Chapter 2

Current Situation of Power System in ACMECS Countries

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Chapter 2

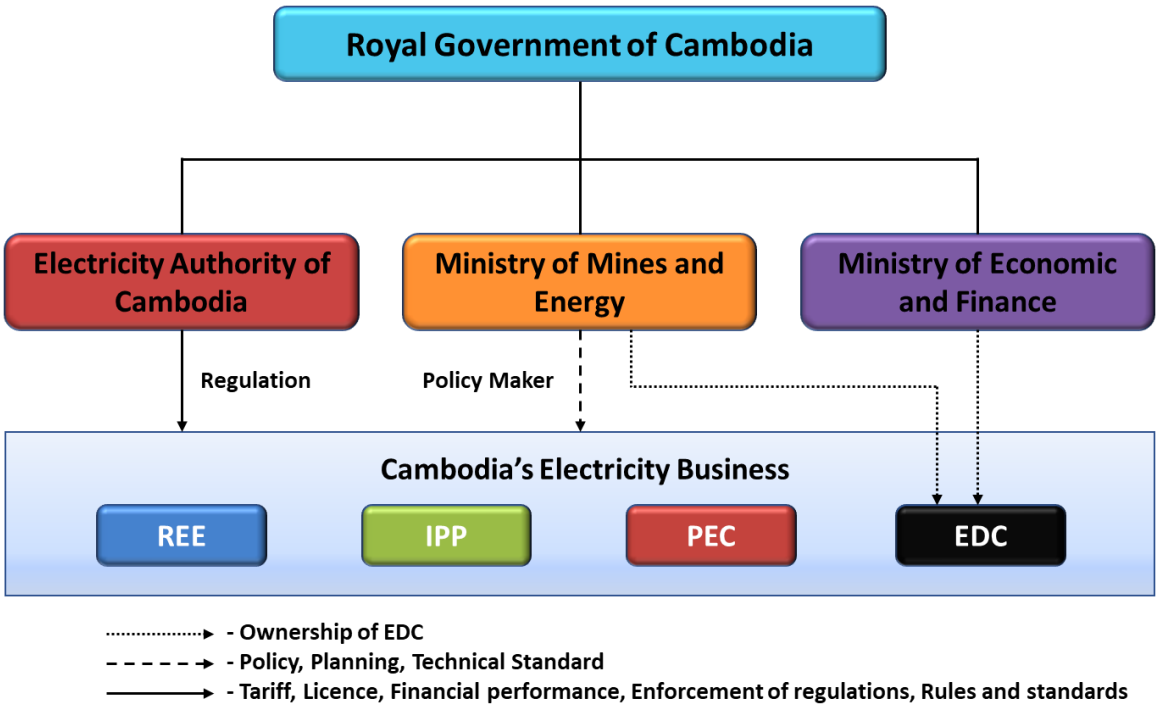
Current Situation of Power System in ACMECS Countries

2.1. Cambodia

2.1.1 Organisation of the Electricity Sector

The Electricity Law of the Kingdom of Cambodia (Electricity Law), issued on 2 February 2001, covers the totality of electricity business from electricity supply services to electricity use. It provides the fundamental concept of electricity business operation, consolidation of requirements for private investment and commercial operation, promotion of electric supply facility operation by the private sector, and rule of principle for a competitive environment. To actualise stable nationwide electricity supply services, the Electricity Law established the Electricity Authority of Cambodia (EAC). The EAC is an independent regulatory agency that executes duties provided in the Electricity Law and authorises the Ministry of Mines and Energy (MME) to manage, create policies, take necessary measures, and create plans for the power sector. Electricite du Cambodge (EDC) is the largest electricity business organisation in Cambodia and is involved in the generation and transmission of bulk electric power as well as electricity supply and distribution. The EDC is jointly owned by the MME and the Ministry of Economy and Finance. Major electricity enterprises, the MME, and the EAC are interrelated (Figure 2-1).

Figure 2-1 Organisational Structure of the Electricity Sector in Cambodia



REE = rural electricity enterprise, IPP = independent power producer, PEC = Provincial Electricity Company, EDC = Electricite du Cambodge
Source: Ministry of Mines and Energy (Cambodia).

1) Ministry of Industry, Mines and Energy

In 2013, the Ministry of Industry, Mines and Energy (MIME) was split into two ministries: the Ministry of Industry and Handicrafts and the MME. The MME shares electricity administration with the EAC, established under the Electricity Law in February 2001. The MME is also responsible for controlling the whole power sector. It sets and administers the energy policies; electric power strategies; power development plan; and technical, safety, and environmental standards.

2) Electricity Authority of Cambodia

The Electricity Authority of Cambodia (EAC) became independent of MIME to ensure effective, high-quality, continuous, and transparent conduct of the electricity business and electricity use per the Electricity Law of February 2001. The EAC is responsible for the regulation and guidance of the electricity business and operates on a stand-alone basis, supported by licensing fees from electricity enterprises. The main functions of the EAC are as follows:

- **Issue and suspend the business licence of electricity enterprises**
- **Approve electricity tariffs**
- **Plan electricity supply regulations**
- **Audit electricity enterprises**
- **Guide electricity enterprises on accounting standardisation**
- **Collect electricity business-related information and produce periodicals**

3) Electricite du Cambodge

The Electricite du Cambodge (EDC) was established in October 1958 as a public corporation when the Royal Government of Cambodia purchased the Compagnie des Eaux et Electricité, which supplied electricity to Phnom Penh, and the Union d' Electricité d' Indochine, which supplied areas other than Battambang. However, since most facilities were destroyed during the civil war, it was reconstructed as Electricité de Phnom Penh in 1979 under the Ministry of Industry to supply electricity to Phnom Penh. In 1992, the name was changed to the EDC and fell under the jurisdiction of the Ministry of Energy. Following the 1993 national election, it became under the jurisdiction of MIME. The ministerial ordinance of March 1996 turned it into a public corporation that generates, transmits, and distributes power throughout Cambodia.

4) Rural electricity enterprise

A rural electricity enterprise (REE) comprises private electricity companies. One group of REEs distributes self-generated electricity, and the other group purchases electricity from the EDC and IPPs and distributes it amongst residents of the area.

2.1.2 Power generation

2.1.2.1 *Oil and natural gas*

Cambodia has promising oil and gas resources. There is an urgent need to assess the extent of these energy resources and start their exploration. Renewable energy sources, such as solar, small hydro, and modern biomass, are available and being used. A large amount of traditional biomass is already being utilised, mainly in rural areas and some urban areas.

The Government of Cambodia has the policy to explore and utilise the country's national resources to enhance the security of energy supply to support the country's economic growth. The government expects to generate electricity from domestic gas by 2025. Table 2-1 shows the assumed production profiles of gas and oil resources in this study.

Table 2-1 Assumption of Natural Gas and Oil Production

Year	Natural Gas Production		Crude Oil Production	
	Million toe	MW/year	Million toe	MW/year
2025	0.5	666	0.5	666
2030	1.0	1,332	1.0	1,332
2035	2.0	2,664	2.0	2,664
2040	2.5	3,330	3.0	3,996

Source: MME data, modified by the author.

2.1.2.2 *Coal*

Cambodia has domestic coal resources, but it is of low quality (2,800 cal/kg–4,500 cal/kg). The country imports coal from Indonesia and Australia for the power and industry sectors. The future expansion plan of the power sector includes imported coal-based power plants. The gross heating value of imported coal is 6,210 cal/kg (net HV: 5,900 cal/kg). The imported coal price from Indonesia is US$85/tonne).

2.1.2.3 *Hydropower*

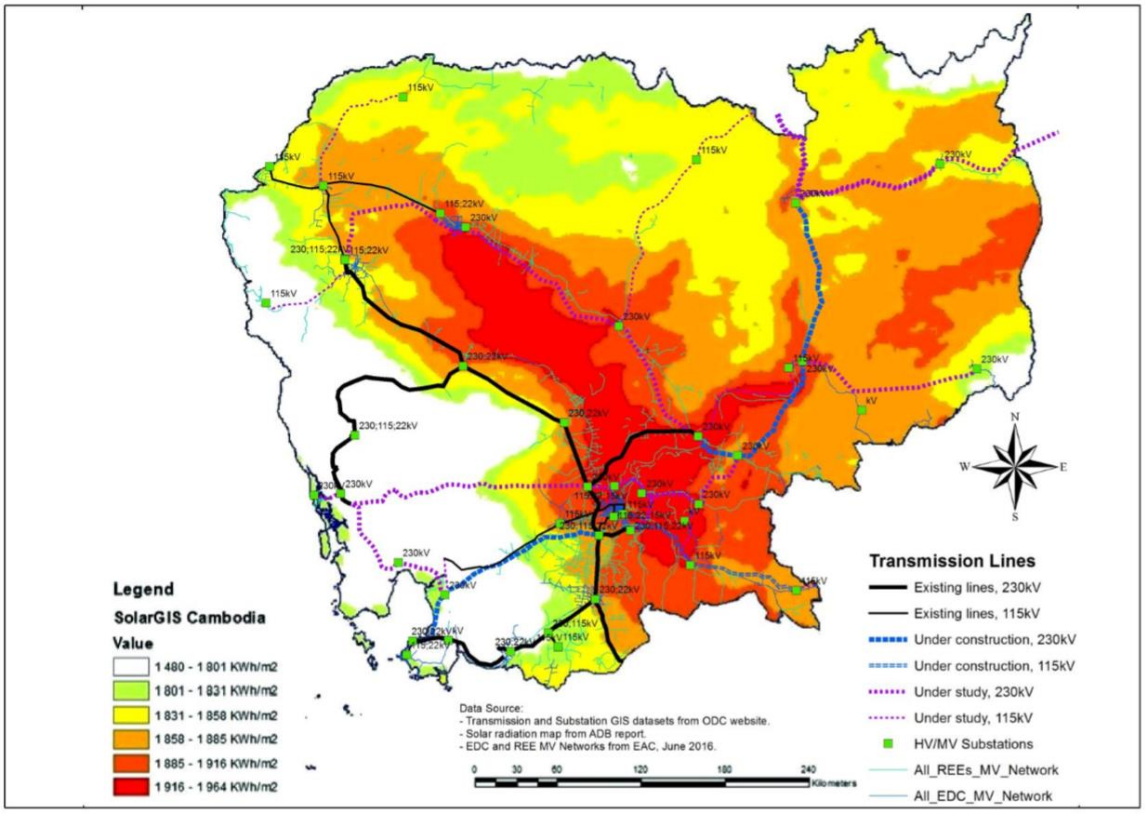
Cambodia has a good potential for hydropower at about 10,000 MW. Various small and medium-sized hydropower projects—Kirirom I, Ochum, Kirirom III, Kamchay, Atay, Lower Russei Chrum, Tatay, Lower Sesan II—are implemented, making about 13% of the potential. With a total installed capacity of around 1,300 MW, these projects would be fully operational by 2019. However, high investments in the construction of hydropower plants and sociopolitical issues hinder large-scale hydropower development. Feasibility and design engineering work on hydro projects is in progress.

The government aims to increase the diversification of power supply, such as hydropower, coal, solar, biomass, and other renewable energy resources. It also intends to limit imported electricity to meet the electricity demand and reduce fuel oil for power generation.

2.1.2.4 *Renewable energy*

Cambodia has excellent solar resources throughout the country. The white area on the map represents the solar radiation, ranging between 1,400–1,800 kWh/m2-year, which is considered very good to excellent. This is equal to or better than the solar resource in southern Europe, the coastal areas of eastern Australia, and the southeast United States (US). The peak solar resource (over 1,900 kWh/m2 per year) around the middle of Cambodia, the solar resource potential, existing, and planned transmission networks, and significant demand centres are well-aligned.

Figure 2-2 Cambodia Solar Radiation Map with Existing and Planned Transmission Network Lines



Source: EDC (2019).

Biomass energy resources are used to meet most of the country's rural population's basic needs (cooking, water heating, etc.). Besides fuelwood, agro-industrial residues such as rice, sugarcane, maize, and cattle excreta are available as fuel. Biomass is also used in the industry sector for copra drying and system generation, and the rice husks in bakeries, brickworks, and other commercial establishments.

2.1.2.5 *Energy imports*

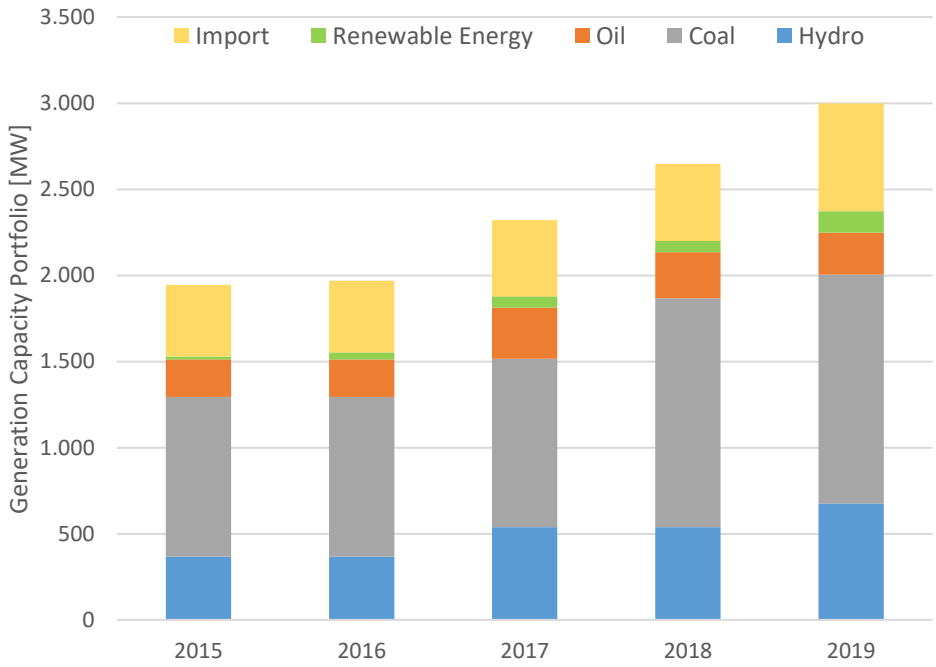
Due to years of civil war and unrest, little exploration and production activities took place; imports entirely met fuel needs. All commercial fuels in Cambodia are imported – from liquefied petroleum gas, gasoline, diesel, and other petroleum products. Cambodia imports electricity from the Lao PDR,

Thailand, and Viet Nam. Due to limited energy resources, oil, natural gas, and electricity are assumed to be imported to meet future energy requirements.

2.1.2.6 *Power generation portfolio*

As of December 2015, the total installed capacity in Cambodia was 1,946 MW. It gradually increased from 2015 and reached 2,999 MW in 2019. The installed capacity growth rate from 2015 to 2019 was 54.1%. Generation relied on coal as the main fuel. The generation capacity of coal accounted for 44.3% in 2019. Next to coal was renewable energy except for hydro, which accounted for 22.5% in 2019. Figure 2-3 shows the generation capacity portfolio in Cambodia.

Figure 2-3 Generation Capacity Portfolio in Cambodia

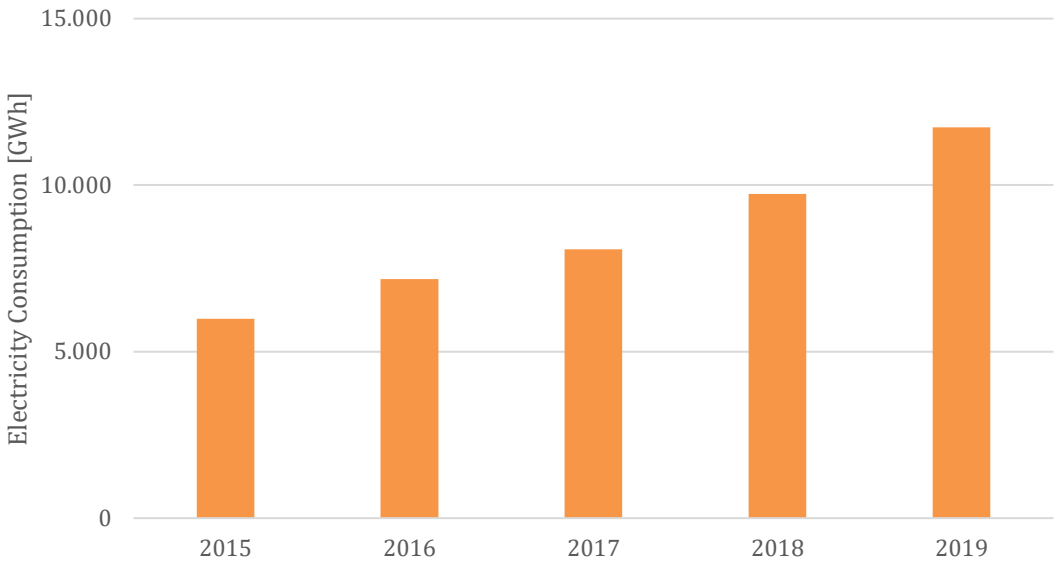


Source: MME data, modified by the author.

2.1.3 Power demand

Figure 2-4 shows the changes in electricity consumption in Cambodia. The electricity consumption in 2015 was 5,990 GWh. However, it skyrocketed from 2015 and reached 11,738 GWh in 2019. Thus, the electricity consumption growth rate from 2015 to 2019 was about 96.0%.

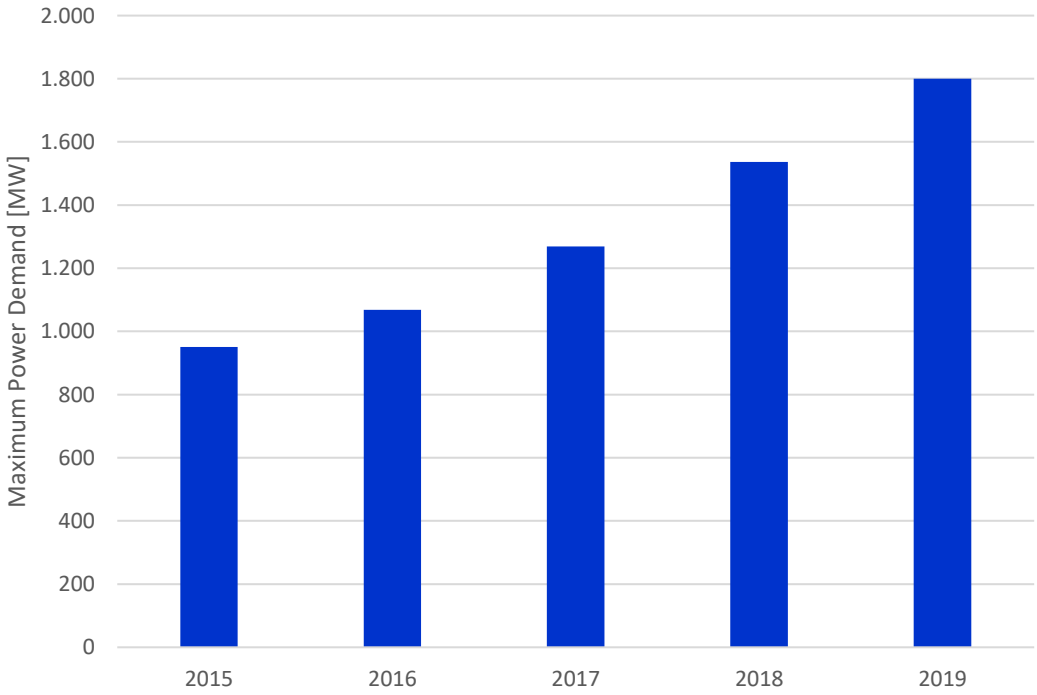
Figure 2-4 Changes in Electricity Consumption in Cambodia



Source: MME data, modified by the author.

The changes in maximum demand is shown in Figure 2-5. Maximum power demand in 2015 was 951 MW. It skyrocketed from 2015 and reached 1,800 MW in 2019. The demand growth rate from 2015 to 2019 was 89.3%.

Figure 2-5 Changes in Maximum Demand in Cambodia



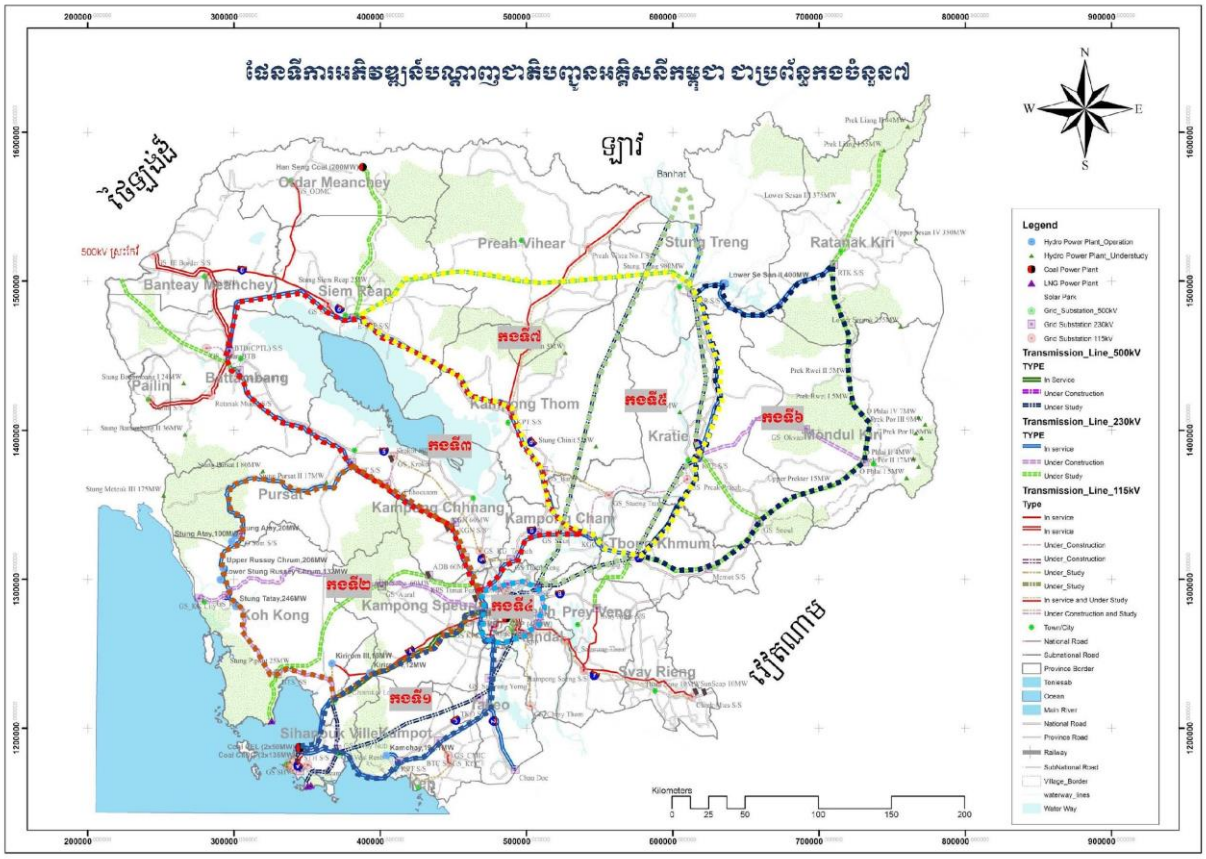
Source: MME data, modified by the author.

2.1.4 Overview of the transmission network

In the Cambodia Transmission System (CTS), electric power demand is overconcentrated in the Phnom Penh metropolitan area; major generators supplying electricity are about 200 or 300 km away from the Phnom Penh demand centre. Surrounded by three neighbouring countries – the Lao PDR, Viet Nam, and Thailand – Cambodia can import electric power from these countries. However, it cannot be connected simultaneously to Thailand's or Viet Nam's power system except with the Lao PDR, which only provides generators. Therefore, if Cambodia would import electric power from both Viet Nam and Thailand, it would be indispensable for the CTS to separate the power system somewhere. The CTS only has 230 kV or less transmission lines for now, but it will be necessary to build a 500 kV transmission line to meet the massive growth of electric demand in the near future.

The power grid map in Cambodia is shown in Figure 2-6.

Figure 2-6 Power Grid Map of Cambodia



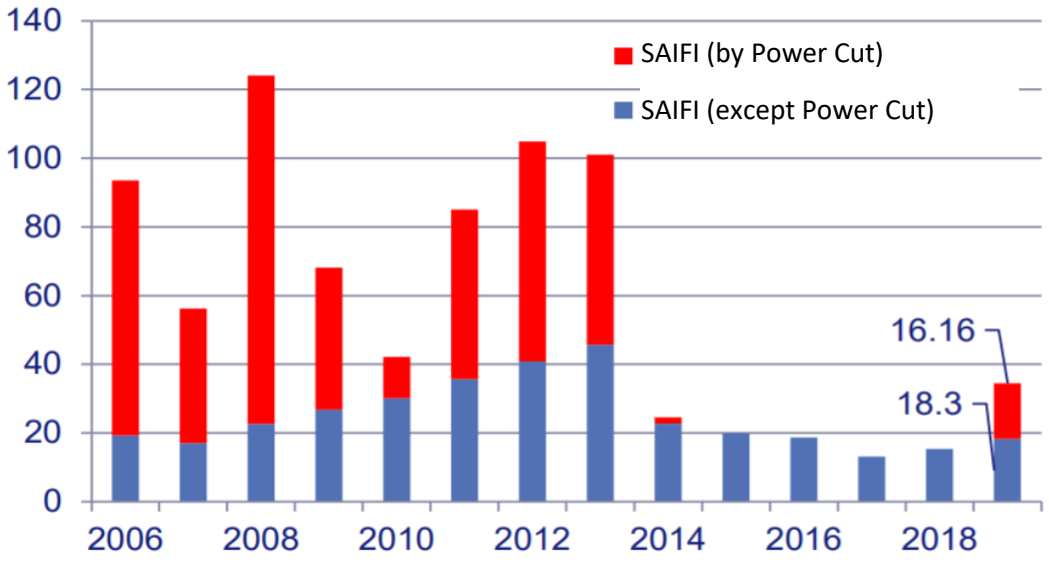
Source: Author via Ministry of Energy and Mines (MEM), Lao PDR.

2.1.5 Power system reliability

The System Average Interruption Duration Index (SAIDI) and the System Average Interruption Frequency Index (SAIFI) are international standards used to monitor the distribution systems' reliability. SAIDI is a system index of the average duration of interruption in the power supply in minutes per customer. SAIFI is a system index of the average frequency of interruption in the power supply. These indices serve as valuable tools for comparing the power system reliability of electrical utilities.

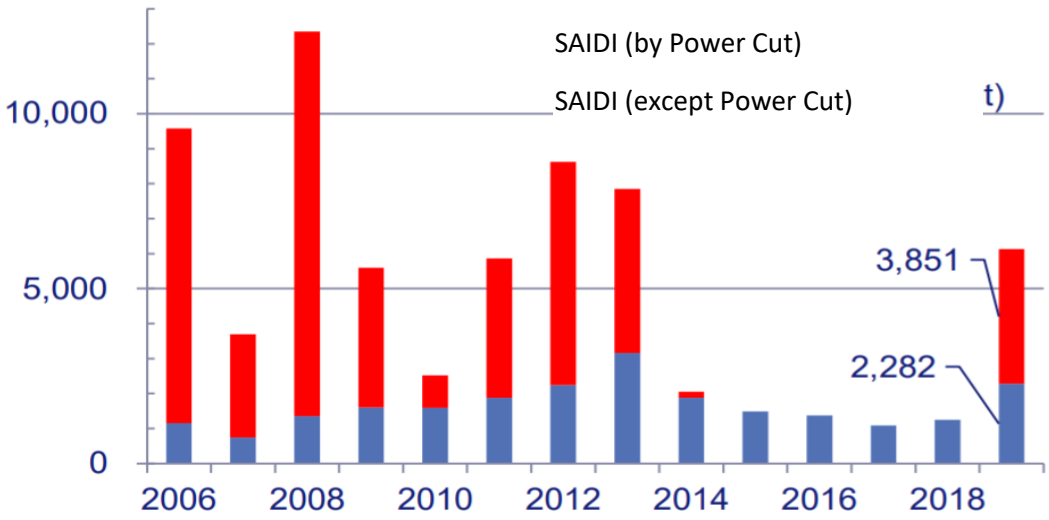
Figures 2-7 and 2-8 show changes in SAIFI and SAIDI in Cambodia, respectively. Before 2014, power outages due to faults and load shedding caused by insufficient supply capacity occurred frequently. Since 2015, the situation has improved, and load shedding has disappeared until 2018. SAIFI in 2015 was about 20 times. It decreased from 2015 to 2018. SAIDI in 2015 was about 1,500 minutes and steadily declined from 2015 to 2018. According to JICA, the power supply became insufficient due to drought, and the load shedding was operated again. Thus, Cambodia's SAIFI and SAIDI are low compared to developing countries (ERIA, 2020).

Figure 2-7 Change in SAIFI in Cambodia



SAIFI = System Average Interruption Frequency Index.
Source: JICA (2020a).

Figure 2-8 Change in SAIDI in Cambodia

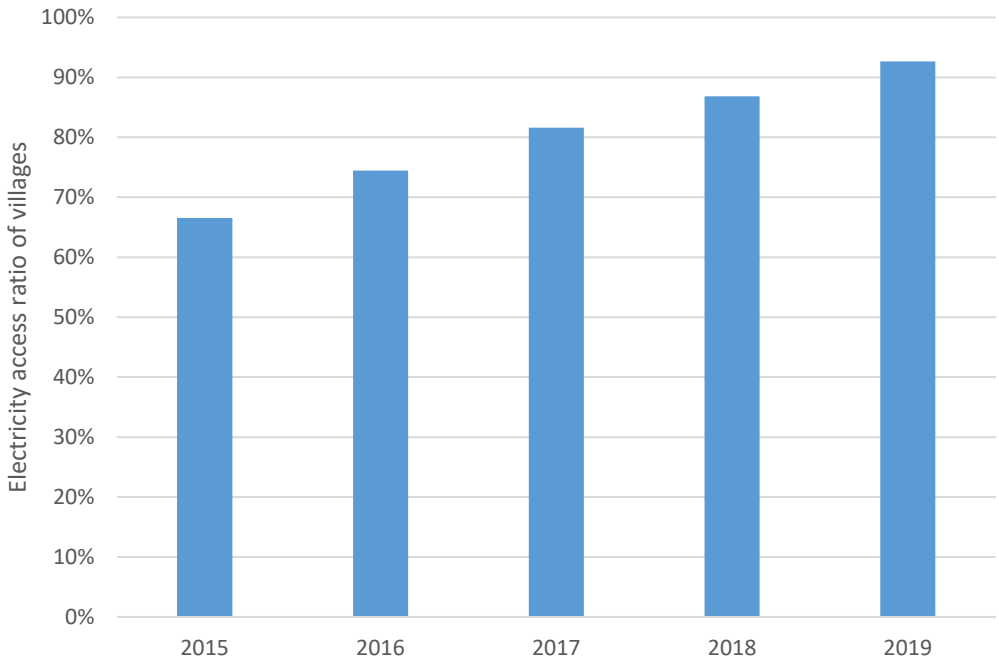


SAIDI = System Average Interruption Duration Index.
Source: JICA (2020a).

2.1.6 Electricity access

Cambodia is amongst the countries in ASEAN with a low electricity access ratio. Figure 2-9 shows the change in the electricity access ratio of villages in Cambodia: from 66.6%, it steadily increased and reached 92.7%. However, this data is just the electricity access ratio of the village; even if the village is electrified, not all households are. According to the MME, households' electricity access ratio is about 20% lower than villages. The MME planned to achieve 100% electricity access of villages in 2020 and at least 70% electricity access of households by 2030. However, the electricity access ratio is still low. Therefore, this study will also analyse the impact of electricity access on GDP in Cambodia.

Figure 2-9 Change in Electricity Access Ratio of Villages in Cambodia



Source: EAC data, modified by the author.

2.1.7 Overview of the power development plan

2.1.7.1 *Background*

The annual increase of nationwide electricity sales from 2012 to 2018 rose 17.6% because of the steady increase in Cambodia's economic growth. Imported electricity from the Lao PDR, Thailand, and Viet Nam was 16.1% of all generated electric power in 2018. In 2017, the first solar power (10 MW) was connected to Cambodia's power grid. Under such a situation, generation development planning has a crucial position in the revision of the power development master plan.

2.1.7.2 *Basic policy*

The basic policy for generation development planning is as follows:

- ❖ Reduce the energy dependency on other countries
  - Utilise hydro potential as much as possible
  - Produce domestic resource
- ❖ Avoid too much overflow or surplus generation at hydropower plants during the rainy season
- ❖ Assume 'no power export' because of the uncertainty of wide-area coordination
- ❖ Consider renewable energy such as wind, solar, and biomass power
- ❖ Finish heavy fuel oil plants when their contracts end.

2.1.7.3 *Peak demand and supply balance*

In general, several approaches exist for reliability evaluation; some are deterministic, and others are probabilistic. The desirable approach depends on the demand size and database quality. The consultants followed the 'N-1' reliability criterion described in the Cambodian grid cord. This is one of the deterministic methods. This concept is to supply capacity sufficiently with no load reduced even if the largest unit experiences forced outage at peak demand. This approach is appropriate for a growing power system like Cambodia because the unit capacity tends to be dominant than the demand size; the statistical data might also be less.

2.1.7.4 *Overview of the power development plan*

The PDP should be linked with the Transmission Development Plan. Therefore, the Generation Development Plan summary is presented with the result of the Transmission Development Plan. Table 2-2 shows PDP 2020–2030 in Cambodia. In the PDP, new power plants that will operate in November and December next year are listed.

The total installed capacity will skyrocket to 17,279 MW by 2030, including the existing generation capacity (as of 2019) of 2,999 MW, the new generation capacity of 14,280 MW, and the retiring generation capacity of 478 MW. Thus, it will be 5.8 times the installed capacity in 2019.

Table 2-2 Power Development Plan 2020–2030 in Cambodia

Year	Plan	Capacity [MW]	Total Installed capacity [MW]
2020	1. Import from Lao PDR by 115kV 2. Don Sahong Hydro Lao PDR 3. Solar Schenitec Kampong Speu + Pursat 4. Attapeu Hydro Lao PDR (Part 1) 5. Import from Thailand by line 115kV 6. Import from Loa by 115kV 7. Disel Oil Phnom Penh 8. Solar Bavet + Battambang + Banteay Meanchey	50 195 20 + 30 100 50 50 400 20 + 60 + 30	3,893
2021	1. Coal Oddor Meanchey (Part 1)	100	4,313

	2. Solar Schneitec Kampong Chhnang + Pursat 3. New Solar	60 + 60 100 x 2	
2022	1. Coal Oddor Meanchey (Part 2) 2. Attapeu Hydro Lao PDR (Part 2) 3. Solar Kampong Chhnang ADB 4. Import from Thailand by line 500 kV 5. Reduce imports from Thailand by 115 kV 6. Coal CIIDG (Part 1) 7. Bio Mass Phnom Penh 8. Complete Disel Oil Engine COLBEN	100 150 60 300 -45 180 350 100 -10	5,183
2023	1. Import from Thailand by 500 kV 2. Reduce imports from Viet Nam 3. Pursat River 1 4. Coal CIIDG (Part 2)	200 -200 80 350	5,613
2024	1. Complete Disel Oil Engine KEP -43MW 2. Attapeu Hydro Lao PDR (Part 3) = 250MW 3. Coal Royal Group (Part 1) 350MW 4. Wind Blue Circle 80MW 5. Coal TSBP Laos (Part 1) 350MW	-43 250 350 80 350	6,600
2025	1. Complete Disel Oil Engine CEP 2. Coal Royal Group (Part 2) 3. Coal TSBP Laos (Part 2) 4. Coal XTPPCL Laos (Part 1)	-45 350 350 350	7,605
2026	1. Ta Tai Leu River 2. Import from Thailand by 500 kV 3. New Solar 4. Coal XTPPCL Loa (Part 2) 5. Russey Chrum Kandal + Veal Thmor Kombot	150 200 100 350 x 2 170	8,925
2027	1. Gas turbine CCGT-CIIDG (Part 1) 2. Coal XTPPCL Loa (Part 4+5) 3. New Solar	600 350 x 2 100	10,325
2028	1. Gas turbine CCGT-CIIDG (Part 2) 2. Coal XTPPCL Loa (Part 6) 3. New Solar 4. SREA PORK Hydro 3A+3B	600 350 200 300 + 68	11,843
2029	1. LOWER SENSAN KROM 3 Hydro 2. STUENG METUEK Hydro 3. Import from Thailand by 500 kV 4. Prek La-Arng Hydro 1+2 5. New Gas turbine CCGT 1 6. New Solar 6, 7, 8	260 100 300 72 + 56 600 200 x 3	13,831
2030	1. New Gas turbine CCGT 2, 3, 4 2. Srea Pork Krom 4 Hydro 3. Stueng TrengNG Hydro 4. New Solar 9	600 x 3 48 1,400 200	17,279

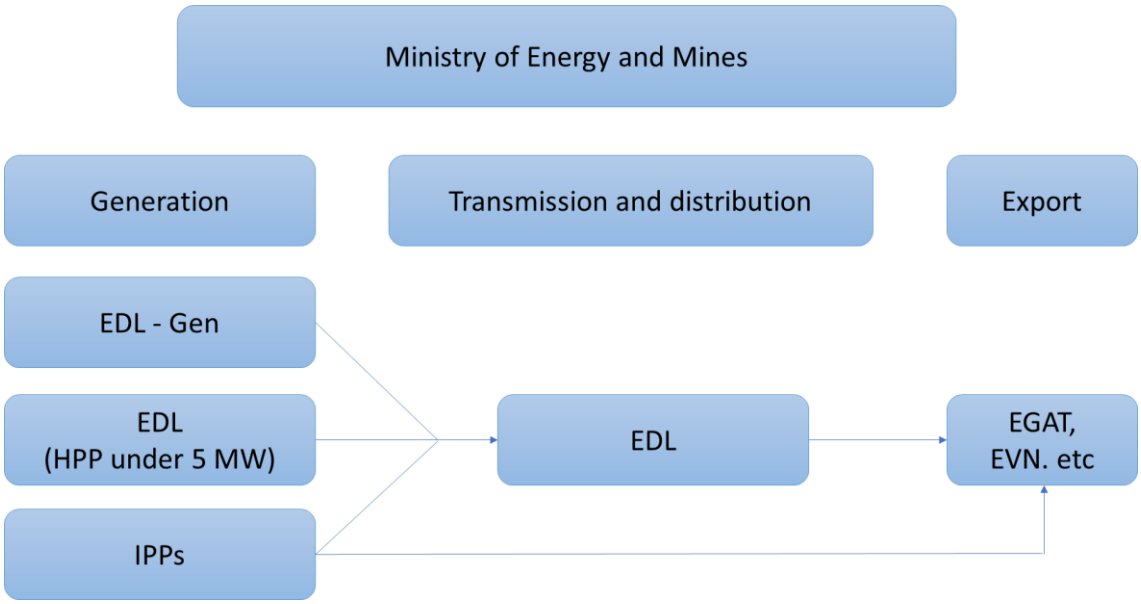
Source: MME data, modified by the author.

2.2. Lao PDR

2.2.1 Organisation of the electricity sector

Figure 2-10 shows the organisational structure of Lao PDR's electricity sector.

Figure 2-10 Organisational Structure of Lao PDR's Electricity Sector



EDL = Electricité du Laos, EDL-Gen = EDL-Generation Public Company, IPP = independent power producer, EGAT = Electricity Generating Authority of Thailand, EVN = Viet Nam Electricity.
Source: JICA (2020b).

1) Ministry of Energy and Mines

The Ministry of Energy and Mines (MEM) of the Lao PDR is the principal authority managing the electricity sector. It has the power to develop and implement laws and regulations governing the sector. Furthermore, in the absence of an independent power sector regulator, the ministry regulates the electricity tariffs. Figure 2-11 illustrates the central departments under MEM.

Figure 2-11 Organisational Structure of MEM (Overview)

Source: JICA (2020b).

2) Electricité du Laos (EDL) is a state-owned electric power utility supplying electricity to domestic consumers through its transmission and distribution lines. The EDL also manages the import and export of electricity. It buys power from several domestic IPPs, EDL-Gen, and from abroad, and exports electricity to neighbouring countries.
3) The EDL-Generation Public Company (EDL-Gen) is an electricity generation company and a subsidiary of the EDL. The EDL-Gen aims to (i) generate energy for the EDL from power plants with a capacity above 5 MW; (ii) invest in or set up joint ventures with other electricity generation projects; and (iii) provide management and maintenance services for other electricity projects.

4) Lao Holding State Enterprise

The Lao Holding State Enterprise is a state-owned enterprise that holds, owns, and manages its shares of four power project companies on behalf of the government.

5) Ministry of Planning and Investment

The main function of the Ministry of Planning and Investment (MPI) is to coordinate with the government's line ministries to prepare for their respective socio-economic development strategies. The MPI is also responsible for implementing investment strategies, promoting regulations, and approving overall investment.

6) Ministry of Finance

The Ministry of Finance defines the financial environment in the country. It determines policies that set the appropriate tax and duties for land use or equipment import.

7) Ministry of Natural Resources and Environment

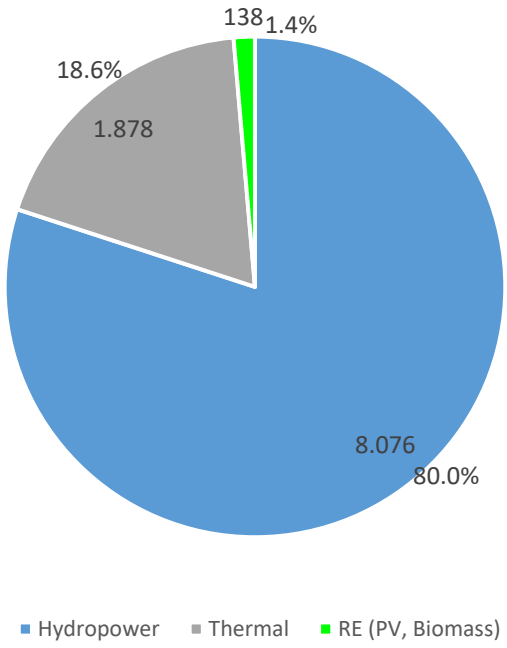
The Ministry of Natural Resources and Environment has overall responsibility for developing and implementing the Reduction of Emissions from Deforestation and Forest Degradation (REDD) and overseeing the management of the forestry sector in the Lao PDR.

2.2.2 Power generation

The Lao PDR has a large potential for hydropower generation. As of 2020, the total installed capacity in the Lao PDR was 10,091 MW, of which 3,734 MW was for domestic use. The total installed capacity portfolio and the total installed capacity portfolio for domestic use are shown in Figures 2-12 and 2-13, respectively. The Lao PDR relies on hydropower as the primary source of generation. The installed capacity of 5 MW or more hydropower accounted for 80%. Next to hydropower was thermal power, which accounted for 18.6%.

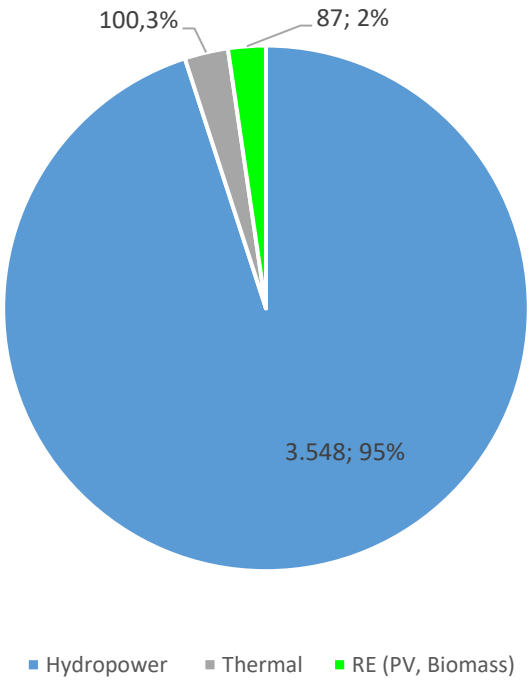
The installed capacity of renewable energy, except for large hydropower, was 138 MW, accounting for 1.4%.

Figure 2-12 Installed Capacity Portfolio in the Lao PDR (as of 2020)



PV = photovoltaic, RE = renewable energy.
Source: MEM data, modified by the author.

Figure 2-13 Installed Capacity Portfolio for Domestic Use in the Lao PDR (as of 2020)

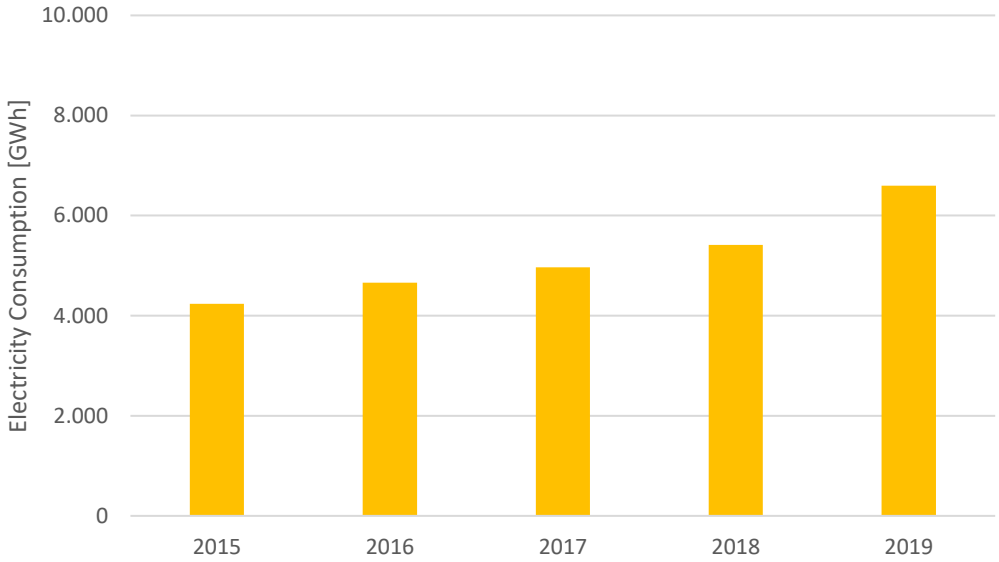


PV = photovoltaic, RE = renewable energy
Source: MEM data, modified by the author.

2.2.3 Power demand

Figure 2-14 shows the changes in the country's electricity consumption. The electricity consumption in 2015 was 4,239 GWh. It steadily increased from 2015 and reached 6,596 GWh in 2019. The electricity consumption growth rate from 2015 to 2019 was about 55.6%.

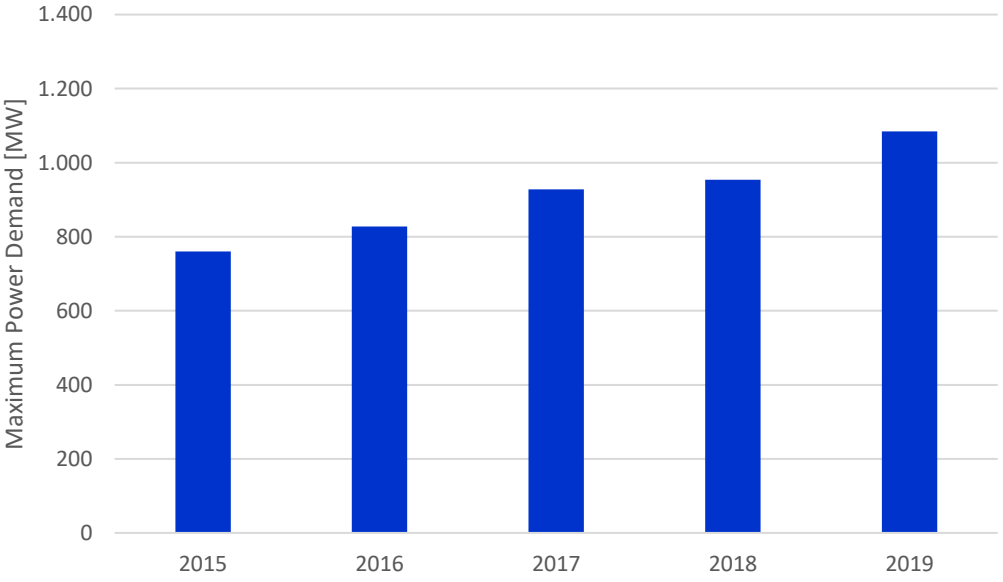
Figure 2-14 Changes in Electricity Consumption in the Lao PDR



Source: MEM data, modified by the author.

Figure 2-15 shows the changes in maximum demand. The maximum power demand in 2015 was 760 MW. It steadily increased and reached 1,085 MW in 2019. The demand growth rate from 2015 to 2019 was approximately 42.8%.

Figure 2-15 Changes in Maximum Power Demand in the Lao PDR



Source: MEM data, modified by the author.

2.2.4 Overview of the transmission network

The current power system comprises transmission and distribution lines at 500 kV, 220 kV, 115 kV, 33 kV, 22 kV, and low voltage. However, the domestic power supply system as of 2017 comprised transmission lines with less than 230 kV because the 500 kV transmission lines are used as a dedicated line to export power to neighbour countries.

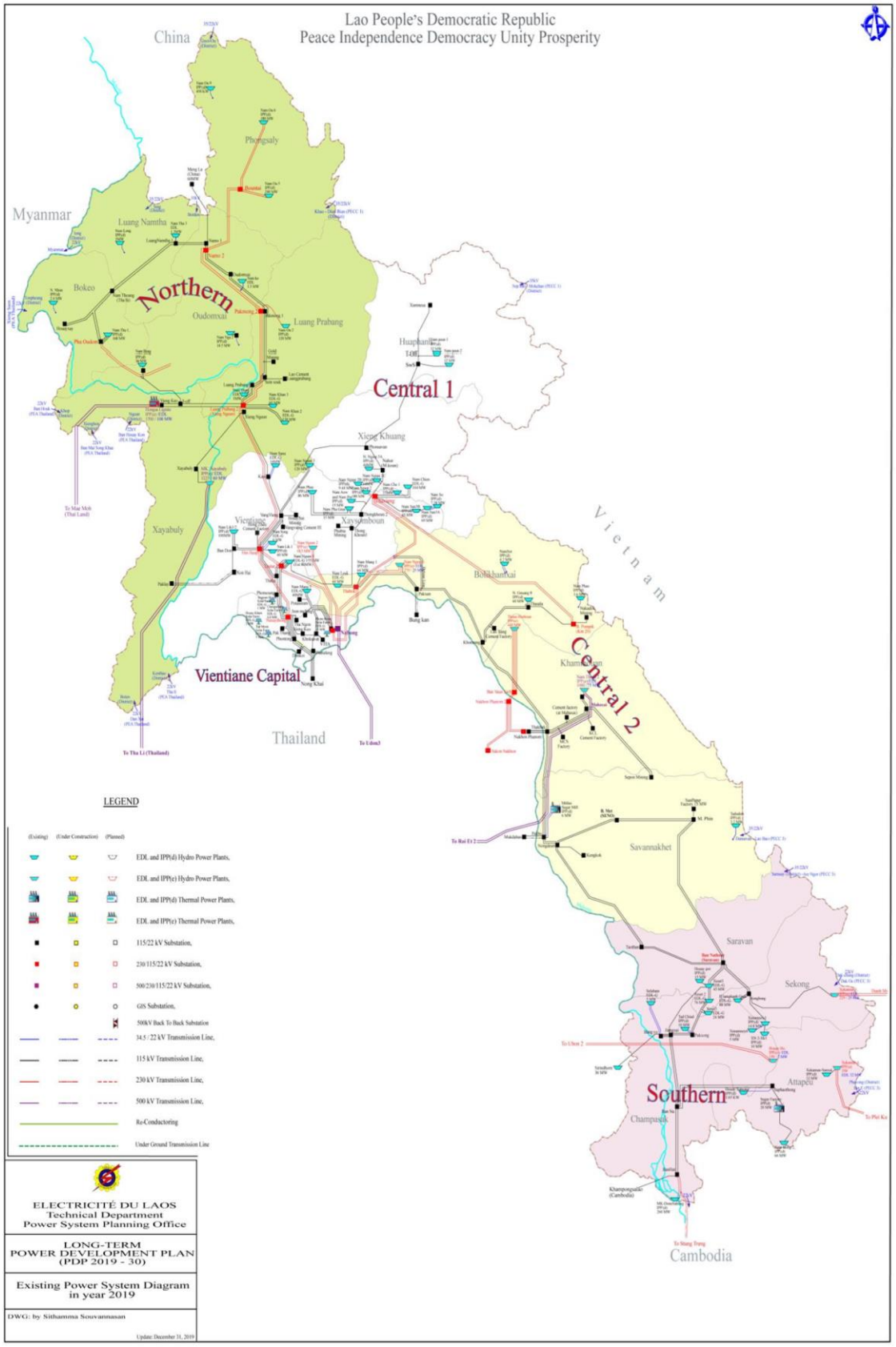
Since the Nam Ngum 1 power station was built in the 1970s and a 115 kV transmission line between Thailand and the Lao PDR was constructed, power generated in the Lao PDR had been exported to Thailand in the wet season, when hydropower generation is abundant. Power is imported from Thailand in the dry season when the generating power is insufficient to meet domestic power demand. In addition, the 115 kV Thakek substation (hereinafter referred to as 'S/S') and Pakbo S/S in Central-2 Area directly received power from Thailand because the interconnection lines between each area (i.e. Northern, Central-1, Central-2, and Southern) had not been constructed. Therefore, the power grid in the Lao PDR was connected to the power grid in Thailand. Power output from power plants and the protection of power flow in the interconnection line between Thailand and the Lao PDR had been controlled by instructions from the national control centre in Thailand.

Recently, the 115 kV transmission line from the independent Northern area to Central-1 area was extended, and transmission and substation facilities connecting Central-2 and Southern started operation in 2016. This means that a single national grid with 115 kV and 230 kV transmission lines were finally actualised by the interconnection line from the Northern Area to the Southern Area via the Central Area. Additionally, 230 kV transmission lines have been adapted for the domestic power supply system due to the increase in power demand and power development in the Northern Area. Also, a 230 kV transmission line between Vientiane, Luang Prabang, and Namo substations has started operation. Furthermore, the national control centre in Vientiane operates the domestic power system in the Lao PDR and collaborates with the Khon Kaen substation in Thailand.

The 500 kV transmission line between Na Bong S/S and Udon 3 S/S in Thailand currently operates at 230 kV and imports power only from Nam Ngum 2 power station (hereinafter referred to as 'P/S') to the Electricity Generating Authority of Thailand (EGAT). Although the Nam Ngum 2 P/S company owns this transmission line, the power generated at the Nam Ngiep 1 power plant was also connected to this line in 2019. To interconnect with neighbouring countries, there are 500 kV and 230 kV transmission lines for direct export of power from IPPs and a 115 kV transmission lines between the EDL and EGAT grids. In addition, the Lao PDR and neighbouring countries trade power by supplying from the domestic power grid and 35 kV and 22 kV distribution lines, which are adopted in areas that are not serviced by the domestic power grid and are more than 115 kV transmission line, such as areas located near the national border.

Figure 2-16 shows the power system and interconnection lines, including projects under construction, in the Lao PDR as of December 2019. In addition, Table 2-3 shows the EDL's transmission line and substation facilities.

Figure 2-16 Power Grid Map of the Lao PDR



Source: MEM data.

Table 2-3 EDL's Transmission Line and Substation Facilities (as of 2020)

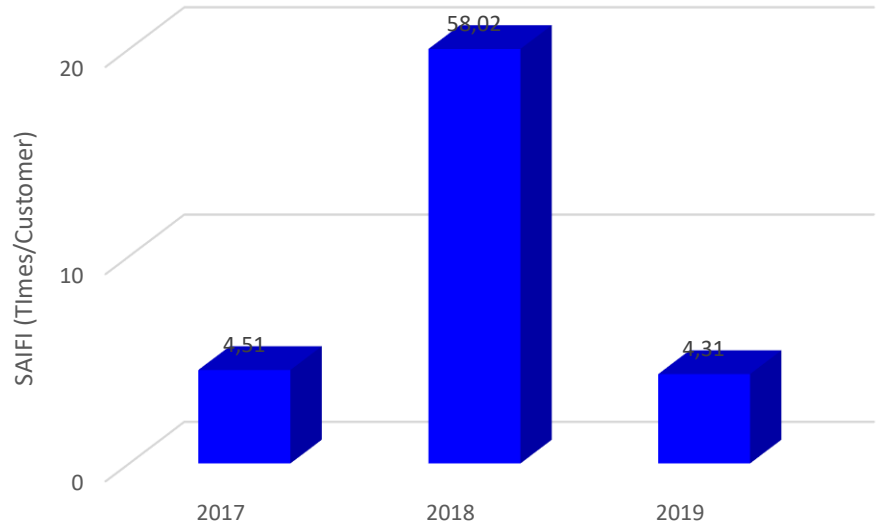
Regional	230 kV and 115 kV substation		230 kV and 115 kV transmission line	
	Number	TR Capacity (MVA)	Circuit number	Length (cct km)
Northern	40	3,240	107	4,982
Central 1	10	1,372	28	773
Central 2	14	826	40	2680
Southern	10	510	26	1387
Whole country	74	5,948	201	9,822

Source: MEM data, modified by the author.

2.2.5 Power system reliability

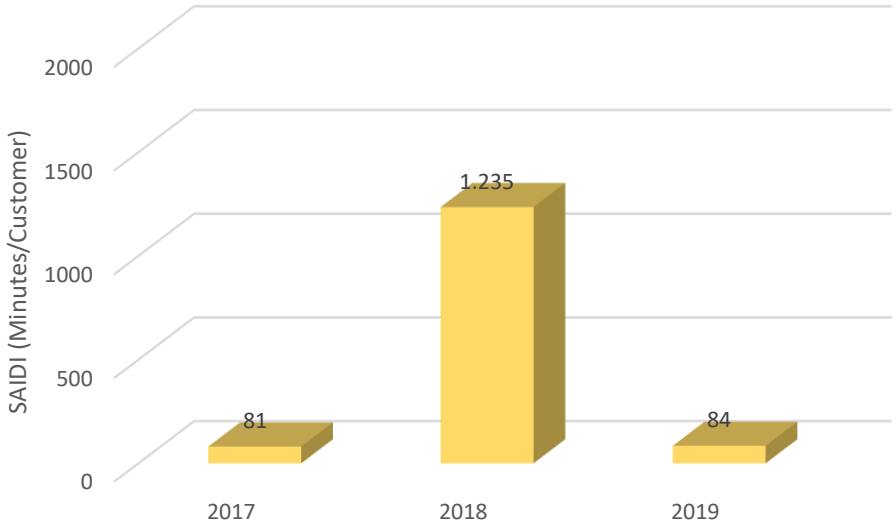
Figures 2-15 and 2-16 show changes in the SAIFI and SAIDI of the Lao PDR, respectively. The SAIFI in 2017 was 4.51 times; that of 2019 was 4.31 times and remained at almost the same level. On the other hand, the SAIDI in 2017 was 81 minutes, and that in 2019 was 84 minutes. It also stayed at nearly the same level. However, both the SAIFI and SAIDI skyrocketed in 2018. The SAIFI was 58.03 times, which was about 13 times higher than in 2017. The SAIDI was also 1,235 minutes, about 15 times higher than in 2017. The power outage in 2018 was thought to be more damaging than that in 2017. Although the SAIDI and SAIFI in 2017 and 2019 were lower than in developed countries, they are considered relatively high than other developing countries (ERIA, 2020).

Figure 2-17 Change in SAIFI of the Lao PDR



Source: MEM data, modified by the author.

Figure 2-18 Change in SAIDI of the Lao PDR



Source: MEM data, modified by the author.

2.2.6 Overview of the power development plan

MEM is responsible for general contracting in the power sector, and EDL is responsible for power purchase agreements for domestic power. The provincial or city government approves power generation projects whose general capacity is under 5 MW. The regional government handles those whose general capacity is under 0.1 MW with technical approval from regional technical departments.

According to JICA (2020b), MEM published the PDP in 2017. In this plan, approximately 14 GW will be exported, while 17 GW will be used domestically. Since the current total capacity is about 7 GW, the Lao PDR will have about 4.6 times the capacity in 2030. The reason for such a huge power generation plan was that the government did not manage it based on the overall supply and demand when it issued licences for power plants. Each power generation company planned it individually. The government also views such an excessive power supply plan as a problem. Considering the sluggish demand in the Lao PDR and the prospect of exporting electricity to Thailand, in March 2019, the Prime Minister, through the secretariat, directed the ministers of planning and investment, energy and mines, natural resources and environment, the mayors, and the prefectural governors to review the power supply plan.

On account of such a situation, in March 2019, the Prime Minister's office announced to the chief of each department concerned that the government would suspend or stop for 2 years the development of projects that are not economically sound for capacities less than 5 MW and renewable energy projects.

In April 2019, the Energy Promotion and Development and Ethnic Group Development Plan, both under MEM, and the EDL submitted the domestic generation plan up to 2030 to the ministry. In the new plan, no more than five new projects are to be developed until 2030 aside from those already under way to minimise surplus electricity. The total capacity for domestic use in 2030 is expected to be 6 GW, approximately one-third of the previous plan (JICA, 2020b).

Per the PDP, the total installed capacity will increase to 13,952 MW by 2030, including the existing generation capacity (as of 2020) of 10,091 MW (Table 2-4). It will be about 1.4 times the total installed capacity in 2020.

Table 2-4 Power Development Plan in the Lao PDR (as of 2019)

Year	Region	Total Capacity [MW]	Capacity [MW]	
			Domestic	Export
2025	Total	13,952	5,845	8,107
	North	8,290	3,916	4,374
	Central 1	651	651	0
	Central 2	2,729	497	2,232
	South	2,282	781	1,501
2030	Total	13,952	5,575	8,377
	North	8,290	3,496	4,374
	Central 1	651	651	0
	Central 2	2,729	497	2,232
	South	2,282	931	1,501

Source: JICA (2020b), modified by the author.

2.1 Myanmar

2.3.1 Organisation of the electricity sector

2.3.1.1 *The Policy of the Ministry of Electricity and Energy*

The Ministry of Electricity and Energy (MoEE) was organised on 1 April 2016 by merging the Ministry of Electric Power and the Ministry of Energy. To efficiently apply all possible opportunities for Myanmar's electricity and energy sector, the MoEE is developing a draft policy called the Myanmar Electricity and Energy Policy.

The draft states that the following measures should be taken during extraction and utilisation of natural resources to fulfil the country's energy needs:

- Minimise the environmental impacts
- Include sustainable utilisation plans for future generations
- Invite local and foreign investments
- Endorse and implement corporate social responsibility activities
- Develop and implement prioritised plans to use electricity and energy systematically and effectively

Under the market-oriented economy, the following are the objectives for defining electricity and energy pricing:

- Set fair and stable prices for electricity and energy consumers
- Ensure fair benefits to both producers and distributors
- Develop and enforce electricity and energy standards and specifications of the country based on international standards and specifications

- Encourage more cooperation with local foreign private partners following the State's economic policies

The objectives for exploring and utilising new renewable energy resources are as follows:

- Improve research and development programmes and awareness-raising activities
- Promote private sector participation by making laws and regulations
- Develop short-term and long-term plans
- Facilitate the operation of power plants by using locally available energy sources such as hydropower and renewable and thermal energy to provide a full and stable domestic electricity supply
- Develop and implement short-term and long-term plans to use liquefied natural gas, liquefied petroleum gas, coal, and other fuel energy sources
- Expand regional power trading when the domestic supply of electricity and energy is sufficient
- Cooperate with neighbouring countries to implement international power grid network and oil and gas pipeline network
- Implement modern petrochemical complexes in cooperation with local and foreign partners, which can produce petroleum and petrochemical products according to international standards and specifications, in line with economic policy, to set short-term and long-term plans to export.

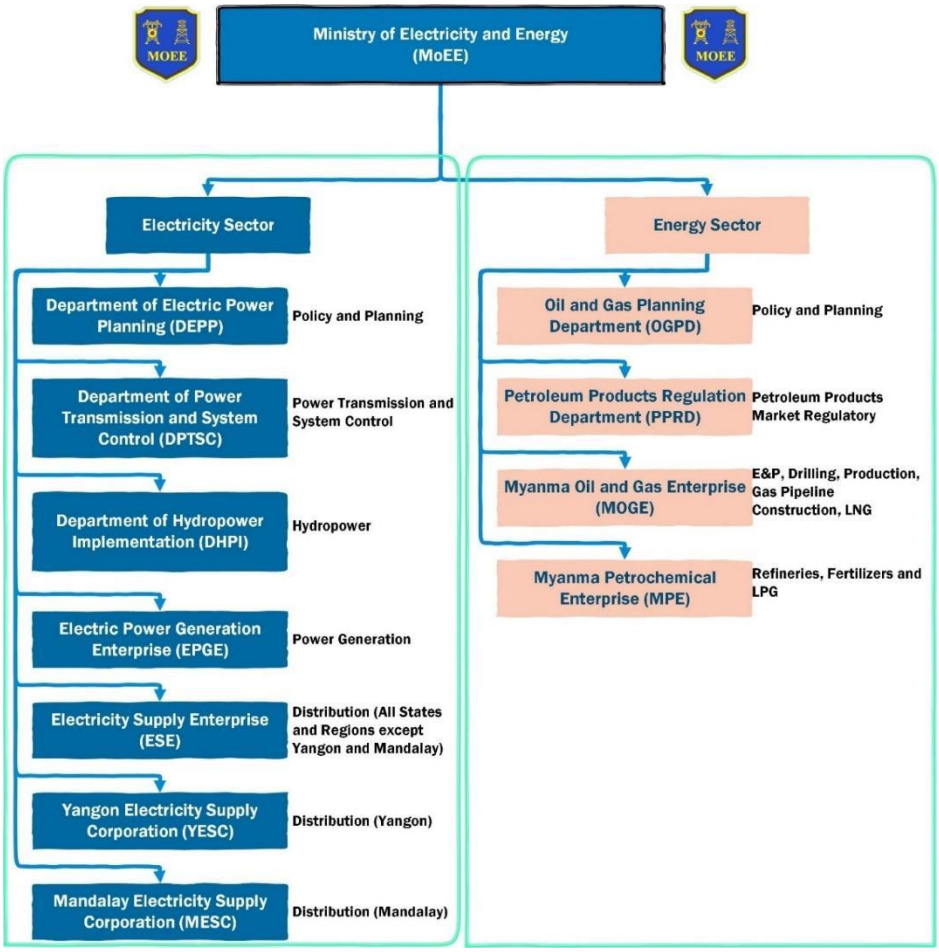
As for energy security, the MoEE will carry out long-term plans to increase reserved energy and formulate a plan to use civilian nuclear energy in line with ASEAN Standards.

Moreover, the MoEE has developed the following policies and plans: National Energy Policy, Electricity Sector Policy, Oil and Gas Sector Policy, Myanmar Energy Master Plan, National Electricity Master Plan, and National Electrification Plan. These were formulated by different international organisations such as the World Bank, JICA, and ADB and should be reviewed and revised to be in line with the current situation, national development plan, and government policy.

2.3.1.2 *Organisational structure*

The MoEE comprises five departments, four enterprises, and two corporations. There are three departments, two enterprises, and two corporations under the electricity sector; and two departments and two enterprises under the energy sector. Figure 2-19 shows the organisational structure of Myanmar's Ministry of Electricity and Energy.

Figure 2-19 Organisation of the Ministry of Electricity and Energy, Myanmar



Source: Authors, adapted from MoEE.

2.3.1.3 *Electricity sector*

The Department of Electric Power Planning (DEPP) is responsible for planning new power projects (thermal, hydro, and renewable); and coordinating with development partners, international organisations, and regional and international countries to develop, generate, transmit, and distribute electricity. DEPP is also responsible for drafting and modernising electricity laws, rules, regulations, and grid codes.

The Department of Power Transmission and System Control plans, implements new transmission lines and substations, and takes charge of the operation and maintenance (O&M) of the Myanmar power system.

The Department of Hydropower Implementation is responsible for planning, designing, and constructing state-owned hydropower plants.

The Electric Power Generation Enterprise plans the local and international tender invitation process on power generation. In addition, it is responsible for the O&M of existing thermal, hydro, and renewable power plants.

The Electricity Supply Enterprise distributes electricity in all states and regions: the Yangon Electricity Supply Corporation distributes in the Yangon Region, and the Mandalay Electricity Supply Corporation is for the Mandalay Region.

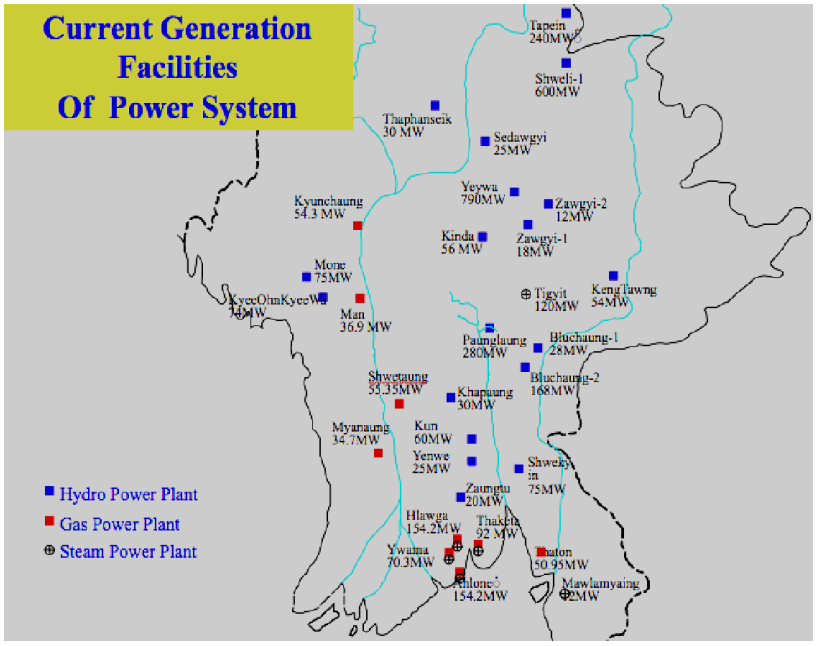
2.3.1.4 *Energy sector*

Two departments and two enterprises oversee the energy sector. The Oil and Gas Planning Department plans oil- and gas-related projects. The Petroleum Products Regulation Department, formerly the Myanmar Petroleum Products Enterprise, regulates the petroleum products market in Myanmar. The Myanmar Oil and Gas Enterprise is responsible for exploiting, midstreaming, and distributing oil and gas. The Myanmar Petrochemical Enterprise runs refineries, fertiliser factories, and the liquefied petroleum gas industry.

2.3.2 Power generation

The total installed power generation capacity of Myanmar is 6,749.9 MW for all power sources, including 3,225 MW for hydropower stations; 3,363.9 MW for gas-fired power plants; 120 MW for coal-fired power plants; and 40 MW for solar farms. In addition, there are some oil fuel self-contained units with a total installed capacity of 101 MW and 33 local small-scale hydropower projects with a total installed capacity of 37,374 MW. Both are mainly used in off-grid regions. Under the Ministry of Agriculture, Livestock, and Irrigation, the Department of Rural Development operates and manages small-scale solar firms, not considered in this study. The primary source of Myanmar's power plants is hydropower, followed by natural gas. The following figure shows the location of Myanmar's main power plants.

Figure 2-20 Power Generation Facilities in the Myanmar Power System



Source: MoEE data.

2.3.2.1 Hydropower

As of August 2020, the total installed capacity of Myanmar's hydropower stations, including 28 hydropower stations, is 3,225 MW. Table 2-5 shows the installed capacity of each hydropower station.

Table 2-5 Installed Capacity of Hydropower Plants in Myanmar

	Power Plant Name	Installed capacity (MW)	Commissioning Year
1	Baluchaung-2	168	1960/74
2	Kinda	56	1985
3	Sedawgyi	25	1989
4	Baluchaung-1	28	1992
5	Zawgyi Dam	18	1995
6	Zaungtu	20	2000
7	Zawgyi Dam 2	12	2000
8	Thapanzeik	30	2002
9	Mone	75	2004
10	Paung Laung	280	2005
11	Yenwe	25	2007
12	Kabaung	30	2008
13	Kengtawng	54	2009
14	Shweli-1	600	2009
15	Yeywa	790	2010
16	Dapein-1	240	2011
17	Shwegyin	75	2011
18	KyeeonKyeewa	74	2012
19	Kun	60	2012
20	Thauk Ye Khat-2	120	2013
21	Nancho	40	2014
22	Phyu Chaung	40	2014
23	Baluchaung - 3	52	2014
24	Chipwinge	99	2014
25	Upper Paunglaung	140	2014
26	Myitthar	40	2017
27	Myoe Gyi	30	2015
28	Yazagyo	4	2018
Total		**3,225**	

Source: MoEE data, modified by the author.

2.3.2.2 Gas power plants

So far, the total installed capacity of gas power plants in Myanmar has reached 3,363.9 MW. Table 2-6 shows the existing gas power plants.

Table 2-6 Installed Capacity of Gas Power Plants in Myanmar

Power Plant Name	Installed capacity (MW)	Commissioning Year
Kyun Chaung	54	1974
Man	37	1980
Shwe Taung	55	1984
Myan Aung	18	1984
Myan Aung 2	16	1975
Thaton (WB)	119	2018
Hlawga	99.9	1996
Ywama	37	1980
Ywama (NiDo)	24	2004
Ywama (240)	240	2014
Ahlone	99.9	1995
Thaketa	57	1990
Thilawa	50	2016
Hlawga	54	2013
Ywama (NEDO)	9	2014
Ahlone	54	2014
Toyo Thai	106	2015
Myanmar Lighting	78	2016
Thaketa	35	2018
Thaketa (UREC)	106	2018
Sembcorp (Myingyan)	225	2018
V power (KP)	90	2015-2016
V power (Myingyan)	90	2019
V power (Thaketa)	400	2020
V power (Thilawa)	350	2020
V power (Kyun Chaung)	22.3	2020
MCM (Shwe Taung)	39.2	2020
Total	3,363.9	

Source: MoEE data, modified by the author.

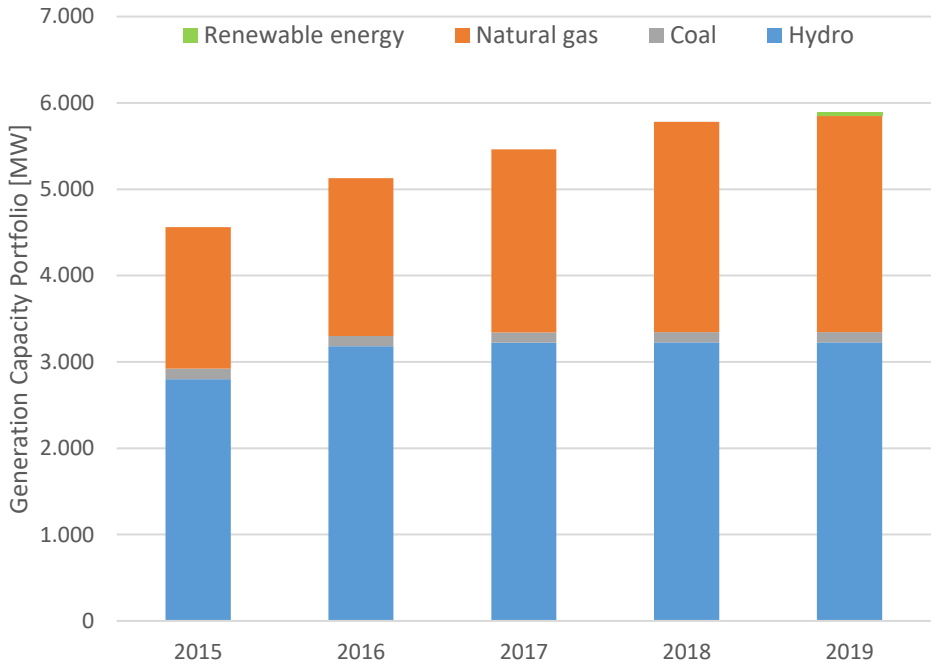
2.3.2.3 Others

The other power generation plants in Myanmar are the 120 MW coal-fired thermal power plant in Tigyit commissioned in 2005 and the 40 MW solar farm in Minbu commissioned in 2018.

2.3.2.4 Installed capacity

In recent years, the gas-fired power generation in Myanmar has developed rapidly, and its proportion in total installed capacity has increased year by year. In 2015, gas-fired power generation accounted for 35.9%, while hydropower accounted for 61.4%. In 2019, gas-fired power generation accounts for 42.5%, hydropower accounts for 54.7%, and the others are around 2.7%. In the future, the portion of the generation mix of renewable energy and thermal energy will be added because of ongoing tender and notices to proceed projects. The change in installed capacity in Myanmar is shown in Figure 2-21.

Figure 2-21 Change in Installed Capacity in Myanmar



Source: MoEE data, modified by the author.

2.3.2.5 Unit generation

According to the latest statistics, the total electricity generation of Myanmar in 2019 was 22,973 GWh, with an average growth rate of 12% from 2017 to 2019; the maximum load is 3,798 MW with an average growth rate of 15% from 2017 to 2019. Table 2-7 shows the change in the total generation from 2015 to 2019.

Table 2-7 Electricity Generation (GWh)

Month / Year	2015	2016	2017	2018	2019
January	1,142	1,252	1,467	1,621	1,781
February	1,053	1,243	1,377	1,521	1,702
March	1,304	1,513	1,591	1,837	2,016
April	1,238	1,429	1,519	1,791	2,007
May	1,390	1,507	1,760	1,919	1,992
June	1,311	1,410	1,641	1,771	1,900
July	1,307	1,479	1,643	1,885	1,938
August	1,326	1,488	1,717	1,881	1,933
September	1,325	1,493	1,712	1,893	1,918
October	1,366	1,537	1,714	1,931	2,048
November	1,316	1,434	1,661	1,820	1,932
December	1,311	1,493	1,617	1,816	1,806
Total	15,389	17,278	19,419	21,686	22,973

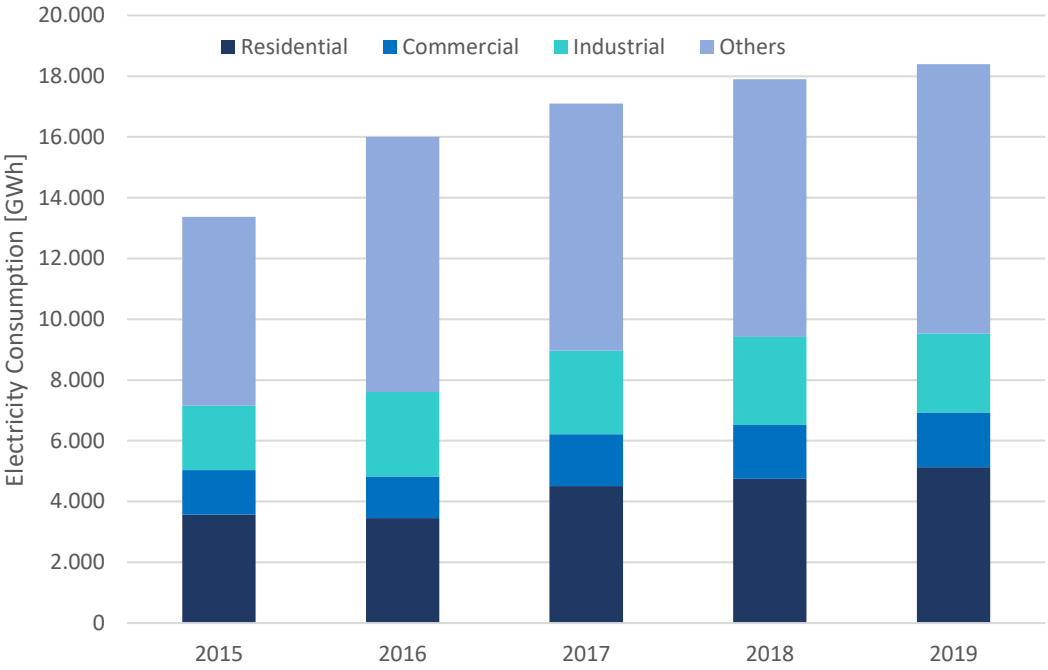
Source: MoEE data, modified by the author.

2.3.3 Power demand

2.3.3.1 *Electricity consumption*

According to MoEE's statistics, 50% of total households had access to grid electricity in 2019. Four sectors consume electricity: residential for household use, industrial for powering industries, commercial for business or bulk use, and others for street lighting and public use. The proportion of these contribution sectors are residential 31.50%, industrial 21.50%, commercial 12.99%, and others 34.02% from 2015 to 2019.

Figure 2-22 Changes in Electricity Consumption in Myanmar

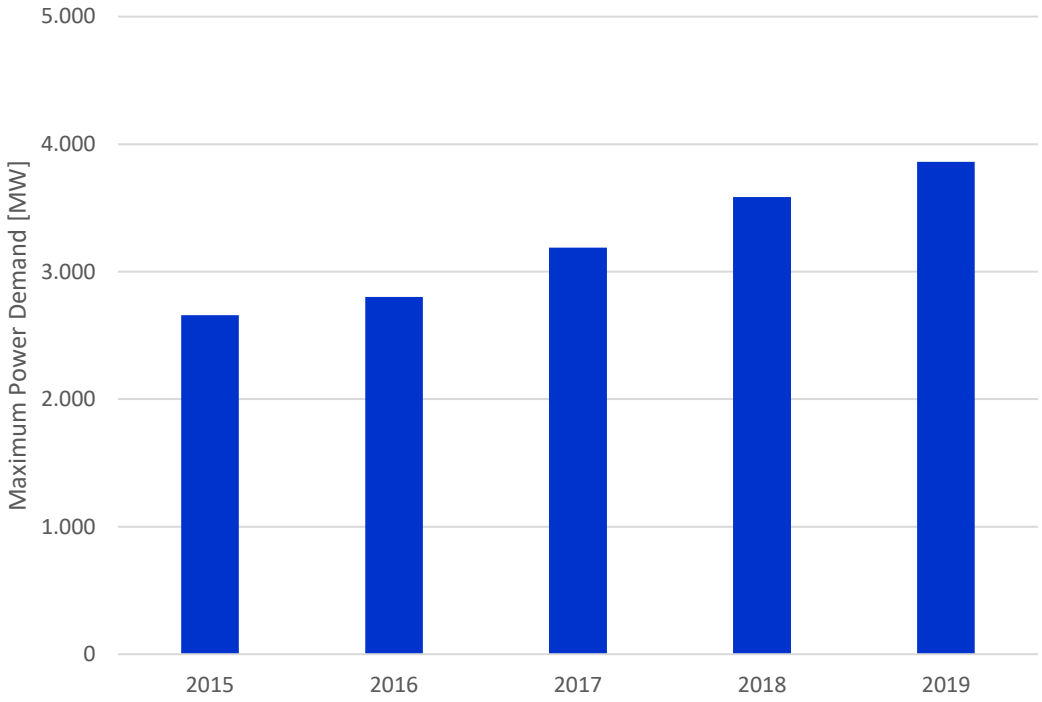


Source: MoEE data, modified by the author.

2.3.3.2 *Maximum demand*

The maximum demand in Myanmar was 2,659 MW in 2015; it steadily increased to 3,862 MW in 2019, with a growth rate of 45.3% (Figure 2-23).

Figure 2-23 Change in Maximum Demand in Myanmar



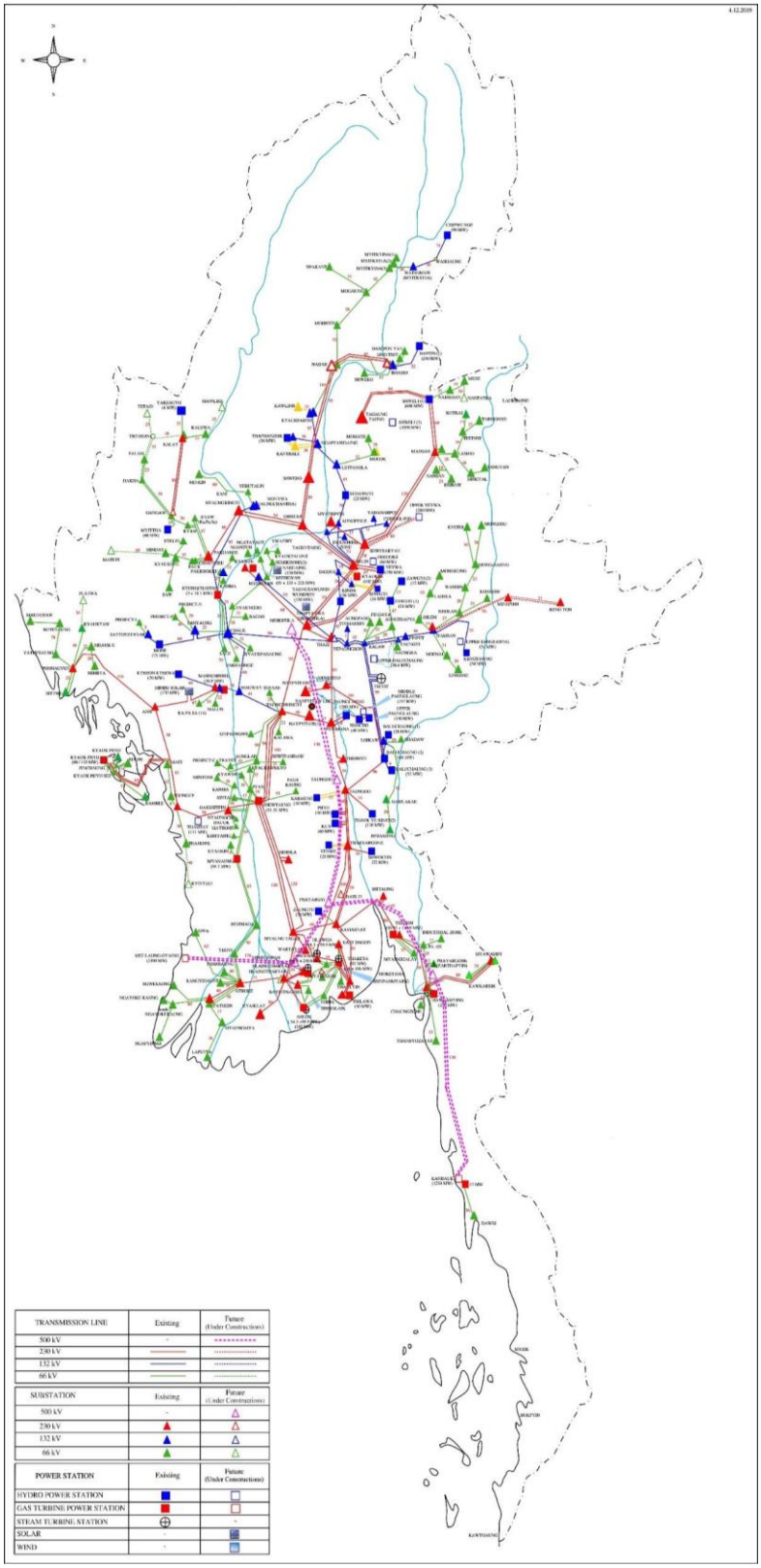
Source: MoEE data, modified by the author.

2.3.4 Overview of the transmission network

The power grid in Myanmar comprises national interconnected power grids (main grid) and isolated power grids in remote areas. Figure 2-24 shows Myanmar's power grid map.

The national transmission line mileage in Myanmar reached 15,319 km as of 2019, with primary voltage levels of 230 kV, 132 kV, and 66 kV. The transmission line is concentrated on the two major load centres, Yangon City and Mandalay City, and extends to surrounding cities. The transmission line covers most states and regions in the centre of Myanmar and some areas in Kachin State in the north, Shan State in the east, and Mon State and Kayin State in the south. In addition, isolated grids are used to supply power to most border and coastal regions. The existing 33 kV, 66 kV, 132 kV, and 230 kV transmission systems in Myanmar are concentrated around the main load centres and transmit electric energy to the load centre from power-gathering places located further north and south.

Figure 2-24 Power Grid Map in Myanmar



Source: Authors.

Table 2-8 Power Transmission Facilities in Myanmar

Voltage Class (kV)	Power Transmission Line		Substation	
	Quantity	Length (km)	Quantity	Capacity (MVA)
230	69	4,767	45	7,716
132	42	2,191	22	2,141
66	307	8,361	357	5,991
Total	418	15,319	424	15,848

Source: MoEE data, modified by the author.

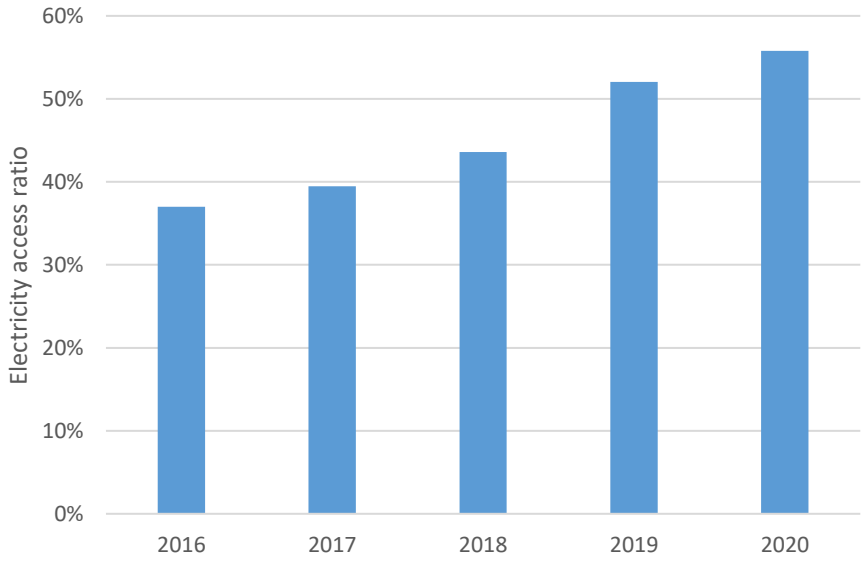
2.3.5 Power system reliability

In Myanmar, the statistics and indices for power system quality and reliability are yet to be fully developed.

2.3.6 Electricity access

The electricity access ratio in Myanmar is the lowest in ASEAN. Nevertheless, the country has been actively developing power infrastructure in recent years, and the electricity access ratio has been gradually increasing. Figure 2-25 shows the change in the electricity access ratio. First, the electricity access ratio was 37%, and then it steadily increased to 50% in 2019. By August 2020, it reached 55.8%. The Myanmar government aims for an electricity access ratio of 100% in 2030, and the progress of electricity access seems to be going well. However, the electrification rate is still low. Therefore, similar to Cambodia, this study also analyses the impact of electricity access on GDP in Myanmar.

Figure 2-25 Change in Electricity Access Ratio in Myanmar



Source: MoEE data, modified by the author.

2.3.7 Overview of the power development plan

2.3.7.1 *Hydropower*

Eight hydropower projects are presently undergoing preliminary work and construction in Myanmar, with a total installed capacity of 1,692 MW (Table 2-9). Only one project is progressing smoothly and is expected to be completed and be operational in 2019. The rest of the projects are progressing very slowly due to several reasons, and may be operational in 2025. Thus, by 2030, Myanmar's hydropower capacity will reach 4,947 MW.

Myanmar has initially identified more than 40 candidate hydropower plant lists with a total installed capacity of more than 30 GW as a long-term candidate for power supply construction.

Table 2-9 Hydropower Projects in Myanmar

Name of Hydropower Project	Installed capacity (MW)	Expected Commissioning Date
Upper Nanhtwan	3.2	2019
Shweli(3)	1050	2025
Deedok	66	2025
Upper Yeywa	280	2025
Middle Paunglaung	100	2025
Upper Kengtawng	51	2025
Upper Baluchaung	30.4	2025
Thahtay	111	2025

Source: MoEE data, modified by the author.

2.3.7.2 *Gas power plants*

Two gas-fired power plants in Myanmar are undergoing preliminary work and construction, with a total installed capacity of 335 MW (Table 2-10). Considering the commissioning and commercial operation of tendering thermal power plants in 2021, the generating capacity of gas-fired power projects in Myanmar will reach around 4,700 MW by 2021.

Table 2-10 Gas Power Plant under Construction in Myanmar

Power Plant Name	Installed Capacity (MW)	Expected Commissioning Date
Kyauk Phyu	135	2021
Kanbauk (UPA)	200	2025

Source: MoEE data, modified by the author.

To alleviate the severe power shortage in Myanmar, the MoEE passed four natural gas and liquefied gas power plant projects and issued notices to proceed on 30 January 2018. Other natural gas and liquefied gas power plant projects are planned to be developed by 2030, with a total installed capacity of around 4,000 MW.

2.3.7.3 *Solar power plants (photovoltaic: PV)*

Solar power plant projects, with a total installed capacity of over 1,000 MW in 30 locations connected with the grid, were invited in international competitive bidding for these power plants to operate at the beginning of the dry season in 2021. By 2030, the total installed capacity of solar power plants will reach 2,000 MW.

2.3.7.4 *Coal-fired power plants*

Most of the planned coal-fired power projects in Myanmar are build-operate-transfer projects, with seven memoranda of understanding and five memoranda of agreement in a semi-stagnating state. Due to environmental protection and other factors, the construction is seriously impeded; therefore, these projects are suspended for the time being. However, developing coal-fired power plants are expected soon to meet the country's electricity demand.

2.2 Thailand

2.4.1 Organisation of the electricity sector

2.4.1.1 *National energy policy*

To cope with the changes in economic and infrastructure development and the ASEAN Economic Community, the Ministry of Energy of Thailand (MoEN) developed the Thailand Integrated Energy Blueprint (Figure 2-26) as follows:

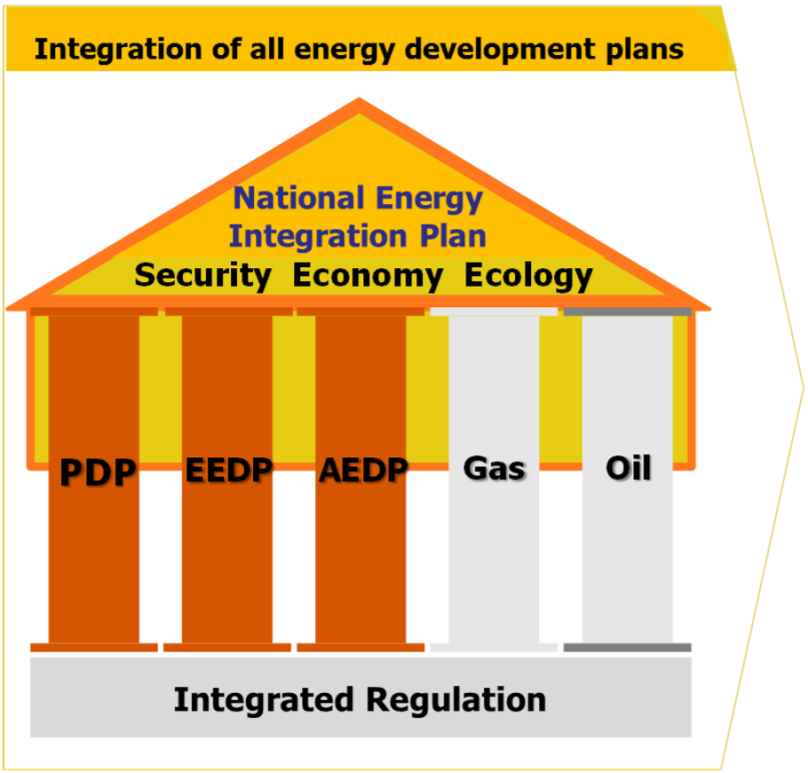
1) Thailand Power Development Plan (PDP)
2) Energy Efficiency Development Plan
3) Alternative Energy Development Plan
4) Natural Gas Supply Plan, and
5) Petroleum Management Plan

The new PDP, called the 'Thailand Power Development Plan 2018–2037 (PDP2018)', focuses on:

- Security - Enhancing the security of electricity generation, transmission, and distribution systems in each area to meet the electricity demand and support economic and social development
- Economy - Maintaining and appropriate costs in electricity generation and promoting low-cost electricity generation to relieve the burden of electricity users and not to pose obstacles to the economic and social development of the country in the long run
- Ecology - Reducing environmental impact by promoting electricity generation from renewable energy and increasing the efficiency of the power system on the supply and demand sides.

PDP2018 focuses on increasing the security of the electricity system by power development and improvement of the transmission system to increase the capability of interregional transmission. The 20-year PDP is divided into 5-year phases for flexibility in operation and investment facilitation, which will respond efficiently to socio-economic conditions and environmental protection.

Figure 2-26 Thailand Integrated Energy Blueprint

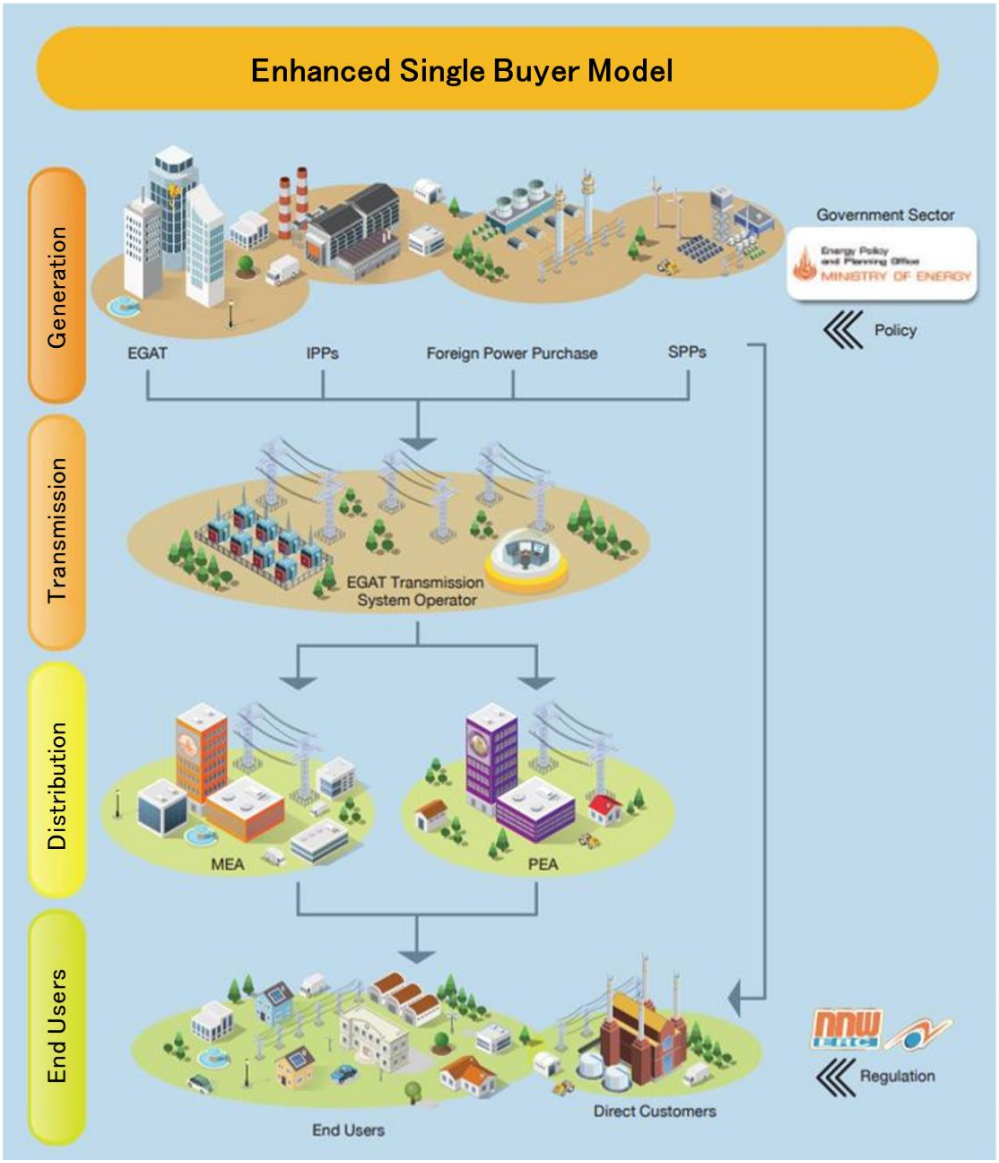


AEDP = Alternative Energy Development Plan, EEDP = Energy Efficiency Development Plan, PDP = Power Development Plan.
Source: MoEN (2016).

2.4.1.2 *Overview of the electricity market structure*

Thailand has adopted the Enhanced Single Buyer Model, authorising EGAT to take charge of the dominant electricity supply and be the sole buyer of electricity. Figure 2-27 shows the structure of Thailand's electricity supply industry. EGAT also serves as the system operator for the National Control Centre, which efficiently controls the dispatch of power plants, electricity generation, and transmission nationwide. In addition, the Energy Policy and Planning Office, Ministry of Energy, is responsible for national energy policies and plans. At the same time, the Energy Regulatory Commission regulates energy industry operations, including electricity prices. Meanwhile, policies are launched to promote private sector participation in Thailand's power market, including IPPs, small power producers (SPPs), and very small power producers (VSPPs), to buy power from renewable energy.

Figure 2-27 Structure of Thailand's Electricity Supply Industry



EGAT = Electricity Generating Authority of Thailand; EPPO = Energy Policy and Planning Office, Ministry of Energy; ERC = Energy Regulatory Committee; IPP = independent power producers (>90 MW); MEA = Metropolitan Electricity Authority; PEA = Provincial Electricity Authority; SPP = small power producer (10–90 MW); VSPP = very small power producer (<10 MW).
Source: EGAT (2020).

2.4.1.3 *Laws and governmental regulations for power companies*

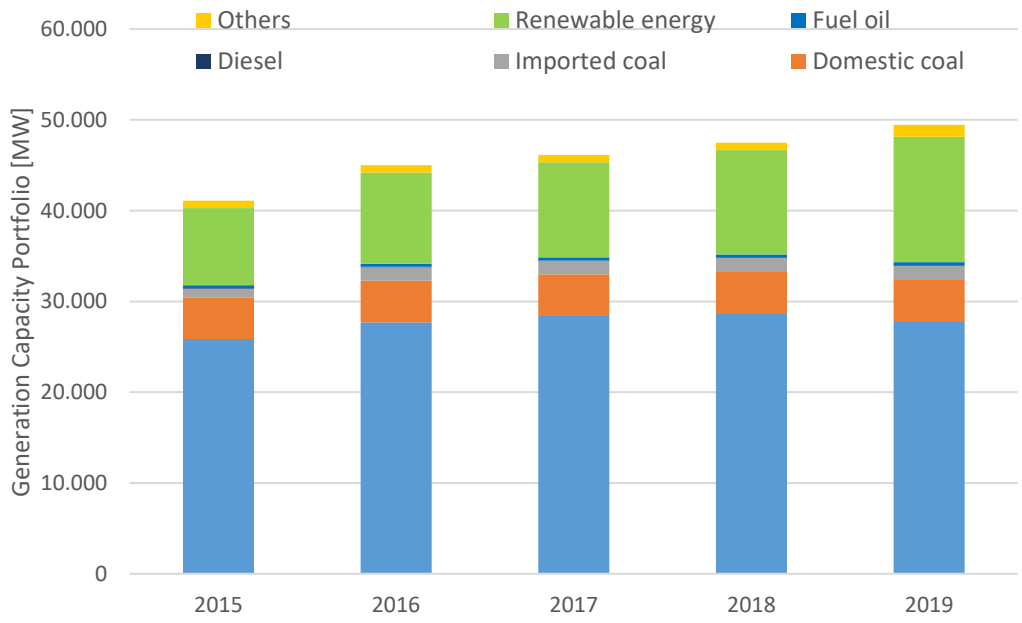
There is a collection of significant Thai legislation concerning the electricity supply industry. For instance, the EGAT Act, Metropolitan Electricity Authority (MEA) Act, and the Provincial Electricity Authority Act provide for the establishment, objectives, authority, and functions of the three principal power utilities. In addition, supplementary and subsequent regulations were developed and amended occasionally to coincide with contemporary social and economic situations, such as those for the SPPs and very small power producers. Lately, the Energy Regulatory Commission Act, which plays a vital role in the balance between energy consumers' rights and suppliers' power, was released in 2007.

Apart from these are laws conforming to international standards and regulations, such as the Factory Act and the National Environmental Quality Act.

2.4.2 Power generation

As of December 2015, the total installed capacity in Thailand was 41,098 MW. It gradually increased from 2015 and reached 49,462 MW in 2019. The installed capacity growth rate for the 5 years from 2015 to 2019 was approximately 20.4%. Generation in Thailand relies on natural gas as the main fuel. The generation capacity of natural gas accounted for 56.4% in 2019. Next to natural gas was renewable energy (hydro, wind, solar, geothermal, and biomass), which accounted for 28.0% in 2019. The generation capacity portfolio in Thailand is shown in Figure 2-28.

Figure 2-28 Generation Capacity Portfolio in Thailand

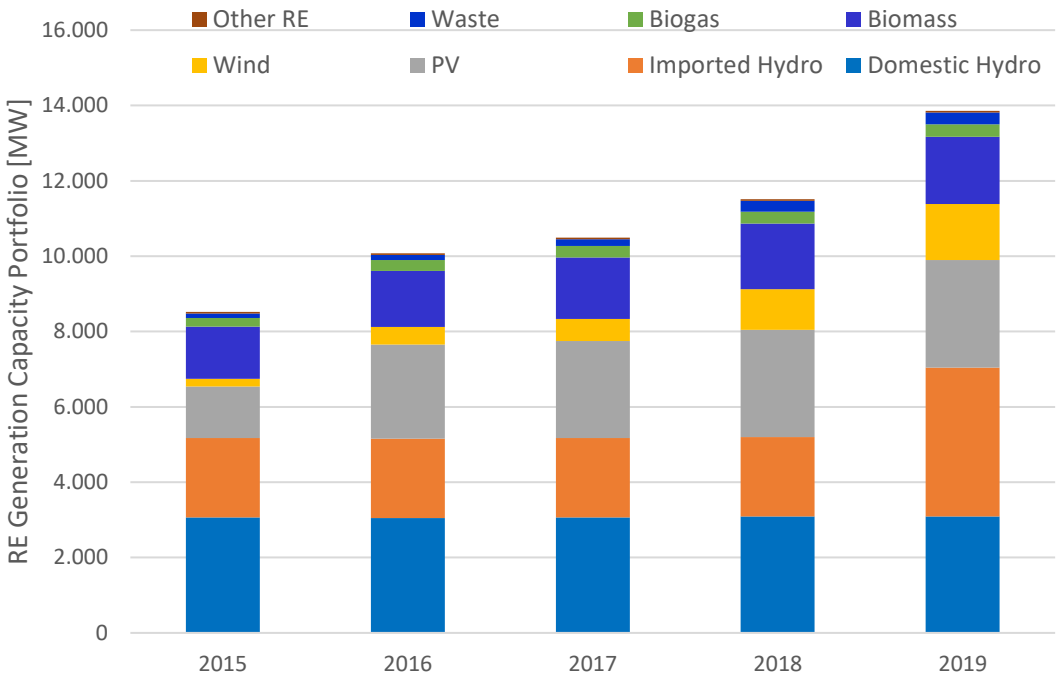


Source: EGAT data, modified by the author.

The generation of renewable energy skyrocketed in Thailand in 2015–2019. Figure 2-29 shows the generation capacity portfolio. The total installed renewable energy capacity was 8,522 MW in 2015 and reached 13,855 MW in 2019. The growth rate of renewable energy generation from 2015 to 2019 was 62.6%. Hydropower generation, including import, accounted for 50.8% in 2019. Next to hydropower was PV, accounting for 20.6%, and wind, accounting for 10.7%.

PV and wind power generation capacities were 1,367 MW and 202 MW, respectively, in 2015. Then PV and wind power skyrocketed and reached 2,854 MW and 1,486 MW in 2019. Thus, from 2015 to 2019, PV increased about 2.1 times, and wind power increased about 7.3 times in Thailand.

Figure 2-29 Renewable Energy Generation Capacity Portfolio in Thailand

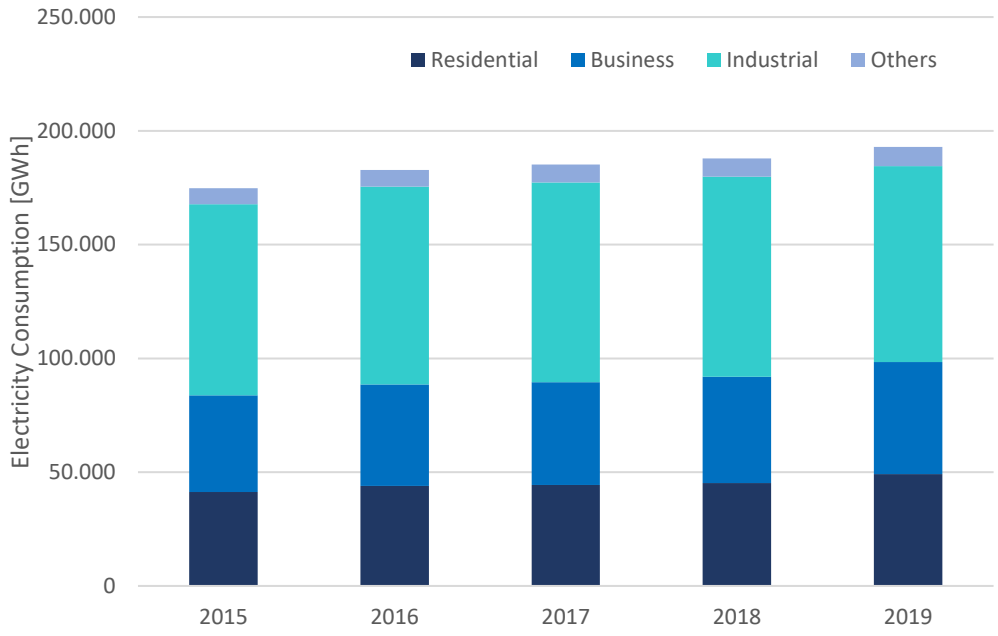


PV = photovoltaic, RE = renewable energy.
Source: EGAT data, modified by the author.

2.4.3 Power demand

Figure 2-30 shows the changes in electricity consumption in Thailand. The electricity consumption in 2015 was 174,833 GWh. It steadily increased from 2015 and reached 192,960 GWh in 2019. As a result, the electricity consumption growth rate from 2015 to 2019 was approximately 14.9%.

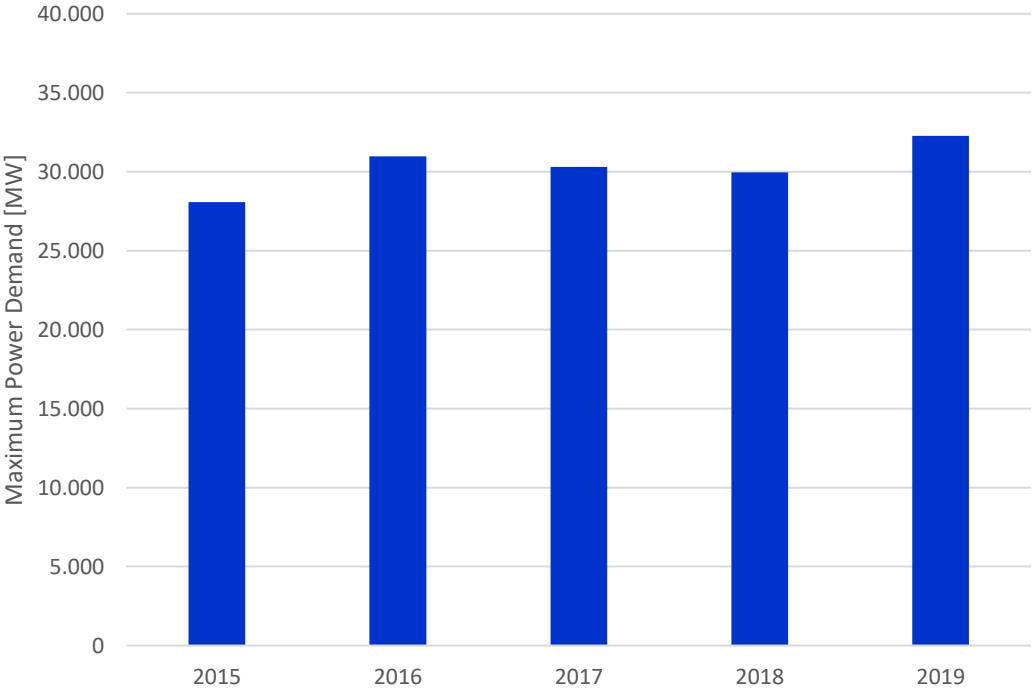
Figure 2-30 Changes in Electricity Consumption in Thailand



Source: EGAT data, modified by the author.

Figure 2-31 shows the changes in maximum demand in Thailand. The maximum power demand in 2015 was 28,082 MW. It steadily increased from 2015, slightly dipping in 2018, and reached 32,273 MW in 2019. Thus, the demand growth rate from 2015 to 2019 was approximately 14.9%.

Figure 2-31 Changes in Maximum Demand in Thailand



Source: EGAT data, modified by the author.

2.4.4 Overview of the transmission network

2.4.4.1 Transmission System Development Plan

As the state enterprise, EGAT solely owns the transmission system, including the 500 kV, 230 kV, and 115 kV transmission lines, as well as the high voltage direct current (HVDC) power exchange (300 kV HVDC link) between Thailand (EGAT) and Malaysia (Tenaga Nasional Berhad) in the southern part of Thailand.

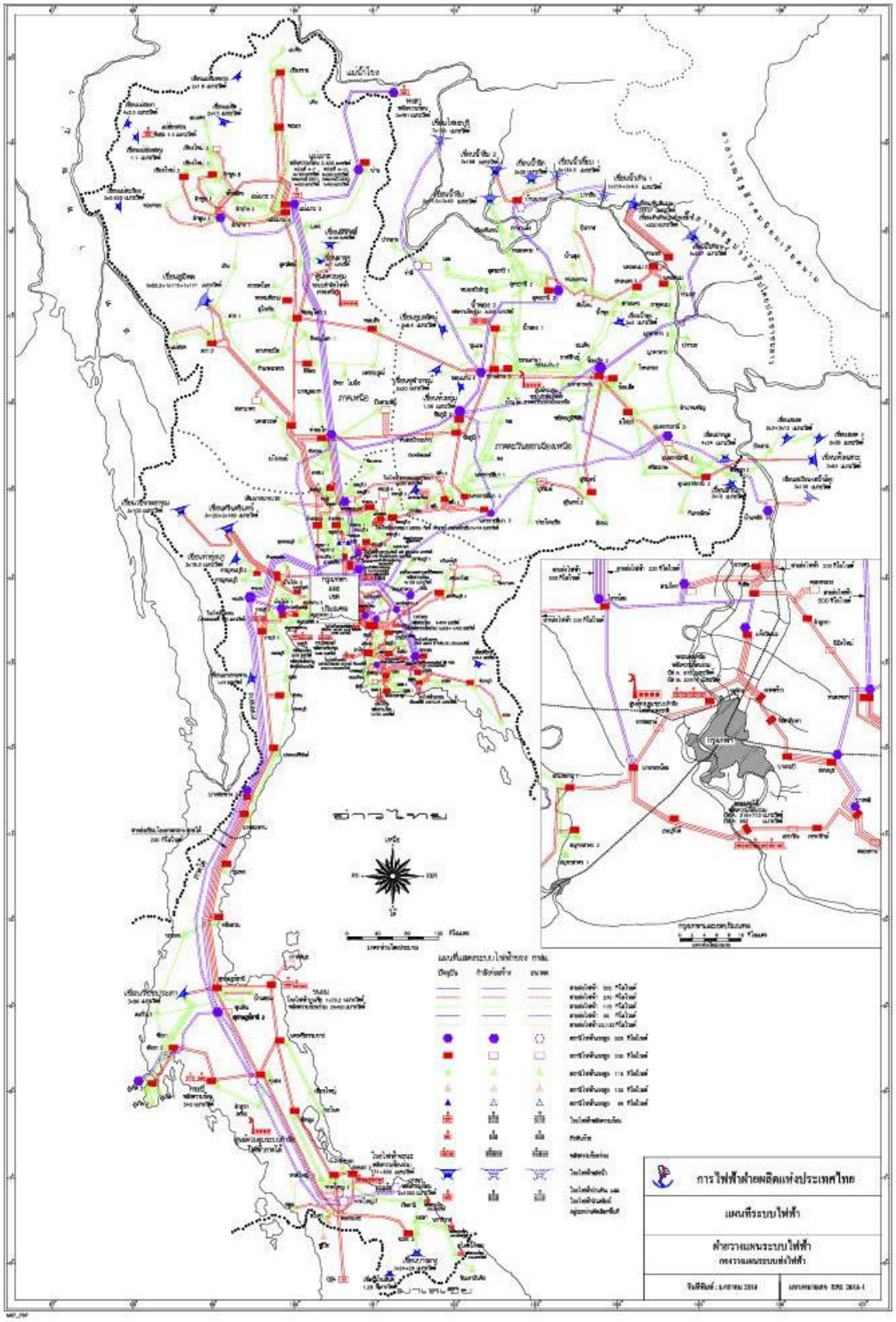
Additionally, to meet the increasing electricity demand, secure the system, and replenish the ageing power equipment, EGAT implements power plant development projects and transmission investment projects to fulfil the system requirements. The line length and number of substations at each voltage level are shown in Table 2-11.

Table 2-11 Line Length and Number of Substations at Each Voltage Level

Voltage Level [kV]	Line Length [Circuit-Kilometers]	Number of Substations
500	6,902.182	22
300	23.066	-
230	15,340.318	82
115	14,185.837	125
Total	36,451.403	229

Source: EGAT data, modified by the author.

Figure 2-32 Power Grid Map of Thailand

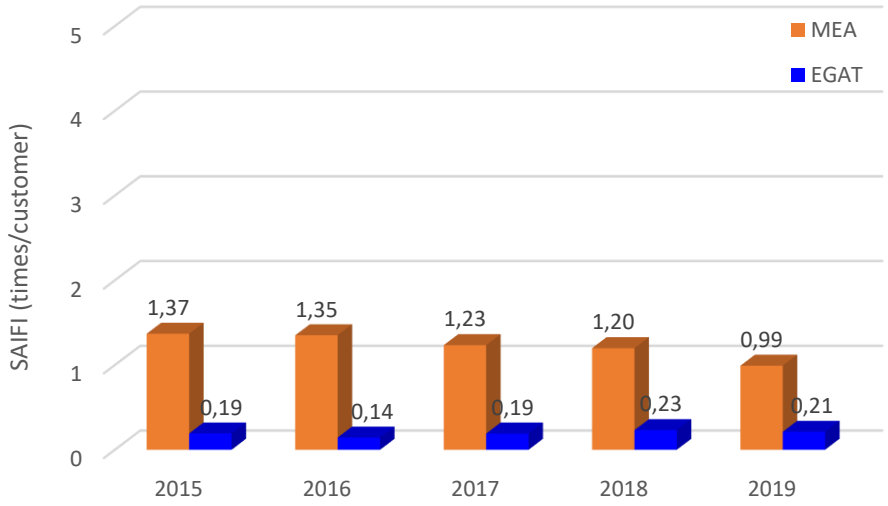


Source: EGAT (2018).

2.4.5 Power system reliability

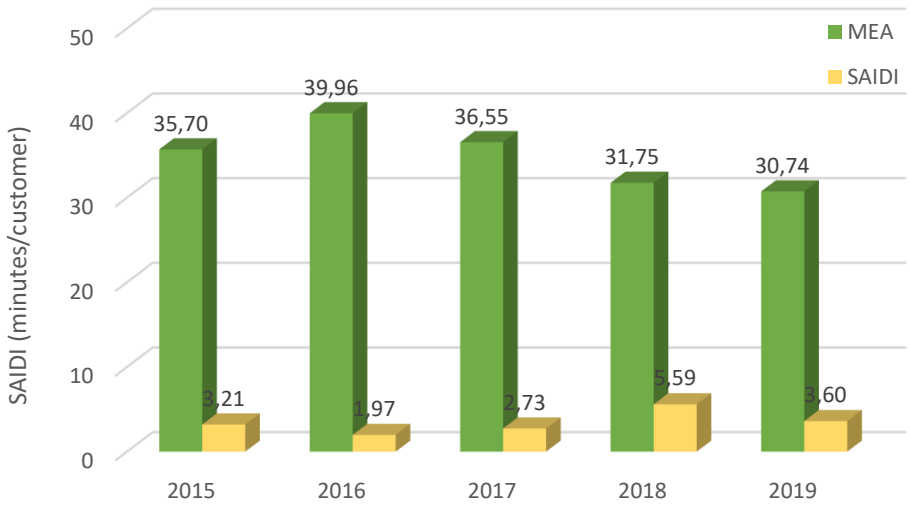
Figures 2-33 and 2-44 show the changes in SAIFI and SAIDI of Thailand, respectively. The SAIFI of EGAT and MEA in 2015 were 0.19 and 1.37 times. MEA's SAIFI steadily decreased from 2015 and was 0.99 times in 2019, about two-thirds of 2015. EGAT's SAIFI remained at about the same level. The SAIDIs of EGAT and MEA in 2015 were 3.21 and 35.70 minutes. MEA's SAIDI rose in 2016 but steadily decreased and was 30.74 minutes in 2019. On the other hand, EGAT's SAIDI changed between 2 and 6 minutes after 2015. From these data, power system reliability in Thailand is sufficiently high compared to developed countries (ERIA, 2019).

Figure 2-33 Change in SAIFI of Thailand



MEA = Metropolitan Electricity Authority, SAIFI = System Average Interruption Frequency Index.
Source: EGAT, MEA data, modified by the author.

Figure 2-34 Change in SAIDI of Thailand



MEA = Metropolitan Electricity Authority, SAIDI = System Average Interruption Duration Index.
Source: EGAT, MEA data, modified by the author.

2.4.6 Overview of Power Development Plan 2018–2037 (PDP 2018)

2.4.6.1 *Frameworks and directions of Thailand's PDP2018*

Thailand's PDP2018 focuses on three pillars:

1) Energy security

- ❖ Emphasising power system security, including generation, transmission, and distribution in each area to accommodate the increasing power demand to support economic and population growth and urbanisation regionally and nationally, as indicated in the National Economic and Social Development Plan
- ❖ Having adequate power plants for energy security to cope with an energy crisis

2) Economy

- ❖ Maintaining an appropriate power generation cost, prioritising the lowest generation to reduce the burden of power consumers and not hinder the country's economic and social development in the long run
- ❖ Managing electricity production cost-efficiently to reflect the actual cost of electricity generation

3) Ecology

- ❖ Promoting microgrids in remote areas, industrial estates, or special economic zones, in line with the power demand in each area, to optimise the use of local resources and reduce the investment in the transmission system
- ❖ Enhancing energy efficiency in the power system in both generation and consumption and introducing demand response to increase the potential of reducing peak demand to cope with an energy crisis, deferring the construction of new power plants, and saving from power imports
- ❖ Developing smart grids to facilitate decentralised generation and encourage more efficient energy use

Therefore, the key principles of Thailand's PDP2018 are as follows:

1) Formulating guidelines on reliable capacity allocation to serve power demand

- ❖ Allocating fossil fuel–based power plants
- ❖ Supporting power plants under the government's promotion policy, for example, committed power purchase from neighbouring countries
- ❖ Tracking the Paris Agreement adopted at COP21 by promoting renewable energy and energy efficiency
- ❖ Considering the economic concept of competitiveness and the change in innovation disruptions

2) Allocating fossil fuel–based power plants and main power plants in each region by considering power plants under the government's promotion policy

a) Optimising the use of potential fuel sources and existing infrastructure in each region to reduce any further investments

b) Alleviating the burden of a long-term commitment of the main power plant by considering the risk of disruptive technology

c) Maintaining the generation capacity in the primary grid and increasing generation capacity from the main power plant in metropolitan areas to reduce dependence on power generation from other regions

3) Proposing a framework for reliable capacity allocation

a) Constructing new fossil fuel–based power plants and ensuring committed power purchase from neighbouring countries

b) Promoting renewable energy and energy efficiency programmes

4) Generating power for own use and/or direct sale - Determining the framework for power generation for own use and/or direct sale is connected to three utility systems (independent power supply), showing a significantly growing trend amongst power producers and consumers classified into three categories:

a) SPP direct customers in industrial estates

b) Business people, who invest in independent rooftop solar to generate electricity for their use (do not sell electricity to the grid)

c) Power producers in the industry sector, who generate electricity for their use, for instance, agriculture and industry

The aforementioned framework for power generation for own use or direct sale was forecasted based on historical trends. However, regarding power generation for own use or direct sale in the future, the government will allow the market mechanism to determine which power producers and consumers will decide on the actual price. This change will affect the overall electricity demand.

2.4.6.2 *Guidelines of power plant allocation*

Main power plants were allocated in each region to maintain the security of the power system, considering the optimal use of potential fuel sources and existing infrastructure to minimise any further investments. Furthermore, power generation from new renewable technologies and risks of disruptive technologies were considered to avoid duplication of investments between the main power plant and renewable energy, alleviating the burden of electricity cost on consumers. Additionally, the generation capacity of primary power generation sources was retained. In contrast, there were new generation additions in metropolitan areas to reduce dependence on the power supply from other regions, primarily focusing on self-adequacy.

2.4.6.3 *Summary of PDP2018*

Thus, per Thailand's PDP2018, the total contracted capacity will increase to 77,211 MW by 2037, including the existing generation capacity (as of December 2017) of 46,090 MW; the new generation capacity of 56,431 MW; and the retiring generation capacity of 25,310 MW.

Table 2-12 Generation Capacity in 2018–2037

	Generation Capacity [MW]
Existing generation capacity as of December 2017	46,090
New generation capacity during year 2018-2037	56,431
Retiring generation capacity during year 2018-2037	-25,310
Total contracted capacity in 2037	**77,211**

Source: MoEN (2018).

Table 2-13 New Generation Capacity in 2018–2037

Type	Generation Capacity [MW]
Renewable energy	20,766
Pumped storage hydro power plant	500
Cogeneration power plant	2,112
Combined cycle power plant	13,156
Thermal power plant (Coal/Lignite)	1,740
Power purchase from neighbouring countries	5,857
New/Replacement power plant	8,300
Energy efficiency programs	4,000
Total	56,431

Source: MoEN (2018).

2.3 Viet Nam

2.5.1 **Organisation of the electricity sector**

2.5.5.1 *Government agency of the electricity sector*

Viet Nam's Ministry of Industry and Trade (MOIT) is responsible for electricity and energy. It formulates energy policies and plans. Three organisations are under MOIT: Institute of Energy, Electricity Regulatory Authority of Viet Nam (ERAV), and Electricity & Renewable Energy Authority (EREA).

1) Ministry of Industry and Trade

MOIT was established in 2007 through the merging of the Ministry of Trade and the Ministry of Industry. MOIT formulates, implements, and supervises laws and regulations, strategic and master plans for industries under its jurisdiction, and licences related to regulatory and investment projects. The ministry also formulates energy policies and plans, and approves electricity prices.

2) Institute of Energy

The Institute of Energy, an organisation directly under MOIT, is a research institute specialising in energy field research analysis and policy formulation. It is also in charge of formulating and revising the PDP, the power master plan, and forecasting long-term demand. Various drafts prepared in the institute are submitted to MOIT for its approval.

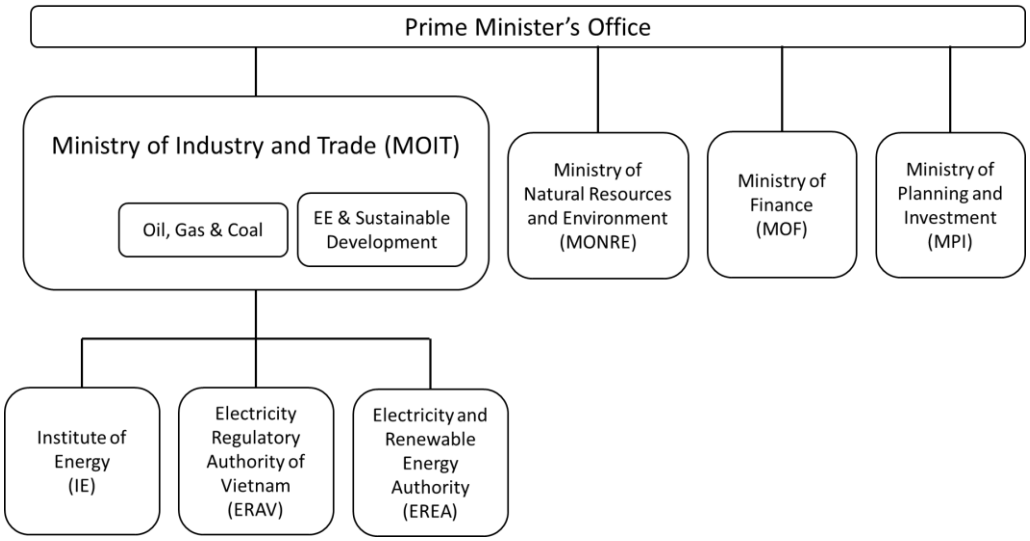
3) Electricity Regulatory Authority of Viet Nam

ERAV, also under the direct control of MOIT, is in charge of formulating and implementing regulations on electricity. The authority's primary functions are issuing electricity business licences, setting electricity prices, and maintaining and monitoring the electricity market. Since it is an internal organisation of MOIT, the latter approves various regulations and electricity prices.

4) Electricity and Renewable Energy Authority

EREA, also under MOIT, formulates policies, systems, and regulations related to renewable energy, and judges businesses for renewable energy power generation such as PV and wind power. EREA is also in charge of formulating the feed-in tariff system for renewable energy. In addition, MOIT approves various systems developed by EREA.

Figure 2-35 Organisational Structure of Government and Regulatory Bodies in the Electricity Sector



Source: Authors.

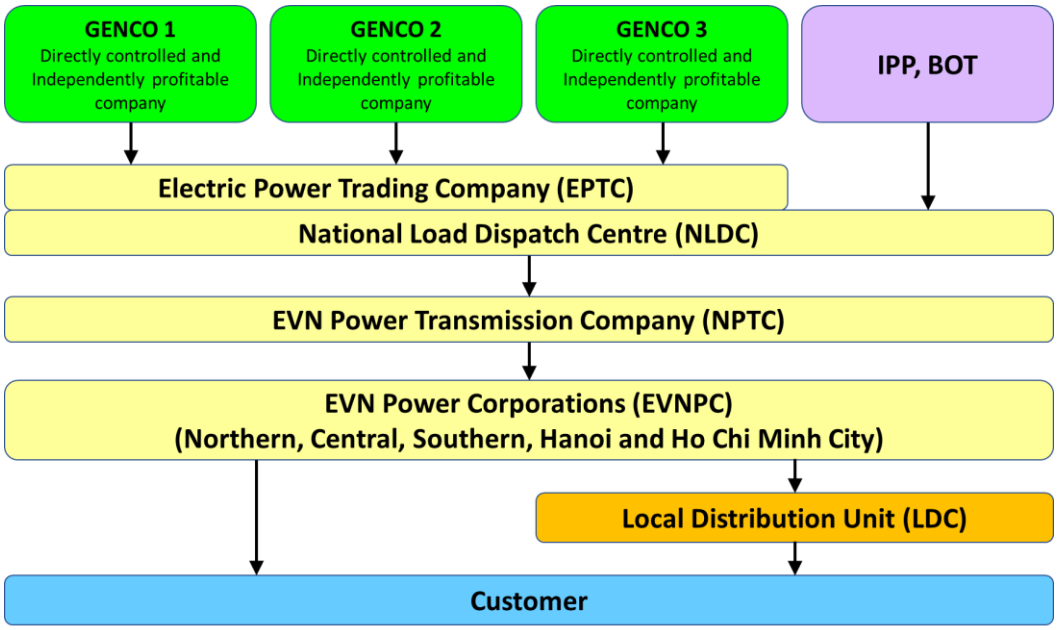
2.5.5.2 *Electric power utility*

The current electric power business in Viet Nam is divided into power generation, power system operation, transmission, distribution, and retail. Viet Nam Electricity (EVN) and its subsidiaries operate each electric power business. On the other hand, the power generation business is open to companies other than the EVN.

Electricity sector reform in Viet Nam began in 2005 following the promulgation of the Electricity Law of 2004 (No. 28/2004/QH11). The sector reform aimed to (i) meet the significant growth in power demand against the backdrop of economic growth and (ii) optimise electricity prices to appropriately allocate the necessary funds for maintaining and expanding the power grid.

In line with the progress of power sector reforms, the EVN integrated four regional transmission companies into one transmission company called the National Power Transmission Cooperation (NPT) in 2008. In the same year, the Electric Power Trading Company was established under the EVN as a single buyer in the electric power market. Then, the EVN was legally separated from the traditional vertically integrated company and was transformed into a holding company in 2009. In 2010, 11 regional power distribution companies were reorganised into five EVN subsidiaries. In 2012, three power generation companies (GENCO 1, 2, 3) were established.

Figure 2-36 Electricity Business Structure in Viet Nam

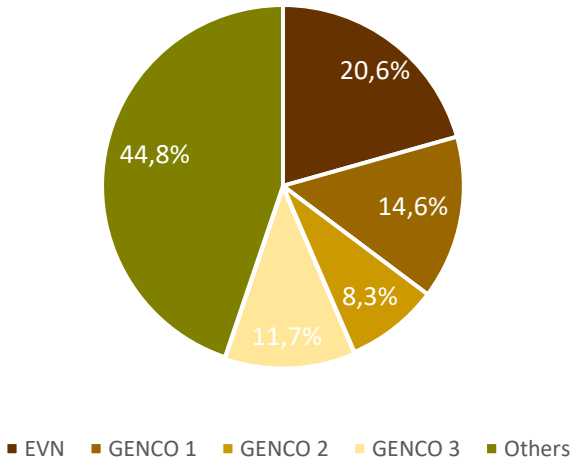


BOT = build-operate-transfer, GENCO – generation company, IPP = independent power producer.
Source: JEPIC, https://www.jepic.or.jp/data/asia06vtnm.html (accessed 8 February 2021).

1) Power generation company

Power generation companies in Viet Nam are broadly divided into the EVN, EVN subsidiaries, IPPs, and build-operate-transfer. GENCO 1, 2, and 3 spun off from the EVN in 2012 as an independently profitable company with 100% EVN. GENCO is assigned power plants owned by the EVN, except for those critical for energy policy. According to the EVN, the ratio of installed power generation capacity owned by the EVN Group is about 55% of Viet Nam's total (20.6% under direct control, 34.6% of GENCO), and about 45% of power plants of other companies such as IPPs. The installed capacity portfolio by company is shown in Figure 2-37.

Figure 2-37 Installed Capacity Portfolio, by Company (as of 2019)



EVN = Viet Nam Electricity, GENCO = generation company.
Source: EVN data, modified by the author.

2) Transmission company

The NPT is a 100% EVN independent profit company established in April 2008. It exclusively operates the power grid throughout Viet Nam. The NPT consists of four power transmission companies (PTCs) and three project management boards (PMBs), and supervises, operates, and maintains 220 kV–500 kV transmission networks. The Institute of Energy formulates the transmission development plan as part of the PDP. On the other hand, the corporate planning department of the EVNNPT reviews the reinforcement plan of 220 kV or more networks every year in cooperation with EVN's corporate planning department. Three NPT PMBs (Northern PMB, Central PMB, and Southern PMB) manage the construction work. The four NPT PTCs operate and maintain transmission equipment owned and operated by regional power companies.

3) Distribution and retail company

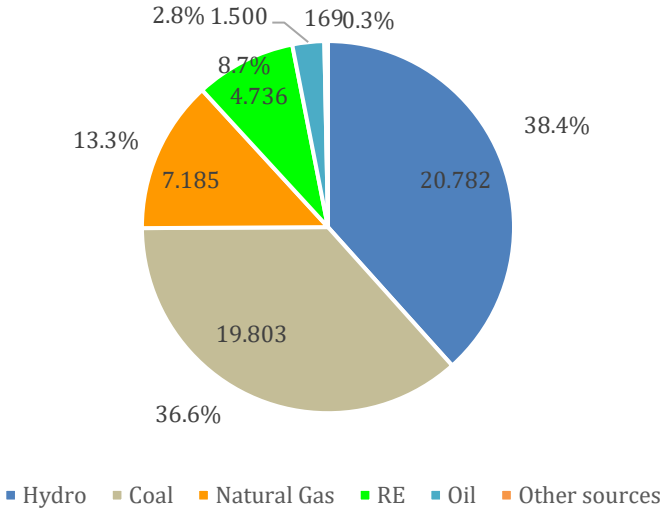
Power Corporation is an independently profitable company with 100% EVN, and is divided into five companies by operation and region. Its main business is planning and O&M of transmission and distribution equipment at 110 kV or less and electricity charge collection.

2.5.1 Power generation

As of 2019, the total installed capacity in Viet Nam was 54,175 MW. Figure 2-38 shows the country's installed capacity portfolio. Generation in Viet Nam relies on hydropower and coal-fired thermal power. The installed capacity of hydropower accounted for 38.4%. Next to hydropower was coal-fired, accounting for 36.6%.

The total installed capacity of renewable energy, including hydropower, was 25,518 MW, which accounted for 47.1%

Figure 2-38 Installed Capacity Portfolio in Viet Nam (as of 2019)

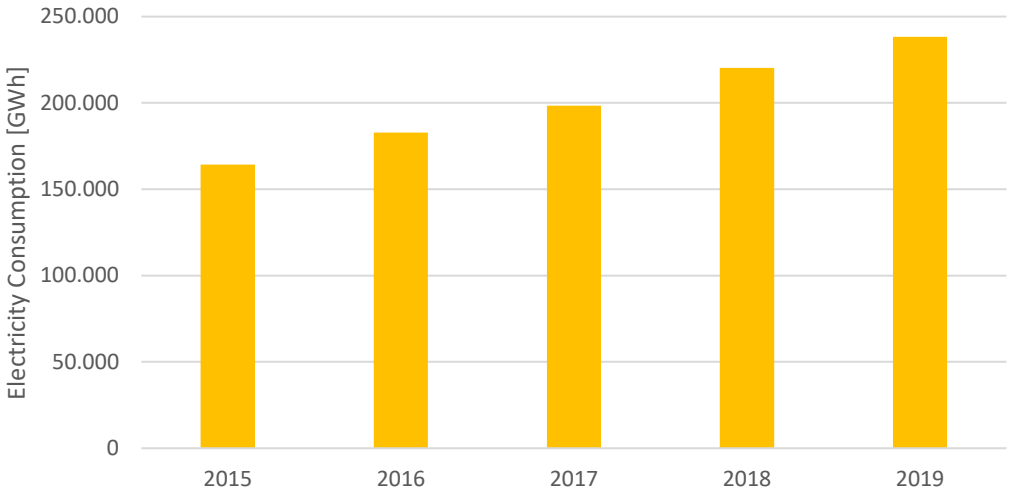


RE = renewable energy.
Source: EVN data, modified by the author.

2.5.2 Power demand

Figure 2-39 shows the changes in Viet Nam's electricity consumption, which was about 165,000 GWh in 2015. However, it steadily increased from 2015 and reached nearly 240,000 GWh in 2019. Thus, the electricity consumption growth rate from 2015 to 2019 was approximately 45.0%.

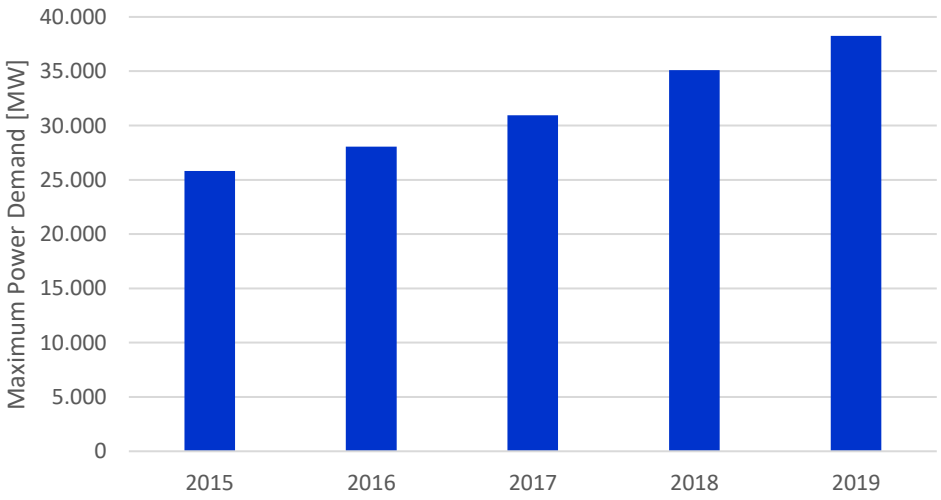
Figure 2-39 Changes in Electricity Consumption of Viet Nam



Source: EVN data, modified by the author.

Figure 2-40 shows the changes in maximum demand of the country, which in 2015 was 25,809 MW. It steadily increased from 2015 and reached 38,249 MW in 2019. The demand growth rate from 2015 to 2019 was approximately 48.2%.

Figure 2-40 Changes in Maximum Demand in Viet Nam



Source: EVN data, modified by the author.

2.5.3 Overview of the transmission network

The power system in Viet Nam has a 500 kV transmission system network from north to south due to the country's geographical characteristics. It operates at 500 kV, 220 kV, 110 kV, and medium and low voltage. The 500 kV and 220 kV networks are bulk power systems operated and maintained by the EVNNPT. Since hydropower stations are located in the northern and central parts of Viet Nam, the power flow of the 500 kV transmission network differs greatly between the wet season, when the hydropower output is large, and the dry season, when it is low. On the other hand, the distribution system, operated and maintained by five EVNPCs – Northern Power Corporation, Central Power Corporation, Southern Power Corporation, Hanoi Power Corporation, and Ho Chi Minh City Power Corporation – comprises 110 kV or less networks.

Figure 2-41 shows Viet Nam's power grid map. In addition, Tables 2-14 and 2-15 show the outline of the power system equipment owned by EVNNPT and EVNPCs.

Table 2-14 Outline of Power System Equipment Owned by EVNNPT

Item	Unit	Quantity
500 kV transmission lines	km	7,516
220 kV transmission lines	km	17,360
500 kV transformers	MVA	33,300
220 kV transformers	MVA	52,688

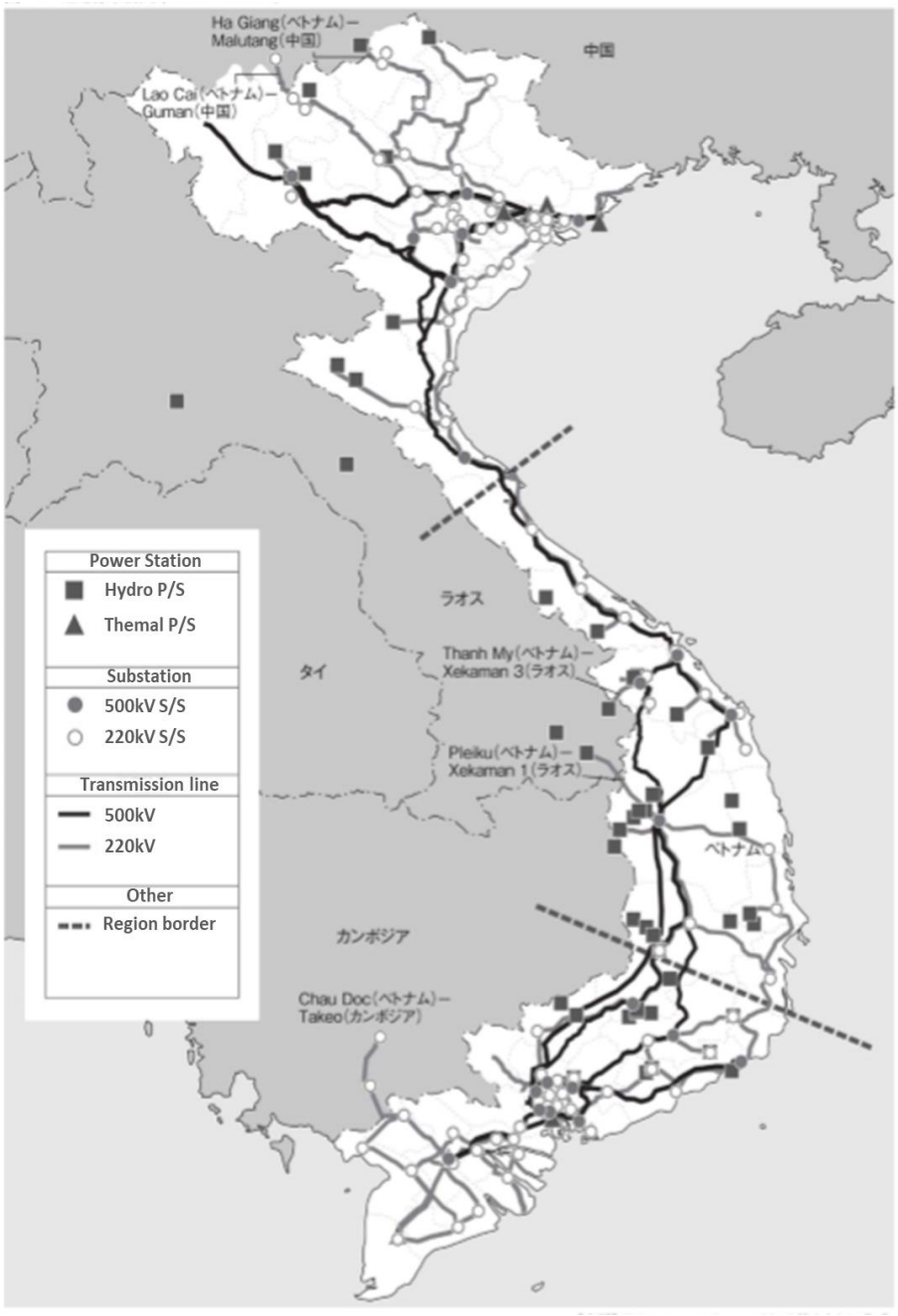
Source: EVN data, modified by the author.

Table 2-15 Outline of Power System Equipment Owned by EVNPC

Item	Unit	Quantity
220 kV distribution lines	km	110
110 kV distribution lines	km	19,628
Medium and low voltage distribution lines	km	491,777
220 kV transformers	MVA	4,250
110 kV transformers	MVA	53,415
Medium and low voltage transformers	MVA	48,147

Source: EVN data, modified by the author.

Figure 2-41 Power Grid Map of Viet Nam, at 500 kV and 220 kV (as of 2016)

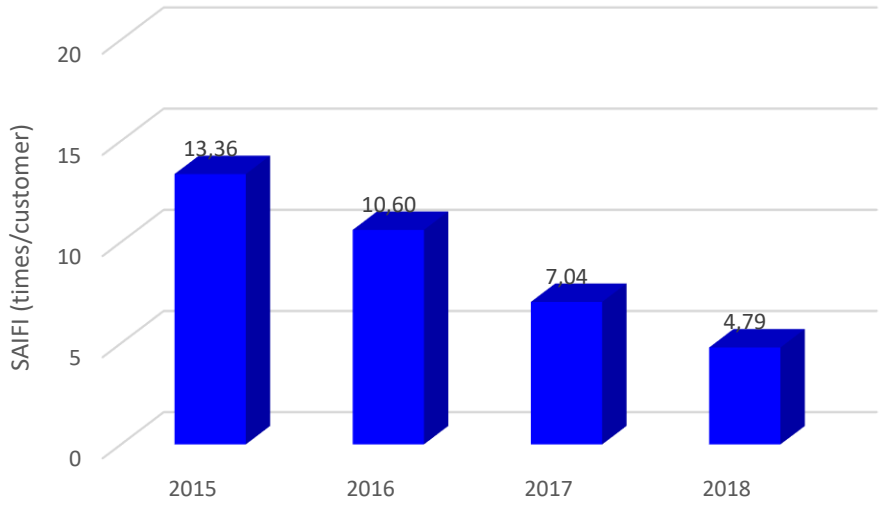


Source: JEPIC (2019).

2.5.4 Power system reliability

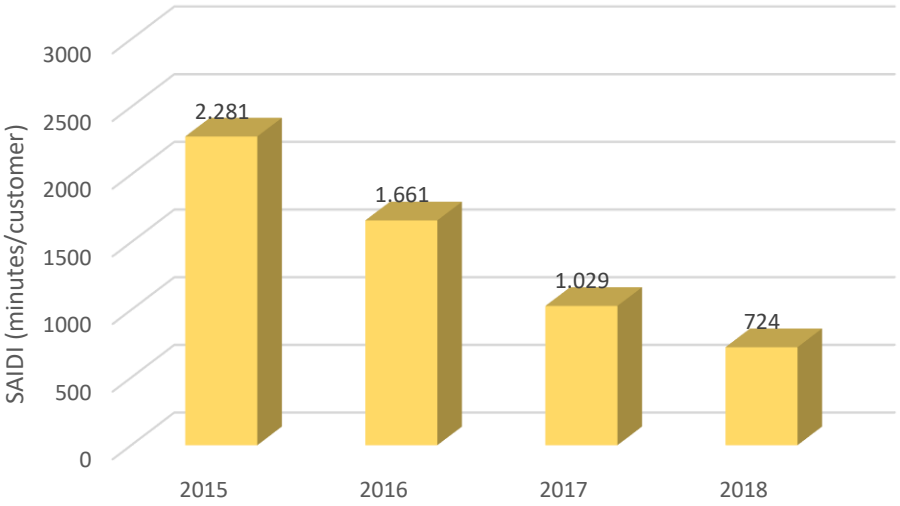
Figures 2-42 and 2-43 show changes in the country's SAIFI and SAIDI, respectively. The SAIFI in 2015 was 13.36 times. It steadily decreased from 2015 and was 4.79 times in 2018, about one-third of 2015. The SAIDI in 2015 was 2,281 minutes, steadily declined from 2015 and was 724 minutes in 2018, also about one-third of 2015. However, the SAIFI and SAIDI were still low than those of developing countries (ERIA, 2020).

Figure 2-42 Change in Viet Nam's SAIFI



SAIFI = System Average Interruption Frequency Index.
Source: EVN data, modified by the author.

Figure 2-43 Change in Viet Nam's SAIDI



SAIDI = System Average Interruption Duration Index.
Source: EVN data, modified by the author.

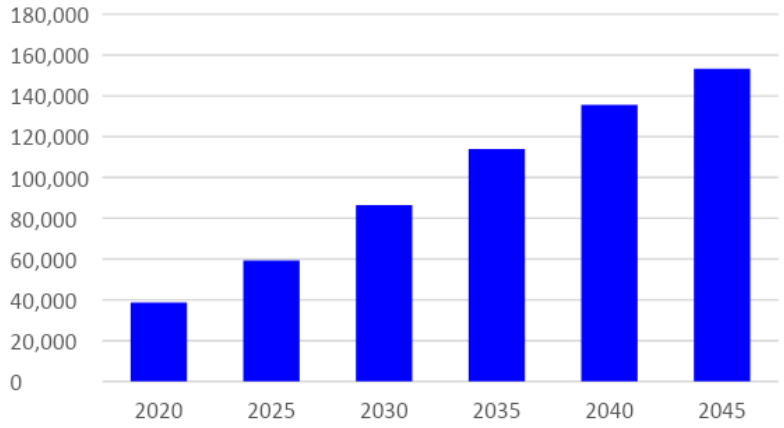
2.5.5 Overview of the power development plan

MOIT has been formulating the PDPs for many years. The latest version is PDP7 rev. The Prime Minister approved the adjustment of the National Power Development Master Plan for the Period 2011–2020 with the Vision to 2030. It strongly emphasised renewable energy development and power market liberalisation (ERIA, 2017c).

Now, MOIT is formulating the draft version of PDP8. According to Baker McKenzie[1], MOIT released the draft proposal for the national PDP for 2021–2030, with a vision to 2045 ("Draft PDP8") for public comments in February 2021. This is the third version of the draft.

The maximum power demand forecast of PDP8 is shown in Figure 2-44. The maximum power demand was 38,706 MW in 2020. It will gradually increase and reach 86,493 MW in 2030 and 135,596 MW in 2040.

Figure 2-44 Maximum Power Demand Forecast of PDP8



Source: Baker McKenzie, modified by the author.

Table 2-16 shows the proposed installed capacity of PDP8. From the breakdown of each power generation type, the capacity of all types will increase. On the other hand, as for the ratio of total capacity, coal and solar power will decrease, and gas and wind power will increase. Regarding thermal power, coal-fired is currently the mainstream, but gas will be the mainstream in the future. Since solar capacity skyrocketed in recent years and it was already 16,640 MW in 2020, the ratio of the total installed capacity will decrease in the future. In addition, the increase in wind power is particularly remarkable. In 2040, the ratio to total installed capacity will exceed hydropower and solar power and will be the third after thermal power. This also suggests that the wind power market in Viet Nam is huge.

❖ **Coal-fired thermal power plants**

The installed capacity of coal-fired power in 2020 was 20,431 MW, 29.5% of the total installed capacity. It will gradually rise and reach 37,323 MW in 2030 and 48,383 MW in 2040. However, the ratio of coal-fired thermal power will gradually decline to 27.1% in 2030 and 20.7% in 2040.

[1] Baker McKenzie is a multinational law firm headquartered in Chicago, Illinois. Founded in 1949 as Baker & McKenzie, it has 77 offices in 46 countries, and over 6,000 lawyers worldwide. It is one of the largest law firms in the world by headcount and revenue.

❖ **Gas-to-power**

The installed capacity of gas thermal in 2020 was 9,030 MW, 13.0% of the total installed capacity. It will gradually increase and reach 28,871 MW in 2030 and 55,704 MW in 2040. The ratio of gas will also gradually rise to 21.0% in 2030 and 23.8% in 2040.

❖ **Hydropower**

The installed capacity of hydropower in 2020 was 20,685 MW, 29.9% of the total installed capacity. It will gradually increase and reach 25,992 MW in 2030 and 55,704 MW in 2040. However, the ratio of hydropower will gradually decrease to 18.9% in 2030 and 13.4% in 2040.

❖ **Wind power**

The installed capacity of hydropower in 2020 was 630, 0.9% of the total installed capacity. It will skyrocket and reach 18,010 MW in 2030 and 45,910 MW in 2040. The ratio of wind power will also rise to 13.1% in 2030 and 19.6% in 2040.

❖ **Solar power**

The installed capacity of solar power in 2020 was 16,640, 24% of the total installed capacity. It will gradually increase and reach 18,640 MW in 2030 and 42,340 MW in 2040. However, the ratio of solar power will decrease to 13.5% in 2030 and 18.1% in 2040.

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Table 2-16 Proposed Installed Capacity of PDP8

Source	2020		2025		2030		2035		2040		2045	
	Capacity [MW]	Ratio	Capacity [MW]	Ratio	Capacity [MW]	Ratio	Capacity [MW]	Ratio	Capacity [MW]	Ratio	Capacity [MW]	Ratio
Coal-fired thermal power	20,431	29.5%	29,523	28.9%	37,323	27.1%	43,843	23.0%	48,383	20.7%	49,918	18.0%
Gas-to-power and oil/diesel - fired thermal power	9,030	13.0%	14,055	13.8%	28,871	21.0%	45,019	23.6%	55,704	23.8%	66,504	24.0%
Hydropower + pumped storage hydropower (including small-scale hydropower)	20,685	29.9%	24,497	24.0%	25,992	18.9%	29,592	15.5%	31,292	13.4%	33,492	12.1%
Wind power	630	0.9%	11,320	11.1%	18,010	13.1%	32,110	16.9%	45,910	19.6%	60,610	21.9%
Solar power	16,640	24.0%	17,240	16.9%	18,640	13.5%	30,290	15.9%	42,340	18.1%	55,090	19.9%
Biomass and other renewable power	570	0.8%	2,050	2.0%	3,150	2.3%	3,860	2.0%	4,510	1.9%	5,310	1.9%
Power import	1,272	1.8%	3,508	3.4%	5,677	4.1%	5,677	3.0%	5,677	2.4%	5,677	2.1%
Total	**69,258**	**100%**	**102,193**	**100%**	**137,663**	**100%**	**190,391**	**100%**	**233,816**	**100%**	**276,601**	**100%**

Source: Baker McKenzie, modified by the author.