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Develop strategies to increase the Non Conventional Renewable Energy power generation in Sri Lanka above 10% level by the year 2015

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Executive summary

Many countries in the world today have drawn up targets to increase the use of renewable energy as an alternative to fossil fuels. Fossil fuels are becoming less attractive to meet the increasing world energy demand due to its volatility, ever increasing nature of price and implications on climate.

Following the world trend in the year of 2008, by releasing a national energy policy, Sri Lanka committed 10% of grid connected electricity from Non Conventional Renewable Energy (NCRE) sources by the year of 2015.

At the end of 2010, 727 GWh (6.7%) of electrical energy supplied to the national grid was from NCRE and the installed capacity of NCRE was 223 MW (7.5%). Grid connected small scale hydropower plants were contributed for the major share. Further NCRE power plants totalling to a capacity of 335 MW from small hydro, wind and dendro thermal technologies have been granted power generation licenses and they are in construction stage and expected to commit operation in 2013.

The objective of the study is to calculate the content of the non conventional renewable energy share expected to be in operation at 2015 and to decide whether that energy content will meet or exceeds the 10% of forecasted energy demand at 2015. Prevailing constraints and barriers are to be identified and then to develop strategies to overcome those identified barriers and constraints while come out with recommendations for promotional policies to increase above 10% level target at 2015.

A detailed literature survey is carried out to find out strategies adopted by the countries leading in NCRE power generation utilization. Published data like long term generation expansion plans, long term transmission expansion plan of Ceylon Electricity Board, and NCRE tariff structures by Sustainable Energy Authority are utilized throughout the study. Expert interviews and the discussions with the independent consultants in the power industry, experts in Ceylon Electricity Board, Sustainable Energy Authority and Public Utilities Commission are carried out in order to find out their views on many of the prevailing issues related to the NCRE promotion as alternative energy utilization in the country.

According to the future electricity demand forecast of Long Term Generation Expansion Plan of 2008 by Ceylon Electricity Board the generation forecast for 2015 is 18,668 GWh.

With the assumption of NCRE share available at 2010 will be fully available in 2015 and if all the committed plants will come into operation in 2015, a total of 2057 GWh of energy will be generated from NCRE technologies in 2015. This theoretical capacity results to exceed the 10% target.

According to the estimation , the untouched NCRE technical potential of 250 MW of small hydro, 1000 MW of dendro thermal and 20,000 MW of wind are available around the country. This potential is still to capture by the least economical cost based generation planning process by the authorities.

Wind power has the highest technical potential for power generation as a NCRE option but the near term capacity of wind is limited due to the grid constraints and inadequate transmission and distribution network.

Further there are many barriers for wind power integration into the power system. Wind introduces additional variability and uncertainty into the operation of power system. The present transmission and distribution systems need expansions and extensions to cater to this additional variability and uncertainty. On the other hand country does not have a state of art wind measurement and wind forecasting systems which are must for proper wind power production and integration system.

As a result of these constraints, Ceylon Electricity Board the main state owned electricity provider to the nation is reluctant to provide licenses for wind power generation and the total capacity of wind are restricted to less than 10% of total installed power generation capacity.

Due to the lack of knowledge on latest and proven technologies associated with wind power, the authorities are not considered wind as a future generation option. This situation can be witnessed by referring the latest version of long term generation expansion plan of CEB released in 2008. The same trend is there in the latest transmission expansion plan where the grid extensions for the wind rich areas are not considered. Further to address the issue of additional variability and uncertainty introduced by wind power integration, more power system flexibility is required. But at the moment country's power system is barely meeting the peak load with a low flexibility.

Mini-hydro power plants which are operating at the moment are always facing problems when at drought conditions and further most of them are still operating at old avoided cost based feed-in–tariff structure which is not attractive at all. Technologies for the dendro thermal power plants are still to emerge and the high moisture content of the fuel is the other problem faced by this particular NCRE technology.

In addition to the above constraints faced by the NCRE developers, there are many issues like limitation of project debt financing and high interest rates, permit and licensing issues, long delays of get approvals for project proposals etc.

The main supportive tool available for NCRE power generation in the country is the cost based technology specific three tired feed in tariff structure introduced in the year 2010 by the authorities.

Key feature of the tariff is, it considered to provide profits to developers from the first year of operation to meet the loan commitments, operation and maintenance costs and reasonable return on equity investments of the investors.

In order to support the NCRE power generation in the country, these prevailing issues have been identified and the strategies are set up to overcome the issues.

Capacity building program for the stakeholders , shaping the national energy planning process in favour of more share for NCRE , tariff rationalization, investment promotions , making the government bodies accountable and leverage of financial support mechanism are the general strategies discussed in detail in the thesis.

Apart from them, the wind specific strategies like investigation planning and design of grid reinforcement, introduction of wind power prediction tools to improve wind forecasting, intelligent system for wind power integration, introduction of grid codes, affiliate with wind research groups and increasing power system flexibility are discussed in detail.

At the moment the country is producing electricity using some of the most uneconomical power generation technologies resulting a very high unit cost of electricity. The thesis suggests that the government should start an accelerated power generation scheme from the NCRE technologies specially wind which is described in latter part of the report under recommendations.

Abstract

World's energy needs are increasing day by day and meeting that ever increasing demand by fossil fuels is becoming difficult due to factors like scarcity of the resource, vulnerability of supply due to political unrest of fuel rich countries, and environmental implications of usage. As a result, Usage of renewable energy resources as alternatives is becoming popular and important.

Sri Lanka has already committed to achieve 10% of grid connected electricity energy from Non Conventional Renewable Energy sources by the year 2015 and launched many programs to support that initiative.

Under this dissertation, a broad study on present and future electricity generation and transmission network of Sri Lanka are carried out referring the most recent CEB publications like Long Term Generation Expansion Plan and Transmission Expansion plans and further using the expert opinions. Special attention is given to calculate present and future (2015) Non Conventional Renewable Energy share of power generation considering the constraints and mentioning the assumptions. Existing policies to promote NCRE power generation are reviewed while discussing the barriers.

Wind has identified as the viable potential candidate as future NCRE power generation option even though the near term capacity is limited due to grid constraints and inadequate transmission and distribution network. It is recommended to the government to start an accelerated wind power harness program by addressing the issues pertaining to the technology. The strategies developed under the study are all about to achieve more than 10% target by the year 2015.

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Abbreviations

ADB	Asian Development Bank
BOI	Board of Investment
CEA	Central Environmental Authority
CEB	Ceylon Electricity Board
DSM	Demand Side Management
FIT	Feed-in-tariff
GOSL	Government of Sri Lanka
IEA	International Energy Agency
IFC	International Finance Corporation
IPP	Independent Power Producers
LECO	Lanka Electricity Company
LTGEP	Long Term Generation Expansion Plan
MOPE	Ministry of Power and Energy
NCRE	Non conventional Renewable Energy
NGO	Non Governmental Organizations
PPA	Power Purchase Agreement
PUCSL	Public Utilities Commission of Sri Lanka
RERED	Renewable Energy for Rural Economic Development
SLSEA	Sri Lanka Sustainable Energy Authority

1 Introduction

1.1 Background

The International Energy Agency (IEA) forecasts that the world's energy needs would increase by 55% by the year 2030 and more than 70% of this increase would occur in developing and newly emerging economies. Reaching this increase by fossil fuels is difficult due to the volatility, price increase and implications to the climate etc. Considering nuclear energy as an alternative, it has its own problems in safety. As a result, many countries in the world today have drawn up targets to increase the use of renewable energy as an alternative to fossil fuel.

Tropical countries in the world like Sri Lanka are blessed with various renewable energy resources. In the end of year 2011, approximately 40% of electricity generation of Sri Lanka was coming from conventional large scale hydro-power plants and the balance is coming from conventional thermal power plants. The country's power system is characterized by a high demand growth rate and total available generation capacity barely meeting the peak load. Even though the major share of electricity generation is from the thermal power technologies, the country has no indigenous fossil fuel resources and the only large scale indigenous primary source for conventional power generation is hydro but it is also limited. The increasing trend of fossil fuel prices and the heavy dependency of fossil fuels on fuel rich countries resulted comparatively high cost for power generation and therefore making losses due to subsidized electricity tariffs. Furthermore the present electricity generation system is operating with a constraint generation capacity together with inadequacy of transmission and distribution networks.

Considering the above facts, the county's energy system is under review and the planning authorities are in the process of development of national plans. The ministry of power and energy (MOPE) of Sri Lanka published the National Energy Policy in 2008 which envisaged reaching 10% of grid electrical energy from Non Conventional Renewable Energy (NCRE) by the year 2015. [1]

The country is in search of NCRE technologies which could cater for the above requirement.

NCRE includes small-scale hydro-power, biomass including dendro-power, biogas and waste, solar-power and wind-power. Other NCRE forms of energy which could be encouraged are wave energy and ocean thermal energy.

1.2 Problem Statement

It has been estimated that the technical potential of still untouched small hydro-power as 250 MW, dendro-thermal power of over 1000 MW and wind-power of over 20000 MW exist in the country[2]. But they are not captured by the least economic cost based generation planning process by the authorities due to existence of various technical, economical, social and environmental barriers.

In the year 2009, 547 GWh (5.5%) of electrical energy served through the national grid was generated by NCRE [3]. The major share of this 547 GWh of electrical energy was came from privately owned small-scale , grid connected mini and micro hydro power plants but the potential is limited for further development. The future developments should be come from wind, solar and biomass technologies with correct supportive policies and strategies which are to emerge with time.

As per the estimated demand forecast of Long Term Generation Expansion Plan (LTGEP) 2008 of CEB the forecasted generation would be 18668 GWh for the year of 2015 [4]. To reach the desired generation target of 10% by the end of the year 2015, the total annual NCRE contribution has to be increased to 1866 GWh.

1.3 Research questions

Under this dissertation, the following key relevant subject areas will be critically reviewed in detail and the questions emerged will be answered with the available published information and using the expert views obtained from the interviews with consultants in the industry.

1. CEB's LTGEP of 2005 and LTGEP of 2008 will be discussed in detail and reviewed for their opinions for NCRE promotion.

2. Environmental implications of base case plans of LTGEP of 2005 and LTGEP of 2008 will be critically reviewed.

3. The CEB's latest transmission expansion plan will be critically reviewed for its position on harnessing possible NCRE technologies into the national grid.

4. The main potentially and economically viable NCRE technology will be identified for detail discussion and its potential, technological, economical and environmental barriers will be discussed in detail supported by expert views.

5. Prevailing technical drawbacks in especially the capability of transmission network to absorb NRE technologies into the national grid, financial constraints of absorbing NCRE into the grid and particular NCRE technology specific problems will be discussed

6. The existing national energy policy and tools, particularly the tariff structures which have been already using to promote NCRE technologies will be discussed in detail and critically reviewed.

7. The already installed, commissioned and operational NCRE plant are to be operated continuously in order to achieve the NCRE target and the problem encountered by them will be discussed.

Further, as a conclusion strategies to overcome the identified barriers will be developed together with tools available and possible other tools to support NCRE target which could be promote through the National Energy Policy (NEP) as policy inputs.

1.4 Objective

Objective of this study is to develop strategies to reach minimum target of 10% of electricity energy supplied to the national grid to be from NCRE by the year 2015. The outcome will be presented to the Public Utilities Commission of Sri Lanka (PUCSL) to consider as a policy input to the government of Sri Lanka

1.5 Methodology

This dissertation is carried out by collecting information in the below described manner and the collected information are analyzed in the relevant sections of the report and summarized the findings.

- A literature survey carried on strategies already adopted by Sri Lanka and strategies adopted by other countries to promote NCRE power generation which are successful in implementing. Local Information for this literature survey is mainly collected from published information from the Sri Lankan government organizations like CEB, SLSEA, PUCSL, Central Bank of Sri Lanka and from the relevant publications by the experts of the subject. Global information is collected from published information from the World Wide Web of the organizations like IEA and World Bank and from published information of experts.

- 2010 data of NCRE share is calculated using the data gathered form CEB and SLSEA. Electricity demand for the year 2015 is taken from the published data from the CEB and the NCRE share is calculated based on the number of plants committed for operation with issued licenses for power generation up to 2015.

- NCRE tariffs published by SLSEA and consultation documents of tariffs by PUCSSL, Long-term generation expansion plans and Transmission expansion plans of CEB are used in discussions.

- Several expert interviews are carried out with the consultants of the industry, some key personnel of CEB, SLSEA and PUCSL, and IPP members in order to obtain their views and not limited to existing NCRE promotion policies, NCRE tariff structures, Long term generation expansion plans and operational viability of NCRE power plants including wind.

2 Electrical power generation in Sri Lanka

2.1 Overview of Electricity Industry

The electricity industry of Sri Lanka is comprised of the following institutions

1. Ministry of Power and Energy (MOPE) – the policy maker
2. Public Utilities Commission of Sri Lanka (PUCSL) – the regulator
3. Sri Lanka Sustainable Energy Authority (SLSEA) – the facilitator
4. Ceylon Electricity Board (CEB) – the main utility provider
5. Lanka Electricity Company (Pvt.) Limited – (LECO) – the utility provider
6. Independent Power Producers (IPPs) – private electricity companies who generate and sold electricity to CEB

MOPE formulates the policies, programs and projects with regard to the subjects of electricity power and energy and implements them. Further investigations, planning and development of electricity facilities throughout the island, renewable energy development, energy efficiency and demand side management comes under the purview of MOPE.

SLSEA is a statutory board recently established to drive Sri Lanka to a new level of sustainability in energy generation and usage and especially promoting of renewable energy power generation. It operates direct under the umbrella of MOPE.

A need for an independent regulator aroused when the electricity reforms act was introduced in 2002 in order to restructure the electricity sector which had numerous problems such as shortfall of generation capacity resulting in load-shedding, severe financial hardships faced by CEB due to mismatch in cost and price of electricity and none cost reflective nature of electricity tariff etc. With the monopoly of CEB, it was believed that CEB is to be too large to be managed efficiently.

Furthermore, there was a necessity to introduce competitiveness to the electricity industry.

PUCSL was established by the Electricity ACT no 22 of 2002 giving provisions to regulate electricity industry to address the above issues.

The latest electricity bill which was published as Electricity Act No. 20 of 2009, with the enactment the PUCSL was empowered as the fully fledge independent regulator in the electricity industry. For the successful implementation of the Electricity Act, proper functioning of PUCSL is vital. PUCSL has assigned broad functionality areas in economic, technical and regulatory fields [5].

CEB is the main and largest electricity establishment (Statutory Board) in Sri Lanka. It controls all the major functions of electricity generation, transmission, distribution and retailing. CEB owns hydro-power plants totaling of 1457 MWs, thermal power plants of 833 MWs inclusive of a coal fired power plant of 300 MW. CEB owns and operates the entire high voltage transmission network and most of the sub-transmission networks. Further CEB owns 76,102 km long low voltage distribution network by the end of 2007 and distributed electricity to 89% of the customers [6].

LECO established in the year 1983, as an electricity distribution company to distribute electricity in the areas where previously served by local authorities. LECO purchases electricity from CEB and distributes electricity in bulk and retail in the designated areas.

From the year 1996, IPPs are in the business of power generations mainly through the thermal power plants by using diesel, residual oil and combined cycle power generation technologies, small scale mini and micro hydro power plants and very recently wind power plants.

2.1.1 Electricity Generation

Since 1950, hydro electricity was developed to a state of 1355 MW comprising of both medium and large hydropower plants. In 1995, Sri Lanka produced 95% of the grid electrical energy requirement from conventional hydropower plants. The dominance of the hydro electricity changed due to non-availability of required hydro potential to construct either medium or large hydropower plants anymore. The growing demand for electricity had to be met by thermal power plants. From 1996 to 2010 Sri Lanka added 1383 MWs by oil fired power plants and in 2011 another 300 MW by coal power plant [6]

When considered NCRE at March 2011, grid connected installed capacity of mini-hydro power (MHP) was 176.05 MW, installed capacity of biomass, agriculture & industrial waste and solar was 12.8 MW, and installed capacity for wind power was 38.15 MW [7]. The total installed capacity is shown in table 2.1.1.

Table 2.1.1: Power Plants in operation in Sri Lanka National Grid, June 2011 [4], [22], [23]

Power Plant	Installed Capacity (MW)	Share of Total Capacity (%)
Hydro and Renewables		
CEB Hydro power plants	1355	41.44
Small Power producers (Hydro)	176.05	5.39
Small Power Producers (Biomass, Solar)	12.8	0.39
Small Power Producers (Wind)	35.15	1.08
CEB Wind Power Plant	3	0.09
Total Hydro and Renewable	1582	48.45
Thermal Power Plants		
CEB Thermal (inclusive of Coal fired power plant)	833	25.51
IPP Thermal (Petroleum)	850.1	26.04
Total Thermal Power Plants	1683.1	51.55
Total Grid Connected power plants	3265.1	100

CEB owns thermal power plants of 200 MW of gas turbine technology, 165 MW of combined cycle technology, 300 MW coal fired power plant technology and 168 MW of diesel power technology totaling to 833 MW of thermal power. The fuels used for those are auto diesel, naphtha, and residual oil. [4]

Independent Power Producers (IPPSs) contribute 850.1 MW to the national grid and the technologies used are combined cycle, and diesel technologies. The fuels used are auto diesel and residual oil.

Off-grid electrification has been very important for rural economic development and for many decades now the technology has being using by Sri Lanka to electrify remote areas where grid extension in comparatively expensive and not economical. Up to June 2011, 2 MW of micro-hydro power plants and 5.8 MW of Solar Home systems had installed off grid for rural electrification [7].

2.1.2 Long term Generation Expansion Plan (LTGEP)

CEB has given statutory powers to develop and maintain an efficient and economical system of electricity supply to the nation. CEB is in the business of generating, acquiring supplies of electricity, transmission and distribution. In order to meet the increasing demand of electrical energy, and to replace the thermal plants due for retirement, generation expansion planning process has to be rolled out in definite time frames. Furthermore, the implementation of least cost generation expansion sequence derived for the base demand forecast to avoid energy shortfall are at utmost important national level objectives [4].

CEB generally adopted econometric modeling process to forecast future electricity demand. Several independent variables such as previous years demand, gross domestic product (GDP), GDP per capita, and population are analyzed using regression analysis techniques. Different consumer categories such as domestic, industrial and general purpose (including hotels), religious and street lighting are analyzed separately due to different consumer habits exists in the categories. Then the final demand is estimated by adding all the categories and further adding the total estimated energy losses in order to derive the future generation forecast. The final outcome forecasted for a planning horizon is called "Base Case Plan".

The global trends of energy mix for power generation suggest that the country is using expensive types of thermal based fuel mix for power generation. This strategy and the price increasing trend of petroleum fuels cause the Government of Sri Lanka (GOSL) to incur heavy losses in financing thermal power plants.

Since 1999, CEB has been reporting losses and the GOSL has to provide grants and subsidies by various means such as direct settlement of fuel bills to the petroleum corporation of Sri Lanka and removing taxes and other levies to prevent financial collapsing of the institution.

Taking a corrective measure, that is using an economical energy mix, these heavy losses could have been reduced substantially.

2.1.2.1 Demand Forecast

CEB forecasted the system energy generation and peak demand from 2008 to 2027 in their Long Term Generation Expansion Plan (LTGEP) in 2008. This forecast was based on GDP growth forecast of Central Bank of Sri Lanka and using forecasted system losses and load factors.

Base load forecast of LTGEP 2008 of CEB is shown in table 2.1.2.1

Table 2.1.2.1: Base Load Forecast [4]

Year	Demand (GWh)	Growth Rate (%)	Gross* Losses (%)	Generation (GWh)	Load Factor (%)	Peak (MW)
2008	8644	6.5	16.2	10314	57.0	2032
2009	9533	9.7	15.7	11313	57.2	2221
2010	10393	8.6	15.4	12283	57.3	2408
2011	11373	8.8	14.9	13360	57.4	2655
2012	12429	8.8	14.5	14529	57.6	2880
2013	13560	9.2	14.5	15861	57.7	3137
2014	14767	8.2	13.9	17156	57.9	3385
2015	16051	8.8	14.0	18668	58.0	3674
2016	17416	8.5	14.0	20255	58.1	3977
2017	18886	8.3	14.0	21944	58.3	4298
2018	20423	8.2	14.0	23753	58.4	4642
2019	22088	8.2	14.0	25689	58.6	5008
2020	23871	8.1	14.0	27763	58.7	5400
2021	25784	8.0	14.0	29988	58.8	5819
2022	27840	8.0	14.0	32379	59.0	6268

*Gross Losses included transmission, distribution and any other non-technical losses

2.1.2.2 LTGEP – December 2005

In 2005, CEB presented a long term generation expansion plan called base case plan which changed the exiting oil-dominant power generation strategy into coal-dominant strategy. It suggested decommissioning of loss making thermal power plants both CEB owned and IPP owned. Accordingly five CEB owned and eight IPP owned thermal power plants have been scheduled to decommission after 2012. The timing of decommissioning would have to be decided based on their performance and loss of revenue to the GOSL.

Coal-fired thermal power plants would come into the picture in several stages to cater to the electricity demand of the country.

Table 2.1.2.2: Generation mix in the Sri Lank Grid (Base Case) [7]

Primary source	Gross Energy Dispatched to Grid (GWh)				Share of Total Gross Energy in the Grid %			
	2007	2010	2015	2020	2007	2010	2015	2020
Hydro	3946	4464	4994	4994	40.2	36.7	28.2	19.5
Biomass, Solar	1	Not included in the long term plan			Not included in the long term plan			
Wind	2	Not included in the long term plan			Not included in the long term plan			
Oil-fired Thermal	5864	7705	1009	2473	59.8	63.3	5.7	9.6
Coal-fired Thermal			11681	18187	0	0	66.1	70.9
Total	9813	12169	17684	25654	100	100	100	100

According to Table 2.1.2.1, the coal fired thermal generation is estimated to reach 70.9% of the total generation in the year 2012 while the oil fired thermal shares to be reduced to 9.6% and due to the limitation of hydro-power potential the share will be reduced to 19.5%.

In the year of 2015, share of renewable from conventional hydro-power plants estimated to reduce to 28.2% while thermal share estimated to reach 71.8% out of which coal share estimated as 66.1%

NCRE is not considered as a viable option for power generation in LTGEP of 2005 and even not included in the plan (Table 2.2.2.1).

2.1.2.3 LTGEP 2008

Large number of factors like cost of development, operation and maintenance cost, forecasted fuel cost and environmental effects were evaluated in order to select available primary energy options. In 2008 plan, remaining hydro power potential and fossil fuel based thermal plants are considered as next viable least-cost options.

The base case plan released in 2008 is shown in Table 2.1.2.2.

Table 2.1.2.3: Base Case Plan 2008 [4]

Year	Peak Demand (MW)	Capacity Additions (MW)							
		Medium Term Diesel	Gas Turbine		CCY	Coal	Hydro	Indo Lanka Connection	Total
			35MW	75MW					
2008	2032								
2009	2221				200				200
2010	2408	200			100				300
2011	2655		175	150					325
2012	2880					285	150		435
2013	3137					785			785
2014	3385					285			285
2015	3674					800			800
2016	3977					300			300
2017	4298					300			300
2018	4642					300			300
2019	5008					300			300
2020	5400					300			300
2021	5819					300			300
2022	6268							500	500
Total		200	175	150	300	3955	150	500	5430

The remaining total hydro power potential has been identified as 870 MW and the screening process used for that selection was the long term generation cost of less than 0.15 US$/kWh [4] .In this projection less than 15 MW capacities are not considered as candidates for LTGEP 2008.

In addition, the report included some interesting proposals such as capacity extension of some of the existing hydro power plants. Capacity extensions were proposed by increasing the capacity of the reservoirs by increasing dam crest and increasing number of generators. The report suggested preparing the hydro power system for peak duty while base load operation will be on thermal power plants. These options would not be viable until adequate capacity additions of thermal power plans are added to the system since the capacity addition of hydro power plants need total shut down.

According to the plan, total capacity additions forecast of 5430 MW will need to be added to the system by 2022. A share of 72.8% would come from coal fired power plants while 88% of this addition would be from fossil fuel based thermal plants. Only 2.8% from large hydro and 9.2% from Indo-Lanka connection are the other suggested additions.

For the planning process and for calculation purposes, crude oil price was taken as 66.7 US$ per barrel and price of coal was taken as 79.1 US$ per ton in this report.

Two price increase scenarios have been considered. The price increase of 20% either in coal price or petroleum price considered while keeping the other fuel prices as fixed. But in reality, prices of both crude oil and coal might increase in deferent percentages which make the calculations questionable. Hence the questionability of accuracy of these assumptions and the increasing trend of both petroleum and coal prices in the world market might keep the low cost electricity production strategy using coal in a vulnerable position.

Improper or no accounting for fuel price risk in power system planning make countries choose short-tem low cost solutions without regard for long-term risk. Further in Sri Lanka, fuel for conventional thermal power generation is always subsidized and hence it do not show the true cost resulting NCRE options difficult to compete with conventional fuels. One key advantage of NCRE is that the fuel is free most of the times.

Even though the NCRE options are briefly discussed in the 2008 plan, no due recognition was given to the NCRE options irrespective of their existence of huge untapped potentials. Although CEB has invested in wind power resource assessment, CEB is not willing and likely to extensively promote wind energy developments unless it is clearly a least-cost solution since CEB generation strategy for future will be the usage of least-cost energy sources and technologies.

2.1.2.4 Environmental implications of Base Case Plan

CO_2 emissions per unit of GDP and CO_2 per Capita values of Sri Lanka are in a low value when compared with the world due to the dominancy of hydro power and low energy intensity of production sectors.

Table 2.1.2.4: CO_2 Emissions of 2008 base case plan [8]

	kg CO_2/2000 US$ of GDP	kg CO_2/2000 of GDP adjusted to PPP	tons of CO_2 per Capita
Sri Lanka	0.51	0.12	0.61
World	0.73	0.46	4.39

Table 2.1.2.5: Air emissions-Base Case scenario [4]

Year	Particulate	SO_X	NO_X	CO_2
	(1000 tons/year)			
2008	0.6	58.7	41.0	3,732.8
2009	0.6	61.7	44.0	4,600.6
2010	0.7	79.9	54.6	5,069.2
2011	0.8	83.6	57.8	5,964.1
2012	1.3	85.8	56.9	6,766.1
2013	3.0	69.9	40.4	8,463.2
2014	3.7	72.0	39.9	9,630.9
2015	4.7	62.8	29.8	11,202.8
2016	5.2	69.9	33.1	12,554.6
2017	5.9	77.8	36.7	13,981.8
2018	6.5	85.9	40.4	15,517.0
2019	7.2	94.6	44.4	17,154.2
2020	8.0	101.4	46.8	18,925.5
2021	8.7	111.0	51.2	20,792.9
2022	9.1	115.2	53.0	21,588.4

According to Table 2.1.2.5, all the emissions are in increasing trend with the introduction of coal based power generation in the planning time horizon. At present CO_2 emission of the country is very low compared the most of the countries and even compared to the world average (Table 2.1.2.4). This is one of the main reasons that the planners are considered coal as main option for future power generation for Sri Lanka.

The basic argument is that to what extend does Sri Lanka have to compensate for CO_2 emissions. The counter argument is that whether we can ignore the warnings of CO_2 intensity increase and the consequences like global warming potential. It is important to understand that we are citizens of the world and not just representatives of one race or one country and we have a right and responsibility to sustain earth.

The 2008 plan selected coal as the main option for future power generation together with oil and hydro as next candidates. Liquefied Natural Gas (LNG) has not considered as a candidate even though LNG emits lower emissions compared to both coal and other petroleum products.

Further the 2008 plan did not provide a level playing field for NCRE irrespective of the national energy policy promises.

2.1.3 Electricity Transmission

The map of the existing transmission network of the Sri Lanka is presented in Figure 2.1.2. Sri Lanka is used 220 kVand 132 kV voltage levels as transmission voltages. The 220 kV systems are used to transmit power from main power stations to main load centers through main grid substation. The 132 kV transmission network is used to interconnect most of the grid substations and to transfer power from other power stations. In 2009, CEB owned 349 km long 20 kV lines and 1763 km long 132 kV transmission network together with 43 numbers of 132/33 kV, 5 numbers of 220/132/33 kV, 1 number 220/132 kV and 4 numbers 132/11 kV substations. The average peak power loss by the transmission network was around 3% of the total load. [9].

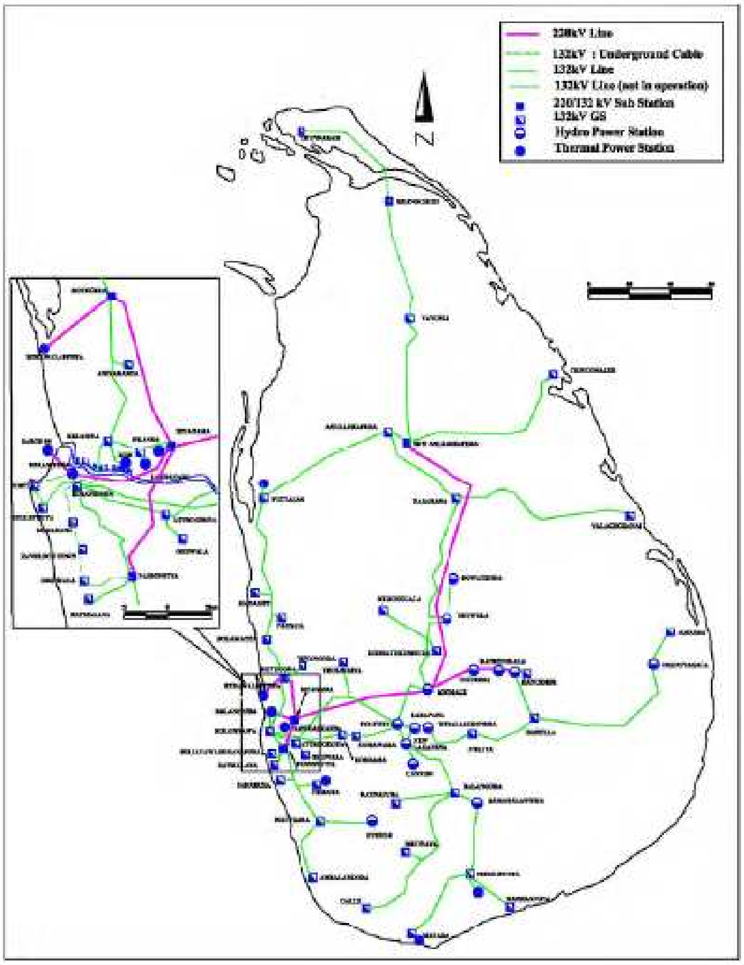

Figure 2.1.2 Map of Sri Lanka Transmission System 2009 [9]

Under its statutory powers, CEB has the right to strengthen its transmission network in order to cater to the load growth and meet with future generation additions. As a result CEB has continuously engaged in developing transmission planning process considering the demand forecast of the country and the process includes identification of overloaded grid substations, and estimation of constructing new grid substations.

One of the main problems of harnessing countries renewable energy potential is whether on-grid non-dispatchable embedded generation capacity has to be within certain limits of dispatchable capacity in order to maintain the power and system stability and integrity.

This problem has not been addressed by the CEB even in their most recent Long Term Transmission Plan (LTTP) of 2010.

When we observe the proposed map of Transmission Network of 2016 (Figure 2.1.3), the transmission network is not covering the main wind potential belt of north-west costal belt. But the latest Long Term Transmission Plan (LTTP) published in 2010 by CEB included projects of augmentation of grid substations to absorb renewable energy projects including construction and augmentation of most of the hill country grid substations to facilitate hydro power generation.

Further a clean energy access improvement project included system control modernization and transmission system strengthening project is also included.

It can be observed that the LTTP 2010 has been developed to cater to the LTGEPs of CEB with strategy based on coal.

The transmission grid to Puttalm and Kalpitiya area where now the wind developments are taking place will be augmented by the plan. But still the wind belt of Mannar Island and suburb costal belt are totally neglected by the plan where a high wind potential exists.

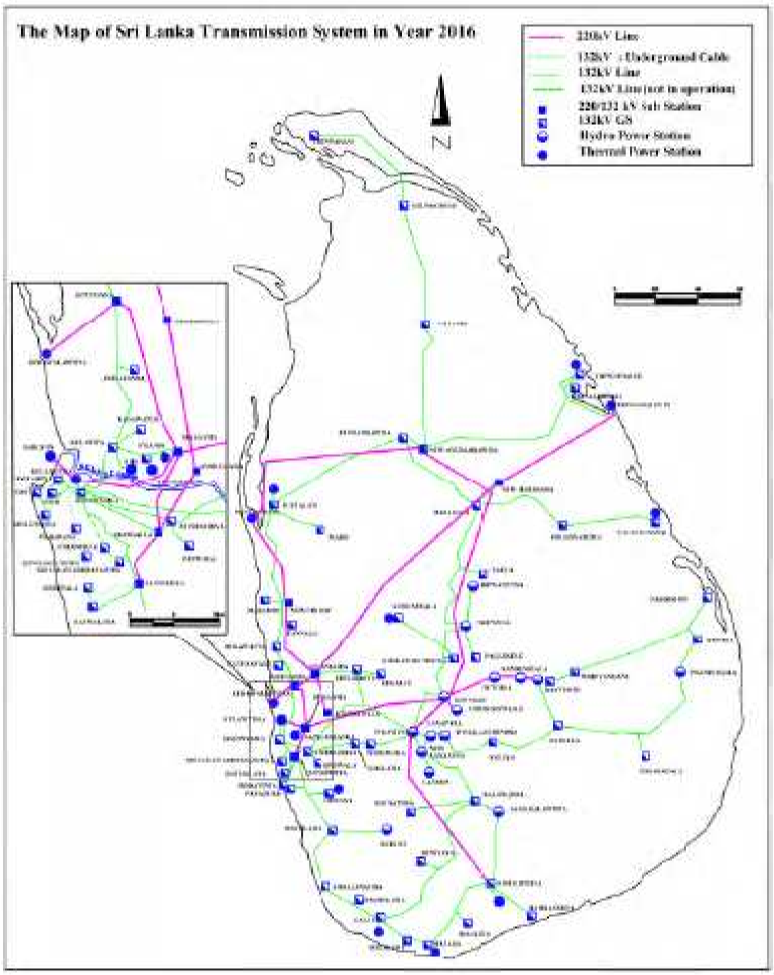

Figure 2.1.3: Proposed Map of Sri Lanka Transmission System 2016 [9]

3 NCRE Target of 2015

3.1 Energy demand contribution from NCRE

Table 3.1.1: Energy & Demand contribution from NCRE [4]

	Energy Generation			Capacity		
Year	NCRE		Systems Total	NCRE		System Dispatchable Total
	GWh	%	GWh	MW	%	MW
2001	68	1.0	6625	27	1.5	1758
2002	107	1.5	6946	38	2.1	1772
2003	124	1.6	7612	43	2.3	1849
2004	206	2.5	8159	77	3.6	2115
2005	280	3.2	8769	89	3.8	2322
2006	346	3.7	9389	111	4.9	2256
2007	353	3.6	9821	119	5.3	2256
2008	463	NA	NA	161	NA	NA
2009	547	5.5	9882	181	6.7	2684
2010	727	6.7	10714	223	7.5	2827

Note: NA – Data not available

According to the available information, end of year the 2010, 727 GWh (6.7%) of electrical energy supplied to the national grid was from NCRE (Table 3.1.1). The installed capacity was 223 MW (7.5%). Still the major share (81%) was from grid connected small scale hydropower plants.

Table 3.1.2 gives a broad idea for what technologies SLSEA has issued permits for constructing NCRE power plants. Even though the potential for development of wind power is huge only 30.85 MWs have been released up to June 2011 due to grid constraints.

Table 3.1.2: NCRE committed & permit issued plants – June 2011 [2]

	Commissioned		Under Construction	
	Nos.	Capacity (MW)	Nos.	Capacity(MW)
Small Hydro	84	181.4	83	178.79
Agricultural waste	2	11.0	2	4.00
Dendro			10	51.75
Wind	4	30.85	10	99.10
Solar			4	1.38
Total	90	223.25	109	335.02

Further SLSEA has already issued permits for NCRE plants totaling of 335 MW consisted of 179 MW of small hydropower, 100 MW of wind, 55 MW of biomass and 1.4 MW of solar power. Most of these plants are under construction and once completed these plants will be added 1330 GWh of annul energy to the system (Table 3.1.3)

Table 3.1.3: Energy Supply forecast from NCRE Committed plants up to 2015 [10]

Technology	Annual Plant (Capacity) Factor	Committed Capacity (MW)	Annual Energy (GWh)
Mini Hydro	42%	178.9	658
Wind & Solar	32%	100.48	282
Biomass & Agriculture waste	80%	55.75	390
Total		335.02	1330

3.2 2015 Energy Scenario

Table 3.2.1: energy scenario at 2015

Year	Total Demand (GWh)	NCRE Share (10%) (GWh)	NCRE Share at 2010 (GWh)	NCRE from Committed Plants (GWh)	NCRE Available in 2015 (GWh)
2015	18668	1867	727	1330	2057

Note: Assumption of NCRE share at 2010 will be fully available even in 2015

According to the table 3.2.1, in 2015, total annual NCRE share to the national grid would be 2057 GWh with a total installed capacity of 558.27 MW.

The target of 10% of electricity energy from NCRE in 2015 to the national grid would be achievable and exceed the target.

4 Policies to promote NCRE

Policies to promote renewable energy have being existing for last few decades in several countries. But policies emerged in many more countries during last 15 years and particularly during the period of 2005-2010 [11]. Even though the successfulness of policies used to promote NCRE technologies are country specific and depending on many variables, those policies also are very common for many countries. As per the Renewable 2010 Global Status Report the common policy types widely used all around the world are fee-in-tariffs, renewable portfolio standards, capital subsidies or grants, investment tax credits, sales tax of value added tax exemptions, green certificate trading, direct energy production or tax credits, net metering, direct public investments or financing and public competitive bidding [11]. The policies already used in Sri Lanka are widely under discussing and some of the relevant policies would be briefly discussed in below chapters.

4.1 Feed-in-tariff (FIT)

The most common type of policy mechanism designed to accelerate investments in renewable energy technologies is feed-in-tariff (FIT). The mechanism guaranteed grid access, long-term generation contracts and a cost based tariff and further characterized with tariff degression that is price ratchets over time. By 2010, at least 50 countries and 25 states/provinces practice FIT [11].

In Sri Lanka, FIT was introduced in 1996 to buy NCRE based electricity. Sri Lanka was the 9th country in the list of FIT introducing countries in the world [11]. Until 2007, the FIT in Sri Lanka was avoided cost based tariff which only managed to attract mini-hydro power plants as the prices offered were not attractive for other capital intensive NCRE technologies [3]

4.1.1 Avoided cost Feed-in-Tariff

According to Dr. Siyambalapitiya at el, avoided cost is the price that the utility would have paid if it had to produce the power itself or bought it.

Rather, it is the cost it would pay if they did not buy the power from renewable power producers [3]. The avoided cost includes the cost of avoided energy of dispatched thermal power plants in the system and the cost of avoided transmission network loss due to connection of embedded generation to the network. The calculation of avoided energy cost involved with the total cost of electricity production of thermal power plants which includes the internal cost of power generation and the external cost of benefits. The internal cost associates with fuel and maintenance cost and the external cost associates with cost of negative impact on the environment and welfare due to electricity production [12]

According to Siyambalapitiya at el, [3] avoided cost of generation is the cost of fuel and other variable operation and maintenance costs of the generation avoided, when a power purchase is made from renewable sources. Further they quoted "assuming merit order dispatch, the generation displaced would be the units from the most expensive power plant (marginal unit) running at that time. The marginal cost of generating this unit is the cost of fuel and other variable operational and maintenance cost of the marginal power plant" from the Standard Power Purchase Agreement between CEB and Small Power Producer, 2004.

Before 2007, NCRE based electricity generation was procured at avoided cost based tariff structure. Initially these plants, mostly mini-hydro plants, were offered 10 year power purchase agreement and latter extended for another 5 years. At present out of total of 95 NCRE power plants, 81 power plants are still operating under the Avoided cost based FIT. Only 14 NCRE plants came to operation after 2007 are operational under new FIT.

Until June 2011, Some of the NCRE power plants operating under the avoided cost based tariff are reaching the expiry of initial 15 years of operation and discussions are in progress under what tariff structure these plants would have to be procured if the relevant authorities are decided to extend or renew the Power Purchase Agreement (PPA) with those power plants.

From 2012 onwards, absorption of these mini-hydro power plants into the new tariff regime will commence and suggestions are already made to procure them under the 3rd tier tariff for another 15 years [3]. This suggestion will only secure the operating fee to the developer and full recovery of maintenance cost which might not be attractive to the developer. The cartel of developers will put some pressure through political system on the government to bargain for a 3-tier full tariff for another life cycle (20 years).

However, to reach the government objective of achieving 10% share from NCRE to the national grid, it is compulsory to operate these plants even at the present rate or in an upgraded phase at a fair tariff rate.

4.1.2 The Cost based, Technology specific and three-tiered tariff

The cost based, technology-specific, and three-tiered FIT was designed to address the problems of negative cash-flow experienced by many previous Standard Power Purchase Agreement (SPPA) projects during the period of loan settlement.

One of the key features of the cost reflective new tariff structure is that , this cost based new tariff structure considered to provide profits to developers from the first year of operation to meet the loan commitments, operation and maintenance cost and reasonable return on equity investment of the investors.

In principal, the new cost based FIT should provide benefits to the electricity consumers in long run. National resourced renewable energy belongs to state and its general public at large and therefore the benefit of the resource should flow to the society. The present tariff provides a high tariff rate to the developer to cover their expenses and to earn reasonable profits for a reasonable period (15 years) and thereafter the tariff provides an operating fee to the developer and full recovery of maintenance cost for the next five years.

The present cost based FIT is managed to attract other NCRE technology specific power plants into the system. As per the updated list of information on already commissioned NCRE based power plants, CEB, in May 2011, 10 MW of biomass agriculture and industrial waste power, 7.2 MW of mini-hydro power and 35 MW of wind power plants are procured under the present tariff structure.

Further SLSEU has already issued permits to the 109 plants of 335 MW (Table 3.1.2) for NCRE technologies which are under construction and will be procured through the present cost based tariff structure.

Dr. Siyambalapitita, [13] highlighted that Sri Lanka is paying the highest NCRE tariff in the world. He argued that in 2009, the renewable share including large hydro was almost exceeding 50% and the present cost of producing electricity from large hydro power plants owned by CEB is only Sri Lankan Rs. 1.65/kWh and why pays such a large tariff to the producers for NCRE. The figures of the new NCRE tariff are given in table 4.1.2 and table 4.1.3.

Table 4.1.2: Three-tier-Tariff (Option1), Nov. 2010 [5]

Technology	Escalable	Escalable	Non-escalable fixed Rate		Escalable year 16+ Base Rate	Royalty to Govt, paid by the power purchase year 16+
	Base O&M Rate	Base Fuel Rate	Year 1 -8	Year 9.15	1.68	10% of total tariff
Mini-Hydro	1.61	None	12.64	5.16	1.68	10% of total tariff
Mini-Hydro - Local	1.65	None	12.92	7.47	1.68	10% of total tariff
Wind	3.03	None	17.78	7.26	1.68	10% of total tariff
Wind Local	3.11	None	18.28	7.47	1.68	10% of total tariff
Biomass Dendro	1.29 (1-15 years) 1.61 (16th year on-wards)	9.10	7.58	3.10	1.68	No Royalty
Biomass (agriculture & industrial waste)	1.29 (1-15 years) 1.61 (16th year on-wards)	4.55	7.58	3.10	1.68	No Royalty
Municipal waste	4.51	1.75	15.16	6.19	1.68	No Royalty
Waste heat recovery	0.43	None	7.13	2.65	1.68	No Royalty
Escalation rate for year 2010	7.64%	5.09%	None	None	5.09%	

Table 4.1.3: Flat Tariff (Option 2), Nov.2010 [5]

Technology	All inclusive rate (LKR/kWh) for years 1-20
Mini-Hydro	13.04
Mini-Hydro Local	13.32
Wind	19.43
Wind-Local	19.97
Biomass (Dendro)	20.70
Biomass (Agriculture & industrial waste)	14.53
Municipal waste	22.02
Waste Heat Recovery	6.64

The cost-based, technology-specific, tariff offers options to the developers either to select tree-tier tariff (Table 4.1.2) or a flat tariff (table 4.1.3). The tariffs and the SPPA will continue to be non-negotiable and will be applicable to projects with a rated generation capacity up to 10 MW and will be valid for 20 years.

'Mini-hydro local' and 'wind-local' mentioned in Table 4.1.3 is plants that use locally manufactured turbine equipment. But this clause is not so clear to the developers.

4.2 Renewable Portfolio Standards (RPS)

RPS also called renewable obligations or quota policy exists at the state levels in the countries where large states or provinces exist especially in United States, Canada and India. In the year 2010, 56 states, provinces or countries have practiced RPS policies [11]. The main characteristic of the policy is that it requires renewable power share in the range of 5 – 20 percent of renewable share by 2010 or 2012. More recent policies have extended the periods to 2015 to 2020 or 2025.

The national energy policy target of reaching 10% of grid connected electricity from NCRE technologies in 2015 is a RPS policy established by the Sri Lankan government.

4.3 Direct Capital Investment Subsidy and Tax Credit

Many international examples could be found for capital investment subsidy and tax credits. India is providing accelerated depreciation and 10 year income tax exemption for wind power [11]. Indonesia provides 5% tax credit by the year 2010 for renewable projects. Philippine provides 7 year income tax exemption and zero Value Added Tax (VAT) rate for renewable energy projects [11].

Furthermore, there are many international examples of reduced import duties for renewable energy equipments. In Korea, duty reduction for renewable equipments is almost 50%. [11]

4.4 Energy Production Payments

Energy production payments, or credits or sometimes called premiums exist in few countries in the global arena of promoting renewable energy. Under this scheme energy production payment or incentive will be granted as fixed price per kWh. As an example India provides Indian Rupees 0.50/kWh production payment for wind power. Among the other countries which practices energy payments are Sweden, Argentina, Netherlands and Philippine [11]

4.5 Net Metering

Net metering also called net billing allows self-generation power to offset electricity purchases. Net metering laws exists in at least 10 countries including 43 US states [11]. Even though the net metering is applying most for small renewable installations, some regulations allow larger size installations.

4.6 Electricity Certificate Trading

The electricity certificate system is a market based support system intended to encourage cost-efficient electricity productions from renewable energy technologies. Under this system, the government issues a certificate to the electricity producers for each MWh of renewable electricity they produce [14]. Demand for the certificate is created by a requirement made under an act that enforce all electricity producers and certain electricity users are required to purchase certificates as per a quote obligation decided on the electricity sale and usage. This certificate can be sold to gain some more additional income over the electricity sale. If those having quota obligation, do not have enough certificates to meet the quota obligation, the authority will decide a quota obligation charge or a fine.

5 Renewable Options Available for future generation

According to the geographical position in terms of tropical climate and natural terrain, Sri Lanka is blessed with very high potential of renewable energy of which hydro-power has been tapped to a greater extend.

In Table 5.1 presents the estimated potential from renewable energy technologies in Sri Lanka by the year of 2015 according to the report prepared by Siemens Power Technologies International for DFCC bank under the RERED project in 2007 [14].

Table 5.1.1: Renewable energy potential by 2015 [14]

Energy Source	Estimated Potential by the year 2015
Solar Energy	11 MW
Wind Energy	50 MW
Mini Hydro	300 MW
Biomass	90 MW

The true potential of renewable energy technologies are found to be substantial especially in the wind and dendro technologies as per the Sustainable Energy Authority of Sri Lanka [2] and the potential is shown in Table 5.2 .

Table 5.1.2: Total Renewable energy potential in Sri Lanka [2]

Energy Source	Estimated Potential
Wind Energy (on-grid)	24000 MW
Mini Hydro (on-grid)	300 MW
Biomass (on-grid)	4000 MW

Taking into consideration high existing potential of the wind and its cleaner nature, a detailed study of wind potential and existing barriers against its promotion is carried out in below paragraphs.

5.1 Wind

Wind is the product of pressure difference in the atmosphere and the wind speed at a given location continuously varies. The power available from the wind is proportional to the cube of the wind speed. The wind speeds are higher at greater heights which are free from wind shear effect taking place close to the ground. Wind as a renewable energy source has its own advantages like cleanliness and free from green house gases when using, widely distributed nature and constantly produce wind patterns throughout the regions all over the world. The main disadvantage is its intermittence nature which couples with major issues when harnessing wind power into electrical energy.

Among all the renewable, global wind power capacity increased the most in 2009 by 38 GW. This represented 41 percent (41%) increase over 2008 and brought the global total to 159 GW [11]. The report stated that over the five year period from 2004 to 2009, annual growth rate for cumulative wind power capacity averaged 27 percent and cumulative capacity doubled in less than three years.

China was top wind power installer in the year 2009 installing 13.8 GW and reaching to a total capacity of 25.8 GW. USA added just over 10 GW of wind power capacity in the 2009 enabling the country to maintain its leading position with installed capacity of 35 GW. USA reached its 2025 renewable target 15 years early. Germany is leading Europe with installed capacity of 25.8 GW [11]

The renewable 2010, the global status report further stated that the off-shore wind industry is promisingly picking up and at the end of 2009, eleven countries had off-shore wind power plants with majority remain in Europe. Another trend is the growing market for small-scale wind systems not only the off-grid systems but also distributed grid-connected projects.

5.1.1 Wind potential in Sri Lanka

Sri Lanka is influenced by two predominant wind flows, the southwest monsoon and the northwest monsoon. The southwest monsoon affects the country from May to September and the wind direction during that period varies from southwest to west depending on elevation and further wind direction become westerly with increasing elevation.

The strong upper-air winds, greater than 10 meters per second (m/s) can extend from few hundred meters above sea level to more than 2000 meters above sea level [15].

The northeast monsoon lasts from December to February and the wind direction is from northeast during this period. This monsoon wind is comparatively weaker than that of southeast monsoon and the peak wind speed is around 7 to 8 meters per second (m/s).

The month of March, April, October and November are inter-monsoon periods and the wind during this period is lighter than they are in monsoon periods.

The first study on county's wind resource was implemented by CEB under the Sri Lanka- Netherlands Energy Program continued form 1989 to 1990. 10 wind measuring masts were erected in southern region under this program in order to collect hourly measurements which later became the base for 3 MW wind pilot power plant project which was commissioned by CEB in 1999. Further another 40 meter wind measuring masts were erected in pre-selected places in Kalpitiya Peninsula (coastal), Knuckles range in hill country, Ambewella in hill country, Mannar Island and Uva and Sabaragamuwa in 2000. But the wind data taken from some of these stations were showed abrupt changes in the wind speeds recorded on an interannual basis. New constructions, growth of trees around the meteorological stations, degration of measuring equipments may have caused the "disappearing wind syndrome" [15]

In August 2003, National Renewable Energy Laboratory (NREL) of USA completed a study on wind resource development of Sri Lanka and Maldives and published a report. According to NREL, the wind maps were created using computational wind mapping system that uses Geographic Information System (GIS) technology, integrated terrain and climatic data sets, and analytical and computational technology.

5.1.2 Wind Potential Estimation

According to the NREL wind atlas report; there are nearly 5000 km^2 of windy areas with good-to-excellent (Wind Power Classification – Table 5.1.2) wind potential in the country. This is excluding the national parks, reserves and cultural heritage sites. Out of 5000 km^{2,} 700 km^2 are accountable for lagoons and the report stated that windy lands represented 6% of the total lands of the country. With the assumption of 5 MW per square kilometer, the total wind potential was calculated as 20,000 MW and accounting the potential of the lagoons the total wind potential increased up to 24,000 MW.

If it is considered the moderate wind resource potential of the country, land area will be increased to 10,000 km^2 and the total wind potential will be increased to 50,000 MW. This report did not account the off-shore wind potential of the country and if that also considered, the total wind potential will be much more than 50,000 MW.

Table 5.1.3: Wind Power Classifications, August 2003 [15]

Class	Resource Potential (Utility Scale)	Wind Power Density (W/m^2) @50 m agl	Wind Speed (m/s) @ 50m agl
1	Poor	0-200	0.0-5.6
2	Marginal	200-300	5.6-6.4
3	Moderate	300-400	6.4-7.0
4	Good	400-500	7.0-7.5
5	Excellent	500-600	7.5-8.0
6	Excellent	600-800	8.0-8.8
7	Excellent	>800	>8.8

Even though the potential is high, the near-term potential wind capacity is limited by several factors. CEB estimated that total wind power capacity greater than 15% of the peak-load would be difficult to achieve without major upgrades to the transmission infrastructure and installing more than 20 MW of wind capacity in any given region may adversely impact grid stability and power quality [16]

6 Barrier to promote NCRE

6.1 Wind

6.1.1 Lack of Wind Measurements

According to Trohn [17], it is critical that meteorology masts be correctly installed in accordance with international standards such as IEC and equipped with calibrated quality wind measuring instruments. Wind mast needs for higher precision in wind speed measurements than what is needed for weather forecasting. An error of 1% on the mean wind speed may translate into a loss of 3% of power generation [17].

At present in Sri Lanka, wind measuring masts are located in several sites in the country but not enough in northern and northwestern parts of the country (Jaffna peninsula) where the high wind potential has been identified by the NREL Wind Atlas report. 40 meter wind measuring masts were erected in pre-selected places in Kalpitiya Peninsula, Knuckles range in hill country, Ambewella in hill country, Mannar Island and Uva and Sabaragamuwa in the year 2000. But the wind data taken from some of these stations were showed abrupt changes in the wind speeds recorded on an inter-annual basis.

The first commercial 10 MW IPP wind power plant installed at Mampuri in Kalpitiya peninsula is developed based on wind data of wind mast installed at Kalpitiya peninsula. Siyambalapitiya al el [18] highlighted in the project design report that the limited resources information availability had been a significant handicap to ensure the long-term optimality of the turbine equipment selection. Further it was stated that a significant risk was remained with the developer and the impact of which will only be known after a few years of operation.

6.1.2 Technological perception and confidence

Until recently the country has only 3 MW pilot gird connected power plant operating at an annual capacity factor of 17% in Hambantota.

The general perception of the country was that wind power was a failure in Sri Lanka due to such a low capacity factor.

The feasibility study of Mampuri wind power plant indicated that the annual average plant factor (capacity factor) was comparatively high as 32% and they indicated that the wind potential of northwest coast is indeed stronger than south where the 3-MW pilot plant is located. Today the authorities are using wind capacity factor as 32% for tariff calculations when deciding NCRE tariffs [19].

Due to the lack of knowledge on the nature of wind technologies and the uncertainty coupled with a new technology, stakeholders are defensive in developing instruments for wind technology. This situation existed certainly with CEB, regulatory authorities and financing authorities. As a consequence, still the wind technology has not become a candidate for LTGE plan and as a result transmission expansion plan did not consider the grid expansion in some of the wind rich locations. Particular grid codes have not been developed by the regulatory authorities and even no specific grid studies including dynamic grid stability have been carried out yet.

6.1.3 Limitations of project debt and high interest rates

Explanatory note of the tariff for NCRE project by SLSEA mentioned that debt: equity ratio of 60:40 is expected for a wind power project. Even though a higher debt: equity ratio is expected and requested from prospective lenders to the Mampuri wind power plant project, the offer from the lenders was limited far lesser rates and offered debt financing only up to 45.5% of the project cost. Further the interest rate for debt financing is high in Sri Lanka. The interest rate available for Mampuri wind power project was 20.28% by lenders whereas the interest rate used by SEA and CEB for calculation for standard tariff was only 17.15% [18].

6.1.4 Permits and licensing issues

Large number of permitting and licensing requirements required for NCRE projects, discourages the investors and most of the time drag the projects unnecessarily. It is noted that project developers have to get approvals from approximately 20 governmental organizations.

6.1.5 Issues of wind power integration in to the grid

Wind tends to experience the largest number of integration issues due to the intermittent nature of the resource, the size of the plant, remote locations and the generator choice.

Intermittency tends to be smoothening out across and between wind-farms located in different areas. Fluctuating power output can cause voltage variations, thermal loading and fault level violations. Further wind power production introduces additional variability and uncertainty into the operation of the power system. To meet these challenges there is a need for more power system flexibility. How much flexibility is required depends on how much wind power is embedded into the system and how much flexibility already exists in the power system.

6.1.5.1 Variability of wind power production

Wind-farms do not operate at all the times due to intermittent nature of wind. As a result backup capacity is needed when there is a gap exists between forecast and actual production capacity. Balancing and backup capacity always comes at a cost. Spatial dispersion of wind power plants that is constructing wind power plants at all viable locations in different regions on the country is a possible measure to handle variability associated with wind power. By adopting this strategy, a sudden loss of wind power in total system could have been avoided.

Wind forecasting is a key essential factor in wind power plants and additional reserves are needed in order to compensate for wind power forecast errors. Since the variability increases with time scale increase, 24-hour forecast errors leads to an overestimation of required forecast ted error reserves. In the Swedish/ Nordic system 1 hour forecast system is used and the main part of the reserves is hydro power plants which have a flexibility of connecting to the system within minutes. Many proven systems in the world are using around 3 hour forecasting systems [20].

Grid reinforcement are needed for handling large power flows and maintaining stable voltage if new wind generation is installed in a weak or congested grids far from load centers, long radius to reach windy areas or where no grids exists. This is the case in Sri Lanka where grid reinforcements are needed to reach the windy areas.

6.1.6 High Transmission system expansion costs

Wind projects are often required to bear the cost of gird extensions which increases the capital cost requirements of the project. Grid reinforcement and grid extensions often benefits the consumer in large and increase the reliability of the grid so the investors on wind power plants always pointed out that the cost should be barred by the grid owner or the government in the cases where the grid is owned by the government owned institutions like CEB in Sri Lanka.

The Mampuri Wind Power plant in Sri Lanka has to bear this unusual long transmission line extension cost. There was a medium voltage transmission line owned by CEB passing within 2 km distance of the wind power plant with adequate capacity to deliver the output of the power plant to the national grid. However CEB has requested a direct transmission line from the power plant to the gantry at Palavi, Puttalam Sri Lanka a direct connection to the 33 kV bus-bars at Palavi Gantry. The reasons given by CEB for this requirement were

- CEB was not sure about the impacts of the wind power plant when connected to an existing medium voltage line being this was the first wind power plant in Sri Lanka

- The voltage at the point of common coupling may rise because CEB's grid substation 33 kV bus-bar voltage is always fixed at 33 kV and not varied to maintain the loading conditions of lines

- There are significant outages of the existing CEB line in the area owing to saline pollution and other defects. The outages experienced in the year 2008 were 180 and such high outage rate will cause major problems to the power plant.

Mampuri wind power plant has to build a new medium voltage transmission line from Mampuri to Palavi with a distance of 13 km. this caused the project cost to increase beyond estimated [18].

CEB's general view is that they expressed a need for better analytical tool and capacity building for determining the limitations of the infrastructure and potential impact of wind integration on CEB transmission system. Without fulfilling these needs, it is impossible to understand the strengths and weaknesses exits in the system and CEB's only choice will be conservative in adding non-dispatchable generation capacity to the system.

7 Strategies

7.1 Strategies to create awareness

7.1.1 Capacity building of stakeholders

Lack of awareness of renewable energy technologies and its advantages has resulted negative sentiment towards renewable energy over the conventional energy sources and technologies.

Lack of required competencies and skills for handling renewable energy projects can be generally seen from all levels of stakeholders including CEB, LECO, Local Provincial Authorities, project approving and policy making bodies SLSEA and PUCSL, and financial institutions. At present a negative approach from most of the above mention bodies have been experienced by the project developers and as a result many renewable energy projects are being unnecessarily delaying.

A national level discussion and a planed capacity building program is required including general public and all the key stake holders to address the lack of awareness issue prevails at the moment. Bringing the NCRE technologies under the national formal education system especially at secondary and tertiary level's curriculums are at utmost importance today to attack the lack of awareness issue.

SLSEA has a key role to play in this capacity building program being it is the assigned institution on promoting renewable energy in the country. SLSEU can get the assistance of many existing capacity building programs of European Union, ADB, and NGOs.

7.2 Strategies to shape the national energy planning process in favour of more NCRE share for future power generation

It is a fact that Sri Lanka as a nation has not properly understood the importance of NCRE promotion in terms of its enomorous potential of some of NCRE technologies and the neediness of reducing dependency of imported fossil fuels.

The LTGEP of 2008 is a good example where the future power generation is mainly on coal which has to be 100% import.

National energy planning process team consists of external consultants, representatives of CEB, LECO, and SLSEA .The plan's responsibility is mainly lies with CEB being the main electricity utility of the country and the plan has to be sanctioned by the regulatory authority PUCSL. The LTGEP is a product of CEB where the opinion of CEB dominates for future generation principally based on least cost power generation options.

In fact there are many divisions and contrasting opinions among the above institutions on national energy planning process especially when deciding the share of NCRE and the selection of particular NCRE technology for the future electricity generation.

Being the most knowledgeable and competent institution on NCRE, SLSEA has a national role to play to enforce the planning team for its share of NCRE in the next LTGEP which is being developing at the moment.

Furthermore, it's government responsibility to strengthen the hands of SLSEA with the necessary legal and regulatory powers in order to propose more independent and impartial plan of NCRE which can be amalgamated with next LTGEP of CEB.

7.3 NCRE tariff rationalization

It is a well known fact that an attractive tariff structure has to be there to attract investors (PIPs) for NCRE power generation. According to that rule many countries of the world today including Sri Lanka designed and implemented feed-in-tariff structures.

The present NCRE cost reflective 3-tired tariff structure has been recently criticized by few experts in the field of power systems in the country highlighting that the tariff is one of the highest in the world.

On the other hand at present, out of the existing 95 grid connected NCRE power plants, 81 power plants are still operating under the previous avoided cost based tariff structure and most of their licenses are going to expire between the 2011 and 2013 period. Still a new tariff structure for those plants has not being decided by the authorities but discussions are in progress. The suggestion is to put them on the 3rd tier of the new tariff structure where the plants will secure only the operating costs of the power plants.

This point is rationalized by the authorities pointing out that these plants are already recovered all their costs in the initial 15 years and now the benefit should go to the general public since these natural resources are belongs to the general public.

Further fossil fuel prices are heavily subsidized in the country and as a result NCRE options are not competing in a level playing field being selected for power generation options. These issues are to be addressed when the authorities are deciding the changes to the new tariff structure and the tariff fixing process needs to be rationalized based on facts and figures and not on the lobbing power of particular interest groups.

7.4 Strategies for investment promotion on NCRE

Until mid of the year 2011, Sri Lankan government has no plans to invest on NCRE projects and PIPs are encouraged to initiate and do the projects in the scale of 10 MW licensing under Standard Power Purchase Agreements (SPPA). As initial investments required for many NCRE projects in the capacity of 10 MW are relatively high, it is required to provide incentives in the form of capital investment subsidies and tax credits.

Registering the NCRE projects in this scale as Board of Investment of Sri Lanka (BOI) projects, lot of concessions could be granted. Considering and following the Indian model of giving 10 year income tax exemption for wind power projects, government could consider granting either 10 year of 15 year income tax exemption for the wind projects.

Further import duty concessions for high capital cost equipments such as Wind turbines and related switchgears, Towers and Blades can be recommended.

7.5 Strategy of making government bodies accountable

Lack of accountability of some key influential organizations and officials due to various reasons such as self agendas, divisions and divergent opinions make unnecessary delays on approval processes.

Most of the projects are unnecessarily delayed due to delaying of approvals for Initial Environmental Analysis (IEA) by the Central Environmental Authority (CEA) of Sri Lanka at the initial stage of feasibility study.

CEA should also consider relaxing certain restrictive regulations and approval procedures in order to promote the NCRE projects considering the promotion as a national priority.

Government should rewrite a plan to make the institutions and officials accountable to support the NCRE projects.

7.6 Strategies to leverage financial support mechanisms

In the recent history of renewable energy technologies promotion in Sri Lanka, dedicated credit support has being provided through external funding agencies like World Bank and its affiliated agencies. One of the successful funding projects was Renewable Energy for Rural Economic Development (RERED) initiated in 2002 which launched to provide electricity access to rural households and small and medium enterprises through the development of off-grid renewable energy technologies.

Energy Conservation Fund (ECF) was established with the mission of promoting energy efficiency in all sectors, control and minimize energy wastage of all consumers, and explore the potential of alternative energy resources is not operating as a fund lending mechanism for the NCRE projects. This fund could be strengthening its capability in order to drive as a mobilization of investment capital mechanism. The methods which can be used to increase funds are attracting funds available for clean development mechanisms (CDM) projects, levying a CESS on energy sector, royalty payment from Standard Power Purchase Agreements (SPPA) and applying Carbon Tax on all thermal generations.

In June 2011, International Finance Corporation (IFC) a member of World Bank group has invested 3.8 million US $ in Senok Group of Sri Lanka helping the company to invest on wind power generation projects. This is a good example of fund availability for NCRE projects and what is required is the correct expertise and strategies to grab them.

The government of Sri Lanka should encourage local banks to provide project capital financing for NCRE projects with reasonable interest rates. This will not only help the promoting of NCRE but also stops the money outflow from the country to the foreign banks.

7.7 Wind specific Strategies

7.7.1 Investigation and Planning of design to grid reinforcement and extension

The transmission and distribution network in Sri Lanka are aging and almost at capacity limits. Infrastructure upgrading is an opportunity to all concerned parties to re-examine, design and operation parameters including integration of wind power in to the system. In Long Term Transmission Plan of 2010 of CEB, wind power integration has not being taken into account and suggests CEB to review the plan in order to include the wind power integration into the proposed Transmission network of 2016.

According to the studies carried out by wind power pioneering countries, the most cost effective way of transmission planning is to plan and expand the transmission network for the final amount of wind power in the system. General practice by most of the leading wind power producing countries is that, the cost burden of grid reinforcement and extension to be shared among the network operators and part of it to the end customers. It is noteworthy to mention that the grid extensions and new transmission lines often benefits the consumers in large and increase the reliability of the grid. Since the CEB is fully owned the transmission network in the country, the government has to fund the transmission system upgradement.

7.7.2 Wind power prediction tools to improve forecasting electricity production

Being a natural phenomenon, intermittent nature of wind and its non-dispatchability differs from other power generation technologies on forecasting which is making challenges to grid system operators. Accurate forecasts of wind power are important to its economic integration in to the power system; better forecasting system improves network system imbalances. Additional reserves are needed in order to compensate for wind power forecast errors.

Today wind energy forecast uses state-of-art sophisticated numerical whether forecast models, wind power plant generation models and statistical methods to predict generation at shorter intervals (minutes) to hourly intervals.

Sri Lanka has to invest on these sophisticated numerical whether forecast models in order to harness wind potential effectively.

7.7.3 *Intelligent wind systems to interact with other power sources in the network*

Modern wind power technologies can control both active and reactive power more quickly than conventional wind power systems. The ability of wind turbines to actually support the power system during grid disturbances is possible with applying correct technologies with new equipment design and power plant engineering. The new grid access rules have to be imposed and implemented in order to encourage IPPs to use latest technologies to support the system operation.

7.7.4 *Analysis and development of grid access rules, technical grid codes and international standards*

All parties connected to a public electricity network must comply with agreed technical requirements. This is essential network to operate safely and efficiently. The technical requirements for power plant components are unavoidably more complex than any other items in the system and these technical requirements are called "Grid Codes" [20].

These technical requirements are usually written by the system operator and often overseen by the energy regulatory body of a county. The requirement modification process to come into a final outcome should be transparent and include consultation with experts, system users, equipment suppliers and other stakeholders.

Basically grid core requirements are lies within following subject areas and specified at point of common coupling between wind farm and existing electricity network.

- Tolerance, the range of conditions on which electricity on the electricity system for which wind farm must continue to operate
- Control of active power,
- Control of reactive power, requirement to contribute to voltage control of network
- Protection devices and power quality
- Low- voltage ride-through (LVRT, also called as FRT –Fault Ride Through) in the event of system fault. The generators must stay online during three phase, single phase and single phase to ground faults and in a range of grid frequency
- The fault clearing time, voltage dip requirements and providing voltage support during the fault

As an example, in German then existing grid codes before 2004, insisted wind turbines to disconnect from the grid if regional voltage drop of more than 20% due to system faults. These additional disconnections would worsen the critical grid situation. From 2004 for the new installations, the regulation was altered such that the wind plants should not disconnect from grid until the voltage drop by more than 80%. [20]

Standardized certificate and testing procedures for entire wind power system, and type approval helps to mitigate market barriers of wind systems integrate into the grid.

Technical requirement of Grid Codes are to be written by the CEB and LECO and are to be overseen by the PUCSL with the help of the panel of experts of the subject matter.

7.7.5 Collaborative research groups

The International Energy Agency Wind Implementing Agreement (IEA Wind) has been active in international collaborative Research and Development and deployment (RD&D) more than a quarter of century. The collaboration includes 19 leading countries of wind technology and the European council. [20]

Hot topics of prevailing wind power technology such as wind power forecasting and modeling for grid system optimization and effects of develop and validate models for executing dynamic and transient stability are deeply discussing in the forums.

Further the countries that have already pioneered in wind power technology are sometimes not willing to exchange the technology due to the fear of losing competitive advantage. Mutually beneficial agreements will help the country for a better technology transfer in this scenario.

Government support for R&D and deployment has always plays a critical role technical system advancement and deployment.

Sri Lanka should participate for active membership of this type of collaborative research group in order to strengthen its capacity building of wind power technology. Since the China and India have already pioneered the technology, Sri Lanka should strive for an effort to form a collaborative R&D programs with both China and India.

7.7.6 Increasing power system flexibility-options

Availability of flexible balancing solutions in the system is an important factor when consider integration of wind power into the system.

The well established and proven balancing solutions involve mostly conventional power generation technologies such as hydropower and thermal options. Hydropower is considered to be as a very fast way of reducing power imbalance due to its fast ramp-up and ramp-down rates. It also has a marginal cost almost close to zero. In thermal generation options gas-fired units are considered to be more flexible which allow rapid production adjustment. Since the Sri Lanka has a considerable share of conventional hydropower, a flexible wind-hydropower system by co-joining wind farms to hydro-power plants could be well designed through integrated resource management tools. This is basically hydro power system to integrate wind energy into its control area.

Storage options such as Powdered Activated Carbon (PAC), Compressed Air Energy Storage (CAES), Flywheels, Batteries, and Fuel Cells are the candidates but storage involves loss of energy and can have an adverse effect on system operation with CO_2 emissions [20].

Availability of interconnect capacity for exchange of power between countries is a significant source of flexibility in a power system provided the capacity should be technically and commercially available. A dialogue already started by Sri Lanka Government for Indo-Sri Lanka interconnection might increase the viability of this option but technically availability might be a problem since the south-India is not only not self sufficient in power but have serious considerations of power quality.

Demand side management (DSM) which is already practicing in Sri Lanka to a particular extend is another viable option of increasing power system flexibility when integrate wind in to the system. Using DSM loads are controlled to responds to power imbalances by reducing or increasing demand. Part of the demand can be time-shifted or simply switched –off. DSM enables a new balance between generation and consumption without making adjustments to generation.

8 Conclusions

On the day of 13th January 2012 from the country's electricity generation, 88% was come from thermal power plants and only 12 % was come from hydro power. Even from that 88%, 47.5% was from IPP thermal power plants which are operated using most uneconomical fuel like HFO, 18.2% was from coal and 22.3% was from CEB owned thermal power plants. The hydro reservoir storage capacity was low as 51.3% due to prevailing dry climatic condition of the country.

The country has recently tendered for 100-MW supplementary power from emergency diesel power generation with a condition that the power has to be available in March 2012.

At present the country is producing the electricity power using the most uneconomical power generation technologies resulting very high unit cost of electricity. The cost burden either the government has to bear or should pass to the consumers but the both options are not favorable at any means. Further the prevailing situation in oil producing countries in gulf region is a clear indication of fuel price increase in near future and if occurs the unit cost of electricity will sky rocketed putting the country's power generation into a deadly broken stage.

To successfully face this frequently happening havoc in power generation, Sri Lanka has no other options than accelerating the harnessing of wind power as the best alternative for power generation as they did in past when harnessing hydro electricity in 1980s since the potential for wind power generation is very high even compared to the hydro electricity potential.

Fulfilling a timely need of the electricity industry, on 4th of January 2012 Sri Lanka Energies (Private) limited a subsidiary of CEB was declared open in Colombo with the primary objective of increasing the renewable energy share of the national grid up to 20% by 2020. This subsidiary is assigned to work towards developing the countries renewable energy industry working very closely with both public and private sectors. Initially the company has a target of undertaking a development of 130 mini hydro power plants with approximate capacity of 250 MW which were abandoned due to various reasons by the private sector. The company will appear in Wind power generation in near future. The government presence in NCRE promotion will increase the competiveness and with the awareness improvement of CEB a positive attitude on NCRE technologies will be created among the CEB employees.

Up to 31st of August 2011, total commissioned NCRE projects capacity was 225.329 MW and the projects signed SPPA were 284.86 MW. Out of the 284.86 MW, 126 MW is from mini hydro, 99.1 MW is from Wind, 55.77 is from Biomass Dendro and 4 MW from Biomass-agriculture and industrial waste. This emphasized that some of the committed NCRE power plants are yet to sign the SPPA with CEB.

SLSEA has already issued energy permits to 11 IPPs to produce wind power totaling of 111.5 MW out of them Mampuri wind power plant (10 MW), Seguvantivu wind power plant (10 MW) and Vidathamunai wind power plant (10 MW) are in operation since June 2010. These plants have already achieved the expected annual energy targets with an average plant factor of 30% to 35%. Frequent grid outages and voltage fluctuations are the key challenges faced by these power plants throughout the last several months of operation mainly due to poor condition of the grid of the area.

Furthermore, most of the wind power plants which got the permissions are at construction stage at the moment. Nirmalapura wind power plant (10 MW), Pavandhanavi (10 MW), Powergen Lanka (10 MW) and the phase 2 of Mampuri (10 MW) are key plants which are being constructing in Kalpitiya peninsula of Puttlam district.

Still the government policy is to promote wind power generation through the IPP in the scale of 10 MW through the Standard Power Purchase Agreements and that is not enough to address the issues prevailing in the power sector. Government should have a mechanism to start an accelerated scheme to harness wind power into its technically and economically viable potential. This should include a mechanism to address the issues facing by the power systems when absorbing and integrating large amount of wind power into the national grid and a long term plan for transmission grid reinforcement and extension. Government should nominate either SLSEA with full powers or create a new institute to implement this accelerated wind power harnessing scheme.

Planning and implementation of following key strategies out of the strategies discussed in the chapter 7 are essential for the success of accelerated wind power production scheme and sustainability of existing mini and micro hydro power system.

If succeeded achieving more than a 10% share from NCRE to the national grid will no longer be a challenge to the nation.

- Capacity building for all stakeholders together with a system to hold the key stakeholders accountable for the success of the accelerated wind power production scheme.

- Provide a level playing field for NCRE to compete with thermal power generation options.

- Program to leverage financial support for the wind power developers together with support for direct capital investment and tax credit facility.

- Rationalize NCRE tariff and extend the license of all IPPs who are still operating under the avoided cost based tariff structure to new cost reflective 3-tier tariff structure for another 20 years once their existing licenses expired. System upgradements of these power plants are to be encouraged by granting subsidies and tax holidays.

- Analysis and development of gird access rules, technical grid codes in order to ensure the power system flexibility, operational safety and operational efficiency when integrating wind power into the national grid.

- Set up a state of art wind forecasting system to address the issue of variability and uncertainty of wind.

- All new wind power plants are to include with intelligent wind systems , hybrid system and energy storage systems in order to address the power system flexibility issues.

- Select some options to act as power balancing solutions when integrating wind largely into the power system. Hydro power generation is the best option to act as reserves for wind.

- Encourage to practice demand side management with incentives where loads can be controlled to responds to power imbalances either by time-shifting the demand or simply switching off the demand without making adjustments to generation.

- Introduce compulsory energy certificate systems at least for the thermal power producers including CEB encouraging them to invest on NCRE based power generation including wind.

Further to plan and implement a large scale island-wide awareness campaign program for an accelerated wind power harnessing scheme is a must to minimize the resistance from the people who are living in the area.

Sri Lanka government commitment to achieve 20% share of grid connected electricity from NCRE by 2020 has to be appreciated and by applying correct strategies the target itself could have be achieved even in year 2015.

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Appendix A

Wind resource map of Sri Lanka [15]