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Prospects of Solar Power for Sustainable Growth and Clean Energy in India

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Abstract: The present paper highlights the current status of solar energy in India and solar energy development in different states of India. Further, it provides an overview of the challenges and barriers faced by solar energy and also reviews the government policies to support solar energy development in India. Over the period, the renewable energy sector in India has emerged as one of the significant players for energy access. Renewable energy can act as an integral part of the energy planning process and can play a much more important role in achieving energy security in the upcoming years. The total installed capacity of grid-connected renewable energy in India was 90399.07 MW and off-grid power capacity was 1253.59 MW during November 2020. The solar energy potential in India is 748990 MW and the renewable energy potential is 896602 MW which shows the large scope available to increase the clean energy capacity. The paper concludes that solar power is the future source of energy in the country. India needs to invest in R&D so that cost of production is reduced further to make solar energy as the cheapest and cleanest source of energy for sustainable development.

Keywords: Solar Power, Renewable Energy, Clean Energy

Section I

Introduction

Electricity - a major source of energy plays a crucial role in any country's industrial and economic progress. India is ranked 3rd as a producer of electricity but still is a power deficit nation. India's rising population and growing economic activities need quick additions to energy generation capacity because there is a direct relation between

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economic growth and energy consumption. India has been continuously increasing its energy generation capacity to cope with demand of the same. Presently, the installed capacity of India is 374.2 GW and most of the power is generated by thermal plants, which contribute heavily to greenhouse gas emissions, having harmful health and environmental effects. India's electricity generation is not sufficient to meet the demand of the country. As a consequence, there is approximately a 7% decrease in the turnovers of Indian companies. India's total peak electricity demand in 2019-20 was 183 GW and is expected to be 235 GW by 2021-22. This involves building more than four times the existing capacity in four years (Seetharaman, 2018). India is facing a problem of power shortage due to its theft. Theft of electricity is common in most parts of rural and urban India and amounts to 1.5 % of India's GDP, which adversely affects the country's economic growth. It is estimated that India will need more than double its installed generation capacity to meet the needs of the economy. Considering the demand for electricity and reducing the use of fossil fuel-based energy, as conventional energy sources like coal and petroleum are limited, the Indian government has taken many steps to promote renewable energy generation. India was the first country in the world to set up a Ministry of Nonconventional Energy Resources in early 1980 (Central Electricity Authority, Ministry of Power, 2016). Solar and wind energy are freely available and they are environmentally friendly. Wind energy systems are not possible at all sites because of low wind speeds and it is more unpredictable than solar energy (Ridaparthi and Prasad, 2014). Solar power a clean renewable resource with zero emission, has tremendous potential for energy which can be harnessed using a variety of devices. With recent developments, solar energy systems are easily available for industrial and domestic use with the added advantage of minimum maintenance. Solar energy could be made financially viable with government tax incentives and rebates. Most of the developed countries are switching over to solar energy as one of the prime renewable energy sources (Srivastava and Srivastava, 2013).

In order to ensure power supply, many companies, factories, businesses and private customers have set up their own power generation capacities. This provides an attractive opportunity for renewable energy solutions. Among the various renewable energy resources, solar energy potential is the highest in the country. In most parts of India, clear sunny weather is experienced 250 to 300 days a year. The annual radiation varies from 1600 to 2200 KW/m^2, which is comparable with radiation received in the tropical and subtropical regions. The equivalent energy potential is about 6,000 million GWh of energy per year (Ministry of New and Renewable Energy, Govt. of India, 2016-17). Due to its pollution-free nature, solar energy has become a very attractive energy

resource nowadays, which can be used for various purposes. Solar energy is the most important renewable energy resource which can lower worldwide carbon emissions. The cost of solar energy technologies has rapidly declined in the recent past years and it is showing potential for continuous declines in the near future (Srivastava and Vinod, 2016). Solar energy can be used for cooking, heating and drying through the Thermal route. It can also be used for lighting, pumping and generation of electricity through the Photovoltaic route. Solar photovoltaic cells when exposed to sunlight, convert solar radiation (sunlight) into electricity. Project finance, asset finance and corporate finance are the three main financing options for implementing solar PV captive power plants. The commercial banks and financial involved in financing solar power plants are ADB, DEG, DBS, ICICI bank, IDFC, IFC, IL & FS, IREDA, PFC, Proparco, Rabobank, SBI and Yes Bank. Over the period of time, the renewable energy sector in India has emerged as one of the significant players in energy access. Renewable energy can act as an integral part of the energy planning process and can play a much more important role in achieving energy security in the upcoming years.

The present paper has been divided into five sections. Section I: apart from the introduction, there is a review of the literature and research aims and objectives; Section II, highlights the current status of solar energy in India and solar energy development in different states of India. Section III reviews the government policies to support solar energy development in India. Section IV provides an overview of the challenges and barriers faced by solar energy. The whole discussion has been concluded in Section V.

Review of Literature

Chikaire *et al.* (2010) discuss various applications of solar energy technologies in agriculture. Solar energy can supplement many farm energy requirements. These sources of energy are clean, risk-free and cause no harm to man and the environment. PV water pumping systems can be used as one of the most cost-effective water pumping options in the agricultural sector. Solar greenhouses can also be considered best for small growers. According to this study, solar energy can cut a farm's electricity and heating bills. Deb *et al.* (2013) in their study 'Prospects of Solar Energy in Bangladesh' discussed the potential and prospects of solar energy in Bangladesh. The study highlighted that Bangladesh is a potential ground for applying solar energy by using both solar PV and STE technology in different aspects. The study discussed the social, economic and environmental constraints of using solar energy in Bangladesh and recommended various solutions for the same. Gangopadhyay *et al.* (2016) estimated that an additional 8000-8700 MW of wind and 3300-3500 MW of solar power would reduce the annual

deficit by approximately three-fourths in Karnataka. The study recommended that a pumped hydro storage facility will reduce the deficits further by 10 % and help in meeting the daily peaks in demand in Karnataka. Ehsanul *et al.* (2018) discussed the merits and demerits of solar energy technologies in their article. The paper highlighted various technical problems affecting renewable energy such as low solar cell efficiencies, low-performing balance-of-systems, economic hindrances like high upfront costs and lack of financing mechanisms; and various institutional obstacles like inadequate infrastructure and lack of skilled manpower resources. Hossain and Rahman (2021) sources and prospects of renewable energy in Bangladesh. Various initiatives taken by the government of Bangladesh to promote solar energy projects were discussed in the study. It has been suggested in the study that Bangladesh should take necessary steps to encourage people to use solar energy as their primary source of energy in order to reduce the burden on grid power supply. Deepu and Kamala (2022) in their study report a literature review on solar energy resources across the globe and its benefits received by consumers during the period 2010-2020.

Aims and Objectives of the Present Study

The present study aims at achieving the objectives as specified below:

1. An examination of the current status of solar energy in India and solar energy development in different states of India.
2. To overview the challenges and barriers faced by solar energy and to review the government policies to support solar energy development in India.

Section-II

Current Status of Solar Energy in India

Central Electricity Authority (CEA) has reported that the total solar energy production was 21.365 billion units during the year 2018. According to the Ministry of New and Renewable Energy, the solar energy capacity has gone up from 2.63 GW in 2014 to 39 GW in 2020. Ministry claimed that investments of over $ 42 billion have been made in renewable energy during the last four years and that the projects set up during the period have created around 10 million man-days of employment per annum.

Wind energy continues to dominate India's renewable energy industry, accounting for over 42.5 % of installed capacity (38433 MW), followed by solar power (37959 MW), biopower (10145 MW) and small hydropower (4740 MW). Under the grid-

connected solar PV power projects (3000 MW) by NTPC and other PSUs tenders, 1250 MW-all in solar park project to Andhra Pradesh, Rajasthan (420 MW in solar park, 230 MW outside solar park), Uttar Pradesh (100 MW outside the solar park), Karnataka (600 MW in the solar park) and Telangana (400 MW outside solar park) have been issued by NTPC Ltd. Projects for setting up of 15,000 MW of grid-connected solar PV power plants through NTPC Limited/NTPC Vidyutvyapar Nigam Limited (NVVN) under National Solar Mission, is implementation (Ministry of New and Renewable Energy, Govt. of India 2019-20).

The Ministry of New and Renewable Energy took an ambitious programme of installing solar pumps in different states of the country and installed 77860 solar pumps during 2017-18, for drinking and irrigation purposes through the state government agencies. Under the new loan scheme launched by IREDA in July 2015, a loan at an interest rate between 9.9 and 10.75 % was provided to promote rooftop solar power projects in the country. To create a database of solar energy potential, the Ministry of New and Renewable Energy has installed 51 solar radiation resource assessment stations.

Table 1: State-wise Solar Energy potential (in MW)

State	*Solar Energy potential (in MW)*
Andhra Pradesh	38440
Arunachal Pradesh	8650
Assam	13760
Bihar	11200
Chhattisgarh	18270
Delhi	2050
Goa	880
Gujarat	35770
Haryana	4560
Himachal Pradesh	33840
Jammu & Kashmir	111050
Jharkhand	18180
Karnataka	24700
Kerala	6110
Madhya Pradesh	61660
Maharashtra	64320
Manipur	10630
Meghalaya	5860
Mizoram	9090

State	*Solar Energy potential (in MW)*
Nagaland	7290
Orissa	25780
Punjab	2810
Rajasthan	142310
Sikkim	4940
Tamil Nadu	17670
Telangana	20410
Tripura	2080
Uttar Pradesh	22830
Uttarakhand	16800
West Bengal	6260
UTs	790

Source: Ministry of New and Renewable Energy- Annual Report 2019-20.

Table 2: Installed Solar PV in India

Year	*Cumulative Capacity (MW)*
2010	161
2011	461
2012	1205
2013	2319
2014	2632
2015	3744
2016	6763
2017	12289
2018	21651
2019	33730

Source: Ministry of New and Renewable Energy- Annual Report 2019-20.

Table 2 shows the installed solar PV in India. The data reveals that the cumulative capacity of installed solar PV in India increased from 161 (MW) in 2010 to 33730 (MW) during the year 2019. Table 3 shows that Rajasthan occupies first rank among the Northern region in India with 4844.21 installed solar power capacity, followed by Punjab and Uttar Pradesh. Gujarat is also one of India's most solar-developed states in the Western region with 2763.55 solar power capacities. Due to the availability of land, political will, investment, transmission, distribution of infrastructure and connectivity, Gujarat has become one of the leading states in solar power generation. Further, Karnataka takes the No. 1 position among Southern states with 7274.92 MW capacity installation during the year 2019-20, followed by Tamil Nadu, Telangana and Andhra Pradesh. Karnataka, Rajasthan, Tamil Nadu, Telangana, Andhra Pradesh, Gujarat and

Madya Pradesh are the leading solar states in India. About 83 % of the installation was done by these states.

Table 3: State-wise Installed Solar Power Capacity (MW)

Andaman & Nicobar	12.19
Andhra Pradesh	3559.02
Arunachal Pradesh	5.61
Assam	41.23
Bihar	149.35
Chhattisgarh	231.35
Dadra & Nagar Haveli	5.46
Daman & Diu	16.56
Delhi	12.19
Goa	3559.02
Gujarat	5.61
Haryana	41.23
Himachal Pradesh	149.35
Jammu & Kashmir	231.35
Jharkhand	5.46
Karnataka	16.56
Kerala	12.19
Lakshadweep	3559.02
Madhya Pradesh	5.61
Maharashtra	41.23
Manipur	149.35
Meghalaya	231.35
Mizoram	5.46
Nagaland	16.56
Orissa	12.19
Pondicherry	3559.02
Punjab	5.61
Rajasthan	41.23
Sikkim	149.35
Tamil Nadu	231.35
Telangana	5.46
Tripura	16.56
Uttar Pradesh	12.19
Uttarakhand	3559.02
West Bengal	5.61
Total	41.23

Source: Ministry of New and Renewable Energy- Annual Report 2019-20.

Table 4: State-wise Solar pumps sanctioned during the year 2017-18

S. No.	*State*	*No. of solar pumps installed*
1.	Andhra Pradesh	15000
2.	Bihar	931
3.	Chhattisgarh	15000
4.	Gujarat	3537
5.	Jharkhand	1180
6.	Karnataka	1077
7.	Madhya Pradesh	14000
8.	Maharashtra (for drinking water)	6022
9.	Orissa	754
10.	Punjab	2556
11.	Rajasthan	7134
12.	Tamil Nadu	1000
13.	Uttar Pradesh	9669
	Total	77860

Source: Ministry of New and Renewable Energy- Annual Report 2019-20.

In the year 2019-20, solar systems having a total capacity of 37959 MW which includes solar study lamps, solar home lights, solar street lights, solar pumps, Mini/ Microgrids and power plants were installed in various states.

Section-III

Section III of the study highlights the various initiatives taken by the government of India to incentivize the production of solar power and to attract various investors towards solar energy projects.

Government Initiatives

The initiatives are stated below-

1. Indian government launched green bonds to finance renewable energy projects.
2. In order to attract overseas investors, the government of India has also introduced various types of incentives like National and state solar auctions and increased investment in the grid.
3. Indian government targets 100 GW of solar energy by 2022. To achieve this target, the government is taking a number of initiatives like
   (i) 10-year tax exemption for solar energy projects.

(ii) New guidelines were issued for states to use unproductive and non-agricultural land for solar parks.
(iii) India also plans to install solar PV on canal tops and banks.
(iv) Central Electricity Regulatory Commission (CERC) has issued supportive regulations to increase transmission capacity.
(v) For grid-connected solar rooftops and also for off-grid solar PV programmes, a subsidy of 30 % of the benchmark cost for general category states and 70 % for special category states, subject to availability of funds.

4. To incentivize the production of solar power in the state, the government of Goa has proposed a 50% subsidy for small consumers and producers of solar power as an amendment to the Goa state solar energy policy, 2017.
5. Department of Financial Services has advised all Public Sector Banks to provide loans for grid-connected rooftop solar systems as home loans/ home improvement loans.
6. The Energy Efficiency and Renewable Energy Management (EEREM) Centre, the Delhi government's nodal agency for rooftop solar projects, has launched a tender for setting up 35 Megawatt (MW) grid-connected rooftop solar projects in the capital under the 'Mukhyamantri Solar Power Program'.
7. To enhance solar energy, the India-led International Solar Alliance (ISA) signed a joint declaration with the European Union (EU) at the world's biggest climate change conference. It aims at mobilizing finance for the development of "affordable solar energy". The ISA aims to mobilize $ 1 trillion to generate 1000 GW of solar energy by 2030.
8. Independent energy advisory and certification body DNV GL launched its first mobile laboratory service for the on-site testing of PV modules across India.
9. Indian railways plan to set up 30 GW solar power (plants) in which there will be solar panels along the tracks and unutilized land. It will help the railways lower their energy bill by Rs. 30,000 crore each year.
10. Ministry of New and Renewable Energy has undertaken an exercise to track and analyze the issues in the fulfilment of solar power purchase obligation and implementation of the solar REC framework in India. This would help various stakeholders to understand the challenges and opportunities in the development of solar power.
11. The government targeted to obtain 8% of the total consumption of electricity from solar energy by 2022.

Ministry of New and Renewable Energy (MNRE, 2017-18), Government of India has sanctioned a scheme proposed by IIT Bombay (IITB), which aims to provide 70 Lakh students in rural India with high quality, affordable clean light through solar study lamp in cheapest and fastest possible way. The scheme covers 5 states of Assam, Bihar, Jharkhand, Odisha& Uttar Pradesh, which have more than 50% un-electrified households (Office of the Registrar General and Census Commissioner, 2011).

Initiatives by States

Electricity Regulatory Commissions of all States/UTs have notified net metering regulations/tariff orders. So far, 20 States namely Andhra Pradesh, Chhattisgarh, Delhi, Gujarat, Haryana, Himachal Pradesh, Jammu & Kashmir, Jharkhand, Karnataka, Kerala, Madhya Pradesh, Manipur, Punjab, Puducherry, Rajasthan, Tamil Nadu, Telangana, Uttar Pradesh, Uttarakhand and West Bengal have come out with Solar Policy supporting grid-connected rooftop systems. Govt. of Haryana, Chhattisgarh, Uttar Pradesh and Chandigarh has issued mandatory notification for installation of solar rooftop plants for certain categories of buildings. Chief Electrical Inspector to Government (CEIG) inspection has been made optional by States of Andhra Pradesh, Tamil Nadu, Karnataka, Gujarat, Madhya Pradesh, Orissa, Haryana, Delhi, Maharashtra and Rajasthan for solar rooftop plants up to a certain capacity (Ministry of New and Renewable Energy, Govt. of India 2017-18).

Achievements

The Indian government has been playing a crucial role in the development and promotion of solar power plants and attained significant achievements technical assistance is being provided to the industries for the development of solar energy plants. Table 5 shows the targets and achievements (physical progress) of the government.

Table 5: Physical Progress (Achievements)

Programme/Scheme wise Physical Progress in 2020-21 & Cumulative up to November 2020			
Sector	*FY- 2020-21*		*Cumulative Achievements*
	Target	*Achievement (April Nov 2020)*	*(as on 30.11.2020)*
I. GRID-INTERACTIVE POWER (CAPACITIES IN MW)			
Wind Power	3000.00	689.80	38433.55
Solar Power - Ground Mounted	9000.00	1395.82	33508.31
Solar Power - Roof Top	2000.00	886.88	3402.18

Small Hydro Power	100.00	57.30	4740.47
Biomass (Bagasse) Cogeneration)	200.00	173.37	9373.87
Biomass (non bagasse) Cogeneration) /Captive Power	50.00	97.24	772.05
Waste to Power	30.00	21.00	168.64
Total	**14380.00**	**3321.41**	**90399.07**
II. OFF-GRID/ CAPTIVE POWER (CAPACITIES IN MW)			
Waste to Energy	10.00	6.71	204.90
SPV Systems	500.00	70.30	1048.69
Total	510.00	77.01	1253.59

Source: Ministry of New and Renewable Energy- Annual Report 2019-20.

Section-IV

Barriers and Challenges Faced by Solar Energy in India

(i) Availability of land and its possession: Land is a scarce resource and per capita availability of land is also very low in India. Lack of adequate land is a major challenge for the installation of solar plants because solar power plants require huge parcels of land. Moreover, if suitable land (non-agricultural, unused, good solar irradiance, free of undulations and trees) is available, then its acquisition is also a challenging task.

(ii) Initial high capital cost: A huge amount of capital is required to set up solar plants.

(iii) Lack of cheap financing: Funding of initiatives is one of the major problems. Commercial banks in our country finance these types of renewable energy projects but these banks provide debt at a much higher rate than that are available in the developed nations.

(iv) Grid Stability: Many regions in some states don't have the required power grid. Utility substations must be properly installed for the transmission of energy with lesser losses.

(v) Lack of trained manpower: There is a need for skilled plant designers, site engineers, and semi-skilled technicians for the construction and maintenance of solar projects. However, there is a shortage of skilled manpower in the manufacturing, construction, R&D and maintenance sectors of solar energy.

(vi) Energy Storage: For storing energy, batteries are used by off-grid PV systems, which increase the complexity of the system.

Section-V

Conclusions and Suggestions

Road Ahead: With the availability of strong sunshine on rooftops across most of the parts of the country, the future of solar power in India is bright indeed. It is expected that around 49 % of the total electricity will be generated through renewable energy by the year 2040 and will approximately save India's Rs. 54000 crore (US $ 8.43 billion) annually. It is also expected that 1,116400 jobs will be generated in India's solar sector by 2022 which will definitely help in solving the persistent problem of unemployment in India to some extent. Solar power is the future source of energy in the country. India needs to invest in R&D so that cost of production is reduced further to make solar energy as the cheapest and cleanest source of energy for sustainable development.

Suggestions: The Suggestions/ Recommendations are mentioned below-

- Rooftop solar energy, offshore solar energy plants and vertical solar plants can be installed.
- The Ministry of New and Renewable Energy along with the Ministry of Finance should promote capital-intensive renewable energy projects through innovative financing measures like clean energy funds, generation-based incentive-linked loan repayment and green bonds.
- The government should install and maintain a world-class grid for transmitting the electricity generated in the power plant.
- There should be proper training and development of human resources for the construction and maintenance of solar power projects in India.

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