FACULTY OF DEFENCE AND STATEGIC STUDIES

GENERAL SIR JOHN KOTELAWALA

DEFENCE UNIVERSITY

RENEWABLE ENERGY AND CHALLENGES TO OVERCOME THE UPCOMING POWER CRISIS

SYNDICATE – 09

INTAKE 37

DS COMMENTS

SUB SYNDICATE MEMBERS

1.	5842	S/C/Q/M/Sgt	MSM MARSHAD
2.	5877	C/Sgt	KGNS KARUNARATHNE
3.	5662	L/O/Cdt	DM ABEYSINGHE
4.	5824	L/O/Cdt	HR MALLIKARACHCHI
5.	5866	O/Cdt	UWDL SENARATHNE
6.	5869	O/Cdt	PMP RODRIGO
7.	5874	O/Cdt	MMUI ABEYKOON
8.	5886	O/Cdt	MDDC JAYARATHNA
9.	5921	O/Cdt	BGAI KAUSHALYA
10.	5923	O/Cdt	KN DILHARA

DECLARATION

We declare that this does not incorporate, without acknowledgement, any material previously submitted for a degree or a diploma in any university and to the best of our knowledge and belief, it does not contain any material previously published and written by another person or ourselves except where due reference is made in the text. We also hereby give consent for our dissertation, if accepted, to be made available for photocopying and for interlibrary loans, and for the summary to be made available to outside.

Date: …………………………. ………………………………..

KGNS KARUNARATHNE

Cadet Sergeant

5877

Syndicate Leader

CERTIFICATION OF SUPERVISORS

Name of the Syndicate Leader : Cadet Sergeant KGNS KARUNARATHNE

Name of the Military Directing Staff : Major HA Basnayaka

Signature of the Supervising Military
Directing Staff : …………………………………………….

Name of the Academic Supervisor : Captain (Retd) Eng SU Dampage

Signature of Academic Supervisor : ……………………………………………

ABSTRACT

1. The Growth of human civilization has led to an increase in consumption of energy. Due to certain reasons power crisis makes a high demand on energy. When we consider about renewable energy there are several types such as:

a. Solar energy
b. Wind power
c. Hydro energy
d. Tidal energy
e. Geothermal energy
f. Biomass energy

2. There are so many environmental effects due to non-renewable energy where we can reduce it with renewable sources. Also economically power crisis makes an impact. When comparing to other sources, renewable energy costs a very cheap amount of generations. Several renewable energy types use different kinds of sources to produce energy. We had a study on CEB reports and they have some long-term, medium-term, and short-term solutions to overcome the power crisis where we also discussed some new ideas. The objective is to provide awareness and sufficient education on the upcoming power crisis and the ways to overcome those challenges.

ACKNOWLEDGEMENT

No one work alone in the journey of life. We would like to express our deep gratitude to Maj. HA Basnayaka for his advice and assistance in keeping our progress on schedule. We would also like to thank Capt (Retd) SU Damage for his patience, guidance, enthusiastic encouragement, and useful criticism provided in this case study. We take this opportunity to acknowledge the service of the library and the training support officers who collaborated in producing this work. The assistance, cooperation, and experience of our fellow undergraduates were essential for the completion of our presentation. Finally, we wish to thank our parents, family members, and loved ones for their support and encouragement throughout this study and syndicate presentation.

CONTENTS

LIST OF TABELS

LIST OF FIGURES

LIST OF ABBREVIATIONS

1.	NCRE	:	Non-Conventional Renewable Energy
2.	CEB	:	Ceylon Electricity Board
3.	IPP	:	Individual Power Producer
4.	MW	:	Mega Watt
5.	US	:	United State
6.	RE	:	Renewable Energy
7.	kW	:	Kilo Watt
8.	CSP	:	Concentrated Solar Power
9.	PV	:	Photovoltaic
10.	ORE	:	Other Renewable Energy
11.	LED	:	Light Emitting Diode
12.	HVDC	:	High Voltage Direct Current
13.	EIA	:	Environmental Impact Assessment
14.	LECO	:	Lanka Electric Company

OBJECTIVES

1. To recognize current power supply in Sri Lanka.

2. To identify the actions taken in Sri Lanka to overcome power crisis.

3. To implement innovative ideas to resolve power crisis in Sri Lanka.

AIM

This presentation aims to provide awareness and sufficient education on renewable energy and the most serious and prevailing challenges to overcome the upcoming power crisis.

CHAPTER ONE

INTRODUCTION

POWER CRISIS

1. The power crisis is the concern that the world's demands on the limited natural resources that are used to power industrial society are diminishing as the demand rises. These natural resources are in limited supply. While they do occur naturally, it can take hundreds of thousands of years to replenish the stores.

CAUSES FOR THE POWER CRISIS

2. It would be easy to point the finger at one practice or industry and lay the blame for the entire energy crisis at their door, but that would be a very naive and unrealistic interpretation of the cause of the crisis.

3. **Overconsumption.** The energy crisis is a result of many different strains on our natural resources, not just one. There is a strain on fossil fuels such as oil, gas, and coal due to overconsumption. Which then, in turn, can put a strain on our water and oxygen resources by causing pollution.

4. **Overpopulation.** Another cause of the crisis has been a steady increase in the world's population and its demands for fuel and products. No matter what type of food or products you choose to use from fair trade and organic to those made from petroleum products in a sweatshop not one of them is made or transported without a significant drain on our energy resources.

5. **Poor Infrastructure.** Poor infrastructure of power generating equipment is yet another reason for energy shortage. Most of the energy producing firms keep on using outdated equipment that restricts the production of energy. It is the responsibility of utilities to keep on upgrading the infrastructure and set a high standard of performance.

6. **<u>Unexplored Renewable Energy Options</u>.** Renewable energy still remains unused in most of the countries. Most of the energy comes from non-renewable sources like coal. It, therefore, remains the top choice to produce energy.

7. **<u>Delay in Commissioning of Power Plants</u>.** In a few countries, there is a significant delay in the commissioning of new power plants that can fill the gap between demand and supply of energy. The result is that old plants come under huge stress to meet the daily demand for power. When supply doesn't match demand, it results in load-shedding and breakdown.

8. **<u>Wastage of Energy</u>**. In most parts of the world, people do not realize the importance of conserving energy. It is only limited to books, the internet, newspaper ads, lip service, and seminars. Unless we give it a serious thought, things are not going to change anytime sooner.

   a. Simple things like switching off fans and lights when not in use, using maximum daylight, walking instead of driving for short distances, using CFL instead of traditional bulbs, proper insulation for leakage of energy can go a long way in saving energy.

9. **<u>Poor Distribution System.</u>** Frequent tripping and breakdown are a result of a poor distribution system.

10. **<u>Major Accidents and Natural disasters</u>.** Major accidents like pipeline burst and natural disasters like eruption of volcanoes, floods, earthquakes can also cause interruptions to energy supplies. The huge gap between supply and demand for energy can raise the price of essential items, which can give rise to inflation.

11. **<u>Wars and Attacks</u>.** Wars between countries can also hamper the supply of energy, especially if it happens in Middle East countries like Saudi Arabia, Iraq, Iran, Kuwait, UAE, or Qatar. That's what happened during the 1990 Gulf war when the price of oil reached its peak causing global shortages and created major problems for energy consumers.

12. **Miscellaneous Factors.** Tax hikes, strikes, military coup, political events, severe hot summers or cold winters can cause a sudden increase in demand for energy and can choke supply. A strike by trade unions in an oil-producing firm can cause an energy crisis.

EFFECTS OF THE GLOBAL POWER CRISIS

13. The growth of human civilization has led to an increase in the consumption of traditional sources of energy. The very basic source of energy is precious fossil fuels. The usage of all these sources is bound to produce certain effects. Some important effects of the global energy crisis are as follows:

a. Environmental effect
b. Economic impact

ENVIRONMENTAL EFFECTS

14. Energy is produced by the burning of non-renewable fossil fuels. This does not only affect the global resources of fossil fuels, but it also affects the environment. The burning of fossil fuels releases greenhouse gases like carbon dioxide and others.

15. These gases create a blanket on the earth's surface, which prevents the release of the short rays of the sun by night. Thus, the energy crisis facilitates making the earth a warmer place by promoting global warming.

16. Greenhouse gases are that which absorb and emit thermal infrared radiation which causes the gradual heating of Earths' atmosphere which is known as the greenhouse effect. There are natural as well as anthropogenic compounds which contribute to this effect. Water vapor (H_2O),Carbon Dioxide (CO_2), Methane (CH_4), Nitrous Oxide (N_2O) and Atmospheric Octane (O_3) (though present only in very minute quantities) are primary greenhouse gases in the Earths' atmosphere. There are also anthropogenic greenhouse gases such as Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs) and Sulphur hexafluoride (SF_6).

17. When considering the greenhouse gases, CO_2 is one of the primary gases which contribute towards warming of earths' atmosphere. Table 1 indicate CO_2 emissions from fuel combustion in each sector in Sri Lanka for the year 2016.It could be observed that approximately 41.5% of CO_2 emission from the electricity sector while major contributor for CO_2 emission is the transport sector which account for approximately 44.8%.

	CO_2 emissions *Million tons of CO_2*	
Total	**20.89**	**100.0%**
Electricity and heat production	8.67	41.5%
Other energy industry own use	0.04	0.2%
Manuf. industries and construction	1.62	7.8%
Transport	9.36	44.8%
Other sectors	1.2	5.7%

Table 01: CO_2 Emission

Source: Internet

<u>ECONOMIC IMPACT</u>

18. According to figures from the central bank, Sri Lanka generated 15,714 GWh of electricity last year (2020). Coal power plants accounted for 36.6 percent, while furnace oil accounted for 26.6 percent. Hydropower provided 24.9 percent, and non-conventional renewable energy sources provided 11.9 percent.

19. However, total electricity generation improved from June 2020, with the restoration of normally to the economy. As the average reservoir level remained healthy during the seven months ending in July 2020, hydropower generation was higher during the period from January to July 2020 compared to the corresponding period of the previous year.

20. When comparing 2019 and 2020 Sri Lanka central bank stated that due to the COVID-19 pandemic electricity cost marginally declined. Large and small Industries was close, and the use of electricity also reduced.

21. The lockdown imposed to curtail the spread of COVID-19 hampered the progress of activities about the construction of new power plants during the first half of 2020.

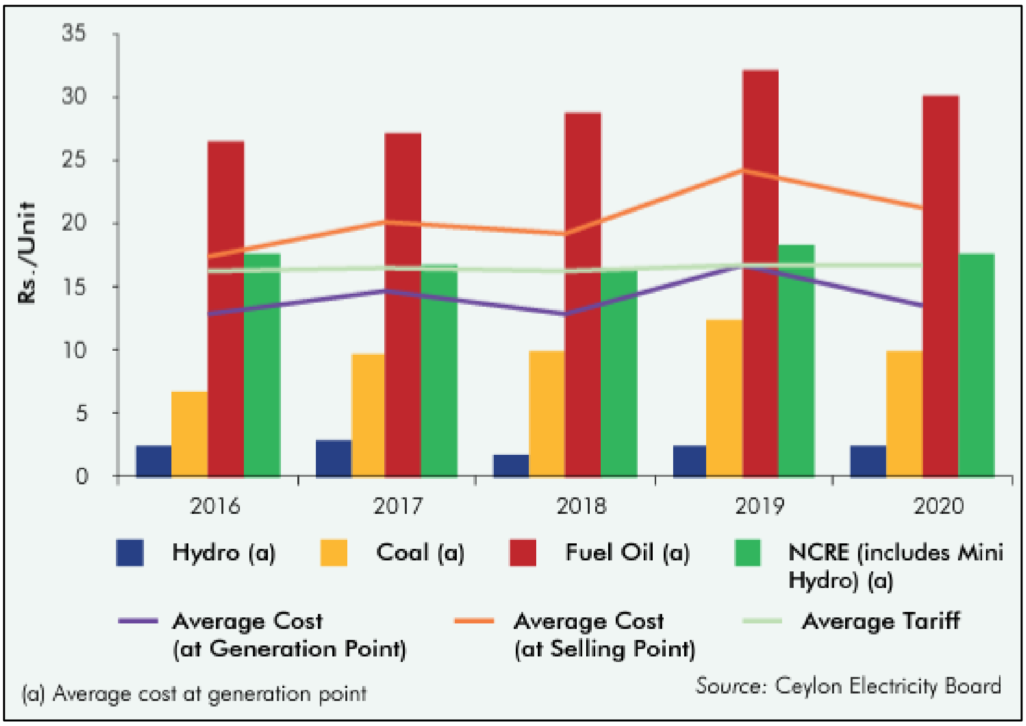

Figure 1: Average cost and average tariffs of electricity - Sri Lanka

Source: Internet

22. Accordingly, hydropower generation increased by 20.4 per cent to 1,853 GWh during the period under review.

23. When compared to the period from January to July 2019, lower demand for electricity alongside high levels of hydro and coal-based power generation resulted in a decline of fuel oil-based power generation by 25.7 per cent to 2,686 GWh during the seven months ending in July 2020.

24. Meanwhile, during the period under review, power generation through non-conventional renewable energy sources (NCRE), including mini-hydro and rooftop solar, increased by 6.8 per cent.

25. Accordingly, the contribution of hydro, coal, fuel, and NCRE to total power generation in the seven months ending in July 2020, stood at 20.6 per cent, 39.6 percent, 29.9 percent and 9.9 percent, respectively. Meanwhile, the CEB accounted for 70.6 percent of the total power generation in the country, while the remainder was generated by IPPs. Meanwhile, the total installed electricity generation capacity of the country stood at 4,316 MW by the end of July 2020.

Item	2019	2020 (a)	Growth Rate (%)	
			2019	2020 (a)
Average Cost of CEB (Rs./kWh)	12.91	9.90	36.0	-23.3
Hydro	2.49	2.32	38.6	-7.0
Fuel Oil	32.12	29.94	11.7	-6.8
Coal	12.45	9.81	25.4	-21.2
Average Cost of Private Sector (Rs./kWh)	26.47	22.56	8.2	-14.8
Fuel Oil	30.16	27.87	-5.7	-7.6
NCRE (b)	18.22	17.55	11.6	-3.7
Overall Average Cost (Rs./kWh)				
Selling Point	24.11	21.20	26.0	-12.0
Generation Point	16.62	13.56	30.3	-18.4
Average Tariff (Rs./kWh)	16.63	16.72	2.0	0.6
Domestic	14.13	14.87	3.9	5.2
General Purpose	23.94	23.91	0.7	-0.1
Government	18.18	18.06	-0.3	-0.7
Industrial	14.72	14.84	0.0	0.8
Hotel	17.71	18.13	0.6	2.4

(a) Provisional
(b) Average cost of hydro is included under NCRE

Source: Ceylon Electricity Board

Table 02: Average cost and average tariffs of electricity – Sri Lanka

Source: Internet.

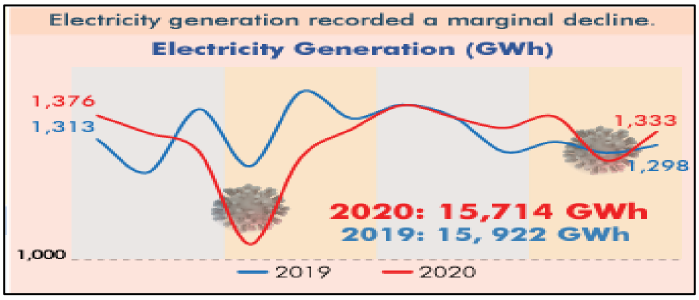

Figure 02: Average cost and average tariffs of electricity - Sri Lanka

Source: Internet

Item	2019 (a)	2020 (b)	Growth Rate (%)	
			2019 (a)	2020 (b)
Installed Capacity (MW)	4,217	4,263	4.1	1.1
Hydro (c)	1,399	1,383	-	-1.1
Fuel Oil (d)	1,282	1,268	12.8	-1.1
Coal	900	900	-	-
NCRE (e)	636	713	4.1	12.1
Units Generated (GWh)	15,922	15,714	3.6	-1.3
Hydro (c)	3,783	3,911	-26.5	3.4
Fuel Oil (d)	5,016	4,182	38.2	-16.6
Coal	5,361	5,754	12.5	7.3
NCRE (e)	1,761	1,866	-3.8	5.9
Total Sales by CEB (GWh)	14,611	14,287	3.7	-2.2
Domestic and Religious	4,863	5,172	4.8	6.4
Industrial	4,392	4,164	2.4	-5.2
General Purpose and Hotel (f)	3,563	3,238	4.4	-9.1
Street Lighting	109	109	0.1	0.2
Bulk Sales to LECO	1,684	1,605	2.7	-4.7
LECO Sales (GWh)	1,646	1,569	5.1	-4.7
Domestic and Religious	692	716	8.1	3.4
Industrial	293	269	1.7	-8.1
General Purpose and Hotel (f)	640	562	3.7	-12.1
Street Lighting	21	22	-	2.4
Overall Transmission and Distribution Loss of CEB (%)	8.2	9.1	-1.3	10.3
Number of Consumers ('000) (g)	6,501	6,636	2.3	2.1
o/w Domestic and Religious	5,692	5,792	2.0	1.8
Industrial	64	66	2.8	2.5
General Purpose and Hotel (f)	744	777	4.9	4.5

(a) Revised
(b) Provisional
(c) Excluding mini hydro power plants
(d) Inclusive of Independent Power Producers (IPPs)
(e) Refers to Non-Conventional Renewable Energy including mini hydro
(f) Inclusive of sales to government category
(g) Inclusive of LECO consumers

Sources: Ceylon Electricity Board (CEB)
Lanka Electricity Company (Pvt) Ltd (LECO)

Table 03: Electricity sector performance (2019-2020)

Source: Internet

26. During the first half of 2020, the Government continued to enhance the electrification level in the country while promoting the use of renewable energy. During the period under review, 17 rural electrification schemes were completed, benefiting 2,319 families. Meanwhile, under the 'Soorya Bala Sangramaya' project, 395 consumers were connected to the national grid under the Net Metering scheme, adding 3.1 MW to the grid during the first half of 2020

27. Furthermore, 1,050 consumers joined the project under the Net Accounting scheme adding 10.4 MW while under the Net Plus scheme 126 electricity producers joined the project, adding 10.3 MW under the Net Plus scheme. By end June 2020, solar power generation encompassed 18,628 solar energy consumers and producers in the country whilst solar power capacity stood at 222.7 MW.

28. However, Sri Lanka does not have a large quantity of fossil fuel resources; thus, it must rely significantly on imports, resulting in high import expenses. Sri Lanka government has stated that renewable energy sources would fulfill 70% of its energy needs by 2030.

29. According to Ceylon electricity board Sri Lanka has always imported 46-50 percent of its overall energy needs. This is a significant economic burden that may be reduced by focusing on renewable energy sources.

30. Avoiding the commissioning of coal-fired capacity would result in considerable fuel cost reductions. When compared to the base case scenario, which largely relies on coal, the 100 percent RE scenario may save US$18-US$19 billion on imported coal by 2050.

31. Savings would grow significantly as we approach 2050, according to this graph. According to the base case scenario, renewable energy will account for 20% of total generation, while coal will account for 50%. By 2050, the 100 percent RE scenario expects non-fossil fuels (including big hydro) to provide 100 percent of electricity, while all coal and gas facilities will be removed progressively by 2045.

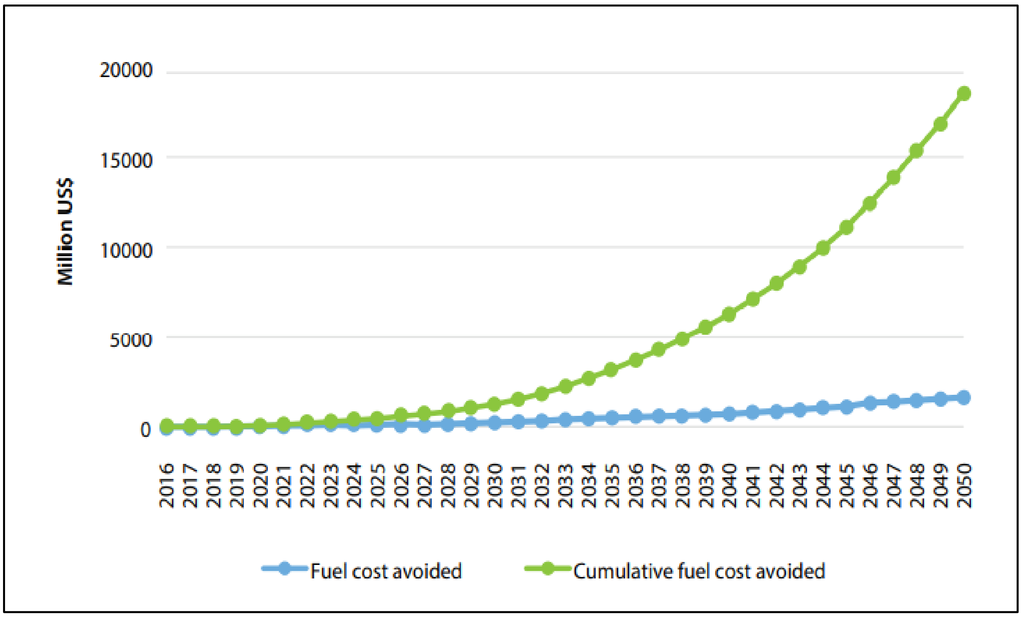

Figure 03: Economics savings from fuel cost avoidance

Source: Internet

32. The Sri Lankan government intends to fulfill the policy goal between 2030 and 2050. In that scenario, wind and solar will play a significant role. Some hydro power projects are currently under construction. In addition to these large-scale projects, the nation has 200 megawatts of hydro mini-power plants.

33. When it comes to renewable energy resources, Sri Lanka has significant solar and wind potential that has yet to be completely exploited and focusing on renewable energy in the future will be a great investment. With yearly solar radiation ranging from 4.5 to 6.0 kWh/m^2/day, the overall wind potential is expected to reach 20000 MW.

34. Furthermore, by reducing the risk of commodity price and currency volatility, the business case for a high RE scenario will be strengthened.

RENEWABLE ENERGY SOURCES

35. A renewable energy source means energy that is sustainable - something that can't run out, or is endless, like the sun. When you hear the term 'alternative energy' it's usually referring to renewable energy sources too. It means sources of energy that are alternative to the most commonly used non-sustainable sources - like coal.

36. The most popular renewable energy sources currently are:

a. Solar energy
b. Wind energy
c. Hydro energy
d. Tidal energy
e. Geothermal energy
f. Biomass energy

SOLAR ENERGY

37. Energy can be harnessed directly from the sun, though only slightly during cloudy weather. Solar energy is used worldwide and is increasingly popular for generating electricity or heating and desalinating water.

38. Solar power is generated in two main ways:

a. Photovoltaics
b. Concentrated solar power

39. **Photovoltaics (PV).** Also called solar cells, are electronic devices that convert sunlight directly into electricity. The modern solar cell is likely an image most people would recognize - they are in the panels installed on houses and in calculators. Today, PV is one of the fastest-growing renewable energy technologies and is ready to play a major role in the future global electricity generation mix.

a. Solar PV installations can be combined to provide electricity on a commercial scale or arranged in smaller configurations for mini-grids or personal use. Using solar PV to power mini-grids is an excellent way to bring electricity access to people who do not live near power transmission lines.

b. The cost of manufacturing solar panels has plummeted dramatically in the last decades, making them an affordable form of electricity. Solar panels have a lifespan of roughly 25 years and come in variety of shades depending on the type of material used in manufacturing.

40. **<u>Concentrated Solar Power (CSP)</u>.** Uses mirrors to concentrate solar rays. These rays heat fluid, which is run through a heat exchanger to create steam to drive a turbine and generate electricity. CSP is used to generate electricity in large-scale power plants.

a. A CSP power plant usually features a field of mirrors that redirect rays to a tall thin tower. One of the main advantages of a CSP power plant over a solar PV power plant is that it can be equipped with molten salts in which heat can be stored, allowing electricity to be generated a few hours after the sunset.

b. Sri Lanka receives significant amount of solar radiation across all geographical regions. The Global Horizontal Irradiance (GHI) varies between 1,247 kWh/m2 to 2,106 kWh/m2. It is interesting to note that the intensity of solar irradiation in lowland areas is high compared to mountainous regions. This is largely due to the continuous presence of clouds in mountainous areas and the shadowing effect of mountains. The intensity variation of Direct Normal Irradiance (DNI) is similar to that of GHI.

<u>WIND POWER</u>

41. Wind Power is one of the fastest-growing renewable energy technologies. Usage is on the rise worldwide, in part because costs are falling.

42. Wind turbines first emerged more than a century ago. Following the invention of the electric generator in the 1830s, engineers started attempting to harness wind energy to produce electricity. Wind power generation took place in the United Kingdom and the United States in 1887 and 1888, but modern wind power is considered to have been first developed in Denmark.

43. Wind is used to produce electricity using the kinetic energy created by air in motion. This is transformed into electrical energy using wind turbines or wind energy

conversion systems. Wind first hits a turbine's blades, causing them to rotate and turn the turbine connected to them. That changes the kinetic energy to rotational energy, by moving a shaft which is connected to a generator, and thereby producing electrical energy through electromagnetism.

44. The amount of power that can be harnessed from wind depends on the size of the turbine and the length of its blades. The output is proportional to the dimensions of the rotor and to the cube of the wind speed. Theoretically, when wind speed doubles, wind power potential increases by a factor of eight.

45. Wind-turbine capacity has increased over time. In 1985, typical turbines had a rated capacity of 0.05 megawatts (MW) and a rotor diameter of 15 meters. Today's new wind power projects have turbine capacities of about 2 MW onshore and 3 - 5 MW offshore.

46. Commercially available wind turbines have reached 8 MW capacity, with rotor diameters of up to 164 meters.

HYDROELECTRIC ENERGY

47. Hydropower is energy derived from falling water. More than 2,000 years ago, the ancient Greeks used waterpower to run wheels for grinding grain; today it is among the most cost-effective means of generating electricity and is often the preferred method where available. The world's largest hydropower plant is the 22.5-gigawatt - Three Gorges Dam in China. It produces 80 to 100 terawatt-hours per year, enough to supply between 70 million and 80 million households.

48. Small-scale micro-hydropower projects can make a big difference to communities in remote locations.

49. The basic principle of hydropower is using water to drive turbines. Hydropower plants consist of two basic configurations: with dams and reservoirs, or without. Hydropower dams with large reservoirs can store water over short or long periods to meet peak demand. The facilities can also be divided into smaller dams for different

purposes, such as night or day use, seasonal storage, or pumped-storage reversible plants, for both pumping and electricity generation. Hydropower without dams and reservoirs means producing at a smaller scale, typically from a facility designed to operate in a river without interfering in its flow. It is also called "run-of-the-river" projects. Many consider small-scale hydro a more environmentally friendly option.

50. Hydro power is a key energy source used for electricity generation in Sri Lanka, which provided almost all the electricity until early 1990s. A large share of the major hydro potential has already been developed and delivers valuable low-cost electricity to the country. Currently, hydro power stations are operated to supply both peaking and base electricity generation requirements. A substantial number of small hydro power plants which operate under the Standardized Power Purchase Agreement (SPPA) and more are expected to join the fleet during the next few years.

BIOMASS

51. Biomass, also called Bioenergy, are fuels that is developed from organic materials. It is a renewable and sustainable source of energy used to supply mainly heat for various applications, while it is marginally used for power generation as well.

52. Bioenergy use falls into two main categories: ‘traditional’ and ‘modern’. Traditional use refers to the combustion of biomass in such forms as wood, animal waste and traditional charcoal. Modern bioenergy technologies include liquid biofuels produced from bagasse and other plants; bio-refineries; biogas produced through anaerobic digestion of residues; wood pellet heating systems; and other technologies.

53. About three-quarters of the world’s renewable energy use involves bioenergy, with more than half of that consisting of traditional biomass use. Bioenergy accounted for about 10% of total final energy consumption and 1.4% of global power generation in 2015.

54. Biomass has significant potential to boost energy supplies in populous nations with rising demand, such as Brazil, India and China. It can be directly burned for heating or power generation, or it can be converted into oil or gas substitutes. Liquid

biofuels, a convenient renewable substitute for gasoline, are mostly used in the transport sector.

55. In Sri Lanka, biomass still plays a dominant role in the supply of primary energy. Large quantities of firewood and other biomass resources are used for cooking in rural households and to a lesser extent, in urban households. Even though a large portion of energy needs of the rural population is fulfilled by firewood, there are possibilities to further increase the use of biomass for energy in the country, especially for thermal energy supply in the industrial sector.

GEOTHERMAL ENERGY

56. By harnessing the natural heat below the earth's surface, geothermal energy can be used to heat homes directly or to generate electricity. Although it harnesses a power directly below our feet, geothermal energy is of negligible importance in the UK compared to countries such as Iceland, where geothermal heat is much more freely available.

TIDAL ENERGY

57. This is another form of hydro energy that uses twice-daily tidal currents to drive turbine generators. Although tidal flow unlike some other hydro energy sources isn't constant, it is highly predictable and can therefore compensate for the periods when the tide current is low.

NON RENEWABLE ENERGY SOURCE

58. Fossil fuels are not a renewable source of energy because they are not infinite. Plus, they release carbon dioxide into our atmosphere which contributes to climate change and global warming.

59. Burning wood instead of coal is slightly better but its complex. On the one hand, wood is a renewable resource – provided it comes from sustainably managed forests.

Wood pellets and compressed briquettes are made from by-products of the wood processing industry and so arguably it’s recycling waste.

60. Compressed biomass fuels produce more energy than logs too. On the other hand, burning wood (whether it be raw timber or processed waste) releases particles into our atmosphere.

ZERO-CARBON OR LOW-CARBON ENERGY

61. Nuclear-generated electricity isn't renewable but its zero-carbon, which means its generation emits low levels or almost no CO_2, just like renewable energy sources. Nuclear energy has a stable source, which means it's not dependent on the weather and will play a big part in getting Britain to net zero status.

CHAPTER TWO

SRI LANKAN POWER GENERATION AND POWER DEMAND

62. The existing generating system in the country is mainly owned by CEB with a considerable share owned by the private sector. Until 1996 the total electricity system was owned by CEB. Since 1996, private sector has also participated in power generation. The existing generating system in the country has approximately 4046 MW of installed capacity by 2019 including non-dispatch able plants of capacity 610 MW owned by private sector developers. The majority of dispatch able capacity is owned by CEB (i.e. about 84% of the total dispatchable capacity), which includes 1398.85 MW of hydro and 1504 MW of thermal generation capacity. Balance dispatchable capacity, which is totally thermal plants, is owned by Independent Power Producers (IPPs).

HYDRO AND OTHER RENEWABLE POWER PLANTS

63. **CEB Owned.** Most of the comparatively large scale hydro resources in Sri Lanka have been developed by the CEB. At present, hydro projects having capacities below 10MW (termed mini hydro), are allowed to be developed by private sector as run-of river plants and larger hydro plants are to be developed by the CEB. Since these run-of river type mini hydro plants are non-dispatch able, they are modeled differently from CEB owned hydro plants in the generation expansion planning simulations. The operation and maintenance cost of these CEB hydro power plants was taken as 12.24 US$/kW per annum.

a. CEB generating system has a substantial share based on hydropower (i.e.1398.85 MW hydro out of 2903 MW of total CEB installed capacity). Approximately 48% of the total existing CEB system capacity is installed in 17 hydro power stations and 32 % of the total energy demand was met by the major hydro plants in 2018. Details of the existing and committed hydro system are given in Table 04 and the geographical locations of the Power Stations are shown in the Figure 04. The major hydropower schemes already developed are associated with Kelani and Mahaweli river basins. Five hydro power stations with a total installed capacity of 369.8 MW (26% of the total hydropower capacity) have been built in Laxapana Complex where two cascaded systems are associated with the two main tributaries of Kelani River, Kehelgamu Oya and Maskeliya Oya. The five stations in this complex are generally not required to operate for irrigation or other water requirements; hence they are primarily designed to meet the power requirements of the country. Castlereigh and Moussakelle are the major storage reservoirs in the Laxapana hydropower complex located at main tributaries.

b. Kehelgamu Oya and Maskeliya Oya respectively. Castlereigh reservoir with active storage of 52 MCM feeds the Wimalasurendra Power Station of capacity 2 x 25MW at Norton-bridge, while Canyon 2 x 30MW is fed from the Moussakelle reservoir of storage 108 MCM.

Plant Name	Units x Capacity	Capacity (MW)	Expected Annual Avg. Energy (GWh)	Active Storage (MCM)	Rated Head (m)	Year of Commissioning
Canyon	2 x 30	60	160	107.9 (Moussakelle)	207.2	1983 - Unit 1 1989 - Unit 2
Wimalasurendra	2 x 25	50	112	52.01 (Castlereigh)	227.3 8	1965
Old Laxapana	3x 9.6+ 2x12.5	53.8	286	0.245 (Norton)	472.4	1950 1958
New Laxapana	2 x 58	116	552	0.629 (Canyon)	541	Unit 1 1974 Unit 2 1974
Polpitiya	2 x 45	90	453	0.113 (Laxapana)	259	1969
Laxapana Total		**369.8**	**1563**			
Upper Kotmale	2 x 75	150	409	0.8	473	Unit 1 - 2012 Unit 2 - 2012
Victoria	3 x 70	210	865	688	190	Unit 1 - 1985 Unit 2 - 1984 Unit 3 - 1986
Kotmale	3 x 67	201	498	154	201.5	Unit 1 - 1985 Unit 2&3 – '88
Randenigala	2 x 61.3	122.6	454	462	77.8	1986
Ukuwela	2 x 20	40	154	2.1	75.1	Unit 1&2 – '76
Bowatenna	1 x 40	40	48	23.5	50.9	1981
Rantambe	2 x 25	50	239	3.4	32.7	1990
Nilambe	2 x 1.6	3.2	-	0.005	110	1988
Mahaweli Total		**816.8**	**2667**			
Samanalawewa	2 x 60	120	344	218	320	1992
Kukule	2 x 37.5	75	300	1.67	186.4	2003
Small hydro		17.25				
Samanala Total		**212.25**	**644**			
Existing Total		**1398.85****	**4874**			
Committed						
Broadlands	2x17.5	35	126	0.198	56.9	2020
Moragolla	2x15.1	30.2	97.6	1.98	69	2023
Mannar Wind Park		103.5	337			2020
Multi-Purpose Projects						
Uma Oya	2x61	122	290	0.7	722	2021
Total		**290.7**	**850.6***			

Table 04: Existing and Committed Hydro and Other Renewable Power Plants

Source: Internet

No.	Power Plant	Capacity MW
	Hydro Power Plants (Existing)	
1	Canyon	60
2	Wimalasurendra	50
3	New Laxapana	116
4	Old Laxapana	53.8
5	Polpitiya	90
6	Kotmale	201
7	Victoria	210.3
8	Randenigala	126.8
9	Rantambe	51.8
10	Ukuwela	38.6
11	Bowatenna	40
12	Samanalawewa	120
13	Udawalawe	6
14	Inginiyagala	11.25
15	Nilambe	3.2
16	Kukule	75
17	Upper Kotmale	150
18	Moragahakanda	25
	Hydro Power Plants (Committed)	
19	Broadlands	35
20	Uma Oya	122
21	Moragolla	30.2
	Hydro Power Plants (Candidate)	
22	Thalpitigala	15
23	Seethawaka	24
	Other Renewable (Committed)	
24	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

Figure 04: Location of Existing, Committed and Candidate Power Stations

Source: Internet

c. Mannar Wind Park is the first large scale wind power project developed in Sri Lanka. During the 1st stage 103.5 MW of wind power will be developed by CEB in the southern coast of the Mannar Island which would contribute 337 GWh of mean annual energy.

64. **<u>Other Renewable Power Plants Owned By IPPs</u>.** Initially, Government of Sri Lanka has taken a policy decision to develop hydropower plants below 10MW capacities through private sector participation. Many small hydro plants and other renewable power plants have been connected to the system since 1996. Apart from mini hydro power plants, during recent years, there has been a substantial increase in Wind and Solar additions to the system.

a. Total capacity of these plants is approximately 610 MW as at 31st December 2018. These plants are mainly connected to 33kV distribution lines. As of 31st December 2018, CEB has signed standard power purchase agreements and issued Letter of Intents for another 539MW of ORE power plants to be developed. The existing Capacity contributions from other renewables as of are tabulated in Table 05.

b. In this study, a capacity and energy contributions from these mini hydro and other non-conventional renewable energy plants were considered in the base case as committed and modeled accordingly.

Project Type	Number of Projects	Capacity (MW)
Mini Hydro Power	197	393.5
Wind Power	15	128.45
Biomass	12	37.09
Solar Power	8	51.36

Table 05: Existing Other Renewable Energy (ORE) Capacities
Source: Internet

THERMAL GENERATION

65. **CEB Thermal Plants.** Majority of the present thermal power generating capacity in the country is owned by CEB with a total capacity of 1504 MW. It is made up of Lakvijaya Coal power plant of 900MW, Kelanitissa Gas Turbines of 195MW, Kelanitissa Combined Cycle plant of 165MW, Sapugaskanda Diesel power plants of 160MW, Uthuru Janani diesel power plant of 24 MW and Barge Mounted Plant of 64MW. The Lakvijaya Coal plant 900MW funded by EXIM Bank China commissioned in 2011 (Phase I) and 2014 (Phase II) was the latest thermal power plant addition to the CEB system.

Plant Name	No of Units x Name Plate Capacity (MW)	No of Units x Capacity used for Studies (MW)	Annual Max. Energy (GWh)	Commissioning
Puttalam Coal Power Plant				
Lakvijaya CPP	3 x 300	3 x 270	5355	2011 & 2014
Puttalam Coal Total	**900**	**810**	**5355**	
Kelanitissa Power Station				
Gas turbine (Small GTs)	4 x 20	4 x 17	382	Dec 81, Mar 82, Apr 82,
Gas turbine (GT 7)	1x 115	1 x 115	703	Aug 97
Combined Cycle (JBIC)	1x 165	1 x 161	1196	Aug 2002
Kelanitissa Total	**360**	**344**	**2281**	
Sapugaskanda Power Station				
Diesel	4 x 20	4 x 17	493	May 84, May 84, Sep 84, Oct 84
Diesel (Ext.)	8 x 10	8 x 9	481	4 Units Sept 97 4 Units Oct 99
Sapugaskanda Total	**160**	**140**	**974**	
Other Thermal Power Plants				
Uthuru Janani	3 x 8.9	3 x 8.9	184	Jan 2013
Barge Mounted Plant	4 x 16	4 x 15.6	515	Acquired in 2015
Existing Total Thermal	**1510.7**	**1383.1**	**9309**	
Committed				
Kelanitissa Gas	3 x 45	130		2021
Committed Total Thermal	**135**			

Table 06: Details of Existing and Committed Thermal Plants

Source: Internet

66. **<u>Independent Power Producers (IPPs)</u>.** Apart from the thermal generating capacity owned by CEB, Independent Power Producers have commissioned diesel power plants and combined cycle power plants given in Table 07.

Plant Name	Name Plate Cap. (MW)	Cap. used for Studies	Min. Guarenteed Ann. Energy (GWh)	Commissioning	Contract Period. (Yrs.)
Independent Power Producers					
Sojitz Kelanitissa (Pvt.) Ltd	163	163	-	GT- March 2003 ST - October 2003	20
ACE Power Embilipitiya Ltd+	100	99.5	697	2005 April	10
West Coast (Pvt) Ltd.	300	270	-	2010 May	25
Existing Total IPP	**563**	**532.5**			
Committed	-	-	-		
Reciprocating Engine Power Plants at the Grid Substations of Habarana, Moneragala, Horana and Pallekelle	4 x 24	4 x 24		2021	
NG fired Combined Cycle Power Plant	300	287		2022	
Committed Total IPP	**396**	**383**	-		

Table 07: Details of Existing and Committed IPP Plants

Source: Internet

CHAPTER THREE

RENEWABLE ENERGY GENERATION EXPANSION OPTIONS

HYDRO POWER CAPACITY EXTENSIONS

67. Sri Lanka was a Hydro Power dependent nation till the late 1990s in which the majority of the power requirement was met from hydropower plants. The hydropower potential in the country has been vastly exploited and only a limited amount of generation projects remains in the pipeline. The portion of this hydro potential has been already exploited under the Upper Kotmale Hydro Power Project, which is the latest addition to a large-scale hydropower project in Sri Lanka.

68. **Mahaweli Complex.** The "Hydro Power Optimization Study of 2004" suggested possible expansions of Ukuwela, Victoria, and Rantambe Power Stations due to high plant factors. Out of those, it is difficult to expand Rantambe for peaking requirements because it has to comply with water release for irrigation demand as a priority.

69. **Laxapana Complex.** Also, under the Hydro Power Optimization Study further, studies were carried out to upgrade Wimalasurendra Power Station, New Laxapana power station & Old Laxapana Power Station. And also for upgrading of the Samanalawewa and Polpitiya Power Stations, studies were carried out from February to June 2010 by POYRY Energy AG, Switzerland. Under the upgrading of Wimalasurendra and New Laxapana Power Stations, planned replacement of generator, turbine governor excitation & controls, and transformer protection have been completed by the Generation Division. The capacity of the New Laxapana Power Station has been increased from 100MW to 115.2MW. The planned replacement of generator, turbine governor excitation & controls of the old Laxapana Project were completed increasing the plant efficiency and also the plant capacity has been increased from 50MW to 53.5MW. Expansion of Polpitiya Power Station implemented and the plant capacity increased to 90MW from 75MW from 2019.

OTHER RENEWABLE ENERGY DEVELOPMENT

70. Growth of other renewable energy sources in Sri Lanka in commercial scale initiated with the development of mini-hydro and wind resources in mid-nineties. The project development was led largely by the private sector with the facilitation of Ceylon Electricity Board and the country's renewable energy industry has been growing continuously over the years with both local and foreign investments. Currently, Ceylon Electricity Board is engaged in developing first large scale renewable energy projects in the country.

71. Share of Other Renewable Energy based generation at present is 11% of total energy generation in the country and its contribution is expected to increase in the future. At the end of 2018, 610.4 MW of other renewable energy power plants have been connected to the national grid and the total comprises 393.5 MW of mini-hydro, 128.5 MW of wind, 51.4 MW of Solar PV and 37.1 MW of biomass based generation capacities. In addition, the rooftop solar PV capacity with a total of 170MW that are embedded at the consumer end is also achieving notable growth in its contribution.

72. At the end of the year 2018, the total renewable energy capacity has reached 2009 MW which includes 1399 MW of Major Hydro and 610 MW of other renewable energy capacity Figure 07 provides the future increase in planned capacities of other renewable energy technologies. The projected target of total another renewable energy capacity by 2021 is 1245 MW which is more than twice of current ORE capacity and aspiring progress in project development and implementation is essential to reach near term targets.

Year	Energy Generation (GWh)		Capacity (MW)	
	Other Renewable	System Total	Other Renewable	Total System Installed Capacity
2004	206	8043	73	2499
2005	280	8769	88	2411
2006	346	9389	112	2434
2007	344	9814	119	2444
2008	433	9901	161	2645
2009	546	9882	181	2684
2010	724	10714	212	2818
2011	722	11528	227	3141
2012	730	11801	320	3312
2013	1178	11962	367	3355
2014	1215	12418	442	3932
2015	1466	13154	455	3850
2016	1160	14148	516	4018
2017	1464	14,671	563	4087
2018	1762	15,305	585	4048

Table 08: Energy and Demand Contribution from Other Renewable Sources

Source: Internet

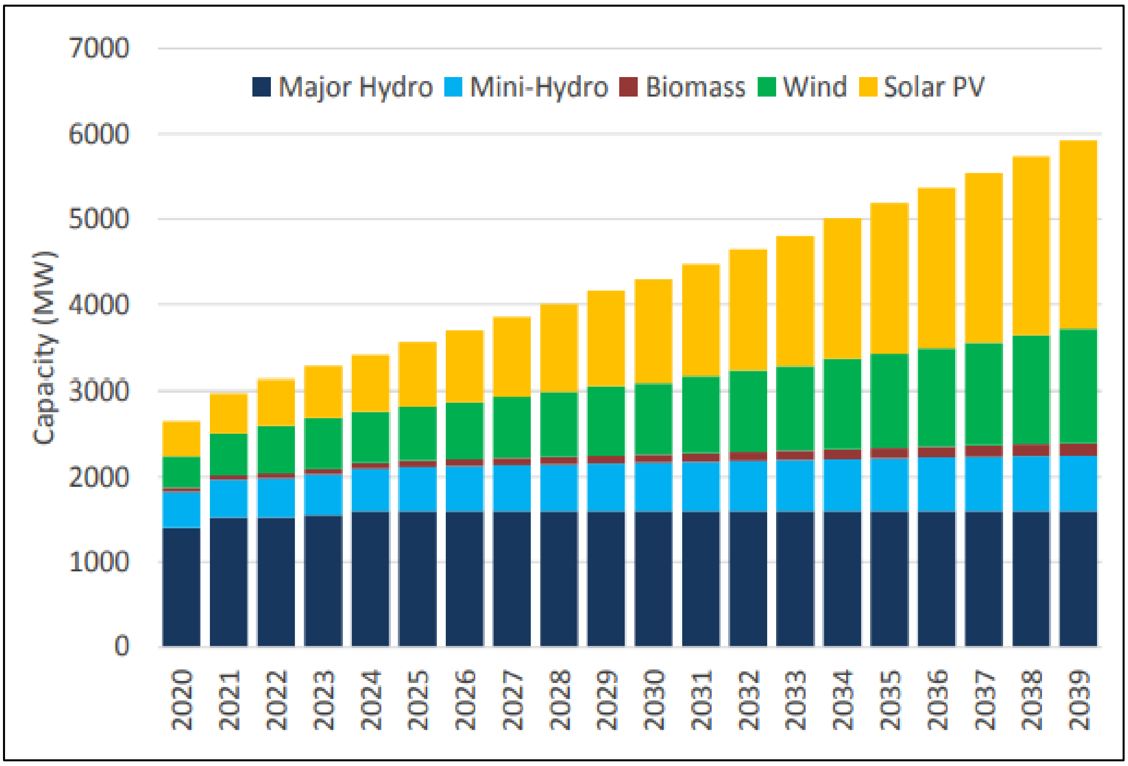

Figure 05: Total Renewable Energy Capacity Development

Source: Internet

WIND POWER DEVELOPMENT

73. Sri Lanka is blessed with quality wind resources mainly located in the North-western coastal area, Northern area and central highland area. Mainly greater wind power potential is available in the areas that are exposed to southwest monsoon. Only a portion of the total available potential is economically exploitable due to various reasons such as competing land uses, accessibility and environmentally sensitive concerns.

74. **Development of Mannar Wind Farm Project.** Ceylon Electricity Board is currently engaged in developing a large scale wind farm project in the Mannar Island located in the Northern Province. The project is located in the southern coast of the Mannar Island and the necessary wind farm infrastructure will be developed under the project. Being one of the attractive wind resources in the country, this 100MW is expected to generate annually around 337GWh. Ceylon Electricity Board received financial assistance from Asian Development Bank (ADB) for the development of this key project. At present, the feasibility study, Environmental Impact Assessment (EIA) and land procurement process have been finalized and the site construction work commences in the first quarter of 2019.

SOLAR POWER DEVELOPMENT

75. Sri Lanka, being located within the equatorial belt, has substantial potential in solar resource. Solar resource maps of the country indicate the existence of higher solar resource potentials in the northern half, eastern and southern parts of the country. Resource potential in other areas including mountainous regions is mainly characterized by climatic and geographical features. Exploitation of available resource requires the consideration of competing land uses and availability of transmission and distribution infrastructure.

76. **Development of Rooftop Solar PV Installations.** Roof top solar systems are starting to play a prominent role in providing energy needs of the electricity consumers and it is an effective form of embedded generation located at the end user. Rooftop solar PV installations can significantly reduce the land use and environmental

concerns particularly in urban and suburban areas with the availability of rooftop spaces. Several schemes are adopted worldwide to create an enabling environment for small scale and roof top PV penetration. The “Energy Banking Facility” for such micro-scale generating facilities, commonly known as the “Net Energy Metering Facility” for electricity consumers was introduced in Sri Lanka in 2010 by the Ministry of Power and Renewable Energy, Ceylon Electricity Boards (CEB) and Lanka Electric Company (LECO). This scheme allows any electricity consumer to participate as a producer to generate electricity with a renewable energy source for own usage as well as to export any excess energy. The installed capacity of the generating facility shall not exceed the contract demand of the customer. The consumer is not paid for the export of energy, but is given credit (in kWh) for consumption of same amount of energy for subsequent billing periods. No financial compensation is paid for the excess energy exported by the consumer. The electricity bill is prepared taking into account the difference between the import and the export of energy. At present, country has about 14,700 such installations under Net metering scheme amounting to 106MW of solar power.

77. **Development of Small Scale Distributed Solar PV Project.** Ceylon Electricity Board initiated the development of 60MW with 1MW Solar PV projects at 20 selected Grid substations through international competitive bidding process. Extending this initiative, its second phase was launched to develop 90 MW of 1 MW solar PV plants with improved contractual terms to provide more facilitation and flexibility to developers. As a results significant number of bids were attracted during this second phase of 1MW solar development projects. Projects from both phases are currently in progress at various stages in the project development activities. This initiative is expected to continue in future to develop 1 MW and 10 MW solar power plants in the country.

78. **Development of Large Scale Solar PV Parks.** Large scale solar PV part development has its own advantageous in economies of scale and also technical challenges. Large scale solar PV park developments is planned for the future and initial assessments and planning work have been initiated for the Poonyryn, Siyambalanduwa in Moneragala areas. Further, Sri Lanka Sustainable Energy Authority has identified resource locations for large scale development in Trincomalee, Ampara, Monaragala, Hambantota, Kurunegala, and Anuradhapura areas in future years.

DEVELOPMENT OF STORAGE TECHNOLOGIES

79. Storage technologies are diverse and their applications are rapidly expanding globally. Their applications in power systems are growing and can range from Energy shifting, Frequency Controlling, and renewable energy fluctuation controlling. The economic value of different technologies varies depending on the type of application, amount of energy required, amount of power required and the location of the application. High Energy density storage systems are suitable for performing energy shifting function in system operation whereas high power density storage technologies are suitable to provide fast power to manage instantaneous and momentary supply demand unbalances. Battery energy storages and pumped hydro energy storages are two major storage technologies applicable to power systems today.

80. **Pumped Storage Hydro Power Development.** Being a matured technology, pumped hydro storage currently accounts for nearly 97% of the storage applications in power systems worldwide. Primarily function of pumped hydro storage was to provide peaking capacity releasing the stored energy and however the technology has now evolved to provide enhanced services to enable flexible grid operation especially with renewable energy integration.

81. **Development of Grid Scale Battery Energy Storages.** Battery energy storage applications in power systems are expanding globally and the technology costs are declining notably. Even though the scale of battery energy storages applications in power systems are small compared to pumped hydro storages, battery energy storages have a wide array of applications in all generation, transmission distribution and consumer end points. Given the range of applications, battery energy storages are employed to enhance the quality and reliability of supply of electricity.

CHAPTER FOUR

OPTIONS TO OVERCOME THE POWER CRISIS

82. To overcome the power crisis in Sri Lanka need to go through a proper energy plan categorizes under short term, medium term and long term solutions.

SHORT TERM SOLUTIONS

83. To achieve short term solutions we can implement some options as educate and motivate people about the crisis and guide them to use electricity in proper manner and also recommend some renewable products and less use of more power consuming old electric devices for day today activities.

84. As a short-term solution, the government might encourage renewable technology and giving concessional loans for solar panel installation. Reduce the tariff and taxes of low power consuming products. Customers can then use solar lights, solar heaters.

85. Awareness campaigns promoting the use of energy-efficient appliances and discouraging the use of defective appliances and electricity theft can also assist to alleviate power shortages to some extent.

86. Government/social groups can promote the adoption of LED lights or compact fluorescent lamps, which consume significantly less electricity than conventional lamps, with the aid of energy efficiency/demand side management initiatives.

MEDIUM TERM SOLUTIONS

87. Provide facilities for insurance and energy permits. Also the Geographical Information System should be updated.

88. Using suitable measures identify the places where efficient renewable power plants can establish. And make enough actions to make it possible. Use Renewable

sources in government sectors such as schools, hospitals religious Places etc. for their Administrative works and provide balance powers to CEB.

89. Increase the Demand for energy efficiency by labeling the electric appliances and promote it among consumers as the value of Labeling.

90. Introduce energy as a subject in the school curriculum and develop school energy groups. Also Contribution to the promotion of energy research at universities and research institutes.

LONG TERM SOLUTIONS

91. There is a specific time that all the factories start their machines and make a high demand on energy which CEB requires to switch alternative generators to produce energy. Therefore to overcome this energy demand every factory can either make separate time schedules or generate required energy by own, using the solar panels, generators and get enough power to start all the machinery.

92. Establishment of an Energy Efficiency Measurement Laboratory and make it as a government sector then we can Certify the each and every products before the product comes to market.

93. Nuclear-generated electricity isn't renewable but Nuclear energy has a stable source, So We can implement Nuclear power Generation with considering economic, environmental and educational requirements and Make long term Actions to overcome the power crisis.

94. Make Proper Agreement with neighbor countries to share energy through High Voltage Direct Current (HVDC) Line.

95. There is a huge energy loss in Energy Transmission Lines to overcome this we can improve the Transmission line By Replacing.

CHAPTER FIVE

CONCLUSION

96. Renewable energy is used to overcome the upcoming power crisis in Sri Lanka also in the world. We have discussed short-term and long-term solutions also can implement few projects to overcome the future crisis.

97. In the absence of power, Inadequacy and high cost of power generation, transmission inadequacy, and reliability and quality of electricity supply High cost and price of electricity, the high debt load of electricity, and the high price of petroleum goods are the issues confronting Sri Lanka's power industry.

98. Because it relies on hydropower, coal, and fossil fuels, Sri Lanka's usage of renewable sources, except hydro, is very low. This will result in an unstable energy supply during the dry seasons, and the unit cost will be determined by the prices set by other nations that sell coal and fossil fuels to the global market.

99. Sri Lanka is now undergoing significant infrastructural and technological development, which will result in high energy demand in the future. As a result, it is critical to conduct the study and assess the global use of renewable energy power harvesting technologies such as pump storage power plants, osmotic plants, ocean current/wave energy harvesting, and so on.

100. The New Government Policy on ‘Deciding the Energy Mix for Electricity Generation in Sri Lanka' identifies the need to diversify the energy mix through the integration of more renewable energy sources such as wave energy, geothermal, ocean thermal, municipal solid waste, and biomass in addition to solar, wind, mini hydro, and biomass.

REFERENCES

Cbsl.gov.lk. 2020. Annual Report 2020 | Central Bank of Sri Lanka. [online] Available at: <https://www.cbsl.gov.lk/en/publications/economic-and-financial-reports/annual-reports/annual-report-2020> [Accessed 12 October 2021].

Cbsl.gov.lk. 2020.[online] Available at: <https://www.cbsl.gov.lk/sites/default/files/cbslweb_documents/publications/annual_report/2020/en/14_Infographics_02.pdf > [Accessed 12 October 2021].

Cbsl.gov.lk. 2020. Real Sector | Central Bank of Sri Lanka. [online] Available at: <https://www.cbsl.gov.lk/en/statistics/statistical-tables/real-sector> [Accessed 12 October 2021].

Data.worldbank.org. 2021. Access to electricity (% of population) - Sri Lanka | Data. [online] Available at: <https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=LK> [Accessed 12 October 2021].

Tradingeconomics.com. 2021. Sri Lanka | Energy & Mining | World Bank Development Indicators. [online] Available at: <https://tradingeconomics.com/sri-lanka/indicators-wb-data.html?g=energy+%26+mining> [Accessed 12 October 2021].

Siyambalapitiya, T., & Wijayapala, W. (2013). Managing the impacts of higher costs of renewable energy. In KDU International Research Symposium Proceedings (pp. 218-224). General Sir John Kotelawala Defence University. https://doi.org/http://ir.kdu.ac.lk/handle/345/1099

S.Abeygunasekara. (2014). Evaluation of Solar Thermal Drying Potential Related with Fish Drying Product in Sri Lanka. International Research Conference Proceedings; Engineering, 246-252. Retrieved from http://ir.kdu.ac.lk/handle/345/1580

HDI.Samarawickrama, & RP.Gnanasena. (2014). Relationship between Feeding Pattern and Envirmental Factors with Production of Biogas Unit. In International research Conference Proceedings; Engineering (pp. 280-282). Retrieved from http://ir.kdu.ac.lk/handle/345/1585

Vicatos, G. and A. Bennett. Multiple lift tube pumps boost refrigeration capacity in absorption plants. J. Energy Southern Afr., 2007; Vol.18: 49-57

Roberto Gonzalo, Karl J. Haberman.Achitecture et efficacité énergétique.Boston:Birkhauser; 2004.

"4 hour Power cut - No power cuts on Sundays". Hiru News. Retrieved 3 April 2019.

"Sri Lanka : CEB announces power cut schedule". www.colombopage.com. Retrieved 3 April 2019.

"Sri Lanka : No power cuts during New Year, permanent solution to the power crisis by May, Minister assures". www.colombopage.com. Retrieved 3 April 2019.

"One tender. Two power companies. Two power plants - Sri Lanka Latest News". Sri Lanka News - Newsfirst. 10 April 2019. Retrieved 11 April 2019.