RESILIENCE THROUGH RENEWABLE ENERGY - AN ASSESSEMNET OF SOLAR ENERGY POTENTIAL IN KERALA

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Abstract

Recent proliferation in energy consumption saddled with low energy supply options left Kerala with a choice of opting a sustainable source of energy with trivial cost and maximum benefit. The state, along with the support of the central government, put forward renewable energy sources in which solar energy technology found to the most viable and efficiently utilisable source. However, the state currently has incredibly uneven dependence on hydropower which inherently has its own limitations. Moreover, hydropower reservoirs are under the urge of threat due to irregular climatic conditions and socio-political contingencies. Despite solar power is abundantly available and proven to be more consistent and have multifunctionality than hydro power, the state lag behinds in deployments due to various reasons. One of the major reasons for slow growth of solar power is lack of cognizance about the potential and applicability of solar technology in the state. The state lacks a clear exhibition of its potential in terms of its land availability and solar insolation rate. Hence this paper attempts to elucidate the current potential of Kerala by assessing the land available for deployments along with the solar radiation capturing rate of various districts of the state. The study analyses the potential of Solar PV applications and Concentrated Solar power applications (CSP) through literature reviews. The evaluations revealed that the grid tied solar potential of grassland, wetland and floating solar PV comes to 10661 MW. Similarly, the grid solar CSP have a potential of 2650 MW. Off grid applications potential is estimated to greater than 32000 MW. Apart from these, solar thermal applications including solar fish drying, solar spices drying and solar water heating systems was also estimated. The study suggests the state have high potential in PV applications rather than concentrated solar power applications.

Keywords: Solar energy, Solar potential, Kerala, Solar PV, Thermal applications

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1. Introduction

Kerala sets an example of sustainable development where high levels of human development are separated from important economic metrics like industrial expansion. Without adhering to the principles of the industrial economy, Kerala is credited as being a pioneer in the strategy toward decentralised development and governance. The state has made great advancements in literacy, healthcare, population control, and poverty reduction. In this sense, Kerala stands for a series of paradoxes that counter the traditional tenets of development economics. Even though Kerala's model has received praise from all around the globe for its high Human Development Index (HDI) score, issues with energy supply (Pillai, 2004), job creation, and food production persist, necessitating a new strategy for the economy's growth.

In Kerala, the electricity sector's expansion has been incredibly uneven. Presently hydropower dominates the state's energy mix (71 per cent of the installed capacity of 2,857 MW as on 31 March 2011). For decades, the state's main energy source has been hydropower. It is evident that more than 55% of the peak demand and 35% of the energy needs are now satisfied by hydroelectric facilities (*Kerala State Electricity Board Limited - Periyar Basin Hydro Projects*, n.d.), whose energy availability prediction is based on a typical monsoon. However, the state's ability for hydropower generation has been severely reduced due to the environmental degradation of the state's rivers brought on by massive sand mining, deforestation in the catchments, and irregular monsoons. Moreover, the domestic and commercial sectors, which together account for around 70 percent of the overall energy consumption, are expected to have very significant increase in energy demand, according to historical consumption trends. Given the rate of urbanisation, rising wealth, and the rapidly expanding services industry, it appears unlikely that demand would slow down in these areas.

In this situation, switching quickly and deliberately to renewable energy sources could be the wisest course of action for the state. The Ministry of New and Renewable Energy (MNRE) estimates that the state has non-conventional energy potential in the range of 1,000 MW for wind, 762 MW for biomass, and 704 MW for small hydropower (SHP). However, other renewable energy sources such as solar, offshore wind, biofuels, and ocean energy, have not yet undergone a full prospective evaluation process. Hence this study attempts to undertake an evaluation of the current status and prospects of the most widely and abundantly available renewable technology, Solar energy, in the state of Kerala through extensive literature review.

2. Types of Solar Technology Projects

Sunlight is a completely free and endless source of energy. The energy potential of solar radiation that strikes the surface of the planet in an hour is more than the amount of energy used by mankind in a year. The solar cell has the ability to convert solar radiation into electric potential while emitting no hazardous by-products. A solar panel is a collection of interconnected solar cells. The conversion of sunlight into energy is done through the use of either concentrated solar power (CSP) or photovoltaic (PV) technology. A huge area of sunlight is focused into a narrow beam using lenses, mirrors, and tracking devices in concentrated solar power plants. Similarly, photovoltaic (PV) uses semiconductors that show the photovoltaic effect to convert solar energy into direct current electricity. Though both techniques are in practice, solar photovoltaic technology gained wide acceptance due to its ease of use and perceived benefits and the state provide attractive financial incentives to both residential and commercial sectors.

3. Resources required for assessing solar potential

3.1. Land availability

Land availability is a major perquisite for solar energy installations. Though solar energy is abundant, conversion of energy into electricity requires the installation of adequate capacity of solar panels. This requires land availability for either ground mounted solar installations or for rooftop installations. Grass land and other wastelands lands are deemed to be suitable for solar potential assessment (WWF India & WISE, 2013). The land availability of Kerala for the assessment of solar potential is depicted in table 1.

Table 1. Solar PV potential Areas

Solar PV Potential	**Potential Area (km^2)**	**Potential (MW)**
Wasteland	85.46	4273.0
Grassland	50.87	2543.5

In order to determine the net area that might be used for solar generating, the technological, geographic, and societal constraints must be taken into account. This net area is to be then translated into potential using the average land utilisation factors for each technology family (50 MW/km2 for solar PV and 35 MW/km2 for CSP).

3.2. Solar Irradiation Data

For solar energy potential assessment, solar irradiation data is essential. However, lack of proper solar irradiation gauging instruments probes a barrier in solar energy markets in India (Kumar, 2020). As a result of limited land supply in Kerala for large, centralised grid-tied solar power facilities, off grid deployments are also promoted. Despite these land limitation, the state's yearly average GHI and DNI lights to a favourable indication for embracing solar energy where an average solar insolation of 4-5kw/m.sq./day is attained

(*NSEFI - National Solar Energy Federation of India*, 2022).Table 2 gives an overview of solar insolation data of 14 districts of Kerala.

Table 2. District wise GHI and DNI data of Kerala.

District	**DNI(kWh/m2/day)**	**GHI (kWh/m2/day)**
Alappuzha	4.29	5.52
Kannur	4.47	5.43
Ernakulam	4.36	5.44
Idukki	4.52	5.44
Kasargod	4.77	5.54
Kollam	4.27	5.50
Kottayam	4.22	5.45
Kozhikode	4.50	5.47
Malappuram	4.70	5.49
Palakkad	4.55	5.51
Pathanamthitta	4.52	5.52
Thrissur	4.60	5.53
Thiruvananthapuram	4.34	5.52
Wayanad	4.68	5.33
Average	**4.49**	**5.49**

(Source -NSEFI - National Solar Energy Federation of India, 2022)

Table 2 confines the suitability of solar energy in various districts. Districts that have great potential in terms of GHI are Pathanamthitta (5.62),Kasargod(5.54),Trissur(5.53) ,Wayanad (5.53), Alappuzha (5.52) ,Thiruvananthapuram (5.52) and Palakkad (5.51).Moreover, the table shows the state's GHI average is 5.49 kWh/m2/day, or 2,003 kWh/m2/year, on an annual basis. The DNI daily average value is 4.49 kWh/m2/day, which equates to 1,639 kWh/m2/year on an annual basis. Any location that has GHI more than 1,500 kWh/m2/year is generally appropriate for solar PV technology. Kerala is extremely appropriate for the development of solar PV systems, according to a straightforward resource-based analysis. However, since the average DNI is much below the cut-off value of 1,800 kWh/m2/year necessary for establishing such projects, the resource values do not support the viability of solar thermal power generation.

Apart from these, the potential and viability of floating solar and agrivoltaic systems are to be assessed. Any sort of water body, including lakes, saltwater lakes, reservoirs, irrigation ponds, minor water sources, dams, rivers, etc., may have a standard floating PV system placed on it. The solar installation is built to float on a raft membrane in the traditional setup. Energy production is evacuated to an established transmission and distribution network on land. All other components, except for the float design, the tracking mechanism, and the internal cabling, are the same as those used in usual ground-based solar PV systems. Use of the water surface, which generates no income, and lower water surface temperatures, which result in greater generation, are floating PV's two main benefits.

In the state of Kerala, a 92 MW floating PV system is set up at NTPC- Kayamkulam covering an area of 450-acre lake. According to officials, the plant's electricity could power about 26,000 homes each day. Moreover, 1.73 lakh tonnes of carbon emissions cut annually are expected. The project, which cost 465 crores to implement, comprises of about 300000 floating solar PV panels that are made in India (*Prime Minister Narendra Modi Launches Floating Solar Power Plant at NTPC-Kayamkulam*, 2022).

According to the Kerala land use land cover map, the entire area of water bodies is around 769 km2, and even using 10% of that area would result in an installed base of 3,845 MW. This amount is regarded as the greatest potential that could be harnessed for floating PV.

Another notable potential of solar applications in Kerala is agrivoltaic plants. Agrivoltaics is the collocation of crops and solar panels together in the same land (Jain et al., 2021). Since the total arable land in Kerala is estimated to be 2235 hectors in 2019 (*Agricultural Land: Kerala: Type of Use: Agricultural Land/Cultivable Land/Culturable Land/Arable Land | Economic Indicators | CEIC*, n.d.) , deploying solar panels over them seems to be an opportunity. However, Kerala is still at its infancy and lack of availability of data and hence and lack of clear technical knowledge impedes the adoption of agrovoltaics in Kerala.

3.3. Rooftop assessment

Estimating the number of roof tops available among individual households and commercial undertakings is one of the prominent steps in assessing solar potential. Previous literature examined that about 80% of rural families and 90% of urban households of Kerala are capable of using solar PV power packs (WWF India & WISE, 2013)since they have shade free rooftops. Moreover, the suitability of rooftop material is a critical factor. According to census data from 2011, homes with thatched roofs and roofs wrapped in polythene were not deemed appropriate for solar PV installation. Out of the other categories, slate and tile roofs were determined to be only acceptable for the installation of 1 kWp solar PV power packs since many of the homes with these roof types were discovered to have 1 kWp systems requiring additional unique kinds of structures. Concrete roofs were thought to be appropriate for 3 kW solar power packs, which need a roof area of about 45 m^2. It was suggested to include 20% more solar module capacity for partially shaded roofs in order to achieve the necessary output of 1 kWp or 3 kW. An aggregate of 31145 MW potential is available from both household and industrial sector (WWF India & WISE, 2013).

4. Potential of other solar applications

4.1. Solar Water Heater

Both residential and business structures employ solar water heating systems. However, only the household potential for solar water heating has been evaluated as information on occupancy levels in commercial and institutional buildings are not readily available. For solar water heating, only homes with concrete roofs that are completely shade-free are deemed ideal (Dwivedi et al., 2013). Literature states that this equates to a 50% availability of rural homes and a 70% availability of urban homes. The 2011 Census provided the information on the number of homes having concrete roofs. Based on these information's, potential of solar water heaters in Kerala is portrayed in table 3

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Table 3. Information on solar water heater potential in Kerala

Parameters	Rural	Urban
Total households with concrete rooftops	1600213	2101144
Feasible house %	50	70
Feasible house number	800107	1470801
No. of houses with 100 LPD	400053	735400
No. of houses with 200 LPD	400053	735400
Total collector area (m2) in 100 LPD houses		
Total collector area (m2) in 200 LPD houses	800107	1470801
Total potential (m2)	1600213	2941602
	2400320	4412422
Total	6812722	

4.2. Solar Water Pumping

Most of the region of the state is fortunate to have ground water that is less than 10 metres below ground level (bgl). According to the research, which is based on a survey of wells located throughout the state's geographic region, 37% of the wells had water levels between 5 and 10 m bgl, while just 12% have levels over 10 m bgl water (ministry of water bodies, 2012).Based on the aforementioned data, it is estimated that up to 10 metres of ground water may be present in 87% of the irrigated land. As currently available solar PV pumps with capacities of 0.5 to 2 hp can readily pump water from a depth of 10 to 12 m, it may be concluded that Kerala has a sizable potential market for solar PV pumping.

According to accepted standards, a solar PV pump with a capacity of 0.9 kW should be adequate to irrigate 1 hectare of land.

Furthermore, it is estimated that all irrigated land (337,560 ha) with water levels lower than 10 m bgl may be converted to solar PV irrigation. Technically speaking, this equates to around 304 MW.

4.3. Solar Process Heating

Kerala also offers huge potential for solar drying system installation, particularly in the fields of fish drying, latex drying and spice drying. The possibility to use this in the production of latex is likewise enormous. However, there has not been a prospective evaluation for this industry because there isn't real data on the process parameters. However, brief descriptions on some of the practicable solar process drying applications are described below.

4.3.1. Solar Fish Drying

Kerala produced 693,000 tonnes of fresh fish in the year 2011–12, of which the fish drying industry utilised around 16%. Salted fish is currently dried using several techniques, including electrical drying, solar drying, and natural or sun drying. The native technique of drying fish in the open sun might result in quality concerns like excessive moisture content, uncontrolled drying, and contamination which were visibly evident through actual onsite inspections. Units may benefit from using solar drying since a regulated procedure leads to quicker drying and a higher-quality product. Additionally, it was shown that solar drying systems for fish drying applications had a payback period of approximately 3–4 years, making this alternative highly practical for the fish industries in Kerala.

The area needed for a sun drying system is projected to be 11,088,000 m2 of solar air-dryer collector area, taking into account the fish drying production figure of 110,880 tonnes in 2011–12 (16 percent of the fresh catch in 2011–12). The realisable potential for solar dryers has been considered to be 75% of this number, or 8,316,000 m2 of the collector area, in order to account for site limits and other constraints.

4.3.2. Solar Spices Drying

Kerala is rich in the production of exotic spices. To guarantee that these spices maintain their appropriate colour and scent during the drying process, attention and gentle handling are required. Most spices are collected between September and October, and drying is necessary throughout those same months. Drying the spices requires a temperature range of 45 to 50 °C (the temperature must not exceed 55 °C). Currently, the drying of spices in traditional dryers using LPG, firewood, or kerosene comes with the risk of smoke inhalation and uncontrolled heating. 300–500 kg of spices can be loaded on each batch, and it uses flue pipes to slowly dry the spices over the course of 24–30 hours while keeping them on multi-story (4-5) mesh trays. To preserve the spices' original moisture content, which was between 70 and 80 percent, it is reduced to between 10 and 11 percent. Additionally, it was mentioned that conventional spice dryers are eligible for a 33 percent subsidy, which could also apply to solar dryers.

According to information from the Indian Spices Board**,** the average yearly output of spices in tonnes is as follows: pepper (31,021), cardamom (7,829), ginger (31,084), turmeric (6,520), cloves (82) and nutmeg (11,412). The yearly production of spices is 87,947 tonnes. The entire potential for drying spices is projected to be 8,794,700 m2 of the collector area, taking into account the requirement of 100 m2 of solar air-dryer collecting area per tonne of batch.

Discussions and future outlook

The study examines solar energy potential of Kerala in terms of solar insolation data and land availability. Furthermore, the suitability of other solar applications including solar water heater, solar water pumping, solar drying and solar processing are investigated throughout the study. To summarise, the grid tied solar potential of grassland, wetland and floating solar PV comes to 4273 MW,2543 MW and 3845 MW respectively .Similarly, the grid solar CSP have a potential of 2457 MW and 193 MW in wastelands and Grasslands. Off grid applications (including household, commercial and solar water pumping) potential is estimated to greater than 32000 MW. Apart from these, solar thermal applications including solar fish drying, solar spices drying and solar water heating systems was estimated to be 8316000 m^2 , 8794700 m^2 and 6812722 m^2 respectively.

From the above figures it is evident that Kerala has a vast potential for embracing solar energy technology. However delving to the facts reveal that though a sum total of 44000 mw and above is estimated from both PV and CSP, actual implementation requires reliable infrastructure, commercial viability and efficient policy framework. Furthermore, though CSP altogether contributes to about 2600 MW, none of it could be financially viable. Apparently, CSP potential seems to be limited since the annual DNI data is below the threshold limit of 1800 kWh/m^2.

Regarding the possibility of decentralised solar, decentralised PV and thermal are fundamentally presuming to share the same roofs. However, given Kerala's low DNI values, PV applications will be a rational choice than going for water heating. Given the vast potential of decentralised applications, the state had initiated deployments much aggressively which in turn will suffice the sustainable goals. Moreover, grid tied solar PV applications in terms of land availability gives a prognostic indication for cent percent attainability of the estimated potential.

Though the study estimated the potential of Kerala in solar energy applications, a much more comprehensive study with latest data can be carried out. Furthermore, the study limited its area of scope to the potential in terms of geographical peculiarity. A techno economic analysis and a behavioural approach toward the solar energy adoption can be carried out so that the practical implications can be drawn out instead of merely drawing out the solar potential.

Conclusion

The rising trajectory of energy demands necessitated the incorporation of solar energy to the energy composition of Kerala. Since Kerala have vast potential for capturing the solar energy, tapping it precisely could be a plausible solution to the rising concerns over energy, environment, and human health. The study revealed that solar PV systems have high potential rather than thermal applications. This calls for a much more transparent framework in institutional setup, policies & regulations and technical support for a wide spread distillation of solar PV so that the energy consumption pattern of the state can be shifted to a much more sustainable source. Decentralised solar applications are proven to be suitable for rural areas even where electricity access is denied. Hence Kerala, through sufficient financial incentives and clear policy framework, can electrify even the marginalised groups which in turn can be a solution to the energy paucity.

References

Agricultural Land: Kerala: Type of Use: Agricultural Land/Cultivable Land/Culturable Land/Arable Land | Economic Indicators | CEIC. (n.d.). Retrieved November 30, 2022, from https://www.ceicdata.com/en/india/agricultural-land-type-of-use-kerala/agricultural-land-kerala-type-of-use-agricultural-landcultivable-landculturable-landarable-land

Central Ground Water Board. 2012. Ground Water Level Scenario in India. Ministry of Water Resources. Faridabad, India

Dwivedi, A., Bari, A., & Dwivedi, G. (2013). Scope and Application of Solar Thermal Energy in India-A Review. *International Journal of Engineering Research and Technology*, *6*(3), 315–322. http://www.irphouse.com

Jain, P., Raina, G., Sinha, S., Malik, P., & Mathur, S. (2021). Agrovoltaics: Step towards sustainable energy-food combination. *Bioresource Technology Reports*, *15*. https://doi.org/10.1016/j.biteb.2021.100766

Kerala State Electricity Board Limited - Periyar Basin Hydro Projects. (n.d.). Retrieved December 1, 2022, from https://www.kseb.in/index.php?option=com_content&view=article&id=69&Itemid=714&lang=en

Kumar, D. (2020). Satellite-based solar energy potential analysis for southern states of India. *Energy Reports*, *6*, 1487–1500. https://doi.org/10.1016/J.EGYR.2020.05.028

NSEFI - National Solar Energy Federation of India. (2022). https://www.nsefi.in/

Pillai, N. V. (2004). *THE POWER CRISIS IN KERALA*.

https://www.researchgate.net/publication/343473894

Prime Minister Narendra Modi launches floating solar power plant at NTPC-Kayamkulam. (2022, July 30). The Hindu.

WWF India, & WISE. (2013). *THE ENERGY REPORT-KERALA 100% RENEWABLE ENERGY BY 2050*.