Solar Resource Assessment in India a Case Study

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Abstract— **This paper represent and assessment on solar power resource available in India. Day by day electrical energy consumption is increasing which also increases the generation of greenhouse gases due to uses of fossil fuel. The pollution level is crossing the danger limit, so world is moving towards practices of renewable energy sources. Solar energy is one of the largest and easily available renewable energy sources. Through this paper an attempt has been taken to discuss the solar resource available in India and the potentials related to solar energy has to be discovered .One detail case study on solar power uses has been given, the problem related to solar power application has been highlighted and finally the future aspect in India on solar power has been mentioned. India collects good annual solar emission although having several climatic zones. With this background India began its study towards renewable energy over three decades ago.**

Index Terms— **Indian Meteorological Department, Direct normal Irradiance, Global Horizontal Irradiance, millions tons of oil equivalent, Ministry of non-renewable energy.**

I. Introduction

The energy scenario in India going through a increasing challenges for its future energy policy. With an installed generating capacity of 2, 11,766.22 MW [1] and a per capita consumption of a mere for 2009-10 is 779 kWh of electricity, India is suffering from huge estimated shortages of nearly 10% in energy terms and almost 17% in terms of peak demand (2007/08). Energy and peak shortages in 2013/14 were 6.7% and 2.3%, respectively [2]. These shortages in the system are increasing rapidly because of increasing demand and our inability to have met more than 40%–50% of the targeted capacity addition required in the last three Five-year Plan periods. This is the situation when over 50% of India's rural population does not even have access to electricity. On the basis of a detailed solar radiation and land resource assessment, the maximum theoretical potential of CSP in NW India is estimated over 2000 GW taking into accounts the viability of different CSP technologies and land suitability criteria. The technical potential is estimated over 1700 GW at an annual direct normal incidence (DNI) over 1800 kW h/m2 and finally, the economic potential is estimated over 700 GW at an annual DNI over 2000 kW h/m2 in NW India. The Indian Government launched Jawaharlal Nehru National Solar Mission (JNNSM), with an inclusive aim to develop and indorse solar energy applications in the country, with an aim of getting grid equivalence for solar power by 2022. For this, a target of 20,000 megawatt (MW) of grid connected solar power has been envisioned, which is in accumulation to an off grid target of 2,000 MW equivalent and increasing growth of solar thermal collector area to 20 million square meters (m^2) by 2022. To achieve this target, the importance of correct, dependable and available solar data was realised and the Government took the choice to increase the data measurement network to fulfil this necessity. The India Meteorological Department (IMD) is the statutory body responsible for measurements and monitoring of weather limitations. Solar radiation data, as a part of the overall checking of weather data, has been available in the country for many decades. Solar radiation standards of Global Horizontal Irradiance (GHI) and Direct Normal Irradiance (DNI) are also available from the Meteonorm software. In 2009 the US National Renewable Energy Laboratory (NREL) released its first version of a satellite-based solar radiation map, which involved both GHI and DNI and covered the North West of India. In 2010 an efficient version of the map was released by NREL that covered the entire country. In the meantime several commercial satellite-derived data sets developed existing for example, 3TIER, the Solemi data set of DLR (Deutsches Zentrum fur Luft- und Raumfahrt –German Aerospace Centre), the iMaps data of GeoModel Solar and the data from IrSOLaV. Although these efforts the consistency of solar radiation data for India is still poor

II. Need For Solar

By 2035, there will be 18% rise in global energy consumption.

The production of nuclear electricity is very expensive. Approximately 21000Cr. Rupees are needed to produce 1MW. If we use water for production we need only 6000Cr. Rupees to produce 1MW, moreover there is always a risk of radiation from the nuclear plants.

A projection in the 12th Plan document of the Planning Commission indicates that total domestic energy production of 669.6 million tons of oil equivalent (MTOE) will be reached by 2016-17 and 844 MTOE by 2021-22. This will meet around 71 per cent and 69 per cent of expected energy consumption, with the balance to be met from imports, projected to be about 267.8 MTOE by 2016-17 and 375.6 MTOE by 2021-22 [3].

The 33% of coal based plants generates large amount of ash with other environmental harmful emission of ashes such as Carbon Di-oxide (CO_2), Sulpher Di-oxide (SO_2), and Nitrous Oxides (NO_x).

India's crude oil reserves tend to be low, with specific gravity varying from 38°API(API gravity express the gravity or density of liquid petroleum products) in the offshore Mumbai High field to 32° API at other onshore basins. In India roughly 880,000 bbl/d of total oil in 2008 is produced. India has over 3600 operating oil wells, according to OGJ. In 2011-12, India was the fourth largest consumer in the world of Crude Oil and Natural Gas, after the United States, China, and Russia. India's energy demand continued to rise in spite of slowing global economy [4].

India's power sector has a total installed capacity of approximately 1, 46,753MW of which 54% is coal based, 25% Hydro, 8% is renewable and the balance is the gas and nuclear based. Power shortage is estimated at about 11% of total energy and 15% of peak capacity requirements and is likely to increase in the coming years. In the next 10 years, another 10,000MW of capacity and investment of about Rs. 24Lakh Cr. are required [5].

Palakkad district of Kerala remains India's only "total electrified district" as on Feb 11th 2010.

III. Work To Be Done

The Jawaharlal Neheru Mission (JNNSM) was launched a few days before the UN Climate Change Summit in Copenhagen on December 2009. On March 5th 2010, The Ministry of New and Renewable Energy (MNRE) published the draft Guidelines for selection of New Grid connected Solar Projects under Phase 1 of JNNSM:

The Mission has set a target of 20,000 MW and stipulates implementation and achievement of the target in 3 phases (first phase upto 2012-13, second phase from 2013 to 2017 and the third phase from 2017 to 2022) for various components, including grid connected solar power [6].

A solar Thermal Power Plant of 140MW at MATHANIA in Rajasthan has been proposed and sanctioned by the Government of Rajasthan. The project configuration of 140MW Integrated Solar combined Cycle Power Plant involves at 35MW solar power generating component and the GEF has approved a grant of US$40 million for the project. The Government of Germany has agreed to provide a soft loan of DM 116.8 million and a Commercial Loan of DM 133.2 million for the project.

Rajasthan Government will promote setting up of solar power projects direct Discomp's of Rajasthan. The total capacity under this category will be distributed equally between SPV and CSP based power plants. The total maximum capacity under this category for phase-1 (upto 2012-2013) is 200MW and additional 400MW in phase-2 (2014-2017).

Rajasthan Govt. also planned to develop solar park of 1000MW in identified areas of Jaisalmer, Bikaner, Barmer and Jodhpur districts in various stages [7].

35,000km2 area of The Thar Desert has been set aside for solar power projects, sufficient to generate 700 to 2,100GW. In July India unveiled a $19billion to produce 20GW of solar power by 2020.

During the 12th Plan period, assuming a GDP growth rate of 9% per annum and elasticity 0.8 as compared to 1.0 during 11th plan mainly due to adoption of energy efficient technologies & other Energy Conservation and Demand Side Management measures being taken up during 11th Plan, electricity demand is likely to grow @ 7.2% p.a. Keeping this in view, the energy generation should increase to a level of 1470 BU by 2016-17 from a level of 1038 BU in 2011-12.

However sensitivity analysis have been carried out assuming 8,9 & 10 % GDP growth rates & GDP-electricity elasticity of 0.9 & 0.8 respectively.[8]

IV. Problem

India with a massive plan generating 20GW solar power within a decade has no company domestically producing silicon. About one ton of polysilicon is required to produce 10MW of solar Cells.

To produce a single metric ton (MT) of silicon metal, raw material inputs of 2.8MT quartz, 1.4MT of coal, 2.4MT of wood chips are required. The reduction reaction is very energy intensive requiring about 13MWhr of electricity to produce 1ton of silicon and contributing over one third or 36% to the silicon metal production cost. About 1.4 MT silicon metal are required to produce 1MT of polysilicon suitable for crystalline silicon PV, about 40% of the quartz starting material is converted to silica fume [9].

The genuine irradiation data that is needed for solar photovoltaic applications is the irradiation estimations on a sloped surface since solar panels are sloped to a certain degree for optimum irradiation. Even the equatorial regions employ sloped panels simply to keep it clean from collection of rain water and dust. The data should be reliable and available for designing, optimization and performance evaluation for solar technologies. Solar energy systems are designed based on the monthly average of global solar radiation and other climatic data. It is rather important to determine the beam and diffuse components of total radiation incident on a horizontal surface.

V. India- Till Date

India is at 5th position in terms of installed capacity after USA, Russia, Japan and china.

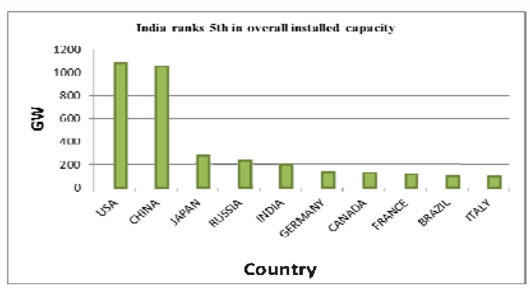

Fig. 1. Position of India by installed capacity

In Bap, near Jodhpur in Rajasthan which receives 2202 kWh/m2 annual equivalent effective DNI (150 W/m2 ≤ DNI ≥850 W/m2) Dalmia Solar company is building CSP plant which is projected to generate 21.39 MU sellable units per year.

The parabolic dish collectors raise the temperature of water up to 650°C generating steam which is used to cook the food. The solar steam cooking system phase 1 is installed at Shirdi has 40 parabolic concentrators dishes placed on the terrace of Sai Prasad Building No.2. They reflect and concentrate the solar rays on the 40 receivers in focus.

The growth of investment in development of renewable energy sources in India 80% accelerated depreciation (which was 100% earlier) for tax purposes in the 1st year of the installation of the project, nil excise duty on manufacture of most of the finished products for utilization and low import tariffs for capital equipment. Apart from this, a 5-year tax holiday is also provided for power generation projects using renewable energy sources. As per the guidelines of the MNRES, the state utilities encouraged renewable energy by offering remunerative price for power purchase and also providing facilities for banking.

India's largest photo voltaic solar plant is presently at Gujrat.

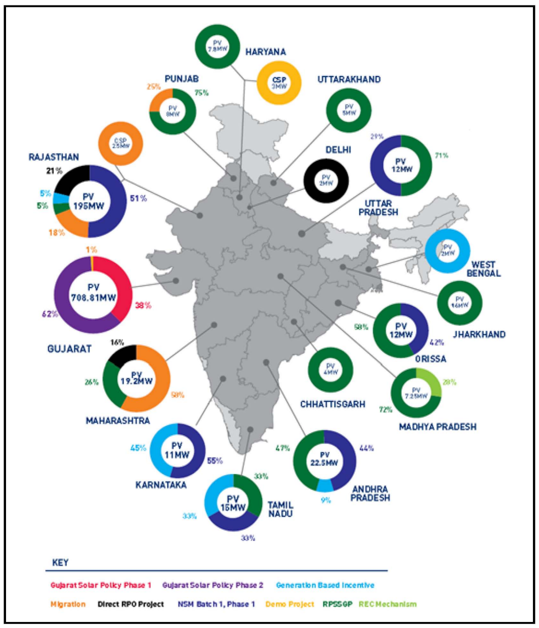

Fig. 2. Various projects across India

Gujarat Solar Park is the name used for a group of solar parks being constructed in Gujarat, India. Certificates of completion were issued on April 19, 2012, for a total of 605 MW, which included some sections that were already operational, and 856.81 MW had been completed by March 31, 2013. One is the Charanka Solar Park, a group of 17 thin-film photovoltaic (PV) power systems, on a 2,000-hectare (4,900-acre) site in the district of Patan. The solar park is expected to save around 8 million tons of carbon dioxide from being released into the atmosphere and save around 900,000 tons of natural gas per year.

By 2012 46, 00,000 solar lanterns and 861,654 solar powered home lights have been installed. These typically replace kerosene lamps and can be purchased for the cost of a few months' worth of kerosene through a small loan. The Ministry of New and Renewable Energy is offering a 30% to 40% subsidy for the cost of lanterns, home lights and small systems up to 210 Wp. 20 million solar lamps are expected by 2022.

Solar PV water pumping systems are used for irrigation and drinking water. The majority of the pumps are fitted with a 200–3,000 watt motor that are powered with 1,800 Wp PV arrays which can deliver about 140,000 liters of water per day from a total head of 10 meters. By 30 September 2006, a total of 7,068 solar PV water pumping systems had been installed, and by March 2012, 7,771 had been installed [10-12].

Bangalore has the largest deployment of rooftop solar water heaters in India. These heaters generate an energy equivalent of 200 MW.

TABLE I. RENEWABLE ENERGY POTENTIAL

Sl.No.	*Source*	**Potential (MW)*	*Installed (MW) as on Jan'12*
1	Wind Power	45,000	16,179
2	Biomass	16,000	1142
3	Small Hydro	15,000	3300
4	Cogeneration-Bagasse	3,500	1952
5	Waste to Energy	2,700	74
6	Solar	Unlimited	481
7	Mandirtala	17.95	46.15

Bangalore is also the first city in the country to put in place an incentive mechanism by providing a rebate of 50 on monthly electricity bills for residents using roof-top thermal systems. These systems are now mandatory for all new structures.

Pune, another city in the western part of India, has also recently made installation of solar water heaters in new buildings mandatory.

In India there are a number of Mono/ Multicrystalline Cells and Module manufacturer. Though the number of cells manufacturer is much less than the Module manufacturer. Some of the important Module Manufacturers of the country are as follows [13]:

1) Bharat Heavy Electricals Ltd., Bangalore
2) Bharat Electricals Ltd., Bangalore
3) Tata Solar, Bangalore
4) Moser Bear Ltd., New Delhi
5) Suntechnic Ltd., Bangalore
6) Webel Solar, Kolkata
7) Photon Ltd., Hyderabad
8) Vikram Solar, Kolkata
9) Sunshine Power, Kolkata
10) Sova Power, Kolkata
11) Titan Power, Hyderabad

VI. SCOPE OF INDIA

India has on average radiation of 4.5-6Kwh/m^2/day with average 280 clear days.

India has total land area of $3.23\times10^{11}m^2$. Even if 1% of this land is used to harness solar energy for electricity generation at an overall efficiency of 10%, use of thermal or photovoltaic methods of power generation can generate 492×10^9 Kwh/year electricity.

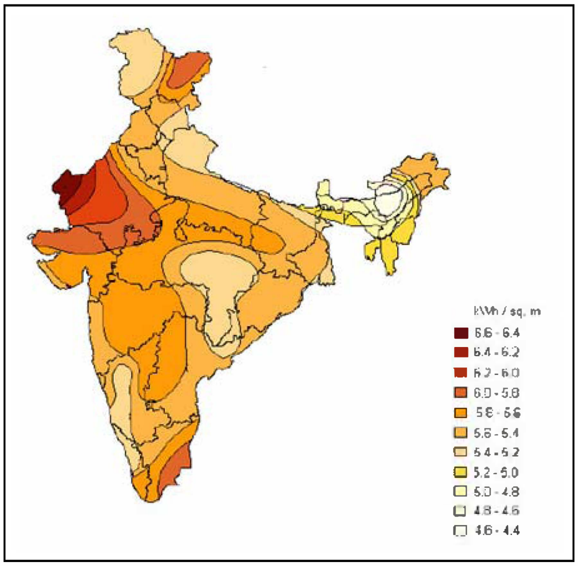

Fig. 3. Solar power density in India

As per MNRE source India has huge potential 84777MW of electricity generation through renewable.

The Draft Renewable Energy Policy, prepared by the ministry of new and renewable energy (MNRE), has set a goal of 10000 MW to be added the total power generation capacity through renewable, which is about 10% of new power generation capacity additions, by the year 2012.

The SOLSILC carbothermic production for silicon route can in principle reduce the cost of feedback to below €15/kg. An exclusive solar generation of capacity of 250 to Kwh units per month would cost around Rs. 5Lakh, with present pricing and taxes [15].

VII. Design And technology

SOLSILC was to develop a new two-step high temperature plasma process for solar-grade silicon production. This work involves with the development of a low-purity Si-process facility in order to control the production process before a clean environment is established. Specially selected carbon-black and quartz are used in the process.

In the process of electrolysis based on the dissolution of quartz in a fluoride-containing bath at 100°C and decomposed of the quartz into silicon and oxygen. Silicon participated at the electrodes. The silicon is crushed and cleaned with acid. In order to obtain a clean product, the silicon is melted and thereafter crystallized into ingots for subsequent sawing into wafers.

The third generation is somewhat ambiguous in the technologies that it encompasses, though generally it tends to include, among others, non-semiconductor technologies (including polymercells and biomimetic), quantumdot, tandem/ multi-junctiocells, intermediate band solar cell, hotcarriercells, photon up conversion and down conversion technologies, and solar thermal technologies, such as thermo photonics, which is one technology identified by Green as being third generation [16]. It also includes:

- Silicon nanostructures
- Modifying incident spectrum (concentration), to reach 300-500 suns and efficiencies of 32% (already attained in Sol3g cells) to +50%.
- Use of excess thermal generation (caused by UV light) to enhance voltages or carrier collection.
- Use of infrared spectrum to produce electricity at night.

VIII. Case study

Sagar Island (also known as Ganga Sagar) lies on the continental shelf of Bay of Bengal about 150 km (80 nautical miles) south of Kolkata, in West Bengal. The area of the island is about 251.59 sq km with 43 villages and a population of over 180408 with population density of 717 / sq km. The latitude of the study area is $21^{o}\ 37^{/}$ N to $21^{0}52^{/}$ N and the longitude of the study area is $88^{0}02^{/}$ E to $88^{0}11^{/}$E. The island suffers from chronic storage of electrical energy due to non availability of grid quality paper. The rivers are tidal in nature and sometimes become about 1 to 4 km wide. Therefore this island is totally isolated from the main island.

West Bengal Renewable Developments agency (WBREDA) in eastern part of India is trying to electricity remote isolated villages of this Sagar isolated island through renewable energies. The underlying issue for this grid connectivity is that rural India will not get 40 % electricity to 50 % of time at the end of 13^{th} plan. Hence, to make 24 hours reliable system of rural India, Renewable Energy Systems must be optimized in the off-grid smart distribution system [17].

TABLE II. Village level electrification status of Sagar island

Sl.No.	*Villages*	*Population -2011*	*Households - 2011*
1	Kamalpur	6601	1341
2	Mritunjoynagar	3142	700
3	Manasadwip	6206	1213
4	Chemaguri	6560	1444
5	Mahendraganj	4554	889
6	Natendrapur	1179	236
7	Haradhanpur	9001	1733
8	Mandirtala	6141	1354
9	Koylapara	3496	722
10	Rudranagar	7126	1423

TABLE III. Village level electrification status of Sagar island

Sl.No.	***Villages***	***Households availing grid electricity (%)***	***Households availing solar electricity (%)***	***Households without electricity (%)***
1	Kamalpur	27.84	55.67	16.49
2	Mritunjoynagar	0	72.92	27.08
3	Manasadwip	17.58	57.14	25.27
4	Chemaguri	22.58	46.24	31.18
5	Mahendraganj	6.58	59.21	34.21
6	Natendrapur	29.41	47.06	23.53
7	Haradhanpur	0	70.23	29.77
8	Mandirtala	17.95	46.15	35.9
9	Koylapara	6.56	78.69	14.75
10	Rudranagar	36.94	40.54	22.52

TABLE IV. CAPACITY AND YEAR OF INSTALLATION OF SELECTED PHOTOVOLTAIC PLANTS

Sl.No.	*Villages*	*Capacity (KW)*	*Year of installation*
1	Kamalpur	26	1996
2	Mritunjoynagar	26	1998
3	Manasadwip	25	1999
4	Chemaguri	25	1999
5	Mahendraganj	25	1999
6	Natendrapur	28.5	2000
7	Haradhanpur	32.5	2000
8	Mandirtala	28.5	2001
9	Koylapara	120	2006
10	Rudranagar	20	2006

IX. CONCLUSION

This knowledge provided a macroscopic view of potential areas with good availability of solar irradiance. The availability of this information, together with data from other sources (viz. simulation models, satellite derived values, etc.) was generally used by the project developers in project designs at the beginning of the missions. In addition, renewable energy has the possible to generate many employment openings at all levels, in rural areas .with solar power being expensive at the current stage of development, tariffs in India are based on a cost plus tariff and set by the Central Electricity Regulatory Commission (CERC). There is an urgent need for conversion from petroleum-based energy systems to one based on renewable resources to reduction requirement on depleting assets of fossil fuels and to moderate climate change. An importance on presenting the real picture of massive renewable energy prospective, it would be possible to attract foreign investments to herald a Green Energy Revolution in India. In 2001 one solar-power station was installed at Mandirtala, Sagar island, West Bengal with power generation capacity of 28.5 (kW). Only, 46.15 % households are using solar-power and 17.95 % house hold is being benefited by grid electricity this village. 35.90 % households are using kerosene. Last of all Koylapara & Rudranagar Hospital solar-power stations are installed in 2006. Solar power systems generate no air pollution during operation, the primary environmental, health, and safety issues involve how they are manufactured, installed, and ultimately disposed of. The most important question is how much fossil energy input is required for solar systems compared to the fossil energy consumed by comparable conventional energy systems. The large amount of land required for utility-scale solar power plants -approximately one square kilometer for every 20-60 megawatts (MW) generated - poses an additional problem in India. Instead, solar energy in particular requires unique, massive applications in the agricultural sector, where farmers need electricity exclusively in the daytime. Even though energy from renewable energy sources is growing rapidly, with markets such as solar cells, wind and biodiesel experiencing annual double digit growth, the overall share is only expected to increase marginally over the coming decades as the demand for energy also grows rapidly, particularly in many developing countries.

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