Solar Power Technologies and Prospective Utilisation of Solar Energy in Kerala: A Techno-Economic Analysis in the Background of Energy Crisis.

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ABSTRACT *Solar power incident on the earth's surface chiefly depends on parameters like topographical location, earth-sun movements andangle of the earth's rotational axis. Solar power is derived directly from the sun`s natural light and its use is both environment-friendly and cost-effective over the long term. Solar power can be used to generate electricity to homes, business and industrial structure.For the last few years, the State faces power crises.The rising power demand supply mismatch the reaping of solar power is the only solution. Kerala, which issituatedin Malabar Coastdevelopinga part of western coast of India. Which receives an annual average solar insolation over 5.5 KWh/sq.m/day.Keralahas very good renewable energy policies for different solar power harvesting methods such as roof top solar photovoltaic plants,off grid solar plants, decentralized wind-solar -hybrid plants etc.*

Keywords: *Urbanization, Colonial India.*

1. Introduction

Solar power is a renewable and sustainable energy source that can be used around the world to generate electricity for a number of different purposes. The daily and hourly records of the amount of sunshine is necessary for estimating global solar radiation values using regression equations and for optimizing the design of a particular solar collector.**[Ramachandra, T.V., 2000]**. Kerala electricity is mainly contributed byconventionalenergy source such as diesel, coal,gas and hydro energy. Kerala the non-conventional energy sources installedcapacity is only 4 per cent. But state acquires better solar radiation ,this resources not using significantly.Since the Stateis facing power shortage, solar energy harvesting couldbe a solution to that problem.This study aims:

- To analyze the performance of power sectors in Kerala,
- To analyze the various applications of Concentrating Solar Power and Solar Photovoltaic in the State.
- To examine the environmental and economic benefits of solar energy in the state energy technologies in Kerala.

The study is based on secondary data. The data sources are the energy reports of World Wide Fund(WWF), Kerala State Electricity Board (KSEB), Agency of Non-Conventional Energy and Rural Technology (ANERT),and Ministry of Renewable Energy (MNRE).For the purposes of analysis and drawing Land Use and Land Cover (LULC), Terrain Slope, Global Horizontal Irradiance(GHI) tools have been used.

2. Power System

Power system in Kerala shows a vigorous role in Kerala's developmental activities. On total installed capacity Kerala's ranks at 16 th position. Energy crisis is the prime limitation for starting new economical projects in Kerala. Kerala State Electricity Board Limited (KSEBL) is the single power entity looking after electricity production, transmission and distributionin the State.

2.1. Electrical Energy Consumption Scenario in Kerala

The 18th electric power supply peak load and energy requirement variations in Kerala.During 2014- `15 to 2016- `17, the peak load electric power supply increasedfrom 4157 MW to 4669 MW, but, during the same period the increase in the energy requirement was from 23554 MU to 26584 MU.

Table 1: energy consumption and growth rate

particulars	Various years				
	2011-12	2012-13	2013-14	2014-15	2015-16
Total consumption of electricity (MU)	15981	16838	17454	18426	19325
Growth rate (%)	-	5.36	3.65	5.5	4.8

Percapita consumption of elctricity(kWh)	478	501	516	544	565
Growth rate(%)	-	4.8	2.9	5.4	8.8

Source: Economic Review 2015-16, Kerala State Planning Board, Govt. of Kerala Thiruvananthapura

Table 2 shows the different energy sources and its installed capacity in Kerala. Hydro electricity is the major energy sources in Kerala .in 2012 the total installed capacity in hydel were 2008.80 MW,thermal installed capacity were 234.60MW,wind energy was 2.03 MW and no production in solar energy.in 20013 ,14 the hydel electricity increased from only 1 MW.,but in 2016 the total hydel electricity increased from 2046 MW.

Table 2: Energy Source and Installed Capacity

Sl.No	Source of energy	Installed capacity (in MW)				
		2012	2013	2014	2015	2016
1	Hydel: KSEBL	2008.80	2007.40	2008.60	2024.15	2046.15
2	Thermal:KSEBL	234.60	234.60	234.60	159.96	159.96
3	Wind:KSEBL	2.03	2.03	2.03	2.03	2.025
4	Solar	-	-	-	-	1.156
5	NTPC	359.60	359.60	359.60	359.60	359.60
6	Thermal: IPP	198.93	198.93	198.93	198.93	198.93
7	HYDEL Captive	33	33	33	33	33
8	Hyde : IPP	10	10	22.11	25.16	25.16
9	Wind: IPP	32.85	32.85	32.85	32.85	41.25

Source: economic review 2012-16,government of Kerala ,Trivandrum

3. Potential Assessment of Solar Power

The basic approach for assessment of solar potential is to work out the net available area suitable for solar generation. This net available area identified in each technology family, namelyConcentrated Solar Power (CSP) and SolarPhotovoltaic (SPV).Solar Photovoltaic (SPV) as a method for generating electric power by using solar cells which convert energy from the sun into a flow of electrons by the photovoltaic effect. InKerala, the potentiality of Concentrated Solar Power and Solar Photovoltaic are converted into electricity assumingaverage for each technology family (50 MW/km^2 for solar PV and 35 MW/km^{2}for CSP)[Central Electricity Authority, 2010**]**.Table6 shows the assessment for solar PV and CSPtechnologies in Kerala.

Table 3: Assessment of SPV and CSP Technologies in Kerala

Parameter	Value	Remarks/sources
Average land requirement(PV)	50MW/km^2	Based on WISE STUDY
Minimum GHI(PV)	1600kWh/m^2	based on field interactions
Maximum slope(PV)	5%	Based on industry norm
Minimum contiguous land	5 acres (.02km^2)	Assuming minimum scale of 1MW
Land availability	Waste land only scenario and grassland only scenario	-

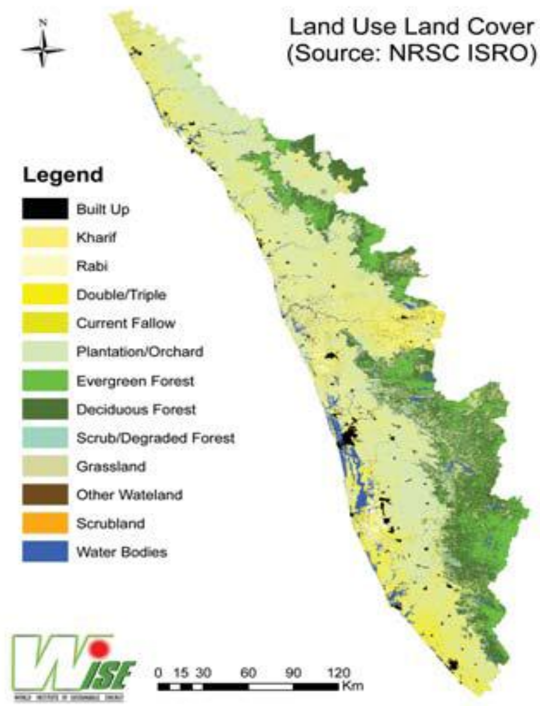
Source: CEA.2010.report of sub –group II & III on integration of solar systems with thermal and hydro power stations.central electricity authority.New Delhi .http://www.cea.nic.in./more_upload/solar_sg2_3_report pdf

3.1 Potential of Grid Tied SPV in Kerala

Figures 1, 2and 3 show the base tools of Land Use and Land Cover (LULC), terrain slope, and Global Horizontal Irradiance (GHI), usedin the analysis. GHI is the total amount of shortwave radiation received from above by a horizontal surface. Annual GHI (Kerala) shown in the figure3is established by the US National Renewable Energy Laboratory (NREL) in cooperation with India's Ministry of New and Renewable Energy (MNRE).

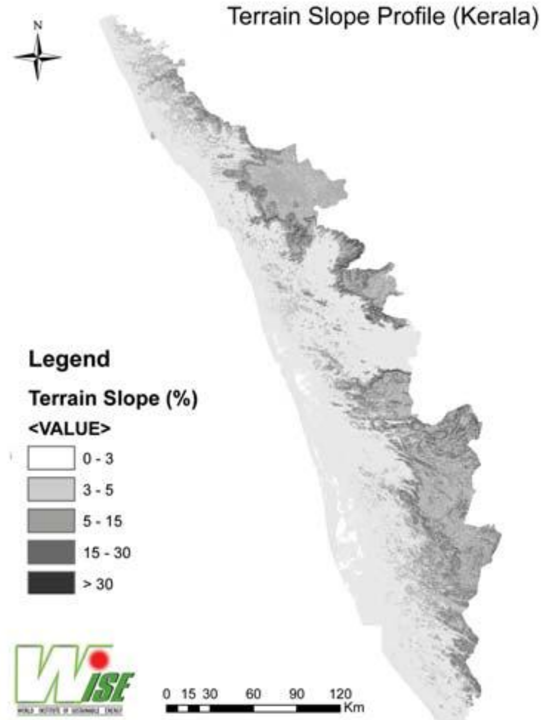
The figure 2 shows the terrain slope of vertical and horizontal dimensions of land surface in Kerala.The figure1displays LULC tool, obtained by classifying raw satellite data into land use land cover categories based on the return value of the satellite image[WISE renewable energy report about Kerala 2013]. This LULC is prepared by National Remote Sensing Centre (NRSC) located at Hyderabad which is one of the centers of the Indian Space Research Organization (ISRO).

Figure 1



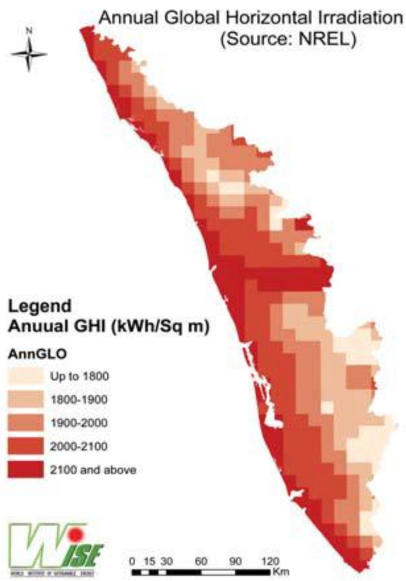
Source:WISE Study About Kerala Renewable Energy Report 2013, WWF-India &World Institute of Sustainable Energy,

Figure 2



Source: WISE Study About Kerala Renewable Energy Report 2013,WWF-India & World Institute of Sustainable Energy, Pune

Figure 3



Source :WISE Study About Kerala Renewable Energy Report 2013,WWF-India & World Institute of Sustainable Energy, Pune.

The WISE study, the three data tools were re-categorized based on the following criteria: land use - wasteland, slope -< 5 per cent and GHI - > 1,600 kWh/m^2.The figure 3 shows that Kerala State GHI is in between1800 - 2100 kWh/Sq m annually.Fromtheresult ofGIS analysis, it can be seen that the wasteland based potential areas are available in almost all the districts in small patches, but the districts with largest potential seem to be Palakkad, Trissur, Mallapuram and Kasargod. Grassland based potential, on the other hand is concentrated more aroundWayanad, Palakkad, Trissur, Ernakulum and Idukki.

The potentiality of grid tied type CSP in Kerala is estimated at 2,649 MW.From the results of the GIS analysis, it can be seen that the wasteland basedpotential areas are available mainly in Palakkad, Trissur and Mallapuram, and withsmall areas in Kasargod, Ernakulum and Alappuzha. Grassland based potential area is concentrated only in Palakkad and Trissur.

3.2.Floating Solar Panels

Floating type SPV power project is a new and emerging concept in India, and could prove to be amajor option for land- starved state like Kerala. A normal floating PV system can be installed on all types of water bodies like lakes, saltwater lakes, reservoirs, small water sources, dams, rivers, etc. The use of floating solar panels has a number of economic benefits when compared to relying on traditional solar panels. The underutilized areas such as reservoirs, dams, canalsetcwill become very productive power stations. Based on the LULCmap of Kerala, the total area of water bodies is estimated to be 769 km^2 and the utilization of even 10 per cent of this area can be capable of being translated into an installed base of 3,845 MW. This figure is considered as the maximum exploitable potential for floating PV[Kerala Renewable Energy Report 2013].

3.3 District –Wise Solar Resource Valuation of Kerala

On the basis of solar resource valuation in Kerala, GHI daily average value is 5.49kWh/m^2/day and the annual value is 2,003 kWh/m^2/year. Similarly, the DNI daily average value is 4.49 kWh/m^2/day,whichcan be translated into an annual value of 1,639 kWh/m^2/year.As a general principle,any site with GHI more than 1,500 kWh/m^2/year is suitable for SPV technology.The value based assessment indicates that Kerala is highly suitable fordeveloping SPV systems. However, the resource values do not supportsolar thermal power generation because the average DNI issignificantly less than the threshold valuesof 1,800 kWh/m^2/year required fordeveloping such projects.

3.4Applications of SPV

The first application of SPV system was used in 1958 to power the space satellite, Vanguard-1. There are numerous applications of solar photovoltaic systems, some of which are lighting, communications, electricity for remote areas, disaster relief, scientific experiments, signal systems, water pumping, charging vehicle batteries, refrigeration, public utilities etc.

3.4.1 Rooftop SPV

Based on the house roof materials categorized in Census 2011, households with thatched roofs and polythene covered roofs were not considered suitable for SPV installation. Out of the remaining categories, roofs with tiles and slates were considered suitable for installation of only 1 kWp SPV power packs [ANERT Report 2011].

3.4.2 Solar Water Heating

Solar water heaters find wide application in large establishments like hostels, hotels, hospitals, industries such as textile, paper, and food processing.Solar water heaters can be either active or passive.An active system uses an electric pump to circulate the heat transfer fluid; a passive system has no pump. Solar water heating systems are used by both households and commercial buildings. The potentiality of solar water heating system inKerala is estimated at 6,812,722 m^2 of the collector area on the basis of 2011 Census.

3.4.3Solar Process Heating

Commercial and industrial buildings may use solar process heating for versatile applications – they are passive heating, day lighting, ventilation air pre-heating, solar drying etc.Keralahas significant potential for installation of solar drying systems, especially in areas of fish drying, spices drying and latex drying.

3.4.3.1Solar Fish Drying.

In 2011-12, the State produced 693,000 tons of fresh fish,of which 16 per cent was usedfor drying[Department of Animal Husbandry Dairying & Fisheries, 2013].At present, a variety of methods are utilized for drying salted fish – sun drying or natural drying, electrical drying and solar drying. The local practice of fish drying in open sun can lead to quality issues like high moisture content, uncontrolled drying and contamination. Use of solar drying can be advantageous for units as the controlled process will result in faster drying and a higher quality product [Harikumar, G.andRajendran, 2007].

3.4.3.2Solar Spices Drying

Kerala is a leading producer of exotic spices. These spices need careful and tender handling in the drying process to ensure that they retain their proper colour and aroma. The average annual productions of spices in tones are[Department of Economics and Statistics 2005]: Pepper (31,021), Cardamom (7,829), Ginger (31,084), Turmeric (6,520), Cloves (82) and Nutmeg (11,412)[Directorate of Economics and Statistics 2013]. Considering 100m^2 of solar air-dryercollector area requirement perbatch of a tone, the total potential for spices drying is estimated to be 8,794,700 m^2 of the collector area.

3.5 Conclusion

Harvesting of solar energy in waste land (barren land) and grass land could meet the present as well as futureelectricitydemand in Kerala.The potentiality of solar power is 44,456 MW (2,650MW ofCSP and 41,806 MW of solar PV).The actual implementable solarpotentialwill depend on technological choices and commercial feasibility.For decentralized SPV, the indicated values suggest a huge potential. Fortunately, as the State has already started tapping it aggressively, it is assumed that the indicated potential can be fully harnessed over time. For grid-tied PV, the potential figures assume 100 per cent availability of identified potential area of about 135 km^2 (80 km^2 of wasteland and 55 km^2 of grassland).n Kerala, as SPV is more technically and commercially feasible, Government should formulate suitable policies which will enrich the SPVs. Solar energy technologies could help address energy access to rural and remote communities, help improve long-term energy security and green-house gas mitigation.Furthermore, the harnessing of these new technologies would contribute to the attainment of the broad goals of our state, viz., increase in the State domesticincome, employmentgeneration, poverty amelioration and self-reliance.

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