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MINI GRIDS IN CAMBODIA

A CASE STUDY OF A SUCCESS STORY

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PREAMBLE

The Global Facility on Mini Grids of the Energy Sector Management Assistance Program (ESMAP) hired Castalia to study the regulation of mini grids in six jurisdictions in Sub-Saharan Africa and Asia (Kenya, Tanzania, and Nigeria; and Bangladesh, Cambodia, and the state of Uttar Pradesh in India). The study's objective is to understand what regulatory settings governments may adopt to scale up electrification through private development of mini grids, drawing on the experience of these six jurisdictions; provide technical assistance to four countries that want to further develop their mini grids framework; and disseminate findings and recommendations globally to inform successful mini grids regulation.

The study focuses on mini grids defined as small, privately-owned and operated systems with generation of up to 10 megawatts (MW) capacity and a network that distributes power to several customers. The study includes small mini grids of less than 1 kilowatt (kW) capacity, also known as 'micro' or 'pico' grids.

The six case studies are intended to be combined in one report. The report is to provide a cross-country comparison of these topics: it examines side by side how each of the countries studied have responded to a specific regulatory question, and presents a decision-tree approach to developing regulatory frameworks for mini grids.

This case study is based on in-depth interviews with a number of key stakeholders in Cambodia, conducted during and after a research trip in August 2017. We supplemented the insights gained from these interviews with extensive background research. Several experts in the Cambodia context and mini grids more broadly reviewed this case study for accuracy and clarity, and we have incorporated their comments while retaining a neutral fact-based position.

Like the other five case studies, this document is structured as follows:

- A brief introduction (section 1 |)
- A brief description of the context of the country (section 2 |),
- An overview of the power sector (section 3 |),
- Main aspects of the policy setting for mini grids (section 4 |),
- Technologies and business models used in the mini grids sector (section 5 |),
- The process to authorize mini grid operators (section 6 |),
- Technical and service standards for mini grids (section 7 |),
- Tariff setting, financing, and subsidies (section 8 |),
- Handling the relationship with the main grid (section 9 |), and
- A summary of lessons learnt from the experience of the country (section 10 |).

1 | INTRODUCTION

The rate of population with an electricity connection in Cambodia has increased significantly over the past three decades, from almost zero in the late 1980s to 5% in 1995, and 56% in 2014. Of those with access to electricity, 58% are connected to privately owned mini grids. The rest (42%) is connected to the main grid, which is owned by the state and operated by Electricité du Cambodge (EDC).

Under *de facto* laissez-faire conditions from the 1960s to 1991, local entrepreneurs expanded electrification mostly through diesel-fired mini grids. The civil war from 1967 to 1975, and Vietnamese occupation until 1991, caused important damage to the country's power sector. The Government was also weak. Before 2000, between 150 and 300 mini grids had emerged mostly informally, according to the Electricity Authority of Cambodia (EAC), the regulator; other studies estimate that there were at least 218 mini grids in 15 provinces (out of 25), and probably a total of 600 nationwide.[1] Due to lack of comprehensive data collection, the number of customers connected to privately operated mini grids at that time is unknown. Estimates vary from 72,000 to 180,000 customers;[2] according to the EAC, however, the latter estimate is highly inaccurate.[3]

Since the late 1990s, the Government started to exert control over the electricity business. In 2001, it adopted the Electricity Law of 2001, which has allowed it to:

- **Regulate**. The Law required all electricity entrepreneurs to get a license from the EAC. To obtain a license, electricity entrepreneurs must adopt national technical standards, and charge tariffs set by the EAC (which was created by the Law).
- **Fund**. Licensees are eligible for grants and concessional loans to expand service. The Rural Electrification Fund (REF) was set up in 2004 to disburse grants from the World Bank. Today its budget mainly comes from EDC, which also provides technical assistance to operators.
- **Integrate mini grids with the main grid**. Mini grids that interconnect to the main grid must decommission the generation assets they used to operate, buy cheaper power from the national utility, and resell it to their customers at a margin.

Government control has had a positive impact on electricity roll-out, quality of supply, and end-user tariffs. In 2016, 327 electricity entrepreneurs operated with a license, up from 311 in 2015. Licensees made around one million new connections between 2005 and 2015. Most licensees (306 out of 311) supplied 24h power by 2015; while in 2003 only 36 licensees (out of 85) provided power 24 hours a day. Power tariffs have also decreased: before 2003, the average tariff was US$0.50 per kWh and up to US$1.00 per kWh.[4] In 2015, the average tariff for the 266 mini grids connected the main grid was US$0.25 per kWh, and US$0.45 per kWh for isolated ones.

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[1] Enterprise Development Cambodia (2001) "Survey of 45 Cambodian Rural Electricity Enterprises"

[2] Enterprise Development Cambodia (2001) "Survey of 45 Cambodian Rural Electricity Enterprises" estimate that there are about 600 mini grids serving a total of about 180,000 customers; Meritec Limited for the Ministry of Industry, Mines, and Energy (2001) "Rural Electrification Strategy and Implementation Programme Survey Report" estimate that mini grids have 72,000 household customers

[3] Meeting at EAC, August 1, 2017

[4] Meritec Limited (2001) estimate that the average tariff was US$0.50 per kWh; Enterprise Development Cambodia (2001) estimate that the tariff was between US$30 and 0.91 per kWh, with an average of US$0.54 per kWh; the EAC estimate that most mini grids charged between US$0.80 and 1.00 per kWh (meeting at EAC, August 1, 2017)

On the other hand, there are signs that the Government's policy of lowering prices of electricity is putting pressure on mini grids' profitability. From 2011 to 2015, the distribution margin has decreased from US$0.16 to 0.10 per kWh;[5] the distribution margin was US$0.17 per kWh in 2001 when tariffs were not regulated.[6] This trend may lead to consolidation in the sector, as operators seek economies of scale while smaller mini grids struggle, and Cambodia's traditional business model for developing mini grids faces increasing uncertainty.

Table 1.1 presents the key metrics of mini grids in Cambodia, including data on mini grids penetration in the country, tariffs and rates, and quality of service.

Table 1.1: Key Metrics for Mini Grids in Cambodia, 2015

Mini grid Penetration		
Number of mini grids	Number	327 (including 16 non-valid)
Average growth in number of mini grids from 2005 to 2015	%	12
Customers served by mini grids	Customers, thousands	1,039.8
	People, thousands	4,783.1
	% of total population	30.7%
	Of the population with access to electricity,% connected to a mini grid	55.6%
Average growth in connections from 2005 to 2015	Thousand/year	95.9
	%/year	29%
Tariffs and Rates		
Cost of connection(1)	US$	652
	% of GDP/Capita	21%
Average subsidy per connection	US$	30.3
	% of GDP/Capita	0.9%
Monthly bill for Tier 2(2) consumption	US$	1.76
	% of GDP/Capita	0.7%
Average tariff(3)	US$/kWh	0.29
Quality of Service		
Availability of electricity	Hours of service/day	▪ 24 hours: 306 ▪ Between 12 and 24 hours: 3 ▪ Below 12 hours: 2

Notes: (1) The cost of connection refers to the cost, for the developer, of connecting new customers.

[5] Castalia estimate, from EAC's annual reports. Tenenbaum, Greacen, Siyambalapitiya, and Knuckles (2005) "From the Bottom Up" estimate an average distribution margin in Cambodia of US$0.14 per kWh

[6] Enterprise Development Cambodia (2001) "Survey of 45 Cambodian Rural Electricity Enterprises" estimate that the cost of generating one kWh is US$0.34, and the average tariff US$0.51 per kWh

(2) A "tier 2" access to electricity is access that allows for consumption of 73 to 250 kWh/year. Source: World Bank/ESMAP (2015), Beyond Connections – Energy Access Redefined (https://openknowledge.worldbank.org/bitstream/handle/10986/24368/Beyond0connect0d000technical0report.pdf?sequence=1&isAllowed=y, Accessed October 4, 2017)
(3) For all mini grids and categories of customers.

2 | COUNTRY CONTEXT

Table 2.1 summarizes statistics on Cambodia's demographics, economy, governance, and electricity sector.

Table 2.1: Cambodia Summary Statistics, 1995, 2005, 2015

		1995	2005	2014
Demographics				
Population	Million	10.7	13.3	15.3
Population growth	Annual average	3.3%	1.6%	1.7%
Rural population	Million	8.8	10.7	12.1
Rural population growth	Annual average	2.8%	1.4%	1.4%
Population density, National	People/sq. km	60.4	75.2	86.5
Economy				
GDP	PPP, 2011 US$ million	3,411.2	6,293.0	16,777.8
GDP per capita	PPP, 2011 US$	1,102.9	1,969.3	3,124.3
Real GDP per capita growth	5-year compound rate	N/A	7%	5%
Debt to GDP ratio	%	N/A	36%	29%
Governance				
Ease of Doing Business rank	See (1)	N/A	N/A	137
Corruption Perceptions Index	See (2)	N/A	2.3	2.3
World Bank Governance Indicator	See (3)	-0.84	-0.88	-0.72
Electricity Sector				
Electricity connection rate, national	% of population	4.9	20.5	56.1
Urban		-	*66.8*	*96.9*
Rural		*0.6*	*12.6*	*49.2*
Electrification growth rate	% change in population with a connection, 5-year compound rate	171.6%	6.2%	12.0%
Population with an electricity connection	Thousands	526.0	2,730.6	8,599.1

Urban		*476.0*	*1,379.2*	*2,627.1*
Rural		*50.0*	*1,351.4*	*5,972.0*
Electrical power consumption	kWh/person /year	13.5	66.8	271.4
	kWh/person with an electricity connection/year	274.8	325.7	483.8
Customers served by the grid	Thousands	N/A	206.5	772.7

Source: World Bank Development Indicators (2016), Transparency International (2016)

Notes: (1) The Ease of Doing Business Index ranks countries from 1 to 190. The closest a country is to 1, the more conducive its regulatory environment is to the starting and operation of a local firm.
(2) The Corruption Perceptions Index ranks countries on a scale of zero to 10, with zero indicating very high levels of corruption and 10 indicating very low levels of corruption.
(3) The Worldwide Governance Index assign scores to countries from -2.5 to 2.5, with higher values indicating higher quality of governance.
N/A: not available

Demographics

Cambodia has a population of 15.6 million people. The growth rate of population has decreased over the past two decades, from 3.3% in 1995 to 1.7% in 2015.

More than three quarters of the population lives in rural areas of the country's 181,035 km². In 2015, 12.1 million people lived in rural areas. Phnom Penh, the country's capital, concentrated 1.7 million people in 2015.[7] This explains a relatively low national population density of 86 people per square kilometer in 2015.

Economy

Cambodia has enjoyed strong economic growth, with real GDP per capita growing at an average rate of 6.2% between 2000 and 2016. GDP per capita almost tripled in 20 years, from US$1,102.9 in 1995 to US$3,278 in 2015.

Agriculture still accounts for a large share of the Cambodian economy (27%). Industry accounts for 32%. Cambodia's largest export is textiles, which represent 72% of exports.[8]

Governance

Cambodia went through almost half a century of deep instability after independence. In 1953, the country obtained independence from France, after almost a century of colonization. After a civil war from 1967 to 1975, the Khmer Rouge took control of the country and established a communist regime, the Democratic Kampuchea, from 1975 to 1979. This most brutal regime, which caused between 1.5 and 2 million deaths in less than four years, was overthrown by the Vietnamese with support of exiled Cambodians in 1979. Vietnam occupied the country until 1991. As a result of the Paris Peace

[7] Central Intelligence Agency, The World Factbook (https://www.cia.gov/library/publications/the-world-factbook, accessed October 12, 2017)
[8] OECD (2012) "Structural Policy Country Notes Cambodia"

Agreements (1991), the country stabilized, adopted a new Constitution in 1993, and held elections the same year.[9]

Democracy remains fragile,[10] with recent concerns over political freedom.[11] Cambodia is a parliamentary monarchy, in which the three branches of power are separated. Its law system is mostly based on civil law. The country is divided into 24 provinces and municipalities.[12]

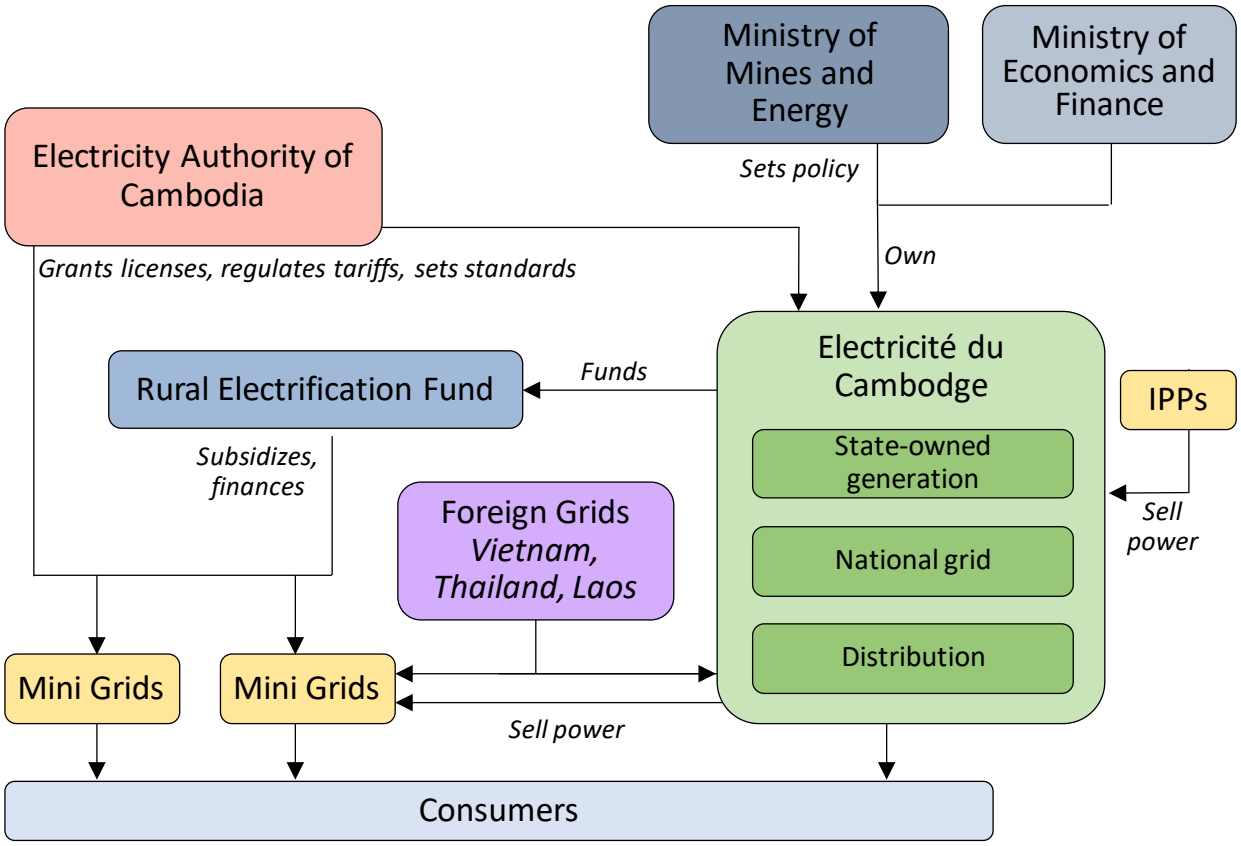
3 | OVERVIEW OF THE POWER SECTOR

The Electricity Law, adopted by the National Assembly on November 6, 2000, and signed by the King on February 2, 2001, defines the main actors in Cambodia's power sector and governs their roles and the relationship between them. The Electricity Law establishes the sector regulator, the EAC, distinguishing between its responsibilities and those of the Ministry of Mines and Energy (MME). EDC is the state-owned power utility. The Law establishes that EAC regulates EDC and all other power service providers, including mini grids, Independent Power Producers (IPPs), and private transmission companies.

Figure 3.1 maps out the structure of the power sector in Cambodia.

[9] Central Intelligence Agency, The World Factbook (https://www.cia.gov/library/publications/the-world-factbook, accessed October 12, 2017)
[10] Cambodia scores 4.27/10 at the Economist's Intelligence Unit Democracy Ranking (The Economist Intelligence Unit's Democracy Index, https://infographics.economist.com/2017/DemocracyIndex/, accessed July 23, 2017)
[11] See, for example, *The New York Times*, "Broadening Crackdown, Cambodia Moves to Disband Main Opposition Party", October 6, 2017 (https://nyti.ms/2xYXSiB, accessed October 12, 2017)
[12] Jennifer Holligan and Tarik Abdulhak (2011), "Overview of the Cambodian History, Governance and Legal Sources" (http://www.nyulawglobal.org/globalex/Cambodia.html, accessed October 12, 2017)

Figure 3.1: Cambodia Power Sector Structure



3.1 MAIN ACTORS

The most important actors of the power sector in Cambodia are the state-owned utility EDC and the non-profit department REF within EDC, the regulator EAC, the MME and the Ministry of Economics and Finance, and IPPs. Mini grids (or Rural Electricity Enterprises, REEs), who play a predominant role in Cambodia's power sector, are covered in later sections.

Electricité du Cambodge (EDC)

EDC is the vertically integrated and state-owned utility, serving 774,613 mostly urban customers in 2015.[13] For historical reasons, EDC's service area is concentrated around Phnom Penh and other urban centers. Before year 2001, EDC focused on areas with more than 2,000 households: the capital and provincial and district towns. Rural communes or village towns with less than 2,000 households had poor road infrastructure, were subject to insecurity after the civil war, land had low density of population. This explains lower interest of EDC, which allowed privately-owned REEs to intervene. Average consumption was very low at the time, and there were no commercial customers. Some towns have since become larger centers with commercial customers.

[13] EDC (2016), "Report on power sector of the Kingdom of Cambodia 2015"

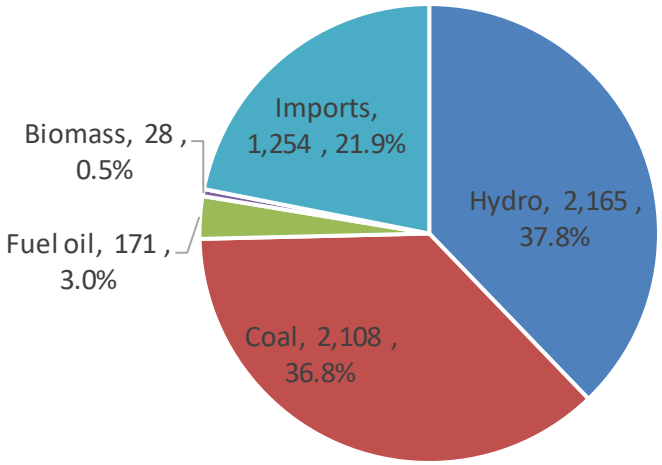
EDC is a state-owned corporate entity governed by the Royal Government of Cambodia. Its Board of Directors includes representatives of the MME, the Royal Government itself (through a Delegate in charge of managing EDC), the Ministry of Economy and Finance, the Council of the Ministers, the Ministry of Justice, and the Chamber of Commerce of Cambodia.

EDC acts as a single buyer, and gets electricity from three main sources:

- IPPs, which generated 4,376GWh in 2015 (over 76% of total generation),
- Imports from Laos, Thailand, and especially Vietnam (1,200GWh), which account for 1,254GWh in 2015 (22% of total generation), and
- EDC's own power plants, which generated 68GWh in 2015 (less than 2%).[14]

Hydro and coal each account for about a third of generation in Cambodia, as Figure 3.2 shows. Hydro generation costs about US$0.057 and 0.07 per kWh; coal about US$0.10 per kWh. The average cost of generation is about US$0.075 per kWh, and is expected to remain constant until 2020.[15]

Figure 3.2: EDC's Generation by Source (GWh), 2015



Source: EDC (2016), "Annual Report 2015"

Rural electrification fund (REF)

The REF is responsible for disbursing subsidies and providing technical assistance to mini grids. The REF was initially co-capitalized by the World Bank and the Government from 2004 until 2012. Since 2012, EDC is responsible for operating and funding the REF. The Asian Development Bank (ADB) and KfW have provided some funding to the REF (US$1 million in 2017, and US$10 million for 2015-2018, respectively).

[14] EDC (2016), "Report on power sector of the Kingdom of Cambodia 2015"
[15] Meeting with MME officials, 7 August 2017

Electricity Authority of Cambodia (EAC)

The EAC is an autonomous body established by the Electricity Law to regulate and monitor the power sector throughout the country. The Prime Minister appoints its three Members for 3-year terms. The EAC is funded exclusively through fees paid by licensees.[16]

The EAC is responsible for ensuring that "the provision of services and the use of electricity [is] performed efficiently, qualitatively, sustainably, and in a transparent manner."[17] The EAC issues licenses, reviews costs and approves tariffs, resolves disputes, and monitors the sector. It issues rules, regulations, and procedures applying to power supply.[18]

Other power sector actors

Other actors in the power sector are:

- The MME, responsible for setting policies and strategies, and planning,
- The Ministry of Economy and Finance, responsible for allocating state budgets and setting economic and fiscal policy, as well as administering state-owned enterprises, including EDC, and
- IPPs, who generate and sell electricity to power suppliers or industrial users through power purchase agreements. IPPs must hold a generation license granted by EAC.

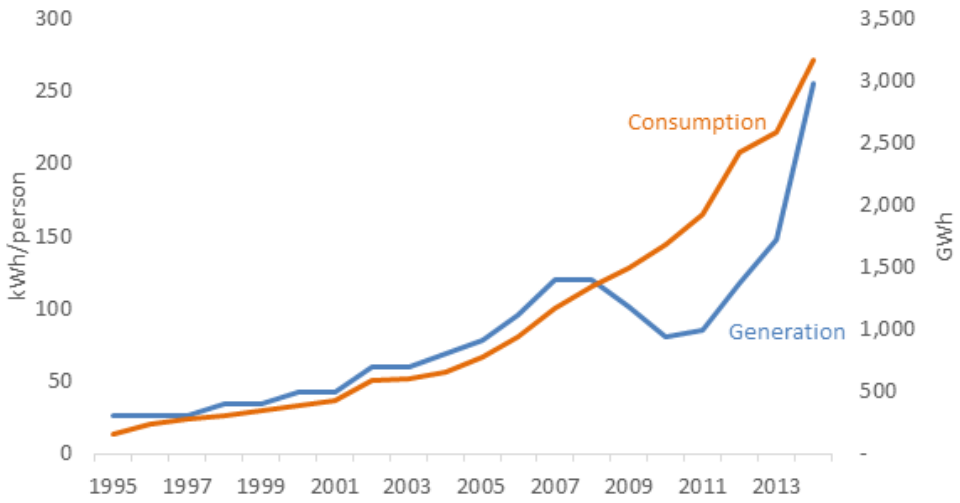
3.2 EVOLUTION OF THE SECTOR

Access to electricity has increased significantly since 2015, with a strong impact on demand. Interconnections grew by over 60% from 2010 to 2014, from around 40% of population with access to electricity in 2010, to 56% in 2014. Over the same period, electricity peak demand skyrocketed to 950MW in 2015, from 486MW in 2010.

Electricity supplied and available capacity correspondingly increased from 2010 to 2015. Electricity sold reached 5,698GWh in 2015, up by over 250% in 5 years. 4,400GWh were generated in Cambodia, the rest being imported (Figure 3.3). Installed capacity exceeded 1,900MW in 2015, a 350% increase from 2010 (Figure 3.4). This was mostly due to developments in hydroelectric and coal generation capacity.

[16] EDC (2016), "Report on power sector of the Kingdom of Cambodia 2015"
[17] Kingdom of Cambodia, "Electricity Law of the Kingdom of Cambodia", article 3
[18] EDC (2016), "Report on power sector of the Kingdom of Cambodia 2015"

Figure 3.3: Evolution of Power Consumption (kWh/person) and Generation (GWh), 1995-2014



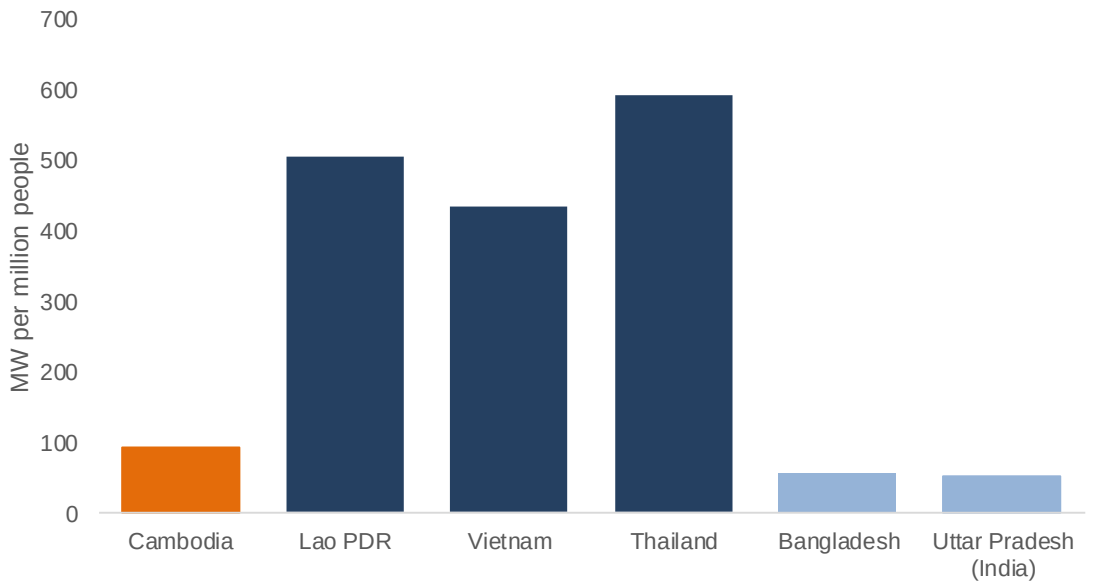
Source: Energy Information Administration, International Energy Statistics: Total Electricity Net Generation, https://www.eia.gov/beta/international/data/browser, accessed July 23, 2017; and World Bank, Electric Power Consumption per Capita, http://data.worldbank.org/indicator, accessed July 23, 2017

Note: The numbers in this figure account for electricity generated within the country, and exclude imports.

Cambodia has a higher installed capacity per capita than the two other case study countries in Asia (Bangladesh and Uttar Pradesh), but lower than its neighbors. Total installed capacity in the country reached 1,972MW as of 2015.[19] As Figure 3.4 shows, Cambodia has only a fifth of installed capacity per capita of Lao PDR, Vietnam, and Thailand.

[19] EDC, "Report on power sector of the Kingdom of Cambodia 2015"

Figure 3.4: Electricity Generation Capacity (MW per million people),2014



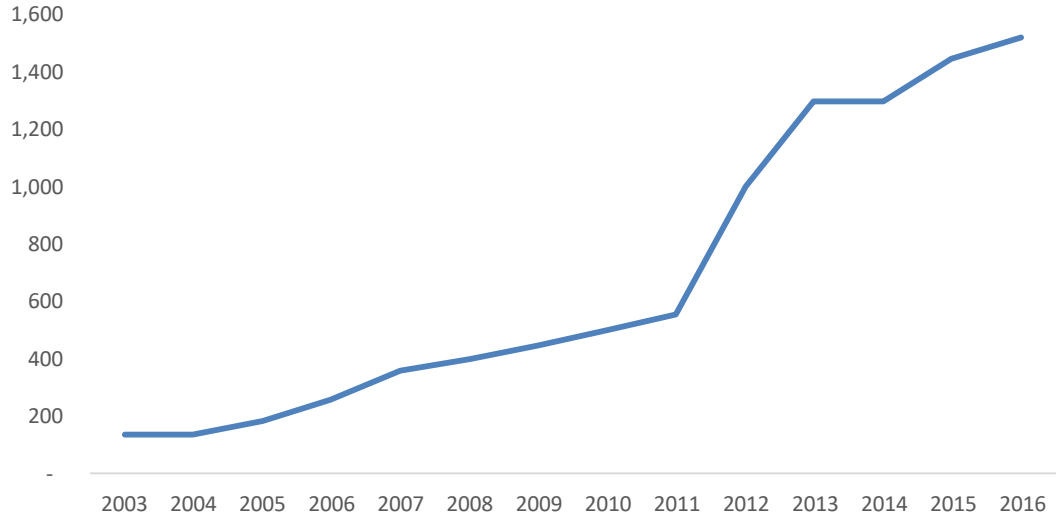
Source: Energy Information Administration, International Energy Statistics: Generation, https://www.eia.gov/beta/international/data/browser, accessed July 23, 2017

Cambodia has recently invested heavily in expanding its high-voltage grid, and now has a network of a size similar to other case study countries, though smaller than some neighbors. From 2011, the length of the network increased by over 250%, reaching 1,448 kilometers in 2015, or 99 kilometers per million people. This is still relatively small compared to neighboring countries such as Laos; with half the population of Cambodia,[20] Laos has 348 kilometers of transmission lines per million people. Other case study countries examined by this assignment (Bangladesh, Uttar Pradesh, Kenya, Nigeria, and Tanzania) have networks ranging from 36 to 117 kilometers of transmission lines per million people.

Private transmission developers have accounted for most of this investment. The first transmission lines built in Cambodia were publicly-owned and operated by EDC. Since 2007, eight private transmission operators have received transmission licenses from EAC. These account for over 1,000 kilometers of new high-voltage lines, or over 75% of the entire system.

[20] Laos is 237,955 km^2, whereas Cambodia is 181,035 km^2

Figure 3.5: Evolution of the Transmission Network (km), 2003-2015

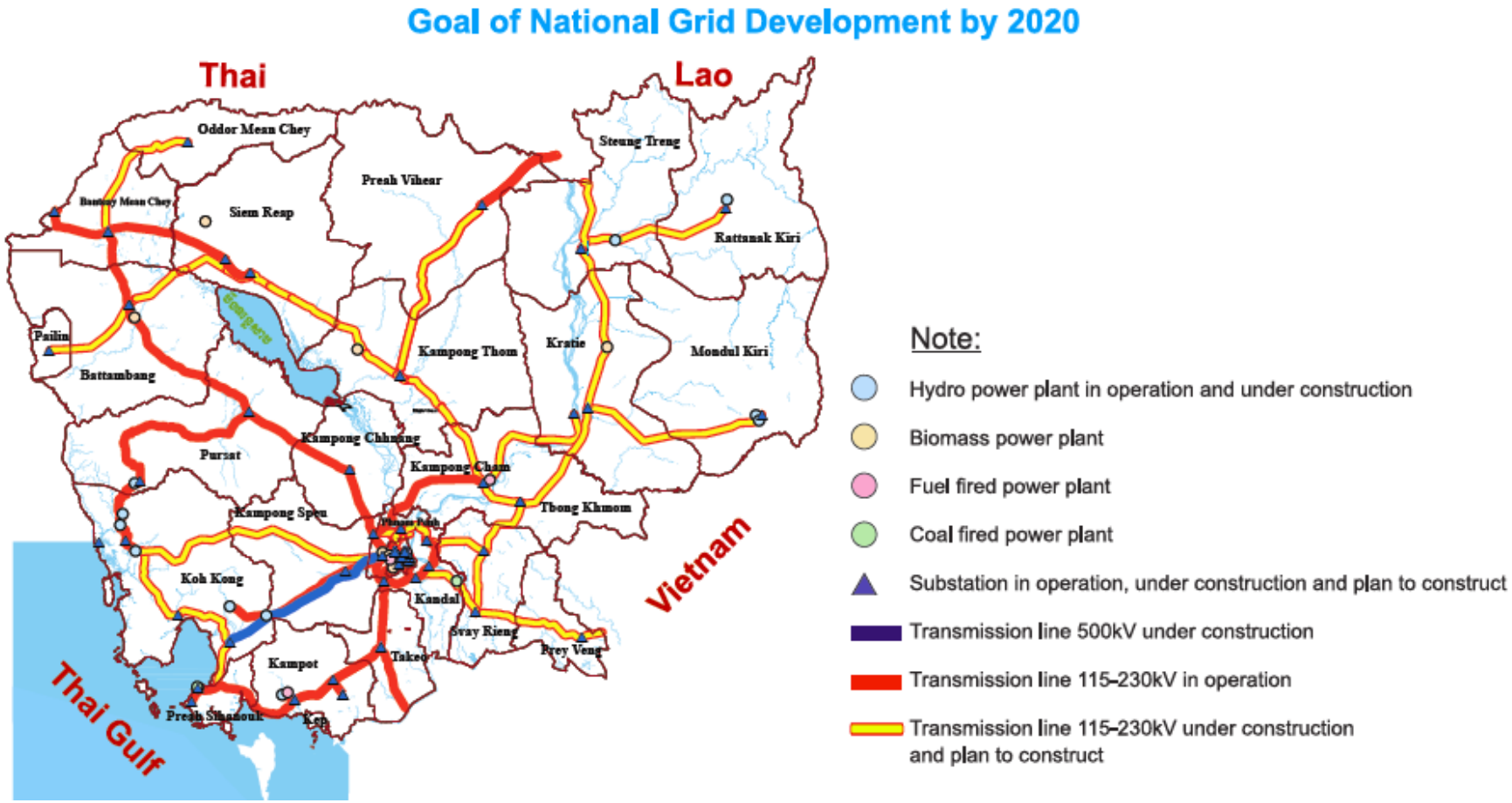


Source: EAC, "Report on power sector of the Kingdom of Cambodia," 2003 to 2015

The country's power infrastructure has progressively expanded from the central region around the capital, Phnom Penh. Most planned developments in generation capacity and new transmission lines are connected in this area (see Figure 3.6).

Cambodia's transmission network was built in separate fragments, which are being progressively connected with the construction of new high-voltage lines. High-voltage segments have been built in different areas, separate from the main grid surrounding Phnom Penh. These high-voltage segments connect remote regions to imported electricity from Thailand and Laos in the West and the North, and Vietnam in the South and the East. Some systems (distribution and transmission) have not yet been connected to the central national grid. The backbone of the transmission system is being extended towards the northeastern regions of the country, with plans to commission new lines by 2020.

Figure 3.6: Cambodia's Existing and Planned National Grid

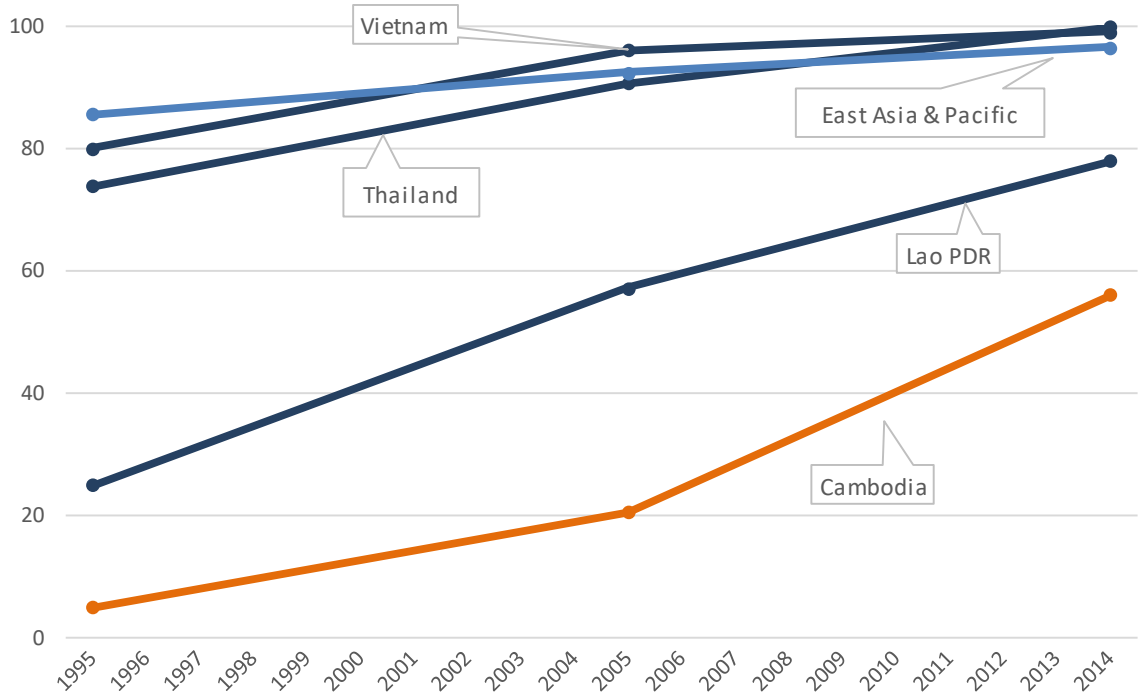


Source: EAC (2017), "Salient Features of Power Development in Kingdom of Cambodia"

3.3 ACCESS TO ELECTRICITY: MAIN GRID AND MINI GRIDS

The level of interconnection to electricity supply in Cambodia has sharply increased in the past decade to almost 60%; however, it remains 42% lower than the regional average (as shown in Figure 3.7). Laos has an access rate of 78%, while neighboring Thailand and Vietnam are at 100 and 99% access to electricity, respectively.

Figure 3.7: Access to Electricity (% of population), 1995-2014



Source: World Bank, Electricity Access, http://data.worldbank.org/indicator, accessed July 10, 2017

Electricity consumption per capita is also low compared to that of Cambodia's neighbors. Electricity sold to consumers in 2015 was 5,205GWh, or 279kWh per capita per year, compared to 2,540kWh in Thailand and 1,439kWh in Vietnam.[21]

The number of customers getting electricity from a mini grid overtook the number of customers of the main grid between 2005 and 2015. In 2005, the main grid had more than twice as many connections as mini grids; in 2015, around 60% of customers were connected to a mini grid. Table 3.1 shows the evolution of electricity connections.

Table 3.1: Evolution of Population with an Electricity Connection, Grid and Mini grids, 1995, 2005, 2015

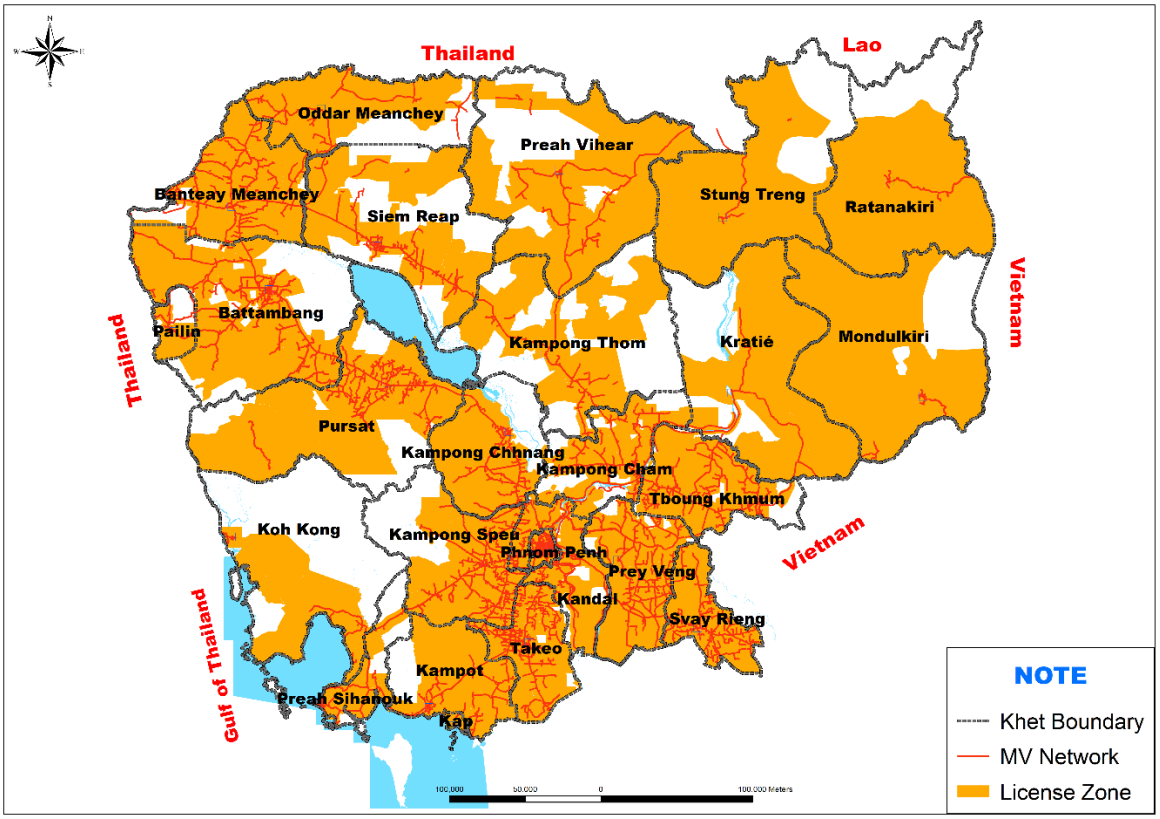
		1995	2005	2015
Population		10.69	13.32	15.52
Urban	Million	1.9	2.6	3.2
Rural		8.8	10.7	12.3

[21] World Bank, Electric Power Consumption per Capita, http://data.worldbank.org/indicator, accessed July 23, 2017

Population served by the main grid	Thousand	-	949.9	3,554.4
Population served by mini grids	Thousand	-	373.1	4,783.1

The 311 mini grids operating in Cambodia in 2015 connect 1.1 million households. All mini grids are privately operated. Over 90% of mini grids are connected to the main grid; the rest are isolated and connect 21,620 consumers.[22] Each mini grid owns a license, with one exclusive service area: in 2015, most of Cambodia's territory was covered by licenses, as Figure 3.8 shows.

Figure 3.8: Map of the Area Covered by Licenses, 2015



Source: EAC, "Map showing the licensee distribution for each province," https://eac.gov.kh/en/publication/map/ (accessed July 20, 2017)

Table 3.2 compares customer statistics, tariffs, and quality of service of grid and mini grid supply. The average tariff for mini grids is higher than the main grid's, and most mini grids provide the same hours of service as the main grid.

Table 3.2: Mini grid and Main Grid Summary Statistics, 2015

		Main Grid	Mini grids
Customers served	Thousand	772.7	1,039.8

[22] EAC (2016), "Report on power sector of the Kingdom of Cambodia 2015"

Share of total customers served	%	44.4%	55.6%
Average tariff[(1)]	US$/kWh	▪ 0.15 below 50kWh/month ▪ 0.18 between 51 and 200kWh/month ▪ 0.20 above 200kWh	0.29
Availability of electricity	Hours of service/day	24	▪ 24 hours: 306 ▪ Between 12 and 24 hours: 3 ▪ Below 12 hours: 2 [(2)]

Source: EAC (2016), "Report on power sector of the Kingdom of Cambodia 2015"
Notes: (1) For all mini grids and all categories of customers.
(2) Thirteen licensees did not operate in 2015.

4 | POLICY SETTINGS FOR MINI GRIDS

The Government adopted a regulated approach to the mini grid sector from the early 2000s. Up until then, there was no regulation in place specific to mini grids.

4.1 FROM A LAISSEZ-FAIRE TO A REGULATED APPROACH

Entrepreneurs started installing mini grids in rural areas of Cambodia in the 1990s under a loose regulatory environment. At the time, the Government was financially weak, and the electricity infrastructure had been damaged by the civil war. The central and provincial governments shared the responsibility of licensing mini grids, which resulted in loose oversight; licensing requirements were low (see section 6 |).

The EAC estimates that there were between 150 and 300 mini grids in operation before 2001. REEs operated isolated distribution systems powered by diesel generators. Other sources speak of 600 mini grids, connecting 180,000 households (roughly 0.9 million people) and 7,000 businesses.[23] This would have represented almost 50% of total electrification. However, according to the EAC, these numbers are likely to be biased by having been based on extrapolating non-representative samples. In 2001, the Rural Electrification Strategy and Implementation Programme Survey Report" estimated that REEs connected 72,000 households.[24] Average generating capacity was 105 kW per REE, all ran diesel generators, losses were high, tariff charged ranged between US$0.31 and US$0.91 per kWh, and household consumption was low.

During the late 1990s, the Government adopted a more proactive role. Based on conversations with the EAC and the MME, the objective was generally to exert greater control. There was a desire to increase

[23] Kariuki, Mukami, and Schwartz (2005) "Small-Scale Private Service Providers of Water Supply and Electricity" estimate that among the 200 customers per mini-grid on average, 94 % is household (see note 2)
[24] Meritec Limited for the Ministry of Industry, Mines, and Energy (2001) "Rural Electrification Strategy and Implementation Programme Survey Report"

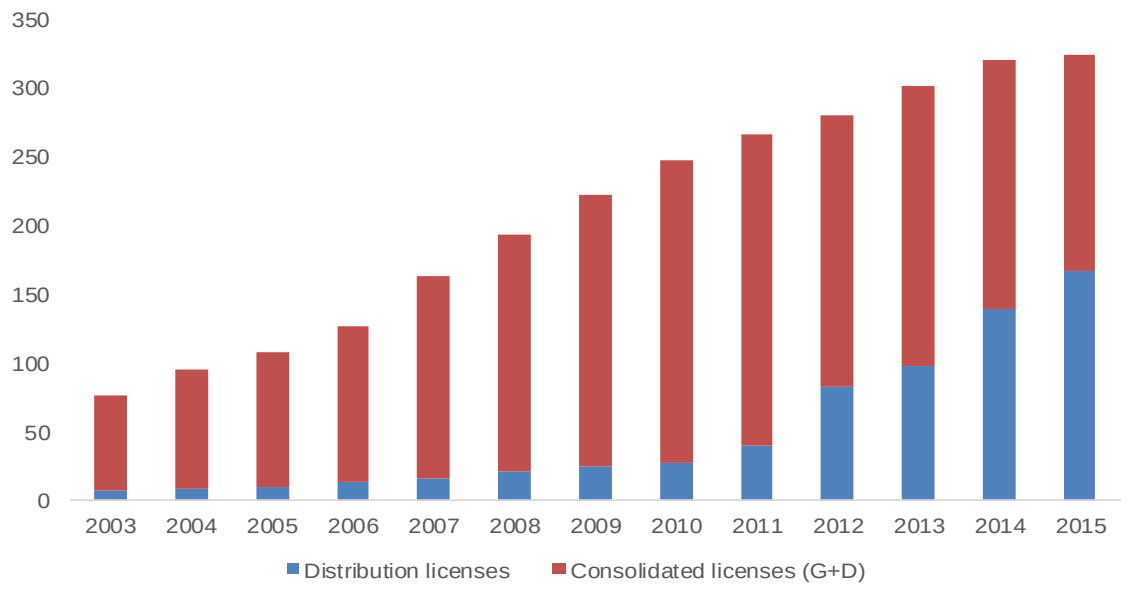
electrification, reduce tariffs and make them more uniform across service areas, and improve service; but no specific targets or a comprehensive appreciation of what implementation would actually require.[25] The National Assembly adopted the Electricity Law of 2001, following discussions started in 1998 and the set-up of a task force that produced a first draft in 1999. The Law set up the EAC (see section 3.1); and required that all providers of electric power services obtain a license,[26] implement technical standards,[27] and charge approved tariffs.[28]

The EAC progressively granted licenses to unregulated mini grids, and then adapted them as the main grid connected them:

- The EAC indicated that, by 2005, all the unlicensed mini grids operating before the regulation had been granted a license. This implies that all licenses issued after 2005 were granted to new mini grids; and that many mini grids were operating without a license before 2005. The EAC notified REEs they needed a license to continue operating, starting with larger operators in province towns and then smaller ones in district towns. Some REEs came spontaneously to seek a license.
- Between 2003 and 2015, the number of licensees has increased from 76 to 324, and an important number of mini grids have been connected. Figure 4.1 shows the transition from unregulated mini grids to distribution utilities: the number of consolidated licenses decreases after a peak in 2011. As of 2015, there were:
- 167 mini grids with a distribution license connected to the main grid (including 5 invalid licenses), up from 8 in 2005,
- 157 mini grids with a consolidated license for generation and distribution, up from 87 in 2005. In 2015, of these:
- 99 were in the transition process (connected to the main grid, and waiting for their license to be converted to a distribution license),
- 30 were isolated mini grids, and
- 28 were not valid.

[25] Meeting at the EAC, 2 August 2017; and with officials of MME, 6 August 2017
[26] Kingdom of Cambodia, "Electricity Law of the Kingdom of Cambodia", article 41
[27] Kingdom of Cambodia, "Electricity Law of the Kingdom of Cambodia", article 42
[28] Kingdom of Cambodia, "Electricity Law of the Kingdom of Cambodia", article 46

Figure 4.1: Distribution and Consolidated Licenses Granted by Year, 2003–2015



Source: EAC, "Report on power sector of the Kingdom of Cambodia," 2004 to 2015

The Government has also been providing financial support for the private sector to continue investing and maintain mini grids. The Government created, by Royal Decree No. NS/RKT/1204/048, the REF in 2004 to provide subsidies for mini grids (see section 8 |).

4.2 POLICY APPROACH TO NATIONAL TARIFF

Before 2001, there was no uniform national tariff. Mini grids could charge any rate to their customers. No information was available on how EDC's tariff was determined before 2001.

From 2001 until 2016, the EAC regulated the tariff of each power provider individually. The EAC regulated mini grids' tariffs after granting them a license, on a case-by-case basis, based on their costs. According to the EAC, tariff setting before 2016 was softer and more generous towards operators. This approach was based on an intuition of what operators needed to improve level of service and invest in expanding it while adapting to the new framework of Government control; and by an appreciation of the difficulty to obtain private sector loans. The approach was not defined by a specific set of indicators or calculations; rather, it consisted of practical solutions as rounding up tariff calculations.[29] EDC's tariffs were also cost-reflective, varying across geographical area.

In March 2016 the Government introduced a standard tariff that applies to all customers supplied by EDC or by a mini grid connected to EDC. (The EAC still scrutinizes cost of service of individual operators; see section 8 | .) The tariff does not apply to isolated mini grids, or mini grids purchasing power from a medium voltage (MV) line fed by imports. The Government has set the level of the standardized tariff until 2020: it will remain constant until then, except for residential consumption above 50kWh per month (see Table 4.1).

[29] Meeting at the EAC, 2 August 2017

Table 4.1: Standardized Tariff for Licensees Buying from EDC, 2017-2020

		2017	2018	2019	2020
Residents consuming less than 10kWh per month	KHR/kWh	480			
	US$/kWh	0.119			
Residents consuming between 11 and 50kWh per month	KHR/kWh	610			
	US$/kWh	0.151			
Residents consuming more than 50kWh per month	KHR/kWh	790	770	760	750
	US$/kWh	0.195	0.190	0.188	0.185
Water pump for agriculture from 9:00pm to 7:00am	KHR/kWh	480			
	US$/kWh	0.119			

Source: EAC (2017), "Salient Features of Power Development in Kingdom of Cambodia"

4.3 EXPANSION PLANNING

The HV system is centrally planned, and implemented by different entities. The MEM is responsible for designing the HV expansion masterplan. EDC and private operators with the appropriate license (transmission or special consolidated license with transmission) build, own, and operate transmission lines.

Expansion of the MV system mainly follows commercial considerations targeting the largest loads. Policies from the Government guide the expansion of the MV system, but there is no central planning. On the one hand, the Government has set a policy of interconnecting mini grids to the main grid; EDC and private companies with the appropriate license expand the MV system and connect mini grids on an opportunistic basis, considering the loads to capture.[30] Neither EDC nor transmission licensees share their expansion plans, although mini grids are informed in advance that they will be interconnected.[31] On the other hand, mini grids have the obligation to expand their distribution system to cover the entire service area of their license.

5 | OVERVIEW OF THE MINI GRID SECTOR

Mini grids emerged as a spontaneous business, exclusively relying on diesel generation (mostly refurbished).[32] Quality of supply was low until they started being regulated and some of them got connected to the main grid. Their tariff is regulated based on cost of service.

5.1 MINI GRIDS TECHNOLOGIES

During the laissez-faire era, quality of supply was poor, and no standards were in place. All mini grids were diesel-fired; some also used biomass in combination with diesel. In 2005, EAC noted that "most of the

[30] Meeting with MME officials, 6 August 2017
[31] Meetings with isolated and interconnected licensees, August 2017.
[32] Enterprise Development Cambodia (2001) "Survey of 45 Cambodian Rural Electricity Enterprises"

service providers in small towns and rural areas have [power service facilities] obsolete or very old, not compliant with technical standards, unsafe in operation and use". This resulted in frequent breakdowns and high losses, with 82% of mini grids reporting losing more than 20% of power generated (including 36% losing more than 30% of power generated). This can mostly be attributed to the fact that most mini grid entrepreneurs were improvised professionals: almost half entered the electricity supply business because they learnt about it from a friend, and less than one in five had an education beyond high school.[33]

Today, mini grids operators decommission their generators as they connect to the main grid and buy power from the grid. They decommission their generators for both regulatory and financial reasons (see section 6 |). Connected mini grids distribute power exclusively bought from the grid. Quality of supply has increased significantly, with almost all mini grids providing power all day in 2015. Losses have also decreased considerably, to less than 15% of power generated.[34]

5.2 BUSINESS MODELS

From the 1990s when they emerged until today, mini grid operators build, own, operate, maintain, and finance their systems. In 2001, almost half of a sample of mini grids had borrowed money to finance their activities. They generally had got finance from relatives or their personal contacts at cheap or no interest rates, and more rarely from commercial banks;[35] this is still true today. Commercial loans are harder to get, with tight requirements on collateral (land title if asking for over 50% of capital expenditure) since assets are of little value to banks, who do not see the opportunity to take over a public service.[36] Many licensees are engaged in other businesses (for example, private lending, or agribusiness).

The number of hours of service has increased progressively. In 2001, less than 10% of mini grids provided power 24 hours per day; more than half provided power for less than 12 hours per day.[37] In 2005, more than half of mini grids (49 out of 85) provided power only for some part of the day; 22 mini grids (25%) provided power for less than 12 hours per day.[38] In 2015, less than 2% of mini grids did not provide power 24 hours per day.

Mini grids use monthly billing (post-paid) on a per-kilowatt hour basis, and tariffs sometimes vary depending on the customer category. Some mini grids have different tariffs for commercial and residential customers. Customers are responsible for purchasing the meter, and installing in-house wiring. Mini-grids seem to also have used monthly billing before 2001.[39]

Mini grids' distribution margins are subject to regulatory activity since the Electricity Law. Connected mini grids buy power from EDC or a private feeder line from a transmission licensee, and resell it to their customers. Their margin (to cover distribution costs and profit) is the difference between the rate at which they buy, and the rate at which they sell; EAC regulates both rates.

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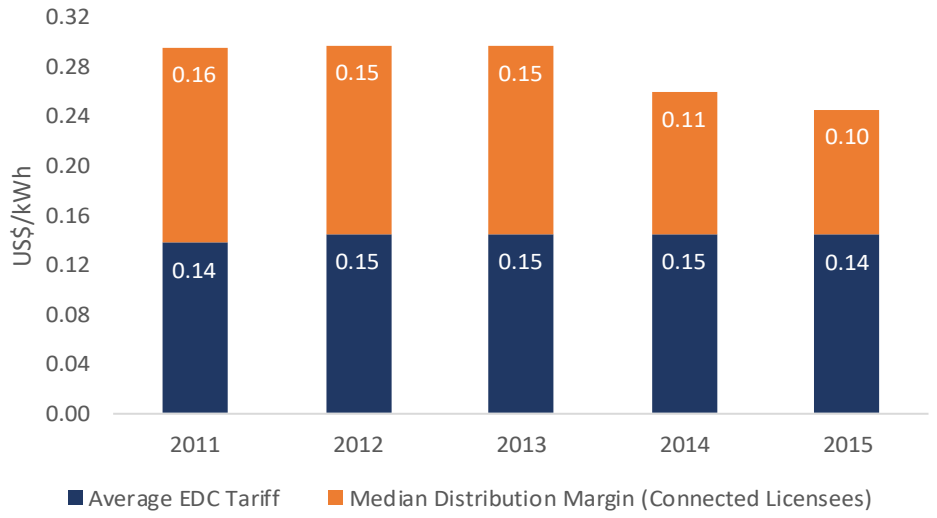
[33] Enterprise Development Cambodia (2001) "Survey of 45 Cambodian Rural Electricity Enterprises"
[34] Meeting at EAC, August 1, 2017
[35] Enterprise Development Cambodia (2001) "Survey of 45 Cambodian Rural Electricity Enterprises"
[36] Meeting at the REF, 2 August 2017 and isolated and interconnected licensees, August 2017.
[37] Enterprise Development Cambodia (2001) "Survey of 45 Cambodian Rural Electricity Enterprises"
[38] EAC (2006), "Report on power sector of the Kingdom of Cambodia 2005", and Baker (2009), "Opportunities and Challenges for Small Scale Private Service Providers in Electricity and Water Supply"
[39] Kariuki, Mukami, and Schwartz (2005) "Small-Scale Private Service Providers of Water Supply and Electricity", Enterprise Development Cambodia (2001) "Survey of 45 Cambodian Rural Electricity Enterprises"

Data suggest break-even distribution margins for connected mini grids, but significantly decreasing since 2011. In 2005, 80% of mini grid operators were making profits.[40] According to the EAC, the regulator does not track profit or distribution margins.[41] In 2015, only eight licensees (out of 311) merged with another licensee that year,[42] suggesting that most operators might have been breaking even; but distribution margins were low, with the median value between US$0.10 and 0.11 per kWh in 2015, down by more than a third since 2011, as Figure 5.1 shows.

Interviews with private sector operators seem to confirm a downward trend in profits, although hard to define precisely. Operators interviewed are satisfied of their ability to remain in business and repay their loans; but find it harder to make a profit (or could not say what profit they actually make) while investing to expand service compared to the early 2000s. Mini grid operators generally have difficulties calculating their actual profit and return on investment (in 2001, almost half operators had never calculated their return on equity).[43] It is not clear that they anticipate asset repair or replacement (or cannot do so),[44] although some of them are aware that their assets are depreciating.[45]

Figure 5.1: Median Distribution Margin (US$/kWh), Connected Licensees, 2011-2015



Source: Castalia calculations from EAC, "Report on power sector of the Kingdom of Cambodia," 2011 to 2015

6 | AUTHORIZING MINI GRID OPERATORS

Before 2001, mini-grids regulation was loose. Only mini grids with capacity above 125kVa (100kW) had to obtain a license from the MME; those with capacity below this threshold may, but were not required

[40] Enterprise Development Cambodia (2001) "Survey of 45 Cambodian Rural Electricity Enterprises"
[41] Meeting at EAC, August 1, 2017
[42] EAC (2016), "Report on power sector of the Kingdom of Cambodia 2015"
[43] Enterprise Development Cambodia (2001) "Survey of 45 Cambodian Rural Electricity Enterprises"
[44] Meetings with isolated and interconnected licensees, August 2017.
[45] Enterprise Development Cambodia (2001) "Survey of 45 Cambodian Rural Electricity Enterprises"

to, obtain a license from the provincial office of the MME. A simple registration was sufficient to obtain a license. In both cases, the license granted exclusivity over the service area. Licenses issued by MME lasted three years; licenses issued by a provincial office of MME lasted for one year only.[46]

Enforcement of the regulation was also weak. Surveys show that 11% of mini grids has a license from the MME; 76% had a license from the provincial office of the MME; 11% of mini grids were registered at a lower level of Government; and 2% did not have any license. Moreover, many mini grids did not respect this regulation. Out of a survey of 45 mini grids, 16 did not obtain a license from MME when they should have, and 6 other did not register at the provincial office of the MME when they should have).[47]

In 2001, the Electricity Law required all electricity service providers to get a license from the EAC. The Electricity Law describes the eight types of licenses that the EAC can issue. The EAC can issue:[48]

- Generation licenses, which give right to "own, operate and manage or control the generation facilities for generating electricity for sale and not solely for own consumption,"
- Transmission licenses, which give the right to "own, operate and manage the power transmission facilities for transferring and delivering or selling the electricity in bulk,"
- Dispatch licenses, which give the right to "control, manage and operate the dispatch facilities for facilitating the delivery and receiving the electricity from the generation, transmission and distribution system,"
- Distribution licenses. A distribution license describes a geographical service area as the one where the licensee "has the right to provide the electricity distribution services," and the "right of ownership, operation, and managing or controlling the distribution facilities for supplying and selling the electricity to the customers."[49] The license gives exclusivity of supply in the distribution area, except for bulk customers who may "select other supply sources from the transmission line or distribution network of other licenses, if they obtain prior approval from EAC,"[50]
- Bulk sale licenses, which give the right to "buy electricity from any Generation Licensees or from the power systems of neighbouring country for sale to Distribution Licensees or to the large customers in one connected power system,"
- Retail licenses, which give the right to "engage in the sale of electric power to consumers". The retail license differs from the distribution license because the licensee cannot own or operate distribution assets,
- Subcontract licenses, which give the right to "supply electric power services according to the subcontract agreement with existing licensee,"
- Consolidated licenses. The consolidated license is the combination of any other type of license. EAC can issue this type of license to "EDC, and to the isolated systems."

Table 6.1 presents the requirements for obtaining a license in Cambodia.

[46] Enterprise Development Cambodia (2001) "Survey of 45 Cambodian Rural Electricity Enterprises"
[47] Enterprise Development Cambodia (2001) "Survey of 45 Cambodian Rural Electricity Enterprises"
[48] Kingdom of Cambodia, "Electricity Law of the Kingdom of Cambodia", articles 30 to 37
[49] Kingdom of Cambodia, "Electricity Law of the Kingdom of Cambodia", article 34
[50] EAC (2014), "Distribution License Providing Electric Power Distribution Service at Some Part of Kandeang District, Bakatn District and Krong Pursat, Pursat Province. Mrs. Kim Siphal"

Table 6.1: Requirements for registration, permit, and license

	Registration	Permit	License
Size	N/A	N/A	No restriction
Location	N/A	N/A	Only areas not already assigned to another licensee
Exclusivity	N/A	N/A	Yes
Administrative procedure	N/A	N/A	1. Applicant sends the application to the provincial or district authority, which forwards it to EAC 2. EAC issues a receipt of application acceptance to the applicant 3. EAC defines a working schedule for publication of the application; site inspection; publication; consultation with applicant; and analysis, within a week after application acceptance 4. EAC publishes the application summary targeted at local authorities and communities, within two weeks after application acceptance 5. EAC determines a period of public consultation, at least 30 days from the date of publication 6. EAC conducts potential site inspection and consultation with applicant 7. EAC approves or refuses, within 15 days after end of public consultation
Relevant information required	N/A	N/A	Distribution and retail licenses: • Distribution: details of intended area of service, details of existing facilities and development plan with details on assets, details on distribution system (voltages, number of phases), details on electricity procurement (PPA, interconnection) and supply (source, quantity) • Economic, Financial and Commercial: statement of technical capacity and experience in the electric sector, share capital of the applicant and indebtedness, sources of funding, total amount of investment, details on tariff (calculation, justification) Consolidated licenses for isolated systems: • Generation: system location, number, type and source of fuel, capacity • Distribution: details of intended area of service, details of existing facilities and development plan with details on assets, details on distribution system (voltages, number of phases) • Economic, Financial and Commercial: statement of technical capacity and experience in the electric sector, share capital of the applicant and indebtedness, sources of funding, total amount of investment, details on tariff (calculation, justification)
Tariff	N/A	N/A	Determined by EAC for each license, by type of customers

Source: EAC, "Report on power sector of the Kingdom of Cambodia", EAC (2002), "Procedures for issuing, revising, suspending, revoking or denying licenses"

The license binds the licensee to:

- Comply with technical and environmental standards set by the MME (see section 7 |),
- For distribution licensees, "ensure the electricity supply to all consumers in the area of the distribution,"[51]
- Sell power at the price set by the EAC, and
- Pay a monthly fee to the EAC, share with it its audited financial statements three months after the end of the financial year, and respond to requests for information from EAC.

EAC grants longer term licensees to operators that show that they have made progress to comply with the service requirements. EAC grants licenses of term 5 to 25 years. Initially, EAC granted provisional licenses for 2 years with the condition that the licensee improve the infrastructure to a specified standard and extend service. Licensees that complied received longer licenses (up to 25 years). If the licensee failed to show progress, the EAC could consider taking punitive action, including revoking the license;[52] however, this has not happened.[53] Table 7.1 shows that from 2014 to 2016, all licensees had licenses of 5 years or more; from 2005 to 2007, more than 50% of licenses were 5 years or less.

Granting of licenses is also implicitly tied to extension of service through definition of the license area and monitoring by the EAC. The opportunity to increase interconnections and revenues of course acts as an incentive; but the expectation of the next license (whether it will be granted or not, and with what duration) is also a motivation. License areas granted by EAC often include zones—mostly the peripheral ones of an area, making areas contiguous—that licensees would rather not have as potentially loss-making. Interviews with private operators and public entities highlighted a generic need to show an effort in expanding service rather than comply with a specific rate of new interconnections.

Licensees report quarterly and annually to EAC. The quarterly report is a simple spreadsheet with power sales per month and customer category. The annual report is a more comprehensive spreadsheet with more precise financial data. Both forms are contained in Appendix A.

When the main grid connects to an isolated mini grid, the consolidated license is converted into a distribution license. According to the EAC, the conversion is automatic,[54] but this process in practice can take several months. This implies that as soon as a transmission line (either operated by EDC or a transmission licensee) reaches the mini grid, the operator must decommission its generation. This is because the new license does not allow the operator to generate: the new license is for distribution only. Also, it would not make financial sense for the operator to use it, even for back-up: the operator cannot claim any generation costs in the tariff calculation from EAC—only the cost of power purchase. Energy generated by the licensee is more expensive, but it would be billed at the same price as the energy bought from EDC, and the licensee would lose money.

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[51] EAC (2014), "Distribution License Providing Electric Power Distribution Service at Some Part of Kandeang District, Bakatn District and Krong Pursat, Pursat Province. Mrs. Kim Siphal"
[52] EAC (2006) "Report on power sector of the Kingdom of Cambodia 2005"
[53] Tenenbaum, Greacen, Vaghela "Mini Grids and Arrival of the Main Grid: Lessons from Cambodia, Sri Lanka, and Indonesia"
[54] Meeting at EAC, August 1, 2017

Interviews with private operators highlighted some uncertainty as to what conditions will actually look like once interconnection happens, or timing for it once the main grid is within reach. Experience of neighboring operators acts as a key reference for expectations of tariff trends and consequent profit margin (for example, expecting that the tariff go from Riel 3,000 per kWh before interconnection to 1,300 in subsequent steps over one to two years, with profit margin stabilizing after that).

7 | TECHNICAL AND SERVICE STANDARDS

Before 2001, mini grids were not subject to any technical or service standards, since they were not regulated. Quality of service was low, with most mini grids providing power only 4 hours per day, as noted above.

The Electricity Law of 2001 requires licensees, whether isolated or connected, to comply with technical and service standards issued by the EAC. These are the "Overall Performance Standards for Electricity Suppliers" and the "Electric Power Technical Standards." Their main specifications are:

- To maintain voltage between 207 and 253V: frequency between 49.5 and 50.5Hz,[55]
- To comply with safety (e.g. wiring, clearance) and environmental regulations,
- To comply with performance standards:
    - Outages should be scheduled 2 days in advance, and last 12h at most,
    - Power should be restored within 6 hours in 60% of the cases, and in all cases within 24h after notification, except in case of MV cable fault, and
- Licensees should respond to customer requests (e.g. connection, incorrect meter reading) within set time limits, and
- To keep records of problems and complaints, and share them with the EAC.[56]

EAC uses a system of incentives and penalties to force mini grids to comply with the standards. First, the EAC grants longer duration licenses if the operator shows it complies with the license. Second, mini grids tariffs depend on the compliance of assets with EAC's standards (see section 6 |). If the licensee's assets do not comply with EAC's standards, they are not allowed in the asset base used by EAC to calculate the tariff. For example, an operator reported that it had to change wooden poles three times before complying with EAC's standards of concrete square-section poles. Finally, licensees received subsidies and technical assistance to comply with the standards (see section 8 |). EAC points to compliance with technical standards as the biggest challenge in mini grids regulation today, under a fast pace of development of the market.

[55] EAC, "Electric Power Technical Standards of the Kingdom of Cambodia", https://eac.gov.kh/en/publication/standard-of-service/ (accessed July 20, 2017)
[56] EAC, "Overall Performance Standards for Electricity Suppliers in the Kingdom of Cambodia", https://eac.gov.kh/en/publication/standard-of-service/ (accessed July 20, 2017)

Table 7.1: Duration of licenses, 2005, 2006, 2007, 2014, 2015, and 2016

	At the end of 2005		At the end of 2006		At the end of 2007		At the end of 2014		At the end of 2015		At the end of 2016	
	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%
Consolidated licenses												
2 to 4 years	78	80.4%	88	77.9%	77	52.7%	0	0.0%	0	0.0%	0	0.0%
5 years	10	10.3%	13	11.5%	45	30.8%	86	47.5%	57	36.3%	38	49.4%
6 to 10 years	9	9.3%	12	10.6%	24	16.4%	56	30.9%	45	28.7%	20	26.0%
11 to 15 years	0	0.0%	0	0.0%	0	0.0%	36	19.9%	52	33.1%	16	20.8%
16 to 20 years	0	0.0%	0	0.0%	0	0.0%	2	1.1%	2	1.3%	2	2.6%
25 years	0	0.0%	0	0.0%	0	0.0%	1	0.6%	1	0.6%	1	1.3%
Distribution licenses												
5 years	5	55.6%	5	38.5%	2	13.3%	25	18.0%	16	9.6%	21	8.4%
6 to 10 years	2	22.2%	2	15.4%	5	33.3%	45	32.4%	53	31.7%	80	32.0%
11 to 15 years	2	22.2%	5	38.5%	7	46.7%	64	46.0%	90	53.9%	141	56.4%
16 to 20 years	0	0.0%	1	7.7%	1	6.7%	3	2.2%	6	3.6%	6	2.4%
25 years	0	0.0%	0	0.0%	0	0.0%	2	1.4%	2	1.2%	2	0.8%

Source: EAC (2006), "Report on power sector of the Kingdom of Cambodia 2007", and EAC data provided on August 4, 2017

The EAC also provides technical advice to mini grids. Licensees may request the EAC's advice on issues such as loss reduction and compliance with technical standards. In response, the EAC sends on-site a team of technicians who provide advice and guidance on how to solve the issue at hand. This assistance is subject to no specific fee. The EAC also provides guidelines on improving operating efficiency, such as lines interventions, transformers operation, or thermal efficiency of engines. One operator also reported having hired EDC staff to help carry out upgrade work on the lines.

8 | TARIFFS, FINANCING, AND SUBSIDIES

The EAC regulates the tariffs of mini grids operators to be cost-reflective. Different subsidy mechanisms are available to help mini grids extend electrification and comply with the quality standards.

8.1 SETTING RETAIL TARIFFS

Because mini grids could charge any tariff before 2003, tariffs tended to be high. The average tariff was around US$0.50 per kWh,[57] with important disparities, and some mini grids charging tariffs of up to US$1.00 per kWh.[58] Fuel costs was the most important factor determining tariffs (between 70 and 90% of production costs).[59] Consumption was limited to basic needs (lighting, television), maintaining the bill affordable to consumers. The average consumption was between 10 and 20kWh per month per household customer. The average bill ranged from US$4 to 12 per month.[60]

Between 2003 and March 2016, EAC calculated and approved cost-recovery tariffs for licensees, as required by the Electricity Act, for each individual mini grid.[61] Mini grids charged their customers the cost recovery tariff calculated by EAC based on:

- Fuel expenses for isolated mini grids (with a fuel cost adjustment mechanism) and the cost of power bought from EDC for connected mini grids,
- Real cost items. To evaluate these cost items, which differ considerably from one operator to another, EAC asks once a year the mini grid operator to fill a comprehensive table of costs, and reviews it. EAC also carries out measurements and checks on assets and expenses on the ground, which is a time-consuming process,
- A return on investment of 10%.[62] This rate was a decision of EAC's, then approved by the MME, and
- Incentives on operating indicators, like losses. EAC sets losses allowed for recovery around the average losses of a sample of 50 licensees.

The tariff-setting process is very resource-intensive, since it requires the EAC to calculate the tariff of each individual mini grid with relatively limited staff (about 30). The EAC controls the asset quantity and

[57] Enterprise Development Cambodia (2001) "Survey of 45 Cambodian Rural Electricity Enterprises" and Meritec Limited for the Ministry of Industry, Mines, and Energy (2001) "Rural Electrification Strategy and Implementation Programme Survey Report"
[58] Meeting at EAC, August 1, 2017
[59] Enterprise Development Cambodia (2001) "Survey of 45 Cambodian Rural Electricity Enterprises"
[60] Meritec Limited for the Ministry of Industry, Mines, and Energy (2001) "Rural Electrification Strategy and Implementation Programme Survey Report"; Baker (2009), "Opportunities and Challenges for Small Scale Private Service Providers in Electricity and Water Supply"
[61] Kingdom of Cambodia, "Electricity Law of the Kingdom of Cambodia", article 48
[62] Tenenbaum, Greacen, Vaghela "Mini Grids and Arrival of the Main Grid: Lessons from Cambodia, Sri Lanka, and Indonesia"

quality of each individual licensee, and takes out of the asset base the assets that it judges do not comply with the standards. This process requires the EAC to visit each mini grid at least once a year; November to March is referred to as 'tariff season', with new rates issued starting in April, and followed by monitoring activity the rest of the year. Interviews with operators suggest a lack of full appreciation of the basis on which some assets may or may not be included in the tariff calculation year after year; or of how the 10% profit margin is ensured.

Residential tariffs have decreased for connected mini grids between 2011 and 2015, as shown in Table 8.1. The decrease for isolated mini grids in 2015 is explained by decreasing fuel costs.

Table 8.1: Evolution of Tariffs, Isolated and Connected Mini grids, 2011-2015

		2011	2012	2013	2014	2015
Isolated mini grids	KHR/kWh	2,296	2,335	1,998	3,082	2,381
	US$/kWh	0.57	0.58	0.49	0.76	0.59
Connected mini grids	KHR/kWh	1,023	1,122	1,104	1,073	927
	US$/kWh	0.25	0.28	0.27	0.27	0.23

Source: EAC (2011 to 2016), "Report on power sector of the Kingdom of Cambodia"

Since March 2016, distribution licensees that buy power from EDC must charge the standardized tariff (see section 4.2). EAC calculates the standardized tariff to reflect "the cost of electricity purchased and the cost of distribution."[63] EAC still computes the cost-recovery tariff of each mini grid; the difference between this and the standardized tariff is to be covered by the REF. Licensees request the subsidy from the REF (either electronically or on paper), and the REF disburses the money within 7 working days. According to the REF, some licensees request the money every month, others for several months at once.[64]

More generally, the EAC has adopted a stricter approach in tariff setting since 2016. This seems to consist of a transition from a more intuitive method to allow for a smoother transition from *laissez-faire* to control; to a more rigorous method based on real calculations to incentivize investments for efficiency and higher quality of service—also considering that subsidized loans are now available. With interconnection to EDC's grid also comes the possibility of accelerated depreciation.

EAC referred to a progressive tightening of tariff levels for licensees, led by intense discussions each year at tariff season. EAC benchmarks operators by grouping them in groups of about 50 (based on market size and customer density, across different provinces). The benchmarking has mostly concerned line losses, which the EAC has helped reduce from a total of over 20% in 2005 to about 1-2.5% on MV lines and 12% on LV lines today. The EAC has also started collecting data on System Average Interruption Frequency and Duration Indices (SAIFI, SAIDI).[65]

Interviews with the EAC and private operators suggest that the transition to a more rigorous tariff setting approach requires some more time to settle in. The calculation of asset base and profit margin

[63] EAC (2016) "Report on power sector of the Kingdom of Cambodia 2005"
[64] Meeting at the REF Department, August 2, 2017
[65] Meeting at the EAC, 1 August of 2017; interviews with private operators confirm these numbers.

may be not fully understood, possibly with some confusion of depreciation numbers as profit. Operators interviewed seem keen to continue expanding their business, but lack a detailed appreciation of what costs, revenues, and profits are likely to be; and rather oriented by the opportunity to increase revenues and expand business, coupled to some uncertainty about what the actual numbers will be.

8.2 TYPE OF SUBSIDIES AVAILABLE

There are subsidies for all stages of a mini grid project except for design, as shown in Table 8.2.

Table 8.2: Overview of Subsidies Available

Project stage	Explicit Subsidies	Implicit Subsidies
Design	None	None
Finance	▪ Interest-free loan of 480,000 Riels (around US$117) to households through the licensee, payable in 36 months ▪ Guarantee on commercial loans for investments in electricity infrastructure to fully cover authorized area ▪ Interest-free loans for investments in electricity infrastructure to fully cover authorized area	None
Construction	▪ Tax breaks for solar PV panels ▪ Capital grants to licensees in areas with low population density ▪ Formerly, capital grants: $45/connection* ▪ Formerly, capital grants: $400/kW for mini/micro hydro; $300/kW for biomass*	None
Operation	Tariff subsidy from the REF	Technical assistance from the EAC

Source: William C. Oung (2008), "Rural Electrification Fund Cambodia. Providing Grants & Promoting Rural Electrification and Renewable Energy Technology"; EDC, Department of Rural Electrification Fund (2016), "Report on Activities of the Department of Rural Electrification Fund for the Year 2015"; Bernard Tenenbaum, Chris Greacen, Dipti Vaghela (2017), "Mini Grids and Arrival of the Main Grid: Lessons from Cambodia, Sri Lanka, and Indonesia"

Note: (*) Output-based subsidies.

The REF has three programs relevant to mini grids; the programs' sources of funds are shown in Table 8.3. The three programs are:[66]

- **Power to the Poor**. This program provides an interest-free loan to households (through the licensee) to finance their connection. This loan is intended to cover: "1) costs of connection fees of the electricity supplier; 2) costs of deposit to be deposited to the electricity supplier; 3) costs for purchase of materials and labour for the installation of wires from the connection point to [the] house; and 4) costs for purchase of material and labor for the installation of in-house wiring." The REF lends to the licensees, who in turn lend at no interest to households.

[66] EDC (2017), "Report on Transferring the Benefits Resulting from the Development of Electricity to the Population in Rural Area for the Year 2016"

- **Program for Providing Assistance to Develop Electricity Infrastructure in Rural Areas** (PPADEIRA). This program provides grants, interest-free loans, and guarantees to private licensees to develop the distribution infrastructure and cover the entire license area.
- The **tariff subsidy**. This subsidy corresponds to the money given to licensees buying power from EDC to bridge the gap between their calculated cost-recovery tariff, and the standardized tariff (see section 6).

Another program for very remote areas is being considered at EDC. It would be available to all licensees. It would consist of a direct construction of the MV line and transformers by EDC through a contractor; and the transfer of that asset to a beneficiary licensee with the obligation of building the LV network.

Table 8.3: Funding of the REF (US$ million), 2012-2017

	2012	2013	2014	2015	2016	2017
World Bank	10.5	-	-	-	-	-
EDC	0.3	4.0	6.0	9.0	40.0	67.0
kfW	-	-	-	2.5	2.6	2.6
ADB	-	-	-	-	-	1.0
Total	10.8	4.0	6.0	11.5	42.6	70.6

Source: REF (2017)

8.3 ELIGIBILITY TO GET SUBSIDIES AND SOURCES OF MONEY FOR SUBSIDIES

EDC, mostly through REF, provides various type of funds, as Table 8.4 highlights. All funds require licensees to own a 5-year license at least, except for the tariff subsidy.

Table 8.4: Eligibility and Sources of Funds, by Subsidy

Subsidy	Conditions	Eligibility	Sources of Funds
Guarantees	Guarantee on commercial loans to finance the construction of MV and LV lines and other related infrastructure	Licensees that own 5-year licenses or more, in "area with high density of population having economic efficiency" (Area 1)	EDC and KfW through REF
Interest-free loans	Loans to finance the construction of MV and LV lines and other related infrastructure. Limit of 50%-60% of the cost of the infrastructure (existing or new), not exceeding 300k, and max tenor of 8 years. 20% capital from licensee	Licensees that own 5-year licenses or more, in "area with medium density of population, where doing electricity business may not be profitable" and "area with low density of population, where doing electricity business is not viable" (Area 2)	EDC and KfW through REF

Capital grants	Grants of up to $300,000 for up to 30% of the project infrastructure cost	Licensees that own 5-year licenses or more, in "area with low density of population, where doing electricity business is not viable" (Area 3)	EDC and KfW through REF
Interest-free loans for connection	Loan to households (through the licensee) for interconnection fees, in-house wiring, and paying for wiring from the connection point to the house. Max 480,000 Riels (around US$117) per household, payable to the Licensee and in turn from the Licensee to the REF in 36 months	Licensee through which the loan is distributed: 5-year license, responsibility for collecting the loan and in case of default Household: no connection, stable house, living in electrified area	EDC and KfW through REF
Tariff subsidy	The REF covers the difference between the cost-recovery tariff and the allowed tariff	Distribution licensees buying bulk power from the main grid and charging standardized tariffs	EDC

Source: EDC, Department of Rural Electrification Fund (2016), "Report on Activities of the Department of Rural Electrification Fund for the Year 2015"

8.4 LEVEL OF SUBSIDIES

There is no methodology to determine the overall budget for subsidies. EDC decides on REF's funding, through its board of directors. The REF makes occasional requests, but does not actively participate in its own budgeting process (which can last up to six or seven months) to determine what funding it needs to achieve specific objectives. The REF rather adapts to what it gets, and at that point prioritizes interventions based on operators' requests, under a resource-intensive process for its staff of about 30.[67]

For the tariff subsidy, the EAC calculates how much money will be required based on its tariff calculations and expected quantities. This calculation informs the allocation from EDC. An approximate rule is that EDC dedicates half of its profits to fund the REF; and disbursed to the REF on a quarterly or semi-annual basis. The REF must disburse within seven days of a correctly filed request.

There is little information on the level of subsidy compared to the cost of the item subsidized.

- The Power to the Poor program subsidizes US$117 per connection for the household. There is no information on the actual costs of the connection for the household; the fee paid to the electricity supplier varies between US$36 and US$250, depending on the amperage and the provider.[68]
- Under the PPADEIRA, the REF may finance up to 60% of the cost of the lines, or may give a grant covering up to 30% of the cost, but there is no information on the subsidy level in practice. In 2015, the REF had financed 2,375km of lines, benefiting 199 licensees.[69]

[67] Meeting at the REF Department, August 2, 2017
[68] Based on connection fees of Mr. Chak Sean (License 334L), Mr. Dong Ly (License 117L), and Mr. Keo Ngoun (License 307L)
[69] EDC (2016), "Report on power sector of the Kingdom of Cambodia 2015"

- For the tariff subsidy, the subsidy represents on average between 15 and 48% of the actual cost of service of licensees. For connected mini grids the cost-recovery tariff averaged US$0.23/kWh in 2015, while the tariff charged to consumers ranged from US$0.12 to 0.20 per kWh, implying a subsidy from US$0.03 to US$0.11 per kWh.

The Government has indicated that it will maintain the tariff subsidy after 2020. As noted, the Government has already approved the level of subsidy up until 2020; it has not indicated the level it intends to set after that date.[70]

8.5 REGULATORY TREATMENT OF SUBSIDIES

Subsidized assets do not give right to earn a return when calculating the cost-recovery tariff, but they are included for purposes of depreciation. In the model used by the EAC to determine the tariff, the subsidy is deducted from the profit calculation; however, the depreciation cost of the entire asset base is included in the tariff (see section 8 | for details on the tariff).

Reporting is tied to getting the correct subsidy level, providing an additional incentive for operators to fill out their reports accurately.

9 | HANDLING THE RELATIONSHIP WITH THE GRID

Since the late 1990s, the Government has seen connecting mini grids as a way to lower electricity costs and improve quality of service. Power generated by EDC replaced more expensive small-scale generation. Interviews with operators give a sense that the Government is pushing consolidation in the sector to keep on lowering power prices, and putting a downward pressure on revenues for licensees. However, this is not an explicit Government policy.

9.1 WHAT HAPPENS WHEN THE GRID ARRIVES

Most of the mini grids in Cambodia have switched their business models: from isolated systems to small power distributors (distribution licensees) buying power from the main grid (or a transmission licensee). There were only 13 distribution licensees in 2006; in 2015, there were 167.

When the grid arrives, the mini grid operator transitions from being a consolidated licensee to a distribution licensee. As noted above, the EAC converts the consolidated license to a distribution license automatically, but the process can take several months. Since the distribution license does not authorize the licensee to generate power, the licensee has to decommission its generation assets. There is no option in the regulation for the utility to buy the licensee's assets.

EAC gives the mini grid a tariff bonus when the main grid arrives. EAC adjusts the cost-recovery tariff (charged to customers, or since March 2016, used to calculated the tariff subsidy) gradually, over several months, from the isolated mini grid to the interconnected one, instead of adjusting it immediately to the

[70] MME, Mr. Victor Jona, Director General, General Department of Energy, Chairman of the Board of EDC, on August 5, 2017

new level of costs. There is no precise calculation of the amount of this bonus, but it compensates the mini grid operator for losing some of its assets linked to generation. However, there is no need to compensate the mini grid operator for the entire remaining value of the generation assets, because diesel generators can easily be resold.[71]

According to the EAC, EDC did not take over the distribution activities of isolated mini grids because EDC lacked personnel and funds to expand and operate the low voltage (LV) network. This allowed private operators to interconnect to EDC while continuing to serve their customers; in turn, letting licensees expand and operate the LV grid allowed EDC to focus on the expansion of MV lines.

No isolated mini grid with a consolidated license has become a small power producer. There is no clear rule preventing a mini grid operator from becoming a small power producer, but implicit policies prevent this option by requiring that power injected into the grid be cost-competitive with large-scale IPPs.[72] This is because most mini grids were diesel-fired, meaning that they were not cost-competitive with power on the grid. There were a few small IPPs that used to sell to isolated mini grids: these either disappeared, or started supplying EDC's grid; examples include Char Chuuk power plant and SOMA Energy. Both use rice husk as fuel (see section 9.3).

9.2 WHOLESALE TARIFF SETTING

Distribution licensees buy electricity at wholesale prices from EDC, or import it from neighboring countries. EDC also imports power from Vietnam and resells it to around 50 distribution licensees in Cambodia. Some private companies have the right to import directly from Thailand and Laos.

The EAC sets the wholesale tariffs for EDC. In 2015, the tariff of power generated by EDC sold to distribution licensees was between US$0.138 and 0.151 per kWh, depending on the distance of the licensee to the EDC grid. In 2017, 2018, 2019, and 2020, the bulk tariff will be respectively US$0.145, 0.144, 0.143, and 0.142 per kWh.

9.3 OBLIGATION OF UTILITY TO PURCHASE OUTPUT

There is no obligation from the utility to purchase mini grids' output. Rather, licensees have to decommission their generation assets as soon as they get connected to the main grid, and so do not inject electricity into the grid.

The EAC may authorize EDC or a licensee to buy power from a small generator, but only if it can provide lower-cost power than the alternative. In 2015, there were only five generation licensees with capacity below 10MW. However, it is likely that these had always been intended as IPPs, and never had retail customers. For example, the Char Chuuk power plant was selling to a mini grid under a generation license, rather than retail.[73]

9.4 POWER PURCHASE AGREEMENTS

The EAC approves PPAs. It mainly focuses on the tariff level and the take-or-pay clause, with consideration for the viability of off-takers.[74]

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[71] Interview with private operator
[72] Meeting at the EAC, 1 August of 2017 and interview with private operator
[73] Innovation Energy Development Group (2015) "Biomass Gasification for Rural Electrification in Cambodia", and EAC (2014) "Report on power sector of the Kingdom of Cambodia 2013"
[74] Meeting at the EAC, 2 August 2017

This section is based on the power-purchase agreement (PPA) signed between SOMA Energy Co., Ltd and BVC Power Development Co., Ltd. SOMA Energy is a 1.5MW rice husk generator; BVC Power Development is a transmission licensee.

The PPA is a take-or-pay, and its tariff was approved by the EAC. The buyer has to purchase a minimum quantity of output [600kW], with the option to buy more [up to 1.2MW]; importantly, the seller has to be able to produce at least this quantity. The tariff of the PPA is a one-part tariff per kWh [0.1322 US$ per kWh], and payments are made in US$. There is no recourse in case of untimely payment from the buyer; instead, late payments give rise to a default interest of 20% per year. The seller has the right to withhold supply if payment is two months late.

Both parties perform the meter reading. There is no specific procedure for meter reading disputes. However, if the metering system malfunctions or stops operating, a "certified laboratory" shall determine the amount of delivered energy during the relevant period.

The PPA includes a *force majeure* provision. The provision, in its English translation, does not seem drafted precisely. It suggests that either party may be excused from its contractual obligations if adversely affected by a *force majeure* event; these events that are typically classed as political (war, riot, demonstration) along more typical natural events that constitute *force majeure*.

The PPA also includes a process to solve disputes. The process involves 30 days of mutual discussions. If at the end of the 30 days the parties have not reached an agreement, they will refer to domestic courts.

The seller seems to be bearing an important share of the risk. Although the PPA is a take-or-pay, the seller has to keep up to the maximum capacity available for the buyer at any moment. The seller is not excused from its minimum sales obligation if it experiences a scarcity of source energy. Also, the seller has to construct, and owns the shallow grid connection.

It appears that the project is not project-financed. Accordingly, it is simpler than a PPA for a larger, project-financed project. For example, there is no evidence in the PPA of a lenders' direct agreement, and so no step-in rights from lenders either.

10 | LESSONS LEARNT

Before the 2001 Electricity Law Cambodia experienced a significant increase in electricity access, but quality of service was low, and power prices were high. The average mini grid provided power less than 12 hours per day, and at a price between US$0.31 and 1.00 per kWh.

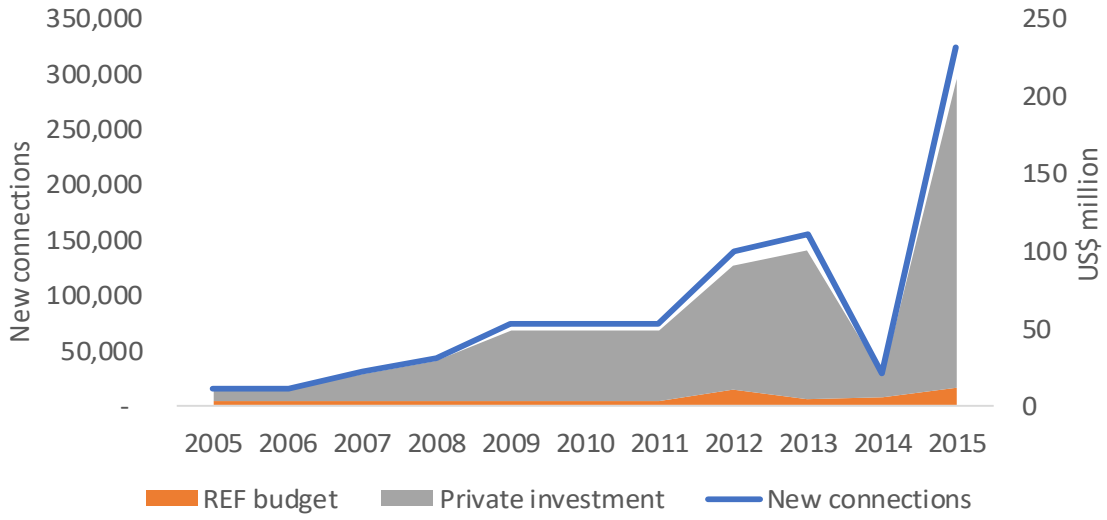
The strategy to transform unregulated, isolated mini grids to regulated and connected suppliers has led to lower prices and higher quality of service. This happened through:

- Connecting mini grids and passing on low costs. The regulated tariffs had the double effect of giving entrepreneurs a guaranteed profit (in 2011, the average distribution margin for connected licensees was US$0.16/kWh), and offering substantially lower power costs to consumers.
- Providing incentives and penalties to improve power quality. The REF provided grants and concessional loans, while the EAC threatened to revoke licenses if licensees did not improve their

infrastructures (or extend service). Licensees also had a safe business, with the exclusivity on the area balanced with obligation to connect all consumers.

The strategy was also successful in improving access to electricity. From 2005 to 2015, licensees have made just below one million new connections. Such a scale of investment cannot be explained only by the REF, whose annual budget for electrification was around US$5 million over the period. This implies that mini grids have invested more than US$50 million per year on average between 2005 and 2015, as Figure 10.1 shows.

Figure 10.1: New Connections and Investment by Licensees, 2004-2015



Source: Castalia calculations, assuming constant cost of connection of US$652

Thinner distribution margins put pressure on the business of distribution licensees. The distribution margin of connected licensees has decreased significantly, from US$0.16/kWh in 2011 to US$0.10/kWh in 2015. On the one hand, decreasing distribution margins incentivize efficiency through tariff reduction. On the other hand, there is a risk is that the business model that helped Cambodia increase electrification may face uncertainty on its ability to sustain investments—particularly when larger reinvestment in assets will be needed.

The role of mini grids in the coming years will depend on the success of increasing service standards and reducing tariffs while allowing for sufficient profitability and sustaining subsidies. The pressure on distribution margins might result in consolidation in the distribution sector, although this process has been limited to date, and consolidation is not thought to be consistent with Cambodian culture.[75] EDC might progressively take over distribution licensees, but there are no indications of this being a policy. The Government and EAC seem to recognize the important role played by private operators historically, and the one they may still play in future years. The extent to which this may actually happen remains to be seen.

[75] Meeting at the EAC, 6 August 2017

Appendix A

[To be provided as part of final report/link on ESMAP website].