Solar Energy In India: An Overview

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***Abstract*: India's solar energy insolation is about 5,000 T kWh per year (i.e., ~ 600 TW), far more than its current total primary energy consumption. India's long-term solar potential could be unparalleled in the world because it has the ideal combination of both high solar insolation and a big potential consumer base density. Also a major factor influencing a region's energy intensity is the cost of energy consumed for temperature control. Since cooling load requirements are roughly in phase with the sun's intensity, cooling from intense solar radiation could make perfect energy-economic sense in the subcontinent located mostly in the tropics. With about 300 clear and sunny days in a year (i.e., 365 days) the calculated solar energy incidence on India's land area is about 5000 trillion kilowatt-hours (kWh) per year (or 5 EWh/yr). The solar energy available in a single year exceeds the possible energy output of all of the fossil fuel energy reserves in India. The daily average solar-power-plant generation capacity in India is 0.20 kWh per m^2 of used land area, equivalent to 1400–1800 peak (rated) capacity operating hours in a year with available, commercially-proven technology. India plans to add about 100,000 MW of solar power capacity by 2020. Solar power in India is a fast developing industry. The India's solar installed capacity reached 30.071 GW as of 31 July 2019. India has the lowest capital cost per MW globally to install the solar power plants.**

***Keywords:* Solar energy, Photo voltaic, Tumkuru, Karnataka, India.**

INTRODUCTION

The change in global climate is one of the significant environmental concerns of our time. The only way to overcome or to reduce this disaster is to cut down the level of green house gases. Many different measures have been adopted world wide to limit the green house gas emission and thus to reduce the harm to the environment. Many developing countries have put various initiatives to stabilize the carbon di oxide emissions to a sustainable level. The electric power sector is one of the extensive origins of green house gas emission. To reduce the green house gas emissions, different policies have introduced in power sector throughout the world. The use of renewable energy as an electrical power sources, is one of the most effective policies taken by the power sectors of all regions in the world. Solar is profitable and operationally most viable renewable energy resources and one of the largest power sources in terms of renewable energy sector.

The Indian government had an initial target of 20 GW capacity for 2022, which was achieved four years ahead of schedule. In 2015 the target was raised to 100 GW of solar capacity (including 40 GW from rooftop solar) by 2022, targeting an investment of US$100 billion.

Installation of solar power PV plants require nearly 2.0 hectares (5 acres) land per MW capacity which is similar to coal-fired power plants when life cycle coal mining, consumptive water storage & ash disposal areas are also accounted and hydro power plants when submergence area of water reservoir is also accounted. 1.6 million MW capacity solar plants can be installed in India on its 1% land (32,000 square km). There are vast tracts of land suitable for solar power in all parts of India exceeding 8% of its total area which are unproductive barren and devoid of vegetation. Part of waste lands (32,000 square km) when installed with solar power plants can produce 2400 billion kWh of electricity (two times the total generation in 2013-14) with land productivity/yield of 0.9 million Rs per acre (3 Rs/kWh price) which is at par with many industrial areas and many times more than the best productive irrigated agriculture lands. Moreover, these solar power units are not dependent on supply of any raw material and are self productive. There is unlimited scope for solar electricity to replace all fossil fuel energy requirements (natural gas, coal, lignite and crude oil) if all the marginally productive lands are occupied by solar power plants in future. The solar power potential of India can meet perennially to cater per capita energy consumption at par with USA/Japan for the peak population in its demographic transition.

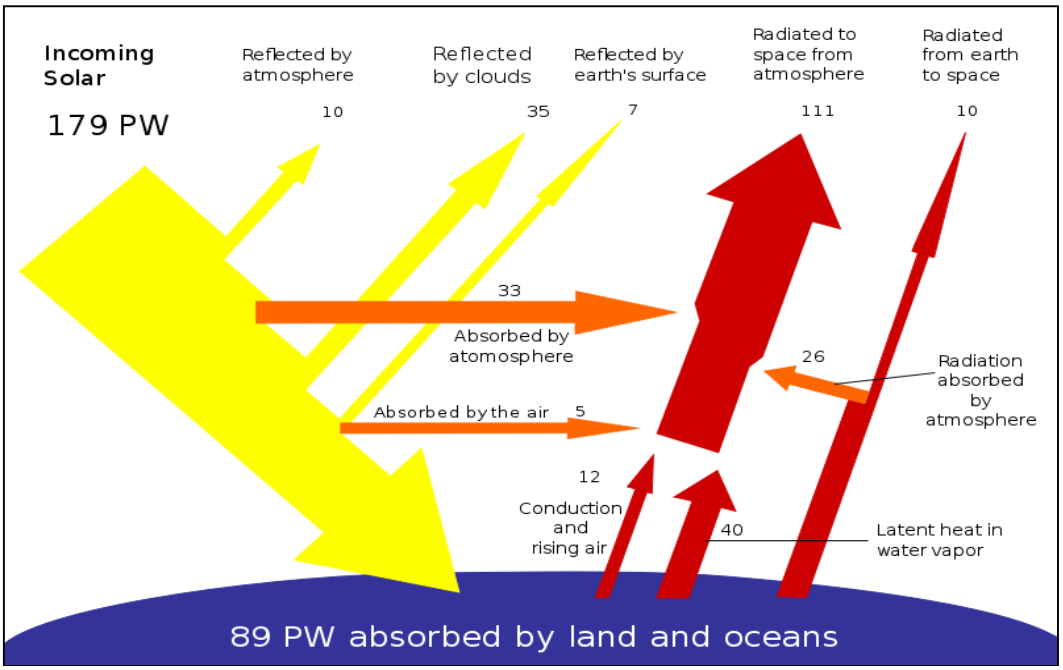

Fig. No. 1: About Half the Incoming Solar Energy Reaches the Earth's Surface

SOLAR RESOURCES OF INDIA

The use of solar power spread exponentially in India during the last few years. There is an affluent amount of solar energy present in India. The average solar insolation received in India is approximately 200MW/km square with an average 250–300 sunny day in a year.

The solar radiation varies geographically. Annual radiation of solar energy is highest in northern region, especially in Ladakh and least in the North-Eastern Region. The solar insolation level in India is more than 5000 trillion kWh per year, whereas daily solar insolation changes from 4 to 7 kWh/m^2, depending on the location. The annual global solar insolation varies from 1600 to 2200 kWh/m^2. It can be observed that some areas of Gujarat, Rajasthan, Madhya Pradesh, Andhra Pradesh and Maharashtra also receive a large amount of solar radiation as compared to other areas of India. The solar radiation level receives lowest in some parts of Arunachal Pradesh and Sikkim.

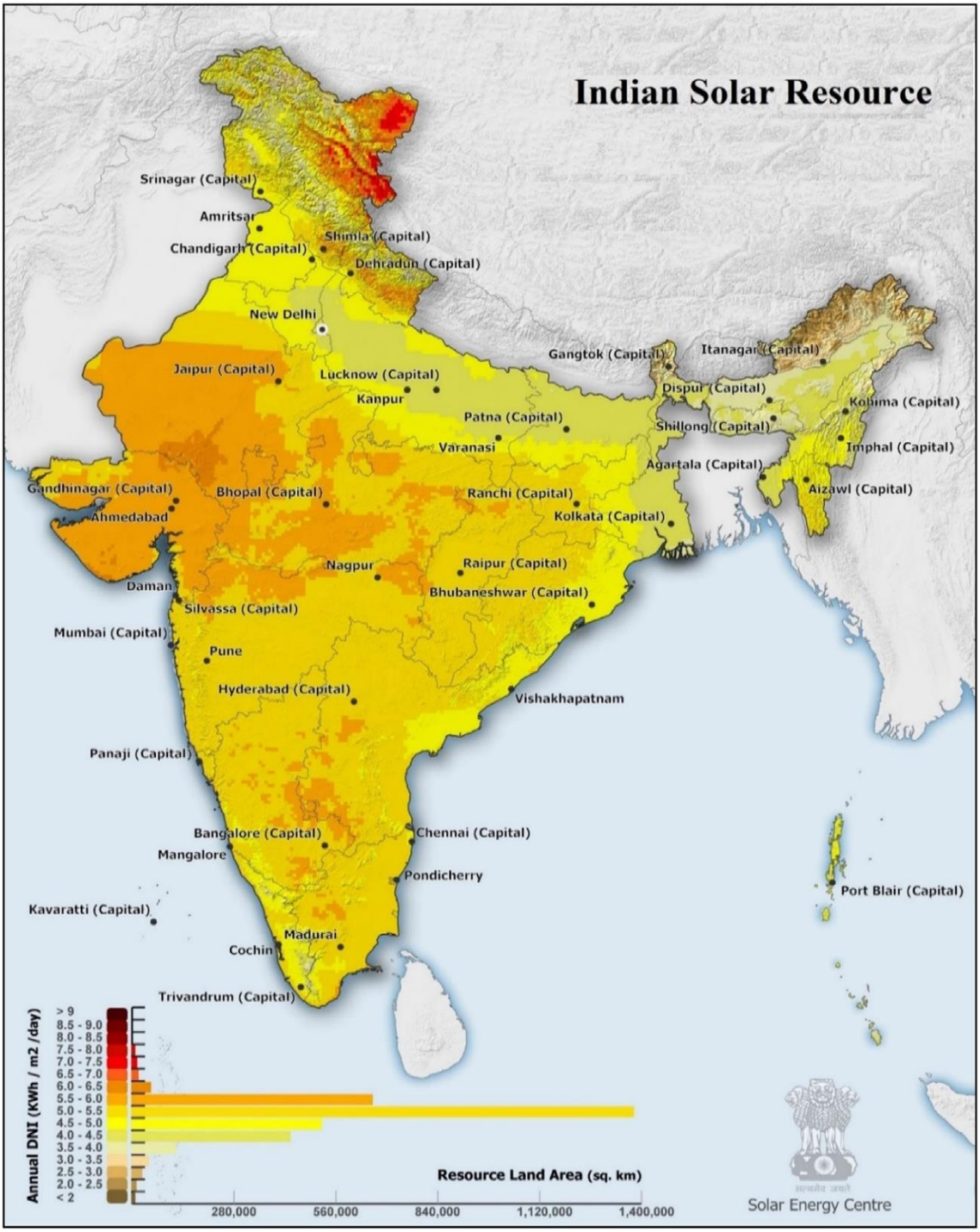

Fig. No. 2: Solar Radiation Map of India
Source: National Renewable Energy Laboratory (NREL)

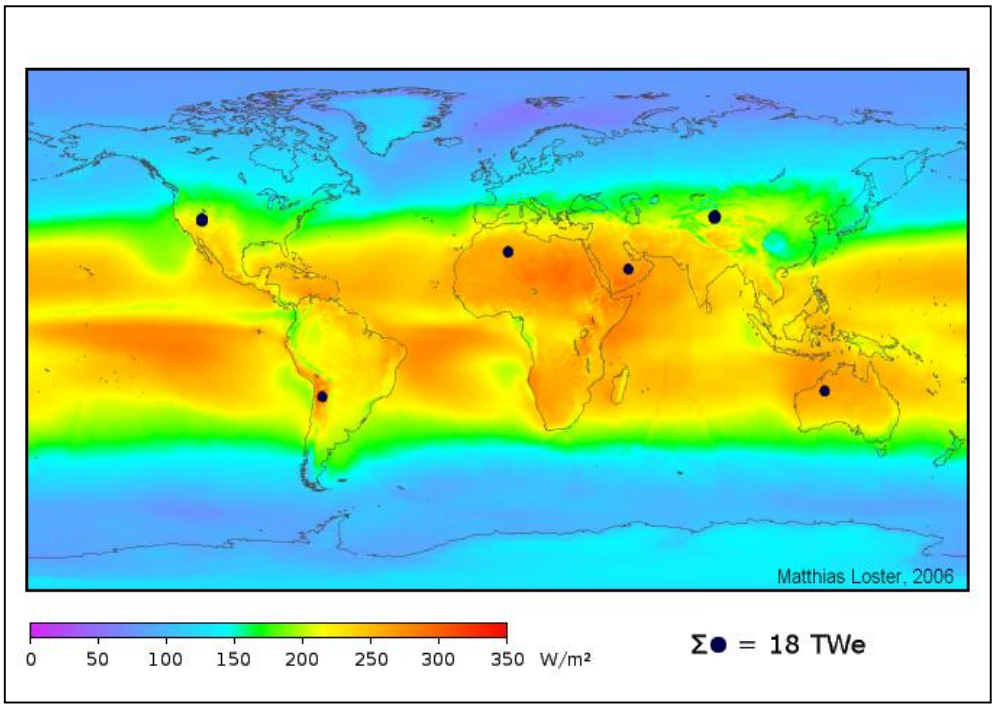

Fig. No. 3: Average Insolation: The Theoretical Area of the Small Black Dots is Sufficient to Supply the World's total Energy Needs of 18 TW with Solar Power

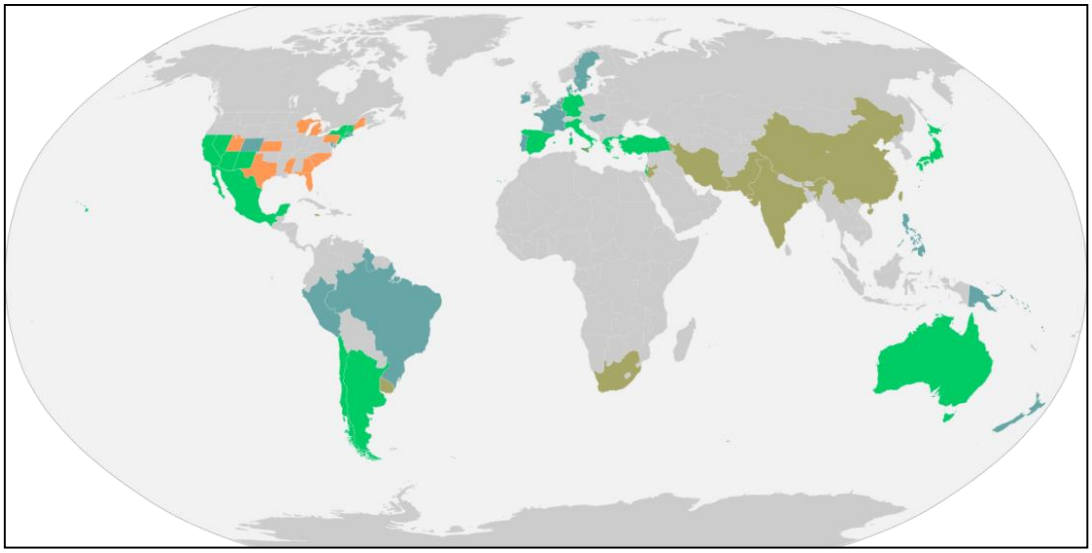

Fig. No. 4: Grid Parity for Solar PV Systems Around the World

REACHED GRID-PARITY BEFORE 2014
REACHED GRID-PARITY AFTER 2014
REACHED GRID-PARITY AFTER 2016
U.S. STATES POISED TO REACH GRID-PARITY SOON

Table 1: INSTALLED SOLAR POWER CAPACITY (MW) IN NORTHERN REGION

INSTALLED SOLAR POWER CAPACITY (MW)					
STATE	**31-03-2015**	**31-03-2016**	**31-03-2017**	**31-12-2018**	**31-03-2019**
Rajasthan	942.10	1,269.93	1,812.93	2,310.46	3,226.79
Punjab	185.27	405.06	793.95	905.64	905.62
Uttar Pradesh	71.26	143.50	336.73	550.38	960.10
Uttarakhand	5.00	41.15	233.49	246.89	306.75
Haryana	12.80	15.39	81.40	203.85	503.68
Delhi	5.47	14.28	40.27	58.02	126.89
Jammu and Kashmir	0.00	1.36	1.36	2.36	14.83
Chandigarh	4.50	6.81	17.32	18.89	34.71
Himachal Pradesh	0.00	0.73	0.73	1.48	22.68
NORTHERN REGION			**3318.18**		**6102.05 (21.43%)**

Table 2: INSTALLED SOLAR POWER CAPACITY (MW) IN WESTERN REGION

INSTALLED SOLAR POWER CAPACITY (MW)					
STATE	**31-03-2015**	**31-03-2016**	**31-03-2017**	**31-12-2018**	**31-03-2019**
Gujarat	1,000.05	1,119.17	1,249.37	1,344.69	2,440.13
Maharashtra	360.75	385.76	452.37	763.08	1,633.54
Chhattisgarh	7.60	93.58	128.86	179.38	231.35
Madhya Pradesh	558.58	776.37	857.04	1,210.11	1,840.16
Dadra and Nagar Haveli	0.00	0.00	2.97	2.97	5.46
Goa	0.00	0.00	0.71	0.71	3.92
Daman and Diu	0.00	4.00	10.46	10.46	14.47
WESTERN REGION			**2701.78**		**6169.03 (21.67%)**

Table 3: INSTALLED SOLAR POWER CAPACITY (MW) IN SOUTHERN REGION

INSTALLED SOLAR POWER CAPACITY (MW)					
STATE	**31-03-2015**	**31-03-2016**	**31-03-2017**	**31-12-2018**	**31-03-2019**
Tamil Nadu	142.58	1,061.82	1,691.83	1,819.42	2,575.22
Andhra Pradesh	137.85	572.97	1,867.23	2,165.21	3,085.68
Telangana	167.05	527.84	1,286.98	2,990.07	3,592.09
Kerala	0.03	13.05	74.20	88.20	138.59
Karnataka	77.22	145.46	1,027.84	1,800.85	6,095.56
Puduchery	0.20	0.20	0.08	0.11	3.14
SOUTHERN REGION			**5948.16**		**15490.28 (54.42%)**

Table 4: INSTALLED SOLAR POWER CAPACITY (MW) IN ESTERN REGION

INSTALLED SOLAR POWER CAPACITY (MW)					
STATE	**31-03-2015**	**31-03-2016**	**31-03-2017**	**31-12-2018**	**31-03-2019**
Bihar	0.00	5.10	108.52	141.52	142.45
Odisha	31.76	66.92	79.42	79.51	394.73
Jharkhand	16.00	16.19	23.27	23.37	34.95
West Bengal	7.21	7.77	26.14	39.84	75.95
Sikkim	0.00	0.00	0.00	0.01	0.01
EASTERN REGION			**237.35**		**648.09 (2.27 %)**

Table 5: INSTALLED SOLAR POWER CAPACITY (MW) IN NORTH ESTERN REGION

INSTALLED SOLAR POWER CAPACITY (MW)					
STATE	**31-03-2015**	**31-03-2016**	**31-03-2017**	**31-12-2018**	**31-03-2019**
Assam	0.00	0.00	11.78	11.78	22.40
Tripura	5.00	5.00	5.09	5.09	5.09
Arunachal Pradesh	0.03	0.27	0.27	4.39	5.39
Mizoram	0.00	0.00	0.10	0.20	0.50
Manipur	0.00	0.00	0.03	1.33	3.44
Meghalaya	0.00	0.00	0.01	0.06	0.12
Nagaland	0.00	0.00	0.50	0.50	1.00
NORTH EASTERN REGION			**17.78**		**37.94 (0.13%)**

Table 6: INSTALLED SOLAR POWER CAPACITY (MW) IN ISLANDS & OTHERS

INSTALLED SOLAR POWER CAPACITY (MW)					
STATE	**31-03-2015**	**31-03-2016**	**31-03-2017**	**31-12-2018**	**31-03-2019**
Andaman & Nicobar	5.10	5.10	6.56	12.61	11.73
Lakshadweep	0.75	0.75	0.75	0.75	0.75
Others	0.00	58.31	58.31	58.31	4.30
ISLANDS & OTHERS			**65.62**		**16.78 (0.06%)**
TOTAL	**3,743.97**	**6,762.85**	**12,288.83**	**17,052.37**	**28,464.17**

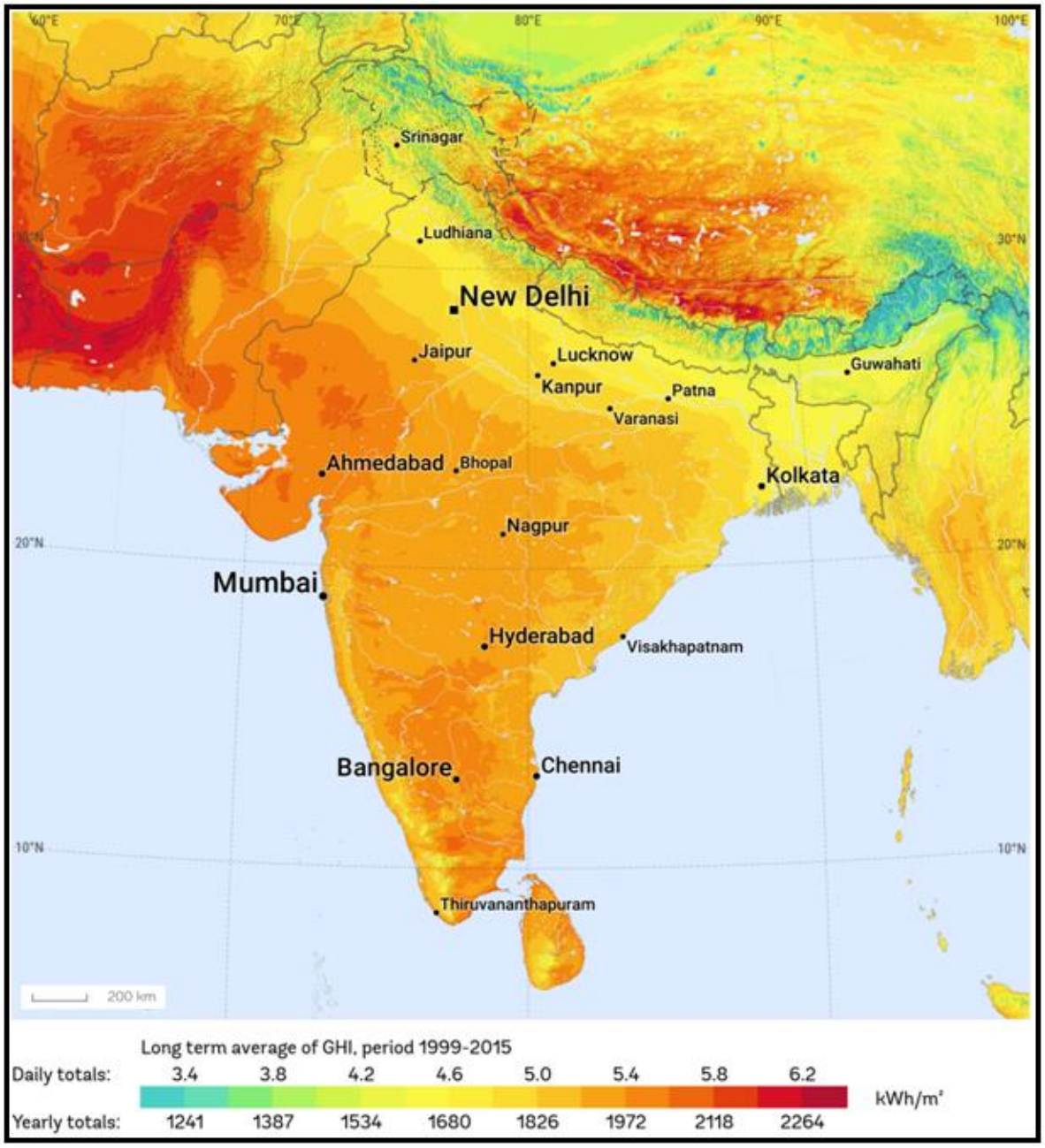

Fig. No. 5: Solar Map of India Based on Global Horizontal Irradiation

SOLAR THERMAL POWER

The installed capacity of commercial solar thermal power plants in India is 227.5 MW with 50 MW in Andhra Pradesh and 177.5 MW in Rajasthan. Solar thermal plants are emerging as cheaper (6 Euro ¢/kWh) and clean load following power plants compared to fossil fuel power plants. They can cater the load/ demand perfectly and work as base load power plants when the extracted solar energy is found excess in a day. Proper mix of solar thermal and solar PV can fully match the load fluctuations without the need of costly battery storage.

The major disadvantage of solar power (PV type only) is that it can not produce electricity during the night time and cloudy day time also. In India, this disadvantage can be overcome by installing pumped-storage hydroelectricity stations. Ultimate electricity requirement for river water pumping (excluding ground water pumping) is 570 billion kWh to pump one cubic meter of water for each square meter area by 125 m height on average for irrigating 140 million hectares of net sown area (42% of total land) for three crops in a year. This is achieved by utilising all the usable river waters by interlinking Indian rivers by envisaging coastal reservoirs. These river water pumping stations would also be envisaged with pumped-storage hydroelectricity features to generate electricity when necessary to stabilise the grid. Also, all existing and future hydro power stations can be expanded with additional pumped-storage hydroelectricity units to cater night time electricity consumption. Most of the ground water pumping power can be met directly by solar power during daytime. To achieve food security, India needs to achieve water security which is possible only by energy security for harnessing its water resources.

ELECTRIC VEHICLES

The retail prices of petrol and diesel are high in India to make electricity driven vehicles more economical as more and more electricity is generated from solar energy in near future without appreciable environmental effects. During the year 2018, many IPPs offered to sell solar power below 3.00 Rs/kWh to feed into the high voltage grid. This price is far below the affordable retail electricity tariff for the solar power to replace petrol and diesel use in transport sector.

The retail price of diesel is 53.00 Rs/litre in 2012-13. The affordable electricity retail price (860 kcal/kWh at 75% input electricity to shaft power efficiency) to replace diesel (lower heating value 8572 kcal/litre at 40% fuel energy to crank shaft efficiency) is 9.97 Rs/kWh. The retail price of petrol is 75.00 Rs/litre in 2012-13. The affordable electricity retail price (860 kcal/kWh at 75% input electricity to shaft power efficiency) to replace petrol (lower heating value 7693 kcal/litre at 33% fuel energy to crank shaft efficiency) is 19.06 Rs/kWh. In 2012-13, India consumed 15.744 million tons petrol and 69.179 million tons diesel which are mainly produced from imported crude oil at huge foreign exchange out go.

V2G is also feasible with electricity driven vehicles to contribute for catering to the peak load in the electricity grid. The electricity driven vehicles would become popular in future when its energy storage / battery technology becomes more compact, lesser density, longer lasting and maintenance free.

India expanded its solar-generation capacity 8 times from 2,650 MW on 26 May 2014 to over 20 GW as on 31 January 2018. The country added 3 GW of solar capacity in 2015-2016, 5 GW in 2016-2017 and over 10 GW in 2017-2018, with the average current price of solar electricity dropping to 18% below the average price of its coal-fired counterpart.

Rooftop solar power accounts for 3.4 GW, of which 70% is industrial or commercial. In addition to its large-scale grid-connected solar photovoltaic (PV) initiative, India is developing off-grid solar power for local energy needs. Solar products have increasingly helped to meet rural needs; by the end of 2015 just under one million solar lanterns were sold in the country, reducing the need for kerosene. That year, 118,700 solar home lighting systems were installed and 46,655 solar street lighting installations were provided under a national program; just over 1.4 million solar cookers were distributed in India.

The International Solar Alliance (ISA), proposed by India as a founder member, is headquartered in India.

Fig. No. 6: World's Largest Solar Park '*Shakti Sthala*' Launched in Karnataka

The 2,000 mw park, named as *'shakti sthala'*, spans across 13,000 acres spread over five villages, in Pavagada, Karnataka.

The world's largest solar park, Shakti Sthala, has a capacity of 2,000 MW and has set up at an investment of Rs16,500 crore at Pavagada in Karnataka's Tumakuru district.

The Karnataka government inaugurated the first phase of a 2,000 megawatts (MW) solar park in the drought-prone Pavagada region of Tumkur district, about 180 km from Bengaluru. The first phase of the Rs16,500 crore park called "Shakti Sthala" will generate 600 MW, while the balance 1,400 MW is expected to be commissioned by the end of this year. The solar project, touted as the largest in the world, is spread over 13,000 acres and five villages. It is part of the "Karnataka Solar Policy 2014-2021" which aims to decrease dependence on traditional power sources and move to environmentally friendly ones to meet the growing power needs of the state.

The solar park is also part of the *"Nava Karnataka Nirmana"* (building a new Karnataka) campaign, used extensively by the party in the run-up to the 2018 assembly elections to highlight its economic development and job creation efforts as well as to attract big ticket, high investment projects to the state. The park ties in with the centre's scheme to generate 100 gigawatts (GW) of solar power by 2020. The land for the solar park has been taken on a 25-year lease by the government from around 2,300 farmers, and in return, they are paid an annual rental of Rs.21,000 per acre, with scope for a 5% increase every two years. The move was intended to curb the mass migration of people from the region which has been declared drought-hit in 54 of the last 60 years. *"Development and economic growth of a nation occurs when its people become partners in the development process".* Karnataka state was the third-largest renewable energy producer in the country and has set a target of sourcing at least 20% from renewable sources in the future.

The park's development was initiated with the creation of the Karnataka Solar Power Development Corp. Ltd (KSPDCL) in March 2015 as a joint venture between Karnataka Renewable Energy Development Ltd (KREDL) and Solar Energy Corp. of India (SECI). NTPC Ltd pulled out of the project a month ago saying it was unable to supply procured power at the agreed cost, According to the agreement, NTPC was to buy 600 MW from six developers at Rs.4.80, and supply it to state electricity supply companies at a bundled tariff of Rs.3.30 per unit. The move left the state government looking for fresh bids. Other setbacks include the postponing of auctions for 1,200 MW capacity and legal complications with another 860 MW. KSPDCL uses the *"plug and play"* model, under which it acquires and develops land as blocks for solar power generation, embedded with the required government approvals, and gives it out to Solar Power Developers (SPDs) through auctions. Karnataka, which continues to face power shortage, increased its capacity from 14,030 MW in 2012-13 to 23,379 MW in January this year, through all sources including hydel, thermal, nuclear and biomass.

CONCLUSIONS

The government is working at revising the solar power generation target to 100,000 MW for 2022 from the current 20,000 MW, Power and Renewable Energy Minister Piyush Goyal said. "We have reset the targets of renewable energy. The earlier target for solar energy was 20,000 MW till 2022, which we are trying to reset to 100,000 MW," he said at an event here organised by The Energy and Resources Institute (TERI) University. "On the solar front, we believe there is enormous potential to take it to 100,000 MW in the next 5-7 years," he added. The minister said the government is working to make solar projects viable by providing grid parity, making it economically viable and ensuring that bankability and returns are reasonably assured. "The three major challenges when I came into office were in the areas of grid parity, reducing project financing costs by seeing how interest rates can go down, and ensuring bankability", Goyal said. "In short, we are trying to make it self-sustaining", he added, in order to help it realise the revised target of 100,000 MW from renewable sources.

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