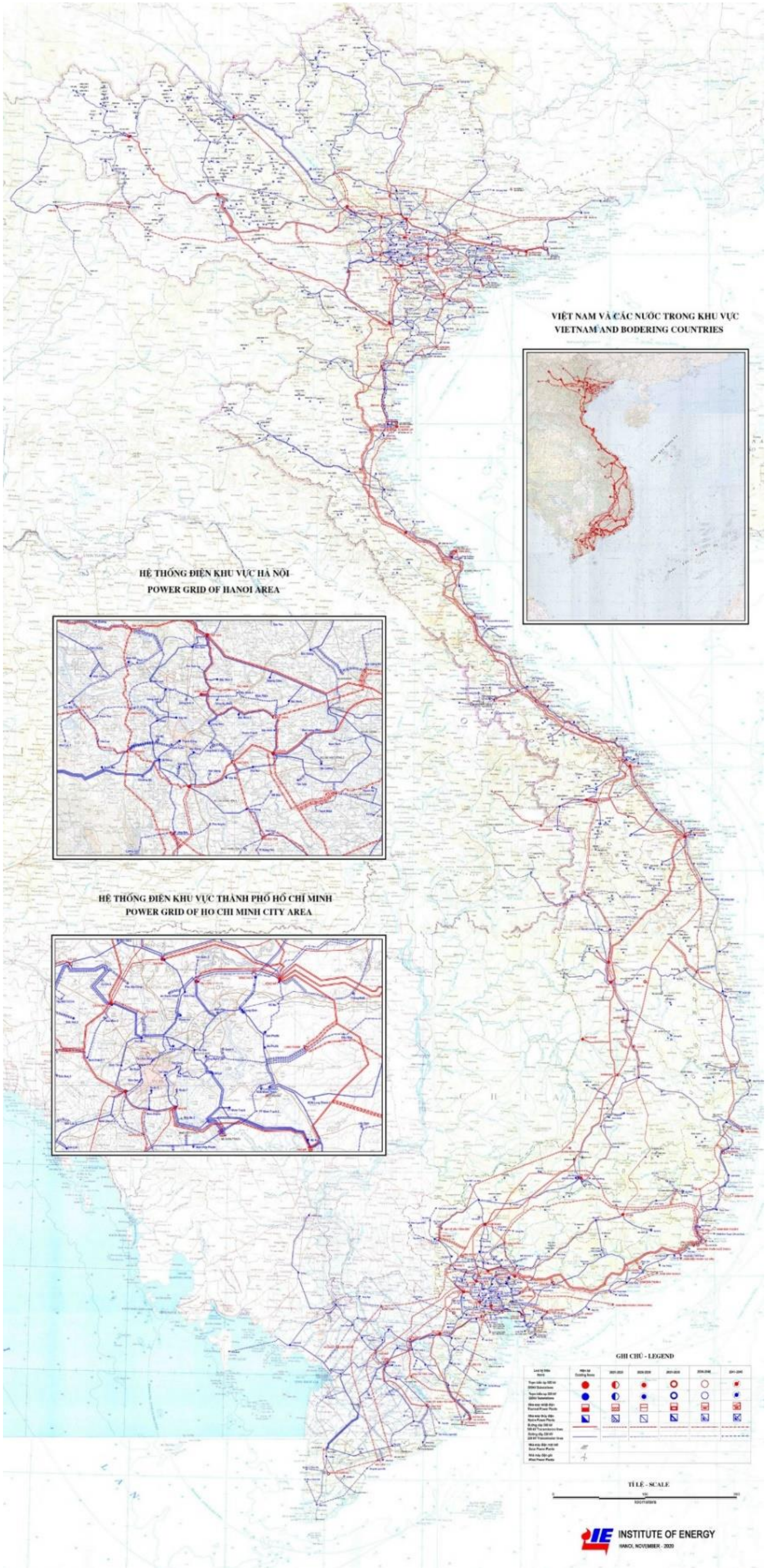
(4) Domestic Transmission System

In Vietnam, 500 kV and 230 kV transmission lines have been constructed as bulk systems, and 115 kV transmission lines have been laid as lower systems.

**Table 1.9.11 Transmission Plants in Vietnam (Unit: km)**

| | 500-220kV | 110kV | Total |
|---|---|---|---|
| 2015 | 22,478 | 37,395 | 59,873 |
| 2020 | 26,497 | 21,559 | 48,056 |
| 2022 | 29,552 | 21,861 | 51,413 |

Source: EVN Annual Report 2022-23




Source: EVN, EVN Annual Report 2021.

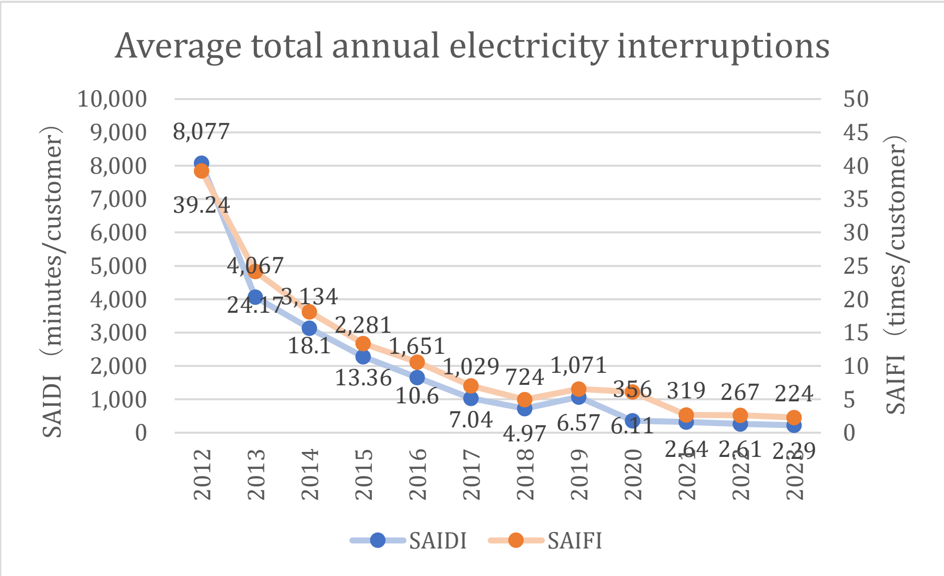
**Figure 1.9.3 Diagram of the domestic power transmission system in Vietnam (as of November 2020)**

(5) Domestic Grid Development Plans

In Vietnam, the Electricity Development Plan (PDP) 2018, formulated in October 2020, includes a domestic grid development plan after 2018. Although the PDP does not include a specific domestic grid development plan, it does include policies for a nationwide grid expansion project, renewal of the aging transmission system, and enhancement of the transmission system to strengthen power stability.

(6) Supply Reliability

Vietnam's supply reliability has been improving year by year. The average outage duration (SAIDI) improved from 8,077 minutes/customer in 2012 to 224 minutes/customer in 2023. The average number of outages (SAIFI) improved 39.24 times/customer in 2012 to 2.29 times/customer in 2023.




Source: https://www.mea.or.th/en/statistics/reliability-indices

**Figure 1.9.4 Supply Reliability in Vietnam**

1.9.5 Status of Existing International Interconnection lines

In Vietnam, the PDP 2018, formulated in October 2020, includes a domestic grid development plan after 2018. Although no specific projects are mentioned for international interconnection lines, the projecting of international interconnection lines is mentioned as follows.

- Continue to study and cooperate on grid interconnection with the Greater Mekong Subregion (GMS) and ASEAN countries for 500kV and 220kV bulk systems.

- Based on the Memorandum of Understanding (MOU) signed between the governments of Laos and Lao PDR, the 500kV and 220kV interconnection lines will be installed with Lao PDR to import electricity from the Lao power plants.
- Maintain grid interconnection with neighboring countries through 220 kV and 110 kV and other transmission lines, and study and implement synchronization measures at 220-500 kV crossing converter stations.
- Build an infrastructure that links power export projects with high economic efficiency, based on ensuring energy security and national defense and security.

The ASEAN Interconnection Masterplan Study (AIMS) III Phase 1 & 2 Update, published in August 2023, outlines the status of cross-border interconnections as of 2022, as well as projections for interconnection development under three scenarios for 2025 and 2040: the Updated Power Development Plan (Updated PDP), the ASEAN Renewable Energy Target Case (ASEAN RE Target), and the High Renewable Energy Target (High RE Target). For Vietnam, the outlook for cross-border interconnections is presented as follows.

**Table 1.9.12 Status and Forecast of International Interconnection Lines in Vietnam (MW)**

| AIMS No. | International interconnection line (country-to-country) | APG Status | Updated PDP | | ASEAN RE Target | | High RE Target | |
|---|---|---|---|---|---|---|---|---|
| | | 2022 | 2025 | 2040 | 2025 | 2040 | 2025 | 2040 |
| 10 | Lao PDR – Vietnam | 570 | 570 | 620 | 307 | 625 | 1,342 | 10,200 |
| 12 | Vietnam - Cambodia | 200 | 200 | 250 | 328 | 1,353 | 7,867 | 10,200 |

Source: ACE, (2023), Findings of ASEAN Interconnection Masterplan Study (AIMS) III Phase 1 & 2 Update.

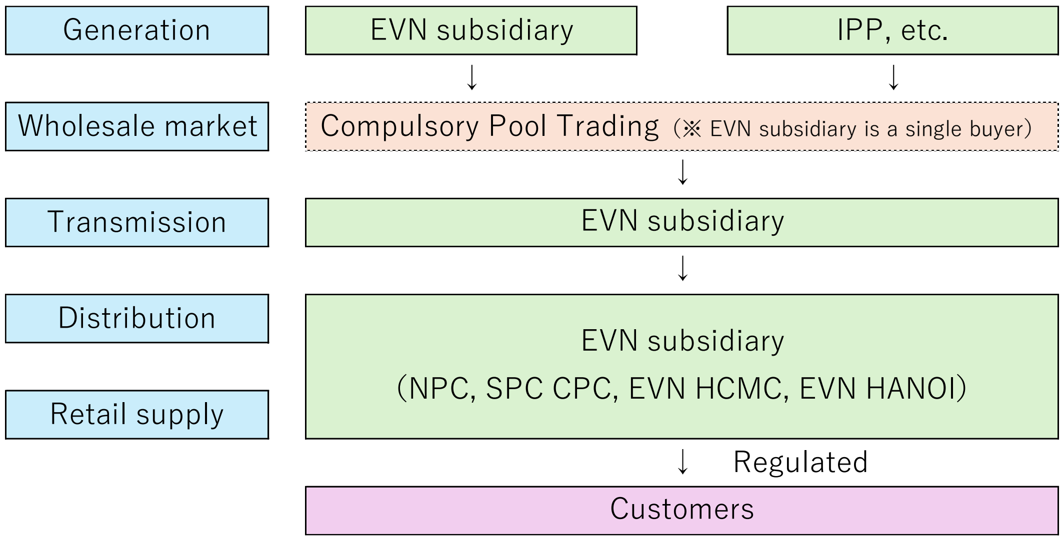
### 1.9.6 Trends in Electricity and International Electricity Markets

#### (1) Electric Utility System

In Vietnam, the liberalization of power generation sector has led to the increase of a large number of independent power producers (IPPs).

The Vietnam Competitive Generation Market (VCGM), which is equivalent to a full pool market, was introduced in 2012. Power sources with more than 30 MW can participate in this market. The Electric Power Trading Company (EPTC), a wholly owned subsidiary of EVN, serves as the single buyer.

Although the liberalization of the retail market is planned to be introduced in the Competitive Electricity Market Roadmap revised in 2013, it does not appear to have been implemented as of 2024.




Source: Compiled by JICA Team

**Figure 1.9.5 Electricity Business System in Vietnam**

(2) Electric Utility Regulations

In Vietnam, the Ministry of Industry and Trade (MOIT) is responsible for formulating electricity and energy policies. Under MOIT, several institutions exist as follows. The Electricity Regulatory Authority of Vietnam (ERAV), is in charge of electricity market development and regulations. The Institute of Energy (IE) is in charge of drafting energy policies, formulating national and regional electricity development plans, and conducting research on electricity facilities and crises.

(3) Major Electric Utility

In Vietnam, subsidiaries of the state-owned utility, Vietnam Electricity (EVN), are responsible for power generation, transmission, and distribution.

Regarding power generation, EVN split its power generation business in 2012 as GENCOs 1-3, except for strategically important power plants. GENCO 1 remains an independent profitable company while GENCOs 2 and 3 are joint subsidiaries.

The National Load Dispatching Center (NLDC), a wholly owned subsidiary of EVN, operates the power transmission system in coordination with the Regional Dispatch Centers located in the northern, central, and southern regions. The NLDC operates the 500kV, 220kV, and 110kV bulk systems and commands the power supply of power plants, while the Electric Power Trading Company (EPTC), a wholly owned subsidiary of EVN, serves as the single buyer under the full pooling system. EVN NPT (National Power Transmission

Corporation), a wholly owned subsidiary of EVN, maintains and manages the 500kV, 220kV, and 110kV bulk grids throughout Vietnam, and is also responsible for the expansion of transmission facilities.

Regarding power distribution and retail supply, there are five power distribution companies: Northern Power Distribution Company (NPC), Southern Power Distribution Company (SPC), Central Power Distribution Company (CPC), Ho Chi Minh City Power Distribution Company (EVN HCMC), and Hanoi Power Distribution Company (EVN HANOI), which are independently owned and operated by EVN.

(4) Electricity trading environment with foreign operators and domestic market

In Vietnam, the 8th National Basic Plan for Electricity Development (PDP8), decided in May 2023, states that Vietnam will effectively implement interconnection and power flexibility with neighboring countries to ensure mutual benefits and enhance the security of the power system. Vietnam promotes electricity imports from Southeast Asian countries (ASEAN) and the Mekong River Basin (GMS), which have potential for hydropower generation. In addition, the country focuses on investment in foreign development to facilitate power supply to Vietnam. Based on the agreement signed between the Vietnamese and Lao governments, Vietnam imports about 5,000 MW (equivalent to 18.8 TWh) to 8,000MW from Laos by 2030. power imports will reach about 11,000 MW (equivalent to 37 TWh) by 2050

## Chapter 2 Status of Interconnection Lines

In this chapter, we will first briefly review the background to the ASEAN Power Grid (APG) and then assess the status of the 18 lines in terms of project status, interference with protected areas, and the existence of opposition movements.

### 2.1 Background

#### 2.1.1 ASEAN Power Grid and ASEAN Plan of Action for Energy Cooperation

The first discussion on cross-border energy trade within the ASEAN region took place during the "Conference on the ASEAN Energy Cooperation Agreement" held in Manila in 1986 and emphasized the importance of cooperation between ASEAN member countries to develop energy resources and improve ASEAN's economic integration.

At the 2nd ASEAN Informal Summit in 1997, the "ASEAN Vision 2020"[1] was adopted, and the first action plan for its realization was adopted at the 6th ASEAN Official Summit in 1998 as the "Hanoi Plan of Action" (a six-year plan from 1999 to 2004). Among these, it was also stated that an electricity interconnection system within ASEAN would be established through the ASEAN Power Grid (hereafter, APG). This was the first time that the APG was clearly stated.

At the 17th ASEAN Ministers on Energy Meeting (AMEM) held in 1999, it was decided to accelerate the implementation of the energy action plan based on the "Hanoi Plan of Action", and the ASEAN Plan of Action for Energy Cooperation (APAEC) (1999-2004)[2], in which all 10 Southeast Asian countries participated as a region for the first time, was adopted. Subsequently, the APAEC was adopted for the periods 2004-2009[3], 2010-2015[4], 2016-2025 Phase I (2016-2020)[5]. The ultimate goal of these plans was to formulate a "Master Plan for Interconnection" to achieve the goals outlined in the ASEAN Vision 2020.

The APAEC Phase II (2021-2025), adopted at the 38th AMEM in 2020, sets ambitious goals and initiatives to improve sustainability and supports the United Nations Sustainable Development Goals (SDGs)7. The theme has been maintained from Phase I (2016-2020), "Enhancing energy connectivity and market

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1 ASEAN, "ASEAN VISION 2020", <https://asean.org/asean-vision-2020/>.

2 ASEAN, "Joint Press Statement of the Seventeenth ASEAN Ministers on Energy Meeting, Bangkok, Thailand, 3 July 1999", 1999-7-3, <https://asean.org/joint-press-statement-of-the-seventeenth-asean-ministers-on-energy-meeting-bangkok-thailand-3-july-1999/>.

3 ASEAN, "Twenty Second ASEAN Ministers On Energy Meeting Media Statement, Makati City, Metro Manila, Philippines", 2004-6-9, <https://asean.org/twenty-second-asean-ministers-on-energy-meeting-media-statement-makati-city-metro-manila-philippines/>.

4 ASEAN, "Joint Ministerial Statement of the 27th ASEAN Ministers on Energy Meeting (AMEM), Mandalay, Myanmar, 29 July 2009", 2009-7-29, <https://asean.org/joint-ministerial-statement-of-the-27th-asean-ministers-on-energy-meeting-amem-mandalay-myanmar-29-july-2009/>.

5 ASEAN, "Joint Ministerial Statement of the Thirty Second ASEAN Ministers of Energy Meeting (32nd AMEM)", 2014-9-23, <https://asean.org/joint-ministerial-statement-of-the-thirty-second-asean-ministers-of-energy-meeting-32nd-amem/>.

integration in ASEAN to achieve energy security, accessibility, affordability and sustainability for all" and the sub-theme "Accelerating Energy Transition and Strengthening Energy Resilience through Greater Innovation and Cooperation"[6] has been added.

2.1.2 ASEAN Interconnection Masterplan Study

The ASEAN Interconnection Masterplan Study (AIMS) is a study of an interconnection masterplan for the APG and was first proposed at the 17th AMEM held in Bangkok, Thailand in 1999. At the 21st AMEM held in Langkawi, Malaysia in 2003, the final report of AIMS (AIMS-I) was agreed upon as a guideline for the implementation of power interconnection projects[7].

Due to the rapid development of ASEAN, a second survey, AIMS-II, was required and was conducted in 2010. The main objective of AIMS II was to promote a more efficient, economical and safe power system through the coordinated development of the power grids of each country in the region as a whole[8], by planning the APG through the interconnection of AMS[9].

The strategy formulated based on these studies was to first encourage participation between two countries across national borders, then gradually expand to a sub-regional basis (north, south, east), and finally move to a fully integrated APG system.

The AIMS-III project was designed to explore the feasibility of multilateral power trading in the ASEAN region, with the aim of strengthening the resilience and modernization of power grids, achieving affordable and resilient power supply, and increasing the share of renewable energy (RE) in power grids to 23% by 2025. This was also a concrete response to the request made at the 35th AMEM in 2017[10].

AIMS-III is composed of three phases, and the first two phases of AIMS-III will develop plans for cross-border transmission infrastructure necessary to support multilateral power trade among ASEAN member states (AMS) and renewable energy (RE) integration in the APG, while Phase 3 will further develop minimum requirements, regulatory frameworks, grid codes and technical standards for multilateral market development[11].

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6 ASEAN, "Joint Ministerial Statement of the 38 ASEAN Ministers On Energy Meeting", 2020-11-19, <https://asean.org/joint-ministerial-statement-of-the-38-asean-ministers-on-energy-meeting/>.

7 ASEAN, "Joint Press Statement of the 21st ASEAN Ministers on Energy Meeting, Langkawi Island, Malaysia", 2003-7-3, <https://asean.org/joint-press-statement-of-the-21st-asean-ministers-on-energy-meeting-langkawi-island-malaysia/>.

8 ERIA, "Study on the Formation of the ASEAN Power Grid Transmission System Operator Institution", <https://www.eria.org/uploads/media/Research-Project-Report/RPR_FY2018_24/Formation-of-the-ASEAN-Power-Grid-Transmission-System-Operator-Institution.pdf>.

9 ASEAN member state

10 ASEAN, "Joint Ministerial Statement of the 35th ASEAN Ministers on Energy Meeting", 2017-9-29, <https://asean.org/joint-ministerial-statement-of-the-35th-asean-ministers-on-energy-meeting/>

11 ASEAN Centre for Energy, "ASEAN Interconnection Masterplan Study (AIMS) III Report, 2024-6-20, <https://aseanenergy.org/publications/asean-interconnection-masterplan-study-aims-iii-report/>.

2.2 Status and Evaluation of Interconnection Lines

2.2.1 Project Status

Nearly 30 years have passed since the ASEAN Power Grid was first proposed in 1997. Some of the projects have progressed and become a reality over this long period of time. Naturally, these existing lines will not be eligible for future support, so they are not included in this survey. As a result of our confirmation, we found that four lines still exist.

**Table 2.2.1 Existing Line among the APG**

| No. | Line | Existing line[12] |
|---|---|---|
| 1 | Peninsula Malaysia- Singapore (Planting – Woodlands, Phase II) | - |
| 2 | Thailand - Peninsula Malaysia (Su Ngai Kolok - Rantau Panjang) | - |
| | Thailand - Peninsula Malaysia (Khlong Ngae – Gurun, 2nd Phase) | - |
| 3 | Internal Malaysia (Sarawak - Peninsula Malaysia) | - |
| 4 | Peninsula Malaysia - Sumatra | - |
| 5 | Sarawak - Kalimantan | ✓ |
| 6 | Philippines – Sabah (Malaysia) | - |
| 7 | Sarawak（Malaysia） - Brunei Darussalam | - |
| 8 | Sarawak（Malaysia） - Sabah (Malaysia) | ✓ |
| 9 | Thailand - Lao PDR | - |
| 10 | Lao PDR - Vietnam (Nam Ou - Dien Bien) | - |
| | Lao PDR - Vietnam (Luang Prabang - Nho Quan) | - |
| 11 | Thailand - Myanmar | ✓ |
| 12 | Vietnam – Cambodia | - |
| 13 | Lao PDR – Cambodia (Ban Hat - Kampong Sralao) | - |
| | Lao PDR - Cambodia (Ban Hat - Preah Vihear) | - |
| 14 | Thailand – Cambodia | - |
| 15 | East Sabah（Malaysia）- North Kalimantan（Indonesia） | - |
| 16 | Singapore - Indonesia (Singapore- Sumatra) | - |
| | Singapore - Indonesia (Singapore – Batam) | - |
| 17 | Lao PDR - Myanmar | ✓ |

12 In AIMS III, there are cases where multiple interconnection lines are referenced in same number. Some of these include a mix of existing interconnection lines and planned interconnection lines. .In this survey, we referred to the "ASEAN Power Grid Interconnections Project Profiles" issued by ACE on September 26, 2024, and classified interconnection lines where all lines with the same No. are completed as "Existing Line," while those with planned interconnection lines remaining were not classified as "Existing Line."

| | | |
|---|---|---|
| 18 | Internal Indonesia (Kalimantan-Java) | - |
| | Internal Indonesia (Sumatra-Java) | - |

Source: Create from ACE, "ASEAN Power Grid Interconnections Project Profiles", 2024-9-26, <https://aseanenergy.org/wp-content/uploads/2024/11/ASEAN-Power-Grid-Interconnections-Project-Profiles.pdf>.

2.2.2 Interference with Protected Areas

Next, examine the possibility that the routes envisioned by the ASEAN Power Grid will encounter protected areas in the countries involved. Note that the starting point, end point and route of many of the projects are not clear. Therefore, we used the map in the "ASEAN Power Grid Interconnections Project Profiles Prepared"[13] as a reference for the starting point and end point. For information on the location of protected areas, refer to "Protected planet"[14].

As a result, it is thought that the plan to connect Ban Hat and Preah Vihear, which is part of the plan to connect Laos and Cambodia, has a very high possibility of interfering with protected areas, and it is also thought that it would be difficult to bypass the protected areas. As for the other areas, it is thought that there is no possibility of interference with protected areas and that it would be easy to bypass them.

**Table 2.2.2 Potential Interference with Protected Areas**

| No. | Line | Interference with protected area |
|---|---|---|
| 1 | Peninsula Malaysia- Singapore (Planting – Woodlands, Phase II) | - |
| 2 | Thailand - Peninsula Malaysia (Su Ngai Kolok - Rantau Panjang) | - |
| | Thailand - Peninsula Malaysia (Khlong Ngae – Gurun, 2nd Phase) | - |
| 3 | Internal Malaysia (Sarawak - Peninsula Malaysia) | - |
| 4 | Peninsula Malaysia - Sumatra | - |
| 5 | Sarawak - Kalimantan | - |
| 6 | Philippines – Sabah (Malaysia) | - |
| 7 | Sarawak（Malaysia） - Brunei Darussalam | - |
| 8 | Sarawak（Malaysia） - Sabah (Malaysia) | - |
| 9 | Thailand - Lao PDR | - |
| 10 | Lao PDR - Vietnam (Nam Ou - Dien Bien) | - |
| | Lao PDR - Vietnam (Luang Prabang - Nho Quan) | - |
| 11 | Thailand - Myanmar | - |

13 ACE, "ASEAN Power Grid Interconnections Project Profiles", 2024-9-26, <https://aseanenergy.org/wp-content/uploads/2024/11/ASEAN-Power-Grid-Interconnections-Project-Profiles.pdf.>.

14 protected planet, "Discover the world's protected and conserved areas", <https://www.protectedplanet.net/en.>.

| | | |
|---|---|---|
| 12 | Vietnam – Cambodia | - |
| 13 | Lao PDR – Cambodia (Ban Hat - Kampong Sralao) | - |
| | Lao PDR - Cambodia (Ban Hat - Preah Vihear) | ✓Difficult to re-route |
| 14 | Thailand – Cambodia | - |
| 15 | East Sabah (Malaysia) - North Kalimantan (Indonesia) | - |
| 16 | Singapore - Indonesia (Singapore- Sumatra) | - |
| | Singapore - Indonesia (Singapore – Batam) | - |
| 17 | Lao PDR - Myanmar | - |
| 18 | Internal Indonesia (Kalimantan-Java) | - |
| | Internal Indonesia (Sumatra-Java) | |

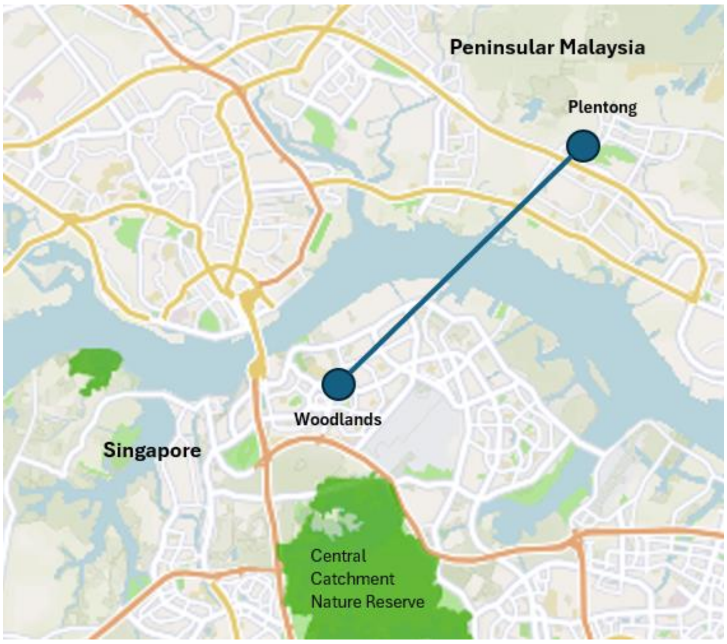
Source: Create from ACE, "ASEAN Power Grid Interconnections Project Profiles", 2024-9-26, <https://aseanenergy.org/wp-content/uploads/2024/11/ASEAN-Power-Grid-Interconnections-Project-Profiles.pdf> and protected planet, <https://www.protectedplanet.net/en>.

1) Malaysia (Malay Peninsula) - Singapore

Planting (MY) – Woodlands (SG)

An interconnection that began operating in 1985 already exists in this section, and the AIMS III study emphasized the need to expand the existing interconnection capacity to increase the amount of renewable energy exchanged in Singapore and to improve supply security. Currently, there are no ongoing feasibility studies being conducted on increasing transmission capacity.

Planting – Woodlands interconnection between the Malay Peninsula and Singapore does not interfere with protected areas, as can be seen below. However, it is necessary to cross the Johor Strait section using a submarine cable or other method, and some construction difficulties are expected.




Note: The area marked in dark green color in the map indicates protected area.

Source: Create from ACE, "ASEAN Power Grid Interconnections Project Profiles", 2024-9-26, <https://aseanenergy.org/wp-content/uploads/2024/11/ASEAN-Power-Grid-Interconnections-Project-Profiles.pdf> and protected planet, https://www.protectedplanet.net/en

**Figure 2.2.1 Map of Protected Area (Peninsular Malaysia – Singapore)**

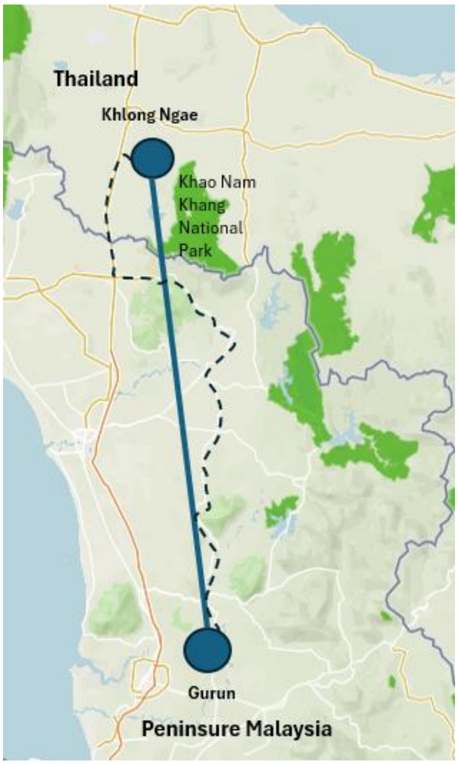
2) Thailand - Malaysia (Malay Peninsula)

Sadao (TH) – Chuping (MY)

Khlong Ngae (TH) – Gurun (MY)

As a mutual connection between Thailand and the Malay Peninsula, AIMS III has two lines under consideration: the Sadao – Chuping line and the Khlong Ngae – Gurun line. Although mutual connections have already been established for both lines, the existing HVDC substations are facing aging issues, and the system is expected to expire in 2027. For this reason, EGAT and TNB have already carried out a pre-feasibility study for the Khlong Ngae - Gurun interconnection line and are currently waiting for approval from both authorities. Based on the ASEAN RE target scenario of AIMS III, the interconnection capacity is expected to reach 1,043 MW by 2040.

The interconnection between Khlong Ngae and Gurun, if a straight line were drawn to connect them, would interfere with Khao Nam Khang National Park, as can be seen below., but if the connection line is drawn along the nearby road (as shown by the dotted line in Figure 2.2.2), although some increase in distance is expected, it is thought that the protected area can be easily avoided.




Note: The area marked in dark green color in the map indicates protected area.

Source: Create from ACE, "ASEAN Power Grid Interconnections Project Profiles", 2024-9-26, <https://aseanenergy.org/wp-content/uploads/2024/11/ASEAN-Power-Grid-Interconnections-Project-Profiles.pdf> and protected planet, https://www.protectedplanet.net/en

**Figure 2.2.2 Map of Protected Area (Peninsular Malaysia – Singapore)**

3) Sarawak (Borneo Island) – Malaysia (Malay Peninsula)

The interconnection line within Malaysia between Sarawak in Borneo and the Malay Peninsula had been planned long before AIMS III, but the existing interconnection line was not built.

The connection point (substation) has not been specified for this section. Therefore, the connection lines shown below are less reliable than those on other maps. If the connection point is close to the point shown on the map, it is possible to avoid protected areas such as the Kuala Wildlife Sanctuary by connecting the connection lines along nearby roads on the land area on the Malaysian Peninsula side, without interfering with protected areas on the land area on the Sarawak side. In addition, there is the Taman Wisata Perairan Kepulauan Anambas Dan Laut Sekitarnya marine recreation park in the sea area, but it is also in the sea, so it is thought to be easy to avoid. Furthermore, it is necessary to cross the South China Sea using a submarine cable or other method for about 600 km, and it is thought that there will be difficulties in construction.


Note: The area marked in dark green color in the map indicates protected area.

Source: Create from ACE, "ASEAN Power Grid Interconnections Project Profiles", 2024-9-26, <https://aseanenergy.org/wp-content/uploads/2024/11/ASEAN-Power-Grid-Interconnections-Project-Profiles.pdf> and protected planet, https://www.protectedplanet.net/en

**Figure 2.2.3 Map of Protected Area (Sarawak - Peninsular Malaysia)**

4) Malaysia (Malay Peninsula) – Sumatra (Indonesia)

Telok Gong（MY）– Perawang（ID）

Telok Gong – Perawang route between Malaysia and Sumatra Island, Indonesia, has been proposed as a cross-border interconnection, but it has not yet been built. Currently, a feasibility study is being conducted with a grant from the US Trade and Development Agency (USTDA) to assess the technical, commercial, environmental, economic, and regulatory aspects.

If the interconnection between Telok Gong and Perawang is drawn in a straight line, as can be seen below, it may interfere with the Giam Siak Kecil Wildlife Reserve and the Sungai Dumai Nature Recreation Park, but if the interconnection is drawn along the nearby road, it is thought that the protected areas can be easily avoided, although there will be an increase in distance. However, it is necessary to cross the Straits of Malacca using a submarine cable or other method, and some construction difficulties are expected.


Note: The area marked in dark green color in the map indicates protected area.

Source: Create from ACE, "ASEAN Power Grid Interconnections Project Profiles", 2024-9-26, <https://aseanenergy.org/wp-content/uploads/2024/11/ASEAN-Power-Grid-Interconnections-Project-Profiles.pdf> and protected planet, <https://www.protectedplanet.net/en>

**Figure 2.2.4 Map of Protected Area (Peninsular Malaysia – Sumatra)**

5) Sarawak (Borneo Island) – West Kalimantan (Borneo Island)

Mambong（Sarawak/MY）－ Bengkayang（West Kalimantan/ID）

The interconnection between Mambong and Bengkayang on the island of Borneo began commercial operation in 2015. Currently, there are no plans to upgrade the interconnection capacity, but AIMS III research has recommended that the interconnection capacity should be expanded to 830 MW in the future.

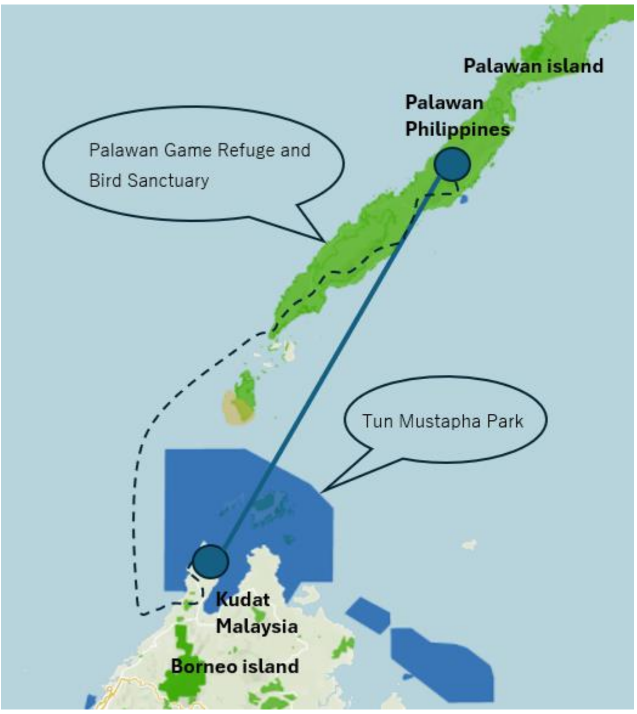
The interconnection line has been completed with loans from the ADB and other organizations, so it is excluded from consideration.

6) Philippines - Sabah (Borneo Island)

Palawan（PH）- Kudat（MY）

The interconnection between Palawan (Palawan Island, Philippines) and Kudat (Sabah, Borneo Island) will extend the interconnection between Sabah and Kalimantan and become one of the important interconnections between systems in the BIMP-PIP initiative to connect Indonesia, Malaysia and the Philippines. AIMS III is expected to have a capacity of 196 MW by 2040.

The connection point on the Palawan side is inside the Palawan Game Refuge and Bird Sanctuary, but it is thought that it is possible to connect the lines along the road (shown as a dotted line on the map). The connection point on the Sabah side, Kudat, is not thought to interfere with the protected area on land, but it is surrounded by the Tun Mustapha Park Marine Reserve at sea. For this reason, it is necessary to divert the link line to a position that can cross this marine reserve. In addition, it is necessary to cross the South China Sea using a submarine cable or other method, and some construction difficulties are expected




Note: The area marked in dark green color in the map indicates protected area.

Source: Create from ACE, "ASEAN Power Grid Interconnections Project Profiles", 2024-9-26, <https://aseanenergy.org/wp-content/uploads/2024/11/ASEAN-Power-Grid-Interconnections-Project-Profiles.pdf> and protected planet, <https://www.protectedplanet.net/en>

**Figure 2.2.5 Map of Protected Area (Philippines - Sabah)**

7) Brunei - Sarawak (Borneo Island)

Lumut（BN）- Tudan（Sarawak/MY）

There is no existing interconnection between Sarawak and Brunei, but a joint plan to connect the two countries is already underway between Sarawak Energy Berhad (SEB) and the Department of Electrical Services (DES) of Brunei. This interconnection project is currently under feasibility study, and SEB and DES have established the Brunei-Sarawak Working Group Committee for the feasibility study and are considering a draft Power Exchange Agreement (PEA). The interconnection between the grids will be connected by a 45km long 275kV HVAC overhead transmission line from the Tudan substation in Sarawak to Lumut in Brunei.

There is a possibility of interference with the Anduki Forest Reserve, but it is thought that it will be possible to connect the coordination line along the road, and it is also thought that there will be no obstacles to construction as it passes through a flat area.


Note: The area marked in dark green color in the map indicates protected area.

Source: Create from ACE, "ASEAN Power Grid Interconnections Project Profiles", 2024-9-26, <https://aseanenergy.org/wp-content/uploads/2024/11/ASEAN-Power-Grid-Interconnections-Project-Profiles.pdf> and protected planet, https://www.protectedplanet.net/en

**Figure 2.2.6 Map of Protected Area (Brunei - Sarawak)**

8) Sabah (Borneo Island) – Sarawak (Borneo Island)

Mengalong (Sabah) - Lawas (Sarawak)

Construction of the interconnection between Sabah and Sarawak on the island of Borneo in Malaysia is currently in the project implementation phase. In 2021, a power exchange agreement and interconnection agreement were signed between the two states to export 30MW of power from Sarawak to Sabah for 15 years. The project was scheduled to begin commercial operations by the end of 2023, but due to issues related to land use permits, it has been postponed until 2Q 2025[15].

Construction has already begun and is excluded from the scope of the study.

9) Thailand – Laos

The following six routes are existing interconnection projects that cross the border between Thailand and Laos.

[15] BORNEO POST online, "S'wak to supply electricity to Sabah in 2Q of 2025, says Julaihi", 2024-11-18, <https://www.theborneopost.com/2024/11/18/swak-to-supply-electricity-to-sabah-in-2q-of-2025-says-julaihi/>.

Upgrades are planned for the Nong Khai (TH) – Dongphosy (LA), Nong Khai (TH) – Thanaleng (LA), and Bueng Kan (TH) – Pakxan (LA) routes, and commercial operations are scheduled to begin on the Nakhon Phanom (TH) – Thakhek (LA) route by 2027.

Tha Li (TH) – Ken Thao (LA)

Nong Khai (TH) – Dongphosy (LA), Nong Khai (TH) – Thanaleng (LA)

Bueng Kan (TH) – Pakxan (LA)

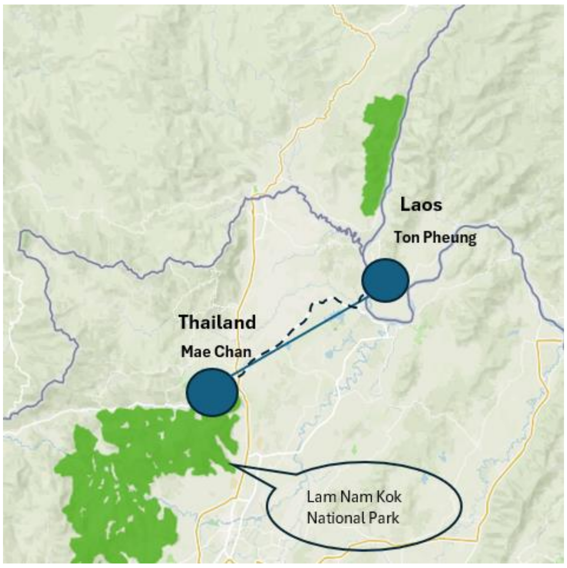
Nakhon Phanom (TH) – Thakhek (LA)

Mudhakan 2 (TH) – Pakbo (LA)

Sirindhom 2 (TH) – Bangyo (LA)

In addition to the above six routes, a priority interconnection between Mae Chan and Ton Pheung is planned. This interconnection will connect Thailand and Laos via an inter-system 115/230kV HVAC overhead transmission line (to be constructed on the 230kV system but initially energized at 115kV).

As can be seen from the map below, there is a possibility of interference with the Lam Nam Kok National Park protected area, but it is possible to connect the tie line along the road (shown as a dotted line in the map), and it passes through a flat area, so it is thought that there will be no problems with construction.




Note: The area marked in dark green color in the map indicates protected area.

Source: Create from ACE, "ASEAN Power Grid Interconnections Project Profiles", 2024-9-26, <https://aseanenergy.org/wp-content/uploads/2024/11/ASEAN-Power-Grid-Interconnections-Project-Profiles.pdf> and protected planet, https://www.protectedplanet.net/en

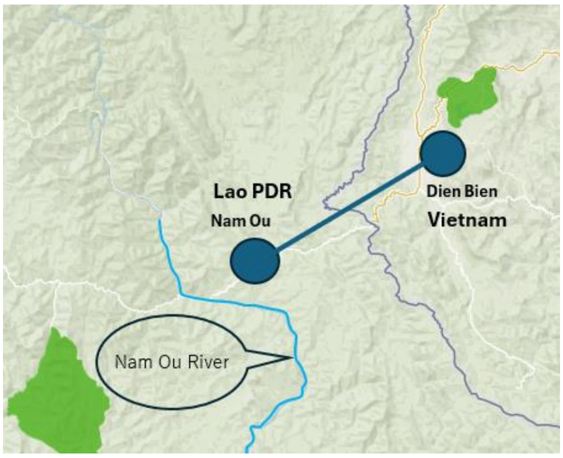
**Figure 2.2.7 Map of Protected Area (Thailand - Lao PDR )**

10) Laos – Vietnam

Nam Ou (LA) – Dien Bien (VN)

Vietnam-Laos interconnection is planned to be constructed using the Grid-to-Grid method, which will enable Laos to purchase electricity from Vietnam. Although no further studies have been conducted, this interconnection is planned to use HVAC overhead transmission lines and be energized at 220 kV, connecting Nam Ou and Dien Bien.

As can be seen from the map below, there is no possibility of interference with the protected area, and it is possible to connect the interconnection line along the road, and there are no obstacles to construction., so there should be no problems with construction. (However, the location of the Nam Ou substation is unknown, and It seems to be located near the Nam Ou River basin. (There are several hydroelectric power plants built in that basin.))




Note: The area marked in dark green color in the map indicates protected area.

Source: Create from ACE, "ASEAN Power Grid Interconnections Project Profiles", 2024-9-26, <https://aseanenergy.org/wp-content/uploads/2024/11/ASEAN-Power-Grid-Interconnections-Project-Profiles.pdf> and protected planet, <https://www.protectedplanet.net/en>

**Figure 2.2.8 Map of Protected Area (Lao PDR - Vietnam)**

11) Thailand – Myanmar

Mae Sot (TH) – Myawaddy (MM)

According to the latest information from HAPUA Working Group 2, there are plans to interconnect Thailand and Myanmar using the Mae Sot (TH) and Myawaddy (MM) interconnectors. The substations will be connected by a 230 kV HVAC overhead transmission line with a maximum capacity of 365 MW, enabling energy exchange between the two countries. EGAT has conducted an in-house preliminary technical study on the feasibility of the interconnection project. However, more detailed studies are needed to confirm whether the interconnection project is technically and economically feasible.

12) Vietnam – Cambodia

Vietnam and Cambodia have a 200 MW grid interconnection that was established in 2009, connecting a substation in Chau Doc (VN) in Vietnam with Takeo (KH) in Cambodia. Due to the large variable capacity of renewable energy in Vietnam, there are plans to further increase the interconnections from Vietnam to Cambodia. Although we have not been able to obtain any additional information on the interconnection capacity, it is predicted that it will take the form of a power purchase agreement to export electricity from Vietnam to Cambodia via a 230kV transmission line.

The connection point (substation) has not been specified for this section. For this reason, the connecting line shown in Figure 2.2.9 is less reliable than other maps. Assuming that it is an expansion of an existing line, there is a possibility of interference with the Boeng Prek Lpov Protected Landscape but considering that it is a flat area and that there is already a line there, it is thought that there will be no obstacles to construction.


Note: The area marked in dark green color in the map indicates protected area.

Source: Create from ACE, "ASEAN Power Grid Interconnections Project Profiles", 2024-9-26, <https://aseanenergy.org/wp-content/uploads/2024/11/ASEAN-Power-Grid-Interconnections-Project-Profiles.pdf> and protected planet, https://www.protectedplanet.net/en

**Figure 2.2.9 Map of Protected Area (Vietnam - Cambodia)**

13) Laos - Cambodia

Ban Hat (LA) – Strung Treng (KH)

Ban Hat (LA) – Kampong Sralao (KH)

An upgrade of the transmission line is planned for the Ban Hat (LA) – Strung Treng (KH) route, and the Ban Hat (LA) – Kampong Sralao (KH) route is scheduled to be completed in 2026

Ban Hat (LA) – Preah Vihear (KH)

Laos is aiming to establish a 500kV overhead interconnection line between Ban Hat (LA) and Preah Vihear (KH) to further enable the export of electricity to Cambodia.

If the location of these substations is as shown on the map below, they will interfere with the Chhaeb Wildlife Sanctuary. To bypass this, it is thought that a considerable detour will be required to draw a tie line along the road that runs nearby.


Note: The area marked in dark green color in the map indicates protected area.

Source: Create from ACE, "ASEAN Power Grid Interconnections Project Profiles", 2024-9-26, <https://aseanenergy.org/wp-content/uploads/2024/11/ASEAN-Power-Grid-Interconnections-Project-Profiles.pdf> and protected planet, <https://www.protectedplanet.net/en>

**Figure 2.2.10 Map of Protected Area (Lao PDR - Cambodia)**

14) Thailand - Cambodia

Watthana Nakhon (TH) – Aranyaprathet (TH) – Industrial Estate (KH)

Thailand and Cambodia are interconnected by the inter-system transmission line of the Watthana Nakhon - Aranyaprathet - Poi Pet Industrial Estate. It was developed to export electricity from Thailand to Cambodia based on a power purchase agreement between the power companies, and has a maximum transmission capacity of 250 MW.

Watthana Nakhon 2 (TH) - Battambang 2 (KH)

Considering Thailand's high renewable energy potential and overall power generation capacity, the interconnection between Thailand and Cambodia is scheduled to be strengthened through the connection between Watthana Nakhon 2 and Battambang 2. The interconnection will be approximately 112 km long, using 230/500 kV (initially energized at 230 kV) overhead transmission lines, with a transmission capacity of 650 MW.

As can be seen from the map below, there is no possibility of interference with protected areas, and the terrain is flat, so there should be no obstacles to construction.


Note: The area marked in dark green color in the map indicates protected area.

Source: Create from ACE, "ASEAN Power Grid Interconnections Project Profiles", 2024-9-26, <https://aseanenergy.org/wp-content/uploads/2024/11/ASEAN-Power-Grid-Interconnections-Project-Profiles.pdf> and protected planet, https://www.protectedplanet.net/en

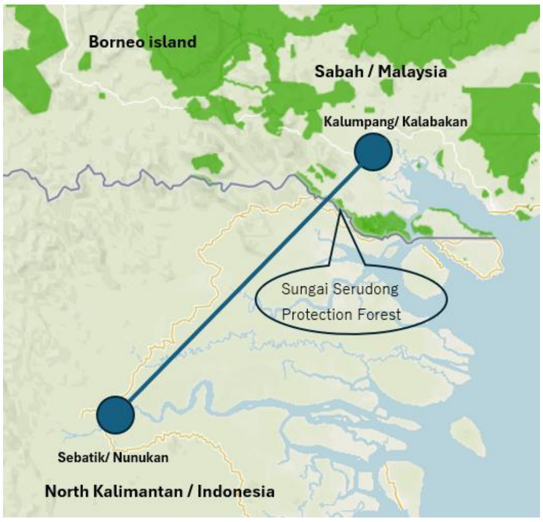
**Figure 2.2.11 Map of Protected Area (Thailand - Cambodia)**

15) Sabah (Borneo Island) – North Kalimantan (Borneo Island)

Sebatik/ Nunukan (ID) – Kalumpang/ Kalabakan (MY)

There is no existing interconnection between the North Kalimantan and Sabah on the island of Borneo. However, a proposed interconnection is currently under feasibility study with support from USTDA. This interconnection will link Indonesia and Malaysia with an overhead transmission line, expand cross-border power trade within the Eastern Subregion, and become one of the important transmission lines that support the establishment of multilateral power trade under the BIMP-PIP initiative.

If the location of these substations is as shown on the map below, they will interfere with the Sungai Serudong Protection Forest, but as it is on flat land, it should not be difficult to divert the route.




Note: The area marked in dark green color in the map indicates protected area.

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**Figure 2.2.12 Map of Protected Area (Sabah – North Kalimantan)**

16) Sumatra (including Batam Island) – Singapore

Paranap (ID) – Singapore

To connect Sumatra and Singapore was being planned under the first AIMS, but as of 2023 there is no existing interconnection between Sumatra and Singapore.

The latest proposal for an interconnection between Singapore and Sumatra Island is to connect Singapore to a 250kV substation in Paranap, Sumatra, and this transmission line is expected to have a maximum capacity of 1,600MW by 2030, using a 100km long submarine HVDC transmission cable.

As can be seen from the map below, there is no interference with protected areas, but there are expected to be some construction difficulties, as the Malacca Strait section will need to be crossed using a submarine cable or some other method.


Note: The area marked in dark green color in the map indicates protected area.

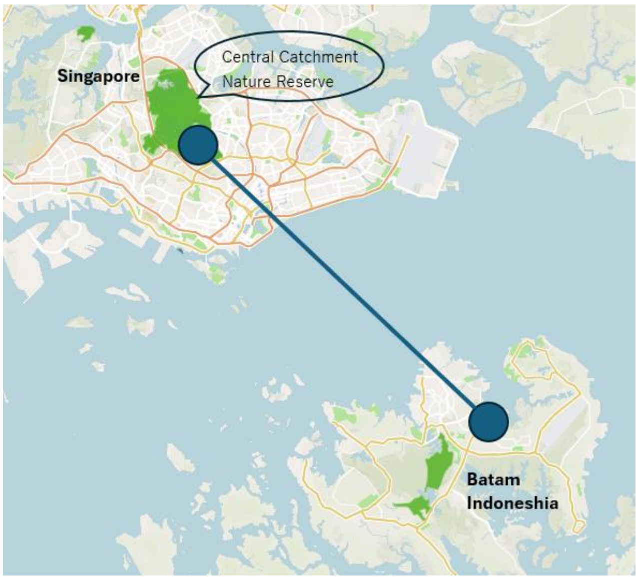
Source: Create from ACE, "ASEAN Power Grid Interconnections Project Profiles", 2024-9-26, <https://aseanenergy.org/wp-content/uploads/2024/11/ASEAN-Power-Grid-Interconnections-Project-Profiles.pdf> and protected planet, https://www.protectedplanet.net/en

**Figure 2.2.13 Map of Protected Area (Sumatra – Singapore)**

Batam (ID) – Singapore

The plan to connect Batam Island and Singapore was initially the fifth interconnection, but it was integrated into the Sumatra-Singapore interconnection. The power from the solar power plant on Batam Island will be connected to Singapore.

If the location of the substation on the Singapore side is as follows, it will interfere with the Central Catchment Nature Reserve, but it is also flat land, so it is not difficult to think that it will not be difficult to bypass it. In addition, it is necessary to cross the Singapore Strait by submarine cable or other methods, and some construction difficulties are expected.




Note: The area marked in dark green color in the map indicates protected area.

Source: Create from ACE, "ASEAN Power Grid Interconnections Project Profiles", 2024-9-26, <https://aseanenergy.org/wp-content/uploads/2024/11/ASEAN-Power-Grid-Interconnections-Project-Profiles.pdf> and protected planet, https://www.protectedplanet.net/en

**Figure 2.2.14 Map of Protected Area (Batam – Singapore)**

17) Laos – Myanmar

Muang Long (LA) – Shan State (MM)

There is an 115kV, 30MW interconnection between Muang Long in Laos and Shan State in Myanmar, which has been in commercial operation since 2022 to export electricity from Laos to Myanmar.

Furthermore, based on the latest Power Development Plan (PDP) of Laos, Laos is planning to construct a 230kV transmission line from Muang Long to Shan State, with the aim of starting commercial operation in 2027. The interconnection capacity will be upgraded regularly in the future to 100MW, 300MW, and 600MW, enabling the transmission of higher hydropower from Laos to Myanmar.

18) Internal Indonesia

Java – Kalimantan

The interconnection plan between Java and South Kalimantan is being proposed by the Indonesian power company PLN and aims to connect the Southern and Eastern Subregions of the ASEAN power grid in order to increase the resilience of the power grid through interconnection between the power grids. The high demand for electricity in Java could be supported by power generation from Kalimantan or by imported energy from Sabah/Sarawak (Malaysia).

The connection point (substation) has not been specified for this section. For this reason, the connecting line shown in Figure 2.2.15 is less reliable than other maps. If the location is as shown in the map below, there is expected to be interference with the Sultan Adam Grand Forest Park Forest Conservation Area, etc., but it is also flat land, so it is not difficult to detour. In addition, it is necessary to cross the Java Sea using a submarine cable or other method, so some construction difficulties are expected.


Note: The area marked in dark green color in the map indicates protected area.

Source: Create from ACE, "ASEAN Power Grid Interconnections Project Profiles", 2024-9-26, <https://aseanenergy.org/wp-content/uploads/2024/11/ASEAN-Power-Grid-Interconnections-Project-Profiles.pdf> and protected planet, <https://www.protectedplanet.net/en>

**Figure 2.2.15 Map of Protected Area (Java – Kalimantan)**

Sumatra – Java

The Java Island is expected to see a huge increase in demand for electricity in the future. For this reason, a proposal has been made to establish a power interconnection between Sumatra and Java to supply electricity from Sumatra, which is well-equipped with coal, gas and renewable energy power plants. Several pre-feasibility studies and technical feasibility studies have been conducted on the interconnection between Sumatra and Java, but due to financial and technical issues, the infrastructure has not been built yet. Under the APG, a plan has been drawn up to connect Sumatra and Java using a 500kV HVDC transmission system that utilizes a submarine cable passing through the strait. The interconnection will be connected through the substations in Muara Enim and Bogor in West Java. It is scheduled to have a transmission capacity of 2,600MW by 2031.

If substations are located as shown on the map below, there is expected to be interference with the Wan Abdulrahman Grand Forest Park and the Gunung Halimun - Salak National Park, but it is also on flat land, so it is thought that it would not be difficult to divert it. In addition, it is necessary to cross the Sunda Strait using a submarine cable or other method, so some construction difficulties are expected


Note: The area marked in dark green color in the map indicates protected area.

Source: Create from ACE, "ASEAN Power Grid Interconnections Project Profiles", 2024-9-26, <https://aseanenergy.org/wp-content/uploads/2024/11/ASEAN-Power-Grid-Interconnections-Project-Profiles.pdf> and protected planet, https://www.protectedplanet.net/en

**Figure 2.2.16 Map of Protected Area (Sumatra – Java)**

### 2.2.3 Presence of Conflicts/Protests

Finally, checked w any opposition movements to the ASEAN Power Grid Project based on various media reports. As a result, we were unable to confirm any opposition movements at the time of this survey.

### 2.2.4 Results of Evaluation

The results of checking whether the route is an existing route, whether it will interfere with protected areas, and whether there is opposition to the route are listed. It is found that many routes do not fall under any of these restrictions. On the other hand, some routes are existing routes and are therefore not eligible for evaluation, and routes that are considered to inevitably interfere with protected areas will be given a lower evaluation in the screening process to be carried out later.

**Table 2.2.3 Results of Evaluation**

| No. | Line | Existing line | Interference with protected are | Presence of conflicts/protests |
|---|---|---|---|---|
| 1 | Peninsula Malaysia- Singapore (Planting – Woodlands, Phase II) | | | |
| 2 | Thailand - Peninsula Malaysia (Su Ngai Kolok - Rantau Panjang) | | | |
| | Thailand - Peninsula Malaysia (Khlong Ngae – Gurun, 2nd Phase) | | | |
| 3 | Internal Malaysia (Sarawak - Peninsula Malaysia) | | | |
| 4 | Peninsula Malaysia - Sumatra | | | |
| 5 | Sarawak - Kalimantan | ✓ | | |
| 6 | Philippines – Sabah (Malaysia) | | | |
| 7 | Sarawak（Malaysia） - Brunei Darussalam | | | |
| 8 | Sarawak（Malaysia） - Sabah (Malaysia) | ✓ | | |
| 9 | Thailand - Lao PDR | | | |
| 10 | Lao PDR - Vietnam (Nam Ou - Dien Bien) | | | |
| | Lao PDR - Vietnam (Luang Prabang - Nho Quan) | | | |
| 11 | Thailand - Myanmar | ✓ | | |
| 12 | Vietnam – Cambodia | | | |
| 13 | Lao PDR – Cambodia (Ban Hat - Kampong Sralao) | | | |
| | Lao PDR - Cambodia (Ban Hat - Preah Vihear) | | ✓ | |
| 14 | Thailand – Cambodia | | | |
| 15 | East Sabah（Malaysia）- North Kalimantan（Indonesia） | | | |
| 16 | Singapore - Indonesia (Singapore- Sumatra) | | | |
| | Singapore - Indonesia (Singapore – Batam) | | | |
| 17 | Lao PDR - Myanmar | ✓ | | |
| 18 | Internal Indonesia (Kalimantan-Java) | | | |
| | Internal Indonesia (Sumatra-Java) | | | |

Source: Create from ACE, "ASEAN Power Grid Interconnections Project Profiles", 2024-9-26, <https://aseanenergy.org/wp-content/uploads/2024/11/ASEAN-Power-Grid-Interconnections-Project-Profiles.pdf>, protected planet, <https://www.protectedplanet.net/en> and research by JICA Team

# Chapter 3 Stakeholder Analysis

3.1 Procedure of Project Implementation

The ACE, with the support of the U.S. Agency for Development (USAID), has developed "A Playbook for ASEAN Power Grid Interconnector Feasibility Studies". This document outlines the typical flow of project implementation for an interconnection line, including feasibility studies based on the use of funds provided by the development partners.

① The Development Partner conducts initial discussions on the support policy, target routes, etc., and submits an offer to the ASEAN stakeholders.

② In response, the governments of the countries concerned, utilities, HAPUA (Heads of ASEAN Power Utilities/Agencies), and ACE discuss the proposal.

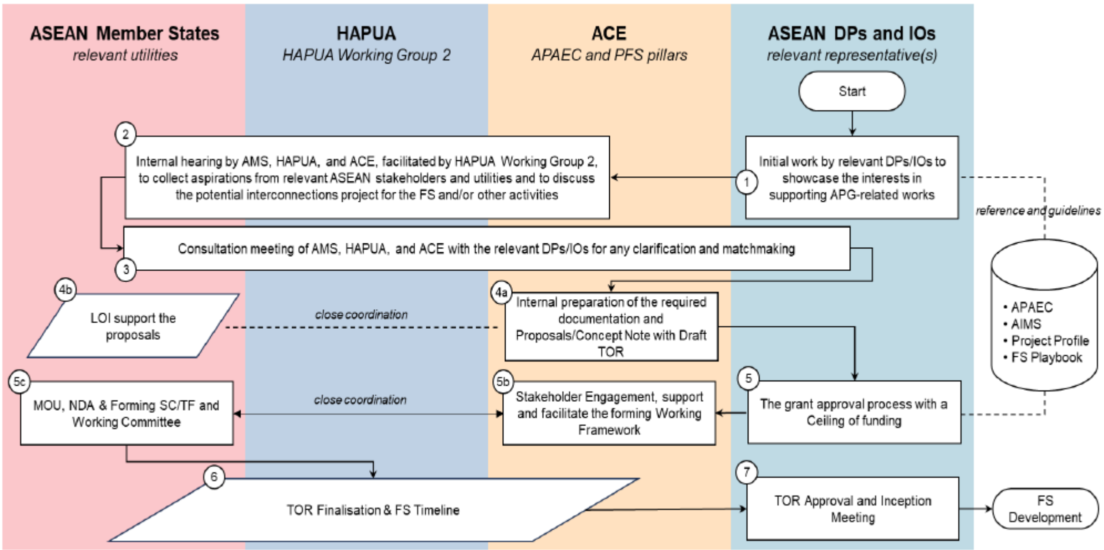
③ ASEAN stakeholders and the Development Partner discuss how to proceed with the project.

④ The government concerned expresses its intention to implement the project (Letter of Intent), and ACE defines the details of the project (Term of Reference).

⑤ The Development partner carry out grant approval procedures. In parallel, the countries concerned and ACE establish the necessary environment for project implementation, such as MOU, non-disclosure agreement, and assignment of work force.

⑥ The TOR is finalized among the parties concerned and the project is launched.

Following this process, the project can be positioned in stage ① of the above mentioned steps. The next stage would require consultation with the ASEAN stakeholders. If the responsible counterparts in the subjected countries have already been identified, one may directly offer the project. But if the counterparts are not identified or if multilateral coordination is required, it is effective to consult with ACE, which is responsible for inter-organizational coordination.




Source; A Playbook for ASEAN Power Grid Interconnector Feasibility Studies

**Figure 3.1.1 Typical Workflow for APG related Projects**

## 3.2 Support for Power Grid Projects

The status of support for each of the interconnectors is as follows. In the case of two interconnectors, 4. Peninsula Malaysia - Sumatra and 15. East Sabah (Malaysia) - North Kalimantan (Indonesia), a feasibility study is being carried out with funding from USTDA. However, due to the policies of the new administration that came to power in the United States in January 2025, supports has been frozen[16].

Asian Development Bank and World Bank consider the ASEAN Power Grid to be an important element in achieving sustainable regional development. However, at the time of this survey, they were not providing support for individual lines. They are considering providing comprehensive support for the APG in collaboration with various support organizations, in addition to ASEAN stakeholders such as ACE and HAPUA[17].

According to ACE, feasibility studies for individual routes are being conducted by The World Bank, the Australian Department of Foreign Affairs and Trade, and the French Development Agency (AFD) (Step 1 identified in the section 3.1). The HAPUA Working Group 2 (HWG 2) under the HAPUA is responsible for promoting the ASEAN Power Grid project. While each of the developing partners has made its own proposals for the routes to be supported, HWG 2 has not yet established a selection process, and discussions are still ongoing (Step 2 identified in the section 3.1).

Meanwhile ACE confirmed that the high development priority routes selected by this project do not overlap with the aforementioned routes proposed by other development partners.

16 Based on Interview with ACE
17 Based on interviews with Asian Development Bank and World Bank

**Table 3.2.1 List of Development Partners' Participation**

| No. | Line | DPs |
|---|---|---|
| 1 | Peninsula Malaysia- Singapore | - |
| 2 | Thailand - Peninsula Malaysia (Su Ngai Kolok - Rantau Panjang) | - |
| | Thailand - Peninsula Malaysia (Khlong Ngae – Gurun, 2nd Phase) | - |
| 3 | Internal Malaysia (Sarawak - Peninsula Malaysia) | - |
| 4 | Peninsula Malaysia - Sumatra | Under F/S funded by USTDA- |
| 5 | Sarawak - Kalimantan | - |
| 6 | Philippines – Sabah (Malaysia) | - |
| 7 | Sarawak（Malaysia） - Brunei Darussalam | - |
| 8 | Sarawak（Malaysia） - Sabah (Malaysia) | - |
| 9 | Thailand - Lao PDR | - |
| 10 | Lao PDR - Vietnam (Nam Ou - Dien Bien) | - |
| | Lao PDR - Vietnam (Luang Prabang - Nho Quan) | - |
| 11 | Thailand - Myanmar | - |
| 12 | Vietnam – Cambodia | - |
| 13 | Lao PDR – Cambodia (Ban Hat - Kampong Sralao) | - |
| | Lao PDR - Cambodia (Ban Hat - Preah Vihear) | - |
| 14 | Thailand – Cambodia | - |
| 15 | East Sabah（Malaysia）- North Kalimantan（Indonesia） | Under F/S funded by USTDA- |
| 16 | Singapore - Indonesia (Singapore- Sumatra) | - |
| | Singapore - Indonesia (Singapore – Batam) | - |
| 17 | Lao PDR - Myanmar | - |
| 18 | Internal Indonesia (Kalimantan-Java) | - |
| | Internal Indonesia (Sumatra-Java) | |

DP = development partners

Source: Create from ACE, "ASEAN Power Grid Interconnections Project Profiles", 2024-9-26, <https://aseanenergy.org/wp-content/uploads/2024/11/ASEAN-Power-Grid-Interconnections-Project-Profiles.pdf> and research at JICA Team

# Chapter 4 Recommendations for the Promotion of ASEAN Power Grid Development

4.1 Assessment of Cross Border Interconnection Projects with high development priority

Based on the analysis in Chapters 1.3, this study selected high development priority interconnection lines from the 18 projects proposed in AIMS III that would be most meaningful for Development partner(DPs) support, including JICA. In selecting the high development priority lines, this study set evaluation criteria and evaluated them in a step-by-step process - Step 1, Step 2, and Step 3. This study aimed to evaluate the projects fairly based on publicly available information, rather than considering individual circumstances.

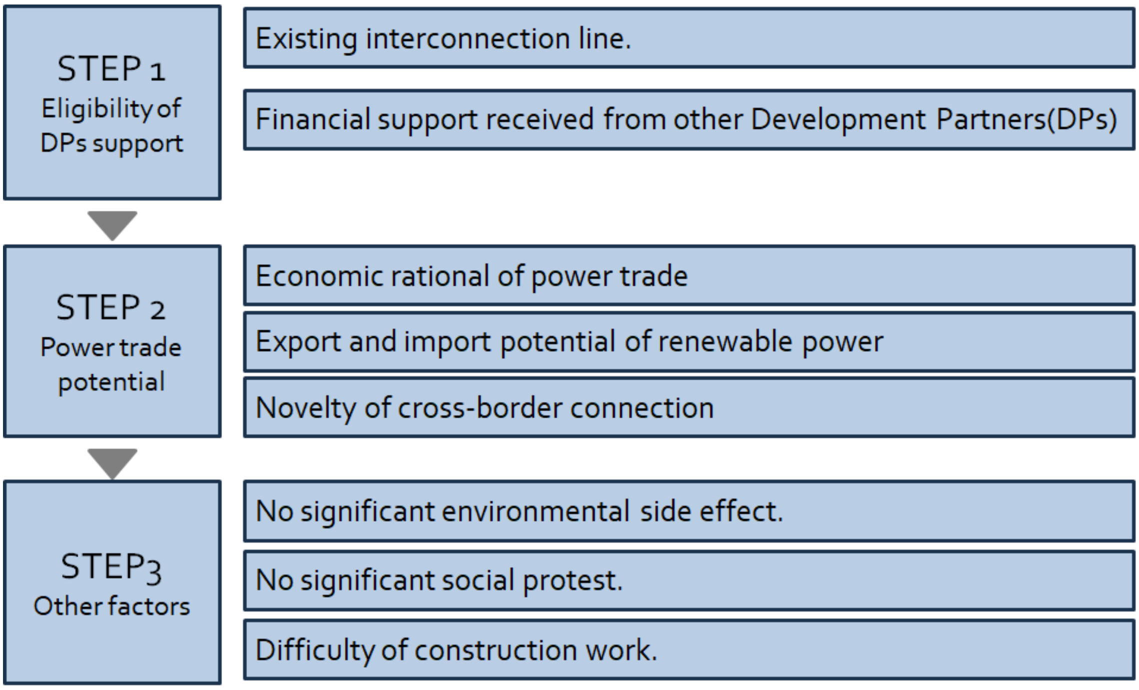



**Figure 4.1.1 Assessment Criteria**

Step 1 evaluated whether the project was eligible for DPs support or not. The evaluation criteria were whether the interconnection line was existing or not, and whether there was support from other development partners. First, step1 checked the ACE report[18] to determine if the line was newly constructed or if it had already started operations or was about to start. Step1 decided to exclude the lines that were already in operation or about to start, which were line No. 5 (Sarawak-Kalimantan) and No. 8 (Sarawak-Sabah). Additionally, while No. 11 (Thailand-Myanmar) and No.17 (Laos-Myanmar) were not yet in operation, Step 1 decided to exclude them due to the current situation in Myanmar.

18 https://aseanenergy.org/publications/asean-power-grid-interconnections-project-profiles/

Step 1 then reviewed the financial support from other development partners by checking their websites. Step 1 decided to exclude lines where development assistance agencies have already confirmed support. This means that the Malaysia Peninsula-Sumatra line (No. 4) and the East Sabah-Kalimantan line (No. 15) have been supported by the U.S. Trade and Development Agency (USTDA) to conduct feasibility studies covering technical, environmental, economic, and regulatory aspects[19]. However, since these studies are considered preliminary, there is still room for DPs to provide financial and technical support. Therefore, Step 1 decided to include these lines in its evaluation. The Philippines-Sabah line (No. 6) was part of a preliminary study between Borneo and the Philippines supported by the Asian Development Bank (ADB)[20]. But since no progress has been confirmed since the study report was published in November 2014, step 1 decided to include this line in its evaluation.

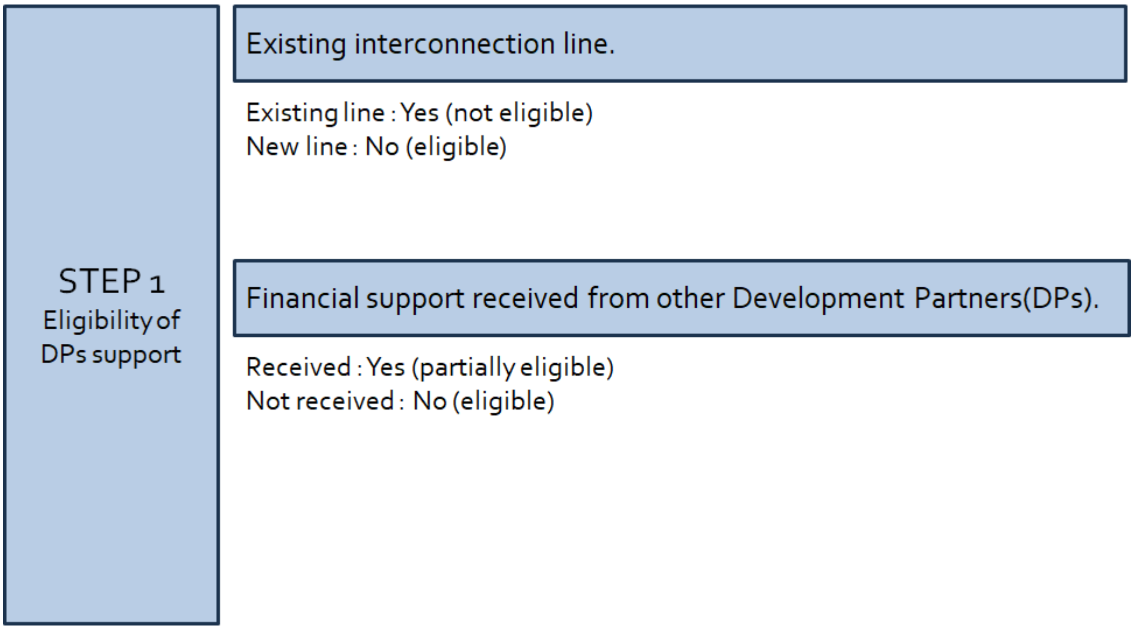



**Figure 4.1.2 Step1 Evaluation Method**

Next, step 2 selected high development priority lines based on the results of Step 1. In selecting the high development priority lines, step2 evaluated the need for cross-border connection. The evaluation criteria in step2 are as follows: the economic rationale of power trade, the export potential of renewable power, the import potential of renewable power, and the novelty of cross-border connection. Each of these four criteria was rated on a scale of 1 to 3, with a maximum possible score of 12. The reasons for adopting these evaluation criteria are as follows. For the economic rationale of power trade, the greater the economic benefits from

[19] https://aseanenergy.org/post/asean-centre-for-energy-to-oversee-ustda-supported-study-on-plns-indonesia-malaysia-cross-border-interconnection-project/
[20] https://www.adb.org/sites/default/files/page/34232/bimp-eaga-borneo-mindanao-power-systems.pdf

power trading between the two countries, the higher the need for cross-border connection. Regarding the export and import potential of renewable power, increasing the large-scale introduction of renewable energy is a challenge for ASEAN countries to meet their greenhouse gas reduction targets, but the renewable energy generation potential varies significantly by country. Countries with low renewable energy potential have high import needs, while countries with high renewable energy potential have export capacity. Step 2 therefore decided that the renewable energy potential of each country is linked to the need for renewable energy power trade. For the novelty of cross-border connection, countries that have never had an interconnection lack prior experience and expertise in establishing such infrastructure. As a result, they have a greater need for support compared to countries with existing interconnections. The following section outlines the evaluation methods for each criteria.

The economic rationale of power trade was based on an assessment of power generation costs (LCOE). In this evaluation, this study referenced the generation costs of the target countries for each line and calculated the difference. For the power generation cost, it referred to the AIMS-III report[21] published by ACE. For example, if the generation cost in Country A is higher than the generation cost in Country B, it would receive a higher score. The rationale is that countries with higher generation costs would have a greater need to import from countries with lower costs, while countries with lower generation costs would have a greater incentive to export to higher-cost countries. On the other hand, between countries with similar cost ranges, the economic benefits of importing and exporting would be relatively limited.

In evaluating the export and import potential of renewable power, this study assigned each country as either an RE exporter (exporting country) or an RE importer (importing country). This was based on the power export and import volumes for each country in 2050, as reported in the 7th ASEAN Energy Outlook published by ACE in 2022[22]. The countries with higher export volumes were considered exporting countries, while those with higher import volumes were considered importing countries. Next, this study assessed the countries' RE potential (in kW) against their peak demand (in kW) in 2050. The RE potential and peak demand data were referenced from the Renewable Energy Outlook for ASEAN[23] co-published by IRENA and ACE. This study subtracts peak demand from RE potential because the RE potential data alone does not clearly indicate a country's export capacity or import needs. For exporting countries, a higher difference (RE potential minus peak demand) indicates greater export capacity, leading to a higher score. For importing countries, a lower difference suggests a higher need for imports, resulting in a higher score.

In addition to the above evaluation, there are also domestic interconnection lines in ASEAN power grid. Specifically, line No.3) Sarawak - Peninsula Malaysia and line No.18) Kalimantan-Java, Sumatra-Java are domestic lines in Malaysia and Indonesia. Due to incomplete data for the individual islands in Malaysia and

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[21] ACE(2023), ASEAN INTERCONNECTION MASTERPLAN STUDY (AIMS-III), Report on Phase-I Capacity Expansion Modelling Updates, 2023

[22] https://accept.aseanenergy.org/the-7th-asean-energy-outlook/

[23] https://www.irena.org/publications/2022/Sep/Renewable-Energy-Outlook-for-ASEAN-2nd-edition

Indonesia, this study made some estimates. Indonesia has projected the power export and import volumes in 2060 for each island in its National Electricity Development Plan (RUKN 2024-2060[24]). Based on this, this study assumed the exporting and importing islands. Next, this study calculated the total national value by subtracting the peak demand from the 2050 renewable energy potential data from IRENA and ACE Outlook.

Then, this study referenced the projected island-specific power generation for 2060 as stated in RUKN 2024-2060 and calculated the proportion of each island's generation relative to the country's total power generation. Finally, this study multiplied the national value by the island's proportion and evaluated the results based on their magnitude. For Malaysia, this study referred to the 2050 island-level export and import data from the MALAYSIA ENERGY TRANSITION OUTLOOK[25] published by IRENA to assume the exporting and importing islands. Next, this study calculated the national total by subtracting the peak demand from the renewable energy potential in 2050 from IRENA and ACE Outlook. Finally, this study multiplied the national value by the island's proportion and evaluated the results based on their magnitude.

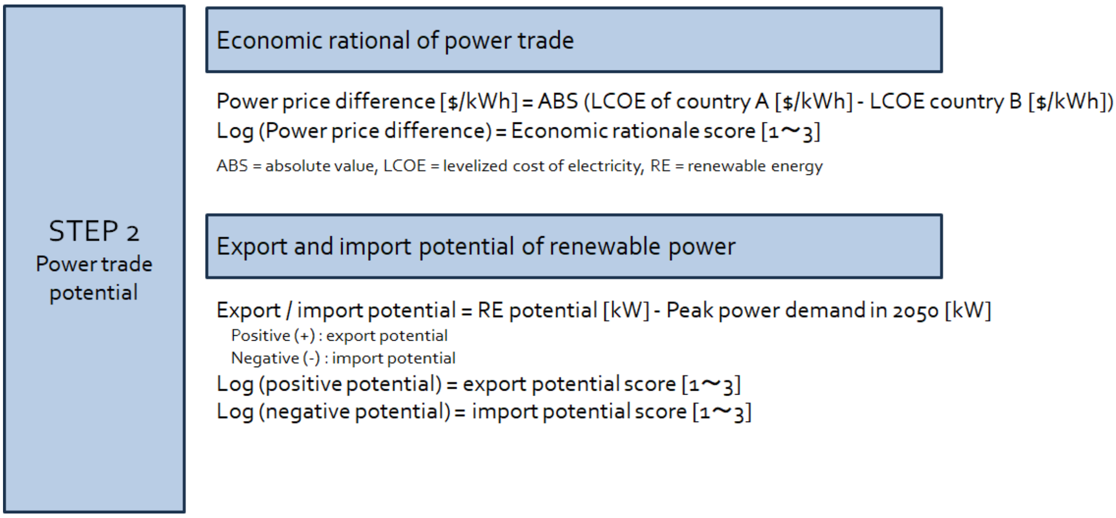



**Figure 4.1.3 Step2 Evaluation Method(1)**

Step 2 finally evaluated the novelty of cross-border connection. This evaluation checked whether the participating countries had prior experience in laying interconnection lines. For countries where cross-border connections had already been established, there was existing knowledge regarding construction and operation, so the need for support was considered relatively low. On the other hand, for countries that had no prior experience with cross-border connection, the need for external support was assumed to be higher. Based on this reasoning, the evaluation was as follows: 3 points for the first interconnection line between the

24 https://gatrik.esdm.go.id/assets/uploads/download_index/files/2f251-rukn-2024.pdf

25 https://www.irena.org//media/Files/IRENA/Agency/Publication/2023/Mar/IRENA_Malaysia_energy_transition_outlook_2023.pdf#page=91

countries, 1 point for countries with experience in multiple interconnection lines, and 2 points for countries with experience in interconnection lines but only one such instance. Using this approach, the four items of Step 2 were evaluated on a scale of up to 12 points, and the top three ranked routes were selected as the high development priority line.

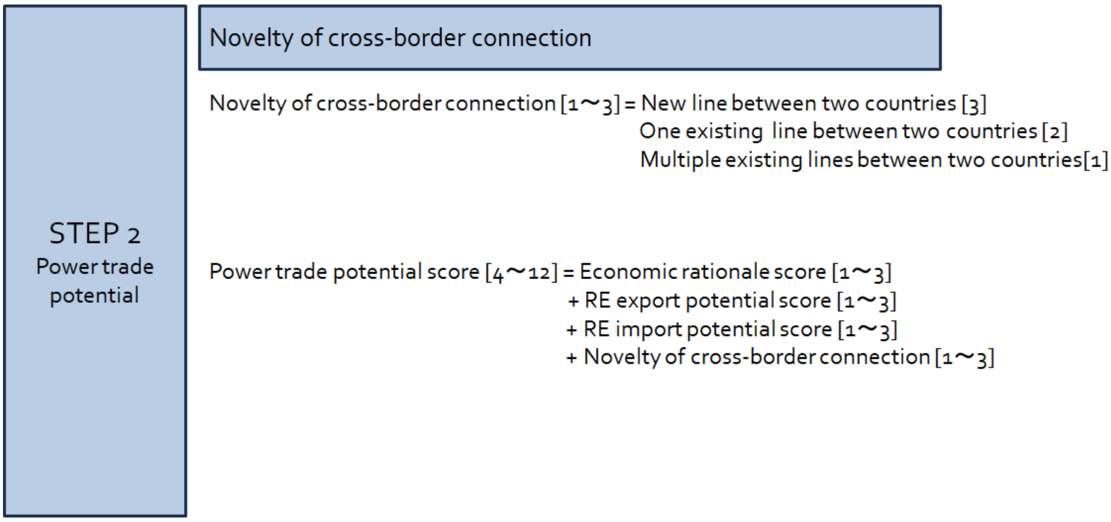



**Figure 4.1.4 Step2 Evaluation Method(2)**

In Step 3, the high development priority lines selected in Step 2 were weighted. Step 3 aimed to differentiate between lines with the same scores by evaluating them as either positive (+) or negative (-). The evaluation criteria adopted in Step 3 were the environmental impact, social impact, and construction difficulty of the lines. For the environmental impact, the possibility of the line passing through protected areas like national parks was checked using publicly available maps. If there was a possibility of passing through such protected areas, the route was given a negative evaluation, as it would require rerouting the transmission line and incur additional construction costs. Conversely, if the route clearly avoided protected areas, it received a positive evaluation. Regarding the social impact, the presence of any extreme opposition to the line was investigated through media reports. Lines facing significant local resistance and lacking community consent were considered to have a higher social risk and were thus given a negative evaluation. Lines without any apparent opposition were evaluated positively. For the construction difficulty, the presence of challenging segments, such as deep-sea transmission or steep mountainous terrain, was checked using map information. Routes with high construction difficulty were deemed to have a higher business risk and were therefore given a negative evaluation.

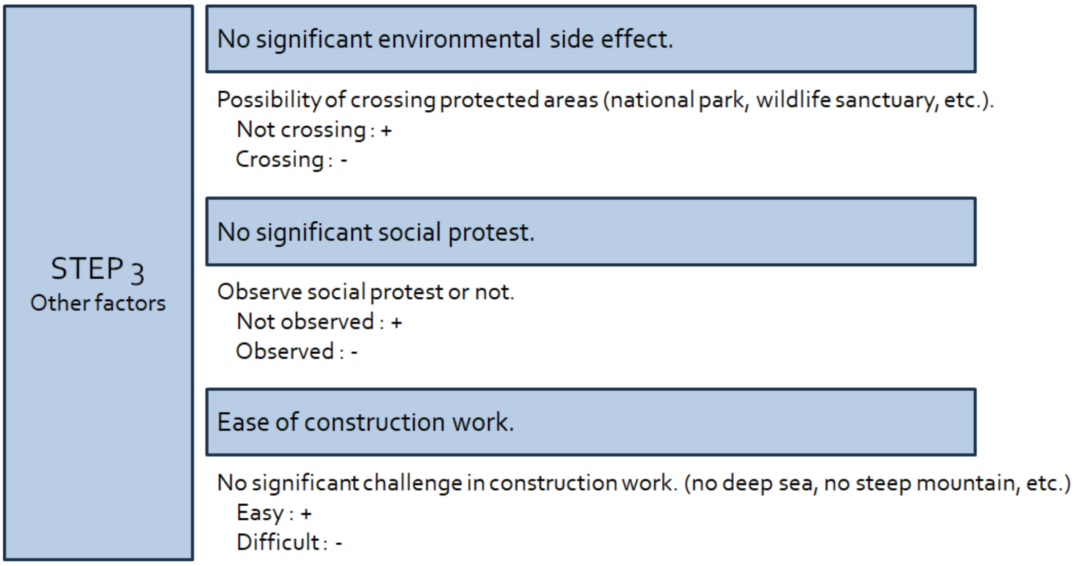



**Figure 4.1.5 Step3 Evaluation Method**

The evaluation results for Steps 1 to 3 are shown in the following figure . The top development priority is the No. 7) Sarawak-Brunei route. The main reasons are that Brunei has very low renewable energy potential compared to its peak demand, and Brunei's electricity generation costs are much higher than Sarawak's, making this an attractive opportunity. Additionally, this would be the first interconnection between the two, giving it high novelty. In Step 3, the environmental and social impacts of the lines were not found to be significant issues. The construction complexity of building an overhead transmission line across Borneo was also not considered a major concern. The second development priority is the No. 16) Singapore-Sumatra, Singapore-Batam lines. This is because Indonesia has very high renewable energy potential for export, while Singapore has low domestic renewable resources and high import needs. As with the Sarawak-Brunei line, this would be the first interconnection between the countries, giving it high novelty. However, the Step 3 evaluation found that the subsea cable routing through the Malacca and Singapore Straits would pose significant construction challenges, offsetting the other positive factors. The third development priority is the No. 6) Philippines (Palawan)-Sabah line. This is driven by the Philippines' low renewable potential relative to its peak demand, creating high import needs, as well as the novelty of the first interconnection. But the Step 3 analysis flagged the challenges of the long subsea cable required between Sabah and Palawan. Based on these evaluations, financial analysis will proceed for the top 3 lines: No. 7) Sarawak-Brunei, No. 16) Singapore-Sumatra/Batam, and No. 6) Philippines-Sabah.

| | Countries | Income Class | STEP1 | | STEP2 | | | | | STEP3 | | | Priority |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| # | | | Existing | DPs | Econo. | RE exp. | RE imp. | Nov. | Total | Env. | Social | Const. | |
| 1 | Peninsula Malaysia- Singapore | Upper Middle and Uppermost-Middle | No | No | 2 | 2 | 3 | 2 | 9 | + | + | - | |
| 2 | Thailand - Peninsula Malaysia (Su Ngai Kolok - Rantau Panjang) | Upper Middle and Uppermost-Middle | No | No | 1 | 2 | 1 | 1 | 5 | + | + | + | |
| | Thailand - Peninsula Malaysia (Khlong Ngae - Gurun 2nd Phase) | Upper Middle and Uppermost-Middle | No | No | 1 | 2 | 1 | 1 | 5 | + | + | + | |
| 3 | Internal Malaysia (Sarawak - Peninsula Malaysia) | Upper Middle and Uppermost-Middle | No | No | 2 | 1 | 3 | 3 | 9 | + | + | - | |
| 4 | Peninsula Malaysia - Sumatra | Upper Middle and Uppermost-Middle | No | Yes | 1 | 2 | 1 | 3 | 7 | + | + | - | |
| 5 | Sarawak - Kalimantan | Upper Middle and Uppermost-Middle | Yes | No | | | | | | | | | |
| 6 | Philippines - Sabah (Malaysia) | Lower-Middle – Upper Middle and Uppermost-Middle | No | No | 2 | 2 | 3 | 3 | 10 | + | + | - | 3rd |
| 7 | Sarawak (Malaysia) - Brunei Darussalam | Upper Middle and Uppermost-Middle | No | No | 3 | 2 | 3 | 3 | 11 | + | + | + | 1st |
| 8 | Sarawak (Malaysia) - Sabah (Malaysia) | Upper Middle and Uppermost-Middle | Yes | No | | | | | | | | | |
| 9 | Thailand - Lao PDR | Upper Middle and Uppermost-Middle - Lower-Middle | No | No | 2 | 2 | 1 | 1 | 6 | + | + | + | |
| 10 | Lao PDR - Vietnam (Nam Ou - Dien Bien ) | LDC or Low - Lower-Middle | No | No | 2 | 2 | 2 | 1 | 7 | + | + | + | |
| | Lao PDR - Vietnam (Luang Prabang - Nho Quan) | LDC or Low - Lower-Middle | No | No | 2 | 2 | 2 | 1 | 7 | + | + | + | |
| 11 | Thailand - Myanmar | Upper Middle and Uppermost-Middle -LDC or Low | Yes | No | | | | | | | | | |
| 12 | Vietnam – Cambodia | Lower-Middle- LDC or Low | No | No | 1 | 3 | 2 | 2 | 8 | + | + | + | |
| 13 | Lao PDR – Cambodia (Ban Hat - Kampong Sralao) | LDC or Low | No | No | 2 | 2 | 2 | 2 | 8 | + | + | + | |
| | Lao PDR - Cambodia (Ban Hat - Preah Vihear ) | LDC or Low | No | No | 2 | 2 | 2 | 2 | 8 | - | + | - | |
| 14 | Thailand – Cambodia | Upper Middle and Uppermost-Middle - LDC or Low | No | No | 1 | 3 | 1 | 2 | 7 | + | + | - | |
| 15 | East Sabah (Malaysia) - North Kalimantan (Indonesia) | Upper Middle and Uppermost-Middle | No | Yes | 1 | 2 | 1 | 3 | 7 | + | + | - | |
| 16 | Singapore - Indonesia (Singapore- Sumatra) | Upper Middle and Uppermost-Middle | No | No | 2 | 3 | 3 | 3 | 11 | + | + | - | 2nd |
| | Singapore - Indonesia (Singapore – Batam) | Upper Middle and Uppermost-Middle | No | No | 2 | 3 | 3 | 3 | 11 | + | + | - | 2nd |
| 17 | Lao PDR - Myanmar | LDC or Low | Yes | No | | | | | | | | | |
| 18 | Internal Indonesia (Kalimantan-Java) | Upper Middle and Uppermost-Middle | No | No | 1 | 2 | 2 | 3 | 8 | + | + | - | |
| | Internal Indonesia (Sumatra-Java) | Upper Middle and Uppermost-Middle | No | No | 2 | 2 | 2 | 3 | 9 | + | + | - | |

**Figure 4.1.6 Results of the High Development Priority Lines:**

Box) Positioning of domestic interconnection lines in the ASEAN Power Grid

The ASEAN Power Grid (APG) was originally intended to make effective use of energy resources, improve the efficiency of power investments and enhance the security of power supply through international interconnection. However, the APG candidate routes also include domestic routes. Specifically, these include routes within Malaysia (#3 and #8) and Indonesia (#18). These routes, with the exception of the existing ones (#8), received relatively high scores of 9 and 8 points in the screening up to Step 2. This is because there is a relatively large difference in renewable energy potential between the regions to be connected and the novelty of the connection, although the difference in generation costs is small because they are within the same country. There are many islands in the southern part of Southeast Asia. And it goes without saying that the strengthening of transmission links is essential for the effective use of energy resources, efficient power investment and the improvement of the stability of power supply in the region. This is in line with the principles of the APG, which is why it was selected as a candidate route. In addition, domestic connections do not require bilateral coordination and therefore have the advantage of being relatively less difficult to implement.

As such, the domestic connection is also an important route that meets the objectives of the APG and is therefore a strong candidate for support.

4.2 Financial Analysis for High Development Priority Route

Financial analysis was conducted for four high development priority routes selected in section 4.1. The assumptions for the high development priority routes are as shown in Table 4.2.1. All transmission lines are double-circuit lines due to avoid the risk of accidents.

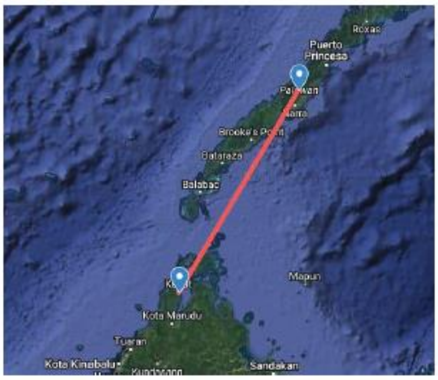
**Table 4.2.1 Assumptions for High Development Priority Routes**

| | Voltage (kV) x Circuits | AC/DC | Line Capacity (MW) | Line Length (km) | |
|---|---|---|---|---|---|
| | | | | Overhead | Submarine |
| Sabah to Palawan | 275 x 2 | HVDC | 196 | 60 | 170 |
| Sarawak to Brunei | 275 x 2 | HVAC | 600 | 45 | 0 |
| Sumatra to Singapore | 250 x 2 | HVDC | 1,600 | 0 | 100 |
| Batam to Singapore | 250 x 2 | HVDC | 1,600 | 10 | 20 |

Source: Assumption by Study Team based on various materials

Details of the sources of Table 4.2.1 are given below.

Saba to Palawan



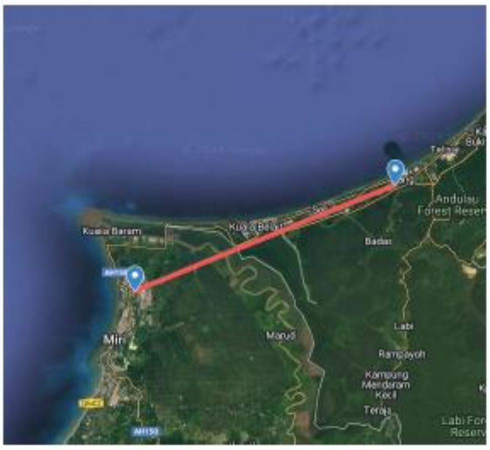

PROJECT OVERVIEW

The Philippines – Sabah interconnection would be one of the important grid-to-grid interconnections in the BIMP-PIP initiative, as it will extend the Kalimantan – Sabah interconnection therefore connecting Indonesia, Malaysia, and the Philippines. The planned interconnection will connect the Philippines and Malaysia through the Kudat substation in Sabah, Malaysia to Palawan in the Philippines, via a 275 kV HVDC subsea cable. Based on the ASEAN RE Target Scenario of AIMS III, the 230km interconnection is projected to have an installed capacity of 196 MW by 2040.

Source: ASEAN Power Grid Interconnections Project Profiles on 14 page

The proportion of 170 km of submarine cable and 60 km of overhead cable is an estimated figure measured by using Google Map.

Sarawak to Brunei




**PROJECT OVERVIEW**

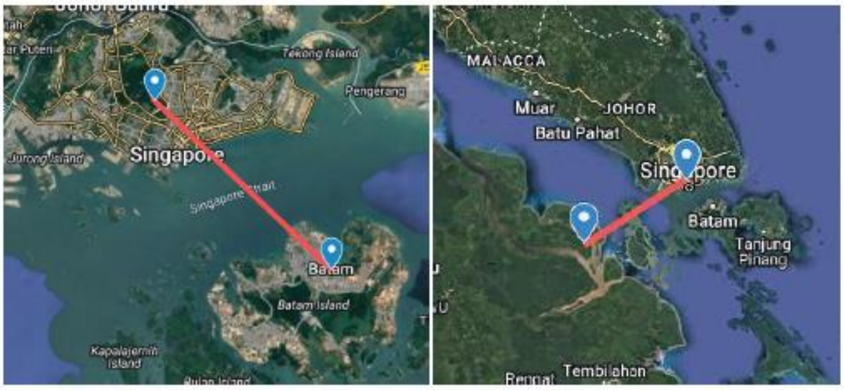
There is no existing interconnection from Sarawak to Brunei Darussalam, although collaborative plans between Sarawak Energy and Brunei's Department of Energy to connect both countries are already in place. The Sarawak – Brunei Darussalam interconnection project is currently undergoing a feasibility study. Brunei Darussalam's Department of Energy and Sarawak Energy Berhad is in the process of establishing the Brunei – Sarawak Working Group committee for the feasibility study, as well as reviewing the draft Power Exchange Agreement (PEA). The grid-to-grid interconnection will connect Sarawak from the Tudan substation in Malaysia to Lumut in Brunei Darussalam through a 275 kV HVAC Overhead Transmission Line, with 45 km in length.

**TECHNICAL SPECIFICATIONS**

| | | |
|---|---|---|
| Connecting substations | : | Tudan (Sarawak/MY) – Lumut (BN) |
| Interconnection Agreement | : | Energy Exchange |
| Voltage | : | 275 kV |
| Transmission System Type | : | HVAC |
| Line Capacity | : | TBC |
| Commercial Operating Date | : | 2028 |
| Line Length | : | 61 - 74 km |
| Line Type | : | Twin Yew (2 x 600 MVA) and Twin Drake (2 x 600 MVA) |

Source: ASEAN Power Grid Interconnections Project Profiles on 16 page

Sumatra and Batam to Singapore




**PROJECT OVERVIEW**

Plans to connect the Sumatera Island and Singapore has been long planned under the first AIMS, in which the SIJORI (Singapore-Johor-Riau) initiative was mentioned. However, as of 2023, there is no existing interconnection between Sumatera and Singapore.

As of September 2024, Singapore's Energy Market Authority has granted approvals to seven projects seeking to import a total of 3.4 GW of low-carbon electricity from Riau Archipelago and the Riau Province.

The interconnection between Singapore and Sumatera will be connected from a 250 kV substation in Paranap, Sumatera, Indonesia. The line will have an installed capacity of up to 1,600 MW by 2030 using a subsea HVDC transmission cable, with a length of 100km. The interconnection capacity is sufficient to support the ASEAN region in achieving the RE share target by 2025 according to AIMS III.

**TECHNICAL SPECIFICATIONS**

| | | |
|---|---|---|
| Connecting substations | : | Paranap (ID) – Singapore |
| Interconnection Arrangement | : | Power Purchase from Indonesia to Singapore |
| Length of transmission line | : | 260 km (~100 km subsea) |
| Transmission technology | : | HVDC Overhead Transmission Line and Subsea Cable |
| Voltage level | : | 250 kV |

Source: ASEAN Power Grid Interconnections Project Profiles on 40 page

The length of Sumatra-Singapore line was given as 260m, but there is no overhead lines in above figure. Therefore, the length of Sumatra-Singapore line is assumed to be 100m. There is no detailed information about the facilities of Batam-Singapore line, so it is assumed same as these of Sumatra-Singapore line. The line length is measured by using Google Map.

### 4.2.1 Calculation Method

The purpose of financial analysis is to obtain some indicators for considering high development priorities. Therefore, it is not intended to strictly evaluate the feasibility. In addition, the Internal Rate of Return (IRR) is calculated based on available information without on-site surveys. Therefore, the required costs for the project are not calculated by using the buildup. The unit investment cost obtained from the Internet is used in calculating IRR. A simple cash flow statement was prepared with only capital expenditure (Capex), operating expenditure (Opex), and income. Transmission and distribution charges to achieve the Financial Internal Rate of Return (FIRR) of 6% are calculated based on revenues and costs because there is no concept of transmission and distribution charges in ASEAN countries. Therefore, it is difficult to set transmission and distribution charges based on certain assumptions.

4.2.2 Assumptions

1) Income for FIRR

The amount of power trade was determined to be 40% of the line capacity considering transient stability, voltage stability, frequency abnormalities, and so on.

The transmission and distribution charges obtained from grid interconnection (annual trade volume kWh/year x transmission and distribution charges US$/kWh) is the income of FIRR.

2) Construction Costs

The construction costs were assumed based on a report from the European Union Agency for the Cooperation of Energy Regulators (ACER) as shown in Table 4.2.2.

**Table 4.2.2 Assumptions of Construction Costs**

| Facility | Unit | Unit cost |
|---|---|---|
| Overhead line (250-300kV x 2) | 1,000 US$/km | 607.2 |
| Submarine line (250-300kV x 2) | 1,000 US$/km | 2,437.6 |
| HVDC converter | 1,000 US$/MW | 165.0 |

Source: www.acer.europa.eu/sites/default/files/documents/Publications_annex/ACER_UIC_indicators_table.pdf（reference date: 2025-03-11）

Details of the sources of Table 4.2.2 are given below.

| Asset category | Subcategory | Average UIC | Median UIC | Q1 | Q3 | N. of assets |
|---|---|---|---|---|---|---|
| Overhead line (million EUR/km) | 110-150 kV 2 circuits | 0,325 | 0,26 | 0,224 | 0,393 | 3 |
| | 220 kV 1 circuit | 0,412 | 0,362 | 0,303 | 0,543 | 7 |
| | 220 kV 2 circuits | 0,53 | 0,503 | 0,442 | 0,673 | 21 |
| | 330 kV 2 circuits | 0,574 | 0,530 | 0,522 | 0,573 | 5 |
| | 380-400 kV 1 circuit | 0,465 | 0,397 | 0,298 | 0,606 | 18 |
| | 380-400 kV 2 circuits | 1,261 | 1,05 | 0,533 | 1,635 | 45 |

(530+574)÷2=552 k EUR/km × US$1.1/EUR=607.2 k US$/km

| | | | | | | |
|---|---|---|---|---|---|---|
| Submarine cable (million EUR/km) | AC | 2,007 | 2,468 | 1,203 | 2,527 | 9 |
| | DC | 1,108 | 1,086 | 0,903 | 1,258 | 6 |

2,216(1,108*2 circuits) k EUR/km × US$1.1/EUR=2,437.6 k US$/km

| | | | | | | |
|---|---|---|---|---|---|---|
| HVDC converters (million EUR/kWh) | | 0,150 | 0,147 | 0,127 | 0,193 | 7 |

150 k EUR/MW × US$1.1/EUR = 165 k US$/MW

3) O&M Cost

Since the transmission line has no rotating parts, the annual O&M costs are assumed to be 1% of the construction cost. This figure (1%) is not significantly different from the figure used by power companies.

4) Project Lifetime

Project lifetime was set at 25 years according to JICA guideline. Although unrealistic, the construction period was set at one year.

5) Target of IRR

Because transmission lines are public infrastructure, they do not require a high rate of return compared to private businesses. For this reason, the target of IRR for the interconnection projects was set at 6%.

4.2.3 Results of Financial Analysis

Generally, financial analysis reveals the following three points: 1) profitability, 2) payback period, and 3) decision-making on project implementation. In addition, sensitivity analysis reveals the parameters that affect the IRR. In this financial analysis, the transmission and distribution charges to achieve an IRR of 6% was calculated. The transmission and distribution charge to achieve an IRR of 6% is cheapest for Sarawak to Brunei, which does not have an AC/DC converter and has a relatively short transmission line, at US$0.0011/kWh, followed by Batam to Singapore, which has an AC/DC converter, a short transmission line, and a large amount of power trade, at US$0.005/kWh. The transmission and distribution charge for Sabah to Palawan with long transmission line and small power trade is high at US$0.0621/kWh. Generally, it is said that transmission and distribution charges are around 30% of electricity tariff. Electricity tariff in ASEAN countries are around US$0.1/kWh, so transmission and distribution charges will be around US$0.03/kWh. Therefore, it is clear that the transmission and distribution charge from Sabah to Palawan is high. Projects with low construction costs and large transmission capacity can recover their investment with low transmission and distribution charges. In this calculation, construction period was assumed one year, but if the construction period is three years, IRR drops to 5.44% and if the construction period is five years, IRR drops to 4.98%. If the project lifetime is extended to 40 years, IRR will be 7.37%. In addition, in this calculation, the amount of annual power trade was kept constant, but if the utilization rate of the interconnection lines increases by 1% each year, IRR will be 8.3%. Tables 4.2.4 to 4.2.7 show FIRR cash flow sheets for the high development priority lines.

**Table 4.2.3 Results of FIRR**

| | Sabah to Palawan | Sarawak to Brunei | Sumatra to Singapore | Batam to Singapore |
|---|---|---|---|---|
| Line capacity (MW) | 196 | 600 | 1,600 | 1,600 |
| Line Length (km) | 230 | 45 | 100 | 30 |
| Annual trade (GWh/year) | 687 | 2,102 | 5,606 | 5,606 |
| Transmission and distribution charge (US$/kWh) | 0.0621 | 0.0011 | 0.0080 | 0.0050 |

**Table 4.2.4 FIRR Cash Flow Sheet (Sabah to Palawan)**

| | 0 | 1 | 2 | 3 | 24 | 25 | |
|---|---|---|---|---|---|---|---|
| Total wheeling charge (1000US$) | | 42,677 | 42,677 | 42,677 | 42,677 | 42,677 | |
| Wheeling charge (US$/kWh) | | 0.0621 | 0.0621 | 0.0621 | 0.0621 | 0.0621 | |
| Capacity (MW) | | 196 | 196 | 196 | 196 | 196 | |
| Utilization rate (%) | | 40 | 40 | 40 | 40 | 40 | |
| Annual trade (GWh/year) | | 687 | 687 | 687 | 687 | 687 | |
| Total Cash In | 0 | 42,677 | 42,677 | 42,677 | 42,677 | 42,677 | |
| Total construction cost (1000US$) | 483,824 | | | | | | |
| Overhead Line length (km) | 60 | | | | | | |
| Overhead unit cost (1000US$/km) | 607 | | | | | | |
| Submarine Line length (km) | 170 | | | | | | |
| Submarine unit cost (1000US$/km) | 2,438 | | | | | | |
| HVDC converters (MW) | 200 | | | | | | |
| Above unit cost (1000US$/MW) | 165 | | | | | | |
| O/M cost (1% of Capex) | | 4,838 | 4,838 | 4,838 | 4,838 | 4,838 | |
| Total Cash Out | 483,824 | 4,838 | 4,838 | 4,838 | 4,838 | 4,838 | IRR |
| Cash Flow | -483,824 | 37,839 | 37,839 | 37,839 | 37,839 | 37,839 | 6.00% |

**Table 4.2.5 FIRR Cash Flow Sheet (Sarawak to Brunei)**

| | 0 | 1 | 2 | 3 | 24 | 25 | |
|---|---|---|---|---|---|---|---|
| Total wheeling charge (1000US$) | | 2,411 | 2,411 | 2,411 | 2,411 | 2,411 | |
| Wheeling charge (US$/kWh) | | 0.0011 | 0.0011 | 0.0011 | 0.0011 | 0.0011 | |
| Capacity (MW) | | 600 | 600 | 600 | 600 | 600 | |
| Utilization rate (%) | | 40 | 40 | 40 | 40 | 40 | |
| Annual trade (GWh/year) | | 2,102 | 2,102 | 2,102 | 2,102 | 2,102 | |
| Total Cash In | 0 | 2,411 | 2,411 | 2,411 | 2,411 | 2,411 | |
| Total construction cost (1000US$) | 27,324 | | | | | | |
| Overhead Line length (km) | 45 | | | | | | |
| Overhead unit cost (1000US$/km) | 607 | | | | | | |
| Submarine Line length (km) | 0 | | | | | | |
| Submarine unit cost (1000US$/km) | 2,438 | | | | | | |
| HVDC converters (MW) | 0 | | | | | | |
| Above unit cost (1000US$/MW) | 467 | | | | | | |
| O/M cost (1% of Capex) | | 273 | 273 | 273 | 273 | 273 | |
| Total Cash Out | 27,324 | 273 | 273 | 273 | 273 | 273 | IRR |
| Cash Flow | -27,324 | 2,138 | 2,138 | 2,138 | 2,138 | 2,138 | 6.00% |

Table 4.2.6 FIRR Cash Flow Sheet (Sumatra to Singapore)

| | 0 | 1 | 2 | 3 | 24 | 25 | |
|---|---|---|---|---|---|---|---|
| Total wheeling charge (1000US$) | | 44,795 | 44,795 | 44,795 | 44,795 | 44,795 | |
| Wheeling charge (US$/kWh) | | 0.0080 | 0.0080 | 0.0080 | 0.0080 | 0.0080 | |
| Capacity (MW) | | 1,600 | 1,600 | 1,600 | 1,600 | 1,600 | |
| Utilization rate (%) | | 40 | 40 | 40 | 40 | 40 | |
| Annual trade (GWh/year) | | 5,606 | 5,606 | 5,606 | 5,606 | 5,606 | |
| Total Cash In | 0 | 44,795 | 44,795 | 44,795 | 44,795 | 44,795 | |
| Total construction cost (1000US$) | 507,760 | | | | | | |
| Overhead Line length (km) | 0 | | | | | | |
| Overhead unit cost (1000US$/km) | 607 | | | | | | |
| Submarine Line length (km) | 100 | | | | | | |
| Submarine unit cost (1000US$/km) | 2,438 | | | | | | |
| HVDC converters (MW) | 1,600 | | | | | | |
| Above unit cost (1000US$/MW) | 165 | | | | | | |
| O/M cost (1% of Capex) | | 5,078 | 5,078 | 5,078 | 5,078 | 5,078 | |
| Total Cash Out | 507,760 | 5,078 | 5,078 | 5,078 | 5,078 | 5,078 | IRR |
| Cash Flow | -507,760 | 39,718 | 39,718 | 39,718 | 39,718 | 39,718 | 6.00% |

Table 4.2.7 FIRR Cash Flow Sheet (Batam to Singapore)

| | 0 | 1 | 2 | 3 | 24 | 25 | |
|---|---|---|---|---|---|---|---|
| Total wheeling charge (1000US$) | | 28,136 | 28,136 | 28,136 | 28,136 | 28,136 | |
| Wheeling charge (US$/kWh) | | 0.0050 | 0.0050 | 0.0050 | 0.0050 | 0.0050 | |
| Capacity (MW) | | 1,600 | 1,600 | 1,600 | 1,600 | 1,600 | |
| Utilization rate (%) | | 40 | 40 | 40 | 40 | 40 | |
| Annual trade (GWh/year) | | 5,606 | 5,606 | 5,606 | 5,606 | 5,606 | |
| Total Cash In | 0 | 28,136 | 28,136 | 28,136 | 28,136 | 28,136 | |
| Total construction cost (1000US$) | 318,824 | | | | | | |
| Overhead Line length (km) | 10 | | | | | | |
| Overhead unit cost (1000US$/km) | 607 | | | | | | |
| Submarine Line length (km) | 20 | | | | | | |
| Submarine unit cost (1000US$/km) | 2,438 | | | | | | |
| HVDC converters (MW) | 1,600 | | | | | | |
| Above unit cost (1000US$/MW) | 165 | | | | | | |
| O/M cost (1% of Capex) | | 3,188 | 3,188 | 3,188 | 3,188 | 3,188 | |
| Total Cash Out | 318,824 | 3,188 | 3,188 | 3,188 | 3,188 | 3,188 | IRR |
| Cash Flow | -318,824 | 24,948 | 24,948 | 24,948 | 24,948 | 24,948 | 6.00% |

The transmission and distribution charges shown in Tables 4.2.4 to 4.2.7 are only tariff for the international interconnection dividing the cost of the international interconnection by the amount of electricity transmitted over 25 years. However, the actual transmission and distribution charge covers the cost of the entire grid such as transmission line, distribution line, substation, maintenance cost, etc., so it should be calculated based on total electricity demand of the entire grid. The incremental cost of the high development priority lines calculated based on total electricity demand of the target countries/regions is as shown in Table 4.2.8. All incremental costs except Sabah to Palawan interconnection are very small and will have little impact on transmission and distribution charge (US$0.03/kWh) mentioned before. However, the incremental cost of the Sabah - Palawan interconnection is very large because electricity demand in Palawan is very small compared with line capacity. This project is not feasible at present.

**Table 4.2.8 Incremental Costs of Priority Projects**

| | Sabah to Palawan | Sarawak to Brunei | Sumatra to Singapore | Batam to Singapore |
|---|---|---|---|---|
| Power demand (GWh/year) | 314 | 4,547 | 54,872 | 54,872 |
| Incremental Cost (US$/kWh) | 0.1359 | 0.0005 | 0.0008 | 0.0005 |

4.3 Considerations and Recommendations for Financial Assistance

4.3.1 Relationship between Projects and Financial Assistance by Development Partners (DPs)

This study has identified that, among the 18 projects proposed in AIMS III, the routes with the high development priority for DPs including JICA are "Sarawak (Malaysia) - Brunei," "Singapore - Indonesia (Singapore – Sumatra; Singapore - Batam)," and "Philippines - Sabah (Malaysia)." Based on these results, and considering the possibility that DPs such as JICA may explore financial assistance, this study summarizes the considerations and recommendations for the formation of financial assistance projects. However, the summarized results are preliminary and do not necessarily lead to the formation of financial assistance projects by DPs based on this study.

4.3.2 Considerations and Recommendations for Formation of Projects with Financial Assistance

The considerations for the formation of projects with financial cooperation are usually clarified through detailed feasibility studies. In this study, for the three high development priority routes, we will extract considerations and provide recommendations based on the findings from desktop research and interviews with ACE, etc.

(1) Sarawak (Malaysia) - Brunei

The considerations and recommendations for the Sarawak (Malaysia) - Brunei route are as follows:

**Table 4.3.1 Considerations and Recommendations for the Sarawak (Malaysia) - Brunei Route**

| Considerations | Recommendations |
|---|---|
| A feasibility study (F/S) is currently being conducted for the Sarawak (Malaysia) - Brunei route.[27] | The feasibility study (F/S) is assumed to be funded by utilities (such as Sarawak Energy) and/or the Brunei government, and the financier has not yet been determined.[28] Generally, for cross-border projects, utilities first conduct the F/S, the government makes a decision, and then ACE evaluates whether the route qualifies as an APG |

[27] https://aseanenergy.org/wp-content/uploads/2024/11/ASEAN-Power-Grid-Interconnections-Project-Profiles.pdf

[28] from the interview with ACE in February 2025.

| | |
|---|---|
| | project. If it qualifies as an APG project, ACE also assists with various adjustments.[29] Therefore, if DPs seriously considers providing financial assistance for this route, it is recommended to consult with ACE and coordinate with the target country governments and utilities while receiving advice from ACE. |
| In February 2025, a meeting was held between the Deputy Ministers of Energy regarding the Sarawak (Malaysia) - Brunei route, and it was confirmed that this route would be promoted.[26,27] | Political leadership is being exercised for this route, so the ACE executives expect that DPs will expedite its approach to providing financial assistance to the governments of both countries and ACE. |
| It seems that the COD for the Sarawak (Malaysia) - Brunei route has been postponed from 2021[28] to 2028[29]. What were the reasons behind this delay? , | The postponement of the COD for international interconnection lines is not limited to the Sarawak (Malaysia) - Brunei route; delays have occurred on many routes. Many countries often experience project delays as they consider the benefits and cost burdens.[30] Therefore, the role of ACE in mediating and ensuring project progress with the mandate of the respective governments becomes crucial. For DPs, utilizing ACE holds significant value. |

(2) Singapore-Indonesia (Singapore-Sumatra; Singapore-Batam)

The following are the considerations and recommendations for the Singapore-Indonesia (Singapore-Sumatra, Singapore-Batam) route:

[29] from the interview with ACE in February 2025.
[26] https://www.sarawaktribune.com/brunei-reaffirms-commitment-to-clean-energy-with-sarawak/
[27] from the interview with ACE in February 2025.
[28] https://www.unescap.org/sites/default/d8files/event-documents/Status%20of%20South-East%20Asia%20Interconnectivity%20under%20ASEAN%20Power%20Grid_Nadhilah%20Shani%2C%20ASEAN%20Centre%20for%20Energy.pdf
[29] https://aseanenergy.org/wp-content/uploads/2024/11/ASEAN-Power-Grid-Interconnections-Project-Profiles.pdf
[30] from the interview with ACE in February 2025.

**Table 4.3.2 Considerations and Recommendations for the Singapore – Indonesia (Singapore-Sumatra; Singapore-Batam) Route**

| Considerations | Recommendations |
|---|---|
| Although the Singapore-Sumatra route and the Singapore-Batam route are considered a single route in the AIMSIII model, should they be regarded as two separate routes in reality? | Since Batam Island is a power generation site, the Singapore-Batam route is not exactly a grid-to-grid connection but rather a grid-to-power generation site (power line). This offers significant benefits to Singapore, which has a high demand for renewable energy imports, and also provides a high certainty of power sales for IPPs developing power sources on Batam Island. These factors make the project attractive and feasible. On the other hand, the main focus of the APG is on grid-to-grid connections. In addition, power lines tend to benefit specific projects, and their contribution to the overall economic development of developing countries will be limited. From these perspectives, the Singapore-Sumatra route may be prioritized in reality. |
| It may be difficult or time-consuming to secure land for renewable energy on Batam Island. | In February 2025, a floating solar panel system manufacturing plant began operations to supply solar power from Batam Island to Singapore.[31] One of the reasons for the adoption of floating solar PV in Indonesia, despite delays in large-scale solar PV projects, is the high cost of securing land for renewable energy and the need to avoid issues related to relocating local residents. These land issues in Indonesia contribute to the preference for floating solar PV solutions.[32] When constructing the Singapore-Batam route, it will be necessary to address the land issues on Batam Island as a renewable power generation site. |

[31] https://www.straitstimes.com/asia/se-asia/indonesias-plan-to-export-solar-power-to-spore-spurs-investment-amid-low-green-energy-adoption
[32] from the interview with a JICA long-term expert at Jakarta in February 2025.

| | |
|---|---|
| Are there any considerations to keep in mind when starting the feasibility study (F/S)? | Generally, for cross-border projects, the utility first conducts the feasibility study (F/S), followed by the government's decision-making. Subsequently, ACE evaluates whether the route qualifies as an APG project. If it qualifies, ACE also assists with various coordination efforts on the route.[29] Therefore, if DPs are to seriously consider financial assistance for this route, it is recommended to consult with ACE and coordinate with the target country's government and utilities while receiving advice from ACE. |
| How difficult is it to lay a subsea cable for the Singapore-Sumatra route? | Although the subsea cable for the Singapore-Sumatra route is planned to be less than 100 km in length,[37] the difficulty level will remain unclear even for ACE until a detailed feasibility study (F/S) is conducted. Additionally, there is a movement to create guidelines at the ASEAN level for subsea cables (power, communication, etc.).[38] It is necessary to consider how much these guidelines will contribute to the smooth installation process and, conversely, how much they will impact installation costs. |

(3) Philippines-Sabah (Malaysia)

The following are the considerations and recommendations for the Philippines-Sabah (Malaysia) route:

**Table 4.3.3 Considerations and Recommendations for the Philippines – Sabah (Malaysia) Route**

| Considerations | Recommendations |
|---|---|
| There are discussions in the Philippines regarding energy security, as 40% of the shares of the National Grid Corporation of the Philippines (NGCP) are owned by China's State Grid Corp.[33] | During the process of electricity market reform, which was initiated due to the excessive debt problem of the former state-owned power company in the Philippines, Chinese capital entered |

[37] https://aseanenergy.org/wp-content/uploads/2024/11/ASEAN-Power-Grid-Interconnections-Project-Profiles.pdf
[38] https://asean.org/wp-content/uploads/2025/01/15-ENDORSED-JOINT-MEDIA-STATEMENT-5th-ADGSOM-v2-Cleaned.pdf
[33] https://tribune.net.ph/2025/01/15/ngcp-ensures-integrity-despite-chinese-stake

| | |
|---|---|
| | NGCP. However, there are some voices of opposition within Philippine public opinion. Therefore, when constructing international interconnection lines, including NGCP, it is necessary to pay close attention to public opinion in both the Philippines and Malaysia. |
| The grid frequency in the Philippines is 60Hz, which is different from other countries. | To build new transmission infrastructure between the Philippines and Malaysia, it is first necessary to enhance interconnectivity at the bilateral level. However, the Philippines has a grid frequency of 60Hz, which is different from Malaysia and other AMS, making the connection a potentially complex challenge.[34] Therefore, it is necessary to overcome this technical challenge for the Philippines-Sabah route. |
| Are there any considerations to keep in mind when starting the feasibility study (F/S)? | Generally, for cross-border projects, the utility first conducts the feasibility study (F/S), followed by the government's decision-making. Subsequently, ACE evaluates whether the route qualifies as an APG project. If it qualifies, ACE also assists with various coordination efforts on the route.[29] Therefore, if DPs are to seriously consider financial assistance for this route, it is recommended to consult with ACE and coordinate with the target country's government and utilities while receiving advice from ACE. |
| How difficult is it to lay a subsea cable for the Philippines-Sabah route? | Although the subsea cable for the Philippines-Sabah route is planned to be over 200 km in length,[35] the difficulty level will remain unclear even for ACE until a detailed feasibility study (F/S) is conducted. Additionally, there is a movement to create guidelines at the ASEAN level for subsea cables |

[34] https://aseanenergy.org/post/how-brunei-indonesia-malaysia-philippines-bimp-initiative-could-leap-frog-the-development-learning-from-the-existing-laos-thailand-malaysia-singapore-power-interconnection-project-ltms-pip/
[35] https://aseanenergy.org/wp-content/uploads/2024/11/ASEAN-Power-Grid-Interconnections-Project-Profiles.pdf

| | |
|---|---|
| | (power, communication, etc.).[38] It is necessary to consider how much these guidelines will contribute to the smooth installation process and, conversely, how much they will impact installation costs. |

4.3.3 Summary

It has been identified that there are multiple considerations when advancing financial assistance for any of the three high development priority routes. If JICA and other DPs proceed to the financing, it is necessary to address the risks arising from above considerations and from considerations that may emerge during future detailed feasibility studies (F/S). On the other hand, some routes already show political commitment; therefore, it is crucial to proceed with a sense of urgency in cooperation with AMS governments, utilities, and ACE.

4.4 Proposal and Notes for Technical Cooperation Programme

4.4.1 Role and Organization ACE

(1) Role

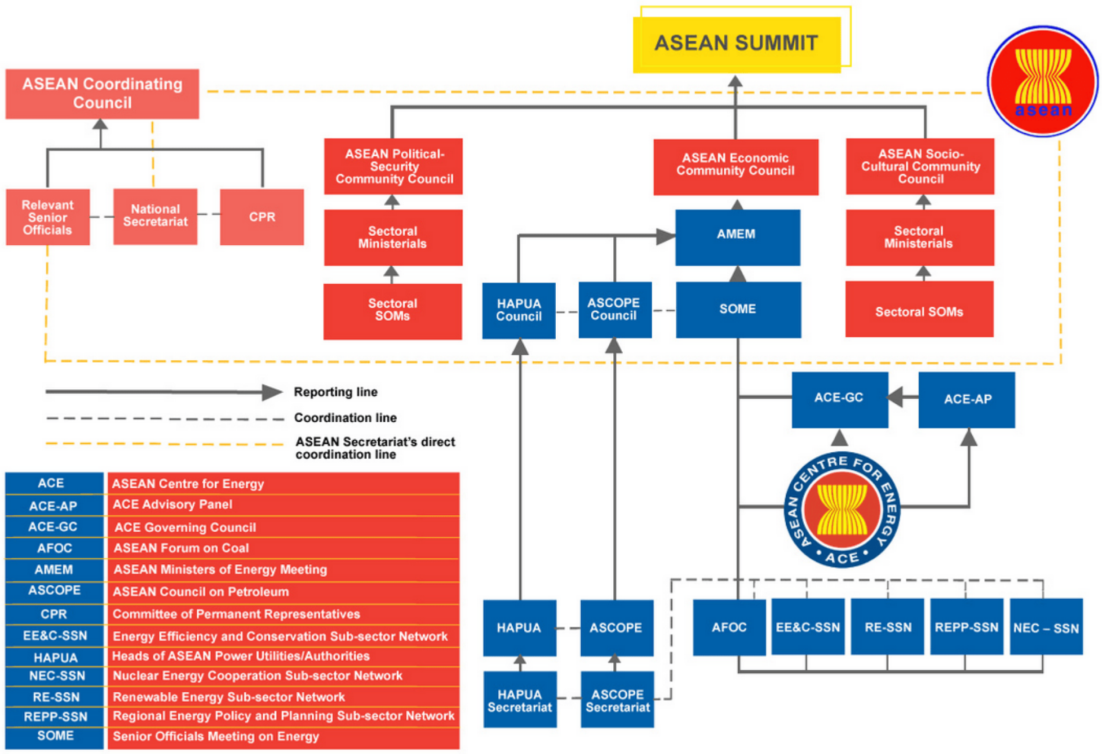
The ASEAN Center for Energy (ACE) is an organization founded in 1999 based on a May 1998 agreement among the ASEAN member states (AMS). It was decided to station in Jakarta in 2003. ACE's vision is to be a catalyst for the economic growth and integration of the ASEAN region by initiating and facilitating multilateral collaborations and collective activities on energy. Its mission is to accelerate the integration of energy strategies within ASEAN by providing relevant information and expertise to ensure the necessary energy policies and programmes are in harmony with the region's economic growth and environmental sustainability. In light of this vision and mission, ACE has three major roles. Originally, the Catalyst function was strong in supporting the management of ASEAN meetings and other activities, but since 2019, when the former director took over, the Knowledge-hub and Think Tank roles have been strengthened.

**Table 4.4.1 Functions of ACE**

| | |
|---|---|
| Catalyst | To unify and strengthen ASEAN Energy Cooperation by providing a platform for sharing, policy advisory, best practices, and capacity building. |
| Knowledge Hub | To provide a knowledge repository for ASEAN Member States (AMS) and services through data management, publication and dissemination. |
| Think tank | To assist AMS on research and identifying practical & specific solution on policies, legal & regulatory frameworks, technologies, and innovative solutions. |

Source: ACE, accessed on 12 March 2025

ACE is placed under the ASEAN Summit and plays a central role in the regional energy sector. It works closely with the energy authorities of member countries as well as the Sub-Sector Network on Energy (SSN) and others.




Source: ACE, accessed on 12 March 2025

**Figure 4.4.1 Structure of Institutions in ASEAN**

(2) Organization

The 7th Executive Director is Mr. Abdul Razib Dawood who took his office in February 2025. ACE has six Departments, excluding the Corporate Affairs Department.

- ASEAN Plan of Action for Energy Cooperation (APAEC) Department
- Energy Modelling and Policy Planning (MPP) Department
- Energy Efficiency and Conservation (CEE) Department
- Sustainable and Renewable Energy (SRE) Department
- Power Generation and Interconnection (PIN) Department
- Fossil, Hydrocarbon, and Mineral (FOM) Department

Department's respective role and number of staff are as follows. In addition to ACE's own energy statistics compilation program and research and analysis, ACE provides secretariat services for ASEAN energy-related meetings, consultation and educational programs for AMS.

**Table 4.4.2 Role and Number of Persons of Research Departments in ACE**

| Department | Role | Number of persons |
|---|---|---|
| ASEAN Plan of Action for Energy Cooperation (APAEC) | ● Review of APAEC progress, analysis for execution, and discussion of future revisions. | 5 |
| Energy Modelling and Policy Planning (MPP) | ● Energy system modelling and analysis.<br>● Energy policy analysis. | 10 |
| Energy Efficiency and Conservation (CEE) | ● Analysis of energy efficiency and conservation. | 9 |
| Sustainable and Renewable Energy (SRE) | ● Analysis of decarbonized energy with a focus on renewable energy. | 4 |
| Power Generation and Interconnection (PIN) | ● Analysis of Electric including ASEAN Power Grid. | 14 |
| Fossil, Hydrocarbon, and Mineral (FOM) | ● Analysis of fossil fuel and mineral resources. | 9 |

Source: ACE, accessed on 12 March 2025

(3) Human resources

Of the 37 research staff members, a total of 3 hold doctoral degrees and 20 hold master's degrees. More than half of the research staff holds degrees from outside the ASEAN region, primarily from Europe. The share of staff with higher education is much higher than usual.

**Table 4.4.3 Education Level of Research Staffs**

| | APAEC | MPP | CEE | SRE | PIN | FOM | Total |
|---|---|---|---|---|---|---|---|
| Doctor's degree | | 2 | | 1 | | | 3 |
| *of which; Earn a degreen outside of ASEAN* | | *2* | | *1* | | | *3* |
| Master's degree | 3 | 5 | 5 | 1 | 4 | 2 | 20 |
| *of which; Earn a degreen outside of ASEAN* | *2* | *4* | *5* | *1* | *3* | *2* | *17* |
| Bachelor's degree | 1 | 3 | 3 | 2 | 2 | 3 | 14 |
| *of which; Earn a degreen outside of ASEAN* | | | | | | | *0* |
| Total | 4 | 10 | 8 | 4 | 6 | 4 | 37 |

Note 1: Figure in the table represents the number of person.

Note 2: The Executive Director, Corporate Affairs (CA) Department, and Executive Director (ED) Office are not included.

Source: ACE, accessed on 29 May 2025

The areas of expertise of the research staff are summerrized as follows. Note that this is a count of the areas of expertise listed by each researcher, based on the researcher introduction page on the ACE website. It does not represent a strict classification, as the number and definition of expertise listed vary from researcher to researcher. Fossil fuel supply about 80% of ASEAN's primary energy needs (IEA, 2024). In comparison, by fuel, the rate of researchers with expertise in renewable energy is high, while the rate of researchers with expertise in fossil fuels is low. In addition, the number of researchers with expertise in nuclear power and hydrogen is low that are expected to play a role in decarbonizing energy system in the future.

In terms of final consumption, while there are a reasonable number of researchers specializing in energy efficiency and conservation (EE&C), the human resources may be weak in terms of expertise in individual sectors such as industry and transportation.

In terms of thematic areas, while there is an abundance of personnel specializing in energy policy, modeling and data analysis, there is a limited number of specialists in geopolitics and security. In addition, there may be a limited number of experts in technology, which will become increasingly important in the future.

**Table 4.4.4 Expertise of Research Staffs**

| | | APAEC | MPP | CEE | SRE | PFS | PFS | Total |
|---|---|---|---|---|---|---|---|---|
| By fuel | | | | | | | | |
| | Fossil fuel | | | 1 | | 1 | 4 | 6 |
| | Renewbles | 1 | | 4 | 2 | 2 | 1 | 10 |
| | Nuclear | | | | | | | 0 |
| | Electric power | | | 1 | 1 | 3 | | 5 |
| | Hydrogen | | | 1 | | | | 1 |
| | CCUS | | 1 | | | | 1 | 2 |
| By end use sector | | | | | | | | |
| | Energy efficiency and conservation | | | 6 | | | | 6 |
| | Industry | | | | | | | 0 |
| | Transport | | | | | | | 0 |
| | Buildings | | | 1 | | | | 1 |
| By issue | | | | | | | | |
| | Energy system | 1 | 3 | | | | | 4 |
| | Energy, climate policy | 1 | 7 | 2 | 2 | 4 | 3 | 19 |
| | Geopolitics, energy security | | 1 | | 1 | | | 2 |
| | Climate, environment | 1 | 4 | | | | 2 | 7 |
| | Modelling, data analysis | 1 | 8 | | 1 | 1 | | 11 |
| | Project development, management | 1 | 1 | 3 | 1 | 2 | | 8 |
| | Technology | | | 1 | | 1 | | 2 |
| | Others | 1 | | 1 | | 1 | 1 | 4 |

Note 1: Figure in the table represents number of persons.

Note 2: The Executive Director, Corporate Affairs (CA) Department, and Executive Director (ED) Office are not included.

Source: ACE, accessed on 29 May 2025

(4) Other principles of activity [36]

ACE is financed by contributions from ASEAN member states (AMS), which form the basis of its activities, and from other organizations, including international development partners, for the purpose of individual programs. When JICA provides the Technical Assistance, it is regarded as the latter.

ACE's programs are either requested by AMS or international development partners, or are independently designed by ACE. In both cases, in principle, the approval of the ASEAN member countries is required. When JICA provides the Technical Assistance, it is regarded as the latter. (detail in the section 3.1)

The employment status of staff can be either regular employment or employment tied to the project. There is no system that allows staff to leave ACE for a long period of time, such as to study abroad, while still employed by ACE. In such cases, the employee must leave ACE, and there is no guarantee that the employee will be reinstated at ACE after completion of the training.

4.4.2 Technical Cooperation received from other Development Partners

The World Bank (WB), Asian Development Bank (ADB), U.S. Trade and Development Agency (USTDA), U.S. Agency for International Development (USAID), CASE, French Development Agency (AFD), and the Economic Research Institute for ASEAN and East Asia (ERIA) are providing technical assistance.

There are two main categories of the Technical Assistance: those aimed at establishing regional electricity markets and those aimed at infrastructure development. The former includes the establishment of wholesale electricity markets, intergovernmental arrangements necessary for multilateral electricity trading, standardization of grid codes and data transfer, and simulated trading exercises. The latter includes workshops on improving electricity quality and integrating distributed energy resources, such loke renewable energy, to power grid.

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[36] From the interview to ACE

**Table 4.4.5 List of Development Partners' Participation in Various Areas under APG**

| No | Outcome Based Strategy | CASE / ESCAP | USAID | USTDA | ERIA | GLOBAL PST CONSORTIUM | ADB | WORLD BANK GROUP |
|---|---|---|---|---|---|---|---|---|
| 1 | Accelerate the completion of APG projects and initiate the expansion of multilateral electricity trading | Roadmap on ASEAN MPT *(AP 1.2 – Milestones 2022)* | Supporting study for IND-MLY FS *(AP 1.1-1.2)* | Feasibility study for INA-MLY interconnection *(AP 1.1-1.2)* | | | | |
| 2 | Work on institutional framework and regulatory capacity as minimum requirements to advance multilateral electricity trading | Roadmap on ASEAN MPT *(AP 2.1-2.4 – Milestones 2021/22)* | | | Study on Intergovernmental Agreement *(AP 2.1-2.2)* | | Shadow Trading/ Regional Power Market Study *(AP 2.2-2.4)* | Regional renewable energy policy and climate financing |
| 3 | Work on harmonising the minimum technical requirements to advance multilateral electricity trading | AIMS III Phase 3 Work *(AP 3.1 – 3.5)*<br>Proposed MPT Pilot *(AP 3.1 – 3.5)* | Data sharing guidelines and framework *(AP 3.4)*<br>WS on Grid code harmonisation *(AP 3.1)*<br>WS on Wheeling Charge *(AP 3.2)* | | | WS on Power Quality Assessment & Technical Report *(AP 3.6)* | Shadow Trading/ Regional Power Market Study *(Supporting AP 3.1 – 3.5)* | |
| 4 | Explore integrating renewable energy and other digital developments into the ASEAN Power Grid | | WS on VRE Grid Integration *(AP 4.2)* | | Study on Hydrogen and Ammonia *(AP 4.2)* | WS on Distributed Energy Resource *(AP 4.2)*<br>WS on Smart Grid Technology *(AP 4.3)* | | Regional renewable energy policy and climate financing |

Infrastructure Development (green) | Market Integration (orange)

MTP = multilateral power trading

Source: ASEAN Centre for Energy, "Existing APG related Project with DPs/IOs (2024 and onwards)"

In addition, some financing facilities are established.

**Table 4.4.6 List of Financing Facilities Applicable for ASEAN Power Grid**

| Development partners | Financing facilities |
|---|---|
| UK International Development | ASEAN-UK Green Transition Fund |
| Global Gateway, European Union | EU-ASEAN Sustainable Connectivity Package (SCOPE)<br>Infrastructure Fund |
| Asian Infrastructure Investment Bank | AIIB blended financing of TA grant and project financing |
| Asian Development Bank | APG Financing Facility |

Source: Compile from the material received from ACE

4.4.3 Proposal and Notes of Technical Cooperation Programme

Based on the survey to ACE, the study propose conduction "Potential of introducing next-generation decarbonization technologies in the AMS" for technical cooperation. Currently available energy efficiency technologies and renewable energy are effective tools for achieving the energy transition. However, it is also becoming clear that carbon neutrality is difficult to achieve with currently available technologies alone. For example, there is a lack of land for the installation of renewable energy, as well as industrial processes and means of transportation that are difficult to convert to electricity. Therefore, it is inevitable that these areas must be addressed in the medium to long term, and for this reason, the introduction of next-generation decarbonization technologies is awaited. This proposed study analyzes and presents the feasibility of introducing such next-generation decarbonization technology, based on the national circumstances of ASEAN countries. It is confirmed that the proposal does not duplicate the technical cooperation menu provided by development partners, so far.

**Table 4.4.7 Outline of Proposed Technical Cooperation**

| | |
|---|---|
| Brief project description | Contribute to the acceleration of ASEAN's energy transition by studying the feasibility of introducing next-generation decarbonization technologies. |
| Current problem | Technology plays a significant role in achieving the energy transition. Various next-generation decarbonization technologies are being developed around the world and are expected to be implemented in ASEAN along with their commercialization. On the other hand, appropriate technologies will vary depending on geographical characteristics and industrial structure. For example, some technologies, such as nuclear power, require a certain level of technological capability (industries, human resources, etc.) and institutional frameworks (safety, nuclear nonproliferation, etc.) as prerequisites for their introduction. Therefore, it is necessary to identify appropriate candidates for next-generation technologies in accordance with national circumstances, and to prepare the groundwork for their introduction step by step. |
| Regionality / Beneficiaries | Contributed to raising the level of policies and institutions in ASEAN member countries. |
| Activities 【Project duration】 | 1. Summarize next-generation decarbonization technologies (characteristics, development companies, development stage, introduction preconditions) (literature review + company interviews) [6 months].<br>2. Study of applicability for ASEAN countries [3 months] (literature review + interviews)<br>3. Confirmation of needs and willingness to introduce the technologies in ASEAN countries [3 months]<br>4. Analyze the feasibility of introducing the technology to ASEAN countries (selection of highly compatible technology, ways to improve investment environment) [3 months] |
| Project management | ACE： Co-conductor of the study<br>Consultant: Energy technology, energy industry |

| | |
|---|---|
| Potential risks | ASEAN member countries' understanding of next-generation technologies is not sufficient, and the study end up with insufficient understanding of their needs |

4.5 Summary and Recommendations for Promoting APG

The ASEAN Power Grid (APG) has made significant progress in promoting regional cooperation and cross-border electricity trade. The APG network is divided into three main regions: the northern region connecting the Mekong countries (Laos, Cambodia, Vietnam, Thailand, and Myanmar), the southern region connecting Indonesia, Malaysia, and Singapore, and the eastern region connecting Kalimantan (Borneo), Brunei and Philippines. The majority of the APG projects have been concentrated in the northern and southern regions, with particular progress observed in the northern region[37]. One of the important milestones is the Laos-Thailand-Malaysia-Singapore Power Integration Project (LTMS-PIP), a multilateral electricity trading project. Unlike the previous APG projects that focused on bilateral trade, the LTMS-PIP enables the transmission of electricity from hydropower plants in Laos to Singapore, passing through Thailand and Malaysia, demonstrating the feasibility of multilateral power trade within ASEAN. On the other hand, in the eastern region, the Brunei-Indonesia-Malaysia-Philippines Power Integration Project (BIMP PIP) has been proposed as a multilateral electricity trading project, but no actual cross-border transactions have been carried out yet.

To promote the ASEAN Power Grid (APG) further, it is crucial to adopt an approach tailored to the specific circumstances of ASEAN. According to expert[38], the diverse political, economic, and social conditions of ASEAN countries make it challenging to apply a centralized approach like that applied in Europe. For the APG, a more realistic approach that respects national sovereignty and existing market structures while enhancing interconnectivity is desirable. In this context, the focus should be on harmonizing technical, regulatory, and market mechanisms to facilitate international power trading efficiently, rather than imposing a uniform model to the member countries. Expert suggests that the APG should adopt a layered market approach. The first layer is to maintain the domestic market mechanisms and regulations of each member country, using the APG as a means to promote cross-border power trading without replacing the national systems. Each member country would retain control over its energy policy, pricing mechanisms, and infrastructure. The second layer involves developing standards for bilateral power system interconnections, including regulatory frameworks, pricing mechanisms, and operational mechanisms tailored to the needs of the two countries. These bilateral agreements can then serve as a basis for the third layer, which involves a multilateral framework enabling large-scale power trading across multiple countries. This multilateral layer requires harmonization on fair pricing, transparent market operations, and coordination to ensure the stability of the power systems, while still maintaining the sovereignty of each country's power system. This layered market

37 https://aseanenergy.org/post/how-brunei-indonesia-malaysia-philippines-bimp-initiative-could-leap-frog-the-development-learning-from-the-existing-laos-thailand-malaysia-singapore-power-interconnection-project-ltms-pip/

38 https://www-linkedin-com.translate.goog/pulse/what-asean-can-learn-from-europes-energy-grid-tale-agya-utama-phd-iwmjc?_x_tr_sl=en&_x_tr_tl=ja&_x_tr_hl=ja&_x_tr_pto=wapp

approach allows member countries to flexibly adjust their policies to their specific circumstances, making it a desirable model for the ASEAN Power Grid.

On the other hand, in the APG, there are areas that require supranational management, not just reliance on national sovereignty. First, as cross-border electricity trading expands under schemes like the LTMS-PIP, there is a need for a regional organization to coordinate and oversee the management of the wide-area power interconnections. This does not necessarily imply market integration, but rather the harmonization of technical standards to ensure security of supply, which is compatible with the principle of preserving national sovereignty. Second, the issue of cost-sharing rules is crucial. In the APG, there is currently no unified framework for allocating the costs of building cross-border transmission lines, which may be hindering progress. To address this, options could include establishing ASEAN-wide cost-sharing criteria or providing ASEAN-level budgetary support for high development priority projects. In this way, to advance the APG, it is important to flexibly employ supranational operation while maintaining the sovereignty of each country.

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