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Exploring the Potential, Achievements, and Challenges of Renewable Energy in Rajasthan

AJAY PAL[1], DR. B.L. SONI [2]

[1] Research Scholar Department of Accounting Jai Narain Vyas University Jodhpur Rajasthan
[2] Assistant Professor Government P.G. College, Barmer Rajasthan

ABSTRACT.

Rajasthan is the best place in India for renewable energy because it gets a lot of sun, has steady winds along some paths, and has a lot of biomass resources. The state's geography and climate work together to make it easier to build large-scale solar and wind farms. This study examines the potential resources, current operational landscape, established policy benchmarks, and challenges associated with Rajasthan's renewable energy deployment. The state has a big share of the country's total renewable energy capacity today. Solar energy is the most popular, followed by wind and biomass. The Rajasthan Solar Energy Policy of 2019 and the Renewable Energy Policy of 2023, which set sector-leading numerical limits, have set unique, short-term goals that are in line with India's goal of reaching net-zero emissions by 2070. However, a number of old and new problems make it hard to deploy quickly. These include ongoing transmission congestion, long land allotment and acquisition processes, the fact that solar and wind energy are not always available, the unstable financial health of utilities, and ongoing uncertainty about procedures or regulations. These problems need to be fixed so that Rajasthan can stay competitive and the country can meet its goals for energy security and sustainable development. Utility-scale energy storage, new inverters, bankable revenue support mechanisms, faster clearance processes, and a bigger, more stable pool of bank debt and equity can all help with this.

Key word: Solar, Biomass, Wind, Renewable Energy, Electricity, coal

Introduction

More and more, renewable energy is meeting our needs. It will also bring even bigger benefits to India's future. The country already has 82 GW of renewable energy generation capacity, and new projects are always being built.

India has about 1.3 billion people, and every year, the number of people grows by 1.58%. This means that there is always a need for more electricity. There isn't enough of a long-lasting supply of fossil fuels to meet this huge need. Solar, biomass, and wind power are the most important renewable resources that the country uses. The switch to renewable energy is even more appealing now that the cost of electricity made from these sources is lower than that made from fossil fuels. Engineers have come up with things like wind turbines, solar photovoltaics, and advanced biomass conversion facilities. For instance, solar systems turn sunlight, which is one of the Earth's renewable megasources and gives off about 120,000 terawatts of irradiance, into clean, long-lasting power. This review looks at the current state of renewable energy by looking at installed capacity and important projects in the solar, wind, and biomass sectors.

We found out about the solar, wind, and biomass energy industries in Rajasthan. We looked closely at the number and size of the renewable energy projects that are being built in the state right now.

Availability of Solar Energy in Rajasthan

Rajasthan is the biggest state in India by land area. It covers 342,239 square kilometers, which is about 10% of the country's total area. It has a lot of issues with making power the old-fashioned way. It's not possible to build big hydroelectric plants because there aren't any big rivers. They can't do that, so they have to rely on thermal generation, which means moving coal from far away. It costs almost half as much to move coal as it does to make thermal power, which raises the price of electricity for everyone in the state.

The state has a western border that is all sandy land. It is called the Thar Desert and is 208,110 square kilometers in size. The weather is usually clear for more than 89% of the days in the state, and the amount of solar radiation is between 6 and 7 kilowatt-hours per square meter per day. If this climate and geography potential is fully realized, Rajasthan could become a top place for solar energy development, which would give people a way to get safe, long-lasting electricity.

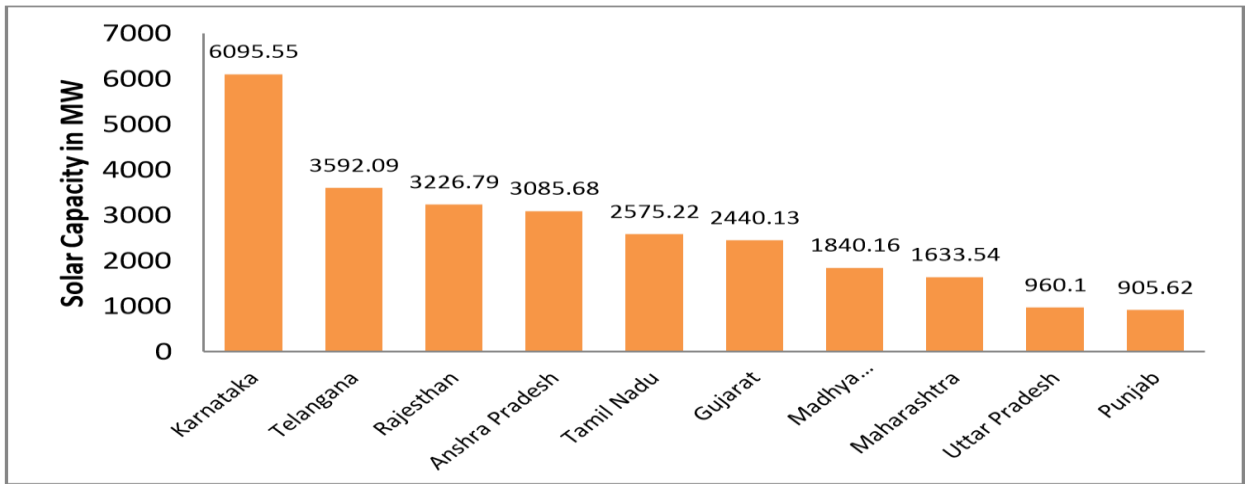


Figure State-wise installed capacity of solar energy in MW till March 2019

The western part of Rajasthan, where Barmer, Jodhpur, Bikaner, and Jaisalmer are located, gets a lot of sun. This is why it is one of the best places in the state to make solar power. Jodhpur, which is called the "Sun City of India," is the best example of this status because it has the most solar radiation absorption on record. According to the U.S. Department of Energy, Rajasthan is now the second most exposed place in the world to solar radiation.

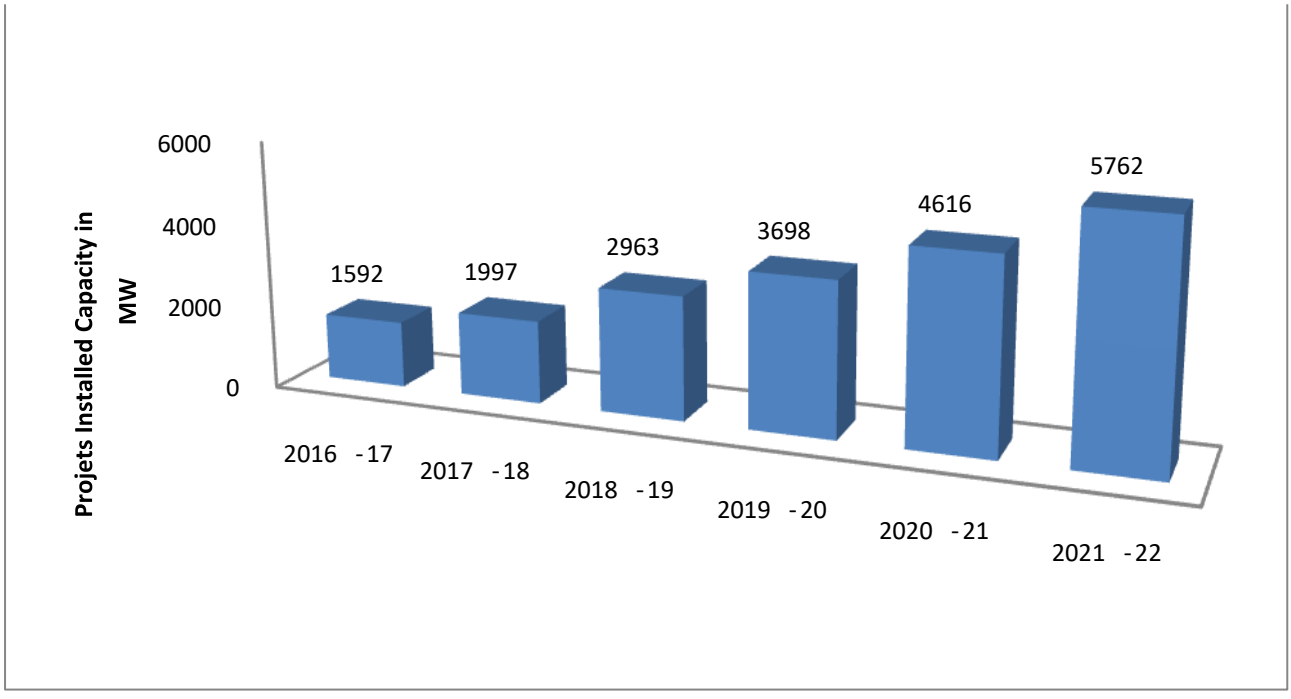
Figure 2 shows the installed solar photovoltaic capacity in megawatts (MW) for each state. Karnataka has the most solar power plants installed right now, and Rajasthan is the third Indian state with the most solar power output overall.

Status and Projects of Solar in Rajasthan

By starting a number of important photovoltaic projects, Rajasthan has become a leader in India for making solar energy. Table 1 gives a short summary of some of these installations. The government of Rajasthan has made a full set of rules and incentives to speed up the growth of solar energy. These rules make it easier to get around regulatory problems, encourage more investment, and set up solar parks to take advantage of the area's lots of sunlight. The Indian government has built a lot of big solar parks all over the country. These parks have been very successful at running their businesses, and together they give off a lot of megawatts (MW) of peak electrical power. Here is a summary of some of these places.

1. Bhadla Solar Park, comprising Phases 1, 2, 3 and 4, has a cumulative installed capacity of 2,255-megawatt peak (MWp).
2. Phalodi–Pokaran Solar Park is under development.
3. Fatehgarh Solar Park is under development.
4. Nokh Solar Park is under development.

Figure Yearly Solar Projects installed capacity (MW) Rajasthan

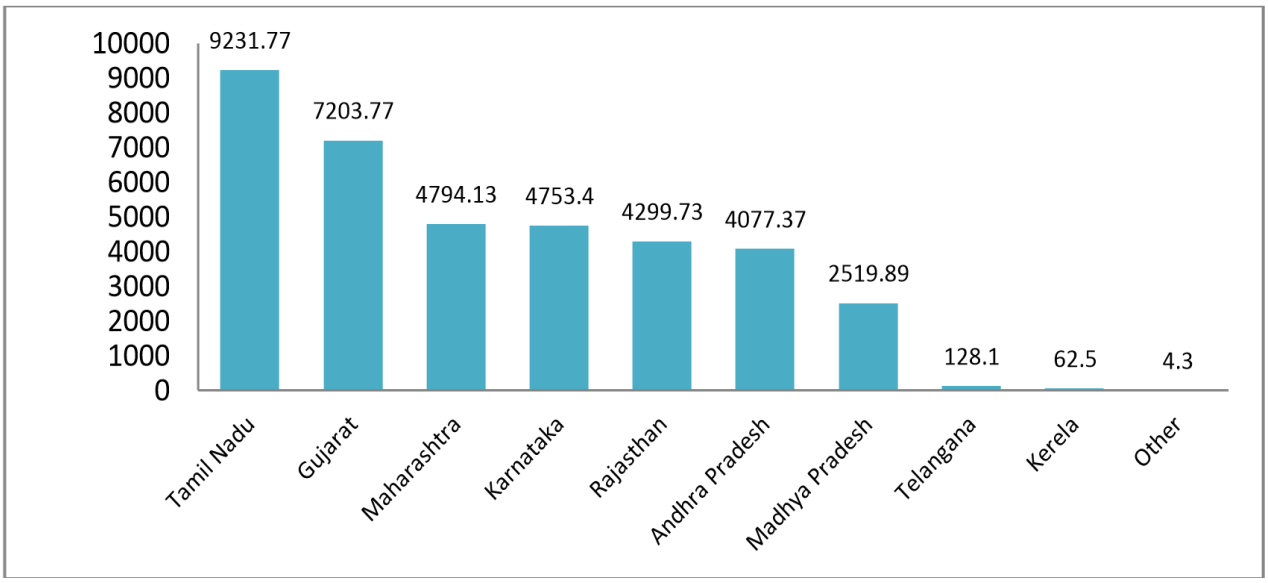


This Figure 3 shows how the solar cell in Rajasthan state is making more and more power every day. The government wants to increase electricity production from 1592 MW in 2016–17 to 5762 MW by 2021–22.

Availability of Wind Energy in Rajasthan

India has a bright future for making wind energy, and right now it is the fourth largest country in the world in terms of total wind power capacity. In 2004, the opening of Asia's tallest working wind turbine showed even more how well the country uses wind resources with its technology and infrastructure. Tamil Nadu has the most wind fleets, but Rajasthan has become a major player, coming in fifth place nationally. The state's installed wind capacity reached 21,833 megawatts in 2018, which is almost 20% of the national wind sector, according to official data. This shows that Rajasthan can add to traditional high-resource areas by building more types of infrastructure.

Figure 4 State wise Wind Power Capacity in MW

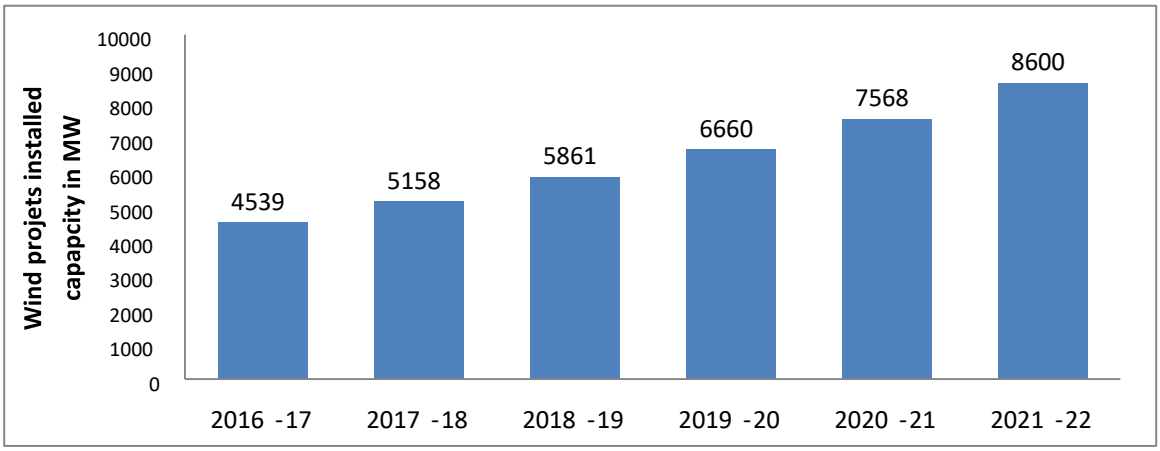


Rajasthan can make 4,315 megawatts of wind power, but it could make 21,833 megawatts of wind power. Wind energy makes up about 17.6% of all the electricity that Rajasthan makes right now. The state government and the Ministry of New and Renewable Energy have worked together on a number of big projects to get more people to use wind power. Because of this, Devghar (Chittorgarh), Harshnath (Sikar), Khodal (Barmer), and Phtodi (Jaipur) have been chosen as priority areas. The Thar Desert is in the western part of Rajasthan, which has some of the most stable winds in the country. This is why the area is a great place to put up wind farms. It doesn't rain very much in the area each year, so the turbines can run for longer periods of time without having to stop because of moisture. The wind park in Jaisalmer is one of the most important parts of the working infrastructure. Now, it is India's second-largest wind energy park on land. The Jaisalmer facility can generate and use a total of 1,064 megawatts of power. There are a lot of high-efficiency turbines spread out over a large area of desert land. This shows that it is the leader in Rajasthan and that the state is dedicated to increasing its renewable energy resources.

Status and Projects of Wind in Rajasthan

Rajasthan has a lot of wind energy projects. Here are some of them in the table below:

Figure Yearly Wind Energy generation by Rajasthan



The number next to this one shows how much more wind energy capacity the state of Rajasthan has added each year. The numbers for the fiscal year 2016–2017 show that the installed capacity is around 4,539 megawatts. According to future policy frameworks, capacity will reach 8,600 megawatts by the end of the 2021–2022 fiscal year.

Biomass Energy in Rajasthan

India is the seventh largest producer of biomass residue in the world, with a capacity of 450 to 500 million tonnes per year. This means that there is a lot of potential for biogenic energy. The Rajasthan government then passed the Biomass-based Power Generation Policy of 2010, which encourages making electricity from agricultural waste. A survey found that 92.5% of the agricultural waste that was collected goes to the local brick kiln industry. The other 7.5% is either eaten in the area or sent to states that are close by. There will be an extra 11.62 million tonnes of mustard stalk and husk every year. This can be used to make electricity from biomass. There are three main types of surpluses that can be turned into something else: husk, soybean stalk, and mustard residue.

Kalpataru Power Transmission Limited built the first commercial biomass power plant in the Gangagar district of Rajasthan. At the Padempur site, the plant can produce 7.8 MW. In the middle of 2006, two more plants were built in Uniyora and Kothputli. Surya Chambal also runs an extra unit in Kota. This made biomass power technology a permanent part of the area and added to the grid of electricity supplies.

Challenges of Renewable Energy in Rajasthan

There are many different types of renewable energy in Rajasthan, and each one has its own problems, like solar, wind, and biomass. There are problems with each type of generation, and the most important ones are listed below:

For Solar Energy:

1. Rajasthan gets a lot of sunlight every year, with an average of 325 days of insolation. However, the high temperatures in the area make photovoltaic modules less efficient at turning energy into electricity, which means that a lot of the electricity they make is not usable.

2. Solar photovoltaic projects in Rajasthan have a lot of problems with the law, like open-access fees, high wheeling tariffs, and the fact that the grid is not always connected. These things all make it harder for projects to get money and stay in business over time.

3. Cleaning PV arrays mechanically in large solar farms uses a lot of water, which makes a maintenance procedure that is otherwise technically necessary a big environmental problem in an area that is already short on water.

For Wind Energy:

1.One of the biggest problems with running the grid these days is that integrated wind capacities are getting more and more complicated, which makes the grid less stable. The current levels of penetration make the network use more energy when resources are plentiful, which is more than the grid can naturally handle. The changing, asynchronous generation profile of modern wind makes stability even worse by making the grid's frequency and voltage go up and down more often.

2. The high-risk exposure that comes with developing wind assets is linked to the money needed up front. Investors have a hard time because the market is down, the costs of parts are going up, and it takes a long time to develop new products. This makes it harder to get the expected cost outcome on time. Long-term debt is even harder to get when there aren't enough low-cost options with strong policy frameworks. This raises the risk of changes in policy and the market.

3. When demand suddenly spikes and is hard to predict, it's harder to measure supply quality. This means that operational risk is higher during ramp schedules. The grid has to find a balance between supply rigidity and generation flexibility because demand is unpredictable. But the security margins that come with them make it even more important to measure and speed up. In this case, the ongoing volatility makes the operational uncertainties that the security of supply metric shows even worse.

For Biomass Energy:

1. Availability of biomass energy is constrained to segments of the annual cycle, being predominantly accessible subsequent to the harvest period, which circumscribes the operational windows of biomass-fuelled energy systems.
2. An additional salient impediment is the financial burden of transporting feedstock. In the economic architecture of biomass plant development and sustained operation, freight expense constitutes a substantial share of the capital and recurring outlay, which thereby constrains the overall financial viability of the technology.

Conclusion

The studies reviewed show that renewable energy technologies have two main goals: to make sure there is always energy available and to protect the environment. Renewable energy systems have a lot more benefits than fossil and nuclear systems. That's why they should continue to be used more in science, business, and infrastructure. Rajasthan, a state in India, has become a key place for ongoing engagement, with a progress portfolio that is still

being worked on. This portfolio has things like generation, modeling, and financing. Most of the activity that has been found is in solar and wind power installations. Each of these is backed by a number of economic, regulatory, and technical measures. Ministerial mandates and state-cabinet resolutions work together to make it easier to get land-acquisition certificates, feed-in tariffs, and new leasing models. Rajasthan's goal for 2022 is to have 22,000 megawatts of power, which will come from both photovoltaics and wind turbines. This number is in line with what the central government said it would do before, but more and more people are starting to see it as the final goal. But the goal isn't met because of a lot of systemic problems that are all connected: bad thermal profiles, wind corridors that generate too much power too often, and the lack of by-product feed for conversion in the solar thermal and biomass segments. These restrictions have led to a strong need for quick infrastructure, regulatory, and financial changes that will align consumption peaks with generation peaks, which will help keep the 22,000-megawatt goal.

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