CHAPTER 2

ELECTRICITY

2.1 Review of the current situation and selected major issues

This chapter focuses on Cambodia's basic electricity plan. The electricity plan of Cambodia has been conducted based on the National Strategic Development Plan (NSDP) 2014–2018.[1] The government focuses on (i) ensuring supply capacity, (ii) improving electrification, and (iii) reducing tariffs. The content has been concluded as follows.

2.1.1 Ensuring supply for the best energy mix

- Reduce reliance on petroleum fuels for electricity generation so supply capacity and diversified energy sources such as hydropower, natural gas, and coal are expanded.
- Hydropower and coal-fired power plants are broadly preferred along with the import of electricity from neighbouring countries.
- Invest in electricity generation infrastructure focusing on technical and economic efficiency and minimising the environmental and social impacts by the private sector, such as independent power producers (IPPs).
- Encourage the efficient use of energy and mitigate the adverse effects on the environment resulting from energy supply and use.

Outstanding issues

- The maximum electricity production from hydropower plants occurred only in the rainy season. In the dry season, the power production generated was only 25%.

[1] http://cdc-crdb.gov.kh/cdc/documents/NSDP_2014-2018.pdf

2.1.2 Improving electrification by expanding transmission and distribution networks

- To reduce electricity losses, transmission and distribution networks are expanded.
- To regionally expand economic cooperation, which maximises the use of resources in the region to achieve the most benefit, Cambodia has been participating in the implementation of a Greater Mekong Subregion (GMS) power trade plan and the ASEAN Power Grid plan.
- To strengthen energy security and ensure an efficient, safe, high-quality, reliable, and affordable electricity supply, all levels of the transmission and distribution networks are developed.
- Invest in transmission and distribution infrastructure focusing on technical and economic efficiency and minimising the environmental and social impacts by the private sector.

To realise the goal that 'by 2020, all villages in the Kingdom of Cambodia will have access to electricity supplied by the national grid and other sources', implementation of the electrification strategy is accelerated.

- Promote regional electricity trade through bilateral and multilateral cooperation.

Outstanding issues

- Due to the high costs required to build electricity infrastructure in numerous rural areas in Cambodia, the electricity supply in rural areas is limited as most areas are not yet connected to the grid.
- The expansion of distribution lines to rural areas is limited, and the unit cost remains relatively high compared to the unit cost in neighbouring countries.

2.1.3 Reducing tariffs to make them more affordable

- Further support the rural electrification fund aimed at acquiring equitable electricity access for all citizens through government funding and social funding by Electricite Du Cambodge (EDC), and seek funding support from other development partners.
- Pursue rational measures for electricity consumption by reducing power tariffs during off-peak hours to serve production and irrigation systems aimed at improving agricultural productivity and accelerating the development of industry and handicraft sectors.

- Maximise revenue inflows through multi-layered revenues such as royalties, production sharing, and income tax to increase the government's financial capacity.
- Reduce tariffs to an appropriate level in the whole country.

Outstanding issues

- Electricity tariffs in rural areas are higher than in urban areas.
- The tariff cost is relatively high compared to the tariff cost in neighbouring countries.

To solve the above outstanding issues, this chapter reviews the current situation, describes the targets for 2030, and considers the necessary policies with a roadmap.

2.2 Generation

2.2.1 Targets by 2030

According to the Ministry of Mines and Energy's (MME) generation development plan for 2017–2030 (Table 2.1) and the forecasted demand by the Economic Research Institute for ASEAN and East Asia's (ERIA) outlook in Chapters 1 and 6, this section describes two cases, Case 1 (Power Development Plan [PDP]) and Case 2 (ERIA_BAU), for the targets by 2030 in regard to power generation calculated using the power generation capacity and several conditions, such as the capacity factor and the loss of transmission and distribution lines.

Case 1 focuses on the relationship between the existing PDP of the MME and forecasted demand (outlook by ERIA). Case 2 is an aggressive pattern that includes the maximal use of solar/wind and biomass power and mainly hydro potential, which is estimated at about 10,000 megawatts (MW) by the hydroelectricity department of the MME.

Table 2.2 presents the revised capacity in the aggressive case (Case 2). In this case, hydro, biomass, and solar/wind capacity will increase by approximately 350 MW/year (3,526 MW/10 years), 30 MW/year (301 MW/10 years), and 36 MW/year (368 MW/10 years), respectively, compared with Case 1 from 2021 to 2030. In order to achieve the best mix in 2030, the coal/gas capacity will decrease by approximately 130 MW/year (–1,317 MW) compared to Case 1 from 2021 to 2030.

Table 2.1 Power Generation Development Plan

No.	Project name	Type	Capacity (MW)	Year	Company
1	Coal Power Plant I-2	Coal	135	2017	CIIDG ERDOS HONGJUN Electric Power Co., Ltd.
2	Sesan II lower	Hydro	400	2018	Hydro Power Lower Se San 2 Co., Ltd.
3	Coal Power Plant	Coal	135	2019	Cambodia Energy Limited (CEL II)
4	Coal Power Plant II-2	Coal	200-250	2020	Cambodia International Investment Development Group (CIIDG)
5	Coal Power Plant II-3	Coal	200-250	2021	Cambodia International Investment Development Group (CIIDG)
6	Coal Power Plant IIII-1	Coal	350	2022	Royal Group Co., Ltd.
7	Stung Sala mum Thun	Hydro	70	2022	
8	Middle Stung Russey Chrum	Hydro	70	2022	China Huadian Lower Stung Russey Chrum Hydro-Electric Project (Cambodia) Co., Ltd.
9	Veal thmor kambot	Hydro	100	2022	
10	Prek Liang	Hydro	120	2022	Asia Ecoenergy Development Ltd.
11	Coal Power Plant IIII-2	Coal	350	2023	Royal Group Co., Ltd.
12	Stung Battambang II	Hydro	36	2023	Stung Battambang II Hydro Power Plant
13	Stung Pursat I	Hydro	40	2023	Stung Pursat I Hydro Power Plant
14	Sambor (Step 1)	Hydro	600	2025	Sambor Hydro Power Plant
15	Sambor (Step 2)	Hydro	600	2026	Sambor Hydro Power Plant
16	Coal Power Plant V	Coal	300	2026	
17	Sambor (Step 3)	Hydro	600	2027	Sambor Hydro Power Plant
18	Coal Power Plant VI	Coal	300	2027	
19	Coal Power Plant VII	Coal	300	2028	
20	Coal Power Plant VIII	Coal	300	2029	
21	Lower Sesan I	Hydro	96	2029	
22	Coal Power Plant VIIII	Coal	300	2030	

Total Capacity in 2030
- Coal/gas: 2,373 MW
- Oil: 251 MW
- Hydro: 1,602 MW
- Biomass: 185 MW
- Solar/wind: 305 MW

Source: Electricite Du Cambodge (2016).

Table 2.2 Aggressive Generation Development Plan (revised existing plan)

No.	Type	Capacity (MW)	Year	Total in 2030 (MW)
1	Coal/gas	-1,317	2021–2030: /10 years	1,056
2	Hydro	+3,526	2021–2030: /10 years	5,127
3	Biomass	+301	2031–2030: /10 years	486
4	Solar/wind	+368	2031–2030: /10 years	673

Source: Author (outcome of the dialogue with the Ministry of Mines and Energy).

Case descriptions

Common condition: Case 1 and Case 2

- Demand is the same as in the outlook by ERIA (Table 2.5)
- Supply (including loss) + import = demand (outlook by ERIA)
- Import: The constant amount of electricity imported from 2020 to 2030 (Table 2.5) Demand = national capacity + electricity imported
- Oil: Gradually reduced high cost as an impact of no oil use from 2020

Case 1: Existing PDP (2017–2030)

- Capacity: Planned capacity mentioned in the power generation development plan, covering the years from 2017 to 2030 (Table 2.1)
- Loss: 10% of the total national power supply is transmission and distribution losses.
- Capacity factor: Coal/gas (85%), oil (85%), hydro (35%), biomass (40%), solar (15%), wind (20%). The capacity factor of hydro plants in the dry season is 35%. In order to ensure essential power generation, the percentage is completely used in the whole year.
- Required import supply: Calculated according to demand – supply. A negative value for imports reflects an excess of electricity power supply in a year and encourages electricity exports or a reduction of electricity generation, while a positive value of imports reflects the need for imported electricity.

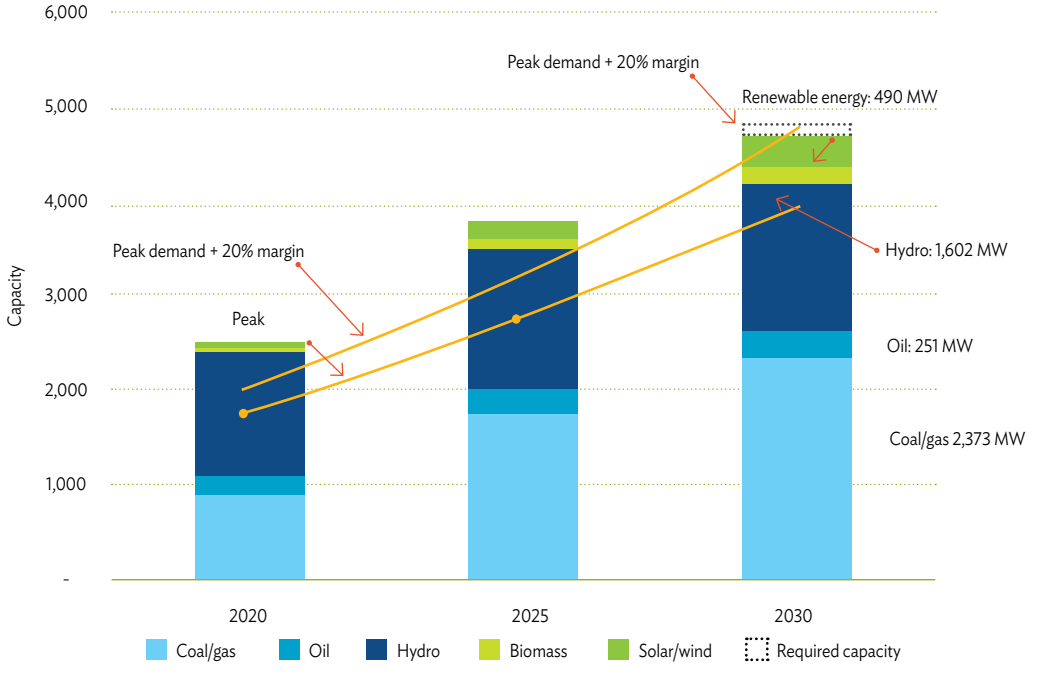
Table 2.3 and Figure 2.1 show the power generation capacity in Case 1. Referring to the existing plan by 2030, a lack of peak capacity will occur in 2030 and peak with a +20% margin in 2030 using estimated data on 2020 and 2025 using the linear extrapolation method. Therefore, this case roughly indicates the capacity needed by 2030 if the current plan is implemented by 2030. Imported electricity is not included in this data, but it is surely an aspect to be considered in the power supply calculation.

Table 2.3 Power Generation Capacity in Case 1

Capacity (MW)\year	2020	2025	2030
Coal/gas	873	1,773	2,373
Oil	251	251	251
Hydro	1,330	1,506	1,602
Renewable energy (biomass, solar, wind)	72	281	490
Total capacity	2,526	3,811	4,716
Peak demand +20% margin	2,017	3,214	4,776
Required capacity	0	0	60

Source: Electricite Du Cambodge (2016).

Figure 2.1 Power Generation Capacity in Case 1



Source: Electricite Du Cambodge (2016).

Case 2: Recommended pattern

- Power supply: The total amount of the power supply is the same as in the current generation development plan from 2017 to 2030.
- Additional capacity (2021 to 2030): Consider only hydro and renewable energy (RE) (biomass, solar/wind) in terms of reducing the use of fossil fuels.
- Loss: 10% of the total national power supply is transmission and distribution losses.
- Capacity factor: Coal/gas (85%), oil (85%), hydro (35%), biomass (40%), solar (15%), wind (20%). The capacity factor of hydro plants in the dry season is 35%. In order to ensure essential power generation, the percentage is completely used in a whole year.
- Required import supply: Calculated according to demand – supply. A negative value for imports reflects an excess of electricity power supply in a year and encourages electricity exports or a reduction of electricity generation, while a positive value of imports reflects the need for imported electricity.
- Oil: Gradually reduced as an impact of no oil use from 2020.
- Import: Gradually reduced as an impact of no imports from 2022.

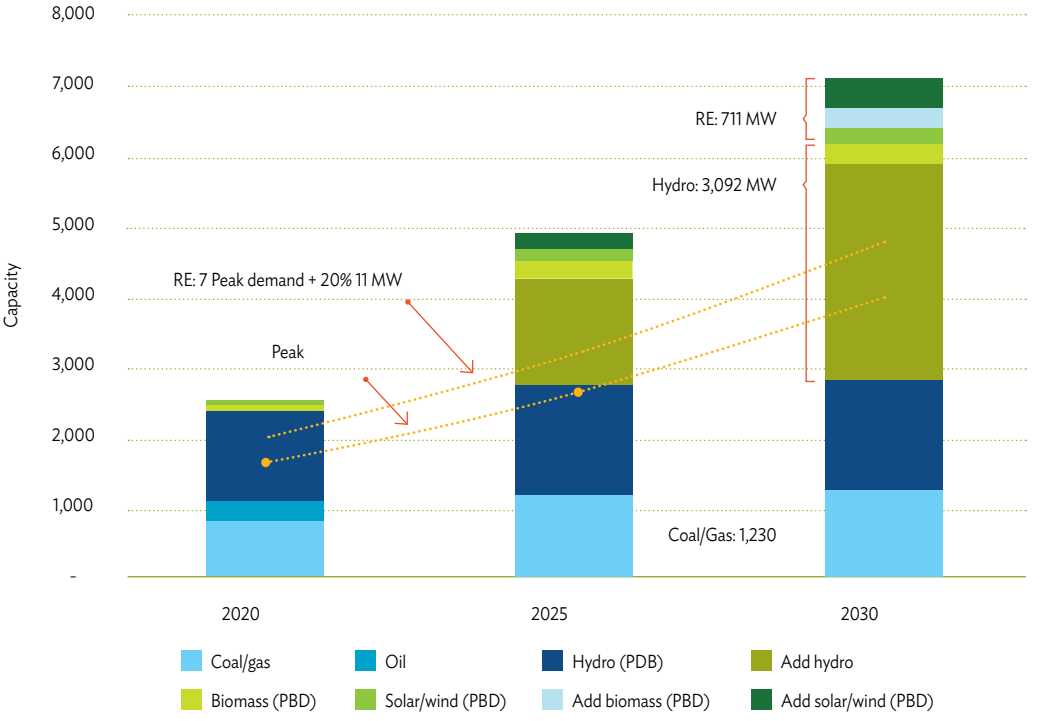
Table 2.4 and Figure 2.2 show the power generation capacity in Case 2. Since constructing new generation capacity requires time, this case only considers additional hydro and RE capacity from 2021 and 2030, respectively. These capacities are also presented in Table 2.2. The total capacity of the current PDP is 4,716 MW in 2030, but the total capacity of the revised plan is 7,081 MW due to a difference in the capacity factor between coal/gas (85%) and hydro (35%). Therefore, if the energy mix is prioritised towards hydro and RE, increased total capacity will be required. In this case, the total capacity is over the peak demand with a +20% margin each year without electricity imports. The figure shows there will be capacity access shown above the dotted line for peak demand with a +20% margin, which benefits operators by having the best-chosen electricity resource, resulting in some long-term economic advantages such as affordable electricity prices, sustainable supply, and high security. To attain these advantages, Cambodia must consider not only power capacity planning but also transmission and distribution planning throughout the country. In the case of electricity exports, enhancement of the interconnection plan is needed.

Table 2.4 Generation Capacity in Case 2

Capacity (MW)\year	2020	2025	2030
Coal/gas	873	1,230	1,230
Oil	251	0	0
Hydro	1,330	3,012	4,694
Renewable energy (biomass)	0	243	485
Renewable energy (solar/wind)	72	372	672
Total capacity	2,526	4,856	7,081
Peak demand +20% margin	2,017	3,214	4,776
Required capacity	0	0	0

Source: Author (outcome of the dialogue with the Ministry of Mines and Energy).

Figure 2.2 Power Generation Capacity in Case 2



RE = renewable energy.

Source: Author (outcome of the dialogue with the Ministry of Mines and Energy).

We consider the energy mix based on the above conditions. Table 2.5 shows the summarised pattern of the power generation plan by 2030. Demand uses the basic plan from the outlook by ERIA as a reference.

Figure 2.3(a) shows the power supply mix and electricity demand in Case 1 for the current existing plan. The dependency on fossil fuels will increase towards 2030 due to the massive use of coal/gas power plants. The percentage in the energy mix will be 68% in 2030. To reach the power demand of 19.7 terawatt hours (TWh) using a controllable supply consisting of coal/gas, hydro, and RE, this percentage will increase to a minimum of 70%, which is also a high percentage for fossil fuel dependency. Therefore, the current plan by 2030 has high potential fossil fuel dependency as fossil fuels are a major energy source in the world today. On the other hand, the overconsumption of fossil fuels can lead to serious environmental issues such as air pollution and global warming. What is more, as this resource is limited, prices will possibly change drastically. Hence, the higher dependency on fossil fuels will result in higher potential risk.

Based on Case 1, we consider a recommended Basic Energy Plan for Cambodia (BEPC) pattern for Case 2. Figure 2.3(b) shows the power supply mix in Case 2. The total supply is the same as in Case 1 (26.2 TWh). In order to reduce fossil fuel dependency, hydro and RE capacity are increased. In 2030, the energy mix of fossil fuels will be 35%.

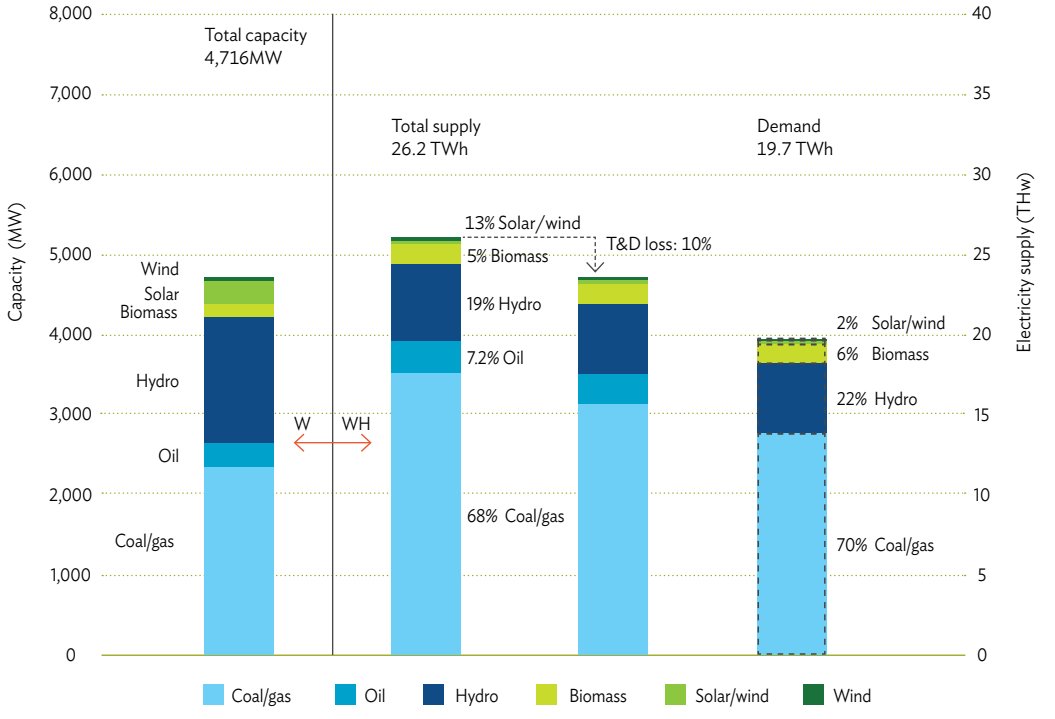
Table 2.5 Summarised Pattern of the Power Generation Plan

Case	Year	2020	2025	2030
	Demand (TWh), BAU outlook by ERIA	**11.8**	**15.0**	**19.7**
Case1 Existing plan (2017–2030)	Planned power supply (TWh)	12.5	20.4	26.2
	T&D loss (10%) (TWh)	-1.2	-2.0	-2.6
	Available power supply (TWh)	11.2	18.3	23.6
	Required import supply (TWh) (demand – available supply)	0.6	-3.3	-3.8
	Energy mix (%) at a maximum			
	- Coal/gas	52.2	64.8	67.5
	- Oil	15.0	9.2	7.2
	- Hydro	32.7	22.7	18.8
	- RE (biomass)	0.0	3.2	5.0
	- RE (solar, wind)	0.1	0.1	1.6
Case 2 Aggressive pattern (reduce imports, improve hydro and RE)	Estimated power supply (TWh)	11.6	19.1	26.2
	T&D loss (10%) (TWh)	1.2	-1.9	-2.6
	Available power supply (TWh)	10.5	17.2	23.6
	Required import supply (TWh) (demand – supply)	1.3	-2.2	-3.8
	Energy mix (%) at a maximum			
	- Coal/gas	56.0	46.4	35.0
	- Oil	8.1	0.0	0.0
	- Hydro	35.1	46.8	55.0
	- RE (biomass)	0.0	4.3	6.5
	- RE (solar, wind)	0.7	2.2	3.5

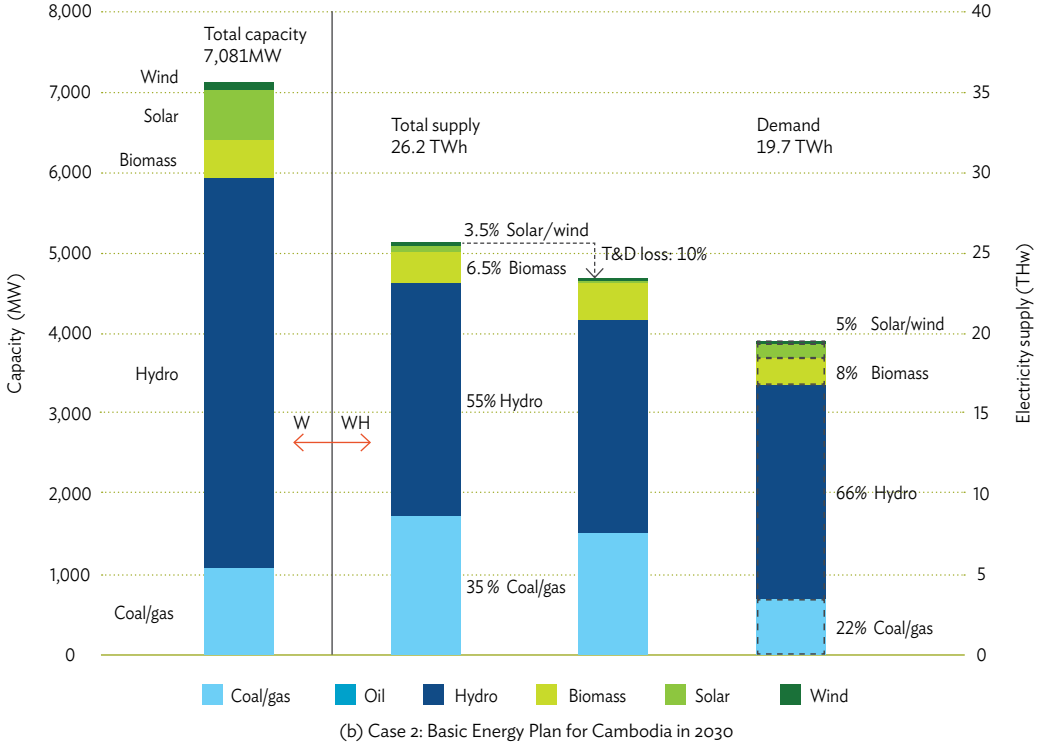
BAU = business as usual, RE = renewable energy, T&D = transmission and distribution, TWh = terrawatt hour.

Source: Electricite Du Cambodge (2016).

Figure 2.3 Power Development Plan and Basic Energy Plan for Cambodia in 2030



(a) Case 1: Power Development Plan in 2030



(b) Case 2: Basic Energy Plan for Cambodia in 2030

MW = megawatt, T&D = transmission and distribution, TWh = terrawatt hour.

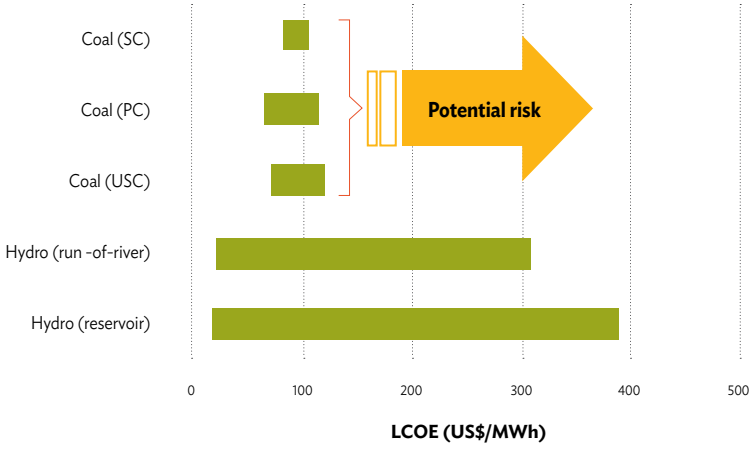
Source: Electricite Du Cambodge (2016) and author (outcome of the dialogue with the Ministry of Mines and Energy).

The reasons for the additional hydropower plant capacity are the following:

- To minimise the potential risk from the coal price
- To improve energy security
- To reduce the environmental impacts (air pollution, global warming)

Figure 2.4 shows the levelised cost of electricity (LCOE) for generating plants in 14 Organisation for Economic Co-operation and Development (OECD) countries plus Brazil, China, and South Africa. The LCOE of coal is relatively lower than for hydropower plants. However, the LCOE of hydro varies widely between US$15/MWh and US$388/MWh as the LCOE of hydropower is strongly correlated with the investment cost (Figure 2.5). Figure 2.6 shows the LCOE component ratios of coal and hydro. The LCOE for hydro contains an 85% investment cost. On the other hand, the LCOE component ratios for coal are 28% investment costs, 35% fuel costs, 27% carbon costs, and 10% operation and maintenance costs. Therefore, there is a possibility that the LCOE costs will be higher than for hydro due to an increase in the imported coal price in the future. Figure 2.7 shows the historical coal price change from 1998 to 2008 in the US, Japan, and northwest Europe. The annual coal prices in 2008 increased drastically by about 3.6–5.2 times from 1998. Where profitability is defined as revenues minus long-run operating costs, the Carbon Tracker Initiative's analysis finds that due to high fuel costs, 42% of coal capacity operating today could be losing money in the world.[2] Therefore, the higher dependency on fossil fuels, in this case coal, resulted in a higher risk potential, including the electricity price.

Figure 2.4 Levelised Cost of Electricity of Coal and Hydro in 2015



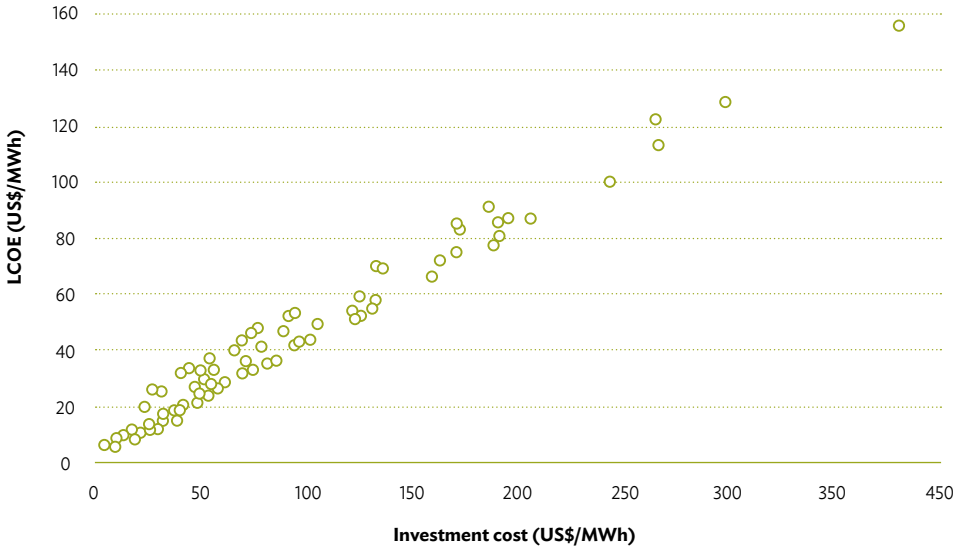
LCOE = levelised cost of electricity, SC = supercritical coal-fired, PC = pulverised coal-fired, USC = ultra-supercritical coal-fired.

Note: Includes 14 OECD countries (Austria, Belgium, Germany, Italy, Japan, the Republic of Korea, the Netherlands, New Zealand, Portugal, Spain, Switzerland, Turkey, the United Kingdom, and the United States) and three non-OECD countries (Brazil, China, and South Africa).

Source: IEA, NEA, and OECD (2015), https://www.oecd-nea.org/ndd/pubs/2015/7057-proj-costs-electricity-2015.pdf.

2 https://www.carbontracker.org/reports/coal-portal/

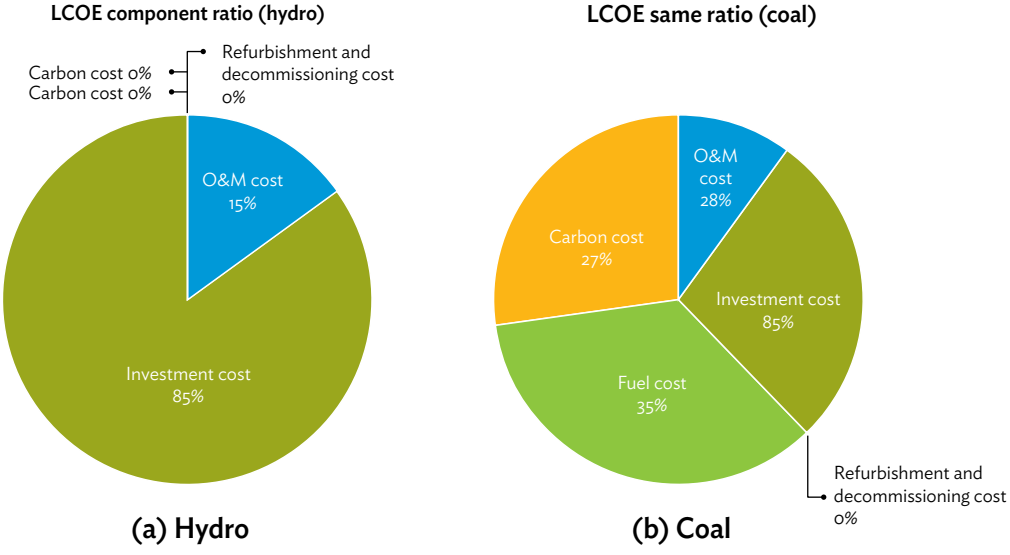
Figure 2.5 Comparison of the Levelised Cost of Electricity with the Investment Cost (hydro)



LCOE = levelised cost of electricity, MWh = megawatt hour.

Source: IEA, NEA, and OECD (2015), https://www.oecd-nea.org/ndd/pubs/2015/7057-proj-costs-electricity-2015.pdf.

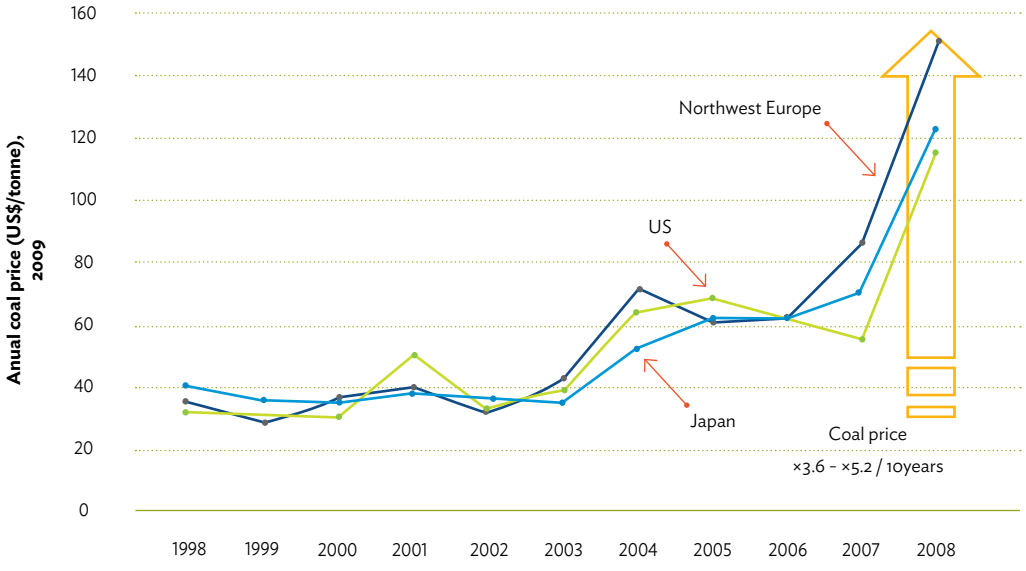
Figure 2.6 Levelised Cost of Electricity Component Ratios for Coal and Hydro in 2015



LCOE = levelised cost of electricity, O&M = operation and maintenance.

Source: IEA, NEA, and OECD (2015), https://www.oecd-nea.org/ndd/pubs/2015/7057-proj-costs-electricity-2015.pdf.

Figure 2.7 Historical Coal Price Change from 1998 to 2008



Source: Breeze, P. (2010), http://lab.fs.uni-lj.si/kes/erasmus/The%20Cost%20of%20Power%20Generation.pdf.

Cambodia relies on imported fossil fuels, including coal. The lack of energy security is linked to the negative economic and social impacts of either the physical unavailability of energy or prices that are not competitive or are overly volatile. Details on energy security are described in Chapter 5.

The conventional coal-fired plants generally used in Cambodia generate some significant disadvantages, including greenhouse gas (GHG) emissions, mining destruction, the generation of millions of tonnes of waste, and the emission of harmful substances. The greater the number of constructed conventional coal-fired plants, the greater the negative impact on the environment. GHG emissions are the result of harmful waste from the combustion of coal, which causes pollution and contributes to global warming. The increase in carbon emissions by coal-fired plants has led to further global warming, which has an impact on climate change. Thermal plants like coal-fired plants emit harmful substances into the environment. These include mercury, sulphur dioxide, carbon monoxide, mercury, selenium, and arsenic. These harmful substances not only cause acid rain but are also very harmful to humans. To mitigate the situation, clean coal technology, such as ultra-supercritical (USC), integrated gasification combined cycle (IGCC), and carbon capture and storage (CCS), will be needed when Cambodia plans new coal power plants.

The targets by 2030 are summarised as follows.

Targets by 2030

- Basic energy mix: Coal/gas (35%), hydro (55%), RE (biomass, solar, and wind) (10%)
- Export electricity to neighbouring country.
- Improve the utilisation of diverse energy sources.

2.2.2 Necessary action plans and policies

The necessary action plans and policies to reach the targets by 2030 are described here. To achieve the targets by 2030, additional capacity is required of approximately 3,000 MW by hydro plants, 300 MW by biomass plants, and 400 MW by solar/wind plants by 2030. However, there will be several challenges in implementation due to the high initial costs, the balance of the environment, and the significant impact of the dry season. In consideration of these challenges, the 'best energy mix' is an alternative solution.

To achieve the target of the best energy mix, the following are necessary:

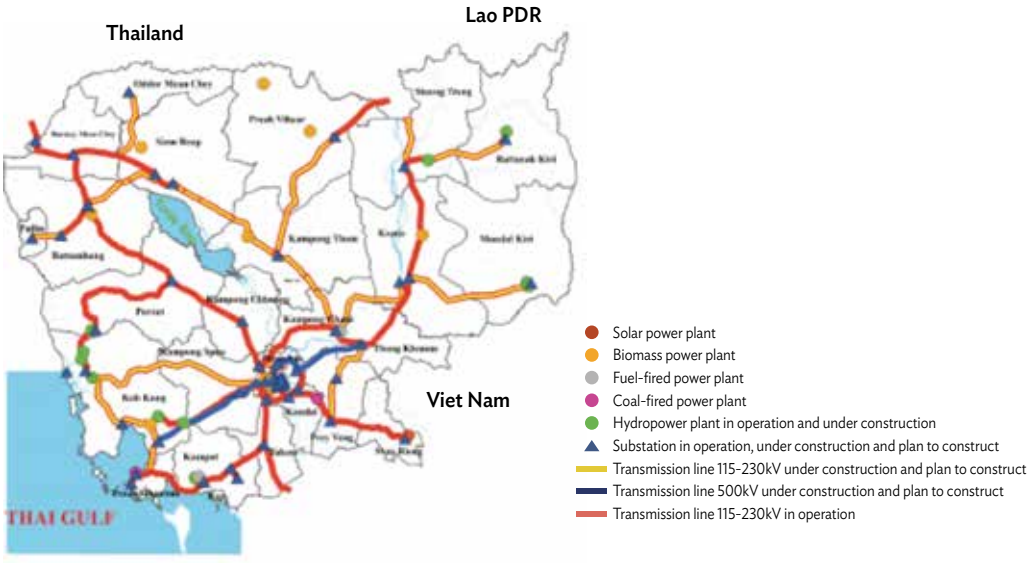
- Massive utilisation of hydro and RE potential
- Application of clean coal technology (USC, IGCC, CCS)
- Conducting power trading (exports and imports) through the GMS and the ASEAN Power Grid (APG)
- Utilisation of domestic gas potential

According to the necessary action plans and policies, it is recommended that the electricity of the BEPC be reviewed on a routine basis (every 2–5 years). The electricity of the BEPC with the best energy mix should be modified as needed.

2.3 Transmission

The national grid consists of three main components: high voltage (HV) substations, HV transmission lines, and the dispatching centre. The development of the national grid has three main objectives: (i) provide the opportunity to develop and integrate all power sources in the country into one grid system, (ii) expand the substations and transmission lines to provide electricity to cities and provinces throughout the country, and (iii) manage and control the operation of power sources to provide electricity to all areas efficiently, sustainably, and safely. The goal of national grid development by 2020 is shown in Figure 2.8. The national transmission master plan of 2016 is presented in Tables 2.6 to 2.8.

Figure 2.8 Goal of National Grid Development by 2020



Source: Electricity Authority of Cambodia (n.d.).

Table 2.6 National Transmission Master Plan (115 kV)

No.	115 kV transmission line	Length (km)	Year	Development partner
1	GS2 – GS Hunsen Park and Grid Substation	5	2017	BT
2	GS7 (SPP) – GS Prey Veng – GS Bavet	160	2017	CEIB
3	Laos Border to GS Preah Vihear	60	2017	CEIB
4	GS Battambong – GS Pailin	80	2017	EDC
5	GS3 – GS Toul Kork	5	2017	EDC
6	GS5 – GS Chroy Changvar	18	2017	Remain from Phnom Penh Loop Line project (CEIB)
7	GS Kampong Cham – GS Praek Prosab (Kratie)	91	2018	AFD
8	GS Svay Antor – GS Prey Veng	46	2018	CEIB
9	GS Preah Sihanouk – GS Ream	12	2018	CEIB
10	GS Ream – GS Chamkar Loung	60	2018	LDP
11	GS Chamkar Loung – Kiriom III Hydro Power	27	2018	LDP
12	GS Kampong Thom – GS Preah Vihear	140	2018	CEIB
13	GS Krolanh – GS Oddar Meanchey	80	2018	LDP
14	Underground Line from GS1 – GS EDC HQ – Stadium – NCC – GS3	14	2019	JICA Phase 1
15	GS Praek Prosab – GS Kratie	30	2021	LDP
	Total	**828 km**		

AFD = Agence Française de Développement, BT = build and transfer, CEIB = Cambodian Export-Import Bank, EDC = Electricite du Cambodge, JICA = Japan International Cooperation Agency, LDP = looking for development partner.

Source: Electricite Du Cambodge (2016).

Table 2.7 National Transmission Master Plan (230 kV)

No.	230 kV transmission line	Length (km)	Year	Development partner
1	GS Kampong Cham – GS Kratie	125	2017	BOT
2	GS Kratie – GS Stung Treng	115	2017	IEB
3	GS Stung Treng – Lwer Sesan II	26	2017	BOT
4	GS Battambang – East Siem Reap – Kampong Thom – Kampong Cham	350	2018	CEIB
5	Phnom Penh Loop Line Phase 2 (NPP – Chroy Changvar – EPP - NPP)	96	2018	CEIB
6	Tatay Hydropower – Phnom Penh	182	2018	BOT
7	GS Koh Kong – GS Koh Kong City	20	2018	AFD
8	GS Chamkar Loung – GS Botumsakor	54	2018	AFD
9	GS Botumsakor – Tatay Hydropower	70	2018	LDP
10	GS Kratie – GS Mondulkiri	170	2019	CEIB
11	GS Ratanakiri – GS Stung Treng	120	2019	CEIB
12	GS Stung Treng – Laos Border	48	2019	LDP
13	GS Beak Chan – GS5 – NCC	20	2020	JICA Phase II
14	GS Tropang Prasat – GS Siem Reap	30	2021	BOT
	GS Tropang Prasat – GS Siem Reap	**1,426 km**		

BOT = build, operate, and transfer, IEB = India Exim Bank.

Source: Electricite Du Cambodge (2016).

Table 2.8 National Transmission Master Plan (500 kV)

No.	500 kV transmission line	Length (km)	Year	Development partner
1	Phnom Penh – Preah Sihanouk	198	2019	BOT
2	Phnom Penh – Soung	96	2021	LDP
3	Soung – Sambo – Stung Treng	-	2025	LDP
	Total	**294 km**		

Source: Electricite Du Cambodge (2016).

2.3.1 Targets by 2030

2.3.1.1 National grid expansion

The HV transmission system, i.e., the 'national grid', will gradually establish grid substations in each district to provide outlets for supplying electricity from the national grid. The grid substations are to be located in the central area of each province to facilitate the development of a sub-transmission system to transmit electricity from the national grid to rural areas. The projects for the expansion of the electricity supply from the national grid and from networks importing electricity from neighbouring countries to the rural areas are to be implemented as the first priority, as they will provide a higher quality and less expensive electricity supply compared to the supply from the existing diesel generators. On the other hand, sudden expansion of the power transmission and distribution network may easily cause electricity shortages for the entire national grid, especially in the dry season. This naturally requires a secure, continuous supply. The current choice in which the power source completely depends on IPP and imports is not necessarily the only way to avoid an intermittent electricity supply from the energy security point of view, yet it should be one of the effective options in the process of promoting electrification. From the above, the direction to preferentially consolidate the transmission and distribution network can be regarded as reasonable.

2.3.1.2 Interconnection line with neighbouring countries

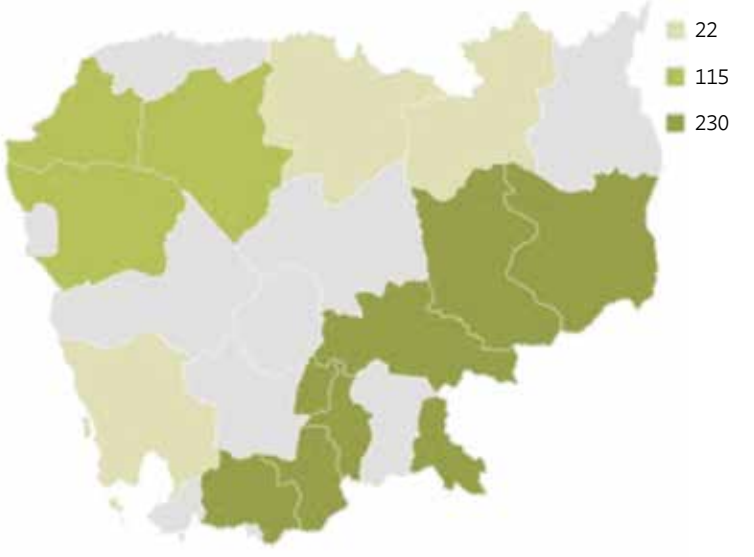
In 2016, Cambodia connected regional countries via several transmission lines.[3] The importing of electricity from Thailand, Viet Nam, and the Lao PDR started at the end of 2007, in 2009, and 2010, respectively. Electric power between Cambodia and Thailand is transmitted at the 115 kV and 22 kV levels. The 115 kV transmission line from Aranya Prathet substation, connecting Thailand to Banteay Meanchey, Battambang, and Siem Reap, was commissioned in 2007. An agreement was signed with Trat Province (Thailand) to supply power to Koh Kong Province and Poi Pet via the 22 kV line. EDC imported power from Viet Nam via a 230 kV transmission line to supply Phnom Den, Takeo Province, and Phnom Penh in March 2009. Since 2002, EDC has imported power from PC2 (Viet Nam) to supply power to Memut and Pnhea Krek Districts of Kampong Cham Province, Bavet in Svay Rieng Province, Kampong Trach in Kampot Province, Koh Thom and Chrey Thom in Kandal Province, Snuol District in Kratie Province, Keo Seima District in Mondulkiri

[3] http://lab.fs.uni-lj.si/kes/erasmus/The%20Cost%20of%20Power%20Generation.pdf

Province, and Kompong Ro in Svay Rieng Province. The 22 kV interconnection line from the Lao PDR to Stung Treng was charged in 2010. In 2015, a new interconnection point from Champasak Province, Ban Hat Substation, Lao PDR, to Kampong Sralu, Preah Vihear Province, Cambodia, was created and the initial design and construction for the 115 kV transmission line was energised at the 22 kV voltage level for the first stage until the transmission line from the Lao PDR border to Chey Sen Substation was completed.

Figure 2.9 shows the areas of electricity imports from neighbouring countries. Each connection between countries has a different grid standard (voltage control or frequency control, etc.) due to the different demand in each area. Therefore, to connect to the national grid and start multilateral trading, harmonisation of the grid standard is needed.

Figure 2.9 Power Installed in Provinces via Several Voltage Interconnections from Neighbouring Countries



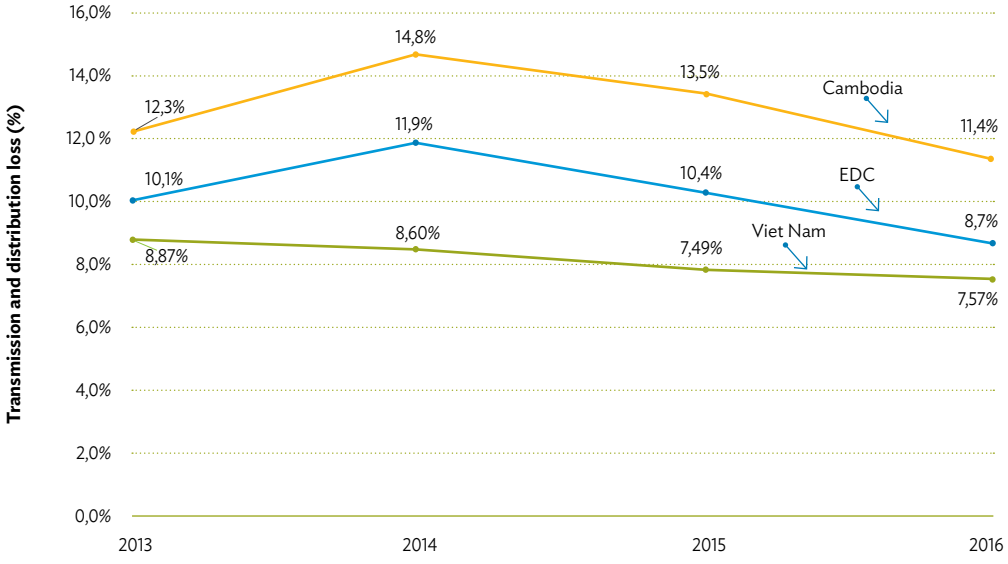
Source: Electricite Du Cambodge (2016) and Electiricty Authority of Cambodia (EAC) (2017).

In order to achieve affordable electricity and to ensure regional energy security by promoting the efficient utilisation of resources in the future, it is recommended to conduct not only bilateral trading but also multilateral trading amongst GMS and ASEAN countries. In the case of Cambodia, although improving the national grid connection, transmission capacity, and interconnection capacity are prioritised projects, Cambodia should conduct a study and trading trial for exporting electricity to neighbouring countries in a parallel way. This would improve connections to the national grid and improve access to energy services in the region.

2.3.1.3 Transmission and distribution loss

Figure 2.10 shows the transmission and distribution loss from 2013 to 2016 for Viet Nam as a reference. The whole country received electricity not only from EDC but also another rural electricity enterprise (REE) distributor. Based on this figure, the transmission loss of the whole country was higher than for EDC. If the whole country can connect to the EDC grid in the future, the difference in the loss between the two lines in the graph will be reduced to the loss by EDC.

Figure 2.10 Transmission and Distribution Loss, 2013–2016



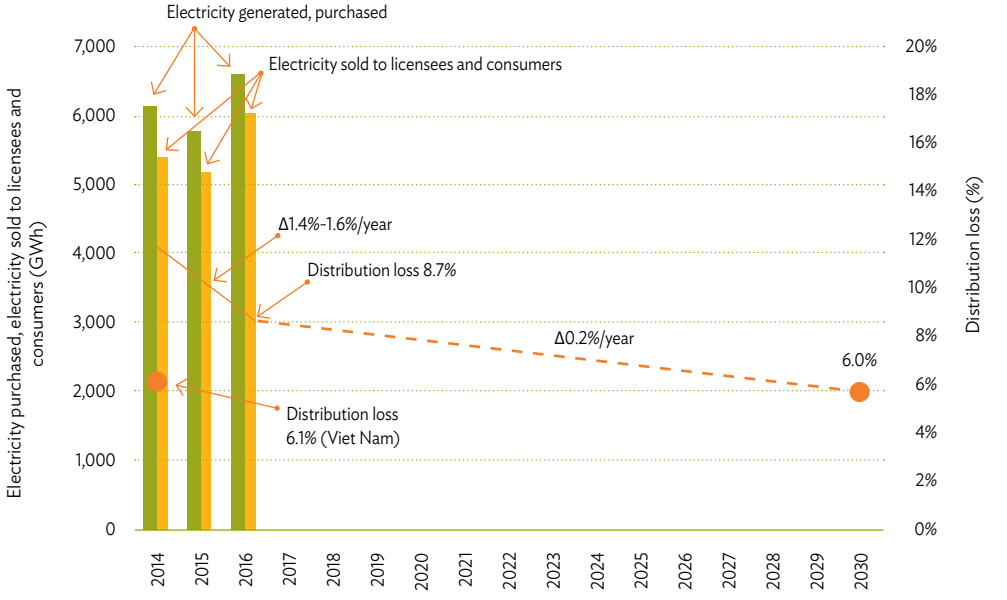
EDC = Electricite du Cambodge.

Source: Electricite Du Cambodge (2016) and EVN (2017a).

Figure 2.11 shows the distribution losses from 2014 to 2016.[4] A higher bar represents purchased energy, while a lower one represents sold energy. The decreasing line is the distribution losses in total by year. At the end of 2016, the Cambodia system distribution loss was 8.7%, which was higher than the distribution loss for Viet Nam (6.1% in 2014, falling in 2016 as an assumption). Therefore, improvement in the quality of electricity (stable voltage level and frequency) through distribution network development is needed for the distribution loss to decrease to be the same as the percentages in neighbouring countries. The distribution loss percentage decreased by 1.4%–1.6% per year from 2014 to 2016. Reducing the loss requires more efforts. Hence, we assume the decreasing percentage is 0.2% per year until 2030 towards 6.0% distribution losses in 2030.

[4] https://www.egat.co.th/en/images/annual-report/2017/egat-annual-eng-2017.pdf

Figure 2.11 Distribution Losses



Source: Author (outcome of the dialogue with the Ministry of Mines and Energy); Electiricty Authority of Cambodia (EAC) (2017); and Asian Development Bank (ADB) (2016).

To improve the distribution losses, the development of distribution lines, maintenance of infrastructure, and standards for distribution equipment are necessary. Table 2.9 shows the distribution network support projects until 2020. In 2012, the Asian Development Bank (ADB) supported the improvement of the electrification rate in some provinces, and today, the Japan International Cooperation Agency (JICA) currently supports the Phnom Penh distribution system until 2020. It is recommended to continue long-term relationships with external support and the development of guidelines for maintaining distribution quality.

Table 2.9 Distribution Network Support Projects

Year	Project	Province	Development partner
2014	Rural Energy Project	Svay Reing	ADB
2016	Second Power Transmission and Distribution Project	Shihanoukville Kampot	ADB (31%) JICA (43%) EDC (21%)
2018	Medium-Voltage Sub-transmission Expansion Sector Project	Kampong Thom Kampong Cham Siem Reap	ADB
2020	Transmission and Distribution System Expansion Project (Phase 2)	Phnom Penh	JICA

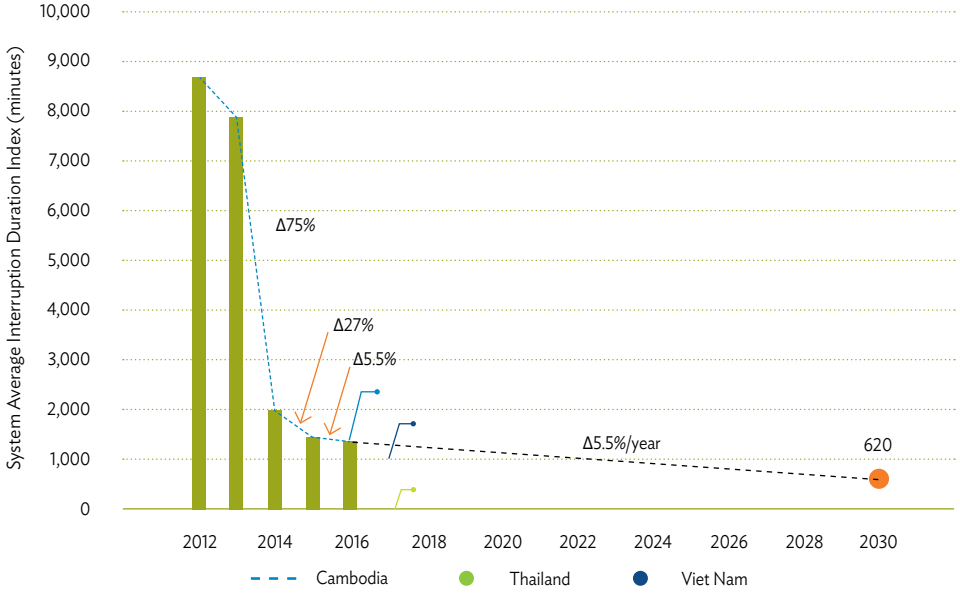
ADB = Asian Development Bank, EDC = Electricite du Cambodge, JICA = Japan International Cooperation Agency.

Source: Kingdom of Cambodia (2014).

2.3.1.4 System Average Interruption Duration Index and Frequency Index

The System Average Interruption Duration Index (SAIDI) and the System Average Interruption Frequency Index (SAIFI) are commonly used indicators for monitoring the reliability of distribution systems and the actual situation of the stable power supply at affordable prices. It is recommended to improve the reliability of power statistics by decreasing the number of minutes and times by years represented in the SAIDI and SAIFI. Figure 2.12 and Figure 2.13 show the progress of the SAIDI and SAIFI from 2012 to 2016, with Viet Nam in 2017 as a reference.[5] The SAIDI and SAIFI decreased from 2012 through increasing electricity capacity. The SAIDI decreased by 5.5% and the SAIFI decreased by 6.5% from 2015 to 2016. If the SAIDI and SAIFI are planned to decrease by the same percentages, 5.5% per year and 6.5% per year from 2016 to 2030, there would be a high possibility of achieving less than 620 minutes for the SAIDI and less than 7.3 times for the SAIFI in 2030. As a further improvement, it is suggested to ameliorate the reliability of the transmission system, such as by improving the relay system, expanding transmission lines, and establishing new grid substations.

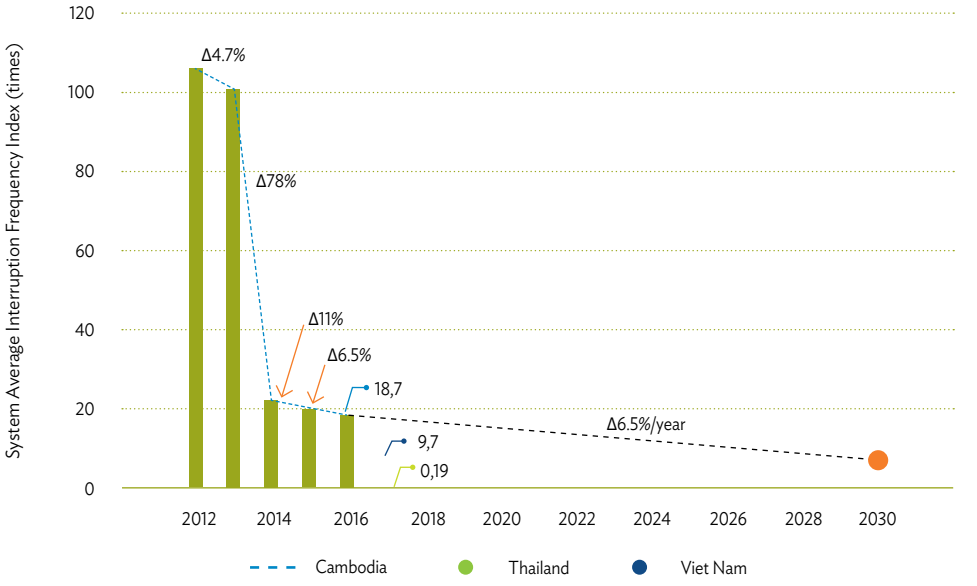
Figure 2.12 System Average Interruption Duration Index (minutes)



Source: Electricity Generating Authority of Thailand (EGAT) (2017); EVN (2017a); and Kingdom of Cambodia (2012).

[5] https://en.evn.com.vn/userfile/User/huongbtt/files/2018/2/AnnualReport2017.pdf

Figure 2.13 System Average Interruption Frequency Index (times)



Source: Electricity Generating Authority of Thailand (EGAT) (2017); EVN (2017a) and Kingdom of Cambodia (2012).

2.3.1.5 Household electrification rate and national grid quality

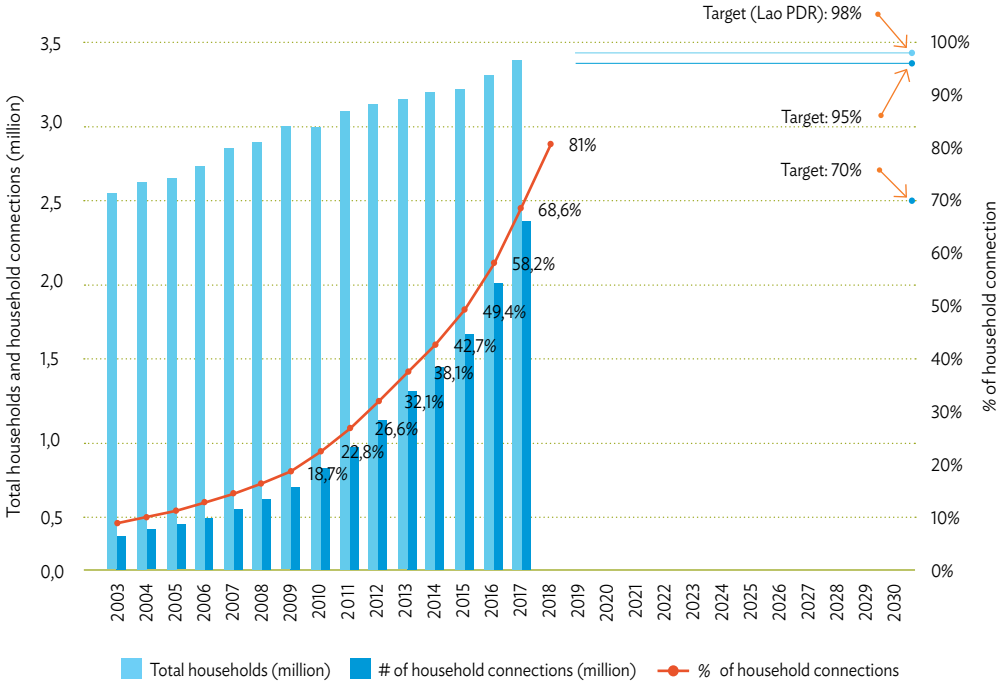
On 30 November 2011, the Government of Cambodia issued the Strategy and Plan for Development of Rural Electrification in the Kingdom of Cambodia (SPDR), a specific strategy and plan to achieve essential targets for rural electrification as prakas (ministry ordinance). This plan was discussed by the Ministry of Mine and Energy (MME), Electricity Authority of Cambodia (EAC), Rural Electrification Fund (REF), and Electricite du Cambodge (EDC) based on the results obtained through cooperation with international organisations and set up as the national goal according to the SPDRE. Under the plan, each organisation is supposed to take action for the targets below:

- Village areas: Achieve an electrification rate of 100%, including battery illumination, by 2020.
- Household electrification: Achieve an electrification rate of at least 70% connection to the national grid by 2030.

Regarding the grid extension, which is the best method for electrification, 80% and 95% of all villages will receive electricity supply from the national grid or from neighbouring countries by 2020 and 2030, respectively, if the government receives funding support to extend the grid. The target is for 70% of households to connect to the national grid by 2030.

Figure 2.14 shows the progress of household electrification until 2018.[6,7] Compared with the target for 2030, which is 70% electrified households, household electrification in 2018 is 81%. In other words, the percentage for 2018 is beyond the target of 70% in 2030. The national grid connection is associated with affordable prices, sustainable supply, and high security. Thus, the target by 2030 should be re-planned to reach over 70%. The new target was set in our meeting with the MME, which is 95% in 2030.

Figure 2.14 Number of Households and the Electrification Rate



Source: Author (outcome of the dialogue with the Ministry of Mines and Energy); Killeen, P. (2013); and EAC's Consolidated report for year 2017.

The targets by 2030 are summarised below.

Targets by 2030

- Transmission and distribution loss: less than 8%
- SAIDI, SAIFI: Less than 620 minutes and 7.3 times, respectively
- Household electrification rate: Change from 70% to 95% of households connected to the national grid

6 https://www.oecd-nea.org/ndd/pubs/2015/7057-proj-costs-electricity-2015.pdf
7 http://www.worldwatch.org/system/files/Laos%20Atlas%20Case%20Study%20FINAL.pdf

2.1.1 Necessary action plans and policies

In order to reach the targets by 2030, the following action plans and policies are necessary.

Achieve less than 8% transmission and distribution losses

To reduce transmission and distribution losses, establishing equipment standards, changing to higher voltage transmission lines, and utilising materials that cut heat loss are recommended. A 500 kV transmission line will be constructed from 2019 to 2025, which will contribute to reducing transmission losses.

- Action 1: Establish equipment standards.
- Action 2: Change to a higher voltage transmission line.
- Action 3: Utilise materials for cutting heat loss.

Achieve less than 620 minutes for the SAIDI and 7.3 times for the SAIFI

To improve the SAIDI and SAIFI, we recommend ameliorating the reliability of the transmission system, such as improving the relay system, expanding transmission lines, and establishing new grid substations.

- Action 1: Build-up the transmission and substation systems (e.g., indoor transmission, two lines/loop connection).
- Action 2: Adopt supervisory control and data acquisition and distribution management systems.
- Action 3: Use underground electric cables.

Achieve 95% of households connected to the national grid

To achieve the recent target for household electrification of 95% of households being connected to the national grid by 2030, continuing national grid expansion and conducting a national grid expansion study, including on grid reliability and multilateral trading amongst neighbouring countries, are needed. The current national transmission master plan will be finalised by 2021 or 2025.

- Action 1: Continue the national grid expansion.
- Action 2: Update the current national transmission master plan, considering grid reliability and multilateral trading amongst neighbouring countries.

2.1.2 Roadmap

For the necessary action plans and policies, the recommended roadmap is as follows.

Short term, 2019–2022:

- Establish equipment standards for the transmission and distribution networks with implementation of the national transmission master plan.
- Study improvements in transmission and distribution losses, SAIDI, and SAIFI.
- Set a new target of national grid electrified households.

Medium term, 2023–2026:

- Continue implementation of the national transmission master plan.
- Consider implementation of a study (transmission and distribution losses, SAIDI, and SAIFI).
- Develop and maintain standardised substations and distribution lines in each province.

Long term, 2027–2030:

- Grid guidelines by the MME for maintaining the quality of electricity.
- Set the next goals for achieving further benefits from electricity.

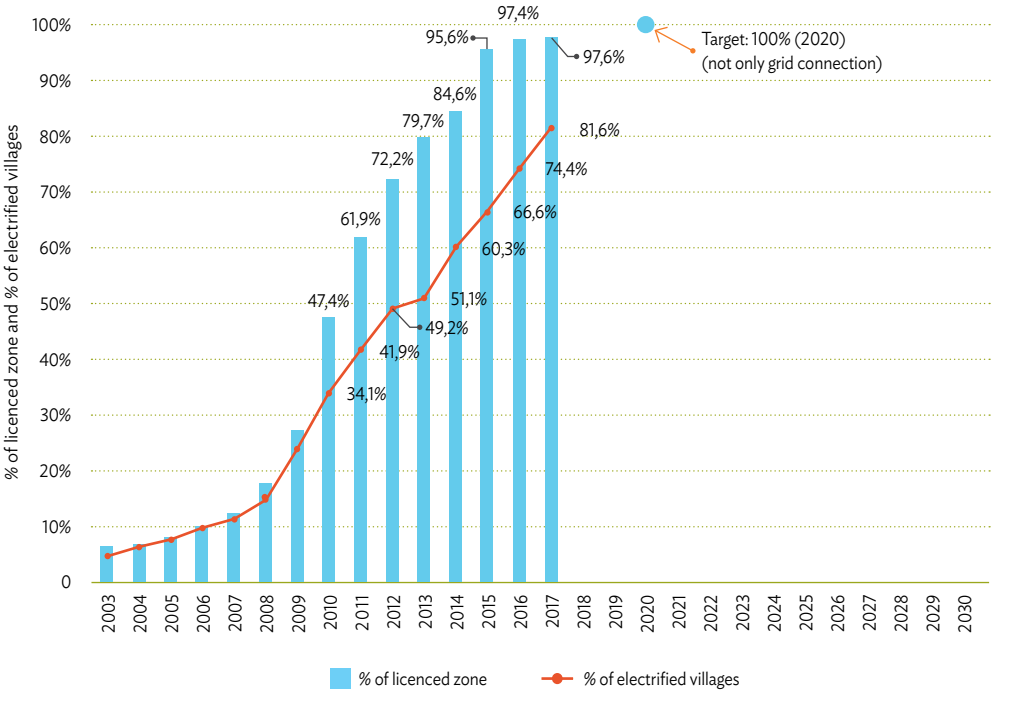
2.4 Distribution and tariffs

The Cambodian government's plan will ensure all villagers will have access to electricity by 2020.[8] The growth in distribution network development and village electrification is shown in Figure 2.15, which presents the shares of grid connections and dispersed power sources. The vertical lines show the share of licenced zones as a bar graph and the share of electrified villages as a line graph. In the last 10 years, electrified zones increased significantly. In 2017, the percentage of achieved electrification licenced zones was 97.6% and the electrified villages rate was 81.6%. According to government plans, the target for the electrified villages rate is 100% in 2020.

The distribution of licenced zones granted and the megavolt (MV) backbone of electrical energy supply system constructed by the end of 2016 are shown in Figure 2.16.[9] In 2016, Cambodia reported that 81.58% (11,558) of villages in the country had access to electricity via the distribution network in operation, and 15.85% (2,245) of villages were related to the distribution network. Looking at the remaining electrification area, 2.37% (336) of villages live without the benefit of electricity.

[8] https://www.oecd-nea.org/ndd/pubs/2015/7057-proj-costs-electricity-2015.pdf
[9] https://www.oecd-nea.org/ndd/pubs/2015/7057-proj-costs-electricity-2015.pdf

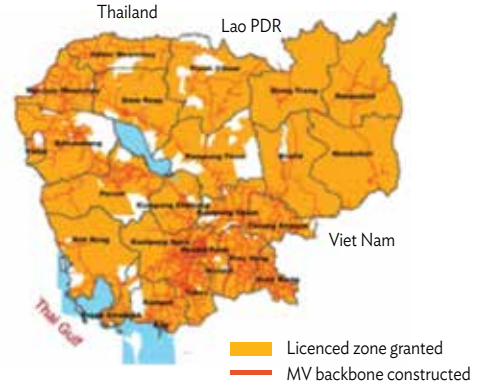
Figure 2.15 Progress of Distribution Network Development and Village Electrification



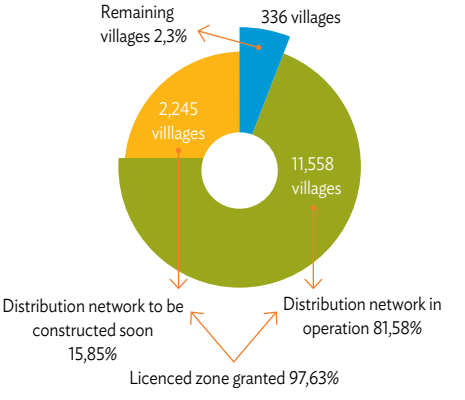
Source: Author (outcome of the dialogue with the Ministry of Mines and Energy) and EAC's Consolidated report for year 2017.

Figure 2.16 Distribution of Licenced Zones and the State of Electrification at the End of 2016

Distribution of licenced zones granted and MV backbone constructed for year-end 2016



Situation of electrification in Cambodia (city + rural as of December 2016)



MV = megavolt.

Source: EAC's consolidated report for year 2017.

2.4.1 Targets by 2030

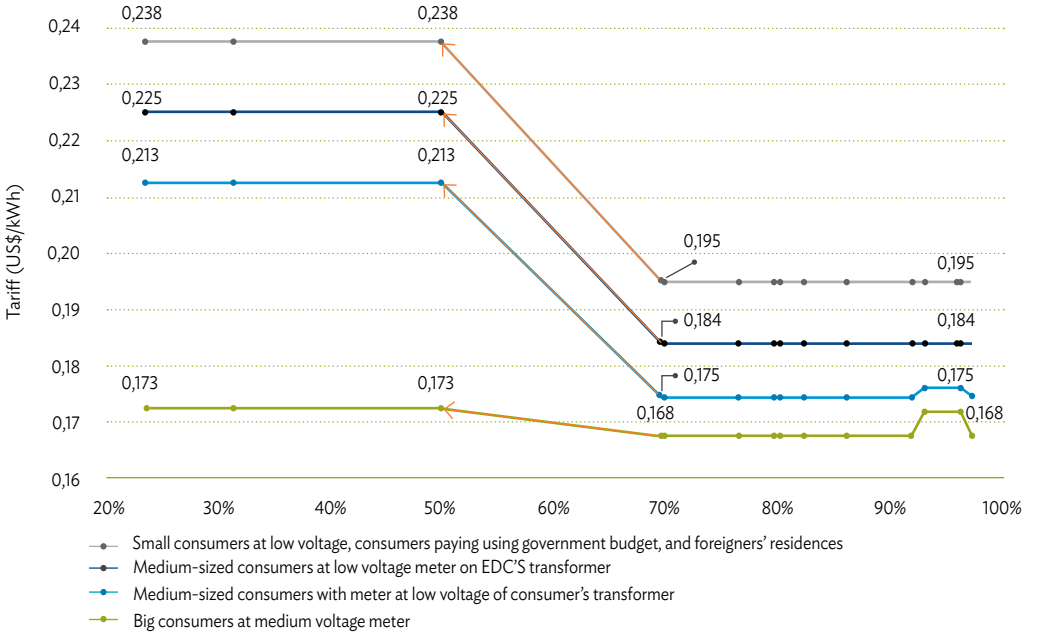
To achieve the targets of the basic energy plan by 2030 of affordability, sustainability, and security, the content should consider not only expanding electrification but also electricity tariffs, especially in rural areas. Cambodia's electricity tariffs are higher than in neighbouring countries, and electricity tariffs in rural areas are higher than in urban areas due to the dependency on high-cost generation, such as small generation systems running on imported diesel fuel, high distribution network power losses, and the lack of subsidies.

2.4.1.1 Tariff differences between urban and rural areas

Figure 2.17 shows all administration, commercial, and industrial consumer tariff differences for villages covered by electricity licenced areas.[10] These tariffs decrease when the covered villages are over 50%. The cost of electricity from own generation, purchases from IPP, and purchases from neighbouring countries or other licensees are the largest components of the cost of electric supply by licensees to the consumers. Hence, the tariffs for electricity depend on the cost of the electricity generated or purchased. With the development of a grid system, the tariffs of licensees purchasing electricity from the grid have become stable. Therefore, the higher percentage of villages covered, the lower the applied tariffs. The tariff differences are 1.03 times for the yellow line and 1.22 times for the remaining lines. In association with the graph, the tariffs also depend on the electricity sources purchased or utilised by licensees. For instance, if diesel/heavy fuel oil (HFO) is utilised, the tariff will be calculated based on it. Generally, diesel costs are higher than other sources and, eventually, the grid connection must be considered from the cost perspective.

[10] 'Salient Features of Power Development in Kingdom of Cambodia', EAC's Consolidated Report for 2017.

Figure 2.17 Difference in Tariffs by Percentage of Villages Covered by Electricity Licenced Areas



Source: EAC's Consolidated report for year 2017 and Electiricty Authority of Cambodia (EAC) (2017).

2.4.1.2 Times of use for tariffs

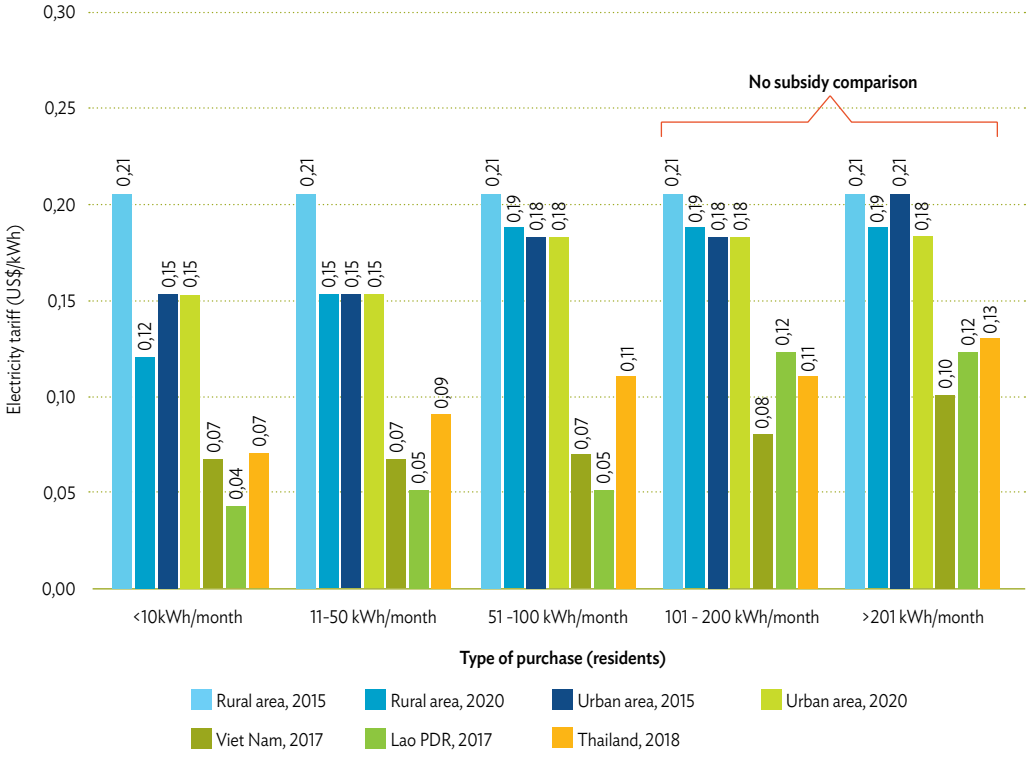
From the above reasonable facts, Cambodia is trying to reduce electricity tariffs. In accordance with the Ministry of Mine and Energy's Prakas (regulation) No. 0094 dated 24 February 2015, the government set out a tariff reduction plan for electric power from the national grid for 2015–2020. Figure 2.18 shows the plan for household tariff reductions from 2015 to 2020 with neighbouring countries as references.[11,12,13] In 2015, the rural and urban area tariffs for electricity usage <10 kWh/month were US$0.205/kWh and US$0.1525/kWh, respectively. The purchase-type tariffs of <10 kWh/month and 11–50 kWh/month had the largest tariff gaps between the rural and urban areas in 2015. In this case, the purchase type >201 kWh/month had no gap between these two areas. According to the reduction plan, such gap is expected to decrease drastically in 2020, with the purchase type <10kWh/month. The subsidised price for only small-type purchases is included in the electricity tariff of neighbouring countries (Thailand, less than 90 kWh/month; Viet Nam, less than 50 kWh/month).[14,15,16] Despite the plan to decrease

11 https://en.evn.com.vn/d6/gioi-thieu-d/RETAIL-ELECTRICITY-TARIFF-9-28-252.aspx
12 https://policy.asiapacificenergy.org/node/580
13 http://www.boi.go.th/index.php?page=utility_costs
14 https://hal-enpc.archives-ouvertes.fr/hal-01572126/file/main.pdf
15 http://www.eria.org/RPR_FY2015_No.21_Annexes.pdf
16 https://www.iisd.org/gsi/sites/default/files/ffs_thailand_czguide.pdf

the tariff for rural areas in 2020 for all purchase types, the tariff is still higher than the tariff in neighbouring countries.

For increasing the priority of defraying rural area electricity costs, it is recommended to conduct cross-subsidies between high and low electricity consumption.

Figure 2.18 Electricity Tariff Differences for Households



Source: EAC's consolidated report for year 2017; EVN (2017b); Policy.Asiapacificenergy (n.d.); and Thailand Board of Investment (n.d).

At its 267th Session, held on 28 August 2014, the EAC approved a time-of-use (TOU) tariff for MV consumers of the EDC supply. The TOU tariff approved is shown in Table 2.10. The TOU tariff is optional, which means it will be an applicable option for MV consumers. For example, if a province is connected at the MV to a grid substation of the national grid, the tariff will be decreased from US$0.139/kWh (during the day time, 7am to 9pm) to US$0.095/kWh (night time, 9pm to 7am). Without the TOU, the basic tariff will be decreased only from US$0.129/kWh to US$0.126/kWh in 2020 by the tariff reduction plan. Conceptually, this TOU tariff is applied for suppressing the electricity utilisation of peak demand under current circumstances. The TOU tariff is expected to become the time-of-day rate system in the future.

Table 2.10 and Figure 2.19 show the MV tariff differences between rural, grid-connected, and urban areas planned until 2020, along with neighbouring countries as references.[17,18] The MV tariff of each rural, national grid, and urban area has been planned to decrease from 2015 to 2020. However, the electricity tariff in Cambodia is still the highest amongst its neighbouring countries despite TOU implementation or after the cost reduction plan to 2020. In terms of achieving affordable tariffs, these TOU and cost reduction plans should be extended to 2030.

Table 2.10 Time-of-Use Tariffs

Applicable to MV consumers	Tariff of use (US$/kWh)	
	7:00–21:00	21:00–7:00
Connected at MV to grid substation of national grid	0.139	0.095
(Ref.) Without TOU tariff in 2015	0.129	
(Ref.) Without TOU tariff in 2020	0.126	
Connected at MV to sub-transmission line of national grid	0.179	0.140
Connected at MV to substation of Phnom Penh system	0.175	0.135
(Ref.) Without TOU tariff in 2015	0.177	
(Ref.) Without TOU tariff in 2020	0.162	
Connected at MV to sub-transmission line of Phnom Penh system	0.190	0.150

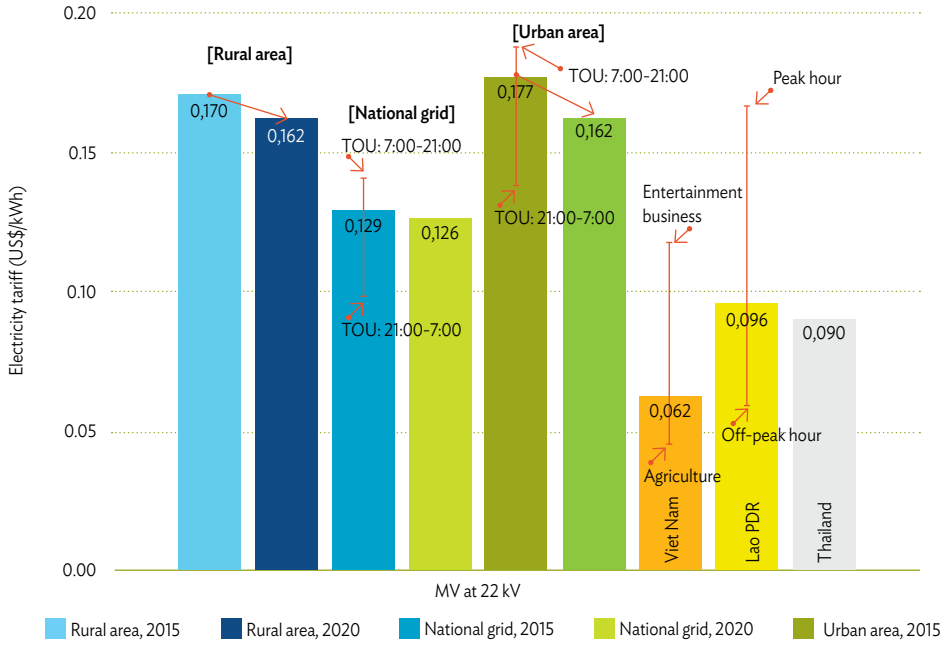
TOU = time of use.

Note: The sub-transmission line is part of an electric power transmission system that runs at relatively lower voltages. It is uneconomical to connect all distribution substations to the high main transmission voltage because the equipment is larger and more expensive.

Source: EAC's consolidated report for year 2017.

17 https://www.egat.co.th/en/images/annual-report/2017/egat-annual-eng-2017.pdf
18 https://en.evn.com.vn/userfile/User/huongbtt/files/2018/2/AnnualReport2017.pdf

Figure 2.19 Electricity Tariff Differences in the MV at 22 kV



MV = megavolt, TOU = time of use.

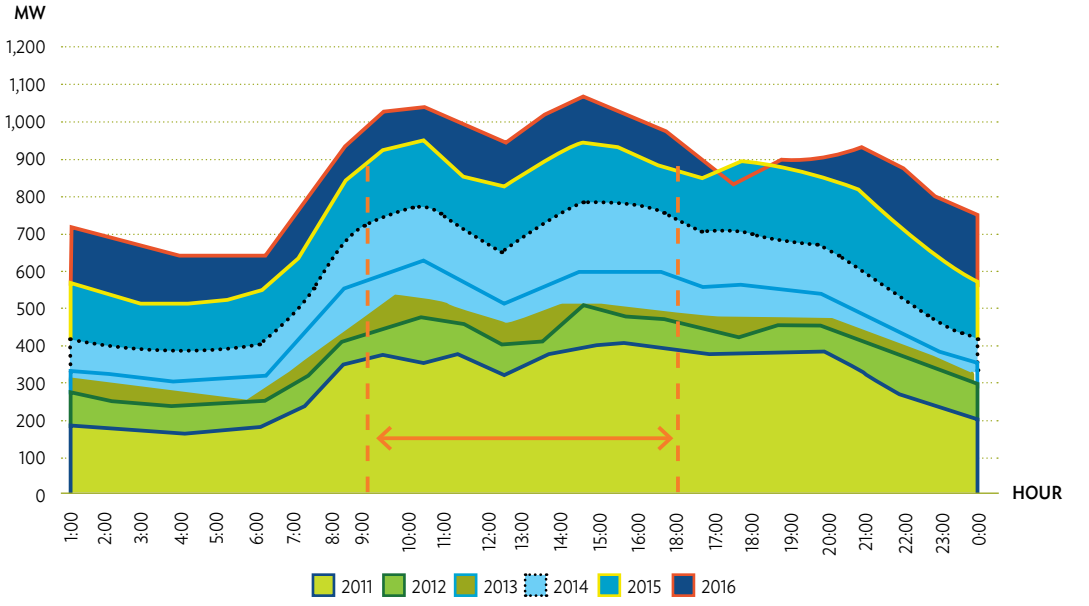
Source: EAC's consolidated report for year 2017; Electricity Generating Authority of Thailand (EGAT) (2017); EVN (2017a); and Policy. Asiapacificenergy (n.d.).

The implementation of the TOU has a positive impact. This can be seen in Figure 2.20, showing peak demand curves for a whole day for 2011–2016.[19] Throughout the years, the curves fluctuate by hours, and the consumption increases. Due to operational and planned reasons, a flat demand curve will benefit operators and planners who choose a beneficial electricity resource.

To improve this situation, two plans are recommended. The first plan is, as an example, an hourly base tariff system applying tariff differences between day and night periods (TOU). Cambodia is conducting basic actions in the agricultural sector and for MV consumers. Water pump tariffs for agriculture from 9pm to 7am are cheaper than during other times. As mentioned above, the TOU has been applied for MV consumers and is expected to be planned for all low-voltage (LV) consumers.

[19] http://lab.fs.uni-lj.si/kes/erasmus/The%20Cost%20of%20Power%20Generation.pdf

Figure 2.20 Demand Differences

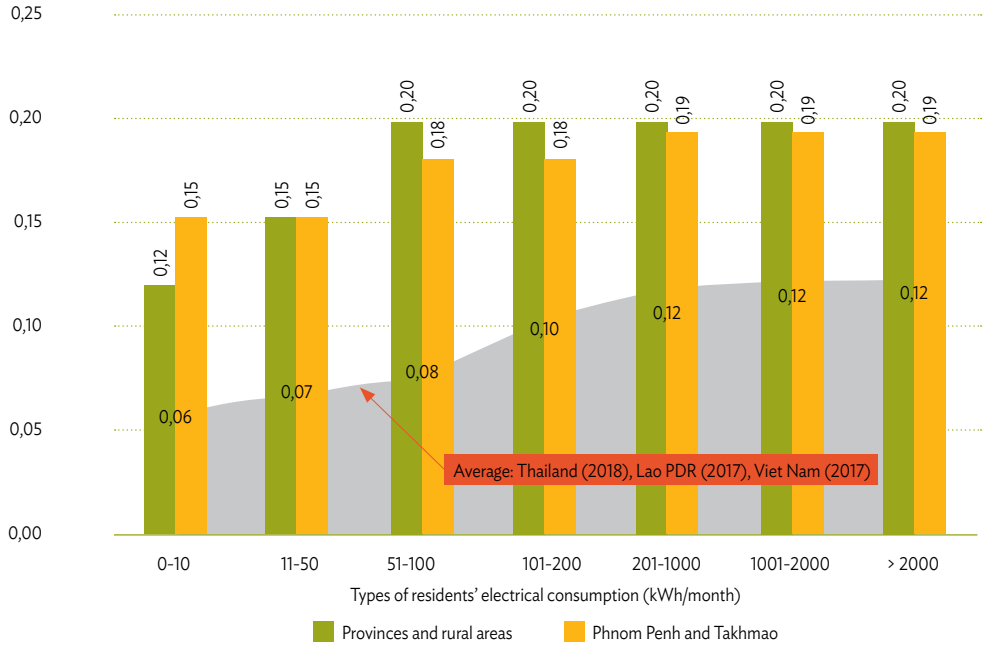


Source: Electricite Du Cambodge (EDC), (2016).

The second plan is for cross-subsidies from high-consumption users to low-consumption users, which increases tariff differences. According to Figure 2.18, the tariffs for electricity use in rural areas for the <10 kWh purchase type in 2020 will decrease more than in urban areas in 2020, although other purchase types of electricity will decrease to almost the same level as the urban tariff in 2020. Figure 2.21 and Table 2.11 show the tariff differences of provinces and Phnom Penh's electrical consumption in 2017.[20,21] The graph shows that the higher the electrical consumption, the higher the applied tariff. Hence, a tariff excess for higher consumption is able to subsidise a tariff for lower consumption.

20 https://www.egat.co.th/en/images/annual-report/2017/egat-annual-eng-2017.pdf
21 https://en.evn.com.vn/userfile/User/huongbtt/files/2018/2/AnnualReport2017.pdf

Figure 2.21 Tariffs for All Types of Residents' Electrical Consumption in 2017



Source: EAC's consolidated report for year 2017; Electricity Generating Authority of Thailand (EGAT) (2017); EVN (2017a); Policy.Asiapacificenergy (n.d.); and Derbyshire, W. (2015).

Table 2.11 Number of Residents Categorised by Capacity of Supply in 2017

Electricity supply (kWh)	Types of residents' electrical consumption (kWh/month)						
	0–10	11–50	51–100	101–200	201–1000	1001-2000	>=2000
Provinces and rural areas							
Number of residents	241,147	902,268	312,543	152,398	90,401	7,564	3,480
Electrical power tariff [US$/kWh]	0.120	0.153	0.198	0.198	0.198	0.198	0.198
Phnom Penh and Takhmao							
Number of residents	116,942	193,369	70,076	92,199	124,200	7,170	2,173
Electrical power tariff [US$/kWh]	0.153	0.153	0.180	0.180	0.193	0.193	0.193
Average tariff (Thailand (2018), Viet Nam (2017), and Lao PDR (2017))							
Electrical power tariff [US$/kWh]	0.060	0.069	0.076	0.104	0.118	0.118	0.118

Source: EAC's consolidated report for year 2017.

To achieve affordable tariffs for residents with low electricity consumption, the case example of cross-subsidies by higher consumption is considered. Table 2.12, Table 2.13, Figure 2.22, and Figure 2.23 show case examples of cross-subsidies for low consumption from high consumption in the rural and urban areas. The targets are set in such a way that the lower tariff is the same as the average of the neighbouring countries. The target of Case 1 is the tariff of '0–10 kWh/month' of electricity consumption, 'US$0.12/month' in the provinces and rural areas, and 'US$0.15/month' in Phnom Penh and Takhmao of 'US$0.06/month'. The target of Case 2 is Case 1 and the tariff of '11–50 kWh/month'. The target of Case 3 is Case 2 and the tariff of '51–100 kWh/month'. Each case is considered to be the same tariff in total. In the most aggressive case, Case 3, the additional tariff is +US$0.32/kWh by over 2,000 kWh/month in the provinces and rural areas. The tariff will be '0.52 kWh/month' from '0.20 kWh/month'. The tariff of less than 100 kWh/month will be the same level as for neighbouring countries.

The acceptable additional tariff in Cambodia can be estimated based on the GDP per capita for Thailand's case.[22] Table 2.14 shows the composition by macroeconomic position in 2018. The maximum cross-subsidy of Cambodia is +US$0.32/kWh (Table 2.12). However, the 1,000 capita of cross-subsidy/GDP per capita shows +US$0.22/kWh, which is still higher than for Thailand. If this case is acceptable, Phnom Penh and Takhmao (Table 2.13) hold the potential for achieving the affordable tariff of less than 100 kWh/month via a cross-subsidy while the provinces and rural areas have the chance to achieve the affordable tariff of less than 50 kWh/month via the cross-subsidy. Therefore, the low consumers are expected to receive the benefits from the cross-subsidy from high consumers in Cambodia.

Table 2.12 Case Example of Cross-subsidy for Low Consumption from High Consumption in Rural Areas

Case	Provinces and rural areas						
	0–10	11–50	51–100	101–200	201–1000	1001–2000	>=2000
1	-0.06 (-0.72%) [0.12->0.06]	+0.00 (+0.00%) [0.15->0.15]	+0.00 (+0.00%) [0.20->0.20]	+0.00 (+0.00%) [0.20->0.20]	+0.00 (+0.00%) [0.20->0.20]	+0.00 (+0.04%) [0.20->0.20]	+0.00 (+0.10%) [0.20->0.20]
2		-0.08 (-1.3%) [0.15->0.07]	+0.00 (+0.03%) [0.20->0.20	+0.00 (+0.06%) [0.20->0.20]	+0.01 (+0.10%) [0.20->0.20]	+0.06 (+1.2%) [0.20->0.26]	+0.13 (+2.6%) [0.20->0.33]
3			-0.12 (-2.3%) [0.20->0.08]	+0.01 (+0.15%) [0.20->0.20]	+0.01 (+0.25%) [0.20->0.21]	+0.15 (+2.9%) [0.20->0.35]	+0.32 (+6.4%) [0.20->0.52]

Notes:

Case 1: Electrical consumption (0–10 kWh/month): Tariff 0.12 -> 0.06 US$/kWh

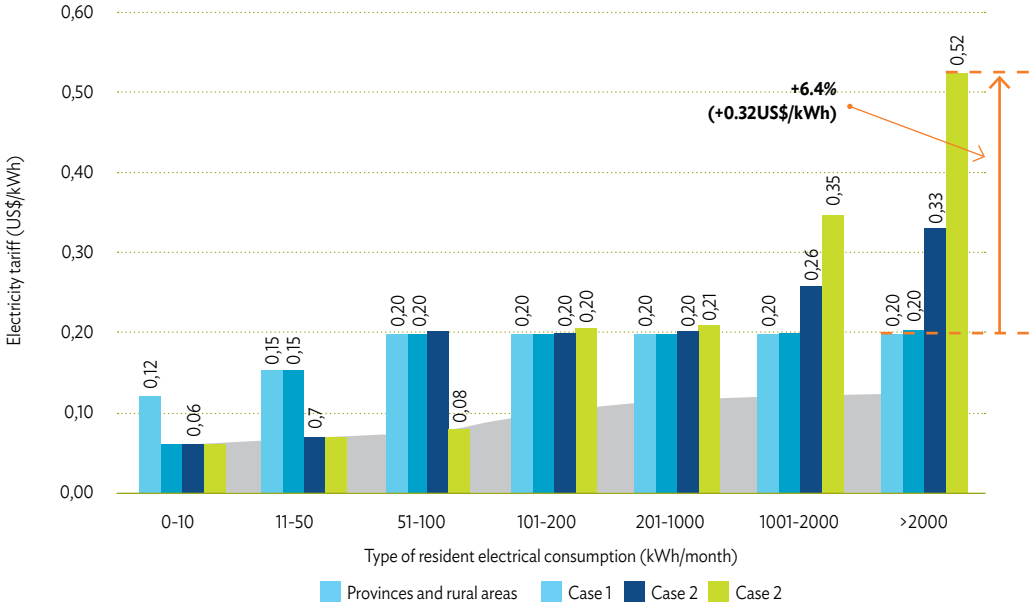
Case 2: Case 1 and electrical consumption (11–50 kWh/month): Tariff 0.15 -> 0.07 US$/kWh

Case 3: Case 2 and electrical consumption (51–100 kWh/month): Tariff 0.20 -> 0.08 US$/kWh

Source: Author (As an outcome of the dialogue with MME, Ministry of Mines and Energy).

22 https://www.imf.org/external/datamapper/NGDP_RPCH@WEO/OEMDC/ADVEC/WEOWORLD

Figure 2.22 Case Example of Cross-subsidy for Low Consumption from High Consumption in Rural Areas



Source: Author (outcome of the dialogue with theMinistry of Mines and Energy); EAC's consolidated report for year 2017.

Table 2.13 Case Example of Cross-subsidy for Low Consumption from High Consumption in Urban Areas

Case	Phnom Penh and Takhmao						
	0–10	11–50	51–100	101–200	201–1000	1001-2000	>=2000
1	-0.09 (-1.41%) [0.15->0.06]	+0.00 (+0.00%) [0.15->0.15]	+0.00 (+0.00%) [0.18->0.18]	+0.00 (+0.00%) [0.18->0.18]	+0.00 (+0.00%) [0.19->0.19	+0.00 (+0.03%) [0.19->0.19]	+0.01 (+0.12%) [0.19->0.20]
2		-0.08 (-1.3%) [0.15->0.07]	+0.00 (+0.03%) [0.18->0.18]	+0.00 (+0.02%) [0.18->0.18]	+0.00 (+0.02) [0.19->0.19]	+0.01 (+0.29%) [0.19->0.21]	+0.05 (+0.97%) [0.19->0.24]
3			-0.10 (-1.8%) [0.18->0.08]	+0.00 (+0.05%) [0.18->0.18]	+0.00 (+0.04%) [0.19->0.19]	+0.03 (+0.63%) [0.19->0.23]	+0.11 (+2.1%) [0.19->0.30]

Notes:

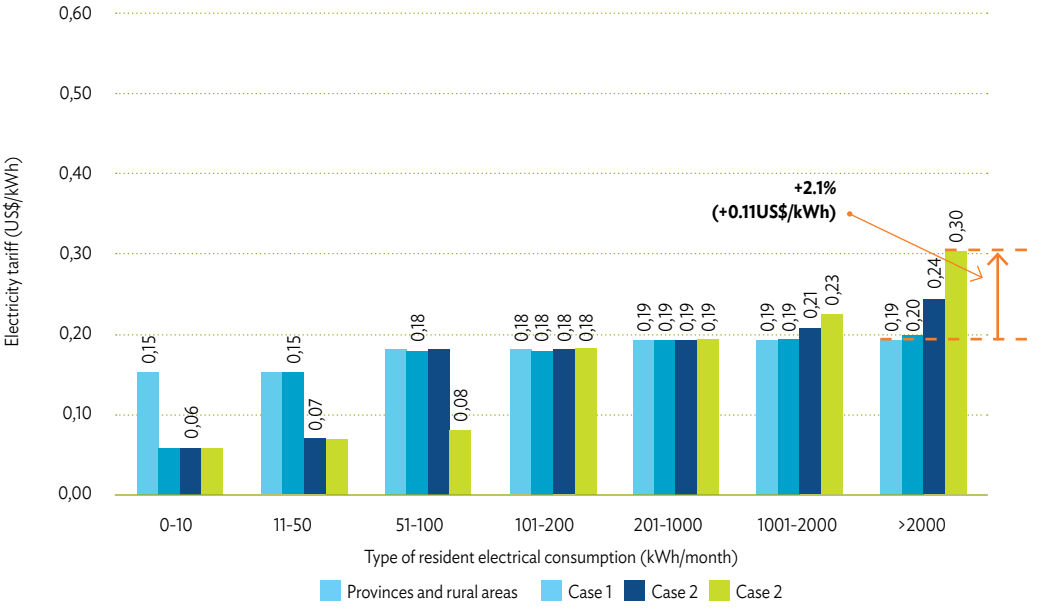
Case 1: Electrical consumption (0–10 kWh/month): Tariff 0.15 -> 0.06 US$/kWh

Case 2: Case 1 and Electrical consumption (11–50 kWh/month): Tariff 0.15 -> 0.07 US$/kWh

Case 3: Case 2 and electrical consumption (51–100 kWh/month): Tariff 0.18 -> 0.08 US$/kWh

Source: Author (As an outcome of the dialogue with MME, Ministry of Mines and Energy)

Figure 2.23 Case Example of Cross-subsidy for Low Consumption from High Consumption in Urban Areas



Source: Author (outcome of the dialogue with the Ministry of Mines and Energy); EAC's consolidated report for year 2017.

Table 2.14 Composition by Macro-economic Position in 2018

Country	Population (millions)	GDP per capita (US$)	Cross-subsidy (US$/kWh)	Cross-subsidy/GDP per capita*1,000 (US$)
Cambodia	16.3	1,485	... +0.32 (Estimated result in 2017)	... +0.22
Thailand	69.2	7,084	... +1.43 (Actual case in 2011 to 2012)	... +0.20

Source: International Monetary Fund (n.d); International Institute for sustainable development (2014).

As described in Figure 2.21, the tariff of Cambodia is higher than that of neighbouring countries despite the continuing increase in electrification rate. The high rates of electricity tariff make Cambodia less competitive in global and regional trade and investment. One factor is due to high generation and transmission costs.[23,24] The main cause regarding the generation cost is the restrictive power purchase agreements, causing unused capacity excess during the rainy season and investment rewards. In order to achieve an affordable tariff, Cambodia should continue national grid expansion and pursue agreements with neighbouring countries to allow exports of surplus generation. In the longer term, Cambodia should actively encourage the expansion of cross-border power trading in the

23 http://www.seac-cambodia.org/wp-content/uploads/2016/06/Cambodia-in-depth-study-on-electricity-cost-and-supplies-Final-Report.pdf

24 http://www.adb.org/publications/series/proceedings-meetings-gms-regional-power-trade-coorcination-committee-rptcc

GMS under the institutional arrangements in place and, in particular, the development of shorter-term trading arrangements. This will provide a means for Cambodia to better balance supply and demand on its electricity system.

In most countries around the world, there is a significantly increasing trend in grid-connected distributed generation, and also a decreasing trend in the generation cost of renewable energy. Therefore, it is also necessary to design a framework for considering grid connection.

The heads of ASEAN power utilities and authorities are implementing a study for establishing the institution for the ASEAN Power Grid, named the APG Generation and Transmission System Planning (AGTP) and APG Transmission System Operator (ATSO).[25] This related institution will support establishing the framework and guidelines for a standardised national grid amongst ASEAN countries.

Below are the summarised targets for 2030.

Targets by 2030

- Prolong the tariff cost reduction plan from 2020 to 2030 in terms of obtaining an electricity tariff at an affordable price.
- Consider the extension of a TOU tariff to LV consumers and enhance the tariff differences between high and low consumption.
- Continue to pursue an agreement with neighbouring countries allowing exports of surplus generation.
- Develop the guidelines for standardised grid connection.[26]

[25] Chea Vannak (2017), 'Cabinet approves power projects', *The Khmer Times*, 20 February.

[26] http://www.meti.go.jp/policy/trade_policy/apec/img/APEC_Guideline_for_Quality_Electric_Power_Infrastructure.pdf

2.4.2 Necessary action plans and policies

Achieve affordable tariffs

Extending the cost reduction plan to 2030, expanding the TOU to LV consumers, and cross-subsidy tariff considerations are expected to achieve affordable tariffs in Cambodia. Under the electricity law, there are two governmental entities responsible for regulating the electricity supply sector: the EAC and the MME.[27] Possessing different functions and responsibilities, these two institutions are expected to conduct the study of a TOU tariff for LV consumers in the short term. As a result, the tariff will be applied accordingly with the type of electricity consumption.

- Action 1: Consider cross-subsidies from high consumers to low consumers.
- Action 2: Conduct a study of the TOU tariff for LV consumers.

Achieve low generation and distribution costs

- Action 1: Continue to pursue an agreement with neighbouring countries allowing the exports of surplus generation.
- Action 2: Develop the guidelines for standardised grid connection.

2.4.3 Roadmap

According to the necessary action plans and policies, the recommended roadmap will consist of three terms as follows:

Short term, 2019–2022:

- Consider the cross-subsidy from high consumers to low consumers.
- Study TOU tariff for LV consumers and tariff difference expansion.
- Study the guidelines for considering a standardised grid connection.
- Cite 'cost reduction' and 'development distribution network' as important legislative goals.

[27] http://www.vdb-loi.com/wp-content/uploads/2018/04/Cambodia-Power-Update-April-2018.pdf

Medium term, 2023–2026:

- Prolong the tariff reduction plan as supported by the current study in the short term.
- Amend the electricity regulation to operate a tariff system by the MME and EAC.
- Establish the guidelines for a standardised grid connection.

Long term, 2027–2030:

- MME and EAC operate a tariff system according to electricity consumption from the economic perspective.
- Review on a routine basis every 2–5 years to attain further benefits of electricity.

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