SRI LANKA

ENERGY SECTOR ASSESSMENT, STRATEGY, AND ROAD MAP

DECEMBER 2019

ASIAN DEVELOPMENT BANK

ADB

SRI LANKA
ENERGY SECTOR ASSESSMENT, STRATEGY, AND ROAD MAP

DECEMBER 2019

ASIAN DEVELOPMENT BANK


Creative Commons Attribution 3.0 IGO license (CC BY 3.0 IGO)

6 ADB Avenue, Mandaluyong City, 1550 Metro Manila, Philippines
Tel +63 2 8632 4444; Fax +63 2 8636 2444
www.adb.org

ISBN 978-92-9261-888-9 (print), 978-92-9261-889-6 (electronic)
Publication Stock No. TCS190557-2
DOI: http://dx.doi.org/10.22617/TCS190557-2

Notes:
In this publication, "$" refers to United States dollars, and "SLRs" refers to Sri Lankan rupees.
ADB recognizes "Ceylon" as Sri Lanka.

Cover design by Jasper Lauzon.

CONTENTS

TABLES AND FIGURES

TABLES

FIGURES

Typical grid substation in Sri Lanka.
(photo by Pushpa Kumara)

ACKNOWLEDGMENTS

This report was prepared by a team led by Aiming Zhou, principal energy specialist, South Asia Department (SARD), N. K. Ranishka Wimalasena, senior project officer (energy), SARD, and consultants Tilak Siyambalapitiya and Pil-Bae Song. The team was supervised by Priyantha Wijayatunga, director, energy division, SARD. Staff support was provided by Angela Francesca O. Bernaldo, project officer, Karen Grace Ochavo, associate environment officer, and Marietta L. Marasigan, consultant. Guidance and support was also provided by Yongping Zhai, chief, energy sector group, Sustainable Development and Climate Change Department.

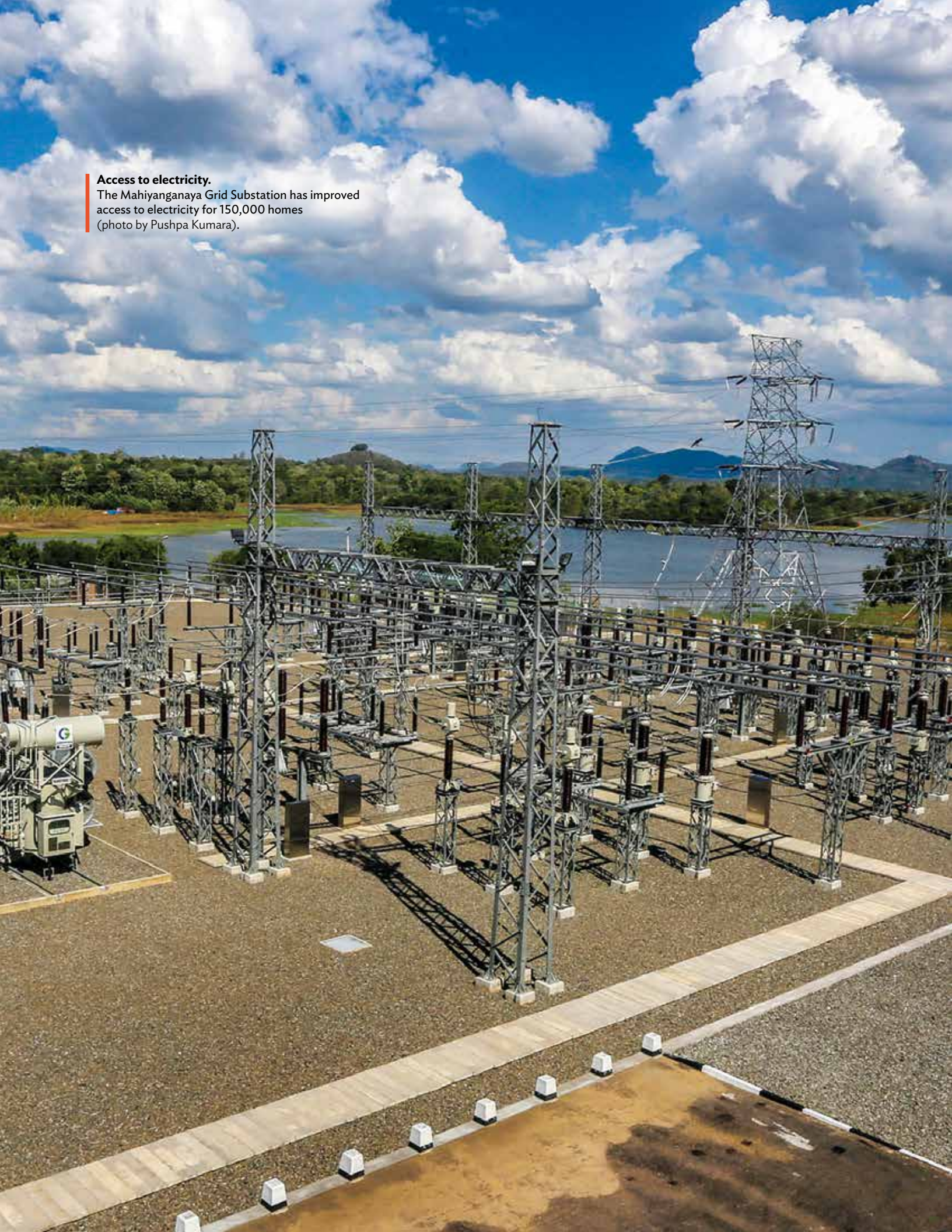
The team was grateful for the guidance and support from the Government of Sri Lanka, Ministry of Power, Energy and Business Development.

ABBREVIATIONS

ADB	Asian Development Bank
BSC	breaker-switched capacitors
CEB	Ceylon Electricity Board
CFL	compact fluorescent lamp
CPC	Ceylon Petroleum Corporation
DSM	demand-side management
EA 2009	Electricity Act No. 20 of 2009
ERA 2002	Electricity Reform Act No. 28 of 2002
GDP	gross domestic product
IMF	International Monetary Fund
IPP	independent power producer
JICA	Japan International Cooperation Agency
LAUGFS	Lanka Auto Gas Filling Stations
LCC	Lanka Coal Company
LECO	Lanka Electricity Company
LIOC	Lanka Indian Oil Company
LNG	liquefied natural gas
LOLP	loss of load probability
LTGEP	long-term generation expansion plan
LV	low voltage
MPRD	Ministry of Petroleum Resources Development
MOPE&BD	Ministry of Power, Energy and Business Development
MV	medium voltage
NRE	new renewable energy
PPA	power purchase agreement
PRDS	Petroleum Resource Development Secretariat
PUCSL	Public Utilities Commission of Sri Lanka
PV	photovoltaic
SLRs	Sri Lankan rupees
SLSEA	Sri Lanka Sustainable Energy Authority
SPP	small power producer
SPPA	standardized power purchase agreement

WEIGHTS AND MEASURES

bbl	barrel of oil
Gcal	gigacalorie
Gg	gigagrams
GWh	gigawatt-hour
kg	kilogram
kgoe	kilogram of oil equivalent
km^2	square kilometer
kt	kiloton
ktoe	kiloton of oil equivalent
kV	kilovolt
kVa	kilovolt-ampere
kWh	kilowatt-hour
$kWh/m^2/day$	kilowatt-hour per square meter per day
Mvar	megavolt-ampere reactive
MW	megawatt
MWh	megawatt-hour
toe	ton of oil equivalent



Access to electricity.
The Mahiyanganaya Grid Substation has improved access to electricity for 150,000 homes (photo by Pushpa Kumara).

EXECUTIVE SUMMARY

Economy. With a population of 21.4 million and a land area of 65,610 square kilometers (km^2), Sri Lanka is a high population density country with 326 persons per km^2 (40th in the world, according to the World Population Review). The country's per capita GDP was $4,065 in 2017. Sri Lanka entered the upper middle-income category of countries (as defined by the World Bank) for the first time this year.

Energy supply and use. Sri Lanka used 12.8 million tons of oil equivalent energy in 2017. At $7.5 of economic output per kilogram of oil equivalent in 2014, Sri Lanka ranks high among countries that report similar per capita economic output. Petroleum, imported as crude oil and finished products, provides the highest share (43% in 2017) of energy to the national economy, followed by biomass (37%), coal (11%), hydro (6%), and new renewable energy (3%). The country has succeeded in delivering modern energy sources to its whole population; petroleum products and bottled liquefied petroleum gas are widely available. Electrification of households reached 100% in 2017. Energy end-users are households and commercial (40%), transport (36%), and industries (34%).

Renewable energy. Much of the hydropower capacity has been developed already for electricity generation: 1,390 megawatts (MW) in larger power plants by the state-owned utility, Ceylon Electricity Board (CEB) and 350 MW in smaller power plants by private investors. About 250 MW of hydropower capacity is in various stages of development, which would most likely be the last medium-scale hydropower plants to be developed. A few more small power plants remain to be developed, by the private sector. The technical resource potential for solar power generation is estimated to be 6,000 MW. Net-metered rooftop solar photovoltaic (PV) was allowed since 2008, and since 2016, surplus energy sent out to the grid was paid. The target capacity of rooftop solar PV is 200 MW by 2020. The exploitable wind power potential is estimated to be 5,600 MW, of which about 130 MW has been developed, with a further 130 MW under construction.

Fossil fuels. Exploration for gas and petroleum have not resulted in commercial production, although some deposits of gas have been discovered in Mannar basin, offshore on the western coast. More exploration is planned in other offshore areas on the west and east coast. About 30% of petroleum requirement is imported as crude oil and processed in the country's single refinery, while the balance requirements are imported as refined products. Liquefied petroleum gas is imported and supplemented with the output of the refinery, bottled and delivered to customers. Coal is imported for electricity generation for the 900 MW power plant, and for smaller industrial applications.

Sector management and regulation. Two ministries are responsible for policy formulation and supervision of energy sector institutions and utilities. The Ministry of Power, Energy and Business Development prepares energy policy, supervises the main state-owned power sector utility CEB, the state-owned distribution utility Lanka Electricity Company, Sri Lanka Sustainable Energy Authority, and several other state-owned entities in the energy sector. The Ministry of Petroleum Resources Development oversees exploration for gas and petroleum, supervises state-owned Ceylon Petroleum Corporation (CPC) and several entities in the petroleum sector. The Public Utilities Commission of Sri Lanka (PUCSL) is the multisector regulator, which is presently empowered to perform the functions of technical, economic, commercial, and safety regulator of the electricity industry. Petroleum and water supply are expected to be assigned to PUCSL for regulation, in the near future.

Ownership of energy utilities. The electricity industry and the petroleum industry are both managed largely by state-owned corporations. Private sector participation in the electricity industry is limited to power generation, while in the petroleum industry, the private sector is engaged in petroleum distribution, bunker supplies, gas distribution, and oil exploration.

Electricity sector reforms. Electricity generation and supply in towns previously handled by private entities were taken over by the government in the 1950s, and in 1969, handed over to the government-owned corporation CEB. Electricity industry reforms commenced in 1983, when distribution previously handled by city councils was transferred to a government-owned company. In 1996, private investors were allowed to produce and sell electricity to the single-buyer CEB. In the same year, feed-in tariffs to enable private investors to build, own, and operate small (up to 10 MW) power plants to use renewable energy, were announced. However, to this date, CEB remains substantially a vertically integrated electricity utility. Unbundling the utility into separate generating, transmission, and distribution companies proposed in the Electricity Reforms Act 2002 did not materialize. The Electricity Act 2009 introduced limited unbundling, where all businesses remain under one corporate ownership, while generation, transmission, and distribution functions were separately licensed. PUCSL commenced regulatory functions in 2009.

Petroleum industry reforms. Similarly, in the 1960s, the government-owned corporation CPC was established to import, refine, and supply petroleum products, previously marketed by private companies. CPC continues to operate the 50,000 barrels-per-day refinery, and imports and markets much of refined products. In 2004, about 35% of CPC's retail outlets were transferred to Lanka IOC. Since 2004, most storage facilities are jointly owned by CPC and Lanka IOC, through a company. After years of planning, the Petroleum Industry Act, which would corporatize the presently government-owned corporation CPC and empower PUCSL to regulate economic, technical, commercial, and safety performance of the sector, has not been presented to Parliament as yet.

Electricity demand and supply. Sri Lanka's per capita electricity consumption was 626 kWh/person in 2017, lower than India and many of the developing countries in Southeast Asia. In 2017, the share of sales to household customers was 37% and to industrial customers was 32%, and the sales to the commercial sector was 29%. As the economy moves toward higher growth in the services sector, the share of electricity sold to industries has been on the decline for several years. Annual sales growth in the past five years was below 9% per year, while the growth in peak demand was below 7% per year. Thus, the load factor has grown from 63% to 68% from 2010–2017, indicating that the mandatory time-of-use tariffs for industries since 2011 and to commercial customers since 2013 have the desired impacts. Completion of household electrification in 2017 and the higher growth in daytime sales to commercial customers also positively impact the load factor.

Electricity demand growth and investment needs. Single-buyer and transmission licensee CEB forecasts that sales will grow at the rate of about 7.5% until 2021, and then decline to about 5% per year by the end of the decade. The peak demand is forecasted to cross 3,000 MW by 2020 and reach 4,800 MW by 2030. Significantly, the time of occurrence of the peak demand is expected to shift from the present late evening (typically 7 p.m.) to early afternoon (typically 1 p.m.), by 2027. To meet the growing demand at the lowest cost, CEB plans indicate the investment requirements for power generation to be $2,400 million from 2020–2025. Matching investments are required for transmission (to inter-connect generating facilities), estimated to be $320 million and in distribution (to serve the growing demand and to improve reliability of supply to customers) a further $60 million.

Petroleum sales growth. No formal forecasts are published by CPC, but it is expected that the growth in sales of petroleum products will remain at 5%– 10% per year. No specific investment plans are published by the petroleum industry entities.

Electricity industry outlook. At present, the electricity industry has three major constraints: (i) capacity shortage and delays in implementation of mainstream power plants; (ii) slow growth in renewable energy development; and (iii) severe financial crisis, mainly attributed to noncost reflective tariffs. The capacity shortage has to be resolved by building larger power plants. CEB has proposed that the two canceled coal-fired power plants be revived and built using the latest technology. Additionally, two combined cycle power plants are required to be built to cater to seasonal shortages of hydropower. CEB expects the liquefied natural gas (LNG) import terminal to be ready by 2023, already behind its previous schedule at 2020. Renewable energy development through solar and wind investments by the private sector is effectively at a standstill owing to legal impediments and lack of clarity on the feed-in tariffs. Solar and wind parks have been put out for competitive bids, but only a handful have materialized. These shortcomings have to be resolved, to create a healthy environment for private investors to build solar and wind power plants in the long term. The financial

crisis would only be managed by PUCSL, with CEB cooperating by submitting information to calculate allowed revenues, and then gradually working through a tariff increase and rebalancing process.

Unfinished reforms in the electricity supply industry. While unbundling of CEB is effectively stalled, it is still an integrated structure with functional units. CEB corporate remains largely intact although it is functionally unbundled. CEB corporate manages the entire institution, while licensed entities within CEB have not been made accountable to the allowed revenue they receive. The present methodology allows the penalties for increased network losses, and incentives for reaching loss levels above the target. Lanka Electric Company (LECO), the only corporate entity in the power sector, distributes about 10% of the total energy and has experienced the benefits of economic regulations, as well as responding to energy efficiency targets. Quality of supply reliability is managed by PUCSL, the direction should by now be catering to the needs of the electricity customers, by establishing reliability targets, measuring or estimating systems, and imposing penalties when targets are violated. Similarly, commercial quality of electricity service requires regulatory oversight. Currently, CEB does not submit to PUCSL, information required for economic, technical, and commercial regulatory activities. Accordingly, determination of allowed revenues and the cost of supply has not been done since 2017.

Reforms in gas and petroleum industry. The petroleum industry remains partially unbundled, while CPC remains intact as a large integrated entity. The Petroleum Industry Act that would establish unbundling and regulatory oversight requires to be completed soon and approved by Parliament. Petroleum pricing is conducted by the Ministry of Finance, which is required to pass on to PUCSL, to establish a more transparent pricing procedure. Sri Lanka does not have a gas industry law; a decision is required on whether a separate gas authority is to be established to manage the planned import of LNG and distribution of regasified LNG, or whether CPC is to be empowered to manage the gas industry as well.

Energy efficiency outlook. Sri Lanka requires the completion of initiatives already in progress to establish and enforce appliance performance standards. Mandatory energy consumption reporting and submission of energy management plans by large customers have not been implemented, although these have been in the regulations for the past several years. Smart techniques to manage demand are still at pilot stage, requiring further efforts to use information technology to improved energy management through demand-side management and demand response techniques.

I. SECTOR ASSESSMENT: CONTEXT AND STRATEGIC ISSUES

A. Overall Sector Context

Sri Lanka, an island country in the Indian Ocean, is transitioning to an upper middle-income economy. Its annual average economic growth was 5.5%[1] from 2001 to 2017.[2] However, the 2017 growth was lower by 3.3% compared with previous years. Sri Lanka's 2017 gross domestic product (GDP) per capita was $4,065.[3] In 2017, the country's maximum contribution to the GDP (56.7%) came from the services sector, the industrial sector contributed 26.9%, while the agricultural sector contributed only 6.8% (footnote 2). Table 1 shows the key economic indicators for 2017.

Table 1: Key Economic Indicators, 2017

Indicator	Unit	Value
Land area	km^2	65,610
Population	million	21.4
Population density	persons/km^2	326
GDP at current market price	$ billion	87.2
GDP per capita	$	4,065
Unemployment rate	%	4.2

GDP = gross domestic product, km^2 = square kilometer; persons/km^2 = persons per square kilometer.
Source: Central Bank of Sri Lanka Statistics Department. 2018. *Economic and Social Statistics of Sri Lanka 2018.*

In 2016, the average household income was SLRs62,237 per month ($386.40), and the poverty headcount index decreased from 15.2 in 2006 to 4.1 by 2016. Sri Lanka ranked 73rd among 188 countries in the United Nations Human Development Index in 2015; in 2012, it ranked 92nd. In 2017, 45.5% of Sri Lanka's labor force was engaged in the services sector, 28.4% was in the industrial sector, and 26.1% was engaged in the agricultural sector.

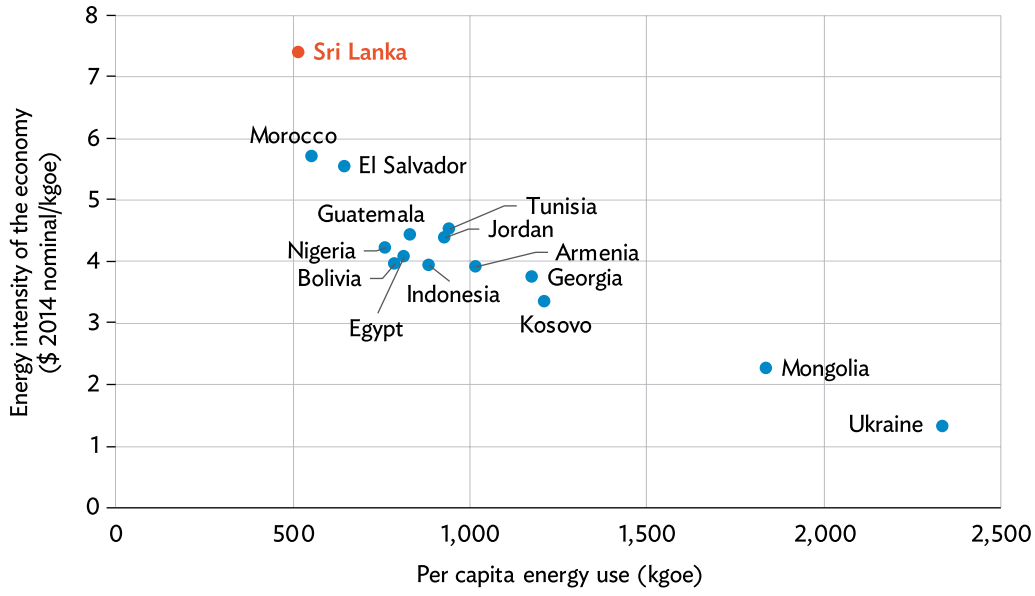
[1] Base year 2010.
[2] Central Bank of Sri Lanka. 2018. *Economic and Social Statistics of Sri Lanka 2018.*
[3] At current market price.

1. Energy Consumption

Sri Lanka's per capita economic output and per capita energy use compare well with countries with GDP in the similar range. Figure 1 indicates that among 15 countries reporting per capita GDP between $3,000 and $4,500 (nominal) in 2014, Sri Lanka has the highest energy intensity[4] in the economy, indicating a comparatively higher economic output per unit of energy used.

Indigenous energy resources are biomass, hydropower, solar, and wind, all of which are renewable. Coal and petroleum are imported into the country. Biomass and petroleum are the dominant primary energy sources. In 2017, petroleum accounted for about 43% of primary energy supply, biomass provided 37%, and coal provided 11%. The share of primary energy supply by different sources is shown in Figure 2. The total primary energy supply in 2017 was 12,850 kilotons of oil equivalent (ktoe).[5] In 2017, per capita primary energy supply was estimated to bet 0.58 toe/person.

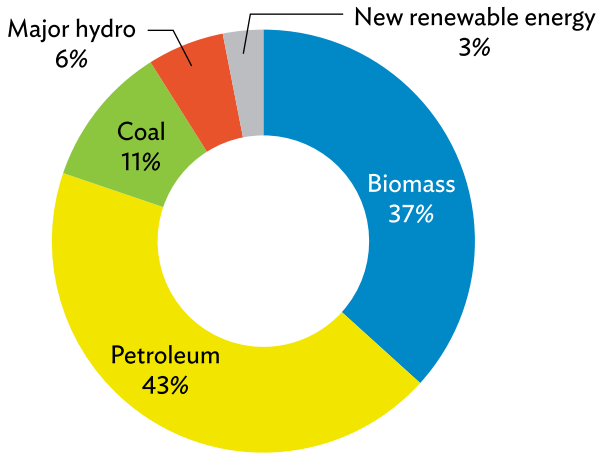
Figure 1: Energy Intensity of Countries with Similar Per Capita GDP



GDP = gross domestic product, kgoe = kilogram of oil equivalent.
Note: Only countries with per capita GDP in the range $3,000 to $4,500 (nominal 2014) are shown.
Source: World Bank. *The World Bank Data Indicators*. https://data.worldbank.org/indicator/ (accessed September 2017).

[4] Economic output per unit of energy used.
[5] Sri Lanka Sustainable Energy Authority. 2019. *Sri Lanka Energy Balance 2017*. Ton of oil equivalent = 10 giga calories (Gcal).

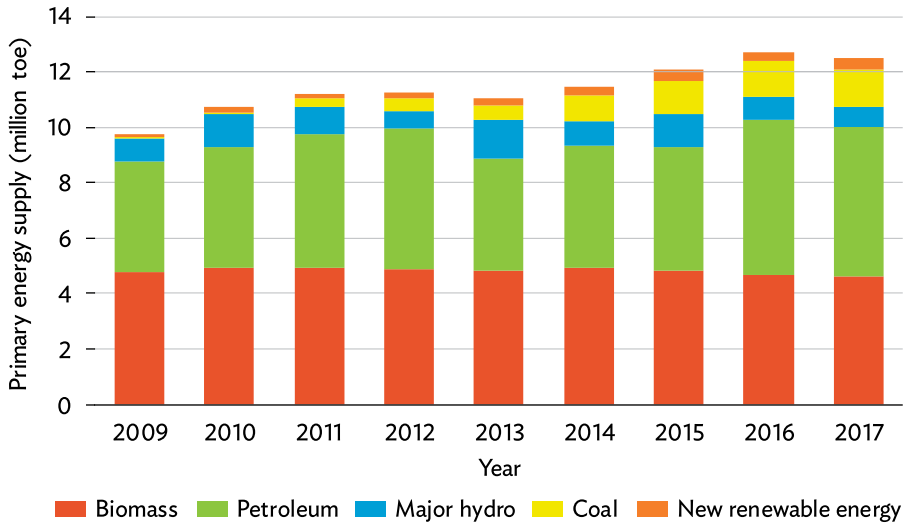
Figure 2: Share of Primary Energy Supply by Source, 2017



Source: Sri Lanka Sustainable Energy Authority. 2019. *Sri Lanka Energy Balance 2017*.

The variation of primary energy supply by different sources from 2009 to 2017 is shown in Figure 3. The share of renewable energy (comprising biomass, major hydro, and new renewable energy) in the primary energy mix is about 46%, showing a 5.8% reduction, compared with 2015. The stagnant supply and demand for biomass, especially in household and commercial sectors, is the reason for the declining contribution of renewable energy to the national energy mix, despite growing contributions of hydropower and new renewable energy sources used for electricity generation.

Figure 3 : Primary Energy Supply, 2009–2017



toe = ton of oil equivalent.

Source: Sri Lanka Sustainable Energy Authority. 2019. *Sri Lanka Energy Balance 2017*.

The dominant secondary energy source is petroleum products, while electricity is the second largest secondary energy source. Table 2 shows the key indicators of the petroleum supply industry.

Table 2 : Key Indicators of Petroleum Industry, 2017

Indicator	Unit	Value	Value
Petroleum products local sales	kt	4,100.1	5,235.0
Per capita petroleum consumption	kg	191.2	244.2
Output of refinery with respect to total consumption	%	38.0	29.8
Average daily petroleum consumption	bbl/day	70,383	89,865
Refinery capacity throughput	bbl/stream day	50,000	50,000

bbl = barrel of oil, kg = kilogram, kt = kiloton.

Source: Sri Lanka Sustainable Energy Authority. 2019. *Sri Lanka Energy Balance 2017*.

Among the primary energy sources shown in Figure 2, hydropower, coal, and new renewable energy sources (small hydro, solar, wind, biomass) are used for electricity generation. In addition, Sri Lanka is likely to continue to use diesel and fuel oil to augment power generation during peak periods, when hydropower generation becomes lower than average, and to bridge the generation gap when planned new power generation projects are delayed.

The objective of the Ministry of Power, Energy and Business Development (MOPE&BD) is to improve the country's power distribution network in providing continuing quality of service and sustaining 100% household electrification.[6] The country's national electrification ratio at 99.3% in 2016, 99.7% by October 2017, and by the end of 2017 had reached 100% electricity accessibility. Table 3 shows the key electricity indicators for 2017.

[6] Government of Sri Lanka, MOPE&BD. *Performance 2017 and Programmes for 2018*. http://powermin.gov.lk/english/wp-content/uploads/2017/10/MoPRE-2017.2018-03-English.pdf.

Table 3: Key Indicators of Electricity Industry, 2017

Indicator	Unit	Value
Total electricity consumption	GWh	13,358
Total installed generating capacity	MW	4,087[a]
Electrification rate	%	100%
Per capita electricity consumption	kWh	626
Hydropower capacity, operational, and under construction	MW	1,981

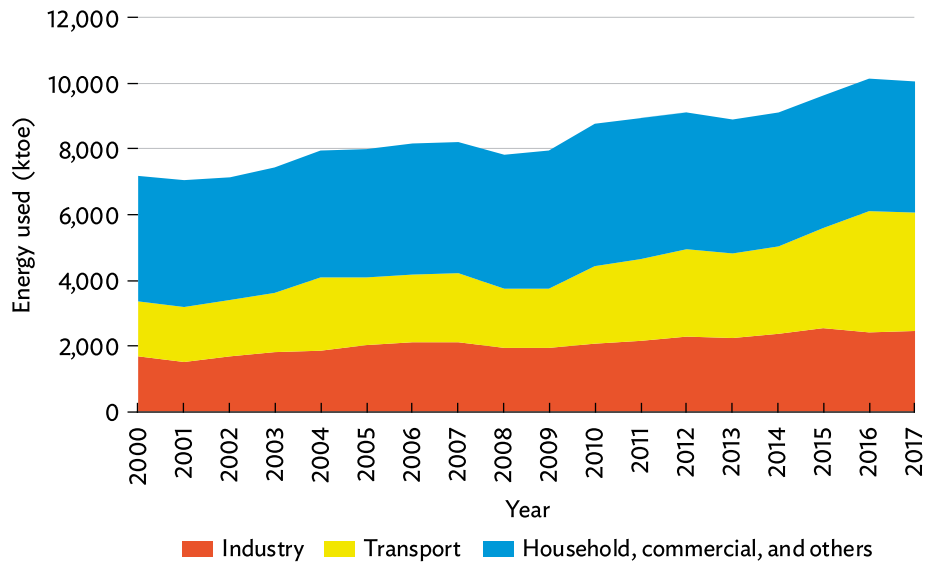
GWh = gigawatt-hour, MW = megawatt, kWh = kilowatt-hour.

[a] Excludes rooftop solar photovoltaic (PV) connections

Source: Ceylon Electricity Board. 2017. *Statistical Digest 2017*. https://www.ceb.lk/front_img/img_reports/1536209909CEB_Statistical_Digest_2017_-_Web.pdf, and other sources.

Out of the 10,122 ktoe total final energy used in 2017, the industrial sector accounted for 24.3%; transport sector 36.2%; and household, commercial, and others accounted for 39.6%. Figure 4 shows the variation of energy demand by each sector since 2000. The reduction of demand for petroleum products in years of price hikes and when hydropower contribution is high (e.g., 2010 and 2013), are evident in the long-term trends.

Figure 4: Energy Use by Sector, 2000–2017



ktoe = kiloton of oil equivalent.

Source: Sri Lanka Sustainable Energy Authority. 2019. *Sri Lanka Energy Balance 2017*.

2. Energy Resources

Biomass. Biomass is mainly used for cooking, and it is also used for thermal energy requirements in the industrial sector. Biomass largely consists of agricultural residues (rice husk, waste from rubber and coconut plantations, yield from woodlots and home gardens) and yields from rubber replantation activities. Other sources are municipal and industrial waste. Although biomass has the largest share of primary energy supply, it has very limited use for electricity generation. As of the end of 2017, there were 10 biomass-based small power producers with a total installed capacity of 26.1 MW. The Sri Lanka Renewable Energy Master Plan estimates that the country has a potential for 2,400 MW of biomass-based generation capacity.

Hydropower. Hydropower is primarily used for electricity generation. Almost all the economic potential has already been developed for hydropower generation in large scale power plants. Most of the major hydropower schemes are associated with Sri Lanka's two main rivers—Mahaweli and Kelani, on which 1,370 MW of large hydro and 20.5 MW of small hydro have been developed by the CEB. About 350 MW of small hydropower plants have been developed by private small power producers (SPPs), while 247 MW of committed power plants are in various stages of development by CEB.

Solar. Solar power is abundantly available in Sri Lanka as the country lies within the equatorial belt. Annual average Global Horizontal Irradiance (GHI) varies from 4.5 kilowatt-hour per square meter per day (kWh/m^2/day) to 6.0 kWh/m^2/day across the country.[7] The Solar Resource Atlas of Sri Lanka, prepared by Sri Lanka Sustainable Energy Authority (2014), provides GHI and Direct Normal Irradiance data across the island with a resolution of 3 kilometers (km) by 3 km. Delays in policy enactments and technical constraints have hindered the early deployment of solar photovoltaic (PV) technology in the country. Nonetheless, by mid-2017 there were eight small-scale solar power plants with a total installed capacity of 51.36 MW developed under the country's SPP program.[8] It is estimated that the technical potential for the use of solar energy for electricity generation is about 6,000 MW. Rooftop solar PV systems became increasingly popular with the introduction of the net-metering system in 2010 and the government-initiated "Battle for Solar Energy" program in September 2016. There were 93.7 MW of rooftop solar PV systems connected to the national grid by end 2017, and the total grid-connected solar PV capacity is targeted to reach 200 MW by 2020.

Wind. In 2003, the National Renewable Energy Laboratory assisted Sri Lanka in developing its Wind Resource Map. The country has good wind energy resources that are concentrated in the north western coastal area and in the central highlands. By end 2017, Sri Lanka had a total installed generation capacity of

[7] GHI is a measure of the amount of solar energy received.
[8] Ceylon Electricity Board. 2018. NCRE Development: Capacity Additions Up to 31 July 2017. https://www.ceb.lk/business_with_ceb/present_status/en#present_status (accessed June 2018).

131 MW. It is estimated that the country can gain a utilizable wind power potential of 5,600 MW.[9]

Petroleum. Figure 2 shows that 43% of Sri Lanka's energy supply continues to depend on imported petroleum products, as the country has yet to discover indigenous petroleum resources. Petroleum products are mainly used for transport, power generation, and industries. Over the past years, Sri Lanka's importation of petroleum products has steadily increased. About 30% of the country's petroleum product requirement in the form of crude oil is imported and processed at the Ceylon Petroleum Corporation (CPC) refinery. The balance requirement is directly imported as refined products.

Coal. With the commissioning of the first phase (300 MW) of the Lakvijaya Coal Power Plant in Puttalam in 2011, and the second and third phases (2×300 MW) in 2014, demand for coal increased to 10% (of primary energy) in 2014 from 0.6% in 2009 prior to the commissioning of the first coal power plant. In 2017, coal provided 35% of Sri Lanka's electricity requirements. The use of coal for electricity generation has remarkably reduced the use of oil for power generation—from the highest share of 62% in 2004 to 18% in 2015—reducing the cost of electricity generation. In some manufacturing industries, coal is used in kilns and boilers.

Gas and petroleum. In 2011, Sri Lanka reported discovery of gas offshore in the Mannar basin in the northwest of the country. The program of exploration continued until 2015, with two more positive gas discoveries in the same area.[10] The findings are mostly gas-bearing, with a smaller potential for liquid hydrocarbons. However, the findings did not proceed toward commercial development, owing to the withdrawal of the party who held the rights for exploration and commercialization, citing the declining oil and gas prices worldwide. The government plans to offer more blocks in Mannar for exploration rights, and is encouraging improved competition. The Mannar basin, according to previous studies, was estimated to hold a reserve of about 1 billion barrels of oil equivalent. For exploration, the Mannar basin has been divided into eight offshore blocks, many of which extend up to 2,000-meter depths. While continuing its efforts to commercialize the gas finds in the Mannar basin, the government plans to initiate a strategic oil and gas exploration program. The Petroleum Resource Development Secretariat (PRDS) is continuing with studies in association with Total S.A., for offshore blocks in the east of the country.[11]

[9] M. Young and R. Vilhauer. 2003. *Sri Lanka Wind Farm Analysis and Site Selection Assistance.* National Renewable Energy Laboratory. Global Energy Concepts, LLC Kirkland, Washington. https://www.nrel.gov/docs/fy03osti/34646.pdf.

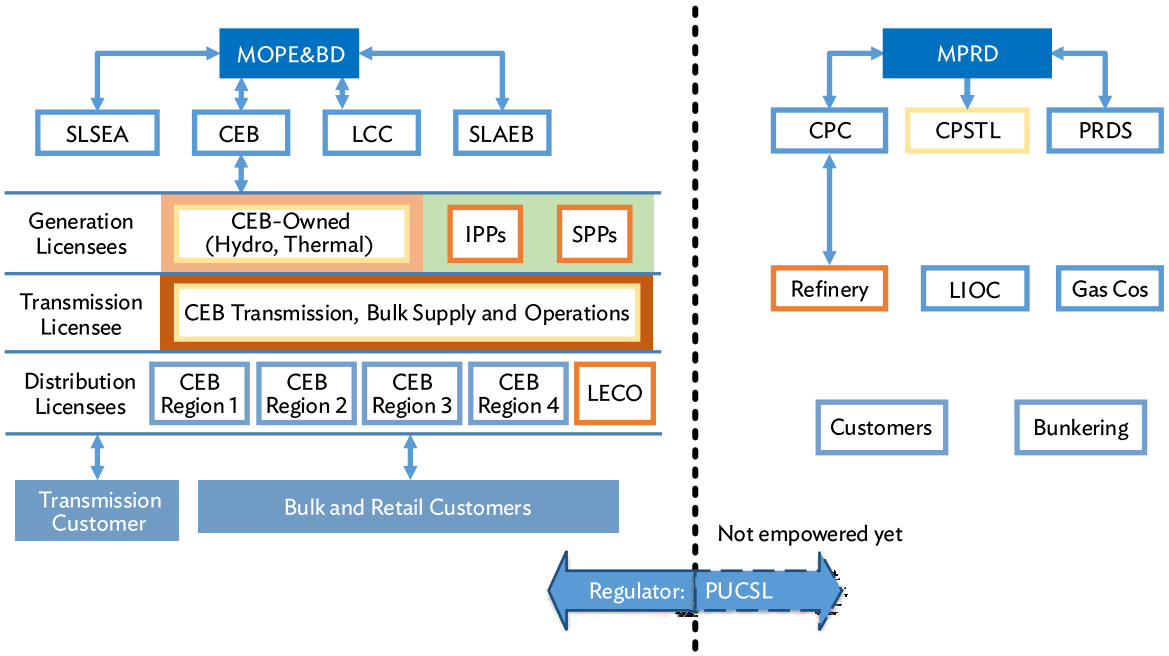
[10] http://www.prds-srilanka.com/exploration/mannarBasin.faces (accessed 3 December 2019).

[11] Petroleum Resources Development Secretariat, *Petroleum Exploration Development Plan*, 25 September 2017.

3. Organization of the Energy Sector

Figure 5 shows the organizational structure of Sri Lanka's energy sector. The MOPE&BD and the Ministry of Petroleum Resources Development (MPRD) both manage the activities of the country's energy sector. MOPE&BD is mandated to (i) formulate and implement policies, programs and projects pertaining to electricity and renewable energy, and all subjects that come under the purview of the institutions within MOPE&BD; (ii) reform all systems and procedures to ensure the efficient conduct of business; (iii) monitor, investigate, and develop electricity facilities throughout Sri Lanka, including hydropower, thermal power, minihydro, coal, and wind power; (iv) extend rural electrification; (v) develop a sound, adequate, and uniform electricity policy for the control, regulation, and utilization of energy resources; (vi) promote energy efficiency; and (vii) develop indigenous renewable energy resources.[12]

Figure 5: Organization of the Energy Sector, 2017



CEB = Ceylon Electricity Board, CPC = Ceylon Petroleum Corporation, CPSTL = Ceylon Petroleum Storage Terminals Ltd., Gas Cos = gas companies, IPP = independent power producer, LCC = Lanka Coal Company, LECO = Lanka Electricity Company, LIOC = Lanka Indian Oil Company, MOPE&BD = Ministry of Power, Energy and Business Development, MPRD = Ministry of Petroleum Resources Development, PRDS = Petroleum Resources Development Secretariat, PUCSL = Public Utilities Commission of Sri Lanka, SLAEB = Sri Lanka Atomic Energy Board, SLSEA = Sri Lanka Sustainable Energy Authority, SPP = small power producer.

Note: Diagram was prepared by the author.

Sources: Ministry of Power and Renewable Energy. 2017. http://powermin.gov.lk/english/. Ministry of Petroleum Resources Development. 2017. https://www.petroleummin.gov.lk/.

[12] Government of Sri Lanka, MOPE&BD. 2018. http://powermin.gov.lk/english/ (accessed September 2018).

Established in September 2015, the MPRD is responsible for both upstream and downstream activities of the petroleum sector. Functions of the MPRD include (i) the formulation of policies, plans, and programs in respect of upstream and downstream petroleum activities; (ii) the enactment of the Petroleum Resources Act and the Ceylon Petroleum Corporation Act; (iii) making necessary institutional arrangements to facilitate operational activities of oil and natural gas exploration and development; (iv) developing and upgrading infrastructure facilities for exploration and development, supply, storage, and distribution of petroleum; and (v) facilitating the importation, export, refining, storage, distribution, and selling of petroleum-based products.[13]

The electricity industry and petroleum industry are both managed largely by state-owned corporations. Private sector participation in the electricity industry is limited to power generation, while in the petroleum industry, the private sector is engaged in petroleum distribution, bunker supplies, gas distribution, and oil exploration.

Institutions supervised by MOPE&BD include: (i) Ceylon Electricity Board, (ii) Sri Lanka Sustainable Energy Authority, (iii) Lanka Electricity Company, (iv) LTL Holdings, (v) Lanka Coal Company, (vi) Sri Lanka Atomic Energy Board, and (vii) Sri Lanka Atomic Energy Regulatory Council. Institutions supervised by MPRD are: (i) Ceylon Petroleum Corporation, (ii) Ceylon Petroleum Storage Terminals (a company with joint ownership between CPC and Lanka Indian Oil Company [LIOC]), and (iii) Petroleum Resource Development Secretariat. LIOC and Lanka Auto Gas Filling Stations (LAUGFS) gas company are both privately owned, while Litro Gas is government-owned.

Ceylon Electricity Board (CEB) is a state-owned corporation established on 1 November 1969 under the Ceylon Electricity Board Act No. 17 of 1969. The CEB is engaged in power generation, transmission, distribution, and supply of electricity. It is also sanctioned to acquire assets and to appoint and promote its officers, following the approved procedures. The CEB has one license for generation, which caters to 71% of the total installed capacity on the grid by the end of 2017. CEB holds the only transmission and bulk supply license in Sri Lanka. CEB also holds four out of five distribution licenses.[14]

Sri Lanka Sustainable Energy Authority (SLSEA) was established on 1 October 2007, through the Sri Lanka Sustainable Energy Authority Act No. 35 of 2007. Its objectives are: (i) to assist in the formulation of the national energy policy; (ii) to identify, conserve, and manage all renewable energy resources and appropriate conversion technologies, conversion, and utilization norms and practices; (iii) to promote the development of renewable energy projects through private investment; and (iv) to conduct research on the development of indigenous resources.[15]

[13] Government of Sri Lanka, Ministry of Petroleum Resources Development. 2018. http://www.petroleummin.gov.lk/web/index.php/en/ (accessed September 2018).
[14] For more information about CEB and its operations, please see https://www.ceb.lk/.
[15] For more information about SLSEA services and activities, please see http://www.energy.gov.lk/.

Lanka Electricity Company (LECO) is a private limited liability company incorporated in 1983 for electricity distribution in Sri Lanka under the provisions of the Companies Act No. 17 of 1982 and Companies Act No. 7 of 2007. Purchasing bulk power from CEB, LECO serves about 565,000 customers in townships along the western coastal belt between Negombo and Galle as of 2017. The CEB and the Ministry of Finance are the major shareholders of LECO, while the other shareholders are mainly state entities.[16]

LTL Holdings was established in 1982 as a joint venture between CEB and European investors Bonar Long of Scotland, initially to produce an indigenous power transformer used in distribution networks. Manufacturing very high-quality transformers conforming to international standards with the state-of-the-art production facilities, LTL Holdings exports about 50% of the production while meeting the entire country requirement. Expanding beyond manufacturing transformers, LTL has diversified into engineering, procurement, and construction contracting of major power projects, including grid substations and power generating stations.[17]

Lanka Coal Company (LCC) was incorporated under Sri Lanka's Companies Act No. 7 of 2007 to procure and supply coal for coal-fired thermal plants in Sri Lanka. Total coal requirement of the Lakvijaya power plant in Puttalam (2.25 million ton/year) is supplied by LCC, and agreements are already signed between LCC and Trincomalee Power Company Limited for the supply of coal for the proposed coal power plant to be commissioned in 2020.[18] With 60% of shares, the major shareholder of LCC is CEB, while the Sri Lanka Ministry of Finance, Sri Lanka Ports Authority, and Ceylon Shipping Corporation are the other shareholders.[19]

Sri Lanka Atomic Energy Board (SLAEB) was established under the Sri Lanka Atomic Energy Act No. 40 of 2014, with the responsibility of facilitating the utilization of radiation and radioisotope technology in medical, agricultural, industrial, energy, and environmental sectors in Sri Lanka. Regulatory functions, previously conducted by the Atomic Energy Authority, have since been transferred to the Sri Lanka Atomic Energy Regulatory Council.[20]

Public Utilities Commission of Sri Lanka (PUCSL). The Parliament enacted the PUCSL Act No. 35 in December 2002 establishing a regulatory commission.[21] PUCSL performs a vital role as a multisector supervisory body, eventually regulating electricity, petroleum, and water service industries. The PUCSL came

[16] For more information about the structure, management and services of LECO, please see http://leco.lk/.
[17] For more information on LTL's diversified activities, please see https://ltl.lk/.
[18] The Trincomalee Power Company Project is currently on hold, owing to a government review of fuel options for power generation.
[19] For more information about Lanka Coal Company, please see https://lankacoal.lk/.
[20] For more information on the activities of Sri Lanka Atomic Energy Board, please see https://aeb.gov.lk/web/, for information about regulatory activities of the Sri Lanka Atomic Energy Regulatory Council, please see http://www.aerc.gov.lk/.
[21] Legal and regulatory documents are available in the PUCSL website: http://www.pucsl.gov.lk.

into operation in 2003 when the first group of commissioners and its director general were appointed. The five-member commission is appointed by the minister-in-charge of policy development in agreement with the Constitutional Council. Initially, the PUCSL was not able to exercise its powers over the power sector because the Electricity Reform Act of 2002 was not operational at that time due to political opposition and opposition from CEB staff. When a new government took office in 2005, it committed to present a new bill on electricity to the Parliament.[22] Following 3 years of consultations, a final bill was submitted and approved as the Electricity Act No. 20 of 2009 that empowered the PUCSL to operate as the regulator of the power sector. The PUCSL acts as the technical, economic, commercial, and safety regulator of the electricity industry. However, petroleum and water service industries are yet to be included into the regulatory functions of PUCSL.

B. Electricity Supply and Use

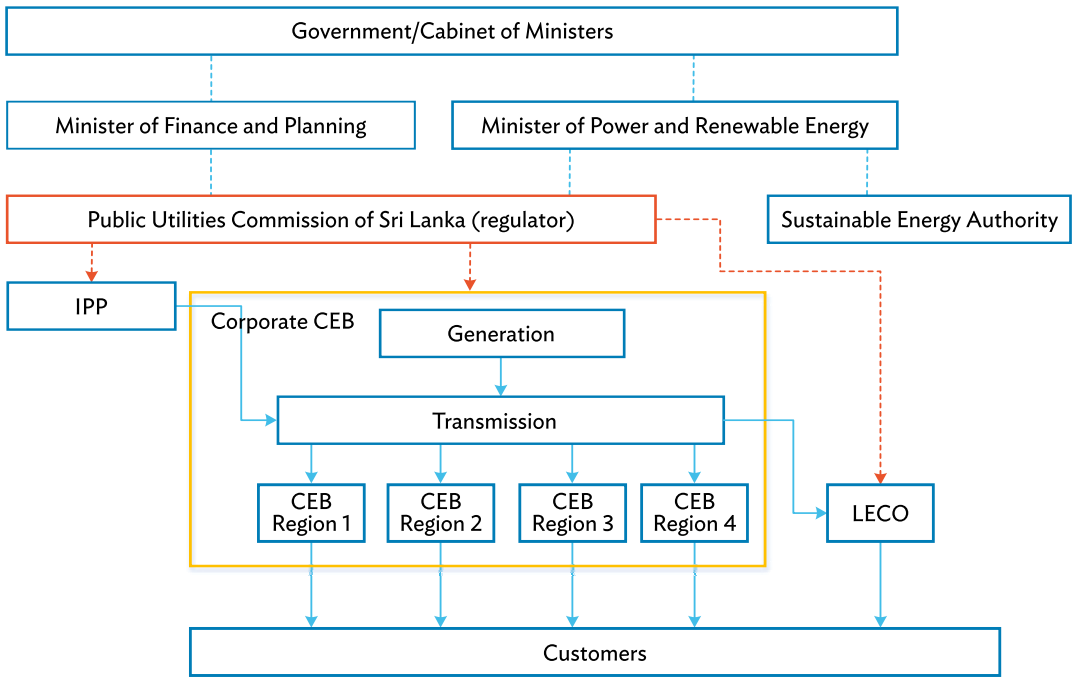
1. Overview of the Electricity Supply Industry

CEB was the monopolistic, vertically integrated national electricity utility from 1969 to 1983, and CEB performed all the functions from generation to retail supply, except distribution within certain cities. Distribution within certain cities and towns was the responsibility of the respective city and town councils, while distribution outside city areas continued to be expanded and operated by CEB. With the power sector reforms in 1983, Sri Lanka established a state-owned company (LECO) for electricity distribution in certain cities and outlying areas. From 1996 onwards, the private sector was allowed to engage in power generation as independent power producers (IPPs) and small power producers (SPPs). The Electricity Reform Act No. 28 of 2002 (ERA 2002) envisaged restructuring of the electricity industry by unbundling CEB and LECO into at least six independent state-owned companies to carry out generation, transmission, and distribution functions. However, ERA 2002 was not implemented and was subsequently replaced with a new act in 2009.[23]

The Electricity Act No. 20 of 2009 (EA 2009) introduced a lesser degree of restructuring of CEB, when compared with the original proposals in ERA 2002. The EA 2009 introduced a single-buyer model, with CEB transmission entity as the designated single buyer as well as the transmission service provider. CEB holds one generation license (to cover all power plants owned by CEB prior to EA 2009), one transmission and bulk supply license, and four distribution licenses. However, these six licensed entities embedded within CEB do not have an independent ownership structure and management. The present electricity industry structure is shown in Figure 6.

[22] A bill is a draft act of Parliament.
[23] Government of Sri Lanka. 2002. Electricity Reform Act, 2002.

Figure 6: Functionally Unbundled Power Sector Monopoly, 2009–present



CEB = Ceylon Electricity Board, IPP = independent power producer , LECO = Lanka Electricity Company.
Source: Author.

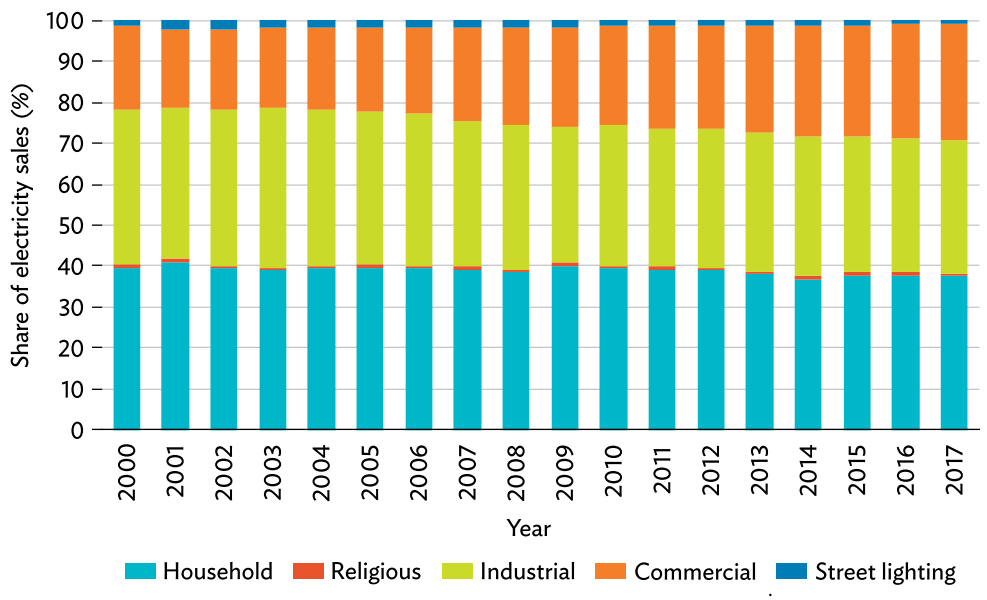
Electricity Sales and Demand Growth

The electricity market in Sri Lanka is dominated by the household and industrial sectors, while the demand in the commercial sector has been increasing rapidly over the recent years. In 2017, the share of sales to the household sector was 37% and to the industrial sector was 32%, and the sales to the commercial sector was 29%. Figure 7 shows that the household market share is stagnant, the industrial market share has been steadily declining over the past 10 years, while the share of sales to the commercial sector is increasing. In general, all customer categories indicate growth in sales, in which the industrial customer group shows the lowest growth in sales.

Figure 8 shows the growth of the total installed capacity in the grid and the system peak demand over the past years. In 2017, the system peak demand excluding the contribution of some SPPs[24] was 2,523 MW (recorded on 17 May 2017).

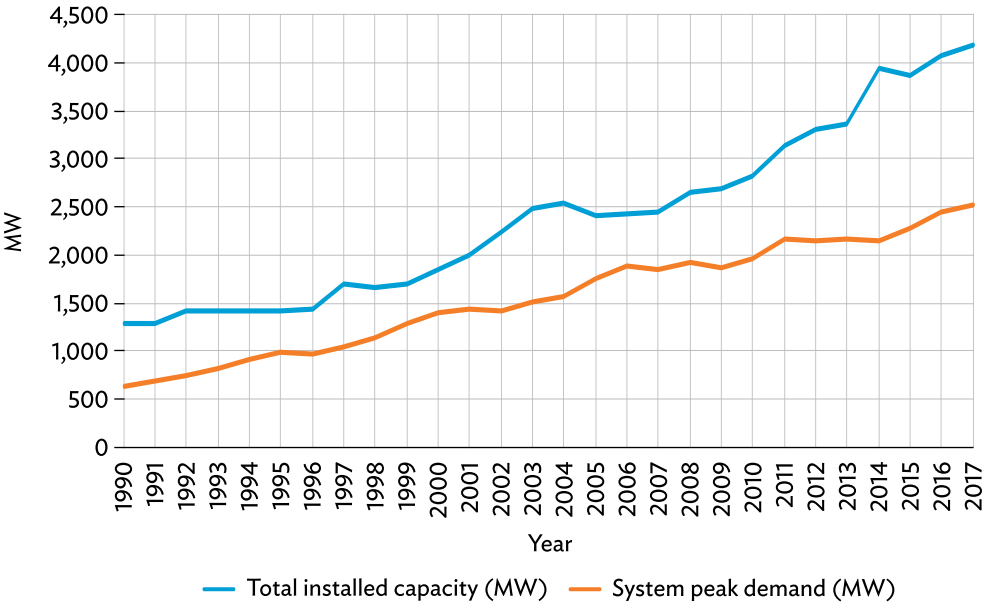
[24] SPPs sell electricity to the single buyer, but they are embedded in the distribution network. Some SPP capacity contributions are not available online, hence their operating capacity may not be accurately represented. Their energy contribution, however, is accurately recorded through monthly invoicing.

Figure 7: Changing Market Structure of Electricity Sales



Source: Sri Lanka Sustainable Energy Authority. 2019. *Sri Lanka Energy Balance 2017*.

Figure 8: Total Installed Capacity and System Peak Demand

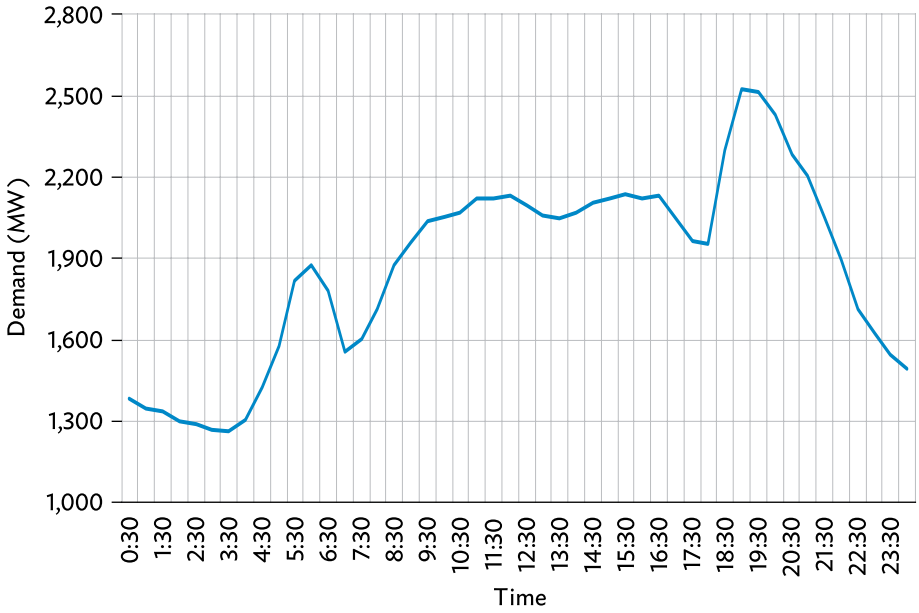


MW = megawatt, PV = photovoltaic.
Note: Total installed capacity includes rooftop solar PV capacity.
Source: Sri Lanka Sustainable Energy Authority. 2019. *Sri Lanka Energy Balance 2017*.

Sri Lanka has a load curve with a steep peak in the late evening. From about 6:00 p.m., the load grows to about 2,500 MW by 7:30 p.m. and falls off after about 8:30 p.m. Therefore, the system requires substantial additional generation capacity only to meet the sharp night peak. The load factor in Sri Lanka is comparatively lower but has been growing in the recent past (Figure 9).

Figure 9 shows the system load profile on 17 May 2017, on which day, the highest daily peak in 2017 was recorded. Figure 10 shows the variation of the system load profile with respect to the peak demand in each year for 2002, 2005, 2011, and 2017. It can be clearly seen that the mid-day demand has significantly increased over the past years. This is mainly attributed to the increasing demand in the commercial sector (offices, banks, and schools), most of which operate from 8:00 a.m. to 5:00 p.m., and the attractive time-of-use tariff introduced to the industrial and commercial customer categories. Owing to the increase in the day-peak, the system load factor too has improved over the past 4 years, and shown in Figure 11.

Figure 9: System Load Profile on 17 May 2017

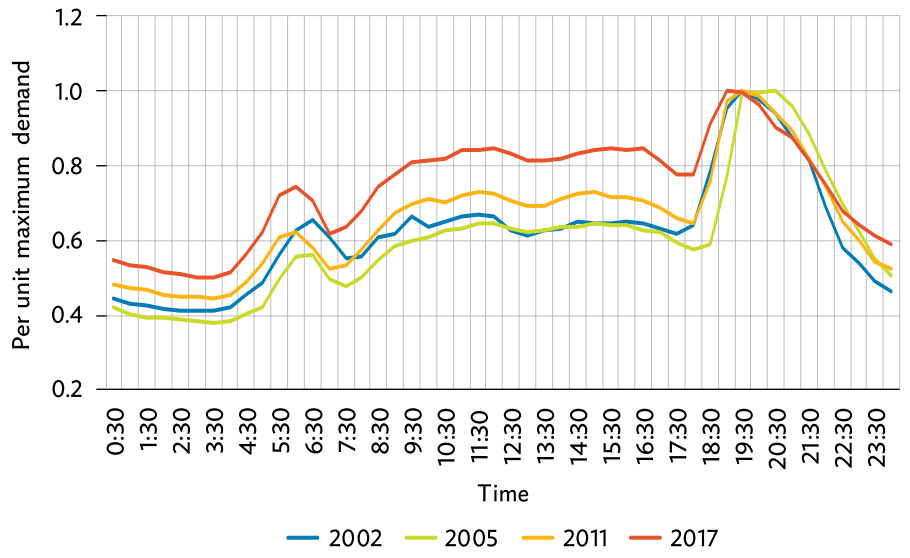


MW = megawatt.

Note: System peak demand has been adjusted to include wind generation small power producers connected to the 132-kilovolt network.

Source: Sri Lanka Sustainable Energy Authority. 2019. *Sri Lanka Energy Balance 2017*.

Figure 10: System Load Profile Normalized to the Peak Demand



Note: System peak demand, prior to 2013, did not include contributions from embedded generation. It has since been adjusted to include embedded wind generation connected to the 132-kilovolt network from April 2013 and for embedded minihydro and biomass generation from May 2015.

Source: Prepared using information available in Sri Lanka Sustainable Energy Authority. 2019. *Sri Lanka Energy Balance 2017*.

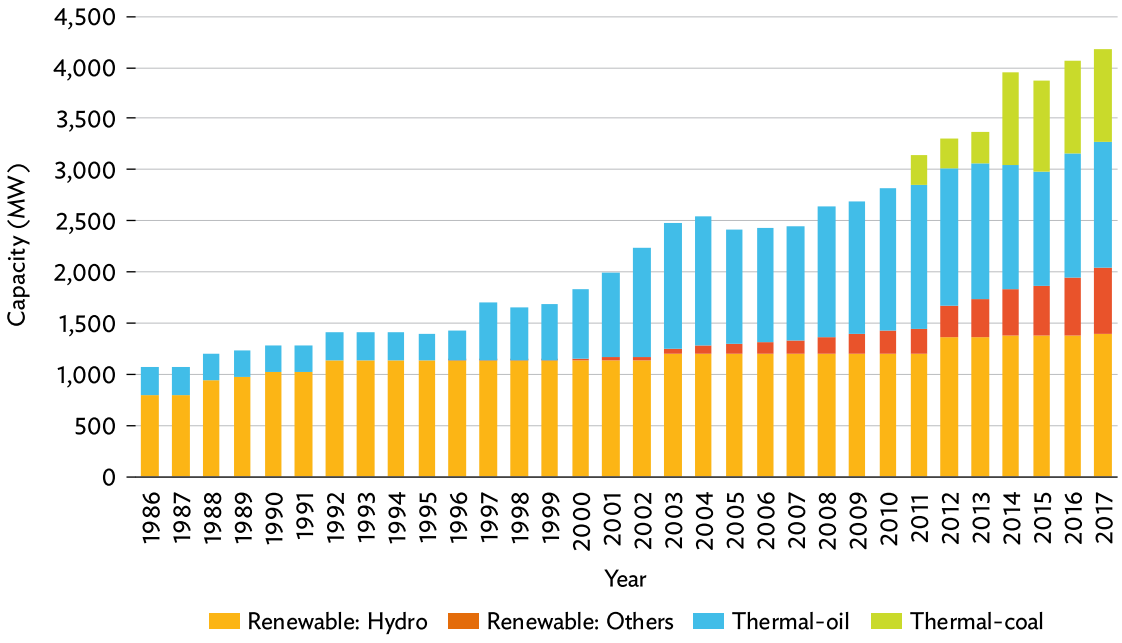
Figure 11: System Annual Load Factor, 2000–2017

Source: Sri Lanka Sustainable Energy Authority. 2019. *Sri Lanka Energy Balance 2017.*

Generation

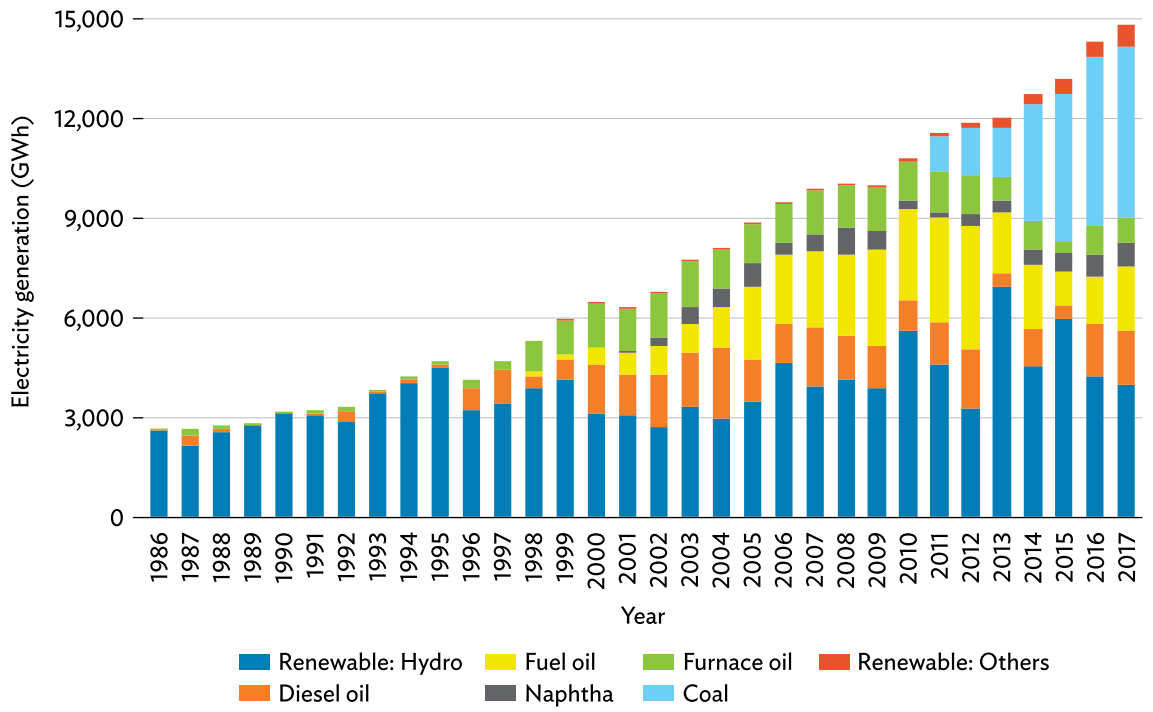
Electricity generation in Sri Lanka was almost 100% from hydropower until mid-1995. However, with the rapid growth in electricity demand during the last 20 years and the limited potential to develop new large hydropower facilities, the power generation mix in the country has shifted to a mixed hydrothermal system. Initially, the state-owned CEB was the only entity allowed to engage in power generation, transmission, and distribution activities. After 1996, Sri Lanka allowed the private sector to participate in its SPP program to develop renewable energy-based power plants to sell electricity to CEB. Since 1996, the private sector could invest in large generation projects as IPPs. Figure 12 shows the capacity mix in generation by technology. Figure 13 shows the growing diversity of fuel mix in electricity generation.

Figure 12: Generation Capacity Mix, 1986–2017



MW = megawatt, PV = photovoltaic.
Note: "Renewable: Others" includes rooftop solar PV capacity.
Source: Sri Lanka Sustainable Energy Authority. 2019. *Sri Lanka Energy Balance 2017*.

Figure 13: Generation Fuel Mix, 1986–2017

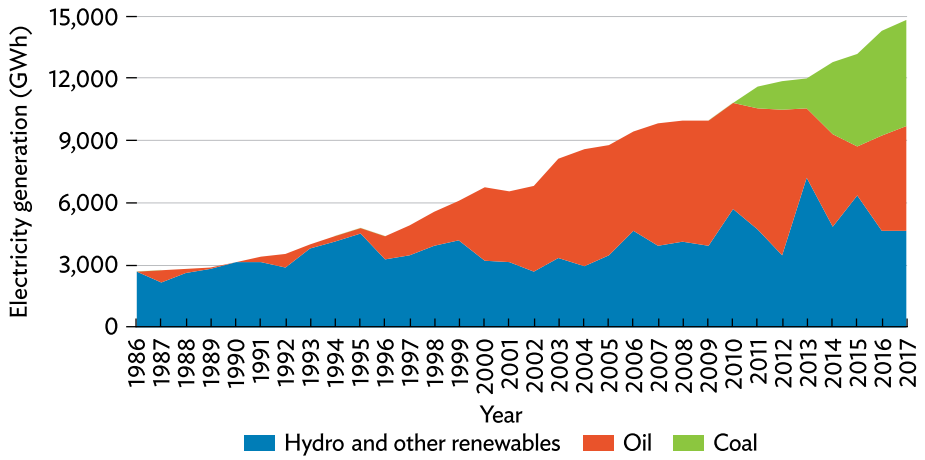


GWh = gigawatt-hour.
Source: Sri Lanka Sustainable Energy Authority. 2019. *Sri Lanka Energy Balance 2017*.

By the end of 2017, the total installed capacity was 4,180 MW including non-dispatchable power plants (small hydro, wind, solar, and biomass) of capacity 562 MW owned by the private sector and 94 MW of rooftop solar PV. Out of the total installed capacity of 4,180 MW, 42% (1,745 MW) was from hydro (both large hydro and small hydro); 51% (2,133 MW) from thermal; and 7% (303 MW) from other renewable sources such as wind, solar, and biomass. In 2015, Sri Lanka reported the lowest share of oil-fired generation of 18% of the total, for the first time since 1996, as shown in Figure 14. Due to the growing demand and delays in other power plant projects, compounded by significantly below average rainfall, the share of oil-fired generation increased to 34% in 2017. Use of oil for power generation has significant impacts on costs of production and customer tariffs. About 69% of the total installed capacity in the country is owned by CEB, while IPPs and SPPs own the rest.[25]

[25] Ceylon Electricity Board. 2017. *Statistical Digest 2017*. https://www.ceb.lk/front_img/img_reports/1536209909CEB_Statistical_Digest_2017_-_Web.pdf (accessed June 2019).

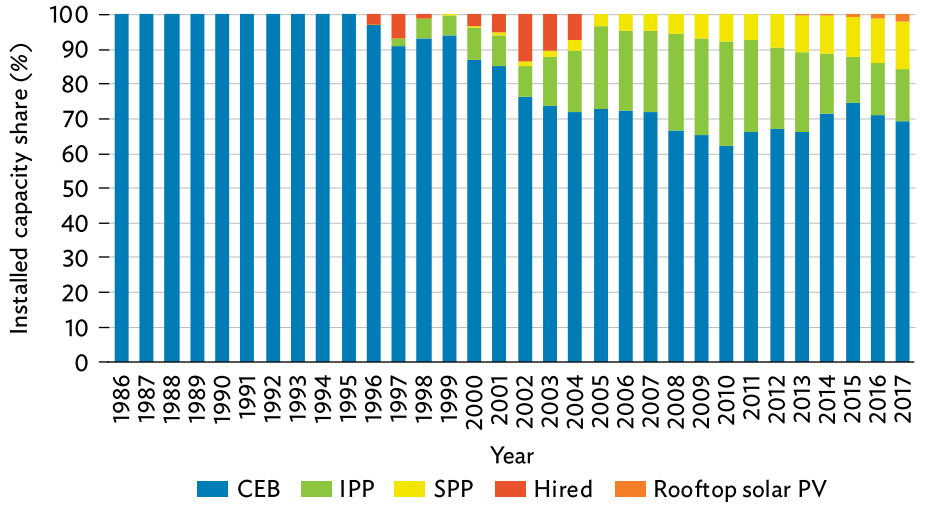
Figure 14: Energy Mix in Power Generation, 1986–2017



GWh = gigawatt-hour.
Note: Hydro and other renewables do not include rooftop solar generation.
Source: Sri Lanka Sustainable Energy Authority. 2019. *Sri Lanka Energy Balance 2017*.

Figure 15 shows the variation of installed capacity share by ownership since 1990, where the lowest CEB share was 62% in 2010. All IPPs are oil-fired, operating on 10- to 20-year power purchase agreements; all SPPs are renewable energy-based,

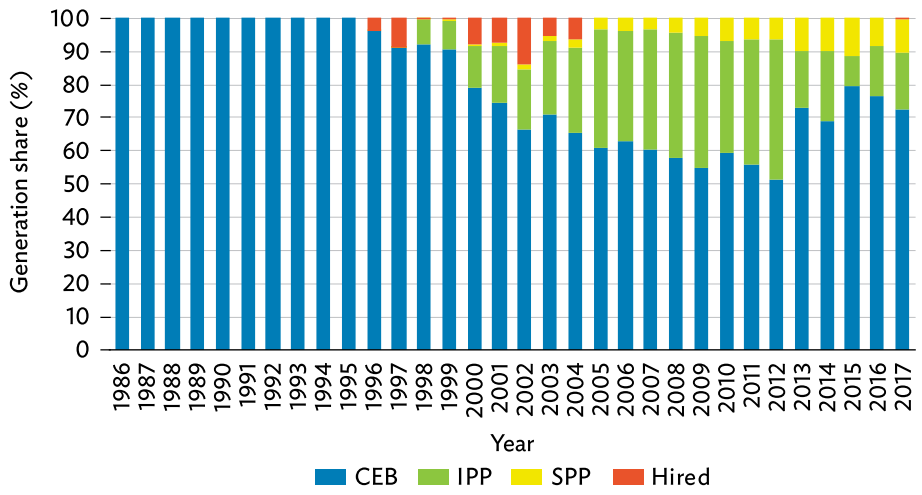
Figure 15: Installed Capacity Share, Ceylon Electricity Board, and Private Power Producers, 1990–2017



CEB = Ceylon Electricity Board, IPP = independent power producer, PV = photovoltaic, SPP = small power producer.
Source: Sri Lanka Sustainable Energy Authority. 2019. *Sri Lanka Energy Balance 2017*.

with 15- or 20-year contracts, mostly operating on feed-in tariffs. A few recent SPPs are paid at tariffs determined through competitive bidding. Figure 16 shows generation by ownership. In 2017, CEB power plants produced 73% of energy, up from the lowest share of 52% in 2012.

Figure 16: Generation Energy Share by Ownership, 1990–2017



CEB = Ceylon Electricity Board, IPP = independent power producer, SPP = small power producer.
Note: Generation from rooftop solar PV is not included.
Source: Sri Lanka Sustainable Energy Authority. 2019. *Sri Lanka Energy Balance 2017.*

Table 4 details the status of electricity generation in 2017. It was a dry year and therefore, contribution to generation from hydropower was comparatively lower. The percentage share in generation from new renewable energy (NRE) sources was 11%.

Table 4: Electricity Generation by Source, 2017

Type of Power Plant	Total Installed Capacity (MW)	Generation (GWh)	Share in Generation (%)
Major hydro	1,391	3,059	21
New renewable energy	656	1,596	11
Total renewables	2,047	4,655	32
Thermal-oil	1,233	5,045	34
Thermal-coal	900	5,103	34
Total	**4,180**	**14,803**	**100**

Source: Sri Lanka Sustainable Energy Authority. 2019. *Sri Lanka Energy Balance 2017.*

Contribution from hydropower plants varies with rainfall. During wet years hydropower generation increases even beyond 40% of energy, but in dry years oil-fired thermal power plants are heavily used to bridge the gap in hydropower generation. Majority of the potential of hydropower has by now been exploited for major hydropower plants and currently,

(i) the CEB is building medium-scale hydropower plants: the list of major hydropower stations of CEB currently operational as shown in Appendix 1. About 247 MW of capacity will be added by 2022 with the ongoing construction of Broadlands (35 MW), Moragolla (30.2 MW), Uma Oya (122 MW), and the planned power plants: Gin Ganga (20 MW), Thalpitigala (15 MW), and Moragahakanda (25 MW); and
(ii) smaller grid-connected hydropower plants continue to be developed by the private sector.

CEB owns eight thermal power plants (Appendix 2) including the last addition of Lakvijaya coal-fired power plant in Puttalam. The total capacity of thermal power plants owned by CEB by the end of 2017 was 1,504 MW, comprising Lakvijaya coal plant (900 MW), Kelanitissa gas turbines (192 MW), Kelanitissa combined cycle plant (165 MW), Sapugaskanda diesel plant (160 MW), Uthuru Janani power plant (26.7 MW), and Barge Mounted plant (60 MW). Locations of existing and committed power plants are shown in Appendix 3.

As hydropower development was limited while the demand continued to increase rapidly, and the construction of planned medium-scale hydropower projects and coal-fired power plants were significantly delayed from 1985–2005, oil-fired thermal power plants had to be constructed to cater to the increasing demand. Expenditure on oil imports increased yearly and generation cost from oil-fired power plants was very high. As the additional costs were not allowed to be fully and promptly passed on to customers by way of tariff increases, these costs were a significant burden on CEB. Sri Lanka's first coal-fired power plant in Puttalam, an investment of about $1.35 million including the 220 kV transmission interconnections to two locations, was financed by the Import–Export Bank of the People's Republic of China. The power plant was completed in 2014. This is a 3x300 MW power plant named Lakvijaya Coal Power Plant and contributed about 35% of the total electricity generation in 2017. The second coal-fired power plant is planned to be in Trincomalee as a joint venture between the National Thermal Power Corporation of India and CEB, as an IPP. The joint venture company named Trincomalee Power Company Limited was established and the power purchase agreement signed in 2013 for the implementation of the Trincomalee Power Project with a total capacity of 500 MW. This planned power plant was expected to be connected to the national grid by 2020, but due to several reasons including the government's concern of coal being used as fuel, this power plant is delayed indefinitely.

Transmission

The CEB acts as the single buyer in the electricity industry, holding the only license issued for power transmission and bulk supply function with transmission voltages of 220 kV and 132 kV. The transmission network consists of 69 grid substations, 601 km of 220 kV overhead lines, at least 2,260 km of 132 kV overhead lines, and 50 km of 132 kV underground cables.

The Northern Province was not connected to the transmission network during the conflict period, but the transmission network was extended to reach Jaffna peninsula. Since mid-2013, the transmission grid has covered the entire country.

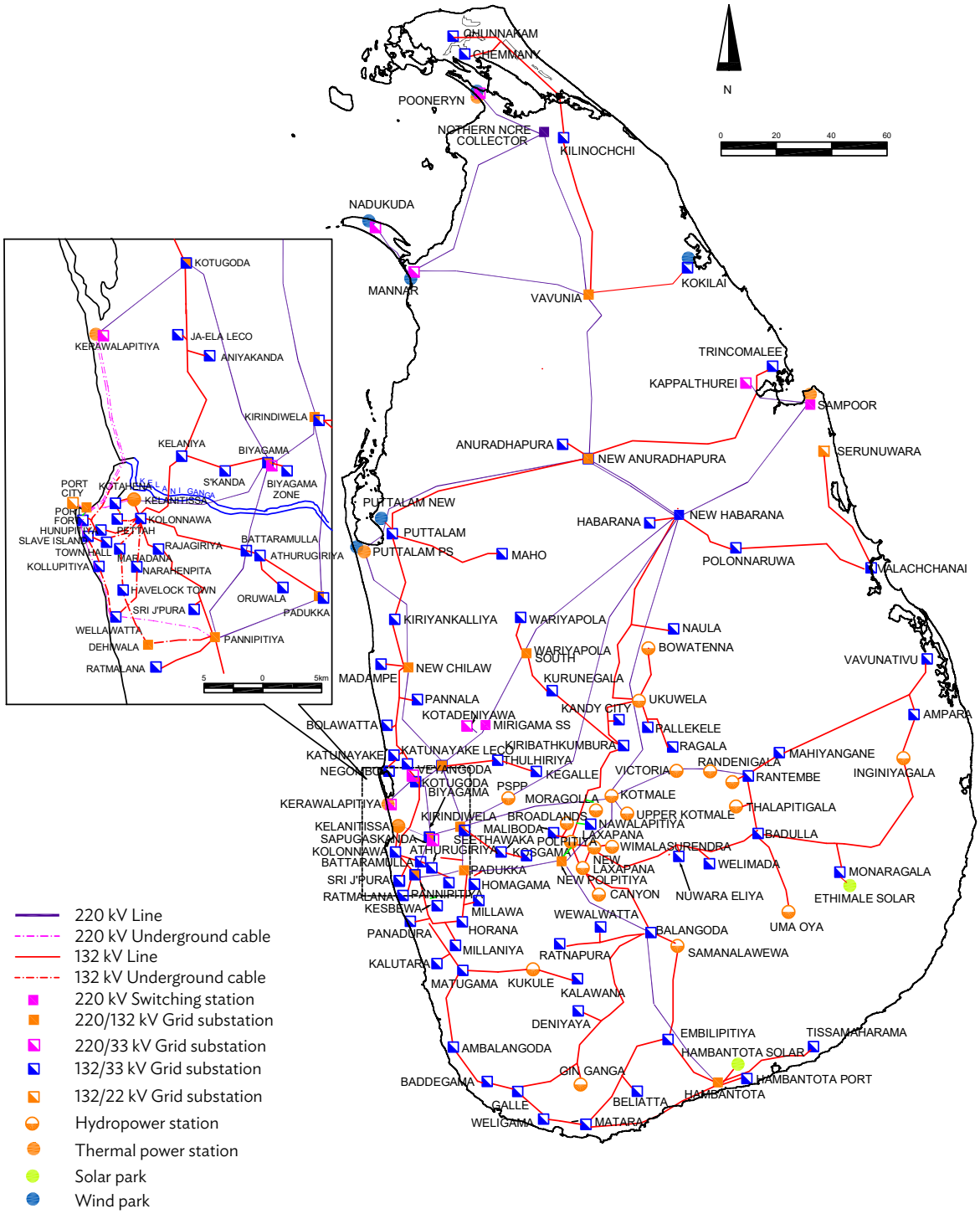
The transmission system from Mahaweli hydropower generating stations, coal power station at Puttalam, and combined cycle power plant at Kerawalapitiya to main load centers through Biyagama, Pannipitiya, Veyangoda, and Kotugoda grid substations, is at 220 kV. Additionally, the 220 kV transmission line from the Kotmale power station to New Anuradhapura grid substation is used to facilitate power transfer to the northern and eastern provinces. The 132 kV transmission system interconnects most of the grid substations and transfers power from other power stations. Several 220 kV/132 kV interbus transformers are installed on the network to facilitate interconnection between two different transmission voltage levels enabling efficient power interchange.

The power system in Sri Lanka is managed by the System Control Centre—a function of the CEB transmission licensee. In 2016, energy loss in the transmission network was at 1.7%,[26] whereas in 2014 it was 2.7%. Transmission development studies are regularly carried out by the transmission licensee, and the transmission development plan is updated every 2 years for a 10-year period. The recently available transmission development plan has identified several transmission projects including the augmentation of existing grid substations, construction of new grid substations, installation of reactive power compensation equipment, and construction of new transmission lines. Implementation of these projects would ensure capacity adequacy and reliability of the transmission network to cope with the demand growth. Uncommitted transmission development projects and power plant connection projects are shown in Appendix 4 and Appendix 5.

Figure 17 shows the planned transmission network of 2025.

[26] Author's calculation based on data available in *Statistical Digest 2017*, CEB and Decision on Uniform National Tariff Adjustment for 1 January to 31 December 2016 published by the PUCSL.

Figure 17: Planned Transmission System, 2025



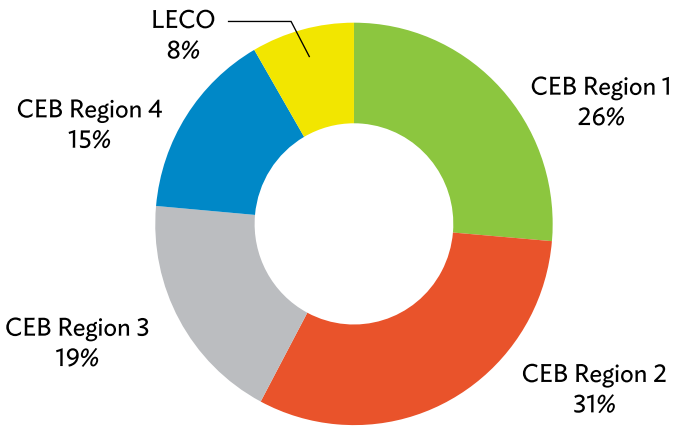
kV = kilovolt, NCRE = non-conventional renewable energy.

Source: Ceylon Electricity Board. 2018, *Long-Term Transmission Development Plan 2018–2027*, December 2018.

Distribution

The PUCSL has issued five distribution licenses—four to CEB and one to LECO. Sri Lanka is divided into five regions, and both power distribution and supply in every region are carried out by the respective distribution licensee. The four CEB distribution licenses cover more than 97% of the land area of the country and 92% of customers. The share of customer accounts by each distribution licensee are shown in Figure 18. The number of accounts by each customer category by the end of 2017 in CEB and LECO are shown in Table 5.

Figure 18: Share of Customer Accounts of Each Distribution Licensee, 2017



CEB = Ceylon Electricity Board , LECO = Lanka Electricity Company.
Source: Ceylon Electricity Board. 2017. *Statistical Digest 2017*. https://www.ceb.lk/front_img/img_reports/1536209909CEB_Statistical_Digest_2017_-_Web.pdf.

Table 5: Number of Accounts by Customer Category, 2017

Customer Category	CEB Regions	LECO
Household	5,425,060	467,939
Religious	37,999	2,604
General purpose	667,062	87,363
Hotel	507	65
Industrial	60,694	3,409
Government	1,807	429
Street lighting	1	3,544
Total	**6,193,130**	**565,353**

CEB = Ceylon Electricity Board, LECO = Lanka Electricity Company.
Source: Ceylon Electricity Board. 2017. *Statistical Digest 2017*. https://www.ceb.lk/front_img/img_reports/1536209909CEB_Statistical_Digest_2017-Web.pdf.

Sri Lanka's distribution network consists of medium voltage lines (33 kV and 11 kV), primary substations (33 kV/11 kV), distribution transformers (33 kV/400 V) and 11 kV/400 V), and low voltage (400 V) lines. LECO distributes at 11 kV and 400 V. Table 6 shows a list of distribution assets owned by each distribution licensee.

Actual losses reported by each distribution licensee and the target losses in 2016 are shown in Table 7. However, in 2017, the total transmission and distribution loss in Sri Lanka was estimated at 8.95% of net generation, which compares well with the 9.84% loss target set by the PUCSL for 2017 in the Decision on Transmission and Bulk Supply Tariffs effective 1 October 2016.

Table 6: Distribution Assets Owned by Each Distribution Licensee, 2017

Distribution Asset	CEB Region 1	CEB Region 2	CEB Region 3	CEB Region 4	LECO
33 kV route length (km)	10,584	9,185	7,106	4,483	–
11 kV route length (km)	1,307	627	45	293	1,065
Low voltage (400 V) circuit length (km)	45,465	40,105	31,615	25,623	3,498
Number of primary substations (in 2014)	34	42	10	33	–
Number of distribution substations (in 2014)	8,225	8,722	5,078	4,406	4,126

CEB = Ceylon Electricity Board , km = kilometer, kV = kilovolt, LECO = Lanka Electricity Company.

Note: By the end of 2017, LV= low voltage.

Sources: Medium Voltage Distribution System Development Plan 2014-2023 of DL1, DL2, DL3, and DL4, LECO, and Ceylon Electricity Board. 2017. *Statistical Digest 2017*. https://www.ceb.lk/front_img/img_reports/1536209909CEB_Statistical_Digest_2017-Web.pdf.

Table 7: Target Transmission and Distribution Losses and Actual Losses in 2016

Licensee	Target Loss for 2016 (% of input)	Actual Loss Reported for 2016 (% of input)
CEB Transmission	3.3	1.7
CEB Region 1	8.2	7.6
CEB Region 2	10.0	9.1
CEB Region 3	8.2	11.7
CEB Region 4	8.6	10.3
LECO	5.0	1.8
All distribution	8.5	8.5
Total transmission and distribution (Sri Lanka National Grid)	11.5	10.3

CEB = Ceylon Electricity Board, LECO = Lanka Electricity Company.

Note: Target loss for 2016 from Decision on Transmission and Bulk Supply Tariffs effective from 1 April 2017.

Sources: Author's calculation from data available in Decision on Uniform National Tariff Adjustment for the period from 1 January to 31 December 2016 published by the PUCSL, *Statistical Digest 2017* by CEB.

Electricity Costs and Prices

With the commencement of the economic regulatory activities by the PUCSL, the costs of supply of electricity have been published. Transmission and generation costs are filed ex ante once in 5 years and are reviewed and approved for a period of 5 years. The current approval covers the period 2016–2020. Generation costs are filed once in 6 months ex ante, reviewed, and approved. Ex post corrections for transmission and distribution costs are done yearly. Ex post corrections for generation costs should be done once in 6 months, but such corrections are not presently conducted. Ex post corrections to recognize the fact that Sri Lanka has a uniform national tariff are conducted once in 3 months.[27] Corrections to other policy-driven commitments of distribution utilities are passed through to the transmission licensee.[28]

The cost of electricity supply and the price of electricity in Sri Lanka for each customer category, as well as to the entire power sector, do not match. Table 8 describes the costs of supply and revenue expected from each key customer category. Bulk customers and nonhousehold LV retail customers provide subsidies to LV household customers. However, such cross-subsidies are inadequate to finance the subsidy required for LV households. A sum of SLRs1.26 per kWh of electricity sold in Sri Lanka was required to be provided to

[27] For example, to account for deviations in the customer mix from its forecast mix at the time of tariff setting.

[28] For example, the buying of surplus generation from rooftop solar PV at government-determined prices.

the sector through government funds. Intrinsically, as government funds are not forthcoming, the sum is reported as losses of CEB—the bulk supplier. Figure 19 shows the average cost of supply at each voltage level for 2016.

Table 8: Cost of Supply to Customers and Revenue, 2016

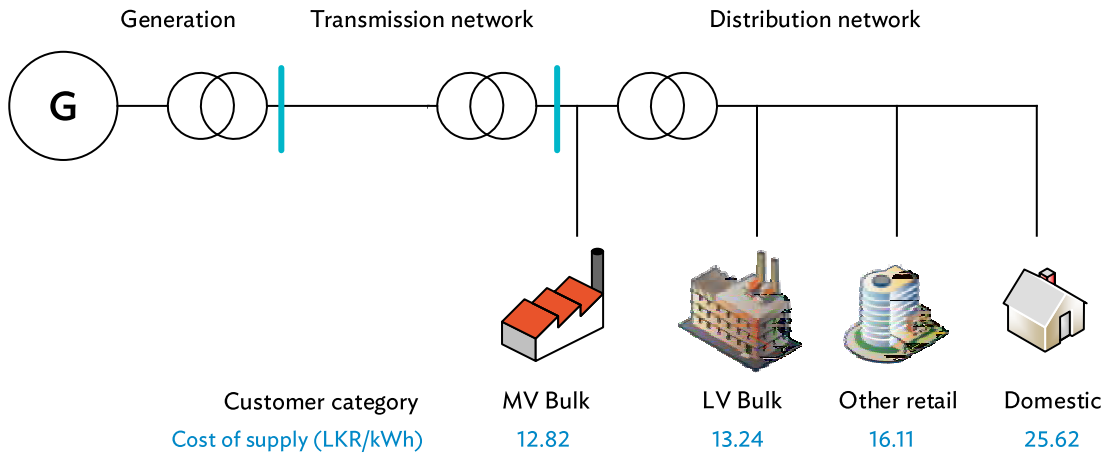
Key Customer Category	Cost of Supply (SLRs/kWh)				Forecast Revenue (SLRs/kWh)	Revenue Gap (SLRs/kWh)
	Capacity-Related	Energy-Related	Retail Services	Total		
MV bulk	5.03	7.78	0.00	12.82	15.07	(2.25)
LV bulk	5.14	8.10	0.00	13.24	17.89	(4.65)
LV: Other retail	6.66	9.26	0.19	16.11	19.17	(3.06)
LV: Households	15.52	9.46	0.65	25.62	15.90	9.72
Sri Lanka	9.15	8.74	0.27	18.15	16.89	1.26

LV = low voltage, MV = medium voltage, PUCSL = Public Utilities Commission of Sri Lanka.

Note: This analysis broadly identifies customer categories by way of voltage of supply. The actual tariff schedule (Annex 6), defines customers by voltage of supply as well by purpose of use. Actual costs are not published by the PUCSL. Actual revenues for 2016 have not been published by distribution licensees.

Sources: Six-month bulk supply tariff announcement by the PUCSL for 2016, Sri Lanka Electricity Pricing Model updated to 2016. All the above are forecasts at the beginning of 2016. Actuals by the end of 2016 may vary, sometimes significantly, owing to variations in hydropower generation and fuel prices.

Figure 19: Costs of Supply at Each Level of Delivery, 2016



kWh = kilowatt-hour, LKR = Sri Lankan rupee, LV = low voltage, MV = medium voltage, PUCSL = Public Utilities Commission of Sri Lanka.

Note: All the above are forecasts at the beginning of 2016. Actuals by the end of 2016 may vary, sometimes significantly, owing to variations in hydropower generation and fuel prices.

Sources: Six-month bulk supply tariff announcement by the PUCSL for 2016, Sri Lanka Electricity Pricing Model updated to 2016.

Electricity costs in Sri Lanka have undergone significant changes in the recent past. This was largely determined by the share of oil-fired generation, and the share of hydropower and other renewable energy in the mix. Table 9 presents the cost of supply of each business unit reflected on customers on average terms, disregarding the voltage at which the sales occur. The dominant cost component is fuel cost, which rose to its highest level of SLRs15.28/kWh in 2013, and declined to SLRs8.62/kWh by 2016 (all costs are on the basis of per kWh sold to end-use customers), as a result of the combined impacts of Sri Lanka's first coal-fired power plant entering full operation from 2015 onwards, and the drop in international coal and oil prices. In 2017, fuel cost increased to SLRs12.74/kWh due to an increase in coal power generation cost and because of the increasing share of oil.

Table 9: Structure of Approved Costs of Supply and Sales Income, 2011–2017

Cost Component		SLRs per kWh Sold						
		2010	**2011**	**2013**	**2014**	**2015**	**2016**	**2017**
Generation	Generation capacity	3.2	2.64	3.06	2.77	3.3	4.05	3.76
	Generation fuel	10.54	8.23	15.28	10.29	10.53	8.62	12.74
Transmission		0.45	0.77	0.75	0.75	0.79	1.1	0.83
Distribution		2.71	2.73	2.72	2.72	2.78	3.7	3.47
Subtotal direct costs		**16.91**	**14.37**	**21.8**	**16.52**	**17.4**	**17.47**	**20.80**
Short-term debt repayment		–	0.59	0.32	0.32	1.49	0.79	0.67
Total cost of supply		**16.91**	**14.96**	**22.12**	**16.84**	**18.89**	**18.27**	**21.47**
		UScts per kWh Sold						
		14.96	13.53	17.13	12.90	13.89	12.60	14.00
Sales revenue forecast (SLRs/kWh)		**13.39**	**13.68**	**18.63**	**na**	**na**	**16.89**	**17.26**
Revenue shortfall (SLRs/kWh)		3.52	1.28	3.49	na	na	1.38	4.21
Revenue shortfall as a % of revenue		26.30%	9.40%	18.70%	na	na	8.20%	24.4%

kWh = kilowatt-hour, PUCSL = Public Utilities Commission of Sri Lanka, SLRs = Sri Lankan rupees, UScts = US cents.

Notes: Data for 2010 is based on pre-Electricity Act 2009 price regulatory arrangement and given here only for reference. Sales income is forecast at approved tariffs, published for years in which a full tariff filing has been done.

Source: Calculated from Tariff Decisions published by the PUCSL. All estimates are ex ante, and the PUCSL conducts an ex post correction to allow for changes in transmission and distribution capital allowances.

Generation of Electricity from Renewable Sources

By the end of 2017, 11% of the generation was from new renewable energy (NRE) and this included small hydro, biomass, wind, and solar. Contribution of each renewable source to generation is shown in Table 10. Entering into small power purchase agreements (less than 10 MW), the private sector contributes to renewable energy development in the country. Sri Lanka has developed almost all the small hydropower resource sites through this initiative and by the end of 2017, the total installed capacity of small hydropower plants was 354 MW.

Table 10: New and Renewable Energy Power Plants Serving the Grid, 2017

Type of Power Plant	Number of Plants	Total Installed Capacity (MW)	Generation in 2017 (GWh)	Share of NRE Generation (%)
Hydro	182	354.0	946	59%
Biomass	10	24.1	78	5%
Solar	8	52.9	74	5%
Rooftop solar PV	11,571	93.7	131	8%
Wind	15	131.0	367	23%
Total	**11,787**	**655.7**	**1,596**	**100%**

GWh = gigawatt-hour, MW = megawatt, NRE = new renewable energy, PV = photovoltaic.

Source: Ceylon Electricity Board. 2017. *Statistical Digest 2017*. https://www.ceb.lk/front_img/img_reports/1536209909CEB_Statistical_Digest_2017-Web.pdf

In 1999, Sri Lanka's first wind power plant was built by CEB in Hambantota as a pilot project and had a capacity of 3 MW. CEB has since issued 15 SPP agreements to private investors to develop wind power plants and by the end of 2017, 131 MW of capacity was operational. Under the Sri Lanka Renewable Energy Master Plan 2014 (REMP) study, it was identified that Mannar has a potential of 375 MW for wind power development out of which CEB is developing 100 MW financed by the Asian Development Bank (ADB).

The government opened the renewable energy sector to private sector participation in 1996. Through this program, Sri Lanka almost completed the development of the country's small hydropower potential. The introduction of the small power producer program also helped mobilize the private sector in investing in small hydropower plants, as the electricity tariffs for production from these site-specific projects were based on avoided cost of generation (Table 11).

Table 11: Avoided Cost-Based Feed-In Tariffs for Agreements Signed up to 2007

Year	Weighted Average Avoided Cost (SLRs/kWh)	Weighted Average Tariff (SLRs/kWh)	SLRs/$ (average)	Weighted Average Tariff (in equivalent UScts/kWh)
1996	2.90	2.90	55.27	5.25
1997	3.01	3.01	58.99	5.11
1998	3.23	3.23	64.59	5.00
1999	2.34	2.86	70.39	4.06
2000	2.97	2.85	75.78	3.76
2001	6.84	4.05	89.36	4.53
2002	7.33	5.71	95.66	5.97
2003	3.54	5.90	96.52	6.12
2004	4.55	5.14	101.19	5.08
2005	8.38	5.49	100.50	5.46
2006	5.22	6.05	103.96	5.82
2007	7.75	7.12	110.62	6.43
2008	14.39	9.12	108.33	8.42
2009	10.07	10.74	114.94	9.34
2010	9.45	11.30	113.06	10.00
2011	11.89	10.47	110.57	9.47
2012	7.84	9.73	127.60	7.62
2013	15.63	11.79	129.11	9.13
2014	21.92	15.13	130.56	11.59
2015	9.31	15.62	135.94	11.49

kWh = kilowatt-hour, SLRs = Sri Lankan rupees, UScts = US cents.
Source: Compiled from annual announcements of feed-in tariff on avoided cost-basis, by CEB.

Such avoided cost-based tariffs, although revenue neutral to the buyer CEB (hence with no adverse impacts on customer tariffs), were only attractive to developers of small hydropower plants. In 2007, a major policy change was implemented—the introduction of feed-in tariffs which are cost-reflective and technology-specific—to attract small power developers to invest in other types of renewable energy, especially wind and biomass. SPP agreements signed from 2008 onwards, are paid feed-in tariffs that depend on the year in which the standardized power purchase agreement (SPPA) is signed, and the resource used. Tariffs paid are shown in Table 12. These tariffs are higher than in many countries, especially in 2009.

Table 12: Cost-Reflective Feed-In Tariffs for Agreements Signed after 2007

Technology	Tariff Offered to SPPs Signing during the Year (SLRs/kWh)				
	2007	2008	2009	2010 and 2011	2012–2017
Minihydro	7.76	11.77	14.58	13.04	17.39
Wind	13.52	18.61	23.07	19.43	not offered
Biomass	12.06	12.77	18.56	20.70	23.44
Agricultural and industrial waste	not offered	9.90	13.88	14.53	17.30
Municipal Waste	not offered	11.59	15.31	22.02	not offered
Waste heat recovery	not offered	7.57	9.71	6.64	9.62
Wave energy	not offered	6.82	not offered	not offered	not offered

Technology	Tariff Offered to SPPs Signing during the Year (in equivalent UScts/kWh)				
	2007	2008	2009	2010 and 2011	2012–2017
Minihydro	7.02	10.86	12.68	11.66	13.63
Wind	12.23	17.18	20.07	17.38	not offered
Biomass	10.90	11.79	16.15	18.51	18.37
Agricultural and industrial waste	not offered	9.14	12.08	12.99	13.56
Municipal waste	not offered	10.70	13.32	19.69	not offered
Waste heat recovery	not offered	6.99	8.45	5.94	7.54
Wave energy	not offered	6.30	not offered	not offered	not offered

CEB = Ceylon Electricity Board, kWh = kilowatt-hour, O&M = operation and maintenance, PUCSL = Public Utilities Commission of Sri Lanka, SLRs = Sri Lankan rupees, SPP = small power producer, UScts = US cents.

Notes:

1. Tariffs paid are denominated in SLRs, with no adjustment for exchange rate fluctuations. Tariffs are shown in UScts/kWh only for purposes of comparison. Tariff paid remains the same, once the agreement is signed, except for an O&M cost escalation provided for the tiered option. Subsequent tariff announcements have no impacts on agreements already signed.
2. For agreements signed until 2011, a three-tier option and a flat-tariff option was offered. Feed-in tariffs over 2007–2011 in above tables show only the flat-tariff option, based on the levelized value of three tiers.
3. Tariff for 2012 published by the PUCSL was disputed by CEB and revised; figures above are revised figures. Years 2012–2017 figures are the tier 1 prices because the levelized tariff option was not offered. Any other technology is offered SLRs23.10/kWh (flat for 20 years).

Source: Compiled by the author from periodic publications of feed-in tariffs by the Ministry of Power and Energy.

Wind power projects have attracted investors from both the public and private sectors but not biomass power projects despite favorable feed-in tariffs. This was mainly due to the difficulty of developers in collecting adequate biomass residues (rice husks, wood, and coconut shells) or to develop sustainably grown biomass plantations, to generate electricity. Energy permits and SPPAs for renewable energy development have been issued by Sri Lanka Sustainable Energy Authority (SLSEA) and CEB, respectively, but deadlines are often violated by the investors. SPPAs are designed to be lenient agreements which do not have any liquidated damages payable by the investor for nonperformance, and CEB transmission licensee is not mandated to purchase energy from the SPPs at all times. However, in operation, SPPAs have demonstrated to be a convenient means by which the private sector can be engaged in power generation from renewable energy. No significant curtailments have been reported although the SPPA does not carry payments for "deemed energy," in case CEB was unable to purchase for technical reasons.

By the end of 2017, eight ground-mounted solar PV grid-connected systems were operational with a combined capacity of 52.9 MW.

The net-metering scheme first introduced in 2010, is increasingly popular among high-electricity consuming household and commercial customers. Net-metered customers are free to install a power generating facility using any form of renewable energy, of capacity up to their existing contract with the distribution utility, and connect the renewable energy facility through their existing electricity connection. Any electricity produced in excess of the customer's requirement at any moment flows to the grid, and such excess energy can be drawn back when the customer's electricity production is lower than the consumption. The monthly charges by the distribution utility comprise the fixed charge plus the charge for net purchase from the grid. Any credits owing to electricity production being higher than the consumption in any given month, are credited to the subsequent month. The increasing-block structure of the household customer tariff caused such net-metered solar PV systems to be installed in high-user household customers. Only a few other types (such as microhydropower plants and wind power plants) connected due to net-metering have been reported.

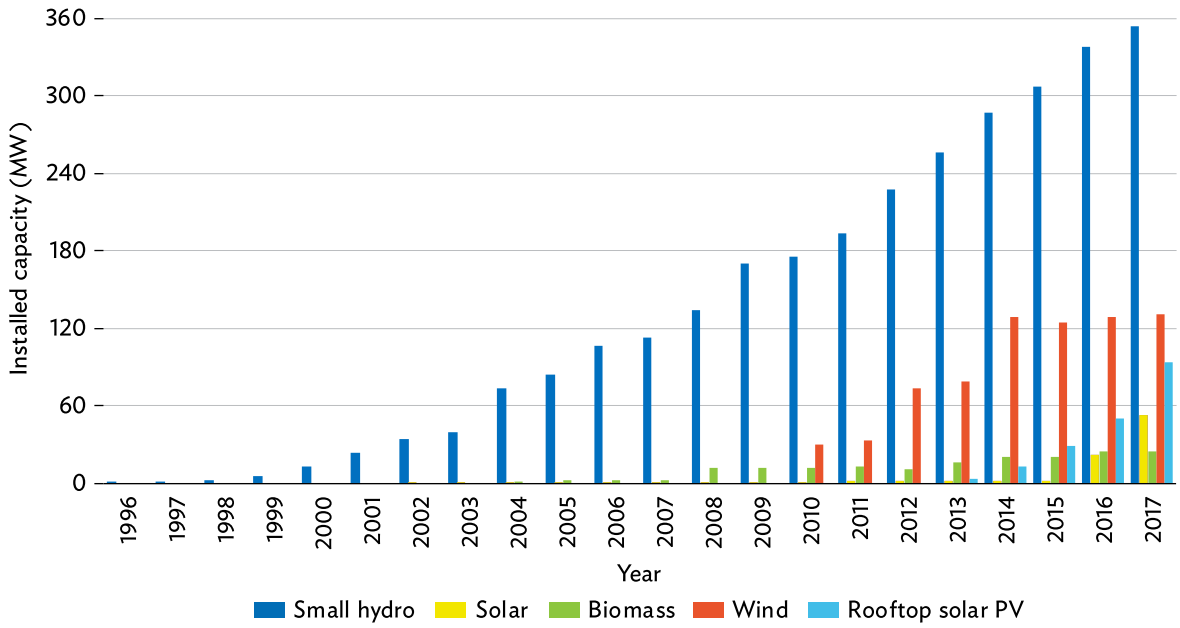
In mid-2016, the government announced an enhancement of the net-metered renewable energy development scheme, by extending the following additional facilities at the discretion of customers owning or planning to build rooftop solar PV systems: (i) at the discretion of the customer, any surplus energy remaining to the customer's credit at the end of each billing month, will be paid SLRs22.00 per kWh; and (ii) a customer may register as a micro solar PV-based electricity producer, and sell electricity at SLRs22.00 per kWh through the customer's existing electricity connection, but through a separate meter. The customer's consumption would be recorded by the existing meter. About 93.7 MW of rooftop solar PV systems were connected to the national grid by the end of 2017.

The rooftop solar PV scheme and its value of SLRs22.00 per kWh for purchases during the day, is significantly higher than the daytime energy price for sale of electricity from the grid to distribution licensees. Sri Lanka's peak demand is at late

evening hours, at which solar PV output is not available, and therefore, there is no direct capacity contribution of solar PV. Daytime average electricity sold from the grid to distribution licensees in 2017 was SLRs11.82/kWh (April to September 2017) and SLRs12.11/kWh (October to December 2017), whereas rooftop solar PV was purchased at SLRs22.00/kWh.

All NRE power plants, net-metered generating facilities, and rooftop solar PV operate as nondispatchable power plants, meaning that such power plants operate at full capacity to harness all the energy available, offering no option to the power plant operators to change their outputs to match the demand for electricity. The tariff paid for NRE is based either on avoided thermal energy costs (for 15 year agreements signed before 2008) or cost-reflective, technology-specific tariffs (for 20 year agreements signed after 2008). The development of NRE for electricity generation is summarized in Figure 20.

Figure 20: Development of Generating Capacity from New Renewable Energy



MW = megawatt, PV = photovoltaic.
Source: Sri Lanka Sustainable Energy Authority. 2019. *Sri Lanka Energy Balance 2017.*

The Renewable Energy Master Plan 2014 recommends the NRE-based generation to operate under the dispatch instructions based on system operating costs and other security constraints, and recommends procuring NRE-based generation through competitive bidding to facilitate price discovery, while discontinuing feed-in tariffs and power plants operating on must-run basis. The master plan also recommends developing wind and solar PV in parks, which would be developed by CEB as the single buyer, to facilitate land allocation and development of common infrastructure.

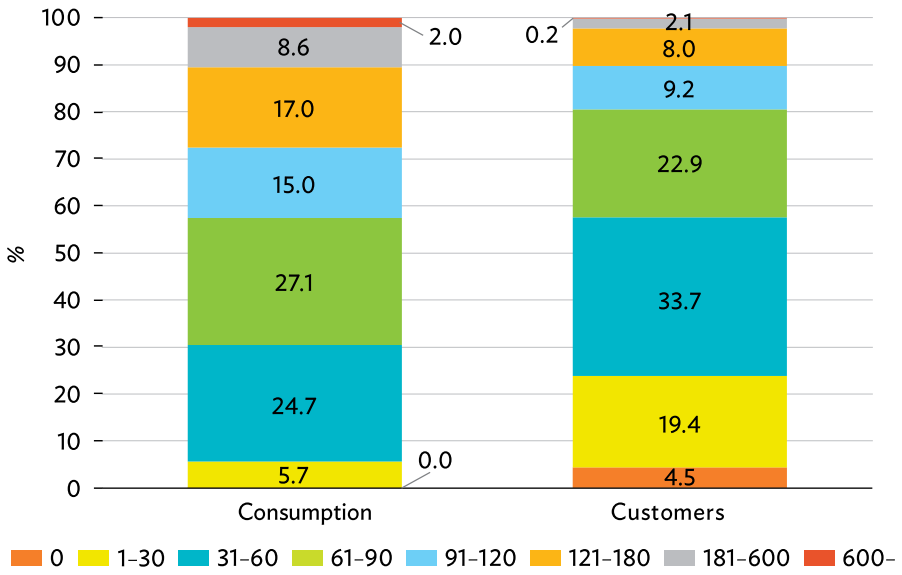
2. Electricity Use and Efficiency

Electricity Market Structure and Subsidies

Sri Lanka's electricity market is overwhelmingly household-oriented, with 37% of sales going to households. The share of electricity sold to the industry is declining, while the share of sales to the commercial sector is increasing (Figure 7). Commercial customers pay significantly higher prices than the cost of supply (Appendix 6).

Subsidy to household customers. Sri Lanka's average sale to household customers has stayed within 66–72 kWh/month for the period 2001–2016. In 2017, the average consumption was 71 kWh/month. However, the cross-subsidy provided by commercial customers and high-user households is inadequate to provide for subsidies to other customer categories. Household electricity use is significantly low for many customers. Figure 21 shows the key features of the household consumption: 4.6% of households record zero consumption, 20% of household customers use less than 30 kWh/month, and 82% of household customers use less than 90 kWh/month. According to the Sri Lanka Electricity Pricing Model of 2016, household customers using below 120 kWh/month are subsidized. Figure 21 shows that only 10.3% of household (approximately 530,000) customers use above 120 kWh/month, and they use 28% of electricity sold to households.

Figure 21: Consumption and Customers in Each Household Consumption Block



CEB = Ceylon Electricity Board, kWh = kilowatt-hour.

Note: Legend shows blocks in household tariff per household per month, in kWh; 4.5% households report zero consumption; 0.1% households in the >600 kWh/month category, use 2% of electricity sold to households.

Source: Information from CEB distribution licensees, for July 2014.

Subsidy providers installing rooftop solar PV. The following features are important: (i) about 25% of households pay a monthly bill of less than SLRs62.00 ($0.40 /month), whereas the cost of supply to this category of households would be SLRs506.00 ($4.50/month); (ii) about 10.3% of household customers, owing to the increasing block tariff, pay on the average SLRs29.00 per kWh, which is higher than the calculated offered price of SLRs22.00 per kWh for the sale of surplus electricity to the grid from the rooftop solar PV system. Accordingly, about 10,000 customers have already shifted to using rooftop solar PV facility. Similarly, commercial customers paying around SLRs23.00/kWh would see rooftop solar PV to be marginally viable and may move to rooftop solar PV generation in large numbers, further eroding the strength of subsidy providers to facilitate subsidies to low users.

Subsidy providers and subsidy receivers. Assessment of subsidy providers and receivers is shown in Table 13. In 2016, (i) about 5 million households using below 120 kWh/month, (ii) all the 37,000 religious premises, and (iii) 55,000 small industries, received subsidies. These subsidy funds were generated within the sector as cross-subsidies, owing to tariffs above the cost of supply charged from (i) about 520,000 households customers using above 120 kWh/month, (ii) all the 680,000 commercial customers,[29] and (iii) 5,300 medium and large industrial customers. In 2016, 3,273 GWh (27% of all sales) was sold to subsidized customers, with the objective of earning the subsidy funds from overcharging customers who used the remaining 73% of sales. Even with the above cross-subsidies, funds would not have been adequate, requiring a subsidy SLRs1.27 per kWh sold in the entire country (implying a further subsidy of SLRs4.64 per kWh on 3,273 GWh sold at subsidized prices).

CEB annual reports do not generally indicate subsidies received from the government to bridge the revenue shortfall, the gap between the PUCSL-approved cost of supply and revenue expected with the PUCSL-approved tariffs. The revenue shortfall (or surpluses) is required to appear in the accounts of the bulk supplier (CEB transmission licensee), and should be financed through the PUCSL-approved mechanisms. However, such reporting does not occur, and the revenue shortfall is implied to be covered by either (i) using a portion of allowed revenue for CEB's generation (capacity), transmission, and distribution entities,[30] or (ii) through short-term borrowing.

[29] Commercial customers include general purpose, hotel, and government categories.

[30] As CEB generation, transmission, and distribution businesses are not revenue-separated, CEB bulk supply business has access to depreciation funds and return on investment funds allowed for such regulated businesses, and uses these funds to bridge a portion of the revenue gap.

Table 13: Subsidy Providers and Subsidy Receivers, 2016

Low-Voltage Retail	Number of Customers	Sales (GWh)	Subsidy Provided to Other Customers (SLRs million)	Subsidy Received (SLRs million)	Subsidy Provided to Other Customers (SLRs/ kWh sold)	Subsidy Received (SLRs/ kWh sold)
0–30	1,248,237	193	–	6,654	–	34.50
31–60	1,821,209	855	–	27,662	–	32.34
61–90	1,356,935	1,138	–	19,173	–	16.85
91–120	564,460	706	–	5,059	–	7.16
121–180	374,689	659	2,168	–	3.29	–
>180	147,882	814	13,895	–	17.06	–
Time-of-use (optional)	5	0	0	–	8.65	–
Subtotal, households	**5,513,417**	**4,366**	**–**	**42,485**	**–**	**9.73**
Religious	37,849	74	–	957	–	12.91
General purpose (1) <300	557,167	467	2,626	–	5.62	–
General purpose (1) >300	113,239	1,065	9,277	–	8.71	–
Industry (1) <300	38,982	49	–	61	–	1.25
Industry (1) >300	16,741	257	–	1,616	–	6.28
Hotel (1)	252	2	9	–	3.68	–
Government (1)	5,634	12	41	–	3.43	–
Street lighting	–	143	–	2,955	–	20.72
Subtotal, Other LV	**769,864**	**2,070**	**6,364**	**–**	**3.08**	**–**
LV Bulk						
General purpose (2)	5,290	1,003	11,550	–	11.52	–
Industry (2)	5,089	2,127	3,501	–	1.65	–
Hotel (2)	313	214	494	–	2.31	–
Government (2)	400	136	646	–	4.75	–
Subtotal, LV bulk	**11,092**	**3,480**	**16,190**	**–**	**4.65**	**–**
MV Bulk						
General purpose (3)	119	312	4,295	–	13.75	–
Industry (3)	231	1,679	148	–	0.09	–
Hotel (3)	11	107	259	–	2.41	–
Government (3)	5	3	19	–	7.63	–
Subtotal, MV bulk	**366**	**2,101**	**4,722**	**–**	**2.25**	**–**
Total	**6,294,739**	**12,016**	**27,276**	**48,074**	**–**	**1.27**

GWh = gigawatt-hour, kWh = kilowatt-hour, LV = low voltage, MV = medium voltage, SLRs = Sri Lankan rupees.
Source: Author's assessments, using the Sri Lanka Electricity Pricing Model 2016, representing the forecast for 2016.

Street Lighting

Status. Street lighting investments, maintenance, and energy costs are the responsibility of local authorities such as the municipal and town councils. The Road Development Authority, on the other hand, carries the responsibility of maintaining street lighting on specific roads. Estimates show that Sri Lanka has at least 400,000 street lights, as stated in a 2012 study assisted by ADB.[31] The total LV line length of distribution licensees is reported to be 146,531 circuit km (CEB: 142,807; LECO: 3,724, as of 2017).

In 2012, an ADB-assisted study observed that: (i) the majority of street lighting equipment are of poor quality and badly maintained resulting in very high energy wastage; (ii) use of incandescent lamps with very poor efficacy; (iii) a high portion of lamps are fitted in very poor quality luminaires with a very low coefficient of utilization; (iv) there is no consistency in types of lamps, luminaire, overhang arms, and height of luminaires; (v) poor quality and use of manual control and quite often indoor-quality control equipment exposed to rain, for controlling the street lighting result not only in creating life hazard situations, but also wasting energy by leaving the lights on during the daytime; (vi) very high uniformity ratio level; (vii) very low lamp life and very high lumen depreciation factor; (viii) absence of separate feeders for street lighting which make it difficult to control and meter; and (ix) majority of street lighting lamps are controlled individually either through daylight sensors or by manually controlled switches. Some of the identified problems resulting from the current street lighting control system were: (i) Photo sensors require cleaning and tuning from time to time to keeping them operating correctly. However, due to the lack of their maintenance and end of their life there are a high number of street lamps are kept on longer than necessary or left on or off continuously.(ii) Manually controlled lights operated by either local government staff or volunteers, are usually turned on early and turned off later than necessary.

Cost of street lighting. Sri Lanka allows public street lighting as free energy, subject to a quota for each distribution licensee. In 2016, a total of 143 GWh (about 1.2% of total sales) was granted as free energy, and its cost of supply of SLRs2,954 million would be distributed across all customers. The burden on the cost of supply is 1.3%, or SLRs0.25 per kWh sold. However, whether the costs incurred brings about the expected services is questionable, owing to the shortcoming stated, most of which remain unresolved. Most streets remain unlit or poorly lit at night, as the energy allocated for street lighting is used largely on inefficient lighting devices.

[31] ADB. 2012. *Demand-Side Management for Municipal Street Lighting (Final Report)*. Consultant's report. (TA 7267-SRI). https://www.adb.org/sites/default/files/project-document/75419/39419-013-sri-tacr.pdf.

Appliances

Only compact fluorescent lamps (CFLs) carry a legally enforced energy performance standard, and a performance label which enables customers to make informed decisions. All CFLs are required to be type-tested for compliance with Sri Lanka regulations, and selling CFL without an energy performance label constitutes an offense. While the scheme is said to be operating well, initiatives to introduce energy performance standards for ceiling fans, refrigerators, air conditioners, water pumps, etc., have not been successful. Energy performance labels are yet to be displayed on any appliance sold in Sri Lanka despite various assistance, including ADB's technical assistance to establish laboratories for performance testing of refrigerators.

A nonmandatory Sri Lanka Standard has been recently issued for light-emitting diode or LED lighting devices. Energy performance is also not mandatory in this standard. Thus, LED lighting devices are sold in large quantities with no applicable standard.

Energy Efficiency in Buildings

The energy efficiency building code was first introduced in 2002 as a standard, and it was revised and published as a code in 2008.[32] A second revision of this code has been completed and a mandatory requirement for new commercial buildings to comply with the code is expected soon. Various agencies have supported improvements to energy efficiency in buildings, the latest being two pilot projects planned to be implemented under the Sri Lanka Green Power Development and Energy Efficiency Improvement Investment Program: (i) to retrofit an existing commercial building to be an energy smart building, and (ii) thermal energy storage retrofit to support additional air conditioning requirements of an existing building.[33]

Energy Management and Energy Auditing

In 2011, Sri Lanka issued energy manager and energy auditor regulations under the Sri Lanka Sustainable Energy Authority Act. The regulation sets out the procedure to accredit energy managers and energy auditors to perform professional functions. Mandatory energy management planning and reporting was introduced for large customers since 2011.

Providing Electricity Access for All

Sri Lanka has set a national policy to provide affordable electricity coverage for 100% of the population. As of 2018, this goal has been achieved[34] as reported by

[32] Sri Lanka Sustainable Energy Authority. 2008. *Code of Practice for Energy Efficient Buildings in Sri Lanka*. https://policy.asiapacificenergy.org/sites/default/files/Building%20CODE.pdf.

[33] ADB. Sri Lanka: Green Power Development and Energy Efficiency Improvement Investment Program—Tranche 1. https://www.adb.org/projects/47037-004/main.

[34] Government of Sri Lanka, MOPE&BD. 2018. *Sri Lanka is the only country in South Asia that achieved 100% electrification*. http://powermin.gov.lk/english/?p=4566.

the Ministry of Power, Energy and Business Development (MOPE&BD), through the successful implementation of a combination of the following strategies: (i) adoption of consistent national energy policies with clear milestones for achieving the target; (ii) establishment of necessary government institutions; (iii) ensuring adequate project financing including investments from bilateral and multilateral development partners such as ADB, Swedish International Development Agency, and the Japan International Cooperation Agency (JICA), among others; (iv) grid extension including to areas that are not financially viable with the government covering the shortfall to make these connections financially viable; and (v) supporting low-income households through innovative schemes to enable them to avail of electricity service connections.[35]

3. Core Sector Issues, Causes and Effects

Core electricity sector issues in Sri Lanka include (i) incomplete sector reforms, weak regulation, and poor utility response to regulatory initiatives; (ii) issues in generation caused by delayed investments in generation, transmission, and distribution; (iii) imminent crisis in generation from 2018 onward; (iv) inadequate investments in transmission and distribution, more specifically for reliability improvement; (v) excessive costs of generation, and more recently, of distribution, resulting in higher overall costs of supply, and higher electricity prices; (vi) constraints to renewable energy development; and (vii) limited financial resources for investment in electricity sector.

Incomplete Sector Reforms

Without any competition in the industry since its formation in 1969, CEB operated as a vertically integrated electricity monopoly—regulated by the Ministry of Power and Energy through the Electricity Act of 1950. Among the major problems faced by the power sector over the period 1970–2000 were: (i) high transmission and distribution losses, (ii) inadequate generation capacity requiring load shedding, (iii) an unusually large share of generation from liquid petroleum products, (iv) financial dilemma faced by CEB owing to mismatch between the cost and price of electricity, and (v) managerial weaknesses and operational inefficiency of the CEB. Restructuring the power sector was therefore identified as a timely necessity to address some of the electricity industry's problems.

Power sector reforms aiming for a modern, efficient, well-managed, customer-oriented electricity industry may have started in 1983. A state-owned distribution company named Lanka Electricity Company (LECO) was established in 1983 to distribute power in the western coastal region, largely taking over distribution networks owned by city councils. In 1996, the private sector was allowed to participate in electricity generation as independent power producers (IPPs)

[35] M. Rajaguru. 2018. *A forward march towards an energy empowered nation: Case study in Sri Lanka*. Presentation at the Asia Clean Energy Forum 2018, Track 3: Energy Access—Session 11 on Meeting the Challenges and Barriers of Energy Access.

and small power producers (SPPs). Such reforms were conducted within the provisions of the Electricity Act of 1950. Electricity Reform Act No. 28 of 2002 was approved by Parliament in 2002 with the intention of unbundling CEB into separate corporate entities for generation, transmission and distribution, but the act was not implemented. The Public Utilities Commission Act No. 35 of 2002 was enacted in December 2002, establishing the sector regulator, the PUCSL. To exercise its assigned powers over the sector as the regulator, a new electricity act was approved by Parliament in 2009 amid political opposition and with significant amendments, as the Electricity Act No. 20 of 2009 (EA 2009).

The MOPE&BD has the mandate to formulate general policy guidelines to the PUCSL in respect of the electricity industry and these guidelines are required to be forwarded to the Cabinet of Ministers for approval. The General Policy Guidelines for the PUCSL issued in accordance with the EA 2009 includes (i) improving access to electricity by households in rural areas; (ii) fuel diversification and security; (iii) formulating an electricity tariff policy to supply electricity at reasonable prices ensuring financial viability of the sector; (iv) addition of adequate generation to fully meet the growing demand for base and peak loads; (v) effective and diligent planning of transmission and distribution systems giving special emphasis on reducing technical and nontechnical losses; (vi) financing electricity projects; (vii) energy conservation; (viii) multisector development to maximize socioeconomic benefits; (ix) ensuring safety in the electricity industry; (x) safeguard the interests of both present and prospective electricity consumers; and (xi) exemptions from licensing off-grid generation, standby generation, etc.

Power sector reforms achieved are mainly based on four elements:

- unbundling CEB, the government-owned monopoly, into separate business units (one for generation, one for transmission, and four business units for distribution);
- introduction of limited competition in generation;
- private sector participation in generation; and
- the development of a new regulatory framework.

The EA 2009 established the framework for operation and regulation of the power sector. Technical, economic, commercial, and safety regulations should be conducted by the regulator (PUCSL) for power sector operations.

Economic regulation: A single-buyer model was introduced in the EA 2009, converting CEB into separate entities with its transmission entity as the single buyer. Although CEB was expected to be vertically and horizontally unbundled to be operated as separate entities operating independently, the six licensees continue to operate under the CEB umbrella without any financial separation. The process of financial unbundling of CEB is still incomplete even after 9 years since the electricity act became operational.

Incomplete implementation of tariff methodology. Following EA 2009, a new tariff methodology was established in 2010, where (i) generation costs are defined by power purchase agreements (PPAs) and planned dispatch, and (ii) transmission tariff and distribution tariffs are determined through an approved methodology. The tariff to end-user basically has three components: (i) bulk supply tariff, (ii) distribution tariff, and (iii) retail supply tariff. The tariff methodology has been operational since January 2011. Since being operational, bulk supply tariffs have not been decided and declared by the PUCSL in a timely manner once every 6 months, and the end-user tariffs are not adjusted in a timely manner, as required in the tariff methodology and rules for tariff filing. The PUCSL was targeting to revise the customer tariffs to be cost-reflective to each customer category by 2015 (as required in the Energy Policy 2008 and general policy guidelines from the government to the PUCSL) with a systematic transition, while reducing the number of (typically poorly defined) customer categories and introducing broad-based time-of-use tariffs. However, the PUCSL was unable to achieve the target of being cost-reflective to each customer category, or to fully implement the tariff methodology.

Economic efficiency. The PUCSL was expected to issue a methodology for setting the efficiency improvement "X-factor"[36] for the second tariff from 2016–2020, but it has not been able to implement the methodology yet. Thus, transmission and distribution licensees operate in a low-risk operating environment, with no target for improvement of financial efficiency. The only risk the licensees face is to meet the loss targets issued by the regulator, but there too, the positive impacts of loss reduction achieved ahead of the PUCSL's target is not visible to licensees, owing to financial aggregation for all CEB licensees. Thus, owing to incomplete implementation of economic regulatory initiatives, electricity customers have not benefited through transparent costing, pricing, and financial management.

Technical regulation. The PUCSL is responsible for publishing relevant technical regulations required in the electricity industry. Accordingly, the Distribution Code of Sri Lanka[37] published in 2012 (i) establishes an equitable and coordinated approach to connect, supply, and maintain the supply of electricity to customers of distribution licensees; (ii) establishes an effective and coordinated approach for operation, maintenance, and development of the electricity distribution networks; and (iii) ensures equitable management of technical matters in the interest of all parties connected to the distribution system, including customers, the transmission licensee, and other users of the distribution system. Although

[36] The X-factor refers to the operational expenditure efficiency index in the revenue control formula applied to transmission and distribution licensees. The escalation of allowed revenue to match CPI, is decreased by the X-factor. Since 2011, X-factor has remained at zero, implying that transmission and distribution licensees are not required to discharge their functions in an increasingly financially "efficient" manner. In nominal terms, transmission and distribution expenses have significantly increased over 2011–2016.

[37] Ceylon Electricity Board. 2012. Distribution Code of Sri Lanka. https://www.ceb.lk/front_img/img_reports/1532500020Distribution_Code.pdf.

the Distribution Code was approved and operational, the elements or the directives to operate it are not properly documented. Therefore, technical quality of service to customers effectively remains unreported and unregulated, 9 years after EA 2009.

The Grid Code has not been finalized and approved by the PUCSL. The current draft Grid Code[38] calls for (i) establishing an effective, transparent, nondiscriminatory, and coordinated approach for operation, maintenance, and development of the transmission system; and (ii) to ensure equitable management of technical matters in the interest of all parties connected to the grid including distribution licensees, customers, generators, and any other users. The Grid Code, when completed, needs to be read in conjunction with the Distribution Code for a complete and appropriate understanding of the requirements, where applicable, especially with respect to the interconnected or overlapping matters. The absence of a grid code is creating issued with the grid and this needs to be urgently addressed.

Publication of performance regulations, demand-side management (DSM) regulations, and the Supply Services Code have been delayed for several years at the MOPE&BD,[39] and was finally issued in 2016. Distribution of performance regulations establish (i) the procedural rules, requirements, and indices for assessment of operational performance of the distribution system of the licensees; (ii) the commercial performance of the retail business of the licensees, and (iii) the methodologies for determining the appropriate values for the said indices and assessing the compensation of customers should performance indices fall below the target levels.

DSM regulations applicable to all distribution licensees were prepared with the objective of encouraging customers to amend their electricity consumption pattern, lowering the consumer's overall cost of electricity by economical and efficient use of resources, reducing greenhouse gas emissions, and complementing the supply-side strategies to help the licensees avoid or postpone costly capacity additions. According to DSM regulations and the tariff methodology in operation, distribution licensees are neither rewarded nor penalized for successful implementation of DSM, and therefore are not expected to absorb any market risks. These factors should be included in the tariff methodology where distribution licensees would increasingly be required to assume market risks, and be rewarded for implementation of DSM.

The Supply Services Code was approved in March 2015.[40] The code deals with the customers' relationship with distribution and supply licensees.

[38] Ceylon Electricity Board. 2018. *Grid Code, Transmission Division*. 4 January. https://ceb.lk/front_img/img_reports/1532500179Grid_Code_of_Transmission_Division.pdf.

[39] Regulations under the electricity act are required to be issued by the MOPE&BD.

[40] Ceylon Electricity Board. 2014. *Supply Services Code*. March. https://www.ceb.lk/front_img/img_reports/1532508776Supply_Services_Code_DD4.pdf.

Revised safety regulation. Under the EA 2009, the PUCSL should issue Electricity Safety, Quality, and Continuity Regulations.[41] The regulation issued in July 2016 includes provisions for PUCSL to (i) take all reasonable steps to protect the public from dangers arising from the generation, transmission, distribution, supply, and use of electricity from any electric line or electrical plant; (ii) take all reasonable steps to eliminate or reduce the risks of personal injury or damage to property or interference with its use resulting from the transmission, distribution, and supply of electricity; and (iii) comply with all supply and safety standards, including without limitation, those contained in the Distribution Code, the Grid Code, and associated Technical and Safety Standards, as applicable to each of the relevant persons.

Commercial regulation. Five licenses held by CEB are unable to act independently in their financial, investment, and operational decisions. The income from sales by the distribution licensees to customers and by transmission licensee to LECO continue to be credited to the CEB corporate account. The bulk supply transactions account which manages (i) all income from distribution licensees, (ii) payments to generation licensees and transmission licensee, (iii) receive any gross subsidies provided by the government, is not established yet by the CEB transmission licensee. Therefore, notionally unbundled generation, transmission, and distribution businesses of CEB remain financially integrated, causing the due profits allowed in the tariff methodology to each CEB licensee to be spent on subsidies promised by the government but not paid. The PUCSL has not made any significant effort to secure the unpaid subsidies from the government or to adjust tariffs to enable such cost recoveries. Accordingly, CEB continues to report losses continuously since 2000, except in 2013 and in 2015, where the profits may be attributed to above average hydropower generation, which would have compensated for the nonpayment of government subsidies.

Issues Owing to Non-Implementation of the Generation Plan

As required in the EA 2009, the transmission licensee should conduct planning studies on long-term generation expansion every 2 years as stated in the license, with the objective of serving the demand at a specified level of reliability at the lowest possible cost. The procedures that should be adopted are stated in the Least-Cost Generation Expansion Planning Code issued by the PUCSL in 2011.[42] The planning period is 20 years and the plan should be updated at least once in 2 years. When the transmission licensee submits a least-cost generation expansion plan, it is reviewed and approved by the PUCSL. Planning criteria in the code are (i) peaking availability of hydroelectric plants and thermal plants to be in accordance with the data furnished by the generation licensees and PPAs and (ii) to abide by the power supply security standards (loss of load probability: 0.8%,

[41] Government of Sri Lanka. 2016. The Gazette of the Democratic Socialist Republic of Sri Lanka. 13 July.

[42] The planning code is an integral section of the grid code. The planning code was approved in 2011, ahead of approving the entire grid code, for the investment planning process to be further streamlined.

reserve margin: 15%). The reference case or the base case is the least-cost plan, and a complete analysis of the plan in terms of year-by-year investment requirements, fuel requirements and costs, and capacity and energy balance is provided. Policy analyses, such as changes in the generation mix and scenario analyses such as differential changes in fuel prices, are also be carried out. The Long-Term Generation Expansion Plan (LTEGP) 2015–2034 prepared by the CEB transmission licensee and submitted to the PUCSL in August 2015, was not approved by the PUCSL. Subsequently, LTEGP 2018–2037 was submitted by CEB transmission licensee in April 2017, and after the public comments, the PUCSL approved a revised base case plan. However, CEB transmission licensee refused to accept it as the base case plan. The transmission licensee recommends the adoption of the least-cost generating plant sequence derived for the base case, and emphasizes the need to implement the plan to avoid energy shortfalls. According to the base case plan, additions to the grid are shown in Table 14.

Table 14: Base Case Generation Expansion Plan, 2018–2037

Year	Renewable Additions	Thermal Additions	Thermal Retirements	LOLP (%)
2018	Minihydro 15 MW Biomass 5 MW Solar 160 MW	100 MW furnace oil-fired power plant[a] 70 MW furnace oil-fired power plant[a] 150 MW furnace oil-fired power plant[a]	8x6.13 MW Asia Power	1.245
2019	Major hydro 122 MW (Uma Oya HPP) Minihydro 15 MW Solar 95 MW Wind 50 MW Biomass 5 MW	2x35 MW gas turbine 1x300 MW natural gas-fired combined cycle power plant – Western Region[c]	–	0.220
2020	Major hydro 35 MW (Broadlands HPP) 15 MW (Thalpitigala HPP) Wind 100 MW (Mannar Wind Park) Minihydro 15 MW Wind 120 MW Solar 105 MW Biomass 5 MW	1x35 MW gas turbine	6x5 MW Northern Power	0.237
2021	Minihydro 10 MW Wind 75 MW Solar 55 MW Biomass 5 MW	1x300 MW natural gas-fired combined cycle power plant – Western Region	4x17 MW Kelanitissa gas turbines	0.107

continued on next page

Table 14 continued

Year	Renewable Additions	Thermal Additions	Thermal Retirements	LOLP (%)
2022	Major hydro 30 MW (Moragolla HPP) 20 MW (Seethawaka HPP) 20 MW (Gin Ganga HPP) Minihydro 10 MW Wind 50 MW Solar 6 MW Biomass 5 MW			0.237
2023	Minihydro 10 MW Solar 55 MW Wind 60 MW Biomass 5 MW	1x300 MW new coal power plant (change to super critical will be evaluated) 163 MW combined cycle power plant (KPS–2)[d]	115 MW gas turbine[b] 4x9 MW Sapugaskanda Diesel Ext.[b] 163 MW Sojitz Kelanitissa combined cycle plant[d]	0.205
2024	Minihydro 10 MW Solar 55 MW Wind 45 MW Biomass 5 MW	1x300 MW new coal power plant (change to super critical will be evaluated)	4x18 MW Sapugaskanda Diesel	0.145
2025	Major hydro 200 MW (pumped storage power plant) Solar 104 MW Wind 85 MW Biomass 5 MW	1x300 MW new coal power plant (change to super critical will be evaluated)	4x9 MW Sapugaskanda Diesel Ext. Minihydro 10 MW 4x15 MW CEB barge power plant	0.026
2026	Major hydro 200 MW (pumped storage power plant) Minihydro 10 MW Biomass 5 MW Solar 55 MW	–	–	0.019
2027	Major hydro 200 MW (pumped storage power plant) Minihydro 10 MW Solar 54 MW Wind 25 MW Biomass 5 MW	–	–	0.012
2028	Minihydro 10 MW Solar 105 MW Wind 45 MW Biomass 5 MW	1x600 MW new supercritical coal power plant	–	0.002
2029	Minihydro 10 MW Solar 54 MW Wind 25 MW Biomass 5MW	–	–	0.008

continued on next page

Table 14 continued

Year	Renewable Additions	Thermal Additions	Thermal Retirements	LOLP (%)
2030	Minihydro 10 MW Solar 55 MW Wind 70 MW Biomass 5 MW	–	–	0.027
2031	Minihydro 10 MW Solar 54 MW Wind 35 MW Biomass 5 MW	1x600 MW new supercritical coal power plant	–	0.005
2032	Minihydro 10 MW Solar 55 MW Wind 45 MW	–	–	0.019
2033	Minihydro 10 MW Solar 54 MW Wind 70 MW Biomass 5 MW	2x300 MW natural gas-fired combined cycle power plants–Western Region	165 MW combined cycle plant (KPS) 163 MW combined cycle plant (KPS-2)	0.023
2034	Minihydro 10 MW Solar 55 MW Wind 70 MW	–	–	0.108
2035	Minihydro 10 MW Solar 54 MW Wind 70 MW Biomass 5 MW	1x600 MW new supercritical coal power plant	300 MW West Coast combined cycle power plant	0.058
2036	Minihydro 10 MW Solar 55 MW Wind 95 MW	1x300 MW natural gas-fired combined cycle power plant–Western Region	–	0.057
2037	Minihydro 10 MW Solar 104 MW Wind 70 MW Biomass 5 MW	–	–	0.230

HPP = hydropower plant, LOLP = loss of load probability, MW = megawatt, PSPP = pumped storage power plant.

[a] To meet the demand from 2018, until major power plants are implemented, 70 MW, 100 MW, and 150 MW power plants are proposed with operation by furnace oil.

[b] Retirement will be based on the plant conditions.

[c] Grid integration of 1x300 MW natural gas-fired combined cycle power plant would be possible once the Kerawalapitiya-Port 220 kV cable is available in June 2018. Gas turbine operation is expected to commence in 2019 and the combined cycle operation is expected in 2020.

[d] Sojitz Kelanitissa is scheduled to be retired in 2023, and will be operated as a Ceylon Electricity Board natural gas-fired power plant from 2023 to 2033 with the conversion. West Coast and Kelanitissa combined cycle plant are converted to natural gas in 2020 with the development of liquified natural gas-based infrastructure.

Source: Long-Term Generation Expansion Plan 2018–2037, Ceylon Electricity Board.

Coal and liquefied natural gas (LNG) will be the major sources of power in the future according to the long-term generation expansion plan (LTGEP) base case, and the contribution from renewable energy-based power plants will also be increased to more than 25% by 2025. To meet the increasing demand and owing to delays in the implementation of Uma Oya and Broadlands hydropower plants, 300 MW furnace oil-fired power plants and 2x35 MW gas turbines are required to be added to the system in 2018 and in 2019. The 3×200 MW pumped storage power plant is also to be connected to the system by 2027 which will reduce the off-peak operational issues of coal power plants. The total investment required for the implementation of the base case plan 2018–2037 in next 20 years is about $14.5 billion.

The PUCSL has approved the LTGEP for the period 2018 to 2037 on 12 June 2018. The status of the generation projects until 2022 in the LTGEP is summarized in Table 15.

Crisis in Generation From 2018 Onward

In 2018, the daily peak demand persistently exceeded 2,500 MW, and this is expected to grow by at least 4% each year with a corresponding or higher growth in energy requirements due to improving load factor. To accommodate this increasing demand, timely implementation of generation projects, at least as planned in the LTGEP is essential. Otherwise, load shedding or procuring expensive oil-fired generation not included in the LTGEP under emergency conditions, will be inevitable.

The last major generation capacity added to the system was the 300 MW unit 3 of the Puttalam coal-fired power plant, commissioned in 2014. While the generation requirements currently grow at rates around 4% annually, no major power plant has entered construction, since the construction of the Lakvijaya Power Plant commenced in 2007 and was completed in 2014. As such, with no power plants of significant capacity entering the construction phase for 11 years from 2007 to 2018, serious generation capacity deficits would occur soon, starting most likely in 2018. Figure 22 indicates the scale of the shortages expected.

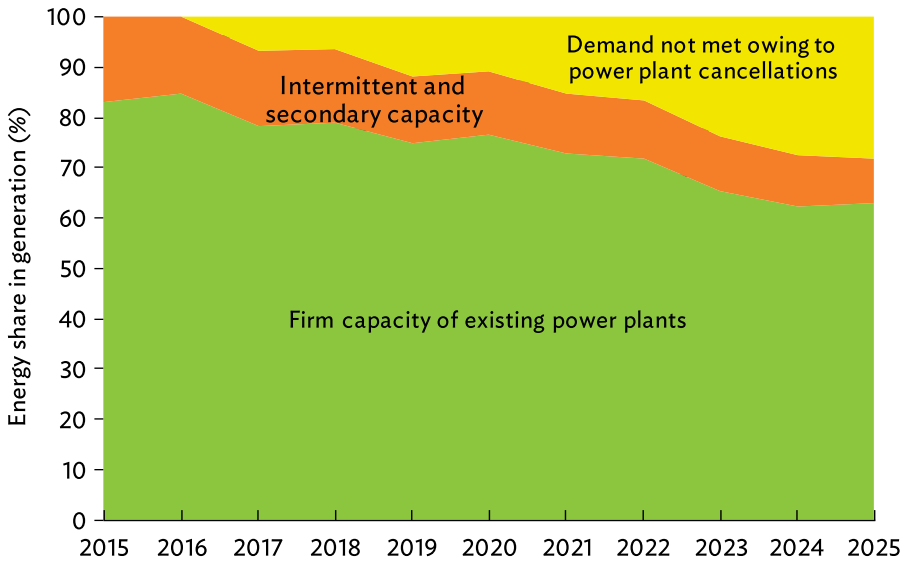
At the same time, it is important that the PUCSL, as the regulator of the electricity industry, develops system reliability standards and system security standards. There are no international standards for these, but these should be developed for the transmission licensee to use in planning and in the operation of the national grid. Similar reliability issues are surfacing when increasing capacities of wind and solar power are added to the generating system, for which norms are required to enable fixing of spinning reserve to overcome intermittency and reserve capacity to overcome seasonality. Advanced wind and solar capacity forecasting techniques require to be implemented as more wind and solar capacity is added, to enable optimization of resource utilization and spinning capacity.

Table 15: Status of New Generation Projects

Generation Projects Required to be Commissioned by January 2022	Scheduled Commissioning Year in LTGEP 2018–2037	Status as of September 2018	Likely Schedule for Commissioning
100 MW furnace oil-fired power plant	2018	No action reported to procure. However, the 100 MW power plant reaching end of term has been extended.	unknown
70 MW furnace oil-fired power plant	2018	No action reported to procure.	unknown
150 MW furnace oil-fired power plant	2018	No action reported to procure.	unknown
122 MW Uma Oya Hydropower Plant	2019	Construction delays owing to water seepage into the tunnels	2020
2×35 MW gas turbines	2019	No action to procure, as yet	2020
300 MW natural gas-fired combined cycle power plant – Western Region	2019	Dispute in procurement process. Construction not commenced, as yet	2022
35 MW Broadlands Hydropower Plant	2020	About 70% of the civil works are completed.	2020
100 MW Mannar Wind Park	2020	Bidding process completed. Contract to be awarded	2020
15 MW Thalpitigala Hydropower Plant	2020	Procurement not commenced as yet	2022
1×35 MW gas turbines	2020	Procurement not commenced as yet	2022
300 MW natural gas-fired combined cycle power plant – Western Region	2021	Procurement not commenced as yet	2022
30 MW Moragolla Hydropower Plant	2022	Bidding process for main civil works completed. Contract to be awarded.	2022
20 MW Seethawaka Hydropower Plant	2022	Procurement not commenced as yet	2024
20 MW Gin Ganga Hydropower Plant	2022	Procurement not commenced as yet	2024

LTGEP = long-term generation expansion plan, MW= megawatt.
Source: Study team assessments.

Figure 22: Estimated Generation Capacity Deficits, 2017–2025



CEB = Ceylon Electricity Board, IPP = independent power producer, PUCSL = Public Utilities Commission of Sri Lanka.

Notes: (i) Firm capacity includes hydrogenation under hydrological condition 5 (very dry), all existing non-dispatchable renewable energy-based power plants, and the capacity of thermal power plants. (ii) The figure reflects a 10-year compound average sales growth of about 5.8%. Recent (2017) sales growth has been 5.2%, indicating that the shortages are most likely to occur. At least two oil-fired IPPs retiring in 2016–2017 have been offered contract extensions.

Source: Adapted from CEB Long-Term Generation Expansion Plan 2015–2034, addendum, pages A11–11 to A11–17, approved by the PUCSL in September 2016.

Issues in Transmission, Distribution, and Network Management

Transmission. Throughout 2015–2016, Sri Lanka suffered three major blackouts within 7 months, 7 years after a major blackout in October 2009. The three most recent blackouts occurred on 27 September 2015, on 25 February 2016, and on 13 March 2016. The report on the study for the first blackout was published 7 months after, when the third blackout occurred. According to the report, the blackout was triggered by the faulty operation of an overfluxing relay in Generator 3 of the Lakvijaya Coal Power Plant. The causes of the second and third blackouts are still unknown and study reports are not available to the public. Inadequate attention, the lack of deeper analyses of system instabilities, and network error, as well as in the management of the utility are perceived to be the major reasons for the recurring blackouts.

CEB, the transmission licensee, is required to establish deeper and more responsible analysis and reporting in cases of complete, partial, or near blackouts, to launch the initiating event, the sequence of events, the operating protection systems that malfunctioned, and to turn each major event in the transmission system into a learning exercise. The variations of operating parameters (voltage,

current, and frequency) are recorded at many locations of the transmission network, and the modeling of the event using transmission network modeling software should be able to reproduce the sequence of events and parameter variations. Such rigorous analysis and publication of results—lacking in the CEB corporate structure—is not mandatory in the grid code. Thus, the analysis of each major blackout is limited to a narration of events. In most situations, even a narrative of events is not published.

Distribution. Issues in electricity distribution are mainly the lack of a concerted effort to improve both technical and commercial quality, to the levels required of modern utilities. Voltage reduction during nighttime when demand is high, at the far end of the distribution networks are very common, despite considerable investments made to improve the technical quality of the distribution network. Moreover, improving customer services while adhering to the PUCSL-issued supply services code should also be considered by the distribution licensees. Special attention should be given to improve safety in electricity distribution. Most electrical installations do not comply with the Institution of Engineering and Technology[43] wiring regulations which have been adopted as the legally applicable regulations in Sri Lanka. The number of deaths due to electrocution had been increasing over the past few years, reaching 180 in 2012. The PUCSL has established a target to reduce incidences of electrocution to at most 20 by 2020. Accordingly, the PUCSL has started planning a process for certification of electricians and periodic testing of electrical installations. The establishment of the certification process is progressing very slowly, and the process is still incomplete.

Constraints to Renewable Energy Development

In 2012, the issuance of standardized power purchase agreements (SPPAs) for wind and solar development was discontinued as the policy of continuing with feed-in tariffs for wind and solar power development was subject to debate. However, all feed-in tariff-based SPPAs signed since 1996 continue to be honored based on tariffs stated in such agreements. From 2012, no provisional approvals (the first step in the approval process for a renewable energy-based power plant) have been issued for wind[44] and solar development. Presently, key institutions, the SLSEA, the PUCSL, and the CEB have been unable to agree and publish a clear policy for the transition from feed-in tariffs to competitive tariffs. Three bidding rounds, one for a 20 MW of wind power generation (concluded in mid-2016), one for a 60 MW of solar PV (concluded in April 2017), and another for a 20 MW of solar PV, have all been announced. The Renewable Energy Master Plan recommended competitive bidding for wind and solar power generation development within a framework of wind and solar parks, where infrastructure would be developed and managed either by the government or by government-owned utilities.

[43] Institution of Engineering and Technology. 2008. *Requirements for Electrical Installations, IEE Wiring Regulations Seventeenth Edition*. United Kingdom: Polestar Wheatons.

[44] Except one provisional approval to CEB to develop a 100 MW wind power plant in Mannar. A project preparatory technical assistance commenced in 2016, for investment financing by ADB.

Sri Lanka's power grid has a peak demand of about 2,500 MW despite the grid being isolated. To absorb renewable energy-based intermittent or seasonal sources, the grid requires a higher reserve margin and spinning reserve than countries with larger, interconnected national grids. Sri Lanka's grid has a capacity of 4,180 MW, of which 2,047 MW (49%) comes from seasonal or intermittent resource-based generation. Sri Lanka's 1,391 MW of hydropower has storage, but most of it is associated with either irrigation or drinking water supplies, and hence are subject to operational constraints, in addition to constraints imposed by seasonality and cascading.[45] Sri Lanka is in a unique situation when absorbing seasonal or intermittent sources for power generation. The actual contribution of 1,391 MW of hydropower capacity may be as low as 200 MW during times of lower rainfall and lower reservoir storage. Similarly, the contribution from 354 MW of mini hydropower plants—all of which have no storage—could be as low as 20 MW during periods of low rainfall. Accordingly, the reserve margin of the generating system requires around 1,400 MW[46] purely to account for seasonality and interannual variations of hydropower generation. Therefore, investment planning and operations planning require special attention and skills. Wind power and solar PV also have constraints of seasonality and intermittency, which add to the reserve margin requirements and spinning reserve requirements.

Sri Lanka's power generation system inherently has lower stored energy owing to a larger share of generation from reciprocating engines and renewable sources including hydropower. Such generators have less than half the stored kinetic energy of a fast steam-driven generator such as a coal power plant or a gas-driven combined cycle power plant. As Sri Lanka's combined cycle power plants are operated on diesel, fuel which is expensive, system operators optimize costs by heavier use of fuel-oil burning reciprocating engines. Accordingly, the resilience of the power system decreases along with its ability to withstand rapid variations of outputs in wind and solar power plants. Analyses conducted under the Sri Lanka renewable energy master plan show that stored energy would be significantly lower during daytime, as solar PV capacity increases.

Accordingly, unless reliability issues are identified, recognized by policy makers, and solutions are implemented, the present indications are that the reliability of the grid would be lowered along with further development of seasonal and intermittent renewable sources of energy for power generation. Sri Lanka has no security standards or guidelines, when dispatch decisions are made, except for the typical n-1 criteria[47] wherever possible. For example, the loss of the largest generator would mandatorily and automatically disconnect a portion of customers, to help maintain the stability of the grid. In countries with comparable

[45] About 1,000 MW of 1,377 MW of hydropower are in two cascades.

[46] Approximately. Long-term generation planning uses reservoir optimization and least-cost planning, using several models including Wien Automatic System Planning model. Security constrained planning model NCP is used for optimization of system operations.

[47] Loss of a single element (a generator, line, transformer, etc.) of an electricity supply system that has many elements ("n")

grids, weak and unreliable systems are not accepted, and aspire to achieve higher levels of reliability. More work, analysis, and a policy dialogue are required to enable stakeholders to appreciate the constraints and implement solutions.

Large Investment Requirements for Sector Development

As Sri Lanka develops into a middle-income country, significant investments are required for the development of the electricity sector, with higher growth rates in demand and sales, and the expectations of higher technical and commercial quality of supply. Limited financial resources in Sri Lanka is one of the major reasons for the delayed implementation of larger projects. Delays affect the electricity industry, causing poor reliability, and poor technical and commercial quality of supply. Table 16 summarizes the investment requirement of the electricity sector from 2017 to 2025.

Table 16: Power Sector Investment Requirements, 2017–2025

Component	Gross Asset Value as of January 2016 ($ million)	Investment Requirement ($ million)								
		2017	2018	2019	2020	2021	2022	2023	2024	2025
Generation	–	301.10	369.71	505.19	582.93	436.58	394.10	368.71	314.35	290.14
Transmission	804.32	117.90	32.08	76.75	118.35	101.31	32.87	61.78	8.77	N/A
CEB Region 1	911.37	24.87	7.90	5.20	1.85	0.54	1.74	0.79	N/A	N/A
CEB Region 2	755.42	18.10	6.48	2.38	7.94	1.03	2.75	4.92	0.20	N/A
CEB Region 3	504.82	10.85	6.19	7.78	5.74	4.10	N/A	0.72	N/A	N/A
CEB Region 4	422.39	4.89	0.19	1.33	0.61	N/A	N/A	N/A	N/A	N/A
LECO	73.61	0.73	3.09	9.59	N/A	N/A	N/A	N/A	N/A	N/A
Total		**478.45**	**425.65**	**608.23**	**717.42**	**543.55**	**431.46**	**436.91**	**323.32**	**290.14**

CEB = Ceylon Electricity Board, LECO = Lanka Electricity Company, MV = medium voltage, N/A = not applicable.

Note: Generation investments include upfront expenditure on generation assets to be commissioned beyond 2025. However, transmission and distribution investments do not include investments required for such assets to be commissioned after 2025.

Sources: Long-Term Generation Expansion Plan (2015–2034), Long Term Transmission Development Plan 2015–2024, MV Plans of the distribution licensees.

Higher Prices to Customer and Excessive Electricity Production Costs

Sri Lanka's electricity prices are generally considered to be "high." This study conducted an assessment of electricity prices in other countries or states in South Asia and Southeast Asia. As customer tariff structures and customer definitions vary across countries, certain countries have block tariffs, while others have uniform tariffs. Multipart tariffs (energy, demand, and power factor penalty) are implemented by some countries, for certain customer categories. Time-of-use tariffs operate in most countries for large customers and are now also being introduced to smaller low-voltage customers. As such, comparing electricity prices in terms of "country-average" or "utility-average" price to customer, would not be meaningful for a cross-country comparison. Therefore, to ensure that customer definitions and tariff structures do not affect the comparison, several "types" of customers were defined, in terms of their measured monthly energy use and (additionally for larger customers) the measured monthly maximum demand. Results are shown in Table 17.

Sri Lanka's electricity prices are high compared with other countries, but are not the highest. Figure 23 shows a comparison of prices paid by medium households, medium-scale industries, and medium-scale commercial customers.

Table 17: Electricity Price Comparison in the Region

Customer	Class	Electricity Usage (kWh/ month)	Maximum Demand (kW)	Average Price in SLRs per kWh (at unity power factor)																	
				Bangladesh	Bhutan	Peoples Rep. of China	Hong Kong, China	Assam, India	Kerala, India	Madhya Pradesh, India	Maharashtra, India	Tamil Nadu, India	Malaysia	Nepal	Pakistan	Philippines	Singapore	Republic of Korea	Sri Lanka	Thailand	Viet Nam
Household	Small	30	–	7.08	0.00	11.22	12.51	12.43	6.33	6.67	9.27	0.00	7.78	6.46	3.63	12.09	24.93	9.67	3.50	13.53	9.94
	Medium	90	–	7.97	0.00	11.22	12.51	13.90	9.00	11.48	9.91	0.00	7.78	11.92	8.40	18.18	24.93	8.48	9.57	15.40	10.09
	Large	180	–	9.13	4.46	11.22	8.33	18.32	10.96	10.84	13.71	2.26	7.78	13.82	9.89	22.37	24.93	12.32	22.24	16.48	10.93
	Very Large	600	–	12.12	6.68	13.82	6.69	18.32	20.04	10.46	22.42	13.94	13.78	17.04	11.35	25.63	24.93	41.42	38.27	18.72	14.76
Commercial	Small	1000	4	18.77	9.32	17.40	21.06	20.65	16.37	14.01	27.10	19.91	17.63	18.63	17.85	22.35	24.93	13.73	21.73	19.33	16.02
	Medium	58,000	232	14.66	7.58	17.40	23.90	20.73	15.30	16.49	37.47	22.47	17.34	18.42	15.82	20.62	24.93	15.40	25.19	18.62	15.59
	Large	600,000	2,400	14.46	7.58	17.51	23.90	20.73	14.95	21.13	34.20	22.47	17.34	18.42	13.23	20.56	22.77	16.16	23.65	18.02	14.44
Industrial	Small	5,000	20	14.81	9.32	15.45	23.90	14.12	15.89	15.73	11.94	15.51	15.64	14.96	13.50	20.35	18.75	11.93	12.24	20.00	10.73
	Medium	65,000	260	14.66	7.58	15.84	24.13	17.53	17.33	17.82	20.29	18.52	16.24	14.01	12.98	19.66	22.77	13.48	15.82	18.62	10.28
	Large	270,000	1,080	14.46	7.58	16.14	24.13	19.41	17.33	19.32	20.29	18.52	13.90	14.33	16.52	20.11	22.59	13.23	15.20	18.02	9.95
	Very Large	1,050,000	4,200	14.46	6.30	15.79	24.13	19.41	17.33	19.32	20.29	18.52	13.07	13.81	12.39	18.26	21.45	16.06	15.19	17.47	9.71

Lowest for the customer category

Highest for the customer category

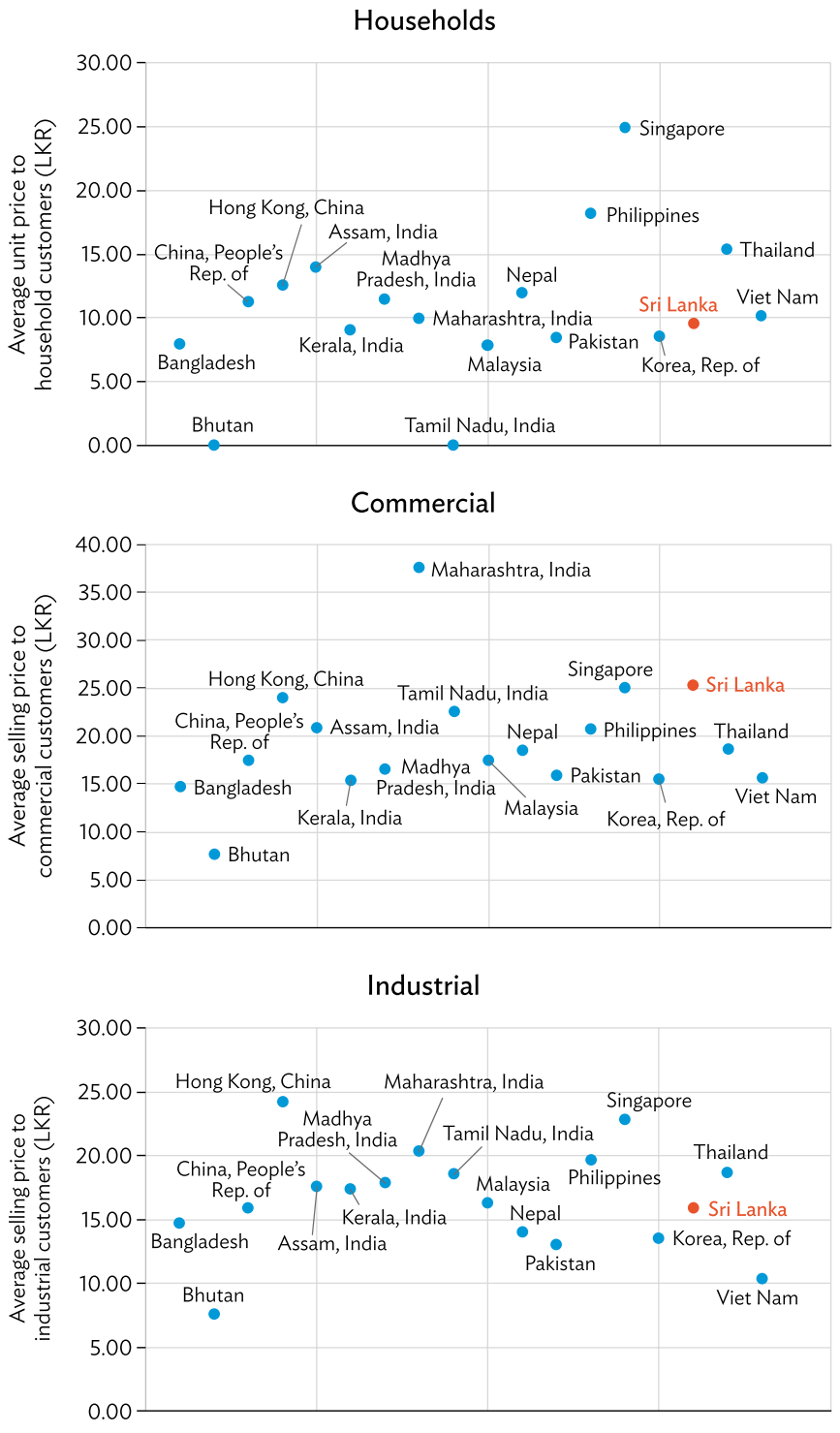
kW = kilowatt, kWh = kilowatt-hour, SLRs = Sri Lankan rupees.

Notes: Electricity use and maximum demand have been defined for typical customers. Thus, the average prices calculated reflect the price of each typical customer located in different areas. Analysis is based on published tariffs. Whether the tariffs are cost-reflective or not, and whether the utilities are profitable or loss making, has not been considered.

1. Sales taxes such as *"Value-Added Tax"* are **not included**. Fuel surcharges, if any, **are included**. For Assam, Kerala, and Maharashtra, *"Electricity Duty"* is **included**. Subsidized rates are included for Tamil Nadu.
2. These are based on published tariffs. Special concessions given to identified customers or within special economic zones are not included.
3. Optional tariffs (such as time-of-use or TOU) are not included. When TOU tariffs are mandatory, a flat load profile has been assumed.
4. Unity power factor is assumed, where relevant.
5. India and Pakistan have different tariff systems for different regions. Out of those regional systems, five from India and one from Pakistan are considered here.
6. For small and medium households of Bhutan, the rural rate was considered.

Source: Study team assessments based on published tariffs as of 14 August 2017.

Figure 23: Comparison of Electricity Prices for Medium-Scale Customers

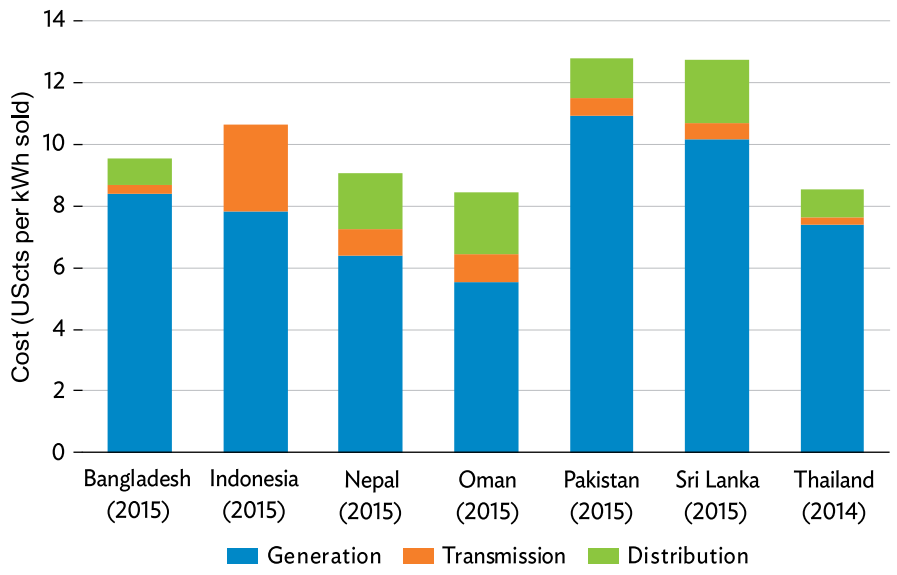


LKR = Sri Lankan rupee.
Sources: Calculated by the author, based on published tariffs of each area or utility, as of 17 August 2017.

Sri Lanka electricity prices are higher than in most countries, for commercial customers. For medium-scale households defined to use 90 kWh/month, Sri Lanka's prices are in the midrange.[48] For medium-scale commercial customers (customers who are neither households nor industries), Sri Lanka's electricity price is high. For medium-scale industrial customers, Sri Lanka's prices are in the midrange. Additionally, Sri Lanka's electricity prices have not been cost-reflective to each customer category and for the entire sector. Electricity prices in 2016 should have been 7% higher if the approved revenue by the PUCSL was allowed to be passed on to customers.

Sri Lanka's electricity production and delivery costs continuously and significantly increased since 2000, as the power requirements were increasingly met with oil-fired generation. The share of oil-fired generation in the generation energy mix was above 50% from 2000 to 2009, declined marginally to 47% in 2010, rose again to 59% in 2012, and has since declined to 18% by 2015. Transparent calculation of costs of supply was conducted by the PUCSL since 2011 based on tariff submissions by the licensees. Approved costs of supply are shown in Table 9. Figure 24 shows a cross-country comparison indicating that Sri Lanka's generation costs and distribution costs are significantly higher than in other countries.

Figure 24: Country Comparison of Electricity Supply Cost



kWh = kilowatt-hour, UScts = US cents.

Notes:

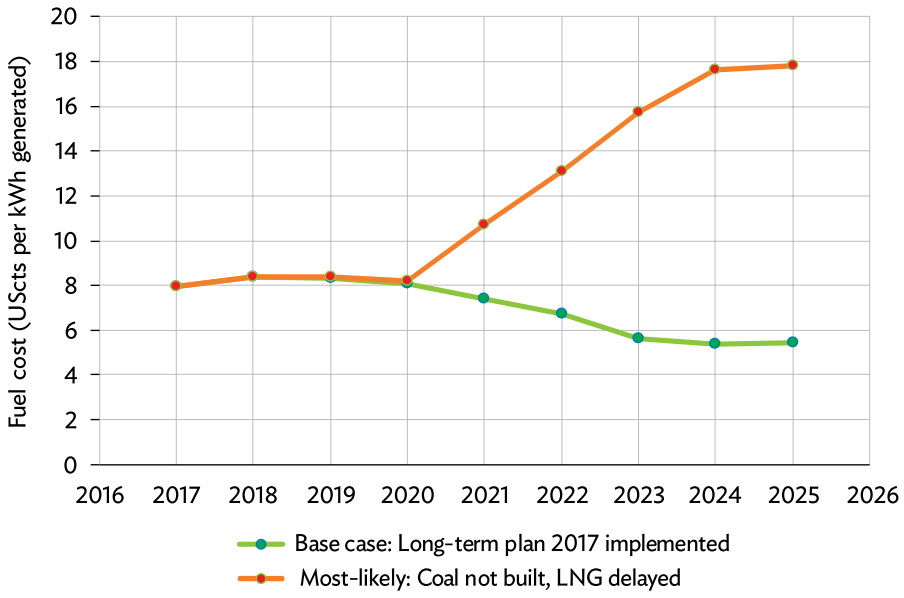
1. Levies such as short-term debt repayments are not included.
2. Indonesia's transmission costs include distribution costs

Source: Author's assessments based on published information in annual reports and regulatory tariff determinations.

[48] Sri Lanka's average electricity consumption in a household is about 71 kWh/month.

Electricity production costs have already commenced their upward trend, as more oil-fired power plants are again dispatched to meet the growing demand and to serve as the seasonal backup. To bridge the gap in capacity caused by a government decision in 2015 to suspend Sri Lanka's second coal-fired power generation project (and by default, the cancellation of the third coal-fired power generation project), the government prevailed over CEB to (i) procure one 300 MW combined cycle power plant operating on diesel fuel to be operational by 2019, with potential conversion to regasified LNG whenever available; (ii) procure 60 MW of diesel generators on short-term rental contracts; and (iii) extend the contracts for two oil-fired power plants which had already reached the end of their 10-year terms. Accordingly, the forecast costs of supply in constant 2016 terms are shown in Figure 25.

Figure 25: Forecast Costs of Supply, 2017–2025



bbl = barrel of oil, Btu = British thermal unit, kWh = kilowatt-hour, LNG = liquefied natural gas, SLRs = Sri Lankan rupees, UScts = US cents.

Notes:

1. Base case: Trincomalee coal-fired power plant replaced with diesel generation, but other planned coal-fired power plants and LNG delivery infrastructure are built on schedule, renewable energy targets met.
2. Most likely scenario: Diesel generation replacing planned coal-fired generation 2017–2025, and LNG delivery infrastructure delayed until 2025, renewable energy targets met.
3. Fuel prices for above assessment: (price in $/bbl) diesel (74), furnace oil (60), naphtha (56), low sulfur oil (62); coal: $75/ton, LNG including terminal charges: $10.3/million Btu, SLRs150/$. Note that Sri Lanka's market fuel prices are presently higher than the prices assumed for the above analysis.

Source: Author's estimates.

C. Petroleum Sector

1. Overview of the Petroleum Industry

Petroleum is one of the two major primary energy sources in Sri Lanka accounting for 46% of primary energy supply. Sri Lanka has long been, and continues to be, an import-dependent consumer of petroleum products. The petroleum distribution market in the country was dominated by an oligopoly of multinational enterprises until the establishment of Ceylon Petroleum Corporation (CPC) as the state monopoly, by an act of Parliament in 1961. Thereafter, all downstream activities such as import, re-export of surplus products, storage, transportation, and wholesale and retail trade activities were entrusted to CPC. As Sri Lanka's petroleum market was small, refining crude oil in the country was not considered important by the companies previously engaged in the market. Identifying the importance of a refinery for processing crude oil, the first refinery was commissioned in Sapugaskanda in 1969 by CPC with a throughput of 50,000 barrels per day. This initiative made the country's supply of petroleum products more secure and the industry to be more profitable. The refinery was able to meet the country's entire demand for key petroleum products for the subsequent decade.

While CPC retained the monopoly for key petroleum products, a competition was brought into the distribution market for several categories of petroleum products such as lubricant, synthetic fiber, and bunkering oil, in 1990. In 2003, Lanka Indian Oil Company (LIOC) was invited to engage in the import and retail distribution of key petroleum products to increase market competition. The storage units at Kolonnawa and Muthurajawela were designated as common-user facilities, by establishing a separate company, Ceylon Petroleum Storage Terminals Limited with a joint participation of government/CPC and LIOC. CPC and LIOC have their own distribution network in the country and pricing decisions of products sold by LIOC are made on its own.

The total storage of all liquid petroleum including crude oil, is 1.2 million metric tons (excluding capacity at power plants, filling stations, and with customers). The annual consumption in 2016 was 4.4 million metric tons. Thus, the storage capacity is adequate to store fuel to meet the consumption of 98 days. The National Energy Policy 2018 states that: "Every player in the petroleum sub-sector downstream retail business shall maintain a strategic fuel reserve equivalent to a minimum of 30 days' consumption at any given time," the available storage including that of crude oil is adequate for 98 days of consumption in 2016 (50 days excluding crude oil storage). Therefore, storage capacity is adequate to main at least 50 days' consumption. However, the petroleum suppliers do not maintain 30 days of stock, as evidenced by frequent supply constraints.

Liquefied petroleum gas or LPG requirements, largely used in urban households and industries, are met mostly through imported sources, supplemented by the relatively smaller production from the refinery. Presently, the LPG distribution

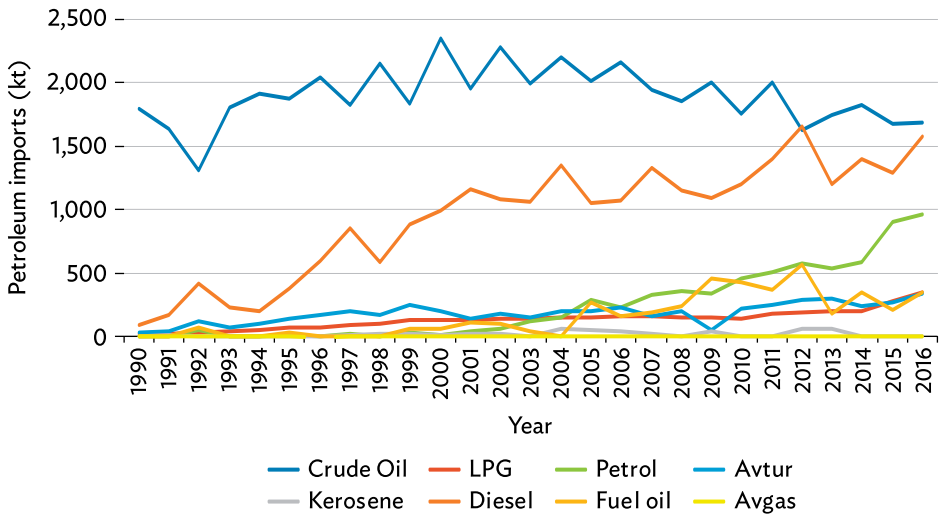
market is a duopoly—the government-owned Litro and the private company LAUGFS.

The petroleum industry is governed by the CPC Act No 29 of 1961 and the Petroleum Industry (Special Provisions) Act No 33 of 2002. These acts enable the minister of petroleum resources development to regulate the industry. A new petroleum act is expected to be approved soon, to facilitate further reforms in the industry and to empower PUCSL to regulate the technical, economic, and safety aspects of industrial entities.

Supply and Demand

As the demand for petroleum products grew and faced with dissimilar growth in demand for different petroleum products, import of refined products was also required to supplement the production at the refinery. In 2015, the demand for petroleum products was around 5,096 metric kiloton (kt), out of which about 32% was met with the locally refined imported crude oil. Figure 26 shows the variation of demand for various petroleum products over the past 25 years.

Figure 26: Import of Crude Oil and Petroleum Products from 1990



Avgas = aviation gasoline, Avtur = aviation turbine fuel, kt = kiloton, LPG = liquefied petroleum gas.

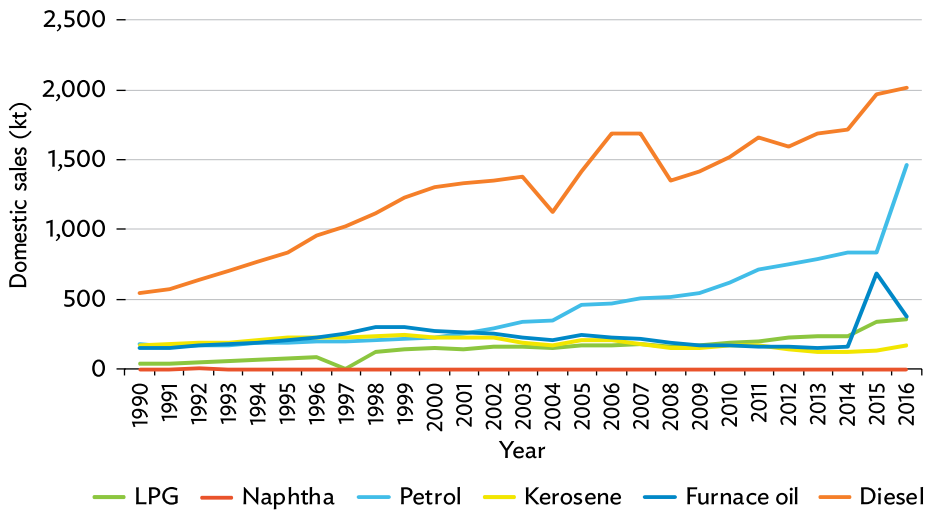
Note: Imports of refined products are required to bridge the gap between production in the refinery and the demand for each product.

Source: Sri Lanka Sustainable Energy Authority. 2019. *Sri Lanka Energy Balance 2017*.

Due to the growing demand, the contribution of the refinery to meet local petroleum demand has decreased over the years and therefore, refined products were required to be imported in increasing quantities. This can be clearly observed in Figure 26 with the increase in the importation of major refined products like diesel and petrol.

Figure 27 shows the domestic sales of main petroleum products over the past 25 years. Apart from the increase in transportation, the use of diesel has significantly increased over the years because of its use in power generation. Furnace oil is also mainly used in industries and for power generation. Owing to the effective rural electrification process in the country, kerosene (largely used for lighting in households without electricity) consumption has progressively reduced over the years.

Figure 27: Domestic Sales of Petroleum Products



kt = kiloton, LPG = liquefied petroleum gas.
Source: Sri Lanka Sustainable Energy Authority. 2018. *Sri Lanka Energy Balance 2016.*

Petroleum Resource Development Activities

At present, oil and gas exploration are carried out in the Mannar Basin and the Cauvery Basin, both administered by the Petroleum Resource Development Secretariat (PRDS). Hydrocarbon deposits have been discovered in two reservoirs, Dorado and Barracuda, with an estimated potential of 300 billion cubic feet and 1.8 trillion cubic feet, respectively. Dorado can produce 70 million scf/day (scf = standard cubic foot) for 9 years while Barracuda can produce 210 million scf/day for 22 years, studies have revealed. Exploration activities are currently being carried out in two offshore blocks off the east coast (of Sri Lanka), and preparations are underway to further explore and develop the discovered gas resources in M2 block in Mannar basin.

Owing to the absence of a natural gas policy, PRDS is facing difficulties in attracting investors for gas exploration. Evaluation of gas export potential, infrastructure development for local market, preparation of flexible contracts, and project execution in ecologically sensitive areas, are some of the challenges faced by PRDS in oil and gas exploration in Sri Lanka.

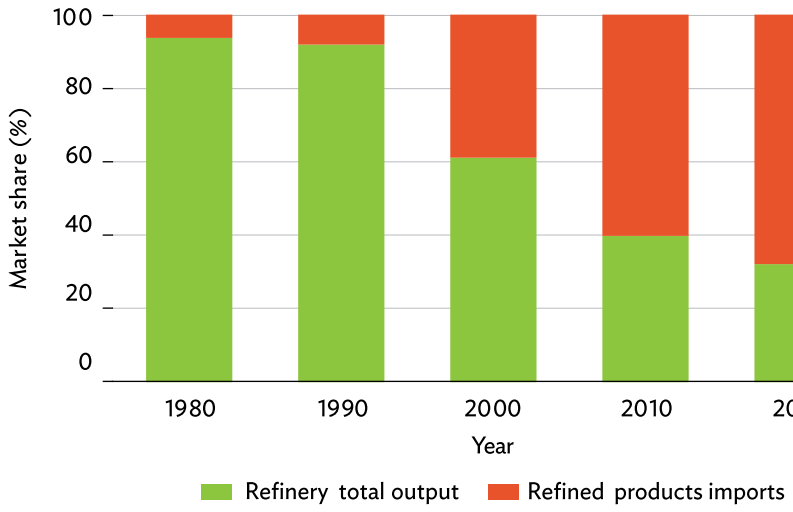
2. Issues in the Petroleum Sector

Inadequate Refinery Capacity

Built in 1969, the Sapugaskanda Refinery was designed to process Iranian light crude oil. Over the years, Sri Lanka has been importing crude oil largely from Iran, with a minor portion from Saudi Arabia. Technical specifications of the refinery do not match with other types of crude oil, and processing other crude oils require state-of-the-art technology. Owing to international issues and US sanctions imposed against Iran, Sri Lanka in the recent past has imported crude oil from Oman (Oman Crude) and from Abu Dhabi in the United Arab Emirates (Murban Crude). Compared with Iranian light crude oil, processing these other crude oil types has reduced the efficiency of the refinery.

The refinery provided the entire petroleum product requirement of the country during the 1970s, and at present, only about 32% of the country's requirement is supplied by the refinery. Figure 28 shows the reduction of refinery output as a percentage of the total petroleum product requirement of the country. With the increasing demand for petroleum products, the refinery has not been able to increase its processing capacity over the past years and therefore, the growing demand is increasingly met with imports of refined products.

Figure 28: Market Share of Refinery Output and Refined Product Imports



Source: Sri Lanka Sustainable Energy Authority. 2018. *Sri Lanka Energy Balance 2016*.

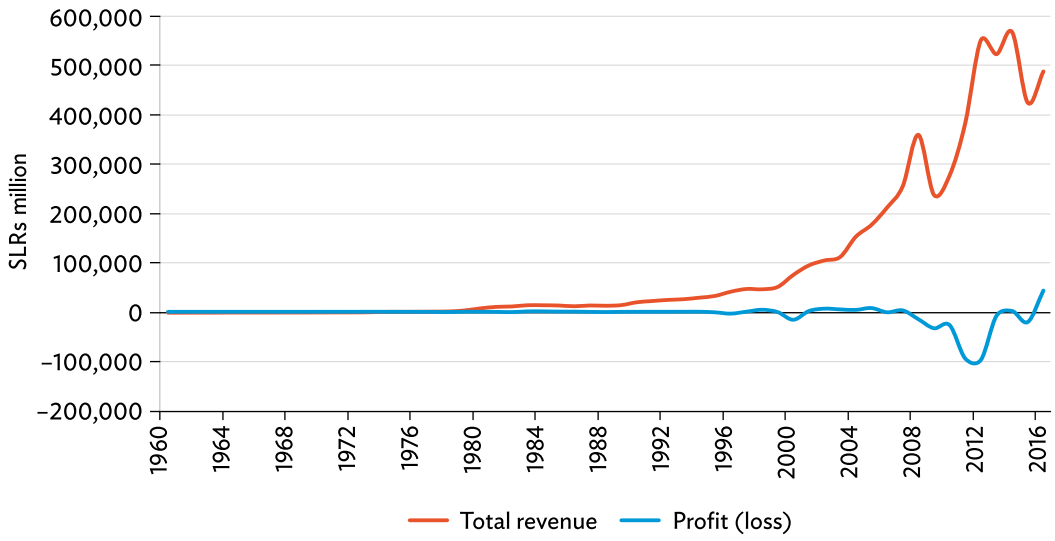
To increase the capacity of the existing refinery or build a new refinery, a large capital investment should be made. Over the past decade, there have been debates on whether (i) to increase the Sapugaskanda refinery capacity, (ii) to build a new refinery at Sapugaskanda (or elsewhere), or (iii) to retire the existing refinery and import the entire requirement of refined products. As of 2018,

debate is inconclusive, while several proposals and initiatives to build an export-oriented refinery at Hambantota in the south with private investments have been made and have not been successful over the past 2 decades.

Need for a Proper Pricing Policy for Petroleum Products

Figure 29 shows the rapid increase in revenue of CPC, and the growing losses reported, especially since 2007. Domestic petroleum prices, until 2002, were generally below the cost of supply even when international oil prices were on the rise. The government introduced fuel subsidies, but these were not paid to CPC owing to fiscal problems. As a result, CPC continued to report financial losses. To address this, the government introduced an automatic fuel price adjustment mechanism for kerosene, petrol, diesel, and fuel oil in January 2003. The pricing mechanism aimed to consider the average international oil prices, freight, taxes, and duties, to determine prices monthly.

Figure 29: Ceylon Petroleum Corporation Sales and Losses



SLRs = Sri Lankan rupees.
Source: Sri Lanka Sustainable Energy Authority. 2018. *Sri Lanka Energy Balance 2016.*

The pricing formula implemented in 2002 promptly passed the benefits of lower international prices to customers, while customers were called upon to promptly bear the additional cost when the international prices moved upward. Monthly price adjustments, upward or downward, usually announced and implemented on the last Sunday of each month, were limited to a maximum of SLRs2.00 per liter.

In February 2004, the Sri Lankan government introduced fuel subsidies to address international oil price increases. Due to political reasons, the government in 2004 discontinued the pricing formula and since then until July 2018, the

pricing of petroleum products was done arbitrarily, and CPC has reported losses each year. In 2018, the International Monetary Fund (IMF) insisted on the government to adopt an automatic fuel adjustment pricing mechanism. The World Bank, in a recent report, noted that Sri Lanka's top 30% of society consumed an overwhelming 70% of fuel sold in the country and subsidies are effectively channeled to the rich. The World Bank called for pricing reforms to fix state enterprises and finances that have now become fiscal risks. Since the nonpoor are the largest consumers of fuel and electricity, the administered fuel prices are an effective subsidy to the nonpoor funded indirectly by fiscal resources.

In July 2018, the formula was reintroduced, and regular price adjustments have recommenced. However, the formula itself or the inputs and sources of information have not been published.

Need for a Systematic Approach to Build LNG Delivery Infrastructure

The feasibility study of 2014 indicated an economic potential for a 1 million ton/year LNG terminal, allowing the power sector to operate optimally under economic dispatch, and a modest demand for nonpower applications such as in manufacturing industries and in transport. No formal offers have been requested for the LNG delivery infrastructure, storage, and regassification. Since the LNG terminal may be used by many stakeholders for importation and storage, the terminal need not be under the CEB or power sector utilities. The more suitable arrangement would be a multiuser terminal facilitated by petroleum sector institutions. With the suspension of coal-fired generating projects, the need for regasified LNG to be delivered to power plants has become urgent. However, unsolicited proposals which do not comply with the government's procurement procedure have been entertained by the Board of Investment and various agencies outside the energy sector. An LNG terminal is a complex investment, and to ensure price competition and to follow procedures laid down in the Electricity Act, the government requires to issue bids, prior to which key decisions are required about the location (Colombo, Trincomalee, Hambantota), capacity (considering that Sri Lanka is a small market), mode (floating or land-based terminal), and associated facilities.

Since the implied policy decision in 2015, alongside the decision to suspend the Trincomalee coal-fired power plant, to commence imports of LNG, no specific decisions have been made about the way an LNG terminal will be established. Meanwhile, one new power plant is being built (300 MW) in anticipation of future LNG deliveries. Since no other power plants are being built to meet the growing demand, the new power plant and 600 MW of existing combined cycle power plants will continue to operate on diesel fuel for several years to come, with all power plants moving to operate at high capacity factor to meet the growing demand. The estimated incremental cost of diesel fuel against LNG would be about $150 million annually by 2020.

Energy Efficiency in Transport

About 26% of the total energy used in Sri Lanka in 2016 was for transport. In 2000, its share was 23%. The per capita transport energy consumption was 128 kilotons of oil equivalent (ktoe)/person in 2016, up from 91 ktoe/person in 2000. Out of all fossil fuels used in the country, 39% was used for transport in 2016, while the share in 2000 was 45%.[49] As passenger transport moves away from public to various mods of private transport, in the Colombo Metropolitan Region, the fuel consumption for transport is expected to increase from 1.4 in 2014 to 4 million liters in 2020, if various issues affecting transport are not resolved. The Colombo Metropolitan Region Transport Master Plan[50] recommended and prioritized interventions to arrest the unsustainable economics costs, time delays, and fuel inefficiency through (i) improvement of public transport with bus priority, and bus rapid services, (ii) railway development including electrification, (iii) light rail transit, and (iv) road widening.

Sri Lanka had 6.3 million vehicles by the end of 2015, 3.3 million (52%) are motor cycles, 1 million (16%) are three-wheelers, and 672,000 are motor cars (11%).[51] From 2008 to 2015, the vehicle population categorized as private vehicles (cars, motorcycles, and three-wheelers) has doubled, indicating a higher affordability of private transport and a clear shift from public transport to private transport.

ADB-assisted Colombo Suburban Railway Project[52] has commenced, to address railway development (including electrification), with upgrades to tracks, communication, signaling, and other infrastructure to improve the quality of services along existing rights-of-way, attract more commuter traffic over four corridors radiating from Colombo from road transport to railways, and to improve energy efficiency through electrification. The project outputs are expected to be in commercial operation starting 2022.

An estimated 7,000 electric cars are in operation in Sri Lanka. An optional time-of-use tariff has been available since mid-2016 for households, to encourage vehicle charging (or other household activities) to be conducted after peak hours (Appendix 6, domestic). It is too early to assess the impacts of this offer to households.

[49] Sri Lanka Energy Balance 2000 and 2016, SLSEA.
[50] Government of Sri Lanka, Ministry of Internal Transport. 2015. Colombo Metropolitan Region Transport Master Plan. July.
[51] Department of Motor Traffic. 2017. http://www.motortraffic.gov.lk/web/images/stories/document/pop2015.pdf.
[52] ADB. 2016. Sri Lanka: Colombo Suburban Railway Project. https://www.adb.org/projects/49111-002/main.

A grid substation control room. Making the system stable, reliable smart grid (photo by Pushpa Kumara).

II. SECTOR STRATEGY

A. Government Strategy, Policy, and Plans

The government energy policy is described in the National Energy Policy and Strategies 2008, 10-Year Development Framework 2006–2016, and the Energy Sector Development Plan for a Knowledge-Based Economy 2015–2025. After a long review process, MOPE&BD published the National Energy Policy and Strategies 2019 in August 2019.[53] Since the revised policy is relatively new, it is prudent to examine the status of implementation of previous policy published in 2008.

1. National Energy Policy and Strategies 2008: Summary Status of Implementation

The Government of Sri Lanka published the National Energy Policy and Strategies in June 2008.[54] The declared policy elements include (i) providing basic energy needs, (ii) ensuring energy security, (iii) promoting energy efficiency and conservation, (iv) promoting indigenous resources, (v) adopting an appropriate pricing policy, (vi) enhancing energy sector management capacity, (vii) protecting consumers and ensuring fair treatment, (viii) enhancing the quality of energy services, and (ix) protecting the community from the adverse environmental impacts of energy facilities.

Prepared in 2006, the government's 10-Year Development Framework envisions "sustainable development of energy resources, conversion facilities and delivery systems to enable access to and use of energy services by the entire population, and the safe, reliable delivery of such energy services at a regionally competitive price, through commercially viable institution subjected to independent regulation."[55] Both the strategy and framework contain a list of strategies, targets, and institutional responsibility in meeting the targets. Key targets that have been fully or partially achieved as planned are described as follows.

Electrification of households. (i) Supply of electricity to 86% of households by 2010 and 95% by 2016 (exceeded the target, reported achievement by 2016 is 99.3%); (ii) households using off-grid electricity to be increased to 6% by 2010

[53] Government of Sri Lanka. 2019. National Energy Policy and Strategies of Sri Lanka, The Gazette of the Democratic Socialist Republic of Sri Lanka, No. 2135/61—9 August 2019.
[54] Government of Sri Lanka. 2008. National Energy Policy and Strategies of Sri Lanka, The Gazette of the Democratic Socialist Republic of Sri Lanka, No. 1553/10—10 June 2008.
[55] Government of Sri Lanka. 2006. *Mahinda Chintana: Vision for a New Sri Lanka, a ten-year development framework (2006–2016).*

(this target was not achieved, since the government decided to accelerate grid connection; the actual share of households with off-grid facilities declined from 2% in 2003 to about 1% by 2015).

Targeted subsidies. (i) By 2007, 50% of the cost of supply of first 30 kWh per month, to be subsidized (not implemented, and by 2016, the subsidy to customers is the 30 kWh/month) was approximately 80% of the cost of supply, meaning that customers paid only about 20% of the cost of supply calculated by the Sri Lanka Electricity Pricing Model); and (ii) entire subsidy to be provided by the Treasury from savings accrued through elimination of cross-subsidies in electricity tariff now in effect, for social reasons (not implemented, but funds required to be received from the Treasury are accurately calculated by the Public Utilities Commission).

Fuel diversity and security. (i) Diversification into coal for bulk power generation, and renewable energy target generation mix for 2015: was hydro (28%), oil (8%), coal (54%), and new renewable energy (10%) (achieved in 2015: hydro (37%), oil (17%), coal (34%), and new renewable energy (11%); and (ii) every player in the petroleum subsector downstream retail business shall maintain a strategic fuel reserve equivalent to a minimum of 30 days consumption at any given time (not implemented).

Enhanced electricity generation. (i) Increasing supply capacity and reducing generation cost by adding a base-load capacity of about 2,400 MW by 2016, including three coal-fired plants with an aggregate capacity of 2,000 MW: (only 1,200 MW was added from 2006 to 2016, of which coal-fired generation was 900 MW), (ii) ensuring 10% of grid energy is supplied from new renewable energy sources by 2015 (achieved 11.2% by 2015), and (iii) system control procedures toward the optimal operation of the integrated hydrothermal power system will be improved by the end of 2007 to ensure maximum energy output from the hydropower system (implemented a new model for reservoir optimization and dispatch decisions under system security constraints, 2013).

Electricity transmission and distribution. Reducing the total technical and commercial losses of the transmission and distribution network to 13.5% of net generation by 2009, and 12% by 2016 (achieved 10.3% in 2016, 8.9% in 2017, while new targets have been defined by the PUCSL to reach 7.5% by 2020).

Energy pricing reforms. (i) The average electricity price to each category of customers will be gradually made cost-reflective (not implemented), (ii) a conducive environment will be created to fully utilize the demand-side management (DSM) opportunities arising from this change (not implemented), (iii) customers and all other stakeholders will be given opportunities to present their views at a public hearing (implemented), and (iv) prices of petroleum-based fuels will be determined using an agreed price formula between the government and the petroleum subsector utilities regulated by the PUCSL (not implemented).

The Government of Sri Lanka, in consultation with the IMF, initiated a reform process aimed at improving debt sustainability and reducing the quantum of debt in July 2016, which was to be concluded by June 2019. Among the reasons for fiscal slippage was the financial losses in nonfinancial state-owned enterprises as with CEB and CPC. The fiscal losses were exacerbated when crude oil prices were over $100/bbl, (i.e., during 2011–2013) given that Sri Lanka had a system of government-controlled petrol and diesel prices in the past. Even though the government has introduced a fuel pricing formula since 2017 in an attempt to change the market prices in line with world price corrections, it has been a politically sensitive issue and any reform, which directly passes on fluctuations in global crude oil prices to Sri Lankan consumer has traditionally been hard to implement.

The government recently adopted the fuel pricing formula that impacts petrol and diesel prices every 10th day of each month. It was expected to adopt a similar pricing reform for electricity by the end of 2018, in accordance with the reform schedule agreed with the IMF, but this has not been implemented even by mid-2019. Adoption of these kinds of reforms is vital to the long-term sustainability of strong economic fundamentals. However, it is likely to be a politically sensitive issue given the rising cost of living, particularly with the Provincial Council elections expected to be conducted in early January 2019. Given the recent Sri Lankan rupees (SLRs) depreciation, especially in October 2018, fuel prices are likely to increase with the next few revisions.

The immediate shocks of this may be passed on to the general consumer as imported inflation through all the above inflation components. As the IMF may not be anticipated this kind of SLRs downside (it was not predicted by either of their publications to date), the practicality of adopting these reforms before the end of the fourth quarter 2018 remains to be seen, given the significant impact of another reform that may further burden the rural lower middle-class consumer. While adopting the electricity pricing reform is a must, it could have been best adopted during the softening of the global commodity prices[56] that is likely to be followed by the current monetary tightening process in European markets. However, the decline of global commodity prices would take at least a year, which may again be a politically sensitive factor by that time, given the anticipated presidential elections focused on campaigns in late 2019, resulting in politics again trumping economics. This means that electricity reform needs to happen sooner, on account of the dynamics mentioned.

Enhanced quality of electricity supply. (i) Energy sector utilities will be compelled by the PUCSL to maintain a minimum quality of supply of products and services (not implemented), and (ii) enhanced quality will be encouraged by permitting reasonable increases in allowed returns to the utility concerned (rate of return regulation on tariffs introduced in 2011 continue to be operational).

[56] Sanjeewa Fernando. 2018. Electricity pricing reform. A bad time to do a good thing? The Morning. 4 October. http://www.themorning.lk>electricity-pricing-reform-a-bad-time-to-do-a-good-thing.

Safety and the environment. Energy sector utilities will be compelled to comply with safety standards issued by the PUCSL as well as environmental standards stipulated by the state (achievements are moderate).[57]

Enhanced energy efficiency at end-use. (i) The appliance labeling program will be made mandatory to identified appliances by mid-2007 (achieved only for compact fluorescent lamps, other standards and laboratories remain in various stages of development); (ii) the Energy Efficiency Building Code will be updated and made mandatory to state sector entities by the end of 2007 (not achieved); (iii) a variety of financing mechanisms will be made available by the end of 2007 to finance energy efficiency improvement (a performance guarantee established in 2006 was concluded a few years later with little success, no such financing scheme are currently operational); and (iv) benchmarks on energy intensity of specific industries will be established by the end of 2007. Specific benchmarks for the energy consumption of commercial, transport, and domestic sectors will be established by the end of 2008 (a limited scope of industrial benchmarks completed, other industries and sectors largely remain uncovered).

Energy efficiency in transport. Fuel diversification in the transport sector will be encouraged through rail and road transport systems based on off-peak electricity supply, and the promotion of biofuels as a high priority research and development need (not implemented).

Sector regulation and regulatory reforms. (i) Establishing an independent regulatory framework and rationalizing the tariff structure (regulatory framework was established by the Electricity Act 2009, rationalizing the tariff structure was not achieved); and (ii) restructuring CEB's long-term and short-term debts (half of its long-term liabilities have been converted to equity and the other half have been rescheduled, with repayment to begin only after the commercial operations of the Puttalam coal-fired power plant have begun).

Energy information system development. (i) The National Energy Database will be enhanced with further disaggregated and refined demand-side data by the end of 2007 (web-based information available for the entire energy sector from 1970 onwards, no significant improvements in demand-side disaggregation).

National energy planning. The planning team shall, by the end of 2007, establish improved methodology, if necessary, to develop demand forecasts, simulate development scenarios, integrate subsector plans, and conduct sensitivity studies.

The overall rate of implementation of strategies and specific actions stated in the National Energy Policy and Strategies of Sri Lanka 2008 was moderate, with the following classifications:

[57] https://www.scribd.com>document>Draft ESQCR-Final-21st-April.pdf.

(i) **Achievements that exceeded energy policy targets for 2015.** Increased electrification of households, increased fuel diversity in electricity generation, reduction of electricity transmission and distribution losses.

(ii) **Achievements that fell short of energy policy targets for 2015.** Enhanced electricity generation, energy pricing reforms, safety and the environment, enhanced energy efficiency at end-use, sector regulation and regulatory reforms, and energy information system development.

(iii) **Policy targets which had minimal progress or no progress by 2015.** Targeted subsidies, energy pricing reforms, enhanced quality of electricity supply, energy efficiency in transport, and national energy planning.

2. Sri Lanka Energy Sector Development Plan 2015–2025

In March 2015, the Sri Lanka Energy Sector Development Plan for a Knowledge-based Economy 2015–2025[58] established a series of thrust areas and targets. In 2016, the government made announcements about the choice of fuel for bulk power generation (coal versus LNG) and an accelerated program to increase electricity generation from solar PV. However, based on recent discussions on fuels and renewable energy, detailed policy documents as required under the electricity act are yet to be issued. Some actions on the thrust areas are being implemented through various policy initiatives.

Thrust areas:

(i) integrated national energy policy formulation,
(ii) a cleaner future through green energy,
(iii) conservation and efficient use of energy,
(iv) customer satisfaction in service and quality,
(v) timely development of infrastructure,
(vi) efficient energy sector institutions and good governance,
(vii) innovative financing for a diverse energy sector, and
(viii) investment in research and development for cutting-edge product development.

Targets:

(i) to make Sri Lanka an energy self-sufficient nation by 2030;
(ii) increase the share of electricity generation from renewable energy sources from 50% in 2014 to 60% by 2020, and finally to meet the total demand from renewable and other indigenous energy resources by 2030;
(iii) increase the electricity generation capacity of the system from 4,050 MW to 6,400 MW by 2025;
(iv) generate a minimum 1,000 MW of electricity using indigenous gas resources discovered in Mannar basin by 2020;

[58] Government of Sri Lanka, Ministry of Power and Energy. 2015. *Sri Lanka Energy Sector Development Plan for a Knowledge-based Economy 2015–2025*. Colombo.

(v) increase generation capacity of low-cost thermal power plants fired by natural gas and biomass to 2,000 MW to reduce the generation costs and diversify generation mix by 2020;
(vi) provide affordable electricity coverage to 100% of the people of the country on a continuous basis before the end of 2015;
(vii) reduce the technical and commercial losses of the electricity transmission and distribution network from 11% to 8% by 2020;
(viii) reduce annual energy demand growth by 2% through conservation and efficient use;
(ix) reduce the petroleum fuel use in the transport subsector by 5% by introducing alternative strategies such as efficient modes of transport and electrification of transport by 2020;
(x) produce the total petroleum product demand of the country through the local refinery by 2025;
(xi) upgrade quality of gasoline to EURO IV and diesel to EURO III by 2018;
(xii) further enhance the quality and reliability of electricity and fuel supply;
(xiii) broaden energy sector investment windows to include bonds, debentures, public–private partnerships, and other novel financial instruments; and
(xiv) reduce the carbon footprint of the energy sector by 5% by 2025.

3. Policy Changes of the Government

From mid-2016, the government has made certain statements about the fuel choice for bulk power generation (coal versus gas) and a new, accelerated initiative for rooftop solar PV installations. In the absence of detailed analyses of technical, financial, and economic consequences, policy declarations as required under the electricity act has not been made.

In late 2016, the government announced a shift to the net-metered renewable energy development scheme, where surplus energy from rooftop solar PV will be purchased at SLRs22/kWh. Daytime average electricity sold from the grid to distribution licensees in 2017 was SLRs11.82/kWh (April 2017–September 2017) and SLRs12.11/kWh (October 2017–December 2017). Owing to ex post corrections, the cost of rooftop solar PV procured is passed on to the bulk supplier, the CEB. Therefore, CEB incurs a loss of revenue, to which a correction is not applied, which in turn is causing the tariff regulation process to be incomplete. As such, the transmission licensee is likely to increasingly disown his responsibility to operate under sound business principles.

In its September 2016 submission of its nationally determined contributions, the Government of Sri Lanka have made several commitments[59] in accordance with an agreement made during the 21st session of the Conference of Parties to the

[59] Government of Sri Lanka, Ministry of Mahaweli Development and Environment. 2016. *Nationally Determined Contributions*.

United Nations Framework Convention on Climate Change. Regarding the energy sector, the government has aimed for a 20% greenhouse gas emission reduction target which amounts to 39,383 gigagrams (Gg) of their total GHG emissions, estimated at 196,915 Gg for the period 2020–2030. The country's specific nationally determined contributions for the energy sector include:

(i) establishment of large scale wind power plants of 514 MW;
(ii) establishment of 115 MW of solar power plants;
(iii) establishment of 105 MW of biomass power plants;
(iv) establishment of 176 MW of mini hydropower plants;
(v) introduction of demand-side management (DSM) activities;
(vi) strengthening sustainable energy related policies with a view to increasing the share of renewable energy from the existing 50%, to 60% in 2020 (the level of 60% expected to be reached in 2020 will be maintained at the same level, until further developments in renewable energy technology allow for increased share of electricity generation from renewable energy sources); and
(vii) converting existing fuel oil based power plants to liquefied natural gas (LNG)

B. ADB's Sector Support Program and Experience

Since 2010, ADB assistance has focused on (i) implementing power sector reforms, (ii) renewable energy development (including wind and other clean energy sources), (iii) energy efficiency improvement, (iv) expanding the transmission and distribution system, (v) improving energy access for lagging regions, and (vi) improvement of reliability and quality of power supply. The technical assistance on Capacity Development for Power Sector Regulation (2011) enabled Sri Lanka to make tariff, technical, and safety regulation activities operational within a short period. The Clean Energy and Network Efficiency Improvement Project (2012) supported transmission infrastructure development, network efficiency improvements, and pilot solar rooftop power generation investments. The Green Power Development and Energy Efficiency Improvement Investment Program (2014) includes support for the construction of a 30 MW run-of-river hydropower plant; transmission infrastructure enhancement; distribution network efficiency improvements; and pilot projects on DSM smart metering, and smart building retrofits. The Supporting Electricity Supply Reliability Improvement Project (2016) includes renewable energy mini-grids for three offshore islands, reliability improvement in the distribution network, and a pilot renewable energy micro-grid in a government building. The Wind Power Generation Project (2017) supports development of a 100 MW wind farm in Mannar Island in the Northern Province and the Rooftop Solar Power Generation Project (2017) provides a credit line to enable institutional and domestic customers to finance installation of rooftop solar PV generation facilities.

ADB's Climate Change Operational Framework 2017–2030[60] supports developing member countries like Sri Lanka in refining and translating their nationally determined contributions into potential investment projects—including assistance to mobilize climate financing support such as ADB's own resources or facilitate access to other international climate financing sources. One of the key operational priorities in ADB's Strategy 2030[61] is to address climate change and enhance environmental sustainability in the region. Toward this goal, ADB will work to ensure that 75% of the number of its committed operations (on a 3-year rolling average, including its sovereign and nonsovereign operations) will be supporting climate change mitigation and adaptation projects. ADB is committed to providing $80 billion in climate change financing from its own resources—both from public and private sector windows from 2019 to 2030. ADB's private sector operations is also looking to increase its participation in infrastructure projects such as renewable energy including assistance in preparing bankable projects that can attract private sector financing, blended financing with ADB's concessional funds and other trust funds, and public–private partnerships.

ADB also continues to provide advisory and technical assistance including promotion of innovative technologies such as incorporating smart grids and energy storage technologies into transmission and distribution projects that can help integrate renewable energy into power systems. As highlighted in its Strategy 2030, ADB will strengthen its role as a knowledge provider, working closely with its developing member countries, like Sri Lanka, to identify their needs, proactively engage in research, produce relevant knowledge products, engage in policy dialogue and deliver appropriate institutional capacity building to help them address specific development issues such as effective regulation and cost-effective tariff setting.

C. Other Development Partner Support

Key development partners active in the energy sector are Japan International Cooperation Agency (JICA), KfW, Agence Française de Développement, Kuwait Fund for Arab Economic Development, the Islamic Republic of Iran, the World Bank, and United States Agency for International Development (USAID).

For power generation, JICA provided assistance to the Upper Kotmale Hydroelectric Project (150 MW, commissioned in 2012) and to conduct the feasibility study for an LNG Terminal (2014). JICA also supported the Vavuniya–Kilinochchi Transmission Line Project in the Northern Province (2013), and the augmentation of the Kilinochchi Grid Substation and the Greater Colombo Transmission and Distribution Loss Reduction Project (2013). The Habarana–Veyangoda Transmission Line is planned to be financed by JICA.

[60] ADB. 2017. *Climate Change Operational Framework 2017–2030: Enhanced Actions for Low Greenhouse Gas Emissions and Climate-Resilient Development*. Manila.

[61] ADB. 2018. *Strategy 2030: Achieving a Prosperous, Inclusive, Resilient, and Sustainable Asia and the Pacific*. Manila.

KfW funded the Jaffna region transmission protection upgrades. Agence Française de Développement is financing several grid substations in urban areas and in areas where small hydro potential is high. The Islamic Republic of Iran, Kuwait Fund for Arab Economic Development, and the People's Republic of China have previously financed rural electrification project components.

Through their respective export–import development banks, the People's Republic of China has financed the 900 MW coal-fired power plant (completed in 2014) and the Uma Oya hydropower plant (presently under construction) is financed by the Islamic Republic of Iran. The World Bank assists with technical support on power system planning. USAID supported the establishment of the Regional Centre for Lighting in 2012 for the Sri Lanka Sustainable Energy Authority (SLSEA), and the center is now managed by CEB.

D. Future Support by Development Partners

By the end of 2016, Sri Lanka's electricity generation, transmission, and distribution infrastructure has reached the key milestones of (i) a reasonable fuel mix in generation, with over 48% of electricity being produced from renewable energy sources, 34% from coal, and 17% from oil; (ii) transmission network completed to cover the entire country; (iii) distribution network expanded to reach over 98.5% of households; and (iv) transmission and distribution losses below 11% of net generation. With major infrastructure projects either already completed or being built under ongoing projects financed by the government and development partners, the focus of new investments is in the following key areas of development:

(i) **Development of base-load generation facilities.** While Sri Lanka claims a big share of renewable energy in the grid (48% in 2015), the country's power generating system continues to be severely affected by the absence of a focused effort to build new, base-load generating facilities to stabilize the generating system and meet the growing demand. When adequate generating capacity is not built, capacity shortages occur when rainfall reduces to below average values. In other words, seasonality and intermittency of renewable energy sources cause the island nation to suffer from generation shortages and consequent increases in costs to purchase emergency power.

(ii) **Development of renewable energy-based generation.** Sri Lanka's 48% share of renewable energy (of which 11% is from nonconventional sources), requires to be developed with a systematic plan. An accelerated program to develop rooftop solar PV has been announced, with very limited information on technical, economic, and financial consequences, and required remedial actions.

(iii) **Improvement of reliability in transmission and distribution.** Sri Lanka's technical quality of supply is not yet being reported by the respective licensees. When such indices are accurately calculated and published, they would most likely be below the standards expected by a modern

society. Specific investments are required to upgrade the design, operating practices, protection, and switching facilities, to improve reliability of the transmission and distribution network.

(iv) **Commercial quality of services by distribution utilities.** Systems require to be improved to serve customers with innovative schemes, reducing burden when dealing with distribution utilities. Investments are required to establish software and hardware to provide good quality services, and to build capacity of utility staff.

(v) **Energy efficiency and DSM.** Investments are required to venture into more sophisticated energy efficiency and DSM measures, to use the investments to the optimum level

(vi) **Gas and petroleum industry.** An LNG terminal with a capacity of about 1 million ton/year has proven to be economical. A refinery with a throughput of about 125,000 bbl/day has proven to be economical. Investments are required on these two crucial petroleum industry facilities.

(vii) **Completing and consolidating energy sector reforms.** The petroleum and gas supply industry has not been brought under regulatory reform. Several key elements of regulatory and structural reforms have not yet been fully implemented. These require completion, to enable a fair service to all stakeholders in the energy industry.

E. ADB Self-Evaluation

ADB's country assistance program evaluation in 2016[62] found that ADB's support to the energy sector in Sri Lanka to be *effective* based on evaluation of individual projects completed. The report found the energy sector assistance to be *effective and efficient*, and the development impacts to be *satisfactory*. Although sustainability was not considered to be satisfactory, the overall rating of the energy sector operations was assessed to be *satisfactory*.

Sustainability of ADB's support was evaluated to be unsatisfactory by the Independent Evaluation Department, largely because the implementation of cost-reflective pricing of electricity, in particular, and tariff setting, in general, has been weak. Sri Lanka's generation mix moved to a favorable position to enhanced energy security, with the introduction of the first coal-fired power plant. The cost of electricity production and delivery declined from SLRs23/kWh in 2013 to SLRs21/kWh in 2016. Since ADB's assistance to capacity building on power sector regulation was established, among other regulatory instruments—the tariff methodology—none of the structural reforms foreseen have been implemented by the PUCSL to date. While the requirement was to simplify definitions of customer categories, the PUCSL further complicated the tariff structure by (i) introducing a customer category "government," which was previously classified as "commercial," (ii) introducing volume differentiation at 60 kWh/month for household customers and 300 kWh/month for commercial and industrial customers; and (iii) further divergence of the actual tariffs from the cost of supply to each customer category.

[62] Independent Evaluation Department. 2016. *Country Assistance Program Evaluation*. Manila: ADB.

Therefore, despite clear policy guidelines, specific principles laid out for tariff setting, a well-documented methodology, and clear identification of a road map for tariff rebalancing and restructuring, the PUCSL has not been able to secure from the government, the subsidies provided by the distribution licensees to various customers on the basis of the government's ad doc directives. The PUCSL has not been able to restructure tariffs to reflect costs and to simplify the structure and definitions. On the part of licensees, (i) CEB generation licensee has not entered into power purchase agreements for its power plants; (ii) CEB transmission licensee has not entered into power sale agreements with the distribution licensees; (iii) CEB transmission licensee has not established the bulk supply transactions account,[63] which is the cornerstone of transparent costing, pricing, and revenue management; and (iv) CEB licensees have not been revenue-separated, which is essential for assigning the responsibility of managing the finances, investments, operating costs, and technical and commercial quality of supply, to individual business units. Owing to the above shortcomings, and the government's interference in key generation projects (ad hoc changes in power plant locations and fuel types) and on pricing of electricity, structural and regulatory reforms implemented since Electricity Act 2009 have had minimal benefits to customers at-large.

Several undertakings on a range of initiatives on tariffs included in the Framework Finance Agreement between the Government of Sri Lanka and ADB on the Green Power Development and Energy Efficiency Improvement Investment Program (dated May 2014) have not been implemented at all. Similarly, undertakings related to technical regulation have also not been implemented. Therefore, benefits to electricity customers and to the government (as the shareholder of CEB) of regulatory and structural reforms have been significantly lower than the expectations.

1. Lessons Learned

Network expansion benefits universal connectivity and efficiency. ADB's support for transmission and distribution development has enabled the transmission grid to be brought closer to load centers, and to extend the distribution network to cover almost every household in the country, reaching 98.5% of households by the end of 2015. The government's own investments are presently closing the gap, to achieve 100% electrification. ADB was continuously engaged over 3 decades as the development partner providing the largest support for transmission and distribution investments in the country. Consequent to the expansion of the network and investments on substations, and relentless efforts of the distribution licensees CEB and LECO, network losses have significantly reduced over the past 2 decades, 8.9% of net generation by 2017. Sri Lanka currently works on a 7.5% target for transmission losses, to be achieved by 2020.

[63] The bulk supply transactions account (BSTA) is an account through which the bulk supply business of CEB transmission licensee would be operated. Surpluses in BSTA (e.g., when fuel expenses decline or high rainfall causes higher hydropower input) and deficits in BSTA (e.g., when power plants get delayed or when rainfall goes below average) would be transparently passed on to customers as credits or surcharges. BSTA requires to be published online.

Generation costs and shortages limit benefits of network expansion. However, recurring shortages of generation capacity and the skewed fuel mix in generation have continued to affect the generating system reliability and costs. In the period since 1980, Sri Lanka experienced rolling blackouts owing to inadequate generating capacity in 1983, 1987, 1992, 1996, 2001, and 2002. As the generating system continues to be dominated by hydropower, capacity shortages affect the generating system when inflows to reservoirs fall below average levels. Despite the existence of a 20-year plan rolling on generation investments required to meet the growing demand, implementation of the plan has been very significantly affected by a variety of issues. Throughout the period 1980–2005, generation capacity shortages owing to non-implementation of the long-term plan, were met with ad hoc decisions by the government on various generating plants, all of which were oil-fired, mostly short-term rentals from private entities and a few oil-fired IPPs with contract periods of 10 to 20 years. All such power plants operate on diesel fuel (and some of the IPPs on fuel oil), causing severe pressure on CEB's finances, because such costs were not allowed to be passed on to customers. Therefore, absence of timely investments on generation, to match the expanding network from which new and existing customers demand more power reliably and at affordable costs, caused the benefits of network investments to be suppressed to a significant extent. Sri Lanka's total cost of electricity supply rose to its highest level of $0.17/megawatt-hour (MWh) in 2013, amid generating 62% of electricity with oil. The cost of supply has since declined to $0.13/MWh in 2016, with the contribution of oil-fired generation limited to a forecast level of 12%.

Looming threat of generating system drifting again toward oil dominance. Investments on bulk power generation, to match forecast demand, are required to be made in accordance with the long-term plan, such that new power plants of the correct fuel type (to manage cost of supply) would be built on schedule (to avoid capacity shortage and blackouts). The inevitable transition to fossil fuels for bulk power generation from previously hydro-dominated status caused a debate that extended from 1985 to 2005, during which period, the increasing demand was met with all oil-fired generation. The debate to move into cleaner fuels, including renewables, has commenced, while for major power plants to produce bulk power has been postponed or canceled. Therefore, Sri Lanka's power generation situation continues to be at high risk and threatens to fall back into oil dominance. The current forecast share of electricity to be generated from oil in 2020 is 25%, with a further 20% produced from new renewable energy (small hydro, wind, and solar). With both oil-fired generation, wind, and solar PV priced in the range SLRs20/kWh to SLRs22/kWh, Sri Lanka's cost of supply, at constant December 2016 fuel prices, is forecasted to increase again to about $0.15/MWh. The additional burden on the fuel bill is estimated to be SLRs63,000 million (about $430 million) annually by 2020, at December 2016 oil price levels.

Unclear government policy causes delays in renewable energy project implementation. ADB supported several initiatives for renewable energy development, which included a 5 MW (cumulative) solar PV rooftop pilot (2012) and estate micro-hydro development (2013), both for grid connection on

net-metered basis. ADB also provided significant technical assistance in 2008 for (i) capacity building at Sri Lanka Sustainable Energy Authority to implement the provisions of the SLSEA Act 2007; (ii) wind and solar resource assessment (2013); (iii) preparation of the renewable energy master plan for Sri Lanka (2014); and (iv) preparation of the Mannar wind power development master plan (2013). From 1996 to 2012, Sri Lanka followed a policy of developing renewable energy by the private sector as embedded power plants, based on a feed-in tariff and a standardized power purchase agreement. Smaller net-metered renewable energy facilities were allowed from year 2010. Since 2012, no new provisional approvals for wind and solar PV have been issued, with indications from the government that such projects would be opened for competitive bidding. However, only 20 MW of wind power and 60 MW of solar PV development have since been placed for competitive bidding while the policy on wider development of wind and solar PV remains unclear.

Incomplete sector reforms reduce benefits to stakeholders. ADB has consistently supported structural and regulatory reforms in the electricity industry. The government's 2009 decision to limit structural reforms to internal unbundling of CEB into six business units with separate licenses (without creating six separate corporate entities), has caused the benefits of reforms to be limited. The six licensees are unable to make independent business decisions, since all decisions and finances are managed by the CEB corporate board. Tariff-related reforms continue to fall short of essential elements; to achieve benefits and effective economic regulation, (i) licensees require to be financially separated and be responsible for all their capital and operating expenditure, which are linked to technical and commercial performance targets, and (ii) licensees require to be financially independent to ensure the benefits of performance exceeding targets and penalties for underperformance are retained with the licensee. Presently, all benefits and indirect penalties on licensee performance are hidden within the corporate financial system. Much of economic, technical, and commercial regulatory instruments and methodologies developed during ADB's capacity building for power sector regulation (2010–2011), as well as regulations developed subsequently by the PUCSL (e.g., DSM regulations, power plant heat rate testing requirement) are yet to be implemented by CEB licensees. Further, the PUCSL has not been able to achieve cost reflectivity in tariffs to each customer category or to simply the tariff structure, and operates without a road map to complete tariff reforms. Recent IMF requirements (2015) to move to cost-reflective pricing has not been achieved.

Slow implementation of energy efficiency initiatives limits benefits of ADB support. Despite support from various agencies since 2000 (ADB, JICA, USAID, and the World Bank), Sri Lanka did not achieve the target of labeling all commonly used appliance by 2012. To date, only compact fluorescent lamps (CFLs) require mandatory labeling of energy performance. Refrigerators, air conditioners, electric fans, and television sets continue to be sold with no requirement to adhere to energy performance standards. Appliance displayed for sale do not carry any energy efficiency information or label to empower the customer to make conscious decisions.

Cross-border interconnections and energy trade are non-existent. Sri Lanka remains electrically isolated from the larger Indian subcontinent. ADB has supported studies on technical and commercial aspects of a prospective India-Sri Lanka interconnection, on which the progress has been slow. The feasibility study on the interconnection jointly conducted by India and Sri Lanka is yet to be completed. Clear indications on how best such an interconnection should be sized, financed, and structured into the markets of the two countries have emerged in the feasibility studies, but no firm decisions have been made. As more renewable energy enters the grid, sharing reserve and spinning capacity become increasingly important, as well as real power interchange between countries. The larger Indian grid would offer such stability to the Sri Lanka grid, and the bottlenecks on the Indian side, especially in the southern grid, are gradually cleared.

Energy policy analysis and sector planning is weak. CEB prepares a long-term generation expansion plan, and accompanying transmission and distribution development plans. However, actual implementation of elements in the plan, especially the generation expansion plan, falls far short of the recommended implementation process, with very significant impacts on reliability (causing blackouts) and economy (higher costs and prices). A strong policy analysis framework and documentation is lacking, which goes beyond the electricity industry, to examine policies on (i) fuel choice and trade-off between coal and gas for power generation, (ii) the role of renewables in power generation, (iii) the role of biomass and gas in industry and transport, and (iii) financial and economic impacts of these choices. These require integrated energy panning, leading to scenario analyses and good financial modeling for forecasting of the performance of the energy sector.

F. ADB's Energy Sector Strategy

ADB's Country Partnership Strategy (2018–2022) issued in July 2017 highlights Sri Lanka's forthcoming transition to an upper middle-income country. Meanwhile, ADB's Country Operations Business Plan (2019–2021) dated August 2018, focuses the energy sector operations in three key areas:

(i) developing renewable energy,
(ii) electricity transmission and distribution (strengthening the stability and reliability of power supply), and
(iii) energy sector development and institutional reform.

Moreover, considering that electricity reforms established under the Electricity Act 2009 have been implemented since 2010, and that petroleum industry legislation has been in preparation for some time, awaiting finalization and implementation, ADB proposes to elaborate sector development and institutional reform as, "consolidating electricity sector reforms and establishing petroleum industry regulation."

Sri Lanka's bulk power generation requires stronger, cheaper base-load generation facilities. Sri Lanka hydropower, which in an average hydrological year serves 40% of electricity sales, is subject to seasonal and interannual variations, causing energy

yield to vary between plus or minus 20% of the yield in an average hydrological year. Intermittency of renewable energy (wind and solar) and their inherently poor contribution to power system stability requires stronger rotating machines to produce the bulk of electricity. While Sri Lanka's coal-fired power plant provides electricity at a significantly lower cost, the country needs a source of energy that can be used for base-load, seasonal, and mid-priced operation, at a cost that would balance out the costs and inherent instability of renewable sources. Further, to support thermal energy requirements in high-temperature[64] industries that require a clean source of energy to fire products, currently use LPG. High-temperature industries are also highly energy-intensive, causing such industries to lose out in the international market. A recent feasibility study[65] showed the technical and economic feasibility of importing LNG into Sri Lanka. Accordingly, ADB proposes the energy sector strategy to include "(iv) support for developing gas industry facilities."

To meet the energy sector strategy, ADB supports the CEB's Wind Power Generation Project in Mannar, which can serve as a benchmark for further development of wind power generation by the private sector. A project for strengthening transmission stability, reliability, and protection was planned for 2018. A project preparatory technical assistance shall identify the most urgent system protection actions to be undertaken by the project. A Distribution Automation and Metering Project is included in the 2021 standby pipeline to establish modern supervisory control and data acquisition distribution systems for remote monitoring and control in all power distribution regions. The technical assistance loan to prepare the Power Development and Interconnection Project in 2018 and 2019, will explore the opportunity to support power trade with India.

ADB shall support the completion of reform components from 2011 to 2015, and open new areas such as a limited power market and power wheeling under "(iii) energy sector development and institutional reform" and the development of an LNG terminal under "(iv) support for developing gas industry facilities."

Energy efficiency and demand management in Sri Lanka has had modest achievements, with a stable commercial specific energy consumption[66] in the economy, and a declining energy consumption in overall energy use. However, energy performance standards and labeling regulations have not been established for appliances that deserve such standards. Demand-side management (DSM) projects have not been implemented by any of the utilities, except for indirect initiatives, such as time-of-use pricing of electricity. In addition, the government is planning—with ADB support—a major upgrade and electrification of the suburban railway network, of which, energy efficiency in transport is a key objective. Accordingly, enhanced energy efficiency and accelerated demand management is included in ADB's strategy for Sri Lanka.

[64] Industries that require operating temperatures more than 1,000 degrees Celsius. Typically, these are energy-intensive industries that use local raw materials.

[65] Oriental Consultants Co., Ltd. 2014. Energy Diversification Enhancement Project: Feasibility Study for Introducing LNG to Sri Lanka. June.

[66] Commercial energy (petroleum, gas, electricity, and traded biomass) used per unit of economic output.

A Mahiyanganaya grid substation.
Taking the grid to all the corners of the country to improve reliability and quality of electricity supply (photo by Pushpa Kumara).

III. SECTOR ROAD MAP AND RESULTS FRAMEWORK

The sector road map in relation to ADB's energy sector strategy outlined in the previous section, is described in Table 18. The problem tree is shown in Figure 30.

Table 18: ADB Sector Road Map and Results Framework

Country Sector Outcomes		Country Sector Outputs		ADB Sector Operations	
Outcomes with ADB Contribution	**Indicators with Targets and Baselines**	**Sector Outputs with ADB Contribution**	**Indicators with Incremental Targets**	**Ongoing and Planned ADB Interventions**	**Main Outputs Expected from ADB Interventions**
Increased use of renewable energy for electricity generation	Baseline: 2016: 50% Target: 2020: 60%	Increased generation of electricity from wind, solar, and hydropower	375 MW of wind power development by 2025	Enhance transmission capacity of the grid in wind resource areas	Anuradhapura–Mannar transmission line completed by 2018 Mannar–Nadukkukda transmission line completed by 2019
			100 MW of wind power added by 2019	Finance a large increment of wind power generation for benchmarking	Mannar 100 MW wind power project completed by 2019
			100 MW of solar PV added by 2020	Concessionary financing for rooftop solar PV in households	50 MW of rooftop solar PV added on net-metering by 2020.
			100 MW of medium-scale hydropower added by 2020	Financing of medium-scale hydropower projects	25 MW Moragolla hydropower project added in 2020
			Four island mini-grids developed	Financing of island mini-grids	Four coastal islands provided with 100% renewable energy-based mini-grids

continued on next page

Table 18 continued

Country Sector Outcomes		Country Sector Outputs		ADB Sector Operations	
Outcomes with ADB Contribution	**Indicators with Targets and Baselines**	**Sector Outputs with ADB Contribution**	**Indicators with Incremental Targets**	**Ongoing and Planned ADB Interventions**	**Main Outputs Expected from ADB Interventions**
Strengthening the stability and reliability of power supply	Baseline: Reliability information published Baseline: 2016: only one distribution licensee out of five publishes. Transmission licensee does not publish reliability information.	Reliability information published by licensees. Reliability and stability of the grid enhanced	All licensees report distribution outage events.	Financing transmission and distribution upgrades, and control centers	Control centers established for each distribution licensee. Transmission and distribution constraints removed by 2019 Comprehensive technical quality of supply reported and regulations operational by 2020
Energy efficiency, demand management strengthened	Appliance energy performance standards and labeling 2016:1 2020:4	Energy performance standards published	Appliance energy performance standards and labeling 2016:1 2020:4	Support appliance labeling activity	Five appliances/ systems have energy performances standards established and labeling scheme operational by 2020
	DSM project implemented 2016: none 2022: complete	DSM project to address lower demand in the night established	Off-peak demand increas-ingly matches with daytime demand for electricity 2016: off-peak is 40% of peak demand 2020: off-peak is 60% of peak demand	Technical and economic evaluation of DSM options and project formulation DSM project implementation assistance for electricity use in nontransport activities	DSM project and others identified by 2018 DSM project implemented by 2022.
	Use of enhanced electricity in public transport 2016: none 2022: suburban electric trains operational	Colombo suburban railway network upgraded and electrified	Demand profile smoothened by electric vehicle charging (cars and buses) and operations (suburban trains)	DSM project implementation assistance for electricity use in nontransport activities	Electric car and buses provide off-peak control-lable demand by 2020 Suburban electric trains operational by 2022 (project by SARD)

continued on next page

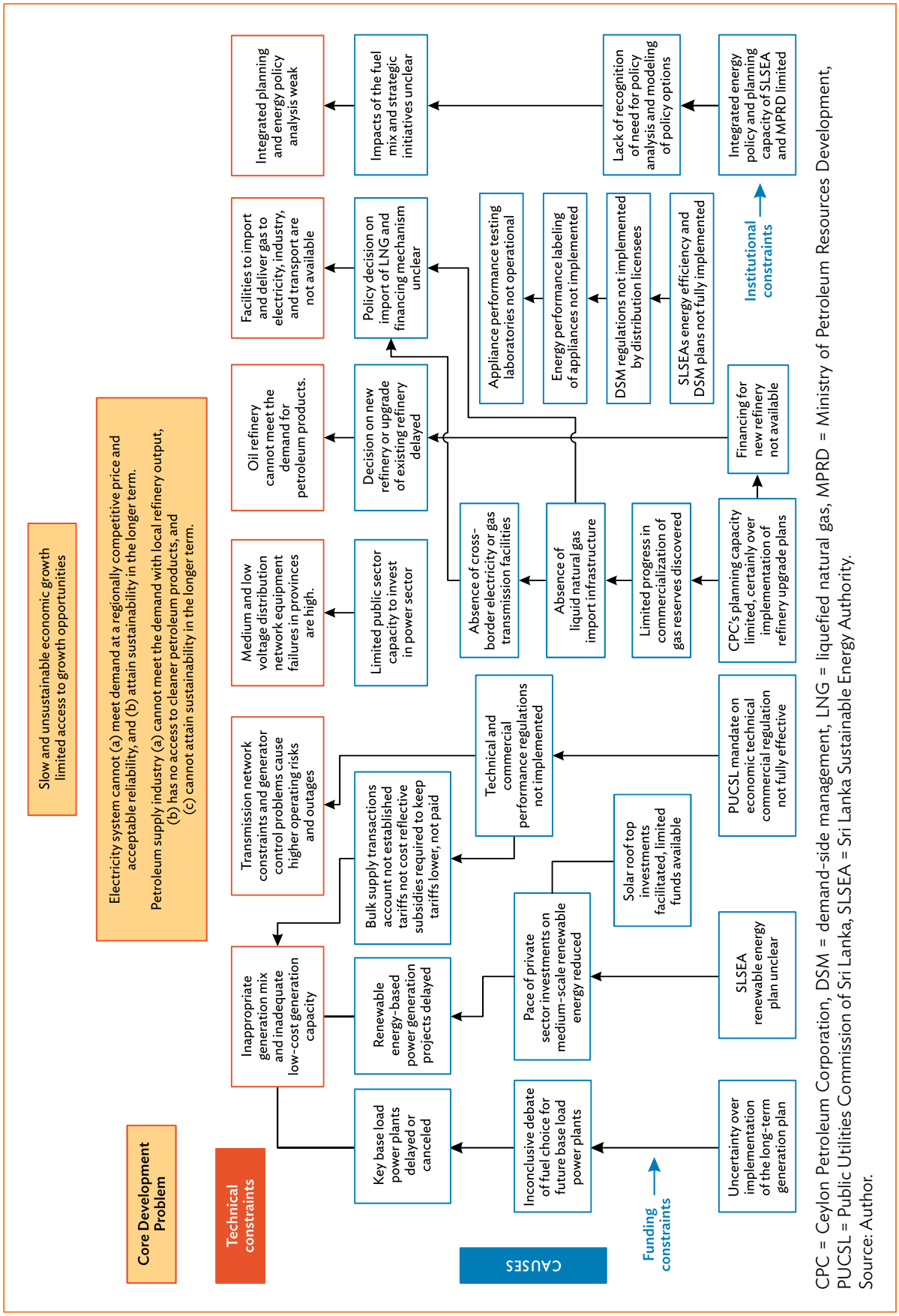
Table 18 continued

Country Sector Outcomes		Country Sector Outputs		ADB Sector Operations	
Outcomes with ADB Contribution	**Indicators with Targets and Baselines**	**Sector Outputs with ADB Contribution**	**Indicators with Incremental Targets**	**Ongoing and Planned ADB Interventions**	**Main Outputs Expected from ADB Interventions**
Consolidating electricity sector reforms and establishing petroleum industry regulation	Electricity sector reforms implementation: 2016: partial 2020: complete	Technical, commercial, and economic regulation in the electricity sector enhanced	Technical and commercial performance monitored and reported 2016: none 2020: full Provisions of economic regulation, including tariff methodology, implemented 2016: partial 2020: complete	Review of electricity act implementation, adherence to license conditions, degree of adherence to tariff methodology	Review conducted, conclusions agreed upon by 2018 Enhanced and compete tariff methodology implemented by 2019 Electricity industry prices comprehensively cost-reflective by 2022
	New petroleum industry act operational. 2016: none 2020: new act operational	Technical, commercial, economic, and safety regulation in the petroleum sector established	Provisions of the new petroleum act implemented 2016: none 2020: complete	Petroleum pricing review, to establish pricing methodology under the new petroleum act	Petroleum product pricing transparently conducted and published by 2020
Developing gas industry facilities for storage and delivery	Import and delivery facilities of liquefied natural gas established. 2016: none 2022: gas imported and delivered to key sector	LNG storage and delivery facilities established	Regasified LNG (R-LNG) delivered to power plants 2016: none 2022: operational R-LNG delivered to industrial zones 2016: none 2022: operational	Project preparatory technical assistance Investment project approved by 2018	Identify projects for ADB assistance by 2017 Project implementation by 2022

ADB = Asian Development Bank, DSM = demand-side management, LNG = liquefied natural gas, MW = megawatt, PV = photovoltaic, SARD = ADB South Asia Department.

Source: Author.

Figure 30: Sri Lanka Energy Sector Problem Tree



CPC = Ceylon Petroleum Corporation, DSM = demand-side management, LNG = liquefied natural gas, MPRD = Ministry of Petroleum Resources Development, PUCSL = Public Utilities Commission of Sri Lanka, SLSEA = Sri Lanka Sustainable Energy Authority.
Source: Author.

APPENDIXES

Appendix 1: Existing Large Hydropower Stations

Plant Name	Units x Capacity (MW)	Capacity (MW)
Canyon	2 x 30	60
Wimalasurendra	2 x 25	50
Old Laxapana	3 x 9.5 + 2 x 12.5	53.5
New Laxapana	2 x 58	116
Polpitiya	2 x 37.5	75
Laxapana Total		**354.5**
Upper Kotmale	2 x 75	150
Victoria	3 x 70	210
Kotmale	3 x 67	201
Randenigala	2 x 61	122
Ukuwela	2 x 18.5	37
Bowatenna	1 x 40	40
Rantembe	2 x 24.5	49
Mahaweli Total		**809**
Samanalawewa	2 x 60	120
Kukule	2 x 37.5	75
Small hydro		20.45
Samanala Total		**215.45**
Existing Total		**1,379.95**

Source: Summarized from information available in Ceylon Electricity Board. 2017. *Long-Term Generation Expansion Plan 2018–2037*.

Appendix 2: Existing Thermal Power Stations

CEB-owned

Plant Name	Fuel	Units x Capacity (MW)	Gross Generation Capacity (MW)	Effective Gross Capacity (MW)	Year of Commission	Annual Maximum Energy (GWh)
Kelanitissa Power Station						
Gas turbine (Old)	Auto diesel	4 x 20	80	65.2	Dec 1981, Mar 1982, Apr 1982,	417
Gas turbine (New)	Auto diesel	1 x 113	113	113	Aug 1997	707
Combined cycle	Naphtha	1 x 161	161	161	Dec 2002	1,290
Kelanitissa Total			**354**	**339.2**		**2,414**
Sapugaskanda Power Station						
Diesel	FO 180cSt	4 x 20	80	69.6	1984	472
Diesel (Ext.)	FO 180cSt	8 x 10	80	69.6	Sep 1997, Oct 1999	504
Sapugaskanda Total			**160**	**139.2**		**976**
Small Thermal Plants						
Barge Mounted Plant		4x16	64	60	Acquired in Jul 2015	421
Uthuru Janani	Diesel	3 x 8.9	26.7	26.01	Jan 2013	182
Small Thermal Total			**90.7**	**26.1**		**603**
Puttalam Coal-fired Power Plant						
Coal Puttalam	Bituminous coal	1 x 300	300	275	2011	1,927
		2 x 300	300	275	2013	1,927
		3 x 300	300	275	2014	1,927
Puttalam Total			**900**	**825**		**5,782**
Total Thermal			**1,511**	**1,330**		**9,775**

continued on next page

Appendix 2 continued

IPP

Plant Name	Capacity (MW)	Plant Type	Fuel	Minimum Guaranteed Energy (GWh)	PPA Effective from	PPA Duration (years)	PPA Scheduled to Mature in	Status
Asia Power Ltd.	50.8	DG	FO 380 cSt	330	1998	20	2018	Contract ends in June, 2018
Sojitz Kelanitissa (Pvt.) Ltd.	163	CC	Auto diesel	1,200	2002	20	2022	Operational
ACE Power Embilipitiya	100	DG	FO 180 cSt	697	2004	10	2014	Re-contracted
West Coast Power	300	CC	FO 180 cSt (low S)	1,840	2009	20	2029	Operational
Northern Power	20	DG	FO 180 cSt		2009	10	2019	Operational
Total IPP	**652**							

CEB = Ceylon Electricity Board, CC = combined cycle; cSt = centi stoke (a unit to measure viscosity), DG = diesel engine generator, GWh = gigawatt-hour, IPP = independent power producer, MW = megawatt.

Source: Ceylon Electricity Board. 2017. *Long-Term Generation Expansion Plan, 2018–2037*. http://www.pucsl.gov.lk/english/wp-content/uploads/2017/05/LTGEP_2018-2037.pdf.

Appendix 3: List of Existing and Committed Power Plants

No.	Power Plant	Capacity (MW)
	Hydropower Plants (Existing)	
1	Canyon	60
2	Wimalasurendra	50
3	New Laxapana	116
4	Old Laxapana	53.5
5	Polpitiya	75
6	Kotmale	201
7	Victoria	210
8	Randenigala	122
9	Rantambe	49
10	Ukuwela	37
11	Bowetenna	40
12	Samanalawewa	120
13	Udawalawe	6
14	Inginiyagala	11.25
15	Nilambe	3.2
16	Kukule	75
17	Upper Kotmale	150
	Hydropower Plants (Committed)	
18	Broadlands	35
19	Uma Oya	122
20	Moragolla	30.2
	Hydropower Plants (Candidate)	
21	Gin Ganga	20
22	Thalpitigala	15
23	Moragahakanda	25
24	Seethawaka	20
	Other Renewable (Committed)	
25	Mannar Wind Park	100
	Thermal Power Plants	
A	Lakvijaya Coal Power Plant	900
B	Kelanithissa PP, Sojitz PP	523
C	Sapugaskanda PP, Asia Power	211
D	Uthuru Janani	27
E	CEB Barge Mounted Plant	60
F	West Coast PP	300
G	Northern Power	38
H	Ace Power Embilipitiya	100

Source: Ceylon Electricity Board. 2017. *Long-Term Generation Expansion Plan, 2018–2037*. http://www.pucsl.gov.lk/english/wp-content/uploads/2017/05/LTGEP_2018-2037.pdf.

Appendix 4: Uncommitted Transmission Development Projects

No.	Description	Commissioning Year
1	Construction of Victoria–Rantambe 220 kV Transmission Line	2020
2	Vavuniya Grid Substation 220 kV Development	2020
3	Colombo Port City Development Project—Phase 1	2020
4	Construction of Homagama 132/33 kV Grid Substation	2020
5	Augmentation of Ambalangoda 132/33 kV Grid Substation	2020
6	Construction of Kerawalapitiya–Port 2nd 220 kV Cable	2021
7	Construction of Hambantota–Matara 132 kV Transmission line	2021
8	Reconstruction of New Anuradhapura–Trincomalee 132 kV Transmission Line with Zebra	2021
9	Construction of Laxapana–Wimalasurendra 132 kV Transmission Line with Zebra	2021
10	Construction of Samanalawewa–Embilipitiya 132 kV Transmission Line with Zebra	2021
11	Construction of Kotugoda 220/33 kV Grid Substation	2021
12	Reconstruction of New Habarana–New Anuradhapura 220 kV Transmission Line	2021
13	Augmentation of Pannala 132/33 kV Grid Substation	2021
14	Augmentation of Aniyakanda 132/33 kV Grid Substation	2021
15	Augmentation of Embilipitiya 132/33 kV Grid Substation	2021
16	Construction of Tissamaharama 132/33 kV grid Substation	2021
17	Installation of BSC at Colombo City Grid Substations	2021
18	Construction of Colombo K 220/132/11 kV Grid Substation	2022
19	Construction of Sub P (Narahenpita)	2022
20	Construction of Sub Q (Town Hall)	2022
21	Construction of Kandy City 132/11 kV Grid Substation	2022
22	Construction of Pannipitiya-Panadura 132 kV Transmission Line with 2xZebra	2022
23	Construction of Mirigama 220/132/33 kV Grid Substation	2022
24	Construction of Kalawana 132/33 kV Grid Substation	2022
25	Construction of Milleniya 132/33 kV Grid Substation	2022
26	Colombo Port City Development Project—Phase 2	2023
27	Construction of Chemmany 132/33 kV Grid Substation	2023
28	Construction of Wariyapola 132/33 kV Grid Substation	2023
29	Construction of Pothuvil 132/33 kV Grid Substation	2023
30	Construction of Serunuwara 132/33 kV Grid Substation	2023

continued on next page

Appendix 4 continued

No.	Description	Commissioning Year
31	Construction of Biyagama Zone 132/33 kV Grid Substation	2023
32	Construction of Ja- Ela LECO 132/11 kV Grid Substation	2023
33	Construction of Katunayaka LECO 132/11 kV Grid Substation	2023
34	Construction of Negombo 132/33 kV Grid Substation	2022
35	Construction of Kahawatta 132/33 kV Grid Substation	2023
36	Construction of Welimada 132/33 kV Grid Substation	2023
37	Construction of Millewa 132/33 kV Grid Substation	2023
38	Construction of Rajagiriya 132/11 kV GIS Grid Substation	2023
39	Construction of Baddegama 132/33 kV Grid Substation	2023
40	Construction of Hambantota Port 132/33 kV Grid Substation	2023
41	Construction of Weligama 132/33 kV Grid Substation	2023
42	Reconstruction of New Laxapana–Balangoda 132 kV Transmission Line with Zebra	2023
43	Installation of 50Mvar BSC at Galle Grid Substation	2023
44	Construction of Keeriyankalliya 132/33 kV Grid Substation	2024
45	Augmentation of Athurugiriya 132/33 kV Grid Substation	2024
46	Augmentation of Kesbawa 132/33 kV Grid Substation	2024
47	Reconstruction of Balangoda–Deniyaya–Galle 132 kV Transmission Line with Zebra	2025
48	Augmentation of Chunnakkam 132/33 kV Grid Substation	2025
49	Augmentation of Valachchena 132/33 kV Grid Substation	2025
50	Construction of Yakkala 132/33 kV Grid Substation	2026
51	Augmentation of Kalutara 132/33 kV Grid Substation	2026
52	Augmentation of Kirindiwela 132/33 kV Grid Substation	2026
53	Capacity enhancement of 132 kV Lynx transmission lines to Zebra—Laxapana Complex	2027
54	Construction of Panadura T—Matugama 132 kV Transmission Line with 2xZebra	2027
55	Installation of BSC at Colombo Port City Grid Substations	2027
56	Installation of 40 Mvar BSC at New Chilaw Grid Substation	2027
57	Construction of 40 Mvar BSC at Padukka Switching Station	2027
58	Construction of Dehiwala–Ratmalana 132 kV Underground Cable	2027

BSC = breaker-switched capacitors , kV = kilovolt, LECO = Lanka Electricity Company, Mvar = megavolt-ampere reactive.

Source: Ceylon Electricity Board. 2018. *Long-Term Transmission Development Plan, 2018–2027*. December.

Appendix 5: Uncommitted Power Plant Connection Projects

No.	Description	Commissioning Year
1	Power transmission facilities related to 70 MW furnace oil-fired power plant	2018
2	Power transmission facilities related to 150 MW furnace oil-fired power plant 35 MW GT	2018
3	Power transmission facilities related to Kelanitissa 2x35 MW GT	2019
4	Transmission Development for Interconnection of 600 MW LNG at Kerawalapitiya	2019
5	Construction of Puttalam Wind Collector 132/33 kV grid substation	2019
6	Construction of Ethimale Solar Collector Grid Substation	2019
7	Power transmission facilities related to Kelanitissa 1x35 MW GT	2020
8	Development of N-Collector Grid Substation	2020
9	Construction of Ginganga 132/33 kV grid substation	2022
10	Connection of Seethawaka Hydropower Plant	2022
11	Power transmission facilities related to 2x300 MW new coal power plant - Trincomalee	2023
12	Construction of Kokilai Wind Collector 132/33kV grid substation	2023
13	Transmission Development for Interconnection of 100 MW Solar at Pooneryn	2023
14	Transmission Development for Interconnection of 300 MW LNG at Kelanthissa	2023
15	Construction of Hambantota 100 MW Solar Collector Grid Substation	2025
16	Construction of Mannar Solar Collector Grid Substation	2026

GT = gas turbine, kV = kilovolt, LNG = liquefied natural gas, MW = megawatt.
Source: Ceylon Electricity Board. 2018. *Long-Term Transmission Development Plan, 2018–2027*. December.

Appendix 6: Customer Electricity Tariffs Applicable from November 2014

Customer Category and Consumption Per Month	Energy Charge (SLRs/ kWh)	Fixed Charge (SLRs/ month)
Domestic (D)		
0–30	2.50	30.00
31–60	4.85	60.00
Above 60 kWh per month		
0–60	7.85	NA
61–90	10.00	90.00
91–120	27.75	480.00
121–180	32.00	480.00
>180	45.00	540.00
Optional time-of-use tariff (active from September 2015)		
Day	25.00	540.00
Peak	54.00	
Off-peak	13.00	
Religious (R)		
0–30	1.90	30.00
31–90	2.80	60.00
91–120	6.75	180.00
121–180	7.50	180.00
>180	9.40	240.00

Customer Category and Consumption Per Month or the Time Interval, if Applicable	Energy Charge (SLRs/ kWh)	Fixed Charge (SLRs/ month)	Maximum Demand Charge Per Month (SLRs/kVA)
Industry (I)			
I-1			
up to 301 kWh/month	10.80	600.00	–
above 300 kWh/month	12.20		
I-2			
Day	11.00		
Peak	20.50	3,000.00	1,100.00
Off-peak	6.85		
I-3			
Day	10.25		
Peak	23.50	3000.00	1,000.00
Off-peak	5.90		
Hotel (H)			
H-1	21.50	600.00	–
H-2			
Day	14.65		
Peak	23.50	3,000.00	1,100.00
Off-peak	9.80		
H-3			
Day	13.70		
Peak	22.50	3,000.00	1,000.00
Off-peak	8.80		
General purpose (GP)			
GP-1			
up to 301 kWh/month	18.30	240.00	–
above 300 kWh/month	22.85	240.00	–
GP-2			
Day	21.80		
Peak	26.60	3,000.00	1,100.00
Off-peak	15.40		
GP-3			
Day	20.70		
Peak	25.50	3,000.00	1,000.00
Off-peak	14.35		
Government (GV)			
GV-1	14.65	600.00	–
GV-2	14.55	3,000.00	1,100.00
GV-3	14.35	3,000.00	1,000.00

kVa = kilovolt-ampere, kWh = kilowatt per hour, PUCSL = Public Utilities Commission of Sri Lanka, SLRs = Sri Lankan rupees.

Notes:

1. "Government" means schools, hospitals, vocational training institutions, and universities including those fully owned by the government, funded through the national budget, and providing services free of charge to the general public.
2. "Month" means a 30-day billing period.
3. Codes refer to the tariff codes presently used for billing by the distribution licensees.
4. Customers in I-2, I-3, H-2, H-3, GP-2 and GP-3, as well as GV 2,3, would pay based on mandatory time-of-use tariffs. Time intervals applicable are as follows.

Interval description	Interval (hours)
Day	05.30 to 18.30
Peak	18.30 to 22.30
Off-peak	22.30 to 05.30

Source: PUCSL. 2014. Customer tariffs effective from September 2014.

Sri Lanka – Energy Sector Assessment, Strategy, and Road Map

This report discusses Sri Lanka's energy sector structure, government strategy, policy, and development plans. It reviews previous support from the Asian Development Bank (ADB) and other development partners, and outlines ADB's experience and strategy in the country's energy sector. The report complements the Sri Lanka–ADB country partnership strategy for 2018–2022 and provides background information about investment and technical assistance operations in the energy sector.

About the Asian Development Bank

ADB is committed to achieving a prosperous, inclusive, resilient, and sustainable Asia and the Pacific, while sustaining its efforts to eradicate extreme poverty. Established in 1966, it is owned by 68 members —49 from the region. Its main instruments for helping its developing member countries are policy dialogue, loans, equity investments, guarantees, grants, and technical assistance.

ADB

ASIAN DEVELOPMENT BANK
6 ADB Avenue, Mandaluyong City
1550 Metro Manila, Philippines
www.adb.org

ISBN 978-92-9261-888-9
9 789292 618889