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Solar Resource Assessment in Jammu and Kashmir State

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Abstract**—***The state of Jammu and Kashmir has diverse agro-climatic zones. The present paper on solar resource assessment in the state of Jammu and Kashmir is based on ten years of average data taken from NREL and SRRA stations. The state is blessed with huge solar potential, both for thermal generation as well as photovoltaic. The same energy can be used for electricity and process heat generation to mitigate growing energy crisis particularly in winter. The data as obtained from NREL and C-WET through SRRA stations revealed that the state is receiving more than 5 kWh/m^2/day of average DNI and GHI every month which in itself can be harnessed for solar thermal energy and photovoltaic power. The average DNI and GHI received from last ten years varied from (1 kWh/day/m^2) to (8kWh/day/m^2) per day.*

Keywords— Solar resource assessment, Jammu and Kashmir, Solar, photovoltaic, thermal, Direct normal radiation, Global horizontal radiation, National Renewable Energy Laboratory.

I. INTRODUCTION

Jammu and Kashmir has extensive energy needs and increasing difficulty in meeting those needs through traditional means of power generation. Jammu and Kashmir is energy starved state though it has one of the best potentials in Renewable Energy viz. Solar Energy, bioenergy, geothermal energy, alternate hydro energy and other alternate sources of energy. The potential energy sources have not been harnessed till date resulting in low capita per energy availability forcing people to use wood, coal and LPG cylinders for heating purpose in winter and switching to kerosene, LPG and other fossil fuels for electricity generation. Developing and encouraging proper resource assessment of all renewable energy sources in state is important in present scenario where there has been acute shortage of energy and electricity. Among all Renewable Energy sources, solar energy can also play an important role in mitigating energy crisis in state. It can provide secure energy supply with additional income to state and shall generate employment in state.

The state of Jammu and Kashmir has large scope of solar energy, however there is wide gap between estimated potential and the cumulative achievements made so far (1). The state is situated in northern Himalayas spreading over 33^0-37^{0}N latitude and 70^0- 80 ^{0}E longitude **(2).** The state comprises of 6.7 percent of total geographical area of country covering over 2.22 lakh square km, of which 30 percent is under cultivation. The mean ambient temperature in Jammu ranges between 13 -33 degree Celsius, in Kashmir the mean ambient temperature ranges in between 0 to 25 degree Celsius and in Leh, region, which actually receives highest DNI in India has average ambient temperature of -8 to 18 degrees Celsius temperature (figure 1). The low ambient temperature gives rise to huge energy requirement. The same energy is needed for power generation (electricity) and heating, which are also either run on traditional electricity and is mostly met through burning coal, firewood and LPG.

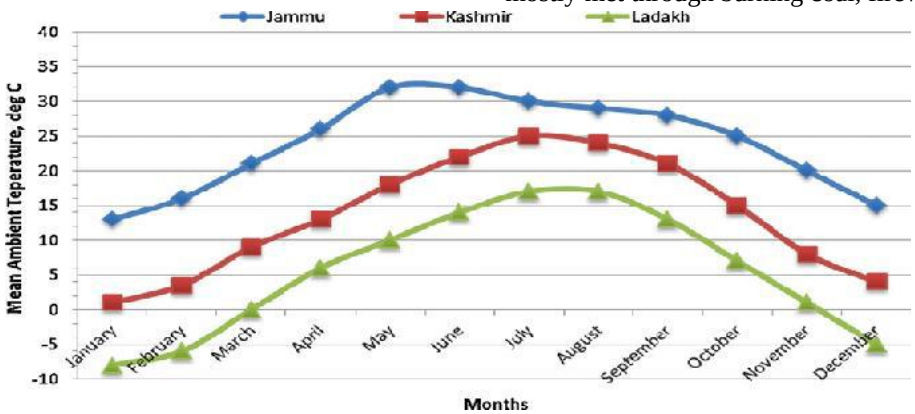

Fig.1: Mean ambient temperature of Jammu, Kashmir and Leh division (10 years data)

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However, the low ambient temperature is an important factor in deciding efficiency of CST technologies. Low ambient temperature and high DNI can give best efficiency in solar thermal production. Leh region in Jammu and Kashmir receives highest sunshine days in whole country and can be one of the best places for solar cooking, solar drying and solar thermal electricity generation through trough collectors or CST technology. The same technologies can even be used for process heat design to ensure heat flow through HVAC systems. Higher DNI ensures higher efficiencies in solar cooking, solar water heating systems and solar green houses. The present studies shall evaluate DNI and GHI for three regions of Jammu and Kashmir. i,e Jammu ,kashmir and Ladakh. The average data of 10 years has been evaluated, the same data has been obtained from NREL and SSRA C-WET data stations. Solar energy is an important renewable energy source that is expected to play a significant role in the future energy supply mix [3–6].

Solar technologies could be characterised as either passive solar or active solar depending on the way they capture, convert, and distribute solar energy. An active solar technique includes using photovoltaic panels and solar thermal collectors to harness the energy. A passive solar technique includes orienting a building to the sun, selecting materials with positive thermal mass or light dispersing properties, and designing buildings that naturally circulate air.

II. ASSESSMENT OF SOLAR ENERGY IN J&K STATE

Electricity and heat can be generated by radiation either through solar photovoltaic route or through solar thermal route. Availability of reliable solar radiation data is vital for the success of solar energy installations in different sites of the country. For solar collectors which are flat in nature, solar radiation data in the form of Global Horizontal Irradiance (GHI) is useful whereas for solar collectors which are concentrating in nature Direct Normal Irradiance (DNI) data is required. Solar thermal power plants are essentially Concentrating Solar Power (CSP) units. For designing solar thermal power plants, DNI data is therefore a pre-requisite. For solar energy needs we mainly differ between Global Horizontal Irradiance, which consist of Direct Irradiance of the sun and the scattered Irradiance and Direct Normal Irradiance (DNI), which is the Direct Irradiance reaching a surface that is always perpendicular to the sun. GHI is important factor to determine efficacy for photovoltaics, while DNI is of special importance for solar thermal applications. Solar energy can be important source of energy in state which is traditionally harnessing hydro energy and dependent on hydel projects or diesel gensets only.

Fig.2: SRRA station by Centre of Wind Energy Technology (MNRE) at Leh for assessment of solar radiation data.

CPV(Concentrated photovoltaic) systems use optics to concentrate a large area of sunlight onto a small solar cell and are either refractive (with lenses) or reflective (with mirrors). To achieve high concentration ratios, the optics have a narrow field of view and only make use of direct normal irradiance (DNI) from the sun. DNI is most accurately measured by a high quality pyrheliometer

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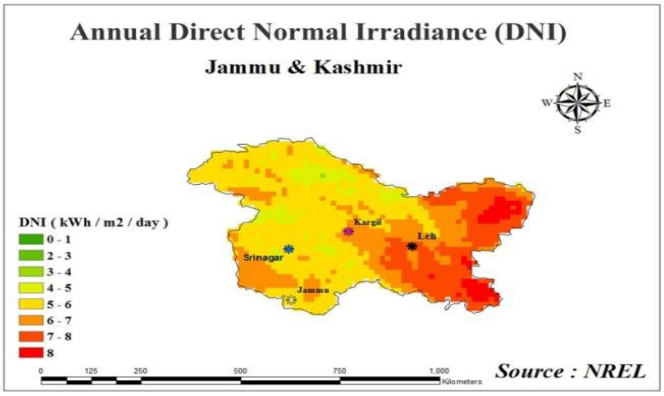
mounted on a precise automatic sun tracker to provide reliable data about the solar radiation input.

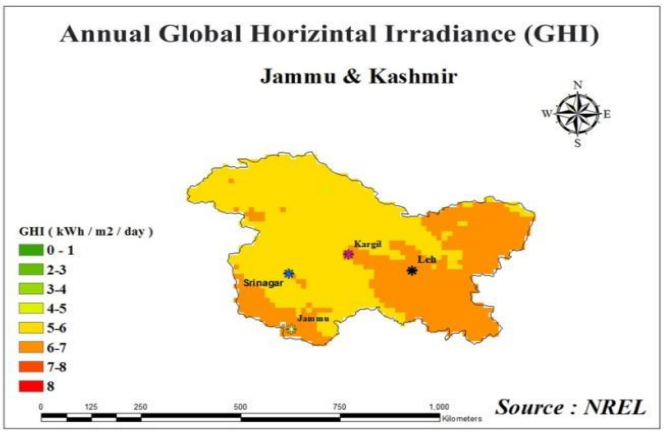
Thermal systems use the direct normal irradiance (DNI) from the sun to generate heat, which can be used as the energy source for steam turbine electricity generators. These systems use mirrors to concentrate solar radiation. Unlike PV cells, they can take advantage of the full spectrum of solar radiation, including ultraviolet and near infrared light, leading to high efficiencies. For such systems it is extremely important to monitor the broadband solar radiation with high precision, because sky conditions have a strong influence on the performance of a CSP plant. To predict the energy yield of a CSP system with a minimum of uncertainty it is crucial to measure solar radiation locally. Satellite measurements and related models don't take into account theof local climatic conditions, such as clouds, nor do they include local aerosols (dust, sand and other particles). Two CSP plants in different locations with equal direct irradiance totals, according to satellite data, may have very different energy outputs, due to differences in clouds and aerosols in the particular locations, which block the incoming radiation. To ensure the reliability and redundancy of the data, a typical CSP solar monitoring station uses high precision instruments with low uncertainty for the measurements of direct, diffuse and global irradiance. This way the direct radiation measurement can be compared with values derived from the global and diffuse radiation.

The amount of solar radiation available over time under the local environmental conditions is a key input for choosing the optimal location, technology and size of a solar energy project. Feasibility studies and technical calculations of a solar energy project always start with energy resource assessment. High precision on-site measurements of solar radiation provide the lowest uncertainty for bankable data about the energy resource and the possible energy yield. Such measurements are performed by a high quality solar radiation monitoring station that measures all three components of solar radiation: direct normal irradiance (DNI), diffuse horizontal irradiance (DHI) and global horizontal irradiance (GHI). Also, other meteorological parameters relevant to the project, such as air temperature, humidity, precipitation, wind speed and direction need to be monitored by a dedicated weather station. The GHI and DNI data obtained and calculated shows a great scope of both solar thermal technology (through CST) and photovoltaic systems. The photovoltaic systems can be developed and installed on both off grid and on grid mode. The Smart grids can be developed to feed this energy (electricity) and the same can be sent to consumer use.

III. RESULTS AND DISCUSSION



Direct Normal Irradiance (kWh /m²/ day)					
Sl.No	Month	Jammu	Srinagar	Kargil	Leh
1.	January	3.44	2.78	2.27	4.78
2.	February	4.38	2.52	2.40	3.77
3.	March	5.31	3.85	3.69	6.13
4.	April	5.65	4.63	5.29	6.76
5.	May	6.37	5.83	6.34	6.97
6.	June	5.21	6.15	5.83	6.68
7.	July	3.88	5.69	5.65	6.49
8.	August	4.31	5.62	5.33	6.45
9.	September	5.40	6.07	6.04	7.43
10.	October	5.65	6.48	7.03	7.95
11.	November	4.49	4.89	6.48	7.58
12.	December	3.95	2.99	3.33	6.05
13.	Annual	4.84	4.80	4.98	6.43



Global Horizontal Irradiance (kWh /m²/ day)					
Sl.No	Month	Jammu	Srinagar	Kargil	Leh
1.	January	2.97	2.60	2.25	2.95
2.	February	3.88	3.06	2.98	3.39
3.	March	5.31	4.59	4.17	5.31
4.	April	6.46	5.67	5.94	6.01
5.	May	7.32	6.81	7.10	7.35
6.	June	7.00	7.20	7.27	7.52
7.	July	6.00	6.70	6.90	7.34
8.	August	5.70	6.17	6.32	6.72
9.	September	5.60	5.71	5.81	6.22
10.	October	4.97	4.92	4.99	5.26
11.	November	3.74	3.56	3.83	4.09
12.	December	2.99	2.60	2.34	3.15
13.	Annual	5.17	4.97	5.00	5.50

Fig.3: Annual Direct Normal Irradiance (DNI) and Annual Global Horizontal Irradiance (GHI) for Jammu and Kashmir state based on 10 years NREL data.

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The annual solar radiation received in all the regions of Jammu & Kashmir is relatively high. Based on hourly estimate of 10 years (2002-11) radiation data collected from geostationary orbit satellites with a resolution of 10 kms, by NREL and ground data, radiation is being estimated. Solar radiation has huge seasonal/monthly fluctuation. Solar radiation is directly linked with day length (no of day hours/day) and angle between sun radiation and surface. During summer sun radiation is more perpendicular than winter. And also, summer day length is longer than winter. The month wise values recorded for the last ten years by NREL along with radiation maps for DNI and GHI, along with annual total are given below. Green colour illustrates lowest range of radiation (0-1 kWh/day/m^2) and red highest (8kWh/day/m^2). For solar energy, January is a very bad month while June is excellent. Monthly variation of DNI and GHI are given in figure 3.

The monthly global horizontal radiation (GHI) for the state of Jammu and Kashmir based on 10 years of average data from NREL is given below:

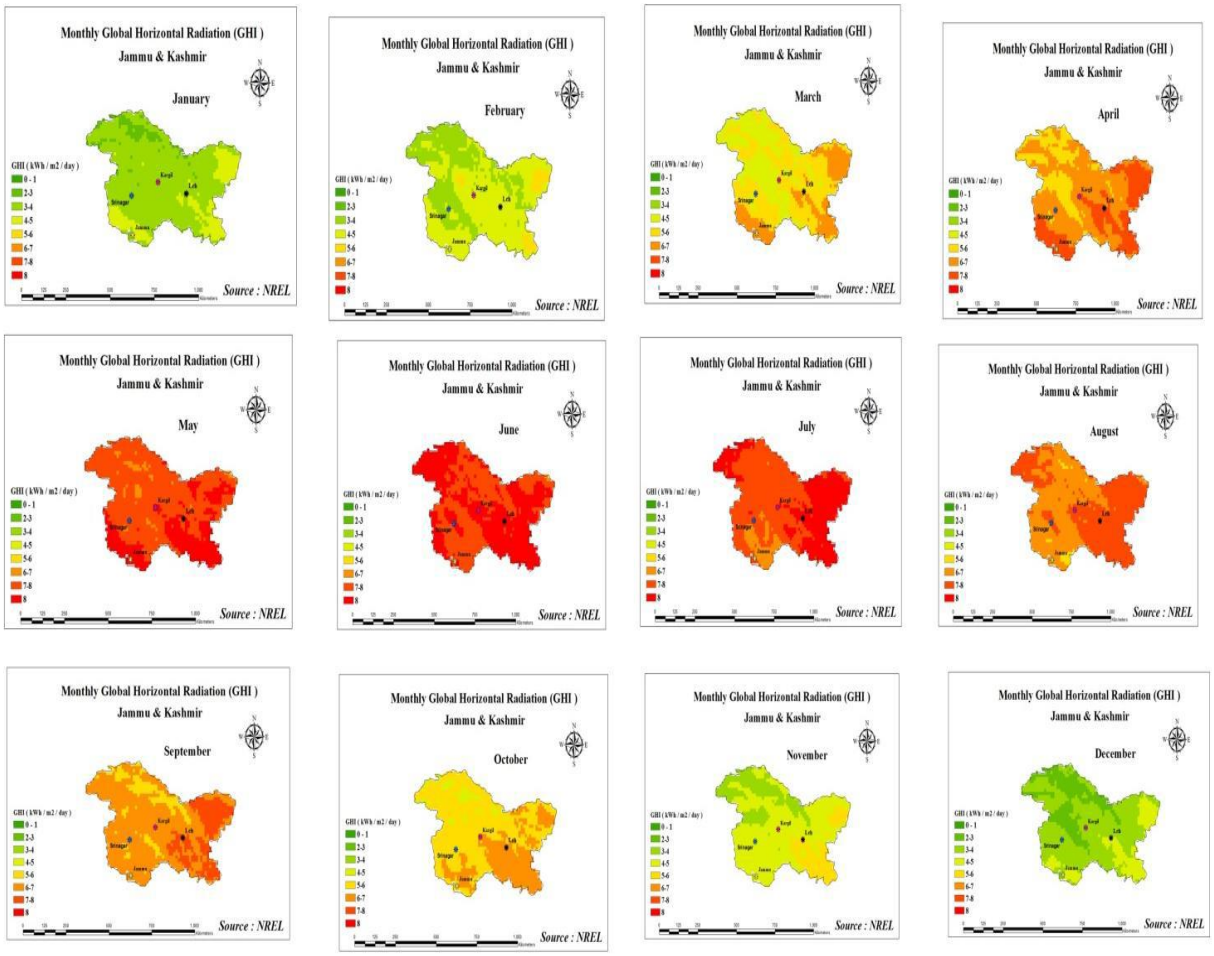

Fig.4: Average monthly global horizontal radiation data for the state of Jammu and Kashmir.

The monthly direct normal radiation (DNI) for the state of Jammu and Kashmir based on 10 years of average data from NREL is given below:

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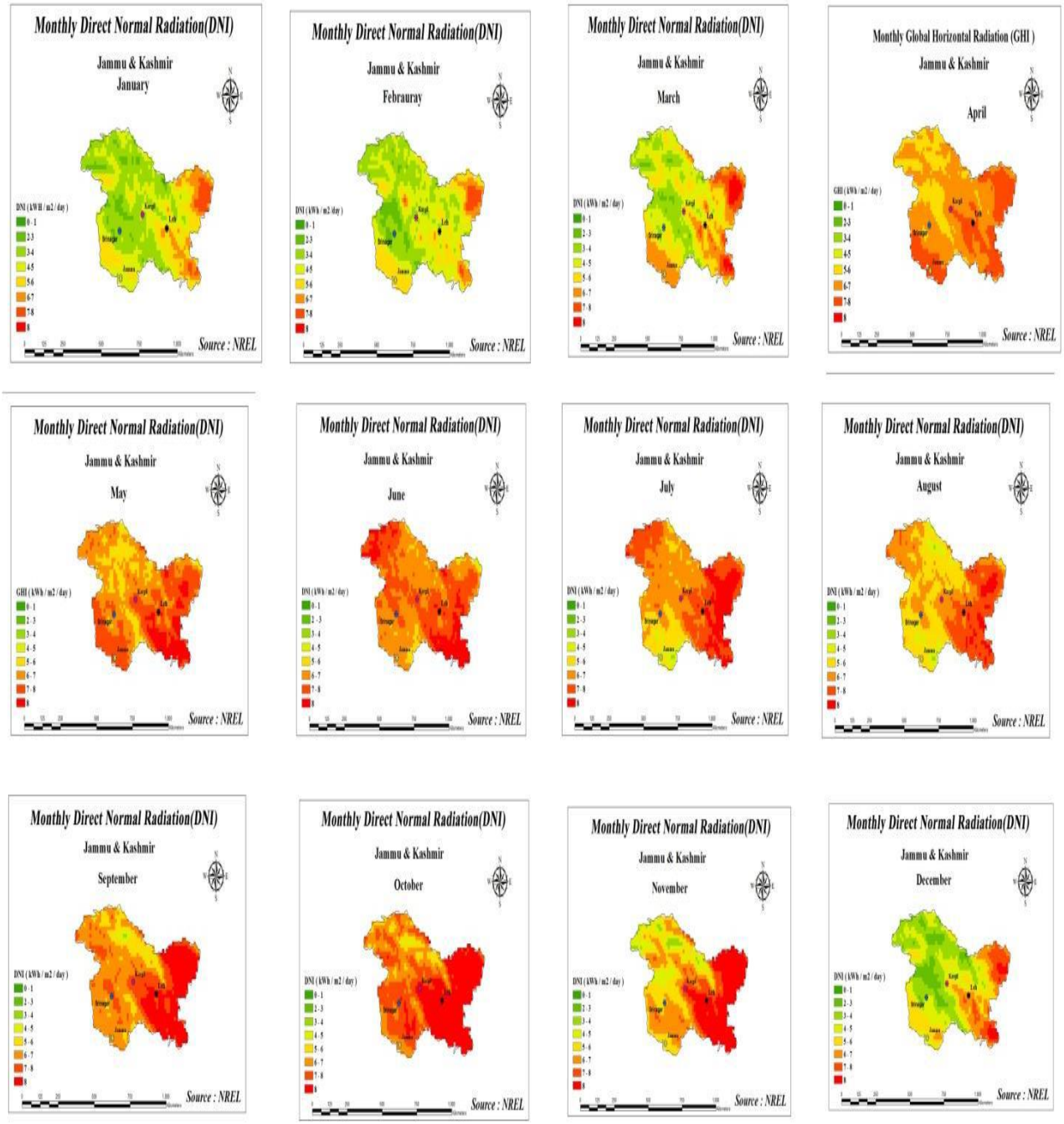

Fig.5: Average monthly direct normal radiation data for the state of Jammu and Kashmir.

During winter, tilt radiation is almost double than the horizontal whereas in summer there is a good horizontal radiation which is helpful in photovoltaic electricity generation. Low ambient temperature with high GHI ensures higher efficiency of solar panels and thus higher efficiency of solar photovoltaic electricity. The Annual global radiation at latitude is around 25% greater than horizontal, especially in Ladakh region. The higher values of DNI in Jammu and Kashmir ensures high efficiency of concentrated solar technologies like parabolic trough and dish collectors have high grade heat application. From the above DNI & GHI map of J&K, it is clear that Leh has highest DNI and GHI. Kargil has second highest DNI in state. Overall, solar radiation is always good in summer months when the demand is comparatively high. During winter months, the demand of electricity can be made available by hybridizing solar photovoltaic and solar thermal technology. This will ensure both electricity and

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heat is made available to areas like Leh, Kargil and Kashmir and parts of Jammu which have inadequate energy solutions at present. The process heat can be utilized by using Flat plate collectors as well as evacuated tube collectors which are mainly used for low grade heat application (under 50- 70^0C). The Solar concentrated technologies (parabolic trough, Parabolic dish collector etc.) are good for high grade heat application (above 100^0C). By switching to appropriate solar energy technologies, the Jammu and Kashmir state can mitigate its growing energy demands based on Clean and green energy.

The results reveal that average GHI and DNI for all regions vary in between 4-8 kWh per square per metre per day. Thus, investment in solar energy is a natural choice for Jammu and Kashmir and for solar resource assessment is mandatory at all locations for proper selection of solar energy technology.

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