



Wind power potential in a changing climate

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Abstract

Because of its extensive coastline and mountainous topography, the state of Gujarat in western India offers a great opportunity for the development of wind power. Alterations in weather patterns may have an impact, not just in Gujarat but also in other parts of the world, on the amount of wind power that can be generated. The effect that climate change will have on Gujarat's wind power output will be complicated and variable, depending on a number of different variables. Alterations in temperature gradients and the patterns of atmospheric circulation might lead to wind pattern shifts, which is one of the possible effects that could occur. These changes have the potential to alter the amount of wind power that can be generated in some places. In addition, severe weather phenomena such as hurricanes, cyclones, and thunderstorms have the potential to cause damage to wind turbines, which in turn lowers both their production and efficiency. Alterations in temperature and patterns of precipitation might potentially have an effect on the maintenance of wind turbines, leading to an increase in the expenditures associated with maintenance. Alterations in both the level of the water and the currents of the ocean may have an effect on the production of electricity by offshore wind turbines. There is a possibility that rising sea levels would increase the likelihood of floods and storm surges, both of which have the potential to cause damage to offshore wind turbines and subsea cables.

Keywords: Wind power, Renewable energy, Climate change , Wind resource assessment, Wind speed variability

Introduction

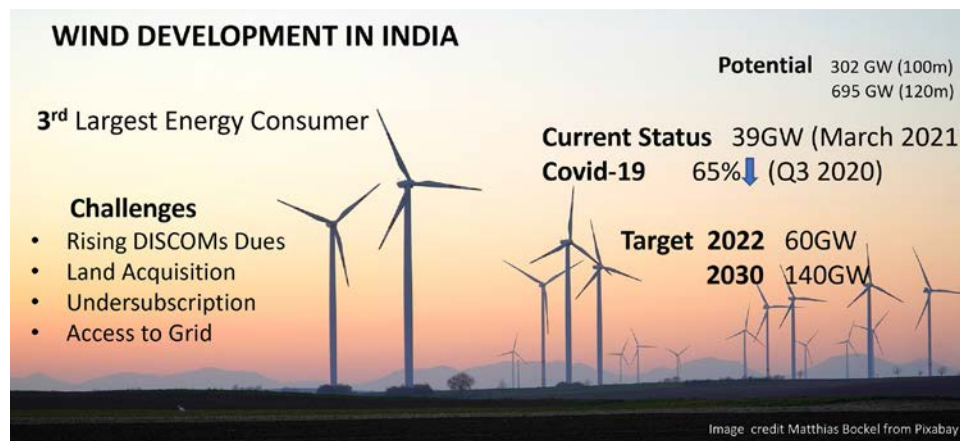
More than half of India's total wind power capacity is located in the state of Gujarat, which has been a leader in the development of wind power in India. Gujarat has been a pioneer in this field. The state has lofty goals for the generation of renewable energy and has set a goal of generating 30,000 MW of renewable energy capacity by the year 2022. Of this total, it is anticipated that wind power would contribute 10,000 MW of the total capacity. A feed-in tariff system, tax exemptions, and faster clearance procedures for wind projects are some of the



policies and incentives that Gujarat has enacted as part of its endeavour to stimulate the growth of wind power. These initiatives have helped to attract major investment in wind power infrastructure in the state, and as a result, numerous large-scale wind power projects have been developed as a result of these efforts. As the climate continues to shift, there are growing worries about the effect that it will have on Gujarat's potential for wind power. Wind power production may be negatively impacted by a variety of factors, including shifting wind patterns, rising temperatures, and severe weather events, all of which have the potential to make wind power less viable in particular places. Researchers, policymakers, and industry stakeholders in Gujarat are working together to better understand the influence of climate change on the potential for wind generation in the state. This is being done in order to solve the problems that have been presented. This involves making efforts to establish more accurate wind resource evaluations, build more advanced wind power forecasting systems, and enhance wind turbine technology. Even while the potential for wind power in Gujarat is still rather high, it is abundantly obvious that the influence that climate change will have on the state's wind resources will need to be carefully studied in order to guarantee the long-term viability of wind power development in the state. It is important to take into consideration a variety of factors in order to get a comprehensive understanding of the potential of wind power in a changing climate in Gujarat. Some of these factors include wind resource assessment, wind turbine technology, wind power forecasting, and the economics of wind energy. When determining whether or not wind power is a viable option in various areas of the state, one must also take into consideration the degree to which the state is prone to experiencing severe weather.

Concerns have been raised concerning the economic feasibility of wind power projects in the state of Gujarat. This is in addition to the possibility that climate change will have an effect on the amount of wind power that can be generated in Gujarat. There are large one-time expenditures connected with the creation and installation of wind turbines, despite the fact that wind power is a renewable source of energy that has a low cost per unit of energy produced. In order to overcome this obstacle, the state government of Gujarat has enacted a variety of laws and financial incentives designed to encourage the expansion of the wind power industry. These include reductions or exemptions from taxes, financial assistance in the form of subsidies, and funding for research and development of wind power technologies. In spite of these efforts, however, there are still some doubts about the state's wind generating plants' potential to be economically viable over the long term. This is particularly true in light of the recent decrease in global oil prices, which has made it increasingly difficult for conventional fossil fuel sources

to compete with renewable energy sources such as wind power. Stakeholders in Gujarat are attempting to build new business models and financing methods in order to help make wind power projects more economically feasible so that they can solve the problems that have been presented. This involves the exploration of new income sources that may assist to balance these costs over the long term, as well as the development of new financing structures that can better manage the upfront expenses involved with wind power production. “Despite the fact that there are still obstacles standing in the way of the expansion of wind power in Gujarat, there is a high possibility that the state will continue to be a leader in the production of renewable energy in India. Stakeholders in Gujarat have the opportunity to assist guarantee that wind power will continue to be an important part of the state's overall energy mix for many years to come if they solve the problems posed by climate change and economic viability.



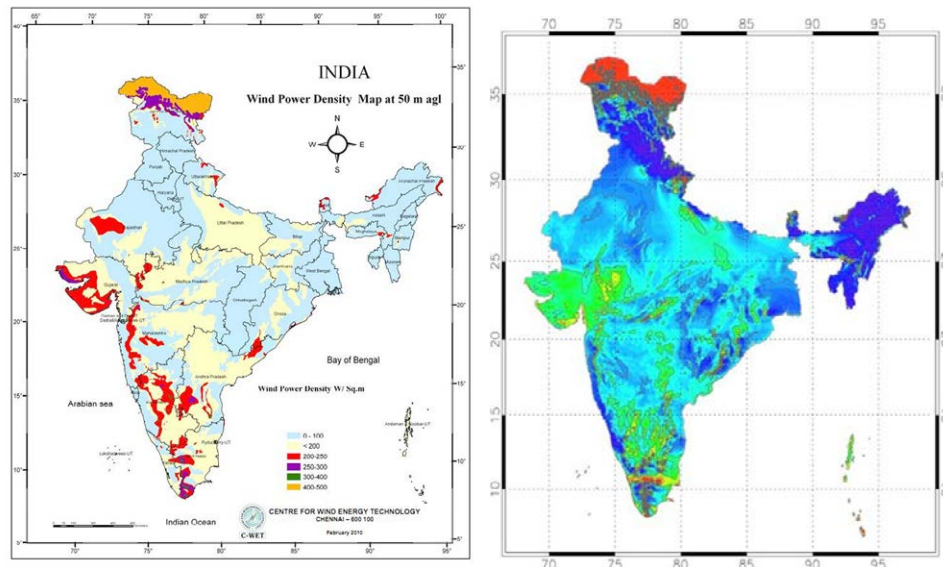
Source : An Overview of Wind Energy Development and Policy Initiatives in India. *Clean Technologies and Environmental Policy*

Numerous studies on India's wind potential have been carried out so far. The first investigations, which employed data from wind monitoring stations with towers that were 20–25 metres tall, suggested that Gujarat has excellent wind resources; however, this height is insufficient for the wind turbines that are now in use. Publications may provide more wind resource evaluations or discussions of the use of wind power in India. The methodologies, data sets, and hub heights that were used in these papers each produced estimations of India's wind resource that were uniquely their own. In order to have a better understanding of this variance, wind resource data from all throughout the nation was studied. They carried out a comprehensive reevaluation study, during which they estimated the potential for land-based wind energy at 80 m, 100 m, and 120 m. It is possible to get the conclusion that good quality wind energy sites have more than five times the current official estimate and thirty times the



official estimate for India that was published in the 2010 Wind Energy Atlas. The authors have a theory that the discrepancy in estimated land availability is the most probable cause for the disparities between these estimations. This theory is presented as a hypothesis. This study uses the Weather Research and Forecasting (WRF) model to simulate the wind at current hub heights in order to provide more precise estimates of the amount of wind resources that are available in Gujarat. This is done because there is a great deal of uncertainty surrounding previous wind energy assessments in India. The estimations of the wind resource are only accurate for the wind speeds and directions. The WRF model is a community numerical weather prediction (NWP) model that is maintained by the National Center for Atmospheric Research (NCAR) in the United States. The WRF model has been successfully applied to wind energy related studies and wind resource. The WRF model allows for accurate simulations of winds near the surface and at heights that are important for wind energy purposes. The capability of WRF to downscale to resolutions of tens of metres enables the resolution of small-scale features. These elements, which are all crucial in determining the wind characteristics, include fronts, sea breezes, and winds affected by orography. As a result, WRF is the most effective method for predicting the distributions of the wind throughout a certain region, in this example Gujarat. Downscaling makes it possible to have a grid spacing of 1.1 kilometres, which is more precise than in earlier investigations. In a similar vein, enhanced temporal resolution, with output occurring every ten minutes, enables the computation of highly resolved error metrics, which we can then use to evaluate our estimations of wind resource. As a consequence, the findings that were acquired from our research may be used to assist in determining the degree to which earlier wind resource assessment studies for the region of Gujarat were accurate”.

One of the states that has the biggest potential for wind energy is Gujarat, and the majority of that potential is located in the north western region of the state, which is located farther inland from the Gulf of Kutch. According to our findings, the yearly average for 2011 shows the highest potential at the same location. However, it also shows a similarly high potential along the south coast of the peninsula (offshore and on the coast between). The following maps are available from CWET. Qualitatively, the areas of Gujarat that have the highest wind resource agree with our findings.



Source: Wind power density at 50 m (left) and 80 m (right). “From CWET (CWET 2014). The International Renewable Energy Agency publishes worldwide wind maps. A 5-km gridded onshore wind speed estimate is available for Gujarat at 80 m above ground. According to IRENA, these data were provided by TIER. A screenshot of the IRENA estimate is shown .

Review of literature

(Draxl et al. 2014) studied Wind Resource Assessment of Gujarat (India) discovered that India is one of the major markets for wind energy worldwide, and India alone is one of the largest markets. Wind energy accounts for 70 percent of India's total contribution to the installed capacity from renewable sources, which accounts for 12.2 percent of India's total installed capacity (International Renewable Energy Agency, 2014). Gujarat was the first state in India to put in place a scheme to generate electricity using wind turbines in the year 1986.. In Gujarat, the total installed capacity for wind energy was 3,093 MW as of February 2013. The only state in India other than Gujarat to have a higher installed capacity for wind power is Tamil Nadu, which is located in the southeast of the country. It is anticipated that the installed capacity in Gujarat would expand as a result of the planning of future projects. One of these projects is an offshore wind farm that will be located in the Gulf of Khambhat in the south-eastern area of the state . In order to facilitate the growth of wind energy in Gujarat, it is essential to conduct reliable wind resource assessments.

(Kumar et al. 2022) studied An overview of wind energy development and policy initiatives in India discovered this and In the previous five years, the renewable energy industry in India has



expanded at a compounded annual growth rate of 15.51 percent, with wind growth accounting for around 8 percent of that expansion. The government of India has been making adjustments in order to develop an energy infrastructure that is secure, affordable, and environmentally friendly in order to drive robust economic expansion. The government has put in a lot of work to make sure that everyone has access to electricity, and they have succeeded in doing so thanks to their efforts. It is adopting a large-scale deployment of renewable energy, mostly solar and wind, as its primary sources of power. This provides a comprehensive analysis of the wind industry in the nation, including topics such as government policy, financial incentives, and achievements. The paper then goes on to analyse the opportunities and challenges facing the wind industry, as well as potential solutions to these challenges in order to meet the projected goal of 140–150 GW by the year 2030. The rise of wind power in the nation has slowed down over the last several years, which may hinder the ambitious renewable energy objectives the government has set for itself. The wind sector is up against a number of challenges, such as the removal of financial incentives, the difficulty of acquiring land, the deteriorating health of DISCOM, changes to the bidding system, and the presence of obsolete wind farms. Reviving the wind energy industry could require taking a few specific actions, such as modernising obsolete wind farms, providing generation-based incentives and tax breaks, reevaluating the country's wind potential, and building competitive renewable energy zones.

Conclusion

As a result of climate change, wind speeds are expected to be greater during the monsoon season, according to recent studies. This might result in a rise in Gujarat's potential for wind power in the near future. On the other hand, over the course of a longer period of time, there is a possibility of a reduction in wind speeds during the non-monsoon seasons, which may have an effect on the total wind power potential. It is important to consider the potential impacts of climate change on wind patterns and to develop appropriate adaptation strategies in order to make sure that Gujarat's wind power potential is harnessed in a sustainable manner. This will ensure that Gujarat's wind power potential is fully realised. Among these options are the exploration of the potential for hybrid renewable energy systems, the implementation of laws that encourage the development of distributed renewable energy systems, and the investment in technology that can endure harsh weather events. It is possible for Gujarat to become a substantial contributor to India's efforts to meet its renewable energy targets provided the necessary policies and investments are put in place. Gujarat has a considerable wind power potential. However, in order to achieve sustainable growth, it is necessary to take into account



the influence that climate change would have on the patterns of wind. It is vital to invest in the research and development of novel wind technologies that can resist harsh weather events and variations in wind patterns in order to guarantee that Gujarat's wind power potential is exploited successfully and in a way that is environmentally responsible. In addition, regulations that stimulate the development of distributed renewable energy systems and that encourage investments from the private sector in renewable energy projects may assist to speed up the expansion of the wind power industry in Gujarat". It is possible for Gujarat to take the lead in wind power production in India and play a substantial part in reducing the negative effects of climate change if the state takes use of this potential. A cleaner and more sustainable energy future for the state of Gujarat and the nation as a whole may be contributed to by the state of Gujarat's prioritisation of sustainable development and investment in renewable energy.

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