

# Development of Solar Energy in India: A SPATIO – Temporal Analysis

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**Abstract**— Solar energy an environmental friendly renewable energy resource that can replace our traditional fossil fuel energy resources has developing rapidly in recent years. No greenhouse gas emissions are released into the atmosphere when you use solar panels to create electricity and because the sun provides more energy than we'll ever need, electricity from solar power is a very important energy source in the move to clean energy production. This article aims to analyse the development trend of solar energy in India and the spatial distribution of solarenergy plants and production in India.

**Keywords:** Energy, Renewable, Traditional, Fossil, Fuel, Greenhouse Gas

## I. INTRODUCTION

Solar energy is the energy obtained by capturing heat and light from the Sun. Energy from the Sun is referred to as solar energy. Technology has provided a number of ways to utilize this abundant resource. It is considered a green technology because it does not emit greenhouse gases. Solar energy is abundantly available and has been utilized since long both as electricity and as a source of heat.

Generation of solar energy has tremendous scope in India. The geographical location of the country stands to its benefit for generating solar energy. The reason being India is a tropical country and it receives solar radiation almost throughout the year, which amounts to 3,000 hours of sunshine.

National Institute of Solar Energy has assessed the Country's solar potential of about 748 GW assuming 3% of the waste land area to be covered by Solar PV modules. Solar energy has taken a central place in India's National Action Plan on Climate Change with National Solar Mission as one of the key Missions. National Solar Mission (NSM) was launched on 11<sup>th</sup> January, 2010. NSM is a major initiative of the Government of India with active participation from States to promote ecological sustainable growth while addressing India's energy security challenges. It will also constitute a major contribution by India to the global effort to meet the challenges of climate change. The Mission's objective is to establish India as a global leader in solar energy by creating the policy conditions for solar technology diffusion across the country as quickly as possible. The Mission targets installing 100 GW grid-connected solar power plants by the year 2022. This is line with India's Intended Nationally Determined Contributions(INDCs) target to achieve about 40 percent cumulative electric power installed capacity from non-fossil fuel based energy resources and to reduce the emission intensity of its GDP by 33 to 35 percent from 2005 level by 2030.

In order to achieve the above target, Government of India have launched various schemes to encourage generation of solar power in the country like Solar Park Scheme, VGF

Schemes, CPSU Scheme, Defence Scheme, Canal bank & Canal top Scheme, Bundling Scheme, Grid Connected Solar Rooftop Scheme etc.

Recently, India achieved 5<sup>th</sup> global position in solar power deployment by surpassing Italy. Solar power capacity has increased by more than 11 times in the last five years from 2.6 GW in March2014 to 30 GW in July 2019. Presently, solar tariff in India is very competitive and has achieved grid parity.

### A. Need and Importance of Solar Energy

No greenhouse gas emissions are released into the atmosphere when you use solar panels to create electricity. And because the sun provides more energy than we'll ever need, electricity from solar power is a very important energy source in the move to clean energy production.

All life on earth is supported by the sun. This amazing resource radiates energy and provides us both heat and light by fusing hydrogen into helium at its core. We call this solar radiation. Only about half of this solar radiation makes it to the Earth's surface. The rest is either absorbed or reflected by clouds and the atmosphere. Still, we receive enough power from the sun to meet the power demands of all mankind — millions of times over. Solar energy—power from the sun—is a vast, inexhaustible, and clean resource.

Sunlight, or solar energy, can be used directly for heating and lighting homes and businesses, for generating electricity, and for hot water heating, solar cooling, and a variety of other commercial and industrial uses. Most critical, given the growing concern over climate change, is the fact that solar electricity generation represents a clean alternative to electricity from fossil fuels, with no air and water pollution, no global warming pollution, no risks of electricity price spikes, and no threats to our public health.

The solar resource is enormous. According to the US Department of Energy, the amount of sunlight that strikes the earth's surface in an hour and a half is enough to handle the entire world's energy consumption for a full year. Just 18 days of sunshine on Earth contains the same amount of energy as is stored in all of the planet's reserves of coal, oil, and natural gas. And, once a system is in place to harness the solar resource and convert it into useful energy, the fuel is free.

## II. OBJECTIVES

To study the development of solar energy in India

To analyse the spatial distribution and production of solar energy in India

## III. METHODOLOGY

The study is conducted on the Development of solar energy in India: a spatio – temporal analysis based on the data

gathered from secondary sources. Secondary data has been collected from the records, books, journals and websites. The relevant information and data have been organized, classified, tabulated and graphed using simple statistical methods.

Sl.No	Year	Installed capacity in GW	Actual production in GW
1.	2010	0.161	-
2.	2011	0.461	-
3.	2012	1.205	-
4.	2013	2.319	-
5.	2014	2.632	0.0336
6.	2015	3.744	0.0460
7.	2016	6.763	0.0745
8.	2017	12.289	1.2090

9.	2018	21.651	2.5870
10.	2019	28.181	3.9270
11.	2020	34.627	5.0130

Source: Central Electricity authority ministry of power, GOI  
Table 1: Trend of solar energy installation and production in India

Solar power capacity has increased by more than 11 times in the last five years from 2.6 GW in March, 2014 to 30 GW in July, 2019. Though the installed capacity was increased steadily from 2012 itself the actual production started increased from 2017. In 2020 the total actual production reached to 50.13MW. India targets installing 100 GW grid-connected solar power plants by the end of year 2022.

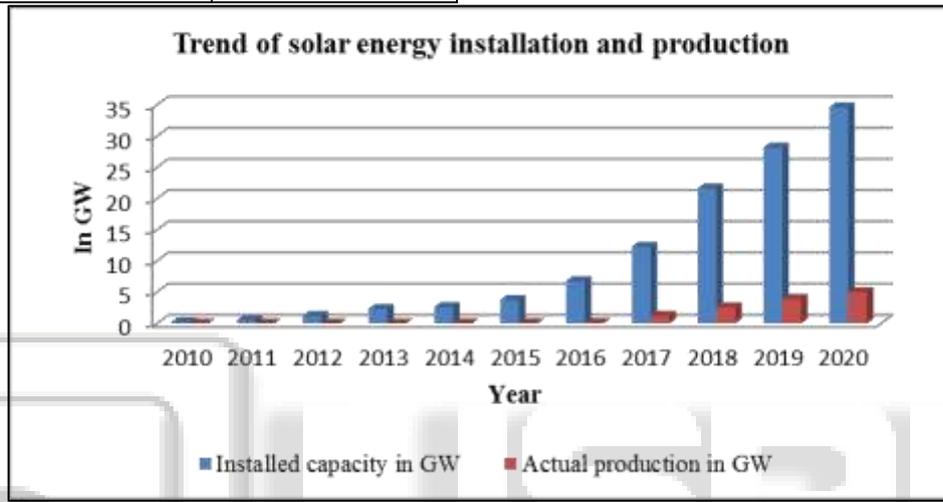


Fig. 1:

#### A. Major States Producing Solar Power in India

The government of India has already set an ambitious target to achieve 100 Gigawatt by 2022. India is at the cusp of a solar revolution, the government has already set an ambitious target to achieve 100 GW by 2022. Keeping the target in

mind, Indian states have already started ramping up their installed solar and wind powered capacity. ET Energy World looks at the top 10 states by installed solar powered capacity. The data is provided by solar power consultancy firm Bridge to India.

Sl.No	States	capacity in MW	%	Actual production in Mw	%
1	Karnataka	6,095.56	21.63	4504	19.63
2	Telangana	3,592.09	12.74	3111	13.56
3	Rajasthan	3,226.79	11.45	3190	13.9
4	Andhra Pradesh	3,085.68	10.94	2938	2.80
5	Tamil Nadu	2,575.22	9.13	2334	10.17
6	Gujarat	2,440.13	8.65	1615	7.03
7	Madhya Pradesh	1,840.16	6.53	1613	7.03
8	Maharashtra	1,633.54	5.80	1148	5.00
9	Uttar Pradesh	960.1	3.40	708	3.08
10	Punjab	905.62	3.21	797	3.47
11	Odisha	394.73	1.40	175	0.76
12	Uttarakhand	306.75	1.08	183	0.63
13	Chhattisgarh	231.35	0.82	146	0.63
14	Haryana	224.52	0.79	50	0.21
15	Bihar	142.45	0.50	80	0.34
16	Others	525.91	1.86	152	0.66
Total		28180.66	100.00	22944	100.00

Table 2: Spatial distribution of solar energy generation in India (2019)

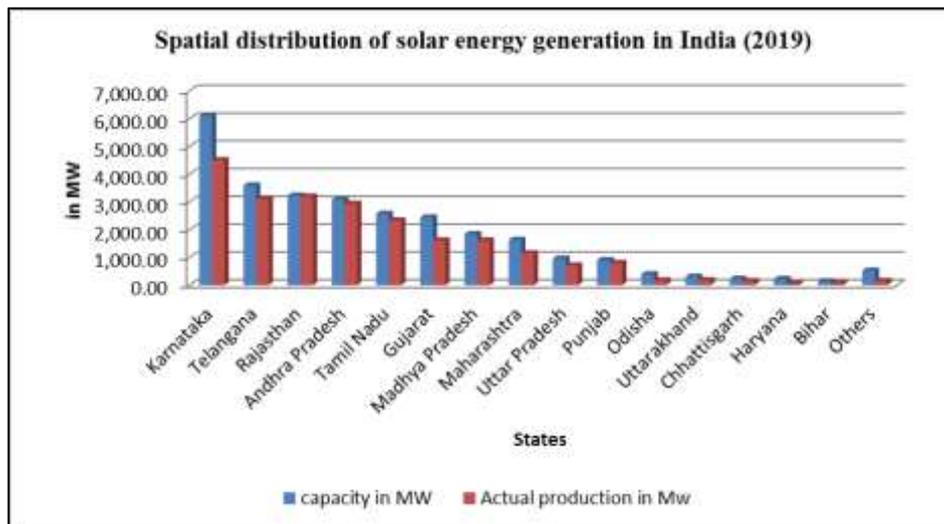


Fig. 2:

1) *Karnataka*

Karnataka tops the list of states with the highest installed solar power generation capacity in the country. The state’s total solar capacity at the end of 2019 stood at 4504 megawatt (MW). While, its total installed electricity generation capacity is 6095.56 MW in 2019, with solar sector’s share at 21.63 per cent.

2) *Telangana*

Telangana houses the second-highest installed solar power generation capacity in the country. The state’s solar capacity at the end of 2019 stood at 3111MW. Its total installed electricity generation capacity stood at 3,592.09 MW at the end of 2019, with solar sector’s share at 12.74 per cent.

3) *Rajasthan*

Rajasthan houses the third-highest installed solar power generation capacity in the country. The state’s solar capacity at the end of 2019 stood at 3190MW. Rajasthan’s total installed electricity generation capacity stood at 3,226.79MW at the end of 2019, with solar sector’s share at 14.11 per cent.

4) *Andhra Pradesh*

Andhra Pradesh houses the fourth-highest installed solar power generation capacity in the country. The state’s solar capacity at the end of 2019 stood at 2938MW. Andhra Pradesh total installed electricity generation capacity stood at 3,085.68 MW at the end of 2019, with solar sector’s share at 10.94 per cent.

5) *Tamil nadu*

Tamil Nadu houses the fifth-highest installed solar power generation capacity in the country. The state’s solar capacity at the end of 2019 stood at 2,334 MW. Tamil Nadu total installed electricity generation capacity stood 2,575.22 MW at the end of 2019, with solar sector’s share at 9.13 per cent.

6) *Gujarat*

Gujarat houses the sixth- largest installed solar power generation capacity in the country. The state’s solar capacity at the end of 2019 stood at 1615MW. Gujarat’s total installed electricity generation capacity stood at 2,440.13 MW at the end of 2019, with the solar sector’s share at 8.65 per cent.

7) *Madhya Pradesh*

Madhya Pradesh houses the seventh-largest installed solar power generation capacity in the country. The state’s solar capacity at the end of 2019 stood at 1613MW. Madhya Pradesh total installed electricity generation capacity stood at 1,840.16 MW at the end of 2019, with the solar sector’s share at 6.53 per cent.

8) *Maharashtra*

Maharashtra houses the eighth-largest installed solar power generation capacity in the country. The state’s solar capacity at the end of 2019 stood at 1148MW. Its total installed electricity generation capacity stood at 1,633.54 MW at the end of 2019, with the solar sector’s share at 5.80 per cent.

9) *Uttar Pradesh*

Uttar Pradesh houses the ninth-largest installed solar power generation capacity in the country. The state’s solar capacity at the end of 2019 stood at 708 MW. Madhya Pradesh total installed electricity generation capacity stood at 960.1 MW at the end of 2019, with the solar sector’s share at 3.40 per cent.

10) *Punjab*

Punjab houses the 10th-largest installed solar power generation capacity in the country. The state’s solar capacity at the end of 2019 stood at 797 MW. Punjab’s total installed electricity generation capacity stood at 905.62 MW at the end of 2019, with the solar sector’s share at 3.21 per cent.

Major solar power production plants in India

Sl.No	Name of the power plant	Location	Year of establishment	Capacity in MW
1	Bhadla Solar Park	Jodhpur district of Rajasthan	March 2012	2055 MW
2	Pavagada Solar Park	Palavalli, Karnataka	Dec 2019	2000MW
3	Kurnool Ultra Mega Solar Park	Kurnool, Andhra Pradesh	2017	1000 MW
4	NP Kunta Ultra Mega Solar Park	Anathapuram, Andhra Pradesh	2020	1500 MW
5	Rewa Ultra Mega Solar	Rewa, Madhya Pradesh	2018	750 MW

6	Charanka Solar Park	Charanka village in Patan district, Gujarat,	2012	690 MW
7	Kamuthi Solar power project	Kamuthi, Ramanathapuram district, Tamilnadu	March 2017	648 MW
8	Sai Guru Solar Park (Pragat)	Sakri, Maharashtra	2017	500 MW
9	Jalaun Solar Park	Jalaun district of Uttar Pradesh.	January 2016	50MW
10	Dharnai (village)	Dharnai in Jehanabad, Bihar	2014	100 KW
11	Cochin International Airport Limited	Cochin International Airport, Kerala, India	2015	40KW

1) *Bhadla Solar Park*

Bhadla Solar Park Power Project is a 2055 MW solar photovoltaic (PV) farm in Jodhpur district of Rajasthan, India, established in March 2012.

2) *Pavagada Solar Park*

Pavagada Solar Park Power Project is a 2000 MW solar photovoltaic (PV) farm in Palavalli, Karnataka, India established in December 2019.

3) *Kurnool Ultra Mega Solar Park*

Kurnool Ultra Mega Solar Park Power Project is a 1000 MW solar photovoltaic (PV) farm in Kurnool Andrapradesh, India, established in March 2017. During a sunny day, the Kurnool Solar Park is able to generate more than 8 million kWh of electricity, which is sufficient to meet virtually the entire electricity demand in Kurnool district. This is currently the largest solar farm in India, up until 2017 it was the largest in the world.

4) *NP Kunta Ultra Mega Solar Park*

The NP Kunta Ultra Mega Solar Park, also known as Ananthapuram Ultra Mega Solar Park, is a solar park spread over a total area of 32 square kilometres (12 sq mi) in Nambulapulakuntamandal in the Ananthapur district of the Indian state of Andhra Pradesh.

The first phase of park was commissioned on 9 May 2016 with a capacity of 200 MW. An additional 50 MW capacity was commissioned on 29 July 2016. A further 750 MW was planned to have been commissioned by March 2018 in the second phase.

5) *Rewa Ultra Mega Solar*

Rewa Ultra Mega Solar Limited (RUMSL) was formed in 2015 in the state of Madhya Pradesh. RUMSL has developed 750 MW Rewa Solar Project and 250 MW Mandsaur Solar Park. 750 MW Rewa Solar Project which is amongst the most significant solar projects in the world, was fully commissioned on 3<sup>rd</sup> January 2020.

6) *Charanka Solar Park*

The Charanka Solar Park was inaugurated in 2012 by then Chief Minister Narendra Modi. It was home to about 250 MW capacity at the time, which has gone up by nearly 2.5 times since then. Solar power generation capacity at Charanka Solar Park in Patan district of Gujrat, the first such project in the country, is soon expected to touch 790 MW. The generation capacity is at about 690 MW at present.

7) *Kamuthi Solar Power Project*

Kamuthi Solar Power Project is a photovoltaic power station spread over an area of 2,500 acres in Kamuthi, Ramanathapuram district, 90 km from Madurai, in the state of Tamil Nadu, India. The project was commissioned by Adani Power.

8) *Sai Guru Megha Solar Park (Pragat)*

Pragat Akshay Urja Ltd have incorporated a special purpose vehicle Sai Guru Mega Solar Park Pvt Ltd. to develop a 500 MW Solar Park under mode 4 of the Government of India policies on development of solar parks and ultra mega solar power projects.

9) *Jalaun Solar Power Project*

Jalaun Solar Power Project is a solar photo-voltaic power generating station spanning two villages of Kuhana and Shajahanpur in Jalaun district of Uttar Pradesh. The plant has been developed by Essel Infraprojects Limited, an arm of Essel Group. The plant is spread on a 250-acre land and is expected to generate 85 MW.

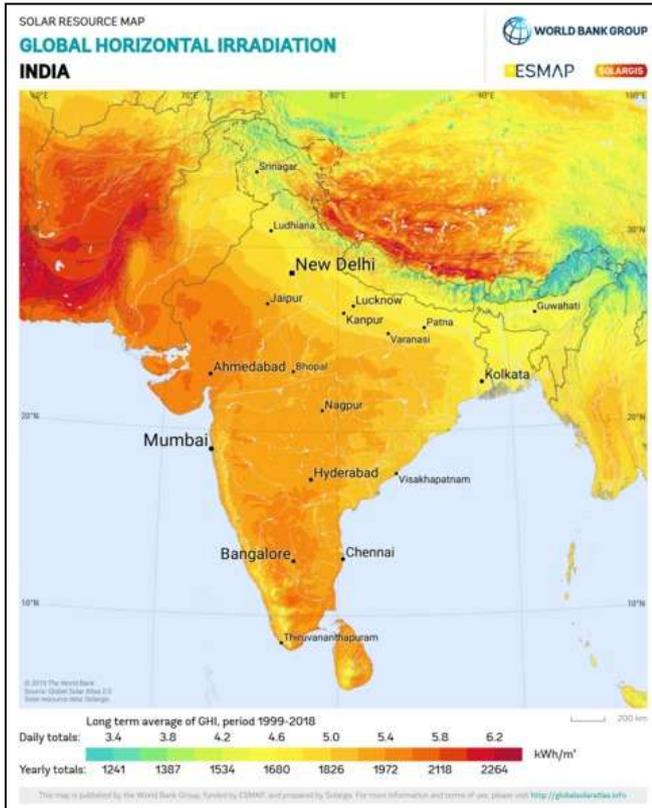
10) *Dharnai*

In 2014, Dharnai in Jehanabad, Bihar became the country's first solar powered village. Three NGOs, Greenpeace India, BASIX (a micro financing organisation) and Centre for Energy Environment Development came together to set up the 100 kilo watt solar powered micro grid that serves about 450 homes and 2,400 residents.

11) *Cochin International Airport*

The CIAL Solar Power Project is a 40 megawatt photovoltaic power station built at COK airport, India, by the company Cochin International Airport Limited. Cochin International Airport became the first fully solar powered airport in the world with the commissioning the plant. India's Cochin International Airport, in the southern state of Kerala is the first airport in the world to be powered entirely by solar energy. Huge power bills prompted the airport to build the 12 megawatt solar plant which has more than 46,000 solar panels.

## B. Solar Resource Map of India



Most parts of India receive good solar radiation 4- 7 kWh/sq. m/day. In the solar energy sector, some large projects have been proposed, and a 35,000 km<sup>2</sup> (14,000 sq mi) area of the Thar Desert has been set aside for solar power projects, sufficient to generate 700 to 2,100 GW. Aggressive bids under the Jawaharlal Nehru National Solar Mission (JNNSM) have produced grid-connect megawatt (MW) sized plants generating even less than 15 US cents per kilowatt-hour (kWh), among the lowest in the world.

## IV. CONCLUSION

In this paper discuss the study of solar energy in India. India has very much unbalanced in electricity production. Production is less and consumption is very much. Solar power is a very good option in India to increase power production. This is also very good for our environmental protection and economic development. Solar power is an unlimited source of energy and our country also provide a suitable climate for this energy but we need some better idea to increase efficiency and decrease production cost. Our government launches some schemes for production of solar power and achieves some successes but we need education and publicity in society for these schemes so that people take some initiative for using renewable energy as much as at a place of conventional energy sources. Indian policies have created investment-friendly market in the country for an entire range of activities announced under the Mission. India centric R&D and local manufacturing are necessary to reduce the cost of achieving Solar Targets. Presently, solar tariff in India is very competitive and has achieved grid parity.

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