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Vitalising Repowering of Wind Power Projects in India

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Suggested citation:
Saraswat, J., Mall, N., & Varun, B.R. (2022). Vitalising Repowering of Wind Power Projects in India. New Delhi: Vasudha Foundation

About Vasudha Foundation:

Vasudha Foundation is a leading policy advocacy and clean energy market enabler with a, not for profit motive. It is India's pioneering organisation promoting environment-friendly, socially just, and sustainable models of energy by focusing on renewable energy and energy-efficient technologies and lifestyle solutions.

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Introduction

India has set an ambitious target of 500 GW of non-fossil fuel capacity by 2030, aiming to leverage its massive renewable energy (RE) resources. The Central Electricity Authority's Report on Optimal Generation Capacity Mix for 2029-30 is expected to guide capacity bifurcation. This report highlights that, wind energy, one of the country's oldest and most developed renewable energy technology, is expected to contribute 140 GW to this goal. The sector has continuously risen over the last three decades, reaching a total capacity of 40.1GW in February 2022, making India the world's fourth-largest market. States with a high Wind Power Density (WPD), such as Tamil Nadu, Gujarat, Karnataka, Maharashtra, Rajasthan, and Andhra Pradesh, are in the lead, accounting for more than half of the country's total wind capacity.

However, the pace of the wind capacity addition in India has plateaued. In the last three fiscal years, India has installed an average of 1.7GW Wind Power Projects (WPPs). Availability of land and acquisition issues have surfaced as the biggest reason for this lacklustre progress. Therefore, it has become necessary to make interventions to reinvigorate the growth of the wind sector in India. **In this context, the repowering of WPPs posits as a rewarding option.**

Benefits of Repowering Wind Power Projects (WWPs)

Repowering of WPPs involves replacing the old/outdated wind turbines with new turbines that have larger nameplate capacity or efficiency as compared to the former. This strategy brings with it sundry benefits which are highlighted in Table 1.

Table 1: Benefits of Repowering WPPs

Category	Benefits	Remarks
Technical	**Increased Generation Per Unit Area**	• Average size of wind turbines has grown over time. In 1985, average turbines had a rotor diameter of 15 meters and a rated capacity of 0.05 megawatts (MW). Onshore turbine sizes of roughly 3.5 MW and offshore turbine capacities of 5–8 MW are available for today's new WPPs. • With decades of efforts in research and development, there are new generation turbines with increased efficiency.
	Significant growth in Artificial Intelligence and Machine Learning Capabilities	• Advances in deep neural networks, genetic algorithms, and reinforcement learning can help in optimally siting wind turbines to generate more electricity. • Presence of good quality data from the operation of the old wind turbines can further improve the siting of new wind turbines.
Financial	**Reduced Operational & Maintenance Costs**	• As old turbines require frequent maintenance, it significantly adds to the operational cost for the developer. Repowering with new wind turbines with fewer moving parts will require fewer maintenance visits. • Availability of spare parts of old turbines presents as another challenge during maintenance visits that will be avoided once new turbines are in place.
	Monetary Benefits of the Decommissioned Old Wind Turbines	• Turbine blades made of glass fiber have potential applications in gravimetric energy storage systems. • Copper and other metal products can be recycled.
	Presence of Evacuating infrastructure	• As these sites have functional and grid-connected wind turbines, there is the presence of electricity infrastructure.
Social	**Land Acquisition**	• As the land acquisition is getting marred with several issues ranging from the local acceptance, impact on flora and fauna, etc., repowering the existing sites available seems to be an easier option
	Jobs	• Repowering will generate jobs across the entire value chain of the wind industry
Environmental	**Noise Levels**	• Larger number of small wind turbines are replaced with a small number of larger wind turbines leading to a reduction in noise levels.
	Reduced Mortality of Avian Creatures	• Low speed of larger wind turbines posits less risk to avian creatures.

Policy Landscape for Repowering WPPs in India

India started deploying wind turbines, at a larger scale, in the mid-1990s as seen in Figure 2. This underscores the relatively large repowering potential in India given the high share of small wind turbines installed during the initial years. As per a study, around 18% of India's over 34,000 wind turbines are older than 15 years. Also, around 10.5 GW wind capacity installed in India has turbine size of 1MW or less.

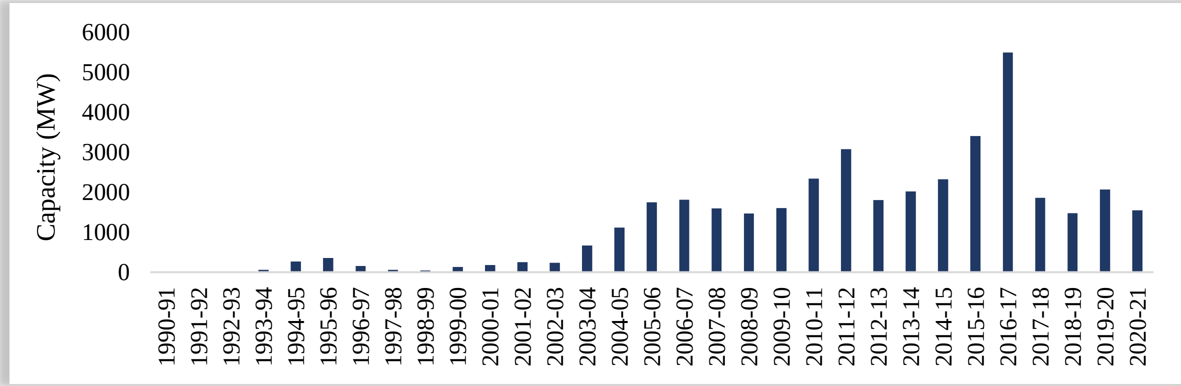
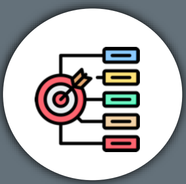


Figure 1: Timeline for Wind Capacity Addition in India

Taking cognizance of this large potential, in August 2016, the Government of India (GOI) came up with a policy for repowering of WPPs. The key tenets of this policy are captured below:



Objective

To promote optimum utilization of wind energy resources by creating facilitative framework for repowering.

Eligibility

Wind turbine generators of capacity 1 MW or less.

Incentive

- Additional interest rate rebate of 0.25% by IREDA over and above the interest rate rebates available to new projects.
- All incentives conferred to greenfield wind projects.
- Augmentation of the transmission system beyond pooling station to be carried by State Transmission Utility (STU).

Novelties

- No PPA violation during the repowering phase.
- Captive plants can procure power from Discoms during the repowering phase.
- Discoms to continue procuring power after repowering (Average of last 3 years of generation).
- State to facilitate additional footprint for higher capacity.

Figure 2: Highlights of National Policy for Repowering of WPPs

This paper also examines the state-level wind policies in order to assess the impact of various interventions to promote repowering of WPPs. As per our analysis, 16 states have released their wind policies. However, only three states - Rajasthan, Andhra Pradesh, Maharashtra - have considered policy instruments and design elements to support the repowering as seen in Figure 3. Of all the states analysed, Gujarat has emerged as the only state that has released a dedicated wind repowering policy in 2018.

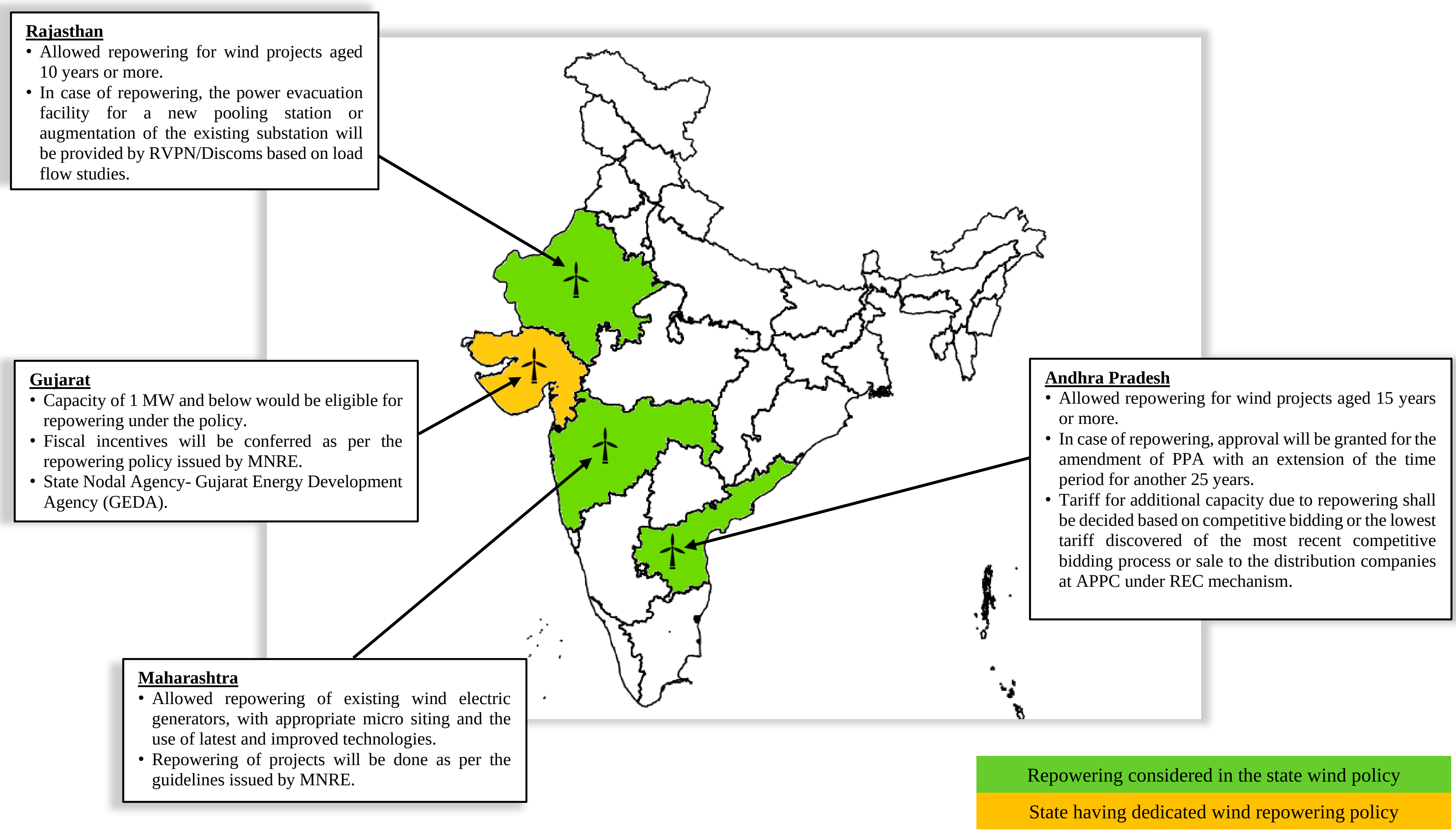


Figure 3: State-Wise Policy Interventions for Repowering

Current Status of Repowering WPPs in India

Despite a proactive approach taken by the GOI to repower WPPs, the progress is minimal. Moreover, no public dataset or tracker is monitoring the repowering achieved. The lack of progress can be attributed to several reasons and are highlighted in Figure 4.

1. Ownership
Multiple owners of wind turbines within the same wind farms making reorganising ownership during repowering a challenge.

2. High Upfront Investment
Owners of many ageing, but still well-performing- wind projects continue to reap significant cash flow. However, on the flip side, repowering requires significant investment.

3. Focus on New Sites
The Focus of state actors is new wind sites as observed in the tenders.

4. Absence of Directive to Retire Old Wind Turbines
No mandatory guideline in place, even under the repowering of the wind power projects policy, to retire old wind turbines after

5. No Clarity on End-of-Life Management
As end-of-life management is at nascent stage in India, there is ambiguity among the owners in dealing with the issue.

Figure 4: Challenges in Repowering of WPPs in India

Leveraging the Government-Funded WPPs to Boost Repowering in India

This paper examines the WPPs funded by the GOI since 1986. It aims to analyse projects across 40 locations on parameters like number of turbines, the capacity of turbines, make and model, year of commissioning/age of the plant, etc. Table 2 captures the state-wise installed turbines and concomitant capacity. As can be seen, around 396 turbines have been installed by state actors resulting in a meager 73 MW of power capacity.

Building on this, Figures 5 and 6 segregate the installed turbines based on their capacity and age across states. Clearly, the maximum number of low-capacity wind turbines are functional in India's most wind-rich states i.e., Tamil Nadu and Gujarat as seen in Figure 7. Moreover, in the states that have relatively a smaller number of potential wind generation sites, the deployment and congestion by low-capacity turbines are leading to reduced generation. West Bengal and Madhya Pradesh belong to this category as seen in Figure 7. As far as age is concerned, the inference remains in consonance with capacity.

Table 2: Challenges in Repowering of WPPs in India

State	Total No. of Turbines	Total Installed Capacity (MW)
Andhra Pradesh	22	7.80
Goa	2	0.11
Gujarat	124	17.84
Karnataka	20	7.08
Kerala	10	2.13
Madhya Pradesh	6	0.59
Maharashtra	47	8.98
Orissa	21	1.19
Rajasthan	17	6.35
Tamil Nadu	120	19.36
West Bengal	7	1.75
Grand Total	**396**	**73.17**

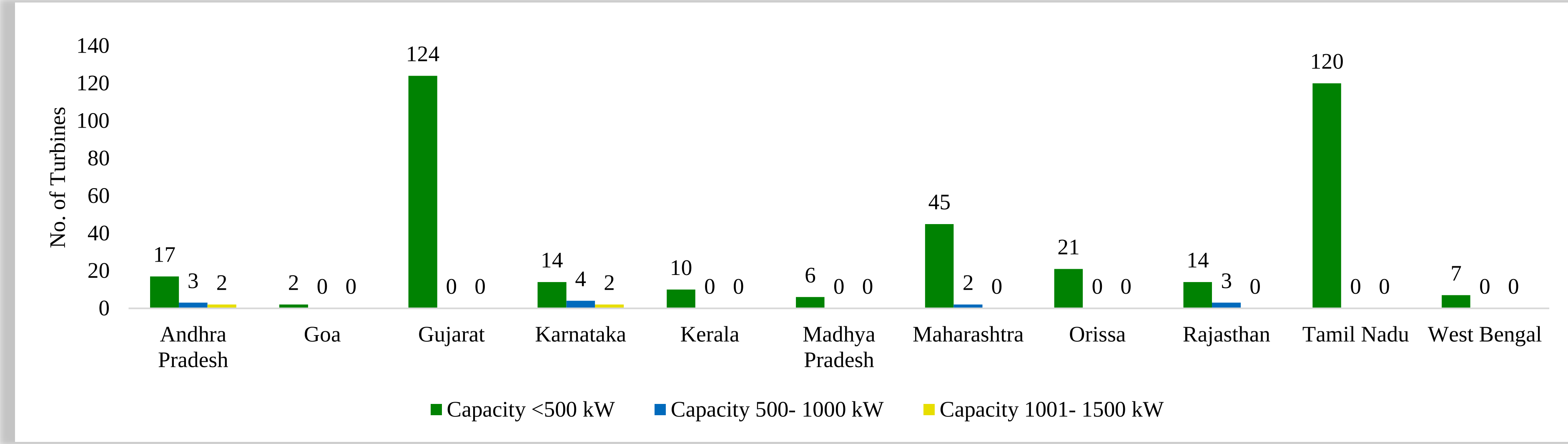


Figure 5: State-wise capacity attribution of wind turbines

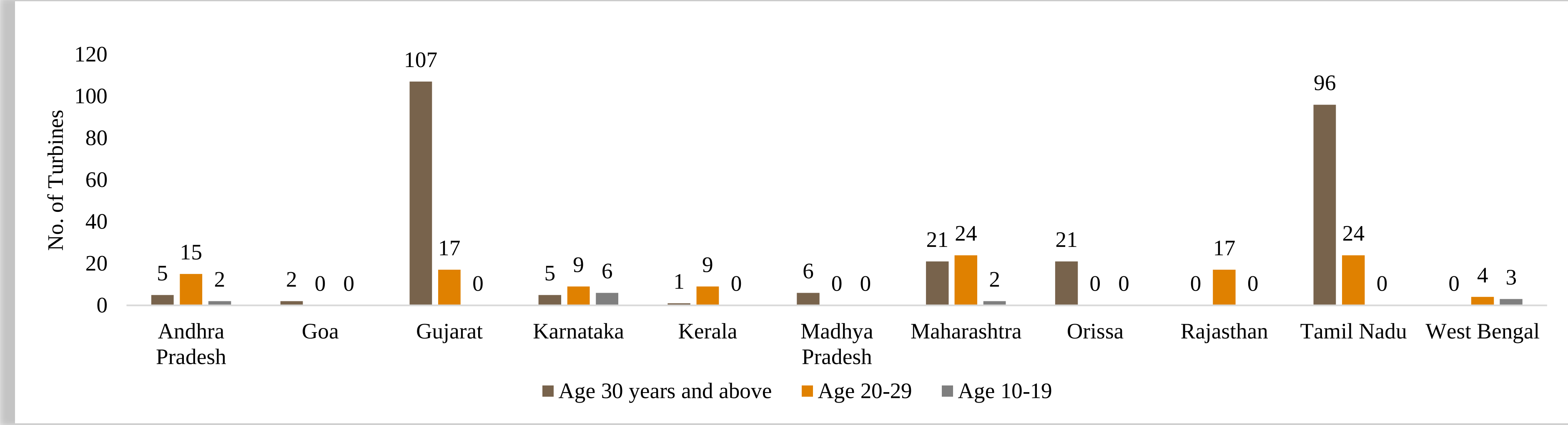


Figure 6: State-Wise Age Attribution of Wind Turbines

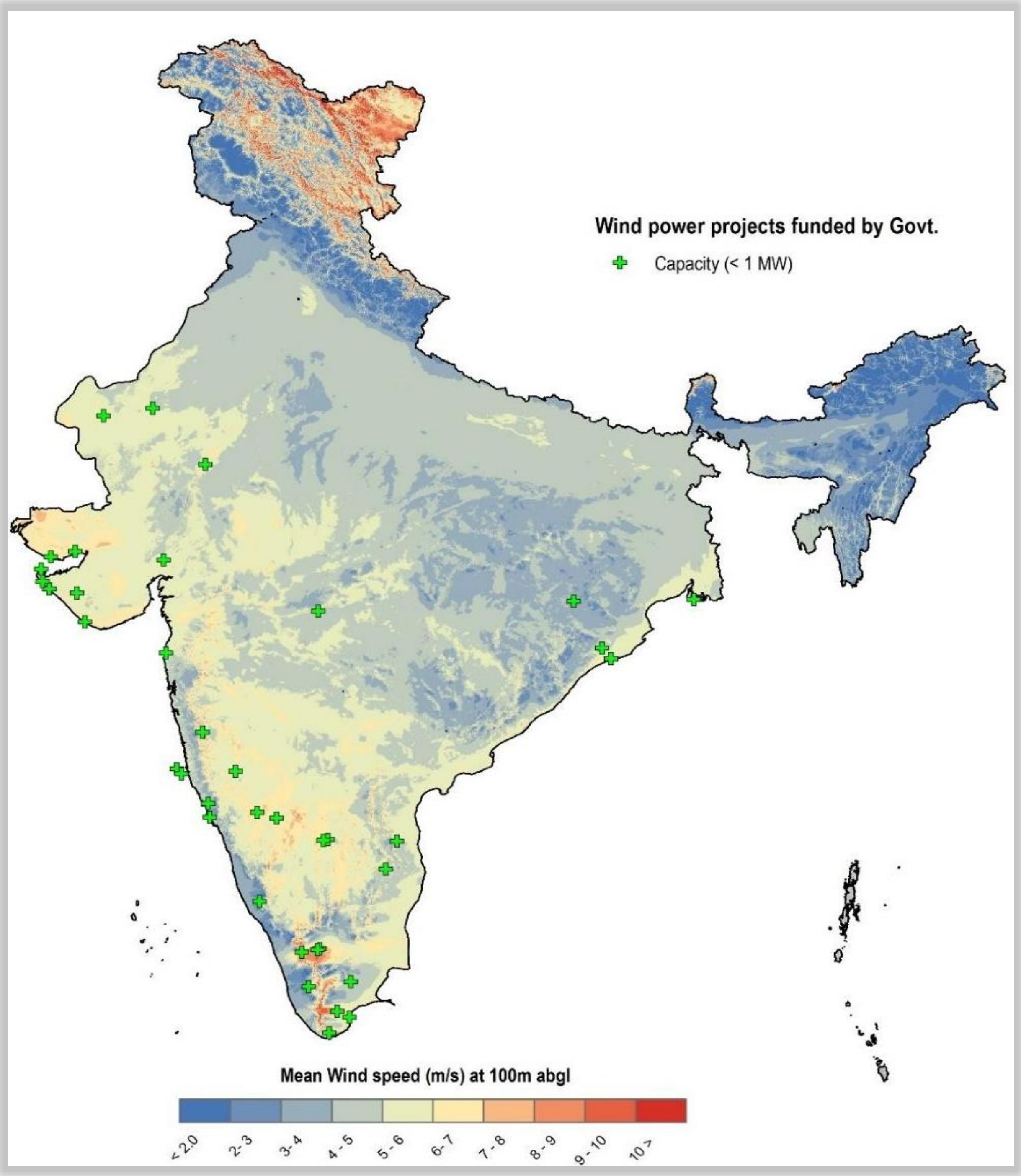


Figure 7: Geospatial Mapping of WPPs Funded by Government

Furthermore, as can be seen from Table 3, the central tendencies of the key parameters i.e., mean and median are overlapping. It can be inferred here that each project has an average of six turbines with an average capacity of ~230 kW and an average operational life of ~29 years.

Table 3: Basic Statistical Description for Key Parameters

Parameters	Mean	Median
No. of Turbines	6.6	5
Capacity of Wind Turbines (kW)	228.58	200
Age of Wind Power Plants (yrs.)	28.72	31

While analysing the data, we also employed the outlier detection technique to find anomalies. Box and Whisker plots present themselves as a simple yet practical outlier detection method. Values that are over 1.5 times of the Inter-Quartile Range (IQR) from Quartile 1 and Quartile 3 are considered an outlier because the region within contains 99.3% of observations. After normalisation, the box plot obtained for the parameters is shown in Figure 8.

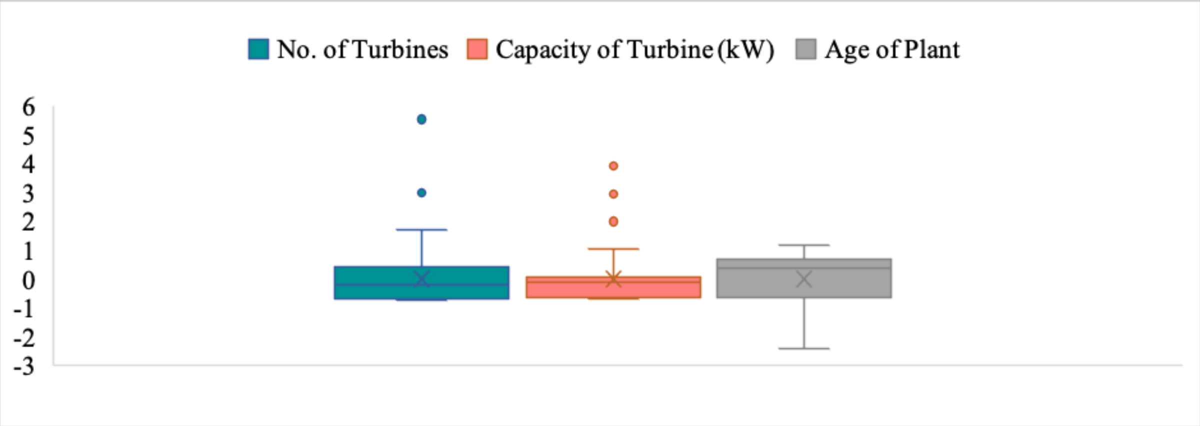


Figure 8: Box and Whisker Plot for Key Parameters

Through this plot, it can be seen that the turbines with a capacity greater than 500 kW were an anomaly for the state projects. Most of the projects funded by the government have sub- par wind turbines compared to the prevailing standards. Similarly, it is an anomaly for state projects to have more than 20 turbines installed under one project and at one location. This showcases that the projects funded by the government were more from a demonstration perspective. And finally, there is no anomaly for the age of WPPs as all of them have been operational for a significant amount of time. **All of these facets indicate that the government-funded WPPs analysed in this section can be taken up for repowering.**

On investigating the correlation amongst each of the parameters, we observed a few key insights. As seen in Figure 9, the age of the plant and associated capacity has a negative correlation with a Pearson correlation coefficient of -0.72. This indicates that as time progressed the state-actors were cognizant of the improving turbine technology and attempted to install higher capacity turbines.

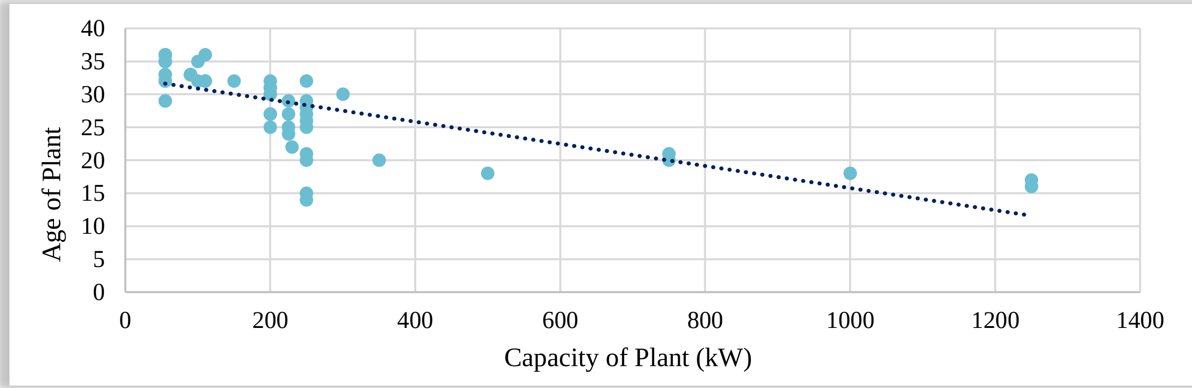


Figure 9: Scatter plot- Age of Plant v/s Capacity of Plant

This fact was further corroborated using a two-tailed hypothesis test. Here, the null hypothesis considered is that the Pearson Coefficient is zero. Following this, the alternate hypothesis is that the Pearson Coefficient value is not zero. For this hypothesis test, we considered the level of significance as 0.05 and since the two tails are symmetrical implies that each tail has an area of 0.025. After calculation of test statistics and critical values, we were able to reject the null hypothesis. **There is enough evidence at a 5% level of significance to conclude that there is a significant linear correlation between the capacity of the turbine and the age of the plant.**

Conclusion

Repowering of WPPs has not picked up in India. With the new capacity addition of WPPs facing sundry challenges, there is an urgent need to boost deployment through novel strategies like repowering by ironing out the systemic issues.

Our analysis demonstrates that the newer WPPs entail larger wind turbines attributed to technology improvements. **And as the older turbines reach their end-of-life, there is a strong case across technical, financial, social, and environmental spheres to decommission them and replace them with new turbines.** Moreover, the easier case for initiation of repowering projects seems to be the ones funded by the government. As seen from the analysis, these projects have been operational for an average of 29 years. Also, these projects do not face some of the challenges highlighted in Figure 4.

Key Suggestions

This section presents a list of imminent suggestions that can be considered to vitalise the repowering of WPPs in India.

Repowering in projects funded by the government should be prioritised. This can be done by issuing dedicated tenders along those lines. It will further open the market for repowering in privately-owned WPPs.

Inclusions in the national policy for repowering WPPs:

- Year-wise targets for repowering WPPs will stave off risk in the sector and will boost the confidence of investors.
- Andhra Pradesh's wind policy allows the extension of PPA post repowering. This can provide the necessary impetus and must be considered for the national policy as well.
- It is necessary to mandate the retirement of old wind turbines post-end-of-life to optimally utilise the natural resources and higher generation per unit of land area.
- There is a need to cap the minimum size of the new turbines in order to have maximum generation and avoid illegitimate usage of incentives by stakeholders.

Data on the repowering of WPPs should be publicly available. Moreover, a separate portal must be created for repowering projects that should be integrated with the MNRE website.

There is a need to examine the impact of several instruments like feed-in tariffs, tax credits, green certificates, investment subsidies, etc., in encouraging repowering in India.

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