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Renewable Energy Sources in Rajasthan for Sustainable Development

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Abstract: *Due to rising living standards, increased industrialization, and modern conveniences, global energy consumption is on the rise. Energy is currently seen as a significant indicator of a country's potential for long-term growth and prosperity. The world's attention has shifted to environmental concerns as a result of the melting ice caps, the excess of greenhouse gases, global warming, and other extreme climatic changes. One possible alternative to relying solely on traditional energy sources is making use of the vast untapped potential of renewable energy sources. Due to the country's large size and dispersed population, the government of India frequently struggles to meet the electricity needs of its entire people through a single, unified national system. Since renewable energy may be employed as a standalone distributed generation system, it is a viable choice in such a scenario. This article provides a brief overview of the state of renewable energy in Rajasthan and its current availability. Researchers, financiers, and developers can use this synopsis of existing materials to better understand the likelihood of technological advancements in renewable energy capture and to plan for the extension of renewable energy generation.*

Keywords: renewable energy generation

I. INTRODUCTION

Natural resource depletion, rising energy use per person, and population increase have all contributed to the urgent need to find new energy sources. In response to environmental concerns on a worldwide scale, many nations initiated climate negotiations under the auspices of the United Nations Framework Convention on Climate Change (UNFCCC). India has opted to take part in this innovative initiative by producing electricity in a carbon-free, environmentally friendly manner. The population of India is second only to China's. The government is making significant headway in its efforts to increase power output to meet rising demand and reduce carbon emissions by producing clean energy, thereby promoting the country's goal of achieving a balanced development. More than 89.22 GW of renewable energy have been installed in various parts of India in the years since 2014, a considerable increase in the country's renewable energy generation. The target of 100 GW for India by 2022 is on track. After the United States and Brazil, India now has the third-largest amount of renewable energy capacity in operation. The alarming increase in energy use over the past few years. Consistent expansion in India's GDP has given consumers more spending power, which has led to a rise in the domestic comfort sector's energy consumption. The percentage of India's total energy consumption that comes from home use is 24.6%. Coal accounts for one-third of global energy production, with 40% used in power generation and the remaining 60% used in industrial applications, as reported by the International Energy Agency in 2017. More coal is being used to generate electricity to meet rising demand, which in turn increases carbon emissions and other hazardous gases. Historically, coal has been used to generate electricity, and switching to alternative natural resources will need expensive and time-consuming infrastructure upgrades. The MW of India's power generation capacity is broken down per source in Figure 1. In 1997, 900 MW of renewable energy capacity was installed; by 2007, that number had climbed to 7760 MW; in 2017, it was 57244 MW; in 2018, it was 69022 MW; and by 2020, it will be 87027.68 MW.

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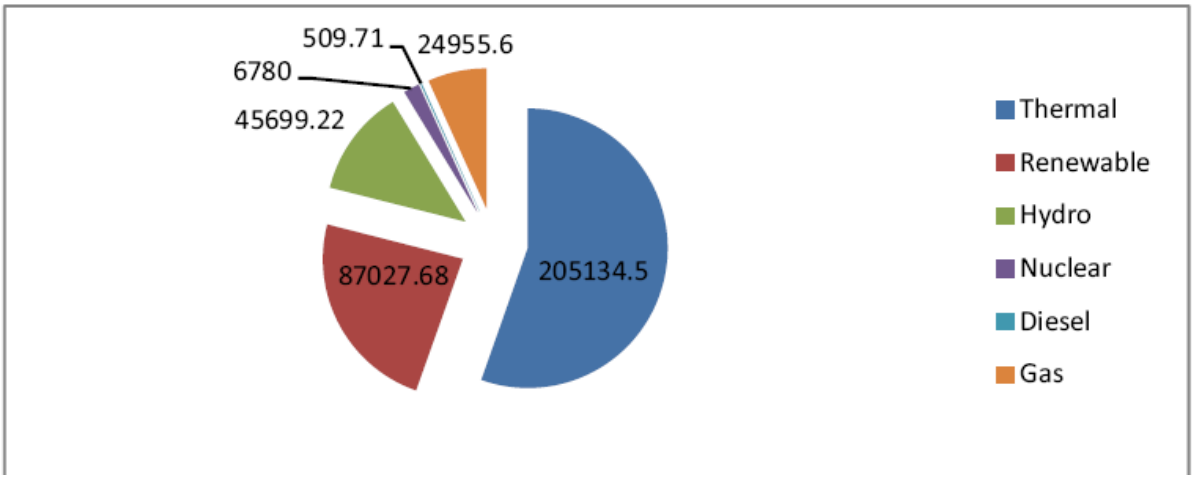
Figure 1: India's Conventional and Renewable Energy Generation Capacity in Megawatts (MW) as of March 31, 2020



The five states in India with the most installed renewable capacity are as follows: Karnataka, Tamil Nadu, Maharashtra, Gujarat, and Rajasthan. In those five states, renewable energy capacity accounts for almost 66.991 percent. A total of 12,953.24 MW (17.485%) is generated in Karnataka, followed by 11,934.38 MW (16%) in Tamil Nadu, 9,238.78 MW (12.532%) in Maharashtra, 7,882.5 MW (10.6%) in Gujarat, 7,573.86 MW (10.224%) in Rajasthan, and finally 7,573.86 MW (10.06%) in Gujarat.Andhra Pradesh, Madhya Pradesh, Telangana, and Uttar Pradesh are also among the most significant states in India in terms of installed renewable capacity, alongside these five. The total installed capacity in India is 91.655%, and it is only used by these nine states.

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 Ground mounted	31379.30	33508.31
Solar power Rooftop	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

The state of Rajasthan is at the forefront of India's efforts to increase its renewable power capacity and convert to a more efficient, affordable, and environmentally friendly energy grid. The state of Rajasthan is the largest in India, and its 300-330 annual clear sunny days make it a solar powerhouse. Commercial solar parks would benefit from Rajasthan's high radiations, wind speeds, and availability of large stretches of bare land. The Bhadla Solar Park in the Jodhpur area is the largest solar park in the world in terms of installed capacity, at 2.25 GW. Figure 2 displays that of Rajasthan's total power generation capacity, 9.8 GW comes from non-conventional sources and accounts for 45.5%, while 43.5% of installed capacity comes from renewable energy sources and accounts for 17.6% of total on-grid generation. Forecasts suggest that Rajasthan can increase its renewable power capacity by 22.6 GW by 2030, bringing the total capacity to an ambitious 175 GW. This boost is due in large part to the addition of solar electricity (18 GW) and onshore wind generation (4 GW). There was an increase of 736.96 MW in total installed generation capacity in 2018-19, according to the Economic Review of Rajasthan 2019-20, making Rajasthan an ideal location for industrial solar farms. The Bhadla Solar Park in the Jodhpur area is the largest solar park in the world in terms of installed capacity, at 2.25 GW. Figure 2 displays that of Rajasthan's total power generation capacity, 9.8 GW comes from non-conventional sources and accounts for 45.5%, while 43.5% of installed capacity comes from renewable energy sources

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Fig. 2 Source wise total renewable Capacity of Rajasthan 2019-20

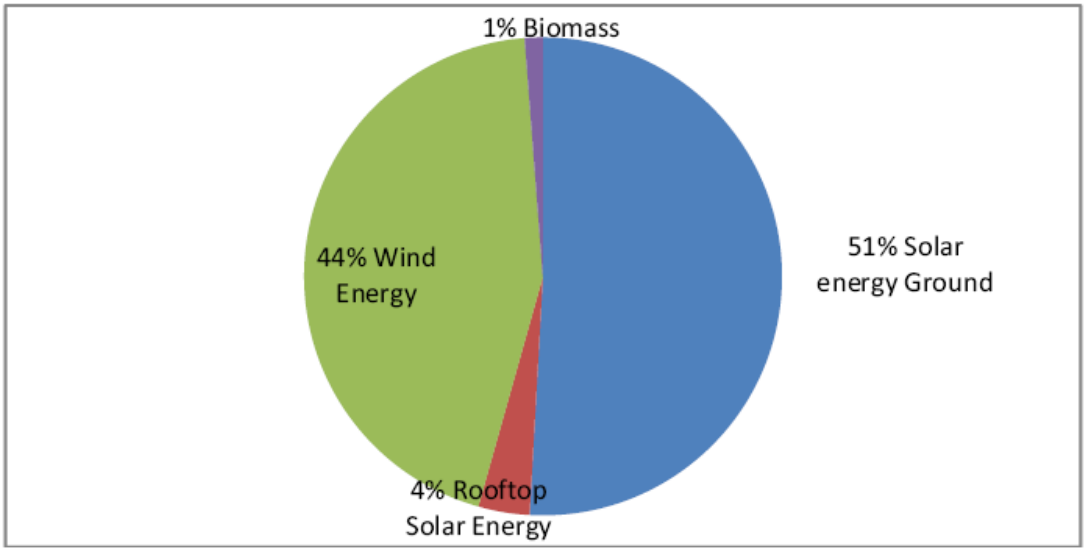

Fig. 2 Source wise total renewable Capacity of Rajasthan 2019-20

a) Solar Energy

After Karnataka, Rajasthan generates more solar power than any other state in India. In 2020, Rajasthan's total installed electricity generation capacity reached 22268.27 MW, with solar capacity reaching 5137.19 MW, or 21.06% of total capacity. Table India intends to use solar parks to facilitate solar power initiatives across several of its states. High sun radiations are concentrated in the cities of Barmer, Bikaner, Jaisalmer, and Jodhpur. Rajasthan has access to two crucial resources: high solar radiation intensity and a huge, flat, unexplored territory. Currently, there are 4996.96 MW of operational ground-mounted solar power plants and 356.80 MW of operational rooftop plants in Rajasthan, for a total of 726 MW.

Six solar farms, covering a total of 2,500 acres, have been established in Bikaner and Jodhpur in the Indian state of Rajasthan. In 2020, the total installed solar capacity in Rajasthan was 5137.19 MW. Dhirubhai Ambani Solar Park in Rajasthan is home to the world's largest Concentrating Solar Power (CSP) power unit, with a capacity of 125 MW. With 1500 MW of capacity, the Jodhpur region was the most powerful in the country. The Bhadla solar farm has a total capacity of 2245 MW, making it the most widespread plant in the world until March 2020. The Bikaner region is home to the only 2.5 MW tower-type solar thermal power plants in the world. In India, this 750-megawatt solar power plant offers the cheapest tariff (2.48 rupees per kilowatt-hour).

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

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Bhadla Solar Park:

Solar irradiation in Rajasthan is rather high, at 5.72 kWh/m2/day, and the state has a solar potential of 142 GW. Located in the Phalodi neighbourhood of the Jodhpur region of Rajasthan is the Bhadla Solar Park. It is one of the largest solar parks in India, covering an area of 10000 hectares (40Km2). The park's intended capacity is 2,000 MW, and construction began in July of 2015. The proposed output was increased to 2.25 GW, or 2,250 MW, at a later date. There were four main phases of the project's development.

In the first stage, which began construction in October 2018, Rajasthan Renewable Energy Corporation Limited (RRECL) collaborated with RSPDCL to create a power plant. It had 7 solar power plants with a combined 75 MW of capacity.

RSDCL has begun construction on Phase II of the Bhadla Solar Park in the village of Bhadla outside of Jodhpur. It has 680 MW of installed capacity across 10 solar power projects. This section of the solar park was built using funding from the MNRE. This plan equips solar parks with the fundamentals like as utilities, buildings, and power evacuation systems. RSDCL was responsible for setting up operations and upkeep.

The third and final phase of the Bhadla solar park is now under construction by the Surya Urja Company of Rajasthan. There are 10 solar power plants with a total of 1 GW of installed capacity. Three hundred megawatts (MW) of solar power plants are being built by Hero Future Energies, two hundred by Softbank Group, two hundred by ACME Solar, and three hundred MW by SB Energy in phase III of the Bhadla solar park.

Adani Renewable Energy Park Rajasthan is currently developing Phase IV. Those 500 MW come from 10 solar power installations. Green Solar Power Plant in Sambhar, India

In 2013, planners developed a blueprint for the Sambhar Ultra-mega Green solar power project. Sambhar Lake, located close to Jaipur, Rajasthan, was supposed to be the site of 4,000 MW worth of solar plants. Sambhar salts limited's 9308-hectare solar installation project has reached completion. The first phase of the project was commissioned at the end of 2016, and by the beginning of 2017, it was generating 1000 MW. After full commissioning of 4000 MW, the plant is expected to generate 6000 MU annually. Sambhar Salts Limited collaborated with Bharat Heavy Electricals Ltd (BHEL), Solar Energy Corporation of India, Power Grid Corporation of India Ltd (PGCIL), Satluj Jal Vidyut Nigam Ltd (SJVNL), and REIL to complete phase I of the project.

Nokh Solar Park

In Rajasthan, Nokh Solar Park is the second largest solar park. The average daily solar radiation in the state is between 4.36 and 7.57 kWh/m2. This solar park covers an area of 1850 hectares and is situated in Nokh, Jaisalmer. This solar farm is part of a Memorandum of Understanding (MOU) between the Government of Rajasthan and NTPC Ltd. This project would require an approximate investment of Rs 4000 Crore in capital. Ultra Mega renewable energy parks will be built by Renewable Energy Corporation Limited (RRECL) in collaboration with other major developers, the Power Finance Corporation, Solar Energy Corporation of India, and the National Hydroelectric Power Corporation. This farm has a current installed capacity of 980 MW.

Fatehgarh Solar Parks

The 9981-acre Fatehgarh solar farm in Jaisalmer has an installed capacity of 421 MW. Jointly owned by Adani Renewable Energy Park Ltd (AREPL) and Rajasthan Renewable Energy Corporation Ltd (RRECL), this venture is responsible for the development of the project at hand. The solar park at Fatehgarh, Jaisalmer, that the Adani company is developing is the first stage of a planned 1500 MW facility. In the designated areas of Jodhpur, Jaisalmer, Bikaner, and Barmer, the government of Rajasthan plans to build solar farms with a combined capacity of 1,000 MW. RREC will function as a hub for the development of solar farms in Rajasthan.

b) Wind energy

Several natural processes work together to create wind energy, including the earth's rotation, the sun's energy, the cooling effects of the water, the difference in temperature gradient between land and sea, and so on. The energy comes from many different places. As turbine technology improves, wind power becomes a more viable energy option. In

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2020, India's total installed capacity of 38.124 GW placed it fourth worldwide in terms of adopting a wind power restriction.

In terms of overall wind power capacity in 2019–20, Rajasthan ranks fifth in the country with 4,337.64 MW. Installed wind capacity in Rajasthan is shown to develop each year in Fig. 3. With an installed capacity of 1064 MW [18, 19], the Jaisalmer Wind Park in Rajasthan ranks as both the world's largest operational wind farm and India's second largest working onshore wind farm. Wind farms will be constructed in several locations close to the cities of Jaisalmer, Amarsagar Badabaug, Tejuva, and Soda Moda. Suzlon Energy established the farm; Mytrah Energy, Hindustan Zinc Limited, Hindustan Petroleum Corporation limited, Rajasthan State Mines and Mineral Limited, Rajasthan Renewable Energy Corporation Limited, and Rajasthan Gums Limited are also involved in the development of the site in various ways.The table below details Rajasthan's installed capacity for wind power by district.

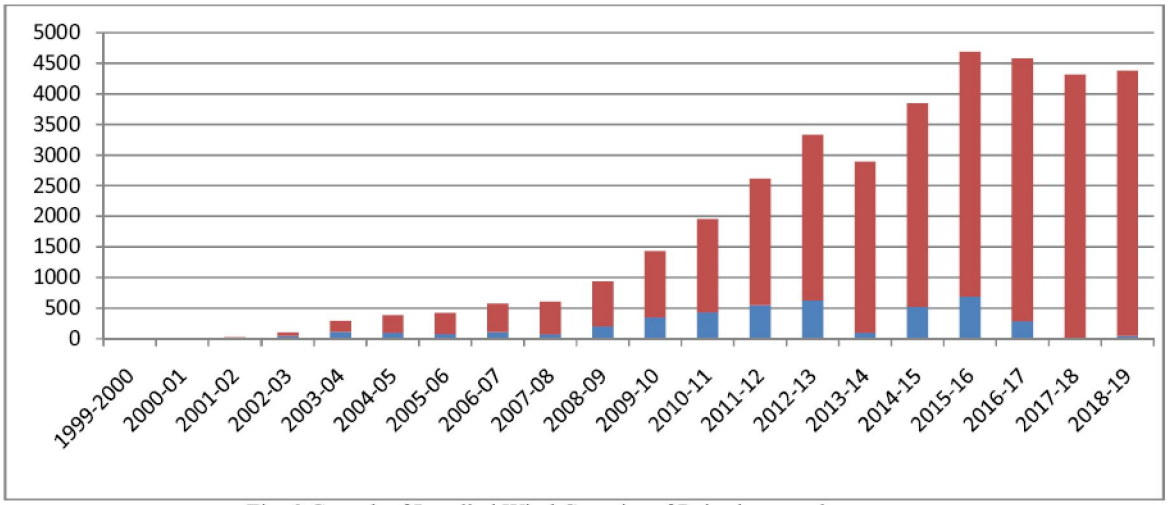

Fig. 3 Growth of Installed Wind Capacity of Rajasthan yearly

TABLE 3: District-wise Status of Wind power projects commissioned in Rajasthan

District	Total Capacity Commissioned (MW)
Jaisalmer	3464.32
Jodhpur	416
Sikar	7.2
Barmer	49.6
Chhittorgarh	355.425
Total (MW)	4337

c) Biomass Energy

Agrarian India benefits greatly from its tropical position, abundant sunshine, and precipitation for Biomass production. India plans to raise its biomass capacity from its current 1 GW to 10 GW. Most of India's biomass-generated power comes from the southernmost states of Andhra Pradesh, Maharashtra, Tamil Nadu, Karnataka, and Rajasthan. Punjab and Chhattisgarh also added some new biomass capacity.

The state government of Rajasthan has made it a top priority to develop alternative energy sources. In 1999, the 'Government of Rajasthan' announced a "Policy for Promoting Generation of Electricity from Non-Conventional Energy Sources" to encourage the use of renewable energy. The "Government of Rajasthan" announced the "Policy for Promoting for Generation of Electricity from Biomass, 2010" afterwards.

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The state of Rajasthan relies primarily on mustard husk and Julie Flora as biomass energy sources. Mustard, cotton, gaur, and Prosopis juliflora all have byproducts that can be utilised as fuel in a biomass power plant. The fuel can be made by combining various residues and crop waste that are readily available. Mustard, gaur, and cotton have consistently reliable and predictable generational cycles. Tonk, Bharatpur, Ganganagar, Alwar, and Modhopur districts are major mustard-growing regions in Rajasthan. In Rajasthan, 61,46,066 tonnes of mustard husk are produced annually, with an additional 27,58,894 tonnes available. Jaisalmer, Bikaner, Barmer, and Jodhpur are just some of the cities where you can find the Prosopis Juliflora tree. There is an annual surplus of 36,32,967 tonnes of Juliflora wood available, out of a total yearly output of 2,92,62,740 tonnes. According to table 4, eleven biomass power plants with a combined capacity of 121.3 MW may be found in Rajasthan.

TABLE 4 Biomass Projects commissioned in Rajasthan

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	Bhanwargarh, Kishanganj, Baran	Mustard Husk
The Rajasthan State Ganganagar Sugar Mills Ltd.	4.95	Kaminpura, Srikarnpu, Sriganganagar	Bagasse
Rajasthan State Ganganagar Sugar Mills Ltd.	1.2	Kaminpura, Sriganganagar	Biomass

d) Small Hydropower

India has the fifth-highest amount of hydroelectric power capacity in the world. In India, 45699 MW (12.35%) of utility-scale hydroelectric capacity has been installed, while 4380 MW (1.3%) of small hydroelectric power units have been put in place. SHP refers to power generation projects with an output of 2 to 25 MW. Small hydro plants in India have a lot of untapped potential. SHP has a potential output of 20 GW, the MNRE has set a target of 5 GW by 2022, and 4.7 GW will have been achieved by the end of 2020. In addition, the state government of Rajasthan has installed minor hydropower capacity of about 24 MW.

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TABLE 5 shows small hydropower projects of Rajasthan.

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:

In June of 2020, the Solar Energy Corporation of India (SECI) held a reverse auction to determine which states could transmit solar power across state lines at the lowest cost per unit. The previous low recorded tariff was INR 2.44 per unit in 2018, while the current low is INR 2.36 per unit, a decrease of 3.3%. Now that the 680 MW Bhadla-II project has been finished, Rajasthan is home to six fully operational solar parks. India's government introduced the 'Kisan Urja Suraksha evam Utthaan Mahabhiyan' (KUSUM) in February 2019 to help ensure the safety of the country's farmers financially and environmentally. The plan will increase solar power capacity by 25.75 GW. The state government of Rajasthan is responsible for putting this plan into action. This plan encourages the use of solar pumps for irrigation, a crucial component of high-tech farming that has a direct impact on farm profitability.

With the goal of establishing 50 solar parks by 2019-20, the capacity of solar parks was boosted from 20,000 MW to 40,000 MW in March 2017. The current process for selecting private entrepreneurs to build solar parks has been improved, and new approaches have been proposed to increase openness. In 2019, a new hybrid wind and solar policy is being drafted with the goal of making Rajasthan the national leader in renewable energy. This programme encourages the use of renewable energy sources and creates jobs for trained and semi-trained workers.

III. CONCLUSION

India is in a great position to achieve its sustainable electricity goals if the country makes the necessary investments in green advancements. When it comes to facilitating the transition to a fully sustainable energy framework, the state of Rajasthan is among the frontrunners. It is predicted that by 2030, renewable energy installations would amount to 860 GW. Renewable energy development in India has multiple benefits, including the creation of local jobs, the electrification of rural areas, and the spread of electric vehicles. However, there are a number of obstacles to the widespread adoption of renewable energy sources. These include the supply-demand gap, the high upfront costs of off-grid applications, public perceptions of risk, and the absence of rules governing the creditworthiness of developers. In addition, India's lofty goals may prove fruitless if the power generated from renewable sources is not used effectively. This document makes an effort to provide a brief overview of the renewable energy options and their use in Rajasthan. This document provides an update on the current situation, capacity installed, government policies to promote them, key accomplishments, and future development. Using the information compiled in this study, scientists and engineers can better understand how to utilise renewable energy and plot a course for expanding renewable energy production. Large-scale integration of Renewable Energy generation into the grid is challenging because of the intermittent nature of RE power. Transmission and distribution systems will need to be upgraded for this to be possible. The ideal generation mix of renewable and nonrenewable energy sources, taking into account all technical choices, must be assessed so that the state can fulfil its future energy demand. Urban India's social acceptance of renewable energy is still in its early stages. The most important aspect in the widespread adoption of renewable energy sources is education. Society as a whole would benefit from learning more about the environmental advantages of renewable technologies. The state government should promote knowledge sharing among businesses, universities, and policymakers worldwide

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to hasten the use of renewable energy. Hybrid projects that combine renewable energy with traditional energy sources and battery storage technologies should be encouraged to make the best use of transmission. It will increase efficiency and make power available at low cost.Although the government is providing funding, it is not nearly enough to increase renewable power generation. For the sake of promoting renewable energy, the government should allocate sufficient funds.

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