ACCELERATING WIND REPOWERING IN TAMIL NADU

CSE PROPOSAL

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The Centre for Science and Environment is grateful to the Swedish International Development Cooperation Agency (Sida) for their institutional support

Maps in this report are indicative and not to scale.

Citation: Binit Das 2024, *Accelerating Wind Repowering in Tamil Nadu: CSE Proposal*, Centre for Science and Environment, New Delhi

Published by
Centre for Science and Environment
41, Tughlakabad Institutional Area
New Delhi 110 062
Phone: 91-11-40616000
Website: www.cseindia.org

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Background

Tamil Nadu is a leader in India's power sector, with a strong and growing electricity infrastructure. According to the Central Electricity Authority, as of March 2024 Tamil Nadu had a total installed power capacity of 39.7 gigawatt (GW), making it the third-largest power-generating state in India, after Gujarat and Maharashtra.

In terms of energy sources, coal and lignite represent the largest share of the state's installed capacity, contributing 37 per cent or 14.9 GW. Gas and oil make up only 3 per cent of the state's total capacity. Nuclear energy contributes to only 4 per cent of the state's installed capacity, equivalent to 1.4 GW. The remaining 56 per cent comes from renewable energy.

Tamil Nadu stands as a pioneer in renewable energy, with a significant portion of its power coming from clean sources. Wind energy serves as the cornerstone of renewable power in Tamil Nadu, boasting a capacity of 10.7 GW as of June 2024, which is the second highest in India. This achievement is primarily driven by strong coastal winds, particularly in the southern districts.

Solar energy is another significant component of Tamil Nadu's renewable energy portfolio, with an installed capacity of 8.2 GW as of March 2024. The state has actively promoted solar power through a range of programmes, incentives, rooftop solar installations, large-scale solar parks, and its Solar Energy Policy from 2019.

Together, wind and solar power make up a substantial portion of Tamil Nadu's energy mix. Solar energy accounts for over 20 per cent of the state's total capacity, with an installed capacity of 8.2 GW. Wind energy, with its 26.70 per cent share, contributes 10.7 GW, playing a critical role in the state's commitment to renewable energy and sustainable development.

When it comes to hydropower, large-scale hydro contributes 5.5 per cent to the total capacity, with 2,178 megawatt (MW) installed. Small-scale hydro, on the other hand, has a much smaller impact, accounting for only 0.3 per cent or 123 MW of the state's total installed capacity.

Although renewable energy makes up 56 per cent of Tamil Nadu's total installed capacity, it accounts for just 28 per cent of the actual power generated. This indicates that three-quarters of the state's electricity is still derived from fossil fuels. With regard to the generation mix, solar contributes 9 per cent and wind contributes 15 per cent.

Figure 1: Installed capacity mix of Tamil Nadu (in megawatt) as in March 2024

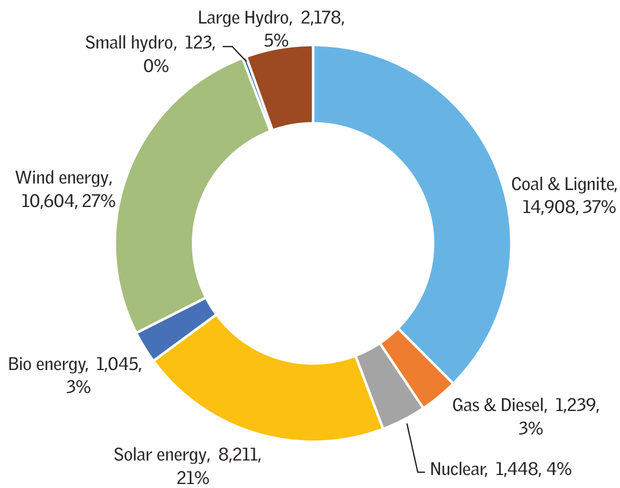
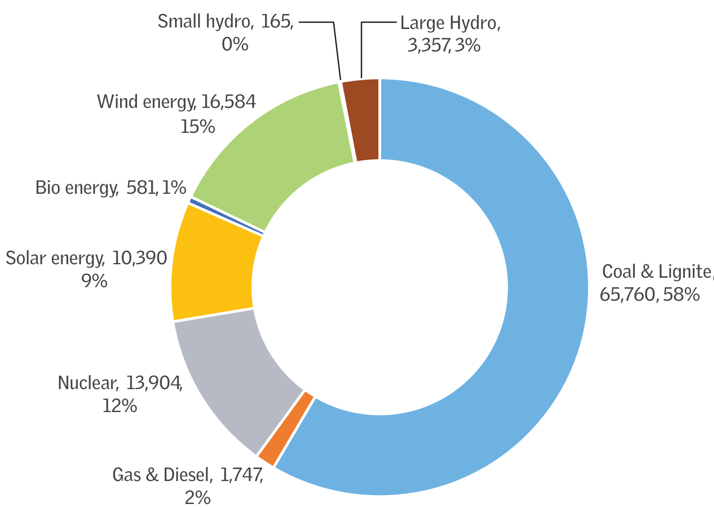


Figure 2: Electricity generation mix (million units)—FY 2023–24



Source: MNRE, Physical Progress and Central Electricity Authority of India.

Together, these figures illustrate Tamil Nadu's commitment to a diverse and sustainable energy portfolio, balancing renewable and traditional sources while progressing toward a cleaner energy future.

Wind energy

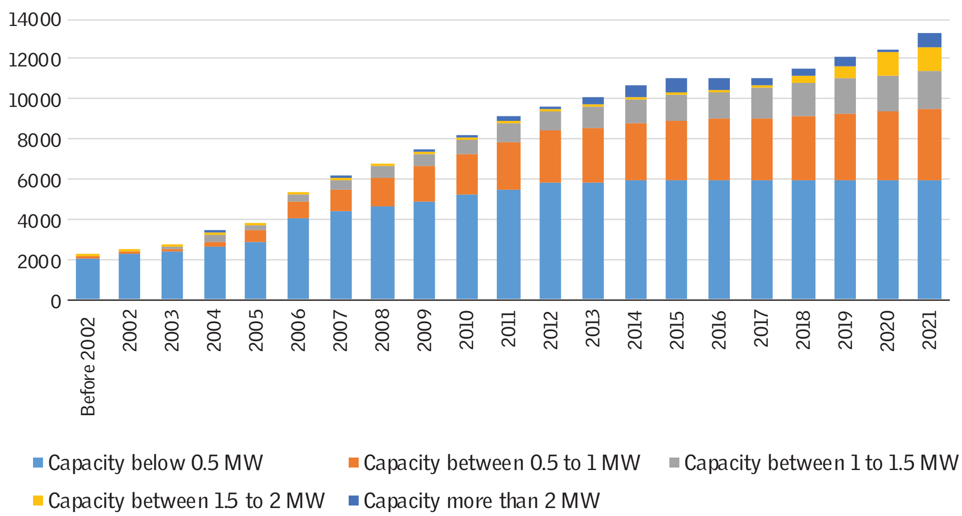
Wind power in India experienced rapid growth in the mid-1990s, largely driven by government policies that were highly favourable to the industry. These policies included a 100 per cent Accelerated Depreciation (AD), exemptions from sales tax, income tax exemption/tax holidays, waivers on excise and custom duties, and the announcement of Generation-Based Incentives (GBI). Additionally, the declaration of Feed-In Tariffs (FIT) further encouraged investment in wind energy. These incentives created a conducive environment for growth and attracted significant investment in the sector. This growth wasn't even across the country; Tamil Nadu became a leader in wind turbine installations, with places such as Palakkad, Sengottah, Aralvaimozhi and Pazhavoor known for their high wind speeds and good geography.

Another significant but lesser-known driver was the Technology Upgradation Fund (TUF), launched by the Ministry of Textiles in 1999 to modernize jute and textile mills. Tamil Nadu, which houses at least half of India's textiles market, benefited greatly from this scheme, especially when the state government introduced a special lending rate of 12.5 per cent for wind projects supplying power directly to textile companies. Given the power-intensive nature of the textile industry, investing in wind energy for captive consumption made economic sense. This investment fixed a major component of production costs, improving the profitability of textile mills.

With an installed wind energy capacity of 10.7 GW as of June 2024, Tamil Nadu ranks second in India, following Gujarat. Notably, Tamil Nadu's wind capacity contributes to roughly one-quarter of the nation's total installed wind power capacity. With the best wind sites in India, aided by favourable policy by the state government and low off-taker risk, Tamil Nadu was one of the earliest states to initiate wind projects. Most of these projects, however, are still operating with turbines that run on old technology, have low hub height and low capacity of less than 2 MW.

As wind technology rapidly evolves, older wind turbines with smaller capacities struggle to compete with modern counterparts. Installed a decade or two ago, these older models generate less electricity, increase safety concerns and frequent breakdown, and occupying valuable space. Globally, the standard capacities of wind turbines are increasing as technology advances. According to the Global Wind Energy Council (GWEC), globally the average capacity of newly installed wind turbines is currently around 3.2 MW. India has also begun installing larger projects. Adani Wind recently received certification for India's largest turbine, a 5.2 MW model with a 160-metre rotor diameter.

Figure 3: Wind turbine profile of Tamil Nadu (up to March 2021)



Source: Indian Wind Power Directory, 2021

Wind turbines are designed to have a lifespan of approximately 20 years. Upon reaching the end of this period, they need to be decommissioned to prevent safety risks. The design life of a wind turbine indicates the duration it is expected to operate safely and efficiently under normal conditions. This factor is critical when assessing the long-term viability and economic feasibility of wind farms.

Figure 3 shows that in 2004, approximately 3,300 wind turbines with capacities under 2 MW were operational in Tamil Nadu. The largest share of these turbines fell within the below 0.5 MW category, totalling around 2,600 turbines.

Most of these early turbines are of smaller hub heights (25–30 m), resulting in underutilization. These aging turbines often result in low Capacity Utilization Factors (CUFs) (10–14 per cent) due to associated mechanical difficulties and inefficiencies.

By replacing old turbines with newer, more efficient models, wind energy production can be optimized for each site, contributing to increased overall installed capacity and wind energy generation. Repowering addresses the problems caused by aging turbines, such as low capacity utilization of only 10–15 per cent and safety concerns.

It also supports environmental goals by reducing carbon emissions, aiding India's climate change mitigation efforts.

Wind power plays a crucial role in reducing the state's reliance on fossil fuels, making it a key component of national energy strategies. However, many wind turbines in Tamil Nadu are over 30 years old, leading to issues like low-capacity utilization, decreased energy production, and safety risks. This has prompted discussions on repowering, which involves replacing old turbines with newer ones. By repowering, energy production will be boosted, performance issues will be addressed, and the state's renewable energy capacity will significantly increase.

Table 1: India's wind repowering potential (MW)

States	Total capacity below 0.5 MW (A)	Total capacity 0.5–1 MW (B)	Total capacity 1–1.5 MW (C)	Total capacity 1.5–2 MW (D)	Total capacity below 2 MW (A + B + C + D)
Tamil Nadu	1181	2919	1813	1473	7386
Maharashtra	243	1,068	1389	731	3,431
Karnataka	0.3	954	652	1,417	3,023
Gujarat	51	1,457	1352	1,805	4,665
Rajasthan	39	1,192	788	915	2,934
Madhya Pradesh	0	290	260	1,012	1,562
Kerala	0	18	0	10	28
Andhra Pradesh	92	378	195	1701	2366
Total	1,610	8,280	6,449	9,067	25,406

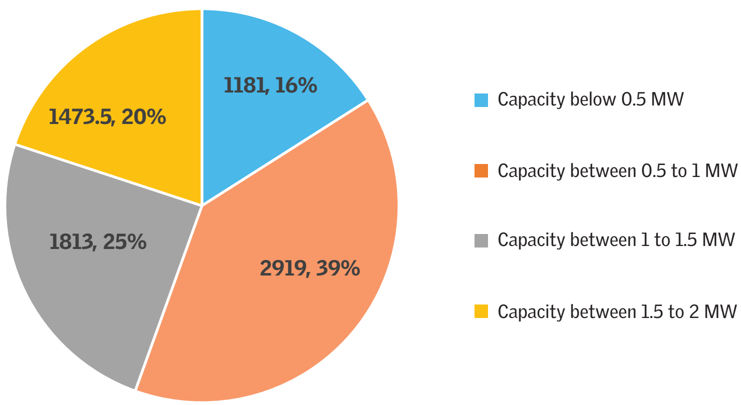
Source: National Institute of Wind Energy

POTENTIAL OF WIND REPOWERING IN TAMIL NADU

Table 1 shows India holds significant potential for repowering wind farms, with a capacity of 25.4 GW. Tamil Nadu leads the nation with a repowering potential of 7.3 GW, highlighting a substantial opportunity to leverage advancements in wind technology for more efficient energy production. (figure 4)

As illustrated in Figure 2, Tamil Nadu's current installed wind turbine capacity of 10.7 GW generates approximately 16.9 billion units of electricity annually. A significant opportunity exists to further bolster the state's wind power production. By strategically replacing older turbines with a combined capacity of 2.4 GW with newer, more efficient models boasting a total capacity of 7.3 GW, Tamil Nadu could potentially achieve a near doubling of its wind energy generation, reaching close to 30 billion units annually. This strategic repowering initiative would demonstrably increase the contribution of clean energy sources to the state's overall energy mix.

Figure 4: Capacity-wise wind turbine in Tamil Nadu
Wind turbines with capacity less than 1.5 MW account for 80 per cent of the total wind turbines



Source: National Repowering & Life Extension Policy for Wind Power Projects, MNRE-2023.

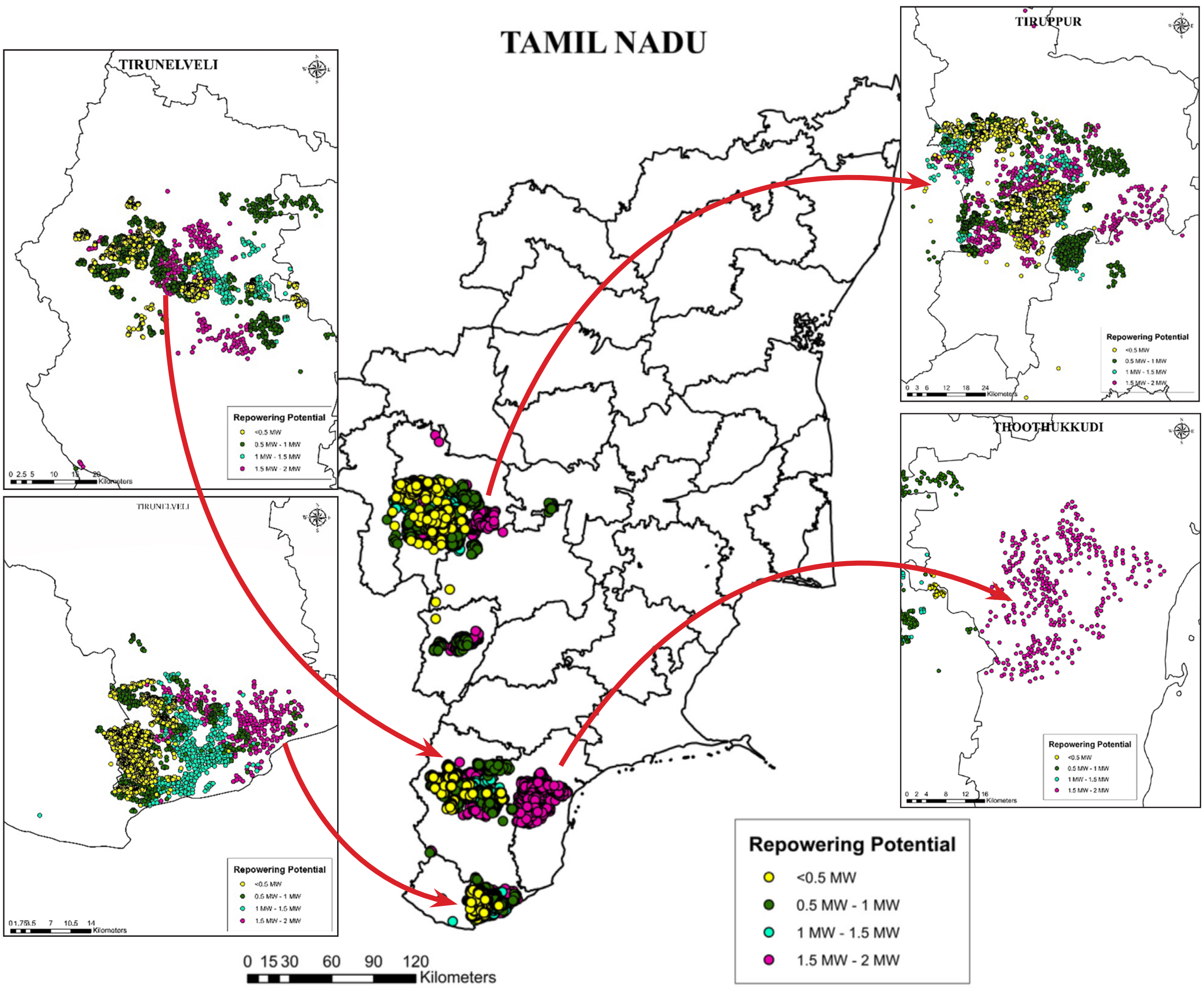
Tamil Nadu emerges as the frontrunner for wind farm repowering across five identified zones: Palakkad, Sengottah, Aralvaimozhi and Pazhavoor. Specifically, locations like Muppandal and Poolavadi hold immense potential for repowering existing wind turbines. (Figure 5)

TAMIL NADU REPOWERING AND LIFE EXTENSION POLICY FOR WIND POWER PROJECTS, 2024

The Tamil Nadu Generation and Distribution Corporation (TANGEDCO) has released the Tamil Nadu Repowering and Life Extension Draft Policy for Wind Power Projects, valid until March 31, 2030, or until a new policy is announced. The policy aims to optimize wind energy resources by repowering and refurbishing old windmills to increase annual energy generation by at least 1.5 times.

The draft policy provides a framework tailored to Tamil Nadu's needs, addressing the challenges and opportunities specific to the state's wind energy sector. Eligible repowering/refurbishment projects include all wind energy generators (WEGs) in Tamil Nadu that have completed 15 years post-installation, with State Transmission

Figure 5: Draft map of Tamil Nadu repowering potential



Source: National Institute of Wind Energy

Utility (STU) connectivity. Repowering involves replacing old turbines with new ones, while refurbishment includes modifications to turbine components or increasing hub height without changing the rotor blade diameter.

The policy addresses implementation arrangements micro-siting norms, banking arrangements, power purchase agreements, and fall in distance regulations, wind-solar hybrid installations, infrastructure development charges, financing facilitation, and other incentives to support repowering projects.

TAMIL NADU'S REPOWERING POLICY POSES CERTAIN CHALLENGES

The draft Tamil Nadu repowering policy has few areas of concern for owners of old turbine. One major issue is the complexities associated with fragmented ownership, which complicates the consolidation and upgrading of older turbines. Additionally, the policy's limitations on wind banking, such as restrictive banking periods and usage hours, are seen as inadequate for fully utilizing the energy generated by repowered wind farms. Ensuring the financial viability of repowering projects remains a primary challenge despite the incentives and benefits offered. These combined issues contribute to a lack of confidence among turbine owners regarding the new policy.

I. Wind banking limitations impacting wind turbine owners

Energy banking involves the exchange of electricity for electricity. In this arrangement, surplus power generated during certain periods is fed into the grid. This surplus energy, referred to as 'banked energy', is then supplied back during times of low renewable energy generation.

May–September are peak wind power generating months, when close to 70 per cent of the annual power is generated. In Tamil Nadu most of the wind generators are captive or group captive consumers. They were used to avail of the state's annual banking arrangement, where they bank excess generation with the TANGEDCO during windy months and consume it during non-windy months.

The draft policy allows annual banking for projects commissioned before March 31, 2018. Projects commissioned after April 1, 2018 can bank energy monthly, up to 50 per cent of total generation. Additionally, the policy restricts the use of banked energy to non-peak hours (8 a.m. to 4 p.m.). This means that the banked energy can only be consumed between 8 a.m. and 4 p.m. to discourage high power consumption during peak hours.

The restricted banking period may not be sufficient for the owners to utilize all the excess energy generated in a year by repowered wind farms. Since wind energy is only feasible for half the year, continuous process industries like the textile or cement industry struggle to sustain renewable energy use for the rest of the year without banking.

The present draft allows owners to bank excess energy with a service charge called as banking charge is paid for at 14 per cent of the energy. The banking charge for wind energy in Tamil Nadu has increased gradually over the years, starting at 2 per cent in 1986, increasing to 5 per cent in 2001, and remaining at 5 per cent until 2009. In 2016, the state regulatory commission set the banking charge at 12 per cent, and now increased it to 14 per cent in 2018. In the new draft repowering policy banking, charge remains the same 14 per cent of excess generation.

The combination of banking charges and the cap of 50 per cent of total generation for encasing excess energy is discouraging extensive power banking.

II. Infrastructure development charges and substation connectivity

According to the draft policy, new wind generators must pay infrastructure development charges at a rate of Rs 30 lakh per MW, with a 10 per cent discount on these charges for additional wind capacity. However, developers connecting to TANGEDCO's distribution system at 33 kV or 110 kV substations must also bear the cost of substation augmentation, including feeders up to 33 kV. If there is a change in injection voltage level, power evacuation depends on the availability of spare capacity at the substation; if not available, developers must arrange alternative evacuation methods. This means that even after paying the infrastructure development charges, developers must still spend on increasing the capacity of substations, which is a discouraging.

III. Insufficient transmission capacity: A hurdle for wind repowering in Tamil Nadu

Many of Tamil Nadu's wind farms, approaching the end of their 15-year lifespan, currently rely on TANGEDCO's 11 kV power lines for electricity evacuation. Repowering these farms to increase their capacity and generation output requires upgrading to at least 33 kV capacity for the generation feeder. This anticipated increase in output could potentially double or triple their current electricity production.

However, the existing 11 kV lines are inadequate to handle this significant increase in power, creating a bottleneck in efficient electricity evacuation. This limitation could lead to transmission congestion and the need for operators to curtail electricity generation to prevent overloading the grid, thereby potentially wasting renewable energy.

IV. Complexities of fragmented ownership

The growth of wind energy in Tamil Nadu has been driven by sales tax benefits, accelerated depreciation introduced in 1992, and the Technology Upgradation Fund (TUF) launched by the Ministry of Textiles in 1999 to modernize jute and textile mills. Tamil Nadu, which houses at least half of India's textiles market, benefited from this scheme, especially with a special lending rate of 12.5 per cent for wind projects supplying power directly to textile companies. Given the power-intensive nature of the textile industry, investing in wind energy for captive consumption fixed a major component of production costs, improving profitability.

Significant private investment followed, supported by turnkey suppliers. Each private player typically owns a few windmills, leading to fragmented ownership. This fragmentation requires a distance between projects and between turbines within a project, complicating repowering efforts. For example, replacing 20 turbines of 250 kW capacity each, owned by different individuals with three turbines of 2 MW capacity each, creates significant ownership issues. Consolidating these into fewer, more powerful turbines complicates the distribution of ownership and benefits. This fragmentation has been a major hurdle, and previous attempts at repowering in Tamil Nadu have largely failed due to these complex challenges. Since this issue is specific to Tamil Nadu, the draft policy should prioritize addressing it.

ON-GROUND EXPERIENCE OF WIND REPOWERING: CASE STUDIES

Driving south from Tirunelveli city in Tamil Nadu, one encounters a bustling scene of buses, trains, students and labourers heading to their destinations. Along the way, hospitals, colleges, shops and numerous temples line the route.

Past Valliyur town, the landscape changes dramatically. Lush green fields surrounded by mountains, grazing livestock and the cheerful chirping of birds welcome travellers into the countryside. Amidst this scenic backdrop, towering wind turbines 50–80 feet tall dominate the horizon.

This picturesque setting unfolds near Muppandal, a village in Kanniyakumari district, renowned for housing India's largest operational wind farm since 1986. Nearby, Karungulam, a panchayat town 15 km from Aralvaimozhi, offers a glimpse of rural life in southern India. Aralvaimozhi Pass, a strategically significant gap in the Western Ghats' southernmost part, hosts wind farms collectively generating about 450 MW of electricity, with over 3,000 windmills.

The Muppandal wind farm, featuring turbines from various private players, was developed by the Tamil Nadu Energy Development Agency (TEDA). Notably, the wind turbines in this region are among the oldest in the country.

We selected the location because this region in Tamil Nadu has been home to windmills since 1986. It contains some of the oldest wind farms, with many turbines still operating despite frequent breakdowns and significantly lower Capacity Utilization Factors (CUFs).

We took a closer look of the following five repowered sites from the region.

- Narasus Spinning Mills, Karungulam
- Narasus Spinning Mills, Kumarapuram
- Hatsun Agro Product Ltd, Kumarapuram
- Ashok Wind Farm Private Limited, Karungulam
- T.P.S. Wind Farm Private Limited, Levengipuram (see *Table 2*)

Table 2: Comparison table: Specification of old versus new wind energy generators (WEGs)

Wind farm	Old WEG	New WEG	Change
Narasus Spinning Mills, Karungulam	Generators: 3 * 250 kW Hub height: 50 m Rotor diameter: 30 m	Generators: 3 * 250 kW Hub height: 50 m Rotor diameter: 30 m	No changes in generator capacity hub height and rotor diameter
Narasus Spinning Mills, Kumarapuram	Generators: 4 * 250 kW Hub height: 50 m Rotor diameter: 30 m	Generators: 2 * 500 kW Hub height: 50 m Rotor diameter: 47 m	Reduced the number of generators but increased their capacity, while also expanding the rotor diameter by 17 metre
Hatsun Agro Product Ltd, Kumarapuram	Generators: 4 * 250 kW Hub height: 30 m Rotor diameter: 30 m	Generators: 4 * 250 kW Hub height: 50 m Rotor diameter: 30 m	Increased the hub height by 20 metre
Ashok Wind Farm Private Limited, Karungulam	Generators: 2 * 250 kW Hub height: 30 m Rotor diameter: 30 m	Generators: 2 * 250 kW Hub height: 50 m Rotor diameter: 30 m	Increased the hub height by 20 metre
T.P.S. Wind Farm Private Limited, Levengipuram	Generators: 3 * 250 kW Hub height: 50 m Rotor diameter: 30 m	Generators: 3 * 250 kW Hub Height: 50 m Rotor Diameter: 47 m	Increased the rotor diameter by 17 metre

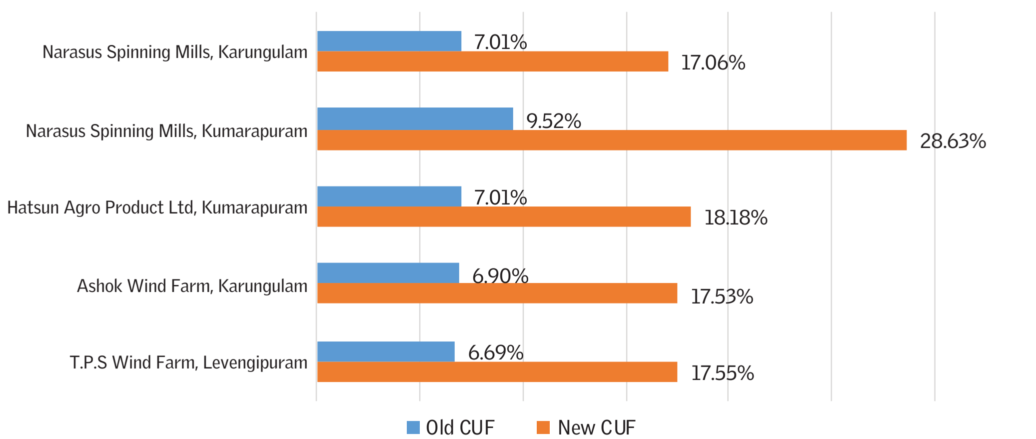
Observations

- The companies that manufactured these old turbines of 250 kW have ceased their production and maintenance support, including spare parts. Now they are producing new-generation turbines with higher capacities. After more than two decades of continuous operation, these turbines experienced issues with slewing bearings (including blade/yaw bearings) and gearbox malfunctions, resulting in significant problems such as pitching failure, diminished energy output and current instability. Consequently, owners decided to replace all the old turbines.
- **Hub height and rotor diameter:** Most owners opted to retain the hub height and rotor diameter, as increasing these parameters would necessitate a complete redesign of site spacing, posing challenges such as increased falling distance and micro-siting issues.

Site spacing refers to the minimum distance required between wind turbines within a wind farm. As wind turbines spin, they create turbulence. If turbines are placed too close together, this turbulence can disrupt the airflow reaching downwind turbines, reducing their efficiency. Wind turbines are massive structures with large, heavy blades that spin at high speeds. In the unlikely event of a blade failure, falling debris could pose a serious threat to people and property.

- **Wind turbine capacity:** Wind repowering owners interacted with CSE shared a common practice of maintaining the new capacity of the wind farm at the same level as the old one. This is because TANGEDCO has not agreed to increase the approved load of the old wind turbines. If they were to increase the load, they would also need to upgrade the substation capacity and components, which involves upgrading the evacuation voltage level and the infrastructure. This is the reason why wind turbine owners repowered but couldn't increase the turbine capacity.
- The five sites that CSE visited featured turbines that were more than 20 years old. Repowering led to a significant tripling in both generation and Capacity Utilization Factor (CUF), mainly due to the replacement of outdated wind energy generators (WEGs) with newer turbines. The case studies on repowering clearly demonstrate this nearly threefold increase in generation. Additionally, in Hatsun Agro, the hub height was raised by 20 metre, and in T.P.S. and Narasus Spinning Mills in Kumarapuram, the rotor diameter was expanded by 17 metre, resulting in a substantial boost in yield (see *Figure 6*). CUF reflects the actual energy output relative to the maximum potential output, and higher CUF indicates better performance.

Figure 6: CUF comparison between old WTG and new WTG



Source: Author's analysis

- The concrete foundation of Ashok and TPS Wind Farm had deteriorated, developing cracks due to the intense vibrations generated by the aged turbines. The vibrations compromised structural integrity and led to rainwater infiltration into the old concrete, weakening the foundation further. So the old foundation had to be removed and a new site rebuilt approximately 20 metre from the old one, with new tower stub for the repowered project.
- During the interaction we found that a scrap dealer from Coimbatore managed the disposal of discarded turbine parts. They sorted through components like the gearbox, generator, foundations and towers, selling salvaged parts to local recyclers to ensure valuable materials were repurposed. However, recycling wind turbine blades and nacelles posed challenges due to their complex construction. Mechanical disintegration techniques like cutting, shredding, crushing, or milling were used to break down the blades into smaller pieces, which were then repurposed as reinforcements in various composite products, insulation materials, or structural components. Recycled materials such as pellets and panels are used in flooring and wall installations, supporting sustainability in construction and manufacturing. Innovative solutions for nacelles include repurposing them to manufacture boat hulls for local fishermen, promoting environmental sustainability and fostering economic growth within the community.

Discussion

From our experiences we found that wind farm owners in Tamil Nadu had ambitious plans to increase their turbine capacity by four times through repowering, replacing old models with more powerful ones. However, TANGEDCO, the state's power utility, posed a significant obstacle. The Mupandal substation couldn't handle the surge in electricity from these upgraded turbines. Additionally, micro-siting restrictions and regulations regarding the minimum distance between turbines and homes (falling distance) hindered the ability to increase the hub height or rotor diameter significantly. With a more comprehensive and flexible policy, these limitations could have been addressed, enabling developers in quadrupling capacity and generation. Now, brand new turbines stand tall, ready to serve for the next two decades, but an opportunity to significantly boost Tamil Nadu's wind power is slipping away.

Economics of wind repowering

After visiting the site and interacting with developers, CSE analysed the costs involved in the demolition, erection and supply of 250 kW wind turbines for both repowered and greenfield projects. The data highlights financial implications, potential savings and payback periods, offering valuable insights into the feasibility and cost-effectiveness of different projects.

Dismantling and disposing of old turbine components, such as towers and foundations, along with excavation, are significant cost factors in repowered projects. These activities cost Rs 14 lakh for a 250-kW wind repowered project.

Reusing existing foundations and access roads can result in significant cost savings of Rs 5 lakh for a 250-kW project. The feasibility of foundation reuse depends on the micro-siting conditions and the structural integrity of the old foundations to support newer, heavier turbines. Since most of the concrete in old foundations is unsafe for new turbines, this becomes an added cost.

Grid upgrade costs for repowering projects can vary significantly, typically in the range of 30–40 per cent of the total repowering investment. This variation depends on the existing grid capacity and the increase in power generation from repowered turbines. These costs directly impact the overall feasibility and payback for repowered projects.

The supply cost for a 250-kW wind turbine, including the nacelle, blade and blade hub, tower, and other components, is Rs 105 lakh. This cost is consistent for new installations and repowered projects. Consequently, the capital cost of the power plant varies significantly between repowered and greenfield projects. The greenfield project has a lower cost at Rs 148.4 lakh compared to the repowered projects, which cost Rs 170 lakh.

The annual power generation varies across projects, with repowered projects like the T.P.S. Wind Farm achieving the highest at 3.84 lakh kWh. Annual savings from wind power generation is close to Rs 27 lakh mainly due to the better efficiency of newer generation turbines.

The additional cost of Rs 22 lakh per 250 kW associated with repowered projects extends their payback period by one year. This highlights that greenfield projects, involving significant initial investments but streamlined processes without complexities like dismantling and grid upgrades, can achieve quicker financial returns.

The economic analysis reveals a substantial gap of approximately Rs 22 lakh per 250 kW turbine (roughly Rs 87 lakh per MW) between the costs of repowering and building new greenfield projects. To make repowering economically viable and attractive compared to greenfield developments, an additional investment of Rs 6,336 crore across Tamil Nadu's 7.3 GW of existing wind capacity would be necessary. This investment aims to bridge the economic disparity and promote the sustainable utilization of existing wind resources in the region.

Table 3: Cost comparison of three repowered projects with new green field project

S. no.	Item description	Repowered project Narasus-Karungulam amount (Rs lakh)	Repowered project Ashok Wind Farm amount (Rs lakh)	Repowered project T.P.S. Wind Farm amount (Rs lakh)	Greenfield project amount (Rs lakhs)
1	De-erection of turbines	0.5	0.4	0.5	0
2	Disposing of old turbine components, towers, excavation, and foundations	14	14	14	0
3	11 KV line work/km	4	4	4	4
4	11 KV four pole EB DP structure	7	7	7	7
5	Transformer, CT PT and meter	7	7	7	5
6	NOC and clearance from authority	10	10	10	10
7	Civil foundation and rebuilding access roads	14	14	14	9
8	Erection	5	5	5	5
9	Safety certificate	1	1	1	1
10	Commissioning and PPA	1	1	1	1
11	Site and pathway clearance	0.6	0.6	0.5	0.5
12	Synchronization	0.5	0.4	0.4	0.4
13	Contingency	0.5	0.5	0.5	0.5
14	Supply and installation of a 250 kW Wind Turbine	105	105	105	105
	Total	**170.1**	**169.9**	**169.9**	**148.4**

Source: Data from the repowered project developers

Table 4: Comparison of cost–benefit analysis and project payback period

	Repowered project Narasus-Karungulam	Repowered project Ashok Wind Farm Value	Repowered project T.P.S. Wind Farm	Greenfield project
Capacity of the power plant (250 kW)	250	250	250	250
Investment of the project (Rs lakh)	170.1	169.9	169.9	148.4
Annual generation of the power plant (kWh)	373,565	383,894	384,240	373,565
Cost of grid power (Rs/kWh)	7.0	7.0	7.0	7.0
Annual savings to owner due to wind power generation (Rs lakh/year)	26.1	26.9	26.9	26.1
Payback period (year)	6.5	6.3	6.3	5.7

Source: Author's analysis

CSE's proposal on wind repowering in Tamil Nadu

Replacing small wind turbine generators (WTGs) with larger ones offers an opportunity for increased energy production and cost-effectiveness, as larger turbines can harness more wind energy and require less land per unit of energy generated. However, this comes with substantial upfront costs and suitability concerns based on wind patterns and grid constraints.

A more nuanced approach involves using lower-rated WTGs with taller towers to capture stronger winds at higher altitudes, enhancing efficiency without significantly affecting nearby turbines. Ultimately, the decision to replace small WTGs should be guided by a comprehensive feasibility assessment considering wind resources, site constraints, cost-effectiveness, and stakeholder feedback.

Given the evident issues with wind repowering, a holistic approach is necessary to address the gaps in Tamil Nadu's draft repowering policy, particularly regarding small wind turbine owners, who have been overlooked. Achieving results from this approach will require the collaborative involvement of all stakeholders.

The following strategies are recommended:

I. Strengthening draft wind repowering policy

Tamil Nadu's draft repowering policy aims to provide a detailed framework tailored to the state's specific needs, addressing the challenges and opportunities in the wind energy sector. The policy covers implementation arrangements, micro-siting norms, banking arrangements, power purchase agreements, falling distance regulations, and wind-solar hybrid installations to support repowering projects. However, old turbine owners remain unconvinced by the policy support. Despite paying Rs 30 lakh/MW as Infrastructure Development Charges, wind project developers face additional, potentially discouraging costs for substation upgrades and alternative power evacuation depending on TANGEDCO substation capacity. Tamil Nadu's aging wind farms, reliant on insufficient 11 kV lines for evacuation, face a bottleneck as repowering for higher capacity requires an upgrade to 33 kV. The policy, however, remains silent on this crucial infrastructure upgrade.

Additionally, the policy neglects the challenge of fragmented ownership, a critical hurdle that plagued previous repowering attempts. The combination of banking charges and the cap of 50 per cent of total generation for encasing excess energy is also discouraging for power banking.

II. Need to upgrade transmission infrastructure

While the state's draft repowering policy aims to revitalize aging wind farms, a significant hurdle exists: the current power transmission infrastructure. Many of these wind farms rely on TANGEDCO's 11 kV power lines to evacuate the electricity they generate. However, repowering these farms to reach their full potential, with increased capacity and generation output, necessitates an upgrade to a minimum of 33 kV capacity for the generation feeder lines.

This is a critical bottleneck. Without this upgrade, the additional power generated by repowered turbines cannot be efficiently transmitted into the grid. It is concerning that there's currently no official circular issued by TANGEDCO regarding these crucial infrastructure upgrades. Furthermore, the draft repowering policy itself remains silent on this matter.

This lack of clarity creates uncertainty for wind farm owners. Upgrading infrastructure is a substantial investment, and they require clear guidelines and support from TANGEDCO to make informed decisions about repowering. Without addressing the transmission capacity issue, the ambitious goals of the repowering policy risk being hampered.

III. Need for land consolidation to benefit fragmented turbines owners

Imagine a wind farm where 20 turbines of 250 kW capacity each are replaced by three turbines of 2 MW capacity each. Since these turbines are owned by different individuals, consolidating them into fewer, more powerful turbines creates significant ownership issues. This fragmentation has been a major hurdle, causing previous attempts at repowering in Tamil Nadu to largely fail.

A land swapping programme can help address this issue. This programme acts like a matchmaking service for land with wind turbines. Landowners with small, scattered plots interested in repowering can participate. The programme facilitates connections between landowners with compatible parcels for mutually beneficial exchanges. It considers factors like size, location and potential wind resources. Once a match is identified, negotiations take place, and if an agreement is reached, the swap is formalized with legal documentation and regulatory approvals.

Alternatively, a collective ownership model for wind farms can be explored. Here, several landowners within the wind farm's area co-own the repowered turbines. They contribute financially to the repowering project and share in the profits generated by the wind farm's electricity production. This approach fosters a sense of ownership and responsibility among community members, potentially leading to greater acceptance and project viability.

Both the land-swapping programme and collective-ownership models can resolve issues of fragmented ownership and ensure equitable benefits, but they require careful planning, strong communication and robust governance structures for success.

IV. Financial incentive to nullify increase in payback period

The Green Energy Open Access (GEOA) can be a game changer for repowering wind farms. Introduced in June 2022, GEOA can significantly increase market access for repowered wind farms. It can enable these farms to bypass the traditional system of selling electricity solely to distribution companies (DISCOMs), allowing them to directly sell their power to a broader range of consumers, including large industrial and commercial entities. However, the draft policy only mentions that wheeling charges can be exempt from open access fees and does not address GEOA's potential benefits.

Repowering Tamil Nadu's 7.3 GW of wind turbines presents a significant opportunity. However, bridging the economic gap with greenfield projects would require an estimated additional investment of Rs 6,336 crore.

The following are some targeted financial instruments that can address these gaps:

- Generation-based incentives: Implementing incentive programmes that reward repowered wind farms for exceeding pre-determined performance benchmarks, such as increase in energy production, can encourage owners to optimize their projects.
- Loan guarantees: Government-backed loan guarantees can substantially lower the risk for lenders, prompting them to provide loans for repowering projects with reduced interest rates and extended repayment terms. Despite additional expenses compared to greenfield projects, the payback period for repowered projects is extended by approximately one year. To enhance the financial appeal of these projects, loan guarantees and interest rebates can help bridge the gap of 80 lakhs per MW. Essentially, a loan guarantee involves a third party committing to cover some or all of the risks associated with a loan for a client lacking adequate bank-worthy collateral.

- Feed-in tariffs (FiTs) for repowered projects: Introducing a stable, long-term (20 years) tariff for electricity produced by repowered wind farms can ensure owners receive assured revenue in the early operational stages, minimizing risks of revenue shortfall. Currently, new wind projects adhere to a competitive bidding process based on tariffs, which means procuring electricity generated from wind farms by selecting developers who offer the lowest tariff. This tariff might slightly exceed the standard FiT to help cover the 80 Lakhs per MW gap.

V. Wind–solar hybridization: A synergistic approach

The hybridization approach leverages the complementary nature of wind and solar resources.

Wind and solar energy production often have different peak generation periods. Wind tends to be stronger during night-time and early morning hours, while solar generation peaks during midday. By combining these resources, overall energy production can be maximized throughout the day, reducing reliance on fossil fuels and enhancing grid stability.

Utilizing existing wind farm infrastructure for solar installations minimizes the need for additional land acquisition. This not only reduces project development costs but also promotes responsible land-use practices.

VI. Need to go back to old banking regulation for repowered projects

The new draft policy allows annual wind energy banking for projects commissioned before March 31, 2018. Projects commissioned after April 1, 2018 can bank energy on a monthly basis, up to 50 per cent of total generation.

But what if all repowered projects had this annual banking option? The benefits could be even greater. Imagine developers strategically selling stored energy during peak hours when electricity prices are highest, boosting their profits. Plus, a larger energy reserve could be created by banking 100 per cent of the generated power. This means less reliance on expensive backup sources like diesel generators during low-wind periods, leading to significant cost savings.

However, there's always a flip side. Banking too much energy might overload the existing grid, necessitating upgrades. Additionally, if everyone banks all their energy, there could be an excess in the market at certain times, potentially driving down prices.

So, banking should be allowed 'slot-to-slot' adjustments only, preventing shifting from high to low generation periods. Slot-to-slot adjustments in energy banking refer to a system where excess energy generated in a specific time period (or "slot") can only be used to offset consumption in the same time period. This means that energy generated during peak hours can only be used to offset consumption during peak hours, and energy generated during off-peak hours can only be used to offset consumption during off-peak hours. The maximum bankable energy should be capped at 50 to 70 percent of the generation between May and September. Any excess banking will be forfeited. Additionally, at least one-sixth of the banked energy available on October 1 must be consumed each month from October to March. Failure to do so will result in the forfeiture of the remaining balance.

The current draft policy restricts the consumption of banked energy to non-peak hours only, i.e. within 8 a.m. to 4 p.m., to discourage high power consumption during peak hours. However, allowing small wind turbine owners to sell their stored energy back to the grid during evening peak hours at a premium rate could help balance grid demand and encourage greater energy storage.

Lower banking fees or rebates provided for utilizing a higher percentage of banked energy should be win-win for both the TANGEDCO and the wind turbines owners by encouraging them to effectively utilize the banked energy and feeding energy during evening peak hours. TANGEDCO should estimate and determine banking charges to cover break-even costs.

In the heart of windswept Tamil Nadu, India's wind-energy champion, lies hidden potential. Ageing wind turbines, once leaders in clean energy production, are nearing the end of their lives. But what if they could be reborn? By replacing these older turbines with efficient, modern turbines, the state could double its wind energy generation and once again become a green giant.

The path to repowering is, however, riddled with challenges. This report delves into the roadblocks and the triumphs of initial repowering projects, from fragmented ownership of turbines to inflexible energy policies. It explores the exciting possibilities and offers a glimpse into the struggles and rewards of harnessing the power of the wind.

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