Renewable Energy Sources In Rajasthan For Sustainable Development

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Abstract.- Globally, energy consumption is increasing drastically due to the economic growth, rapid industrialization and increasing domestic comforts. Also energy is now considered to be important criteria for sustainable development of any country. Melting of ice caps, overabundance of greenhouse gases, global warming and other drastic climatic changes worldwide, has turned attention towards environmental issues. Exploiting the enormous potential of renewable energy sources could be one of the alternatives of total dependency on the conventional energy resources. In India, the population is sparsely scattered in vast geographic location, because of which the government often cannot provide electric power to the entire citizen through the centralized national grid. In that case, renewable energy is a good option to as it can be used as a stand-alone distributed generation system. In this paper, the availability and current status of renewable energy in Rajasthan is summarized. This summary of available resources helps researchers, investors and developers to find probability of improvement in technologies to harness renewable energy and to map out further expansion of renewable energy generation.

I. Introduction

Exponential growth in population, increasing per capita consumption of energy and drying up of natural resources has forced to look for alternative sources of energy. Looking towards global environmental problems, various countries around the world came together with climatic negotiations, namely, UNFCCC. India is an active participant of this novel drive and decided to generate clean, green and carbon free energy [1,2]. India has the largest population in the world after China. The government is making impressive progress to increase electricity generation as per growing demand as well as reducing carbon emissions by producing clean energy for balanced development of the country. In the last few years, from 2014, renewable energy generation in India has grown significantly, with more than 89.22 GW of renewable energy installed in different part of the country. India is on track to reach the goal of 100 GW by 2022. Currently India has the world’s third largest installed renewable energy capacity after USA and Brazil [3]. Rise in the energy consumption in recent years is frightening. Due to consistent growth in India GDP, consumer purchase power has increased which resulted in increased use of energy in domestic comfort. Domestic energy consumption is 24.6% of total energy consumption in India. According to IEA report 2017, one-third of total energy produced worldwide is produced from coal and 40% of which is consumed in electricity generation and remaining in industrial use. Growing energy demands requires an increase in generation capacity and generation from coal means increase in carbon emission and harmful
gases. Coal has been the main source of electricity generation and replacing coal with other natural resources requires infrastructural changes that result in an increase in costs and delays [4, 5]. Figure 1 shows India’s source-wise electricity generation capacity in MW.

Electricity generation from renewable energy sources stated in 1997, the total installed capacity at that time was 900 MW, later it was 7760 MW in 2007, and it was raised to 57244 MW in 2017 and further increased to 69022 in 2018 and reached 87027.68 MW in 2020 [6].

![Fig. 1 Conventional and Renewable energy Generation Capacity of India in MW (31 March 2020)](image)

Karnataka, Tamil Nadu, Maharashtra, Gujarat and Rajasthan are India’s top five states in installed renewable capacity. Those five states have about 66.991% of renewable energy capacity. Karnataka ranked 1st at 12,953.24 MW (17.485%), Tamil Nadu 2nd at 11,934.38 MW (16%), Maharashtra 3rd at 9,238.78 MW (12.532%), Gujarat 4th at 7,882.5 MW (10.6%) and Rajasthan 5th at 7,573.86 MW (10.224%) [6]. Alongside these five states, Andhra Pradesh, Madhya Pradesh, Telangana and Uttar Pradesh are the other most important Indian state of installed renewable capacity. These nine states account for 91.655% of total Indian installed capacity [7, 8]. Table 1 shows growth in total grid connected installed capacity of India in year 2019 and 2020.

### Table 1 Growth in Grid Connected Renewable Power

| Renewable sources | Total capacity (2019) | Total capacity (2020) |
|-------------------|-----------------------|-----------------------|
| Wind power        | 37505.18              | 38433.55              |
| Solar power       | 31379.30              | 33508.31              |
| Solar power       | 2333.23               | 3402.18               |
| Small hydropower  | 4671.55               | 4740.47               |
| Biomass power     | 9861.31               | 10145.92              |
| Waste to energy   | 139.80                | 168.64                |
| Total             | 85908.37              | 90399.07              |

II. Renewable Energy in Rajasthan

Rajasthan has a leading role in expanding India’s renewable power capacity and transferring the electricity grid to a cost-effective, inexpensive and environmentally friendly electricity system. Rajasthan has the largest geographical area in the country and also it shines brightly on the solar map of the country, as there are 300-330 clear sunny days. High radiations, wind speeds and convenience of huge barren land square measure are factors
that make Rajasthan as an appropriate location for commercial solar parks. Bhadla Solar Park, situated in Jodhpur district, is the World’s largest solar park (2.25 GW). Rajasthan has 9.8 GW non-conventional capacity, which is 45% of total power generation capacity and generates 56.5% of total grid-connected generation while 43.5% of installed capacity is from renewable energy sources which produce 17.6% of total on-grid generation as shown in Fig 2. According to forecasts, Rajasthan can add 22.6 GW of renewable power to the ambitious target of 175 GW by 2030. This increase includes 18 GW of new solar power and 4 GW new onshore wind energy. As per economic review of Rajasthan 2019-20, the total installed generation capacity is 21,175.90 MW and there is an increase of total 736.96 MW during 2018-19 [9, 10].

![Fig. 2 Source wise total renewable Capacity of Rajasthan 2019-20](image)

**a) Solar energy**

Rajasthan have second largest solar power generation capacity in the country after Karnataka. Total installed electricity generation capacity of Rajasthan in 2020 reached to 22268.27 MW while solar capacity is 5137.19 MW, which is 21.06% share of total capacity as shown in Table 2. India has planned to assist solar power projects in many states through solar parks. Barmer, Bikaner, Jaisalmer and Jodhpur are the core areas of high solar radiations. The high level of solar radiations and the large flat, undeveloped area are two vital resources that are available in Rajasthan. The estimated potential of solar power in Rajasthan 142 GW as per MNRE assessment and 4996.96 MW ground mounted solar power plants are operational and 356.80 MW rooftop plants, which was 726 MW in 2014 [11, 12].

Rajasthan is now home to six solar farms in Bikaner and Jodhpur, spread over 2,500 hectares. Rajasthan's total solar capacity stood at 5137.19 MW in 2020. The largest 125 MW Fresnel-type CSP power station in the world is located in the Dhirubhai Ambani Solar Park in Rajasthan. The Jodhpur district stood first with 1500 MW installed capacity. Bhadla solar farm is the most widespread plant in the world upto March 2020, with a total capacity of 2245 MW. The exclusive tower-type solar thermal power plant with an output of 2.5 MW is located in the Bikaner area. This plant has the lowest tariff in India (2.48/KWh) for a 750-MW solar power plant [13, 14].
**TABLE 2 Growth in Installed solar power in Rajasthan**

| Year   | Capacity Added (MW) | Cumulative capacity (MW) |
|--------|---------------------|--------------------------|
| 2014-15| 942.10              | 942.10                   |
| 2015-16| 327.83              | 1269.93                  |
| 2016-17| 543.00              | 1812.93                  |
| 2017-18| 519.84              | 2332.77                  |
| 2018-19| 894.02              | 3226.79                  |
| 2019-20| 1911.12             | 5137.19                  |

Bhadla Solar Park:
Rajasthan has high solar irradiation of 5.72 kWh/m2/day and solar potential of 142 GW with an advantage of available vast and affordable land. The Bhadla Solar park situated at Phalodi in Jodhpur district, Rajasthan. With a spread area of 10000 hectares (40Km2), it is one of the wide-ranging solar parks in India. This park was proposed for 2000 MW capacity and construction started in July 2015. Later this proposal was raised up to 2250 MW (2.25 GW). The project was developed in four stages [15, 16].

Phase I: Phase I started in October 2018 and was developed by Rajasthan Renewable Energy Corporation Limited (RRECL) with RSPDCL. It was having 7 solar plants of total installed capacity of 75 MW.

Phase II: Second phase of the Bhadla Solar park started in April 2019 and developed by RSDCL at Village Bhadla, Jodhpur. It has 10 solar power plants of total installed capacity of 680 MW. This phase was developed under MNRE scheme of solar park development. This scheme provides basic infrastructure like light, water, office buildings, power evacuation system, etc. for solar parks. Operation and maintenance were arranged by RSDCL.

Phase III: Surya Urja Company of Rajasthan is developing a phase III of the Bhadla solar park. It has 10 solar power plant of total installed capacity of 1000 MW. The companies developing solar power plants in phase III of the Bhadla solar park are Hero Future Energies (300 MW), Softbank Group (200 MW), ACME Solar (200 MW), and SB Energy (300 MW).

Phase IV: Fourth phase is developed by Adani Renewable Energy Park Rajasthan. It has 10 solar power plants of 500 MW capacity.

Sambhar Ultra-Mega Green Solar Power Project
The outline of the Sambhar Ultra-mega Green solar power project was prepared around 2013. The plan was to prepare 4000 MW solar projects on Sambhar Lake near Jaipur Rajasthan. The solar project was finalized to install on an area of 9308 hectares of Sambhar salts limited. 1000 MW generation started with the commissioning of the first phase of the project by the end of 2016. The expected generation of the plant is 6000 million units per year after full commissioning of 4000 MW. The phase I of the project was completed through a joint venture of Sambhar salts limited with Bharat Heavy Electricals Ltd (BHEL), Solar Energy Corporation of India, Power Grid Corporation of India Ltd, (PGCIL), Satluj Jal Vidhyut Nigam Ltd, and REIL [15].

Nokh solar park
Nokh solar Park is the second wide-spread solar park of the Rajasthan. Year-round solar radiation in the state ranges from 4.36 kWh/m2 to 7.57 kWh/m2 per day. This solar park is located at Nokh, Jaisalmer and spread
over an area of 1850 hectares. The Government of Rajasthan and NTPC Ltd signed a Memorandum of Understanding (MOU) to generate 925 MW solar power from this solar farm. The estimated capital investment of this project would be about Rs 4000 Crore. Renewable Energy Corporation Limited (RRECL) will develop Ultra Mega renewable energy parks in joint venture with other leading developers and Power Finance Corporation, Solar Energy Corporation of India and National Hydroelectric Power Corporation for developing solar parks [16]. The present installed capacity of this farm is 980 MW.

Fatehgarh Solar Parks
Fatehgarh solar park is spread over an area of 9981 acres in Jaisalmer with an installed capacity of 421 MW. This project is developed by a joint venture company of Adani Renewable Energy Park Ltd (AREPL) and Rajasthan Renewable Energy Corporation Ltd (RRECL). Adani group is building the first phase of developing 1500 MW solar park in Fatehgarh, Jaisalmer [14, 15]. The government of Rajasthan will create solar farms with a capacity of 1,000 MW in the recognized zones of the Jodhpur, Jaisalmer, Bikaner and Barmer regions. RREC will go about as a nodal organization to create solar parks in Rajasthan.

b) Wind energy
Wind energy is combined effect of several phenomena like earth’s rotation, solar energy, ocean’s cooling effects, difference in temperature gradient of land and sea etc. It is broadly dispersed sources of energy. Wind energy is emerging out as a bright source of energy due to technological advancements in turbine system. India stood fourth in introducing a wind power limit on the planet with the total installed capacity of 38.124 GW in 2020 [17].

With total capacity of 4337.64 MW wind power in the year 2019-20, Rajasthan is on the fifth rank in the country. Fig. 3 shows year-wise growth of installed wind capacity in Rajasthan. The Jaisalmer Wind Park, situated in Rajasthan is one of the world’s largest operational wind farm and India’s second biggest working onshore wind farm with an installed capacity of 1064 MW [18, 19]. The site for the wind farms includes areas near Jaisalmer, Amarsagar Badabaug, Tejuva and Soda Moda. The farm was set up by the Suzlon Energy and other companies involved in various activities of development are Mytrah Energy, Hindustan Zinc Limited, Hindustan Petroleum Corporation limited, Rajasthan State Mines and Mineral Limited, Rajasthan Renewable Energy Corporation Limited and Rajasthan Gums Limited [20, 21]. Table 3 shows district-wise wind installed capacity of Rajasthan.
India is an agrarian country with tropical location, bountiful sunshine and rains that makes ideal conditions for Biomass production. The present installed capacity of biomass in India is around 1 GW and further planned to increase it 10 GW. Andhra Pradesh, Maharashtra, Tamil Nadu, Karnataka and Rajasthan are the major states producing electricity from biomass. Some new capacities of biomass are added by Punjab and Chhattisgarh too [22, 23].

The Government of Rajasthan has made the implementation of non-conventional power projects in the Rajasthan a high priority. The ‘Government of Rajasthan’ issued a “Policy for Promoting Generation of Electricity from Non-Conventional Energy Sources” in 1999, to promote power generation from renewable. Later the ‘Government of Rajasthan’ had issued a “Policy for Promoting for Generation of Electricity from Biomass, 2010” [24, 25].

Mustard husk and Julie Flora are the main biomass energy sources in Rajasthan. The waste and residues of mustard, cotton, gaur and Prosopis Juliflora can be used as fuel for power generation in a biomass power plant. The fuel can be prepared from the combination of different available residues and crop waste. The generation of stalks of mustard, gaur, and cotton are quite stable and predictable. Mustard is mainly grows in the areas of Rajasthan like, Tonk, Bharatpur, Ganganagar, Alwar and Modhopur districts. The yearly generation of mustard husk in Rajasthan is 61,46,066 tons per annum and the excess availability is 27,58,894 tons per annum. Prosopis Juliflora is grown in particular areas of Jaisalmer, Bikaner, Barmer and Jodhpur. The annual generation of
Juliflora wood is 2,92,62,740 tons per annum out of that 36,32,967 tons per annum is surplus availability. Rajasthan houses total eleven biomass power plants of total capacity of 121.3 MW as table 4 shows developer-wise biomass projects of Rajasthan [26, 27, 28].

| Developer | Capacity (MW) | Location | Biomass used |
|------------|---------------|----------|--------------|
| Kalpataru Power Transmission Ltd. | 7.8 | Padampur, Sri Ganganagar | Mustard Husk |
| Kalpataru Power Transmission Ltd. | 8 | Khatoli-Unlara Tonk | Mustard Husk |
| Surya Chambal Power Ltd. | 7.5 | Rangpur-Ladpura Kota | Mustard Husk |
| Birla Corporation Ltd. | 15 | Chanderi Chittorgah | Mustard Husk |
| S.M. Environment Technologies Pvt. Ltd. | 8 | Pacchar-Chhipa Barod, Baran | Mustard Husk |
| Transtech Green Power | 12 | Kachela Bagsari Sanchor, Jalore | Prosopis Juliflora |
| Sathyam Power Pvt. Ltd. | 10 | Punjiyas Tehsil-Merta, Nagaur | Mustard Husk |
| Sanjog sugar & Eco Power Pvt. Ltd. | 10 | Sangaria, Hanumangarh | Mustard Husk |
| Orient green Co. | 8 | Bhanwargah, Kishanganj, Baran | Mustard Husk |
| The Rajasthan State Ganganagar Sugar Mills Ltd. | 4.95 | Kaminpura, Sriganganagar | Bagasse |
| Rajasthan State Ganganagar Sugar Mills Ltd. | 1.2 | Kaminpura, Sriganganagar | Biomass |

**d) Small Hydropower**

India is world’s fifth country for installed hydroelectric power capacity. The total installed utility scale hydroelectric capacity of India is 45699 MW, which is 12.35% of total capacity and 4380 MW small hydroelectric power units have been installed which is 1.3% of total generation capacity [29]. SHP is the projects of generation capacity of 2 to 25 MW capacity. India has huge potential for small hydro plants too. The assessed capability of SHP is 20 GW and MNRE set an objective of 5 GW by 2022 and the out this 4.7 GW has been accomplished before the end of the year 2020 [30]. Government of Rajasthan has also installed around 24 MW small hydropower capacity in the state.

| S.No. | Name of Power House | Capacity (MW) |
|-------|---------------------|---------------|
| 1     | Anoopgarh PH-I      | 4.50          |
| 2     | Anoopgarh PH-II     | 4.50          |
| 3     | Pugal PH-I          | 1.50          |
| 4     | Pugal PH-II         | 0.65          |
| 5     | RMC Mahi-I          | 0.80          |
| 6     | RMC Mahi-II         | 0.165         |
| 7     | Mangrol             | 6             |
| 8     | Suratgarh           | 4             |
| 9     | Charanwala          | 1.20          |
| 10    | Birsalpur           | 0.535         |
| Total |                     | 23.85         |
Current achievements:
Solar Energy Corporation of India (SECI) carried out reverse auction for interstate solar power transmission with the lowest per unit cost in June 2020. Earlier the lowest tariff recorded was INR 2.44 per unit in 2018 and now it is INR 2.36 per unit, which is 3.3% lower. There are six fully functioning solar parks in Rajasthan with completion of Bhadla-II project of 680 MW capacity. India launched ‘Kisan Urja Suraksha evam Utthaan Mahabhiyan’ (KUSUM) February 2019 with the aims of providing financial and water security to farmers. This scheme will add 25.75 GW solar power capacity. This scheme is implemented in Rajasthan with the help of state government efforts. This scheme promotes usage of solar pumps for irrigation which is important for hi-tech agriculture and also reduces cost of cultivation.

In March 2017, under solar parks scheme, the capacity of solar parks is increased from 20000 MW to 40000 MW with an objective of establishment of 50 solar parks by 2019-20. Existing mode of selection of private entrepreneurs in the development of solar parks has been corrected and some new methods have been presented to bring more transparency in the system.

To establish Rajasthan as national leader in renewable energy, new hybrid wind and solar policy is framed in 2019. This policy promotes harnessing of renewable energy and provides employment to skilled and semi-skilled manpower resources.

III. Conclusion
With the correct investments in green innovations, India is all around situated to accomplish sustainable power targets. Rajasthan is one of the leading states that pursue towards cleaner energy which is an essential function in empowering the nation’s change to a completely supportable energy framework. There are estimates that suggest that renewable energy installations would reach 860 GW by the year 2030. Advancements in renewable energy in India will create jobs for locale, rural electrification and promote electric mobility too. But there are several challenges in utilizing renewable energy such as a mismatch in supply-demand, lack of financial support for the high initial cost of off-grid applications, risk perception, lack of policies for developer’s credit. Also, if power generated from renewable sources is not properly utilized, the ambitious targets of India may be proven unfruitful. In this paper, an attempt is made to summarize the availability and utilization of renewable energy sources in Rajasthan. The current status, installed capacity, government policies to promote them, major achievements, and subsequent development are discussed in this paper. The data collected in this paper will enable researchers and developers to identify a scope of improving technologies to harness renewable energy and chart a path for further expansion of renewable energy production. From the above-discussed status of the state, the following points can be concluded:

- Due to the intermittent nature of Renewable Energy generation, its large-scale integration into the grid is a difficult task. It requires up-gradation of transmission and distribution infrastructure.
- To meet the future energy demand of the state, there is a need for proper assessment of optimal generation mix of renewable and non-renewable energy sources with all technological options considered.
- Social recognition of renewable energy is still not very promising in urban India. Awareness is the
crucial factor for the uniform and broad use of renewable energy. Information about renewable technology and its environmental benefits should reach society.

- To enhance the faster adoption of renewable energy sources, the government should encourage manufacturing in the state by promoting the transfer of ideas between industry, academia, and policymakers from around the world.
- For effective utilization of transmission, hybrid projects should be promoted which include renewable resources along with conventional sources and battery storage systems. It will optimize the production as well as provides power at competitive prices.
- Although the government is providing financial support to enhance renewable power generation it is not sufficient. The government should provide enough budgets for the encouragement of green energy generation.

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