SOLAR AND WIND RESOURCE ASSESSMENT IN SRI LANKA

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Abstract

Sri Lanka is an island in the Indian Ocean, situated in the south of India. The total installed capacity of electricity in the island was 2223 MW at end 2003[2]. The demand for power rises by 8-10 percent per annum and it is necessary to promote installed capacity in 100 MW in each year [1]. Therefore, Sri Lanka looking towards to increase renewable energy sources.

The Solar and Wind Resource Assessment (SWERA) is a pilot project designed to compile such data in 14 developing countries including Sri Lanka to facilitate investments in solar and wind energy projects funded by Global Environment Facility (GEF) during the period of years 2000 to 2005. The aim of the project is to support decision-making, develop policy based on science and technology, and increase investor interest in renewable energy projects and ultimately to reduce Global Hazardous Gas (GHG) emissions.

The National Engineering Research and Development (NERDC) of Sri Lanka is a government organization and partner institution for SWERA project from the country. The NERDC is working with local institutions of Survey Departments, Meteorological Department, Ceylon Electricity Board, Universities of Moratuwa, and Ruhuna to make available reliable, accurate and easily accessible solar and wind resource data.

The NERDC acquired capability of evaluation of wind and solar data in assessing of wind energy resources in Sri Lanka. New information tools of regional and national maps of solar and wind energy resources and geographical information system (GIS) have been developed by the NERDC with the support of the United Nations Environmental Programme.

The outcome of SWERA is to facilitate industry, investors, researchers and government agencies in deploying solar and wind energy projects. Thereby, it indirectly helps to reduce environmental pollution by dissemination of clean energy.

1. Introduction

Sri Lanka is an island in the Indian Ocean, situated in the south of India. The electricity generation of Sri Lanka was mainly from hydropower. With the increase of population and demand, a few thermal power plants were set-up. As the increase of fossil fuel use and increase in crude oil price in the world market the government is looking towards to promote renewable energy sources.

The National Engineering Research and Development (NERDC) of Sri Lanka is a partner institution for SWERA project from the country. The NERDC assessed wind and solar resources and provided surface information to develop solar and wind maps in Sri Lanka. SWERA encourages in deploying solar and wind energy projects.

2. Energy Scenario in Sri Lanka

The main indigenous source of primary commercial electrical energy in Sri Lanka is hydropower with an estimated potential of about 2000 MW. Biomass or fuel wood is the other major primary energy source, which provides 53% of the country's total energy requirement. Sri Lanka has no proven resources of fossil fuels and the total fossil fuel requirement of the country is imported either as crude oil or as refined products.
Therefore, the major primary energy sources of Sri Lanka (including both commercial and non-commercial sources) are; hydropower, petroleum and fuel wood. The share of these in the gross primary energy supply in 2000 is shown Figure 1.

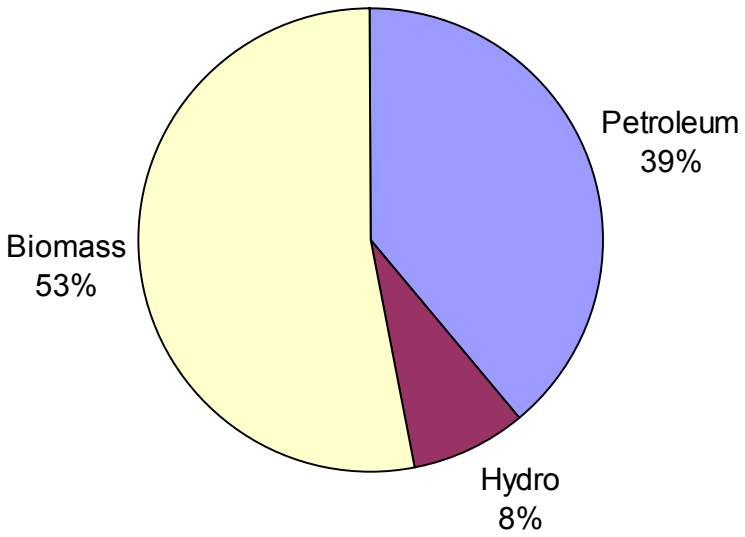

Figure 1: Gross primary energy supply by source (2000)
Source: Energy Conservation Fund, Sri Lanka

The total installed capacity of electricity in the island was 2223 MW at end 2003 [2]. The reliance of hydropower is 60% and the balance comes out from diesel and thermal power. The number of household electrified is 2,364,858, which is of 57% of total population [3]. As under normal circumstances the demand for power rises by 8-10 percent per annum, it is necessary to increase installed capacity in 100 MW in each year [3]. Therefore, Sri Lanka looking towards to increase renewable energy sources.

In view of creating a competitive market for energy; reforms were initiated in the commercial energy sector to address inefficiency, supply shortages, irrational pricing policies in 2002. With the objective to ensure stable and reliable power supply in the future a new electricity reform act was promulgated in 2002. As part of reform, paved the way for a greater level of private sector participation.

3. Renewable Energy Sources

Renewable energy has low impact on environment, compared with conventional sources of energy and become prime potential energy source for the future. A very few renewable energy technologies were implemented in Sri Lanka which include a wind farm, biomass, biogas and photo voltaic applications. The scenario of renewable energy sources is indicated in table 1.

Table 1: Sri Lanka's RE scenario

	Number of plants	Total installed capacity (MW)	Typical installation size	Main present funding mechanism	Main barriers
Wind	05	3	600 kW	Donor Private	Resource Assessment; Financing; Remunerative tariff
PV	SHS 30,000	1.2	40 W	World Bank, GEF	Lack of policy on energy; costs
Hydro <10 MW	14 3000	50 20	Depend on site conditions	World Bank, GEF	Availability of resource, investment cost

Source, NERDC 2004

The capacity of the wind farm is 3 MW and is of a grid-connected unit, operated by the Ceylon Electricity Board. Although it was located near coastal area in the down

south in Sri Lanka, full capacity could not be extracted from the farm. The capacity factor is around 13% according to NERDC survey. It was not the real location as CEB planned and they had moved to it present location because of environmental issues. Due to lack of resource assessment and lack of accessibility to potential sites there were barriers in promoting wind energy technologies in the country.

Biomass is used as 52% of the primary energy supply in Sri Lanka. The major use is for household cooking and the balance of 24% is consumed in the industries. The industries mainly use biomass for thermal applications such as wood burning furnaces in Tea industry and tile kilns, paddy husk for par-boiling paddy, bakeries etc.

Now, biogas technology is becoming popular in Sri Lanka due to increase of LPG prices and short period of recovery of capital investment. The NERDC developed a semi-dry batch type domestic type (using paddy straw as raw material) biogas units and improved continuous type versions of Chinese and Indian type biogas units. These units are constructed in the country by NERDC directly and other private sector stakeholders participation, to use biogas for domestic cooking need. A few large-scale units are also constructed as an environmental friendly digestion technique of city market garbage.

As no more access for major hydropower, mini/micro hydro sites were developed for rural electrification need with public and private sector participation. The Energy Services Delivery (ESD) Project funded by World Bank-GEF, carried out a survey in seven districts of Sri Lanka and identified 444 technically viable sites with a potential of about 18 MW. Accordingly, 1,400 households were benefited by ESD project. The share of renewable energy technologies (RET) in total primary energy is about 53.1% whereas their share in total electricity production is about 0.1% [6].

A few dendro plants have been commissioned recently in Sri Lanka. The capability of fabricating biomass gasifier for thermal application has been developed within country; those for electricity generation are being still imported.

4. Initiatives for Development of Renewable Energy

Now, the Sri Lankan government has recognised that off-grid technologies (solar PV, and micro hydro) has a role in the energy mix of the country and policies are changing to accommodate them (i.e. lowering of duties for solar PV modules). Also, for grid-connected renewables (mini hydro and wind power) it has created policies and regulatory framework has been developed.

Under ESD Project, which concluded in year 2003, the Sri Lanka Government has promoted energy efficiency and renewable energy successfully. The project targets were exceeded for providing rural energy access through Solar Home Systems, grid

connected small hydro projects and off-grid village hydro systems. As a continuation RERED project was started in year 2004.

The foundations have been laid by the Sri Lanka for sustainable growth of the renewable energy industry in Sri Lanka. However, certain critical barriers still need to be addressed.

5. Barriers in Development of Renewable Energy

The major barriers in concern with electricity generation using renewable energy sources are listed below.

- In earlier projects there were no proper procedures available in Ceylon Electricity Board (CEB) to promote renewable energies. However, Small power purchase agreement (PPA) was introduced in 2002.
- Difficulty in financing of renewable energy projects (grid and off-grid). However, ESD project made a successful progress.
- There are uncertainties in policy regime and absence of long term and rewarding PPAs.
- There is a lack of countrywide data on biomass and hydro resource.
- Applications of off-grid projects are in remote and rural areas. The transaction cost is high for promoters and no effective micro credit schemes available for customers.
- Less private sector participation.
- In certain wind-rich areas of the country transmission grid is weak.
- Limited experience in electricity generation using biomass.
- Poor bio mass supply for sustainable operation of plants.
- Limited awareness and experience among stakeholder.
- Lack of proper policies and environmental regulations in promoting renewables.

6. Solar and Wind Resource Assessment Project

The Solar and Wind Resource Assessment Project funded by Global Environment Facility (GEF) during the period of years 2000 to 2005, provides solar and wind resource data and geographic information assessment tools to public and private sector executives who are involved in energy market development. It demonstrates the use of these instruments in investment and policy decision-making and builds local capacities for their continuous use. The project will enable private investors and public policy makers to assess the technical, economic and environmental potential for large-scale investments in technologies that enable the exploitation of two increasingly important sources of renewable energy. During the pilot project, tools for

analysis and use of resource information is being developed, a global archive and review mechanism is being initiated, regional/national solar and wind resource maps generated and national assessment demonstrations performed. The overall goal is to promote the integration of wind and solar alternatives in national and regional energy planning and sector restructuring as well as related policymaking. The project will enable informed decision-making and enhance the ability of participating governments to attract increased investor interest in renewable energy. Fourteen developing countries including Sri Lanka are directly involved in the pilot stage of the project. Global and regional maps will be available to all developing countries.

7. Development of Solar and Wind Energy Resources high resolution map

7.1 Wind resource assessment

The Ceylon Electricity Board has collected wind data at North Central region (Anuradhapura, Kalpitiya) and 14 locations in Southern region (Hambantota area) for 2 years period. These data obtained with 1 hour logging time at a height of 40m. Wind masts of 40m heights have been installed in the Central Hill Ambewela, and in the Knuckles range Hunnasgiriya and Rathida and data is being collected from 2 ½ years period with 10 minute logging time. Accordingly, wind data for more than 23 locations of has been collected around Sri Lanka.

In addition the Meteorological Department collects surface wind data of every 3 hours at 22 locations around the country for 30 years period. However, 2 -3 stations are not functioning at present. Also, it has 3 balloon stations in Colombo, Puttalama and Trincomalee. Every 6 hours period balloon data is being collected at 1000ft level. The Meteorological Department is collecting marine wind data by communicating with ships and buoys, which are traveling near the country.

Wind Atlas software Programme (WAsP) model was used to make predictions at required locations using collected wind data and to develop time based information. In this task, required surface information was obtain by the 1: 50,000 scale survey maps, which were developed by the survey department of Sri Lanka. The wind above the ground surface of 200 m is calculated with the Karlsruhe Atmospheric Mesoscale Model (KAMM) using climatology of geostrophic wind on the large scale. Simulations were performed for classes of different geostrophic wind [4]. The classes are weighted with their frequency to obtain statistics for the simulated wind. The results were treated similar to real observations to make wind Atlas files for WAsP. These files can be employed to predict the local wind at a required site. National Renewable Energy Laboratory (NREL), USA uses a Global Information System (GIS)-based wind resource mapping technique to produce the wind map for Sri Lanka [5]. There is nearly 5000 km^2 of windy areas with a grading of good-to-excellent wind resource potential in Sri Lanka. About 4100 km^2 of the total windy area is on land. Therefore, windy land represents about 6 % of the total land area (65,600 km^2) of Sri

Lanka. If a conservative assumption of 5 MW per km^2 is made, this windy land could support more than 20,000 MW of potential installed capacity. The windy lagoon areas are estimated to encompass 700 km^2 with a potential installed capacity of 3,500 MW. Hence, the combined wind potential for Sri Lanka is estimated to be more than 24,000 MW [8].

The results of wind mapping analysis are tabulated in the following table (table 2).

Table 2 Wind Mapping Analysis of Sri Lanka

No.	Region	Wind Resource (W/m^2)
1	Central hills	Above 800
2	Surrounding coastal hills	500-800
3	Islands surrounding Jaffna Peninsular	500-600
4	North and North-West coastal area	400-500
5	North and North-West away from coastal area	300-400
6	South-East valley	300-400
7	South-East far from coastal area	200-300
8	North away from coastal area (towards North-Central region), North-Central and South (away from central hills)	200-300

7.2 Solar Resource Assessment

The availability of solar energy data in Sri Lanka is limited. The Meteorological Department is collecting solar radiation data only at Colombo for a period of 38 years. However, they have data of sunshine hours in 35 locations and cloud cover in 10 locations around the country for more than 20 years period.

The METSTAT solar radiation model was developed [5] using quality-assessed data collected from 1978 to 1980 at 29 U.S. National Weather service sites. The model calculates hourly values of direct normal, diffuse horizontal, and global horizontal solar radiation. Input parameters to the model include total and opaque cloud cover, aerosol optical depth, precipitable water vapor, ozone, surface albedo, snow depth, days-since-last-snowfall, atmospheric pressure, and present weather. The model uses deterministic algorithms to calculate accurate monthly means for each hour and statistical algorithms to simulate the statistical and stochastic characteristics of measured multiyear data sets. In this model, the selected input parameters of opaque cloud cover and aerosol optical depth is randomly varied. The developed statistical algorithms simulated the effect of random hour-to-hour changes in aerosol optical depth. This provides estimates of hourly solar radiation with representative statistical characteristics of measured data.

DATSAV2 data consist of surface weather observations taken around the world. The primary reason for these weather observations is to support forecasting and aviation; consequently, most stations are located at airports. The observations are sent across the Global Telecommunications System (GTS), from which they are collected and decoded by the Air Force Global Weather Center (AFGWC) for forecasting purposes.

The annual and seasonal climatological solar radiation maps for Sri Lanka was developed using the 40-km resolution gridded cloud cover data (Real-Time Nephanalysis) provided by the National Climatic Data Center as input to NREL's Climatological Solar Radiation (CSR) model [7]. The CSR model incorporates most of the deterministic algorithms of the parametric METSTAT model described above.

In both model, dimensionless transmittance values are used to calculate the direct beam and diffuse sky solar radiation elements for each atmospheric parameter that absorbs or scatters radiation. The transmittance values are then multiplied by appropriate extraterrestrial (top-of-the-atmosphere) solar radiation in watt-hours per square meter (Wh/m^2) to find surface solar radiation in Wh/m^2. An assessment of the solar resources has been developed for Sri Lanka using a methodology that converts cloud cover information, derived either from surface observations or satellite imagery, into solar resource estimates. The annual results, has shown the range is 4.5 to 6.0 $kWh/m^2/day$ for Sri Lanka [7].

The summery of results of solar mapping analysis are given in table 3.

Table 3 Solar mapping analysis of Sri Lanka

No.	Region	Solar Potential Tilted at Latitude ($kWhr/m^2/day$)
1	Jaffna Peninsular, South-East near coastal area and North Central	5.5-6.0
2	Region not lying in 1 & 3	5.0-5.5
3	Southern coastal area, Colombo, Southern Colombo and South-East coastal area	4.5-5.0

8. Discussion

To cope up with increase of demand of power annually and as the Sri Lanka has abundance of environmentally friendly renewable energy this energy can be utilized for future country needs. The SWERA project in Sri Lanka facilitated in developing wind and solar potentials of the country with the support of UNEP using developed tools and facilities. The results of the assessment can be used to promote the integration of wind and solar alternatives in grid and off-grid applications in planning,

designing and policymaking. The Sri Lanka government can attract entrepreneurs to invest on renewable energy projects as the trends in power generation has to change from fossil fuel to renewables, thereby to reduce dependency of imported fossil fuel use and ultimately to reduce Global Hazardous Gas (GHG) emissions.

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10. References

[1]. Annual Report 2002, Central Bank of Sri Lanka, 2003
[2]. Annual Report 2003, Central Bank of Sri Lanka, April 2004
[3]. Ceylon Electricity Board. Long term generation expansion plan (2003-2017). June 2003
[4]. http://www.risoe.dk/ita/regneserver/projects/kamm.htm
[5]. Maxwell E.L. (1998) METSTAT-The solar radiation model used in the production of the NSRDB. Solar Energy 62, 4, 263-279.
[6]. National Engineering Research and Development Centre. Country Report for SWERA. 2004
[7]. Solar Resource Assessment for Sri Lanka and Maldives, (2004) Dave Renné, Ray George, Bill Marion and Donna Heimiller (NREL) Chris Gueymard (Solar Consulting Services)
[8]. Wind Energy Resource Atlas of Sri Lanka and the Maldives, D. Elliott, M. Schwartz, G. Scott, S. Haymes, D. Heimiller, R. George National Renewable Energy Laboratory