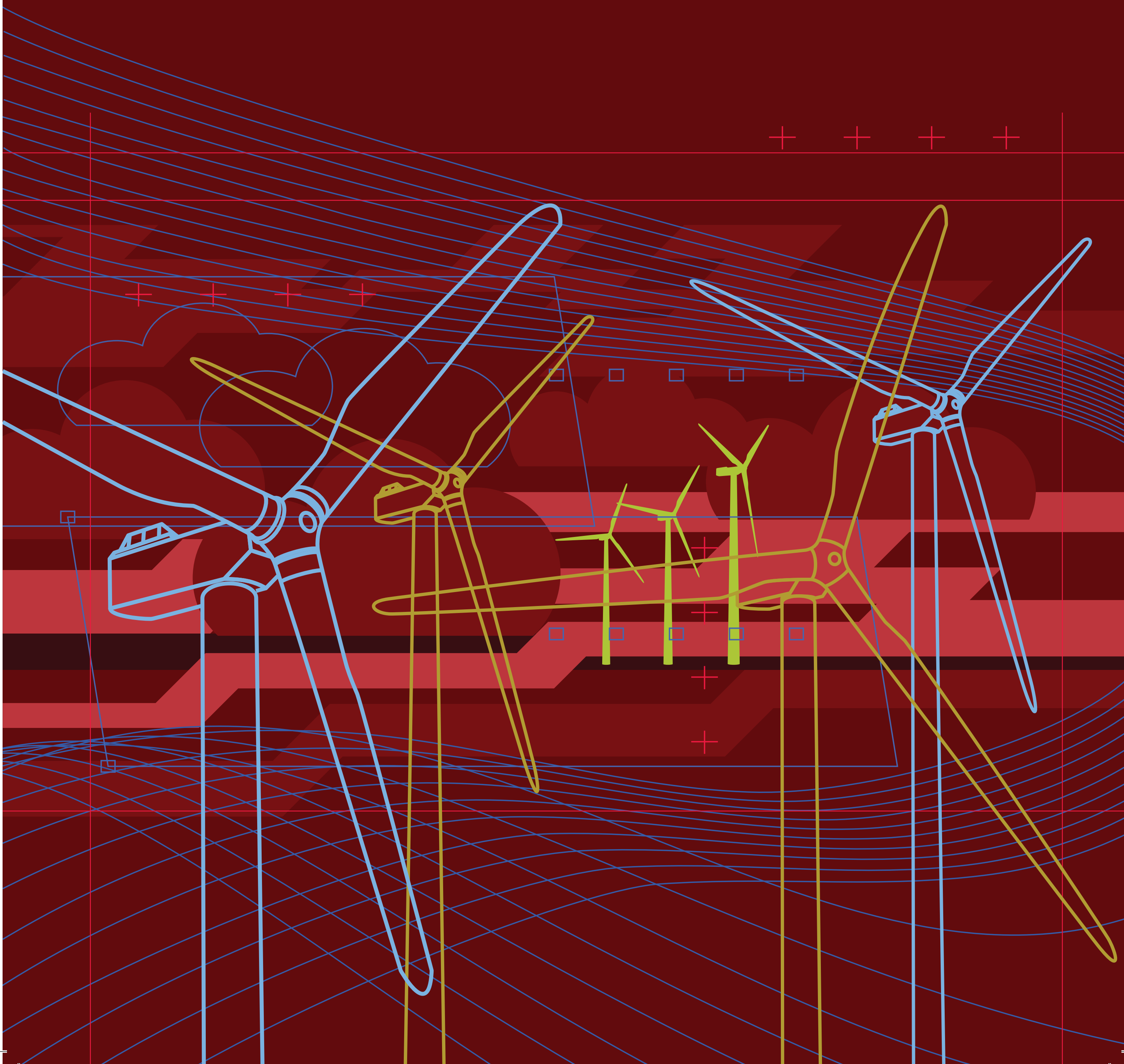
FACILITATING WIND REPOWERING

ADDRESSING BARRIERS IN MANUFACTURING, FINANCE, AND INFRASTRUCTURE FOR LEGACY WIND FARMS



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Research direction: Nivit Kumar Yadav

Author: Binit Das

Research support: Nishant Raj

Editor: Rituparna Sengupta

Cover and design: Ajit Bajaj

Production: Rakesh Shrivastava and Gundhar Das

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Centre for Science and Environment
41, Tughlakabad Institutional Area
New Delhi 110 062
Phones: 91-11-40616000
Fax: 91-11-29955879
E-mail: cse@cseindia.org
Website: www.cseindia.org

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Executive Summary

India's wind repowering sector holds a transformative potential worth INR 1.39–1.52 lakh crore, offering the possibility of unlocking 25.4 GW of enhanced capacity from aging wind infrastructure. Despite possessing some of the world's most wind-rich sites, India's wind capacity is built on outdated infrastructure. Tamil Nadu alone operates more than 8,800 turbines totalling 6.25 GW, many of which rely on obsolete technology. Similarly, Maharashtra, Karnataka, and Gujarat together host thousands of sub-megawatt machines installed over two decades ago. These turbines, mostly below 1.5 MW with capacity utilization factors of 10–14 per cent, occupy high-potential Class I wind zones but fail to meet current efficiency standards. The 2023 National Repowering and Life Extension Policy for Wind Power Projects requires a minimum 1.5-fold increase in energy generation from repowered sites, highlighting the pressing need for systematic infrastructure modernization. Yet this significant potential remains largely unrealized, hindered by three critical structural challenges that require urgent and coordinated action—upgrading Category A sites with next-generation turbines, aligning and strengthening transmission infrastructure, and mobilizing targeted investments to drive wind repowering success.

Critical structural barriers

1. Equipping Category A sites with next-generation turbines

India's premier wind corridors, including Tamil Nadu's Muppandal and Gujarat's coastal regions, require turbines capable of handling both high wind speeds (~10 m/s) and high turbulence intensity (TI 0.16). However, the current Revised List of Models and Manufacturers (RLMM) issued by the Ministry of New and Renewable Energy (MNRE) offers only six certified models rated for TI 0.16—all of which are under 1 MW capacity and have hub heights below 100 metres. These models are technically inadequate for effective repowering, which requires 2–3 MW turbines with higher hub heights. Moreover, India's current turbine supply primarily caters to sites with TI 0.12–0.14, rendering the country's best wind corridors effectively unserviceable.

2. Aligning transmission systems

Tamil Nadu's wind evacuation system exemplifies critical infrastructure constraints. For example, the Muppandal region still relies on legacy 11 kV feeder systems designed in the 1990s for 200–600 kW turbines. Modern 1.5-2 MW turbines face grid compatibility issues such as current overload risks, voltage instability, and increased transmission losses. Upgrading to 33 kV or higher evacuation systems demands substantial replacement of switchgear, transformers, and supporting infrastructure. Additionally, many wind-dense zones lack 400 kV substations, creating critical capacity bottlenecks.

3. Mobilizing investments for wind repowering success

Repowering economics differ fundamentally from greenfield wind projects, involving distinct costs such as dismantling, site preparation, and evacuation upgrades. Current financial policies fail to accommodate these specific needs, offering no support for dismantling and site reclamation, no capital offset for grid infrastructure upgrades, and no differentiated capital subsidies for repowering requirements.

The challenge is compounded by the ownership structure of India's aging wind capacity, a significant portion of which is held by retail investors, individuals, and small-to-medium enterprises that entered the sector during its early phase, drawn by tax incentives such as the Accelerated Depreciation scheme. These small stakeholders now find themselves in a financial trap: their aging projects generate insufficient revenue to justify reinvestment, yet they lack viable exit options due to asset valuation uncertainties and the inability to transfer grid evacuation rights to potential buyers. The current competitive bidding system favours large developers, effectively excluding these small investors from participating in repowering opportunities despite their substantial ownership of repowering-ready capacity.

Without targeted fiscal incentives, concessional loans, performance-based grants, or specialized financial instruments designed for small investor participation in repowering, project viability remains compromised on both technical and ownership fronts.

Integrated solution framework

Addressing these challenges requires coordinated action across three critical fronts:

— **Manufacturing scale-up:** Accelerate certification of global turbine platforms adapted for Class I conditions and provide R&D grants and Production-Linked Incentive (PLI) scheme extensions for high-turbulence turbine development.

— **Evacuation infrastructure modernization:** Establish coordination mechanisms between MNRE, CEA, and state utilities, while mandating site-specific load flow studies and grid upgrade planning for all repowering projects.

— **Financial reform:** Create a National Repowering Fund for capital support and soft loans via IREDA/REC, incentivizing dismantling, infrastructure retrofits, and performance-linked generation gains.

Strategic impact

Unlocking India's repowering market requires an estimated **INR18,000–25,000 crore investment in manufacturing and infrastructure**. This investment can catalyze over INR 1.5 lakh crore in private investment, significantly increase energy output from existing sites, and optimize land use in resource-rich corridors.

Conclusion

Repowering represents more than asset replacement—it is a system-wide upgrade requiring manufacturing innovation, infrastructure overhaul, and tailored financial architecture. Without integrated action, India's wind sector will remain under-optimized, limiting its contribution to the country's 500 GW non-fossil power target and broader climate goals. The time for coordinated intervention is now, as the repowering opportunity represents a critical pathway to maximizing India's wind energy potential while advancing national renewable energy objectives.

1

INTRODUCTION TO WIND REPOWERING

HIGHPOINTS

India has around 25.4 GW of aging wind turbines (<1.5 MW) on prime wind sites, operating inefficiently compared to modern tech. These are eligible for repowering, valued at INR 1.39–1.52 lakh crore.

The National Repowering and Life Extension Policy (Dec 2023) requires repowered projects to generate at least 1.5 times more energy than before to qualify.

Only Tamil Nadu, Gujarat, and Karnataka have repowering policies. Most turbines are on high-resource Class I sites but face turbulence and wake issues.

India's renewable energy sector has witnessed remarkable progress, with wind energy emerging as one of the earliest and most significant contributors to the nation's clean energy transition. However, a substantial portion of India's installed wind turbine fleet now consists of aging infrastructure, characterized by sub-megawatt capacities, lower hub heights, smaller rotor diameters, and suboptimal energy yields. These early-generation turbines, many of which were installed over a decade ago, occupy some of the country's most wind-rich sites but operate at efficiencies far below contemporary technological standards. Recognizing the need to modernize this aging infrastructure, the Ministry of New and Renewable Energy (MNRE) introduced the National Repowering and Life Extension Policy on 7 December, 2023. This policy represents a strategic shift in India's wind energy strategy, emphasizing the replacement or refurbishment of outdated turbines to maximize energy output from existing high-potential sites while minimizing land-use conflicts and regulatory hurdles associated in repowering projects.

The case for repowering is compelling. Modern wind turbine generators (WTGs) offer substantially higher efficiency, advanced aerodynamic designs, and sophisticated control systems that can significantly enhance energy generation without requiring additional land. Older turbines, often rated below 1.5 MW, were designed under technological constraints that are now obsolete. By repowering these assets, India can unlock latent capacity at prime wind sites, thereby improving the overall productivity of its wind energy portfolio. MNRE estimates the national repowering potential at approximately 25.4 GW, applicable to turbines below 2 MW. This figure underscores the vast opportunity to augment wind energy output through strategic retrofitting along with greenfield expansion. States such as

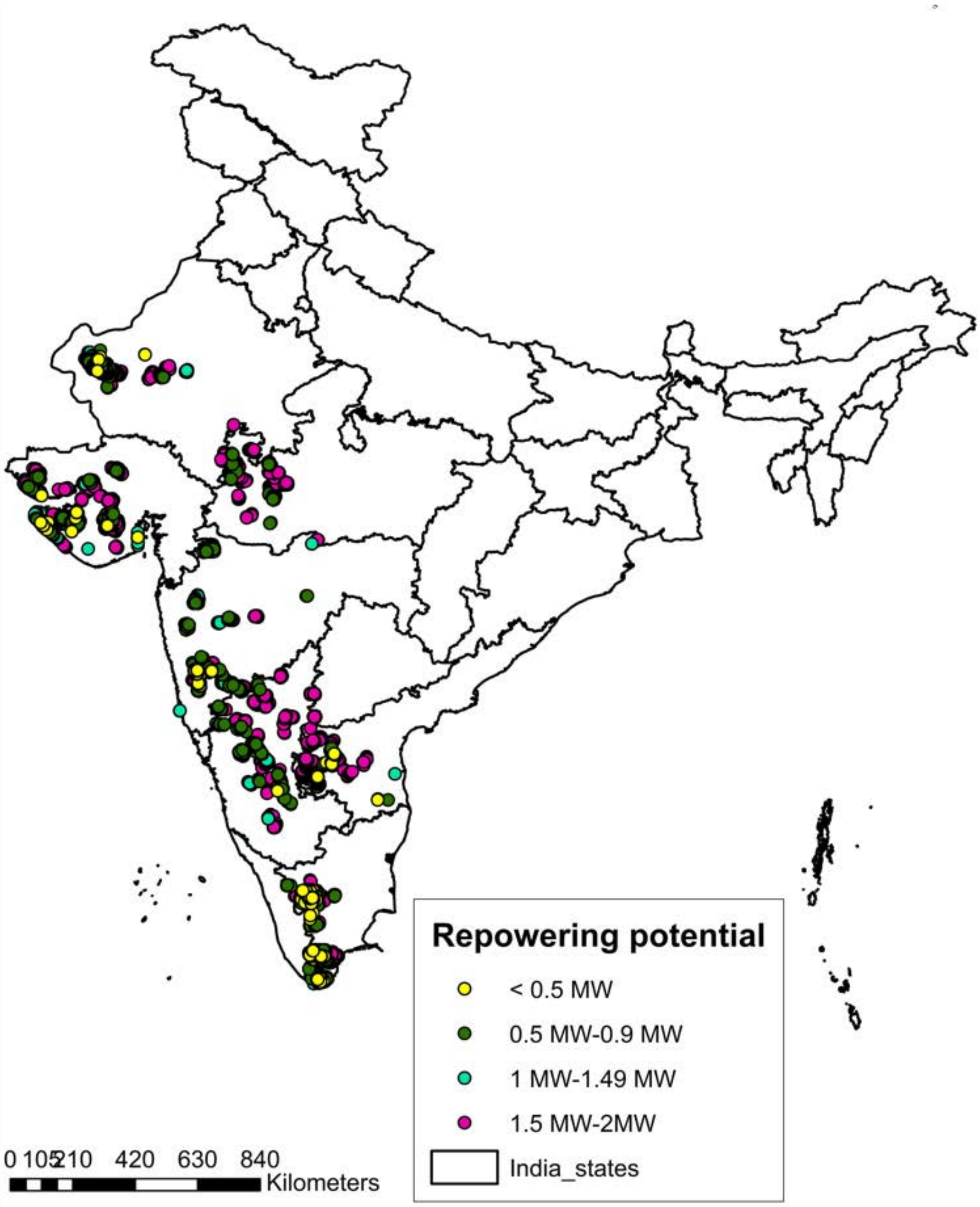
Table 1: India's wind repowering potential (MW)

States	Wind repowering potential (MW)	Turbine cost with Rs. 5.5 crore/MW	Turbine cost with Rs. 6 crore/MW
Tamil Nadu	7,386	40,623	44,316
Maharashtra	3,431	18,871	20,586
Karnataka	3,023	16,627	18,138
Gujarat	4,665	25,658	27,990
Rajasthan	2,934	16,137	17,604
Madhya Pradesh	1,562	8,591	9,372
Kerala	28	154	168
Andhra Pradesh	2,366	13,013	14,196
Total	25,406	1,39,733	1,52,436

Source
Potential: National Institute of Wind Energy
Market Size: CSE's estimation

Tamil Nadu, Maharashtra, Karnataka, Rajasthan, and Gujarat collectively host a significant share of these sub-2 MW turbines, with Tamil Nadu alone accounting for over 8,800 older machines totalling 6.25 GW.

Map 1: India's repowering potential map



Source: National Institute of Wind Energy

The National Repowering and Life Extension Policy establishes clear eligibility criteria to identify turbines suitable for repowering. These include (a) WTGs non-compliant with MNRE's quality control orders, (b) turbines that have completed their certified design life, (c) units with rated capacities below 2 MW, (d) turbines voluntarily selected for repowering after 15 years of operation, and (e) machines requiring replacement due to safety, performance, or manufacturing defects. A critical stipulation is that repowered projects must demonstrate at least a 1.5x increase in actual energy generation compared to pre-repowering levels, ensuring that only meaningful upgrades qualify for policy benefits.

To facilitate implementation, the National Institute of Wind Energy (NIWE) has been tasked with creating a comprehensive repowering potential map, detailing turbine models, ownership patterns, feeder connections, and geographic coordinates. This GIS-enabled database will provide granular, state-specific insights to streamline developer decision-making and reduce project uncertainties. Preliminary data reveals that Tamil Nadu's 8,810 old turbines include 3,865 units below 0.5 MW and 4,127 in the 0.5–2 MW range. Similarly, Maharashtra has 3,275 aging turbines (3.18 GW), Karnataka hosts 2,440 machines (3.03 GW), and Rajasthan contains 2,655 turbines (2.88 GW). Even states with smaller wind footprints, such as Andhra Pradesh and Kerala, present viable repowering opportunities.

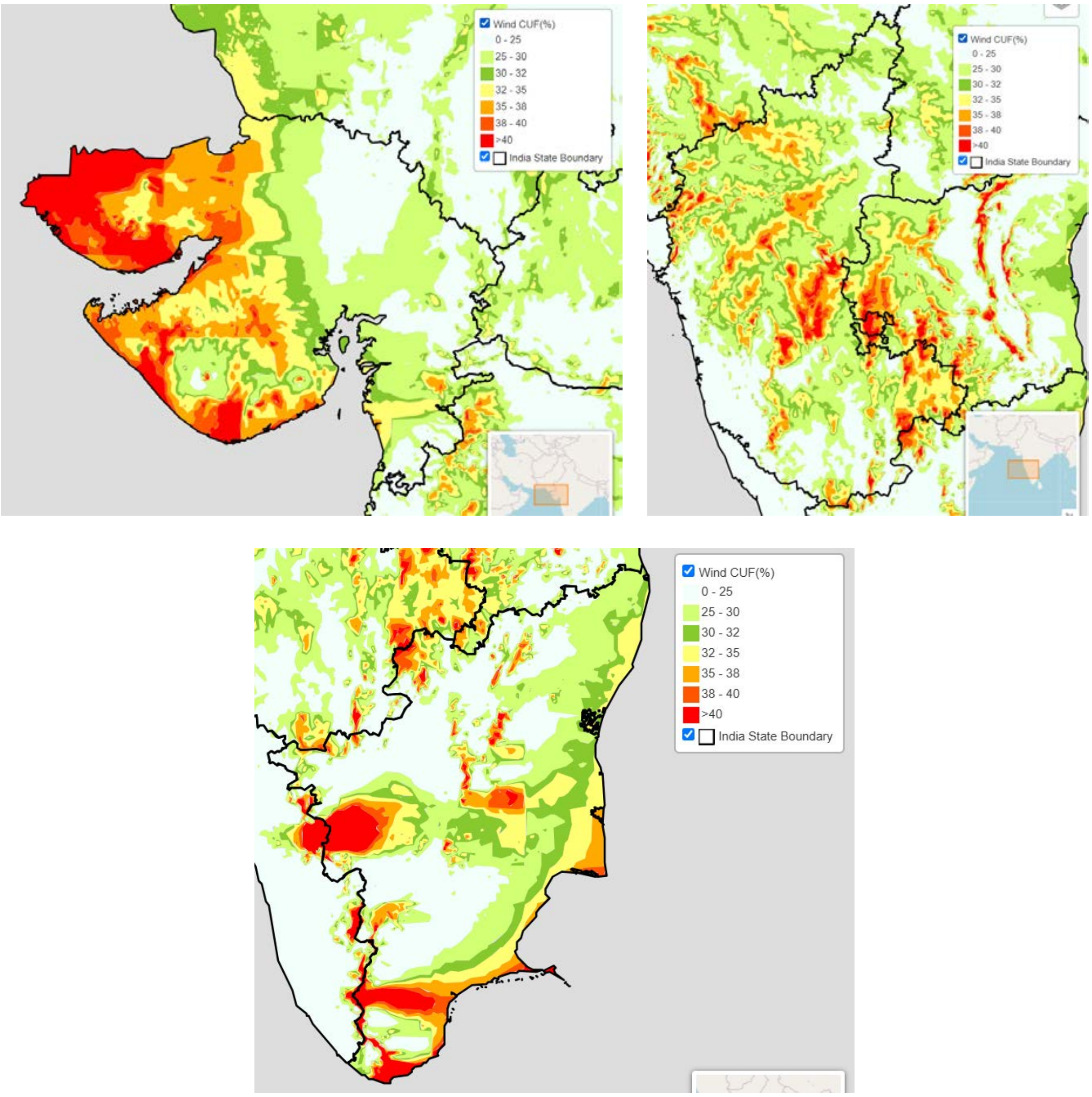
This table shows the wind repowering market size in India, which represents a significant economic opportunity distinct from new wind development. Here's the market analysis:

The repowering market spans 25,406 MW of existing wind capacity that could be upgraded, representing a market value of INR 1.39–1.52 lakh crores.

Tamil Nadu emerges as the dominant repowering market with 7,386 MW (29 per cent of total), followed by Gujarat (4,665 MW) and Maharashtra (3,431 MW). These states installed significant wind capacity in earlier phases using older, smaller turbines that are now candidates for repowering with modern, more efficient units.

Among all the Indian states, Gujarat, Karnataka, and Tamil Nadu are currently the only ones that have implemented dedicated, standalone policies specifically focused on wind repowering. These policies represent a formal and structured approach by the respective state governments to address the challenges and opportunities associated with replacing aging, less efficient wind turbines with modern, high-capacity machines.

Map 2: Wind resource at 150 meters above ground level (AGL)



Source: National Institute of Wind Energy, Resource Portal

The following sections will provide a detailed examination of the repowering frameworks adopted by Gujarat, Karnataka, and Tamil Nadu. This includes an overview of their respective policy instruments, eligibility criteria, technical and operational guidelines, and the institutional mechanisms set in place to support implementation.

Wind speed distribution

The wind speed map of India, prepared by the National Institute of Wind Energy (NIWE), presents a comprehensive visual representation of the spatial distribution of wind speeds across the country. Utilizing a colour-coded gradient system, the map delineates zones of varying wind speed intensities.

The central purpose of this wind speed map is to support the identification of high wind potential zones and to classify them into distinct wind resource categories, also referred to as site classes. By identifying areas that fall within higher wind class categories, stakeholders are better equipped to prioritize repowering efforts and new installations.

A significant observation from the map is the dense concentration of existing wind turbines in Tamil Nadu. These turbine installations are primarily located in the southern and western districts of the state, regions that have historically been at the forefront of wind energy development in India.

Moreover, the wind speed map reveals that many of these historically significant wind zones align with what are classified as Class I wind sites. These areas are characterized by high average wind speeds and are considered among the most resource-rich in the country. However, due to their early development and high turbine density, these sites also exhibit elevated turbulence intensity and are prone to wake effects. The proximity of multiple turbines contributes to aerodynamic interference, which in turn affects overall efficiency and operational reliability. Consequently, while these Class I zones remain highly attractive from a resource standpoint, any repowering initiative undertaken within them must be informed by meticulous micro-siting practices and modern technological adaptations. These measures are necessary to counteract the performance issues associated with wind turbulence and wake interactions.

The NIWE's wind resource map at 150 m serves as a critical tool for guiding wind energy policy and investment decisions across India. It delineates regions with high wind energy potential and pinpoints areas with high wind speeds, particularly within densely clustered wind zones. This spatial analysis supports strategic site selection and infrastructure planning for optimized wind power deployment.

2
EQUIPPING CATEGORY A SITES WITH NEXT-GENERATION TURBINES

HIGHPOINTS

India's prime wind sites (especially Tamil Nadu and Gujarat) have high turbulence intensity (0.16), but most RLMM-listed turbines are built for 0.12–0.14, limiting suitability.

Of 35 approved turbine models (14 manufacturers), only a few from Suzlon, Vestas, etc., are certified for Category A (high turbulence). Most high-capacity modern turbines (2-5 MW range) cannot operate effectively in India's most challenging but resource-rich wind sites.

Original equipment manufacturers hesitate to develop high-turbulence turbines due to high R&D costs and low global demand.

The National Institute of Wind Energy lacks wind data at modern hub heights (120–140 m), hampering design. Experts urge faster certification and full supply chain incentives.

Wind turbines function similarly to reciprocating engine generators, converting wind energy into mechanical energy and subsequently electrical power. Wind drives the rotor through a low-speed shaft to a gearbox, then to a high-speed shaft powering the generator. What distinguishes wind turbines—especially utility-scale models—is the placement of nearly all components atop towers reaching 120 meters (390 feet), critical for efficient and safe wind energy capture.

Several characteristics set wind turbines apart from conventional generators, particularly in classification, installation, and performance evaluation. These distinctions are codified through International Electrotechnical Commission (IEC) standards, notably IEC 61400-1, which outlines design requirements ensuring structural integrity and safe operation under expected site conditions throughout planned lifetime.

Wind turbine design and classification under IEC 61400-1

IEC 61400-1 defines wind turbine classes based on three critical parameters: average wind speed at hub height, extreme 50-year gust wind speed, and turbulence intensity. These parameters guide manufacturers in designing turbines that withstand mechanical loads imposed by wind regimes, ensuring turbines are neither over-engineered (increasing costs unnecessarily) nor under-designed (risking premature failure).

The average wind speed (Vave) is the 10-minute mean wind speed expected over a 50-year recurrence period, referred to as reference wind speed (Vref). This parameter is crucial because power available in wind is proportional to the cube of wind velocity—small increases in wind speed result in large increases in available energy but significantly higher mechanical loads.

Table 2: IEC 61400-1 wind classes

Wind turbine class	I	II	III	S
V ave (m/s)	10.0	8.5	7.5	Values specified by designer
V ref (m/s)	50.0	42.5	37.5	
Turbulence Category A	0.16			
Turbulence Category B	0.14			
Turbulence Category C	0.12			

Source: International Electrotechnical Commission, IEC 61400-1

Table 3: Revised list of models and manufacturers (RLMM) wind turbine models (as of 1 May, 2025)

Large scale (3+ MW) - 14 Models

Manufacturer	Model	Capacity (MW)	Rotor diameter (m)	Hub height (m)
W2E (Germany)	MWL-160-5.2MW	5.2	160	120/140
Sany (China)	SI-16840	4.0	166.8	139
WEG (Brazil)	AGW 147/4.2	4.2	147	120
Windey (China)	WD147-3000	3.0	145.9	100
Windey (China)	WD164-3300	3.3	163.95	139.73
Envision (China)	EN-156/3.3 MW	3.3	156	120–143
Envision (China)	EN-182-5.0	5.0	181	105.56
Suzlon (India)	S144-3.0/3.15 MW	3.0/3.15	144	105–160
Suzlon (India)	S133	2.6-3.0	133	105–160
Vestas (Denmark)	V155-3.6 MW	3.6	155	102.5–137
Inox (India)	DF/3000/145	3.0	145	100–140
Senvion (Germany)	3.1M130	3.1	130	130
Siemens Gamesa (Spain)	SG 3.4-145	3.4	145	127.5–133.5
Siemens Gamesa (Spain)	SG 3.6-145	3.6	145	127.5–133.5

Medium scale (2–3 MW) - 12 Models

Manufacturer	Model	Capacity (MW)	Rotor Diameter (m)	Hub Height (m)
GE (USA)	GE 2.7–132	2.7	132	94–130
Suzlon (India)	S111 DFIG	2.1	111.8	90–140
Suzlon (India)	S120 DFIG	2.1	120	105–140
Vestas (Denmark)	V100–2MW	2.0	100	75–100
Inox (India)	DF/2000/113	2.0	113	92
Senvion (Germany)	2.3M120	2.3	120	120
Senvion (Germany)	2.3M130	2.7	130	120–140
Siemens Gamesa (Spain)	G114–2.0MW	2.0	114	106–110
Siemens Gamesa (Spain)	SG 2.2–122	2.2	122	127

Small Scale (<1 MW) - 9 Models

Manufacturer	Model	Capacity (kW)	Rotor Diameter (m)	Hub Height (m)
PowerWind (India)	PowerWind 56	900	56	71
Pioneer Wincon (India)	750/49 (various)	750	49-57	61.5–90
Siva (India)	SIVA 250/50	250	30	50
Siva (India)	SIVA 225/40	225	30	50
Southern Wind	GWL 225	225	29.8	48.7

Source: Revised List of Models & Manufacturers (RLMM), Ministry of New and Renewable Energy

The extreme wind speed is the highest average wind speed, measured over short intervals (typically three seconds or 10 minutes), expected once in 50 years. Turbine structures must withstand these extreme conditions without damage.

Turbulence intensity quantifies wind speed variability around the mean, typically measured over 10-minute intervals. It's expressed as the ratio of standard deviation of wind speed fluctuations to mean wind speed. Turbulence causes fluctuating loads contributing to fatigue and wear, making understanding and designing for turbulence essential for turbine longevity.

IEC wind turbine classes

Based on these parameters, IEC classifies wind turbines into three main classes with subcategories based on turbulence intensity:

- **Class I**: Designed for high average wind speeds (10 m/s) and high mechanical loads. Built to withstand demanding wind conditions with smaller rotors and shorter towers to minimize structural loads.

- **Class II**: Intended for medium wind speed sites (8.5 m/s average). The most common commercial class balancing energy capture and structural demands.

- **Class III**: Suitable for low wind speed sites (7.5 m/s average); generally, features larger rotors to maximize energy capture from less energetic wind sites.

Each class divides into categories A, B, and C, corresponding to high, medium, and low turbulence intensities of 0.16, 0.14, and 0.12 respectively. Most commercially available turbines, including those in MNRE's Revised List of Models and Manufacturers (RLMM) updated May 2025, are designed for turbulence intensities of 0.12 and 0.14 but not 0.16.

Turbine design implications for different classes

Turbine design varies significantly between classes to optimize performance and durability. Class III turbines for low wind speeds typically feature very large rotor diameters to capture maximum energy from available wind. Operating in gentle wind conditions reduces mechanical stress and fatigue, allowing lighter structural designs.

Conversely, Class I turbines must endure high wind speeds and intense turbulence. They're constructed with robust materials and design features, including smaller rotors and shorter towers, to reduce mechanical loads and increase reliability.

These design choices make Class I turbines heavier and more expensive but necessary for demanding conditions.

Turbulence intensity and performance impact

Turbulence intensity critically influences turbine design by directly affecting fatigue loads on components. High turbulence leads to rapid fluctuations in wind speed and direction, causing cyclic stresses that shorten turbine lifespan if not properly addressed. Complex terrain—hills, forests, or built environments—increases turbulence levels.

In Class I sites, characterized by high wind speeds and significant turbulence, turbine selection must carefully consider these conditions for long-term reliability. The majority of commercially available turbines suitable for Class I sites, including repowering projects, have turbulence intensity ratings of 0.16, with sub-750 kW category reflecting typical site conditions.

Commercial turbine models for repowering in Class I sites

India has significant installed base of older, small-capacity wind turbines (less than 1 MW), mostly located in Class I wind sites with high wind speeds but challenging turbulence conditions. These older turbines typically have low-capacity utilization factors (CUF) of 10–14 per cent. Modern turbines designed for Class I sites can double or triple energy generation due to improved technology and optimized design.

Repowering projects replace outdated turbines with newer models tailored to specific wind class and turbulence conditions. However, per the RLMM updated May 2025, there's a noticeable absence of turbine models explicitly engineered for Class I conditions. These high-wind, high-turbulence environments require turbines with reinforced structural designs and optimized rotor configurations capable of withstanding extreme mechanical loads. The current RLMM gap highlights critical need for expanding availability of robust, certified turbine models suitable for demanding operating conditions.

The RLMM list reveals significant technological advancement in wind turbine capacity creating substantial repowering scope. The approved models range from 225 kW turbines to modern 5.2 MW units, representing wide range of available capacity. With 35 approved models from 14 manufacturers, older wind farms can replace multiple small turbines with fewer, larger units on the same land. Modern turbines feature larger rotor diameters (up to 181m) and taller hub heights (up to 140m), enabling higher capacity factors.

The dataset reveals an interesting mismatch between India's Class I site requirements—characterised by high wind and high turbulence—and the limited availability of certified turbine models suited for such conditions in the current market.

- Only a **handful of turbines explicitly rated for Category A** (**0.16 turbulence intensity**) are currently available—most notably from Suzlon, Pioneer Wincon, Siva, and Vestas.

- A large number of **utility-scale, modern turbines** (**3–5 MW range**) fall into **Class S**, this suggests manufacturers are focusing more on flexible 'site-specific,' designs.

- Many of the turbines with 0.16 turbulence intensity are relatively **low capacity** (**sub-1 MW**), such as Siva 250 kW, Pioneer Wincon 750 kW models — underscoring how most **high-capacity models** (**≥2 MW**) are not yet fully suited for India's Category A zones at scale.

The manufacturing challenge

Critical manufacturing gap in high-turbulence turbines

India's wind energy sector faces a significant manufacturing bottleneck that threatens repowering potential. Most RLMM-certified turbines are designed exclusively for turbulence intensities of 0.12 and 0.14, creating a conspicuous absence of models capable of operating in 0.16 turbulence environments. This gap is particularly problematic for India's prime wind sites, especially dense installations in Tamil Nadu's and Gujarat's Class I zones, which exhibit high turbulence characteristics requiring turbines with enhanced structural robustness and specialized rotor configurations. The manufacturing deficit directly limits repowering project effectiveness in India's most resource-rich wind corridors, preventing full utilization of exceptional wind resources available in these challenging operating environments.

Urgent need for OEM innovation and market response

Original equipment manufacturers must urgently develop and certify turbines specifically engineered for Class I, Category A conditions with turbulence intensity ratings of 0.16. These high-wind, high-turbulence environments demand turbines incorporating advanced materials, sophisticated control systems, reinforced structural designs, optimized aerodynamic profiles, and enhanced fatigue resistance capabilities. The current RLMM limitations highlight the critical need for expanded domestic and international OEM participation in developing robust, certified turbine models suitable for extreme operating conditions. This manufacturing gap represents both a critical constraint and significant market opportunity, requiring immediate OEM attention to unlock India's full wind energy potential through successful repowering initiatives.

Table 4: Manufacturing mismatch — insights from stakeholder discussions

Issues	Collected perspectives
High turbulence tolerance missing in RLMM	The RLMM has limited models certified for high-turbulence Category A conditions, leaving a supply gap. Most available turbines cannot withstand the 0.16 turbulence intensity typical of these locations.
Cost of turbine development	Developing turbines for Category A conditions demands significant R&D, advanced engineering, and rigorous testing through Site Suitability Assessments (SSA) and Mechanical Load Assessments (MLA). However, OEMs are hesitant to invest, citing limited global market demand to offset the high development costs.
Lack of high-resolution data	To accelerate turbine certification and manufacturing tailored for high-stress environments, the National Institute of Wind Energy (NIWE) must urgently undertake on-site wind measurements at 120m and 140m hub heights across all identified Category A sites. Without this high-resolution data, OEMs face barriers in turbine design, certification, and deployment.
Limited support for components	Accelerate certification of turbine platforms for Class I conditions, while extending PLI schemes or R&D grants to support high-turbulence turbine development. Expand PLI to cover OEMs, component, and sub-component makers, and incentivize technology for repowering.

Source: Based on the inputs from the roundtable, *Addressing Current Risks in Wind Repowering* held on 25 June, 2025

Analysis

On 25 June, 2025, a roundtable on, 'Addressing Current Risks in Wind Repowering,' convened 25 of India's foremost wind energy experts and industry leaders to tackle the sector's most pressing challenges. The discussion brought together some of the most crucial organizations shaping India's renewable energy future — including experts from manufacturing sectors such as Senvion, Suzlon, Envision Energy, Strat MRO, Pioneer Wincon, Adani New Industries, and Indian Wind Turbine Manufacturers Association (IWTMA). The discourse brought to light some critical bottlenecks in India's manufacturing sector.

While most modern turbines are designed for sites with relatively low turbulence (in the range of 0.11 to 0.14 turbulence intensity), the reality in many Indian wind sites — particularly those designated as Category A locations — is quite different. These sites often experience much higher turbulence, closer to 0.16, creating a significant mismatch between the technology available in the market and the actual conditions on the ground.

This mismatch creates a clear supply-demand gap that experts identified as one of the biggest risks to the success of repowering projects particularly in Category A sites. India's Revised List of Models and Manufacturers (RLMM) currently includes very few turbines certified for high-turbulence, Category A conditions. As a result, developers looking to repower aging projects in these high-wind, high-turbulence sites have very limited technology options to choose from. When we look closer at the turbine data, it becomes clear why this gap exists—only a handful of manufacturers, such as Pioneer Wincon and SIVA, currently offer turbines rated for 0.16 turbulence intensity. The majority of turbine models offered by the largest OEMs, including Senvion, Envision, Vestas, Suzlon, Siemens Gamesa and Adani are designed for sites with lower turbulence levels and more common globally.

The economic challenge behind this shortage of suitable turbines is also significant. Designing and manufacturing turbines capable of withstanding higher turbulence is a much more demanding process. It requires advanced engineering solutions, and rigorous mechanical load and site suitability assessments at the certification stage. However, OEMs have so far been cautious about making such investments, as the domestic market for high-turbulence turbines are limited.

Experts at the roundtable also highlighted a key data gap that is making this challenge even harder to address. The National Institute of Wind Energy (NIWE) has not yet conducted detailed wind measurements at the actual hub heights of today's modern turbines — typically 120 to 140 meters — at all identified Category A sites. Without high-quality, high-resolution wind and turbulence data at these heights, OEMs cannot design and certify turbines that are truly optimized for these challenging site conditions.

To overcome these barriers, participants proposed a set of regulatory and financial measures. They recommended that certification processes for turbine platforms designed specifically for Class I, high-turbulence conditions should be accelerated to bring more options into the market quickly. They also called for extending India's Production Linked Incentive (PLI) schemes and research grants specifically to support the development of such turbine platforms. Importantly, they suggested that PLI coverage should not stop at OEMs but should also include component and sub-component manufacturers. This recognizes that addressing such challenge requires strengthening the entire supply chain ecosystem—from advanced materials and control systems to specialized components—which are critical for enabling effective and commercially viable repowering projects in India's most wind-rich, but technically demanding sites.

WIND REPOWERING POLICY COORDINATION GAPS

Wind repowering policy coordination gaps India's wind repowering sector is facing a serious policy gap that is holding back progress on its renewable energy goals. Despite having over 25 GW of repowering potential locked in ageing wind turbines, the lack of consistent policies across key states—Tamil Nadu, Karnataka, Gujarat, and Maharashtra—is limiting investment and slowing the transition towards the national target of 500 GW renewable energy capacity by 2030.

Among these states, Tamil Nadu is the only one that has taken concrete steps towards repowering. In 2024, it introduced a dedicated policy that mandates repowering for all wind turbines older than 20 years, regardless of their size. The state has also set up a dedicated agency, the Tamil Nadu Green Energy Corporation Limited, to streamline approvals. It allows developers to combine wind and solar components in the same project, bank up to 50% of their energy, and continue with their existing power purchase agreements (PPAs).

Karnataka, by contrast, does not have its own repowering policy and instead relies on the Ministry of New and Renewable Energy's (MNRE) 2023 guidelines. This approach leaves several gaps, as the state does not offer its own incentives or support mechanisms. While repowering is allowed for turbines under 2 MW, the lack of state-level backing means developers are often left without the necessary infrastructure or financial clarity to proceed.

Gujarat's stance is even more limiting. It permits repowering only for turbines with a capacity of 1 MW or less. There is no state-specific policy, and repowering is treated under general renewable energy guidelines. This creates a lack of clarity and structure—there are no dedicated incentives, no clear project approval mechanisms, and no formal support for grid integration.

Maharashtra lags the most. Its 2015 renewable energy policy does not mention repowering at all. With no formal guidelines, incentives, or institutional framework, developers are left in the dark about how to proceed. The absence of state policy effectively shuts the door on repowering projects altogether.

One of the core challenges is the differing definitions of project eligibility across states. Tamil Nadu focuses on turbine age, requiring repowering for all machines older than 20 years. Karnataka uses a size-based definition and only covers turbines below 2 MW, while Gujarat sets the bar lower at 1 MW. Maharashtra has no criteria at all, resulting in complete policy ambiguity.

Performance requirements also vary widely. Tamil Nadu expects repowering projects to generate at least 1.25 times more energy, and even refurbished turbines must deliver a 1.1 times improvement. Karnataka sets the bar even higher at 1.5 times, while Gujarat and Maharashtra have not specified any performance standards, making it difficult to measure project effectiveness.

Financial frameworks are another area of disparity. Tamil Nadu charges a development fee of 30 lakh per MW, whereas the other states impose no such charges. This leads to uneven project costs and distorts market competition, as investors face very different financial requirements depending on the state.

The classification of project types adds further confusion. Tamil Nadu distinguishes between standalone repowering, group-based efforts, and life-extension projects. Karnataka follows the MNRE model but interprets

life-extension projects differently. Gujarat and Maharashtra, lacking any definitions, offer no guidance at all, leaving developers unsure about what qualifies and what does not.
PPAs—critical for revenue certainty—are also handled differently. Tamil Nadu permits developers to retain and extend their existing PPAs after repowering. Karnataka provides partial continuity through MNRE guidelines. Gujarat, however, relies entirely on competitive bidding with no contractual guarantees, while Maharashtra provides no PPA framework at all.

Administrative systems vary just as much. Tamil Nadu has streamlined the entire process through a single nodal agency with defined timelines and online application systems. Karnataka divides responsibilities between two agencies, which can create confusion. Gujarat depends on the Gujarat

Energy Development Agency (GEDA), but its process lacks proper documentation and clarity. Maharashtra has no dedicated agency or approval system for repowering. Grid connectivity support is also inconsistent. Tamil Nadu helps developers upgrade to higher voltage connections with active support from the state transmission utility. The other states do not offer similar assistance, making technical integration more difficult and expensive.

Tamil Nadu is the only state that allows wind-solar hybridisation within repowering projects and permits energy banking—both of which improve financial viability. These features are missing from the other three states' approaches, despite their growing importance for developers and utilities alike. Perhaps the most fundamental issue is the complete lack of coordination among states. There are no shared data systems, no joint discussions, and no attempts to align repowering efforts. This siloed approach is inefficient and undermines national progress. Repowering is not just a state-level concern; it affects the entire grid, national targets, and overall energy planning.

The consequences of this policy fragmentation are serious. Investors face uncertainty and inconsistent regulatory requirements, making it difficult to scale projects or deploy capital efficiently. Developers must adapt to different rules, costs, and procedures in each state, which drives up costs and slows down implementation. Without coordination, India risks leaving high-potential wind sites underutilised—squandering a major opportunity to scale up renewable power quickly. To fix this, a few urgent steps are needed. First, states should agree on common eligibility criteria, whether based on turbine age or size. This would create predictability and make it easier for developers to plan. Second, performance benchmarks should be standardised—setting a uniform target of 1.25 to 1.5 times improvement would provide a clear signal about the expected benefits of repowering.

Financial frameworks also need to be harmonised. States should either all apply similar development fees or eliminate them altogether. Approvals should be managed through a single-window system in each state with a clear 45-day decision period. States must also provide technical and financial support for grid upgrades to ensure smooth integration.

An inter-state coordination body is urgently needed. It could facilitate the sharing of best practices, track progress, and push for harmonisation. All states should allow wind-solar hybrids and energy banking, which would improve the financial and technical feasibility of repowering. Additional incentives—beyond the central government's modest interest subsidies—could help attract more private investment.

Finally, setting clear implementation deadlines—say 18 to 24 months per project—would prevent delays and ensure new capacity comes online in a timely manner.

3
ALIGNING TRANSMIS-SION SYSTEMS

HIGHPOINTS

Early 11 kV evacuation systems (built for 200–600 kW turbines), designed for small 200-600 kW turbines, are inadequate for 1.5–2 MW+ repowered capacity.

Upgraded turbines overload legacy systems, causing power losses, voltage instability, and equipment stress.

Many wind clusters lack essential components for handling repowered capacity, including high-capacity pooling substations (33/110 kV or 66/220 kV), pooling substations, SCADA, smart relays, and proper grid planning.

High upgrade costs, unclear policies on approvals and cost-sharing, and forced curtailment reduce revenue and undermine viability.

Wind energy repowering represents a critical strategy for maximizing renewable energy generation from existing sites by replacing older, smaller turbines with modern, higher-capacity units. However, this transition faces a fundamental challenge: the existing transmission infrastructure was designed for the technological and capacity limitations of earlier wind turbine generations. The mismatch between upgraded generation capacity and outdated evacuation systems creates significant bottlenecks that threaten the economic viability and technical success of repowering initiatives.

The infrastructure mismatch problem

Historical context

Early wind farms were developed with transmission infrastructure designed for smaller turbines, typically ranging from 200 kW to 600 kW capacity. These systems utilized lower voltage evacuation networks, commonly 11 kV feeder systems, which were adequate for the power outputs of first-generation wind technology. The infrastructure was sized and configured based on the technical requirements and economic constraints of that era.

Modern wind turbines, however, have evolved dramatically in scale and efficiency. Current repowering initiatives often involve installing turbines with capacities of 1.5–2 MW or higher. This technological leap creates fundamental incompatibility with existing transmission systems.

Technical constraints

The primary technical challenge stems from the current-carrying limitations of lower voltage systems. When higher-capacity turbines feed power into networks designed for smaller generators, several critical issues emerge:

I. **Current overload**: Higher power generation translates to increased current flows through existing conductors. Legacy 11 kV systems may lack adequate current-carrying capacity to handle these increased loads without risking thermal damage or safety violations.

II. **Voltage regulation problems**: Increased current flows cause greater voltage drops across transmission lines, potentially creating voltage quality issues that affect both wind farm operation and grid stability. These problems become particularly acute during high wind periods when repowered turbines operate near rated capacity.

III. **Power loss inefficiencies**: Transmission losses increase exponentially with current levels. Higher power flows through lower voltage lines result in disproportionately higher energy losses, reducing the economic benefits of repowering and wasting renewable energy resources.

IV. **Equipment ratings**: Existing switchgear, protection systems, transformers, and control equipment were rated for original capacity levels. Repowering may exceed these ratings, requiring comprehensive equipment replacement or modification.

Economic and policy implications

I. Investment risks

The infrastructure upgrade requirements create substantial economic implications for repowering projects. Wind farm owners face uncertainty regarding technical requirements, approval processes, and financial responsibilities for transmission upgrades. Without clear regulatory frameworks, investment risks increase significantly, potentially deterring participation in repowering programs.

The capital requirements for upgrading transmission infrastructure can be substantial. Moving from 11 kV to 33 kV systems, for example, requires replacement of conductors, switchgear, protection systems, and potentially substation equipment. These costs must be factored into repowering economic analyses and may affect project viability.

II. Revenue and regulatory gaps

Infrastructure constraints in repowering projects lead to direct economic losses as limited evacuation capacity forces operators to curtail generation, reducing revenue and undermining returns on investment. This not only wastes valuable renewable energy but also runs counter to clean energy targets. Compounding the problem, existing policies often overlook the critical need for transmission upgrades. Ambitious repowering goals are rarely matched with clear guidelines on infrastructure requirements, cost-sharing, and approval processes, creating regulatory uncertainty. Such gaps increase investment risks for developers and pose significant barriers to realizing the full potential of repowering initiatives.

Critical missing elements in current approaches

I. Protection system compatibility

Legacy protection systems designed for smaller turbines may not adequately protect higher-capacity installations. Modern turbines have different fault characteristics, requiring upgraded protection schemes that can coordinate with both new and existing equipment. This includes considerations for fault current levels, protection sensitivity, and coordination with upstream protection devices.

II. Aging infrastructure reliability

Many existing wind farms operate with transmission infrastructure that is 20–30 years old, approaching end-of-life. Beyond capacity constraints, reliability concerns emerge as aging equipment becomes more prone to failures, creating additional operational risks for repowered installations with higher capital investments.

III. Load flow and power quality issues

Repowering can significantly alter power flow patterns in regional networks. Higher generation concentrations may cause reverse power flows, voltage fluctuations, and harmonic distortions that existing infrastructure wasn't designed to handle. These power quality issues can affect neighbouring installations and grid stability.

Table 5: Transmission infrastructure challenges—stakeholder perspectives

Issues	Collected perspectives
Inadequate evacuation capacity of legacy feeders	— The majority of aging wind farms are still connected to 11 kV and 33 kV feeders, originally built for small, sub-megawatt turbines. — These low-voltage lines cannot efficiently handle the much higher capacities expected from repowered clusters with modern 2–3 MW turbines. — The result is technical inadequacy, higher line losses, frequent overloading, and poor power quality, limiting the effective utilization of repowering investments.
Need for systemic upgrade of grid voltage levels	— Although minor capacity increases (~50 per cent) are possible within existing 11/33 kV networks, fully realizing the potential of repowering requires upgrading feeder voltages to 33/66 kV and reinforcing downstream infrastructure. — Without such upgrades, the grid becomes a bottleneck that constrains repowering output and undermines grid stability.
Absence of modern pooling substations	— Many clusters lack high-capacity, centralized pooling substations (33/110 kV or 66/220 kV) needed to efficiently collect and transmit increased power from repowered sites. — The lack of such substations also hampers the ability to implement smart control systems and integrate repowered generation into the wider grid effectively.
Lack of advanced monitoring and control systems	— Critical SCADA systems, smart protection relays, and dynamic voltage/reactive power controls, essential for real-time monitoring and compliance with modern grid codes, are largely absent in older clusters. — This makes the system prone to faults, inefficient operation, and voltage/reactive power imbalances, jeopardizing grid stability as capacities increase.
Weak grid integration planning and oversight	— Existing substations are often isolated and not configured in ring-main or LILO arrangements, reducing operational flexibility and increasing outage risks. — Enforcement of updated grid code compliance and telemetry integration with SLDCs remains insufficient, leaving system operators blind to dynamic conditions at repowered clusters.

Source: Based on the inputs from the roundtable, *Addressing Current Risks in Wind Repowering* held on 25 June, 2025

Analysis

The insights are based on a roundtable on 'Addressing Current Risks in Wind Repowering,' that took place on 25 June, 2025. The event brought together independent power producers, developers and other experts such as Serentica Renewables, ReNew Energy, TÜV Rheinland, RE4Climate, Vayulo Energy, WRI India, and the Wind Independent Power Producers Association (WIPPA).

The discussions revealed a fundamental infrastructure mismatch that creates what we might call an 'electrical bottleneck,' problem in wind repowering projects. To understand this challenge, imagine trying to pour water from a large bucket through a narrow straw. The repowering process essentially replaces many small buckets with fewer, much larger ones, but the straws connecting them to the main system remain the same narrow size they were decades ago.

The problem begins with feeder capacity: upgraded turbines strain the outdated lines, leading to power losses as heat, degraded quality, and potential equipment damage. In short, while the new turbines are efficient, the existing grid simply can't support their full output.

Experts recommend systematically upgrading feeders to 33 kV or 66 kV, along with strengthening transformers and protection systems. Without these investments, repowering could undermine grid stability rather than enhance it.

Another gap is the lack of modern pooling substations. These act as collection points, consolidating power from multiple turbines before sending it to the main grid. Many older wind clusters lack high-capacity substations at 33–110 kV or 66–220 kV levels. Without these, it's difficult to manage the larger, more variable output of repowered sites or to integrate them smoothly into the wider grid.

Monitoring and control systems are also outdated or missing. Modern wind farms rely on systems like SCADA, smart relays, and voltage controls for real-time monitoring and grid code compliance. These are essential for balancing loads and ensuring reliability, but they are largely absent in older clusters.

Finally, the grid itself needs better planning and configuration. Many substations operate as isolated nodes rather than interconnected networks, increasing outage risks. Updated grid codes and better telemetry with state control centres are also needed to monitor and manage these higher capacities effectively.

The takeaway is clear: repowering cannot succeed through upgrading turbines alone. The entire electrical system—feeders, substations, controls, and grid integration—must be upgraded in a coordinated way. Without this, repowering risks falling short of its potential to support India's clean energy goals.

CASE STUDY: TAMIL NADU'S MUPPANDAL WIND COMPLEX

Tamil Nadu's Muppandal region provides a compelling illustration of these challenges. As India's largest onshore wind farm installation with approximately 1,500 MW capacity, the region faces critical infrastructure bottlenecks that threaten repowering initiatives.

The existing 11 kV power evacuation system, established during initial development phases in the 1980s and 1990s, cannot adequately handle the higher outputs of modern turbines. The current infrastructure includes twelve feeder circuits serving approximately 241 wind generators producing 55.9 MW through two 25 MVA transformers commissioned in the mid-1990s.

It indicates that upgrading to minimum 33 kV capacity is critical for effective power evacuation. However, this requires comprehensive replacement of switchgear, protection systems, transformers, and control equipment, along with physical infrastructure modifications.

The case demonstrates how the absence of coordinated planning between generation enhancement and transmission development creates implementation challenges. Without clear regulatory frameworks and upgrade guidelines, wind farm owners face substantial uncertainty regarding technical requirements and financial responsibilities.

110/11KV MUPPANDAL SUBSTATION LOAD DETAILS

SL No	Name of Feeder	System Voltage	No of WEGs	Connected Load (MW)
	Power Transformer No. I	110/11 kV	119	29.575
1	Kannanaloor Feeder	11 kV	20	4.8
2	Jeyajothi Feeder	11 kV	28	7.6
3	Lakshmi Feeder	11 kV	17	4.025
4	Texmo Feeder	11 kV	17	4.4
5	BBTC Feeder	11 kV	6	1.4
6	MEPCO Feeder	11 kV	10	2.5
7	Muthoot Feeder	11 kV	20	4.625
8	Kavalkinaru Feeder	11 kV	1	0.225
	Power Transformer No. III	110/11 kV	121	29.45
9	Gomathi Feeder	11 kV	17	4.375
10	Ramco Feeder I	11 kV	20	5.275
11	Ramco Feeder II	11 kV	23	5.475
12	Windfarm Feeder I	11 kV	17	4.775
13	Windfarm Feeder II	11 kV	20	4.05
14	SIV Feeder	11 kV	23	5.3
15	SS Bay	—	1	0.2
	Total: 240 WEGs, 59.025 MW			

Source: 110/11KV Muppandal Substation, SS No. 5904

4

MOBILIZING INVEST-MENTS FOR WIND RE-POWERING SUCCESS

HIGHPOINTS

Wind repowering demands high upfront costs, often more than new projects, as it includes turbine replacement and upgrades to foundations, roads, and electrical systems. Returns are less predictable due to site constraints, making financing harder to secure.

Many aging wind projects are owned by small investors who entered early for tax benefits like Accelerated Depreciation. Now, they face low returns, can't compete in today's bidding market, and lack both exit options and tailored financing.

Banks lack tailored loan products and treat repowering as new projects. No performance incentives, pooled financing, or standardised risk tools exist—making funding inaccessible or expensive.

India's wind energy sector faces a clear challenge: although the country has about 25 GW of old wind capacity ready for repowering, the financial support needed to make this happen is still lacking. This funding gap is one of the biggest hurdles to meeting India's renewable energy goals, as it holds back the upgrade of existing wind projects that could produce much more power from the same land area.

Capital intensity conundrum

Wind repowering projects are naturally expensive and need large upfront investments, often beyond what current owners can afford. The financial challenge is bigger because repowering isn't just about swapping turbines—it also involves major site upgrades that can cost more than building a new project. Modern turbines, though more efficient, need stronger foundations, wider roads for bigger components, and improved electrical systems to handle more power.

The return on investment for repowering is also less predictable than for new projects. New projects benefit from picking ideal sites and designs, but repowering has to work within existing site limits, which can reduce potential returns. This mismatch between what banks expect and the real economics of repowering makes it hard to get suitable financing.

On top of that, it's hard to value the old assets. Unlike in other industries where equipment has clear depreciation timelines, many wind turbines in India run past their expected life, making it tricky for owners and buyers to agree on their worth. This uncertainty makes it harder to design financing that fits the complex process of upgrading old projects.

Retail investor financial trap

A large part of India's old wind capacity is owned by small, individual investors who entered the sector in its early days, drawn by attractive tax benefits like the Accelerated Depreciation (AD) scheme. Today, many of these investors are stuck — their aging projects don't earn enough to justify new investment, yet they also have no easy way to sell and exit.
The end of the AD scheme has changed the investment picture for these owners. Without the tax breaks that made wind projects appealing earlier, they now face high costs and uncertain returns if they want to reinvest.

This problem is worse because small investors, despite holding much of the repowering-ready capacity, are effectively shut out of today's market. Competitive bidding favours big developers with lower costs, and small investors can't compete.

At the same time, there are no feed-in tariffs or guaranteed PPAs tailored to repowering, leaving buyers and sellers without a clear way to transact.

Industry feedback shows that investors under old PPA regimes have little interest in reinvesting or owning new wind assets. This isn't because they don't see the benefits of repowering, but because the current financial system doesn't make it worthwhile for them.

Regulatory barriers to financial viability

The current regulatory system adds to the financial challenges faced by repowering projects. A major issue is that grid evacuation approvals—which allow a project to connect to the power grid—cannot currently be transferred. This creates a serious barrier when existing owners, especially small investors, want to sell their aging wind projects. New developers who purchase these projects cannot inherit the grid connection and instead have to apply for new approvals.

This restriction forces developers to go through complex and lengthy approval processes for fresh evacuation capacity, adding significant time, cost, and uncertainty to repowering projects. The inability to sell projects along with their existing grid rights makes these assets less attractive to buyers, reducing demand and slowing investment in repowering.

The inconsistent and fragmented policies across different states further complicate the financial picture. Open access policies, which are intended to allow projects to sell power to third-party consumers, are often unpredictable and change frequently. Unclear and shifting charges under these policies have made many third-party sale agreements unreliable, creating uncertainty about future revenues and discouraging long-term investments in repowering projects.

Another key concern is that open access charges are often designed with the goal of protecting the financial interests of distribution companies (DISCOMs), rather than creating a level playing field for renewable energy development. These high and inconsistent charges add yet another layer of financial risk, making repowering projects harder to justify economically and harder to finance.

Market structure and financing instrument gaps

The current market lacks tailored financial products for repowering projects. Traditional project finance models do not suit the unique challenges of repowering, which involves replacing old assets, modifying sites, and working with existing infrastructure. Without dedicated financing options, developers depend on standard mechanisms that fail to reflect the specific risks and cash flow patterns of repowering.

Banks also have limited experience with repowering, often lacking the expertise to assess its risks and design suitable solutions. This gap leads to cautious lending, which can result in poor financing terms or rejection of viable projects.

The lack of performance-based incentives adds another challenge. Unlike new projects with clear benchmarks, repowering must show improvement over current performance, which requires better evaluation methods. Without standardized metrics and benchmarks, structuring performance-linked financing is difficult.

Credit assessment practices are also underdeveloped. Repowering involves complex factors like the condition of existing assets, site limitations, and potential gains, which are not well captured by traditional risk assessment tools. This makes it hard for lenders to properly evaluate and price repowering risks, further limiting access to suitable financing.

Financial risk assessment challenges

Assessing financial risks for repowering projects is challenging due to factors not fully considered in current evaluation methods. Checking the condition of existing assets needs specialized knowledge, which many lenders lack, leading them to make cautious assumptions and charge higher interest rates.

Predicting the performance of repowered projects is also complex. It requires detailed simulation that takes into account site-specific limits, the state of existing infrastructure, and how new technology fits in. The absence of standard methods and reliable benchmarks makes it hard for lenders to judge project viability and set fair financing terms.

Forecasting revenues adds another layer of uncertainty, with shifting policies, unpredictable tariffs, and market changes making it hard to calculate expected earnings and build confidence in repayment ability.

Finally, repowering projects' reliance on existing grid connections, shared systems, and coordination with nearby projects introduces risks that traditional finance models are not designed to handle. These interconnected risks are hard to measure and manage, making repowering projects seem riskier than they may actually be.

Table 6: Financial barriers—feedback from industry discussions

Issue area	Collected perspectives
Inadequate financial instruments and banking support	— Banks do not offer loan products designed for the unique risks and cash flows associated with repowering projects. They treat these as entirely new (greenfield) projects which is not the reality. As a result, risk is seen as too high, and projects often face very expensive loans or outright rejection. Lenders also struggle to assess the value of old turbines and parts, making it hard to accept them as collateral. — The financial sector lacks clear methods to evaluate the specific risks, cash flows, and collateral involved in repowering. Without such frameworks, banks remain cautious, overestimate risks, and are reluctant to lend at reasonable terms.
Fiscal policy and incentive structure gaps	— Taking away incentives like accelerated depreciation has reduced investor interest, especially among small businesses and individual investors who drove early wind power growth. Current tax and subsidy policies treat repowering just like new projects, even though repowering is more complicated. — There are no financial rewards linked to better performance, no GST relief, and no special tax benefits for repowering projects. This lack of targeted fiscal support makes repowering less appealing to investors compared to new wind projects.
Market access and tariff structure limitations	— Competitive auctions shut out small investors, who can't compete with the low prices and large scale of big developers — even though these small owners' control much of the wind capacity that needs repowering. — Current power purchase agreements (PPAs) and tariffs are designed for new projects, not repowered ones. There are no special tariffs or contracts for repowered projects, especially for small owners, leaving them without a clear way to sell power profitably.
Open access policy uncertainty and revenue predictability	— Unpredictable and inconsistent open access charges across states make it hard for investors to forecast revenues. Sudden hikes in these charges have made many third-party power sale deals unprofitable. — Policies are often designed to protect DISCOMs rather than encourage renewable energy. There is no stable, long-term open access policy, which weakens investor confidence and discourages investment in repowering.
Institutional and structural financing barriers	— Small wind farm owners lack collective financing mechanisms to pool resources and share risks, making it hard for them to invest in larger repowering projects. Similarly, there is no structured support for decommissioning old turbines, which adds significant costs and discourages timely upgrades. — On top of this, public sector companies have not stepped in to lead or showcase successful repowering projects, leaving private players to shoulder all the risks alone.

Source: Based on the inputs from the roundtable, *Addressing Current Risks in Wind Repowering* held on 25 June, 2025

Analysis

The explanation draws from the roundtable on 'Addressing Current Risks in Wind Repowering,' that took place on 25 June, 2025, which brought together leading sector experts and consultants from Idam Infrastructure Advisory, Climate Hub, Everrenew, and Windplus Eagle.

This dialogue underscored the urgent and systemic risks facing India's wind repowering ambitions. With insights from some of the most experienced voices in the sector, the discussions exposed critical gaps: Repowering in India is misunderstood by both financiers and policymakers. Repowering is essentially upgrading an existing wind site to produce more energy—much like renovating a house you already live in. But banks and regulators continue to treat it as if it's a brand-new construction. This mismatch has created unnecessary hurdles, making what should be a simple upgrade into a risky and unattractive proposition.

The main issue is financial. Banks assess repowering projects just like new ones, ignoring the fact that these sites already have proven wind resources, existing infrastructure, and steady revenue streams. Because lenders don't have loan products designed for repowering, they often assume higher risk, undervalue the assets, and offer loans at higher rates—which discourages investment.

On top of this, fiscal policies have not kept up. Earlier tax benefits like accelerated depreciation, which helped small investors, have been removed. These small owners still control much of India's older wind capacity — exactly the turbines that need upgrading — yet today's policies do not account for the added costs of dismantling old machines and improving sites.

The current market structure makes things worse. Competitive auctions, which are designed for large developers, leave smaller operators out of the game. Ironically, most of India's repowering potential sits with small owners who can't access the current mechanisms to modernize their projects.

Power contracts and tariffs also don't suit repowering. They are designed for brand-new projects, which have very different economics. Repowering involves both the cost of removing old machines and installing new ones, even though it benefits from better wind and existing infrastructure. Without contracts tailored to this situation, it's hard to show clear profits.

Frequent changes to open access policies—which allow power sales to third parties—further hurt confidence. Investors need stable, long-term revenues, but unpredictable charges and rules make planning difficult.

Finally, there's no clear institutional support. Small owners lack ways to pool resources or share risks, and there is no clear process for dismantling old turbines. Public sector companies, which could have set an example, have not stepped up to lead.

What's clear is that repowering needs a fresh, dedicated approach—with financial products, policies, and institutional support built specifically for its unique challenges. Without this, India risks wasting a big chance to modernize its wind sector and scale up clean energy.

5 CONCLUSION AND RECOMMENDA-TIONS

HIGHPOINTS

Existing 11 kV infrastructure (e.g., Muppandal) is unfit for modern turbines and require urgent upgrades, load flow studies, and coordination by MNRE, CEA, and state utilities.

Legacy grids have high losses, low voltage stability, and insufficient capacity, limiting repowering feasibility.

Unlocking potential requires hybrid models with solar, pooled financing for fragmented assets, PSU involvement, and reformed PPAs to boost confidence and scale.

India's wind repowering sector presents a 25.4 GW opportunity, but progress is hindered by major structural and technical bottlenecks. This technical assessment identifies three key challenges: (1) lack of high-turbulence certified turbines suited for Class I wind sites, (2) inadequate power evacuation infrastructure incapable of supporting modern turbine capacities, and (3) fragmented policy frameworks that fail to coordinate infrastructure, manufacturing, and regulatory planning. Addressing these challenges with an integrated, time-bound strategy is essential to unlock the sector's potential and position India as a leader in wind energy optimization.

Critical Findings

1. Inadequate turbine supply for Class I Sites

India's most productive wind sites—Class I locations in Gujarat and Tamil Nadu developed in the 1990s—experience high turbulence intensity that renders most available turbines unsuitable for repowering. These prime zones, including Muppandal and Radhapuram in Tamil Nadu, and Lamba and Bhogat in Gujarat, host over 10,000 aging turbines requiring replacement.

The manufacturing gap is stark: India currently lacks certified wind turbines suited for high-turbulence Class I Category A sites (0.16 turbulence intensity). Of the 35 turbines listed in MNRE's Revised List of Models and Manufacturers (RLMM), only six are rated for 0.16 turbulence—all under 1 MW capacity and 100-meter hub height. Most available models are certified only up to 0.12 or 0.14 turbulence intensity, making them unfit for repowering legacy high-wind locations where modern 2-3 MW turbines are needed.

2. Incompatible transmission infrastructure

Legacy 11 kV evacuation systems designed for 200-600 kW turbines are technically incompatible with modern 1.5-2 MW turbines. The Muppandal wind complex exemplifies this constraint—241 turbines generating 55.9 MW operate close to evacuation capacity limits. Current-carrying capacity, voltage regulation, and energy losses create serious bottlenecks that undermine repowering feasibility across India's aging wind clusters.

3. Inadequate financial mechanisms

Current financial support structures fail to address repowering's unique challenges. The incentive system lacks targeted provisions for high-turbulence turbine development, transmission upgrades, and fragmented asset consolidation. Wind repowering policies remain highly fragmented across states—Tamil Nadu mandates repowering for projects over 20 years, Karnataka targets turbines below 2 MW, and Gujarat restricts it to 1 MW or less. Performance benchmarks and financial structures vary widely, creating regulatory uncertainty that discourages investment.

Recommendations

1. Turbine technology and manufacturing

Accelerate high-turbulence turbine development Priority must be given to developing, certifying, and manufacturing turbines rated for 0.16 turbulence intensity in the 2-3 MW range with robust structural designs. These high-capacity turbines with taller hub heights must be fast-tracked for inclusion in the RLMM. Adapting proven international turbine platforms can accelerate deployment timelines.

Strengthen manufacturing incentives: Extend and expand production-linked incentive (PLI) schemes to include not only OEMs but also component and sub-component manufacturers. Support original equipment manufacturers through targeted R&D grants to scale up production of robust structural parts required for high-capacity, tall-hub turbines, fostering supply chain resilience.

2. Transmission infrastructure and grid readiness

Establish comprehensive infrastructure planning: All new repowering initiatives must be supported by load flow studies and evacuation system upgrade plans, particularly transitioning from 11 kV to 66 or 33 kV systems in aging wind clusters. A central coordination mechanism involving MNRE, CEA, and State Transmission Utilities must streamline execution.

Prioritize critical infrastructure upgrades: States such as Tamil Nadu, Gujarat, and Karnataka should prioritize infrastructure upgrades, with Tamil Nadu's Muppandal complex serving as a demonstration zone. Issue technical guidelines and standardized cost-sharing models between developers and utilities, alongside single-window clearances for transmission approvals.

3. Financial support and investment mechanisms

Create a national repowering fund: Establish a specialized national fund providing targeted financial support for repowering projects, focusing on both turbine upgrades and transmission infrastructure enhancements. This fund should subsidize capital-intensive activities such as dismantling old turbines and installing taller towers, reducing upfront costs and investment risks.

Implement transparent cost-recovery models: Transmission utilities must adopt clear and standardized cost recovery frameworks reflecting actual system utilization. Introduce charges aligned with grid usage to incentivize utilities to prioritize upgrades critical for repowering. Mandate transparent cost-sharing mechanisms between developers and utilities.

Facilitate preferential debt financing: Financial institutions such as IREDA, REC, and PFC should offer concessional loans with interest rate discounts specifically for repowering projects meeting technical criteria for enhanced turbine performance and grid readiness. A 0.25 per cent interest rate concession can significantly lower financing costs and improve project viability.

Restore accelerated depreciation benefits: Bring back the Accelerated Depreciation (AD) benefit to attract retail investors and small-to-medium enterprises back into the repowering market. The AD scheme would provide immediate tax savings, helping offset high upfront costs and making projects more financially appealing.

Enable cooperative financing solutions: The fragmented ownership of many old wind farms requires innovative financing approaches that combine several small assets into larger, viable repowering projects. Cooperative repowering allows multiple small owners to share infrastructure, use common evacuation systems, and pool finances. Offer special financial packages for the first 2 GW of repowering projects as demonstration pilots.

Promote hybridization opportunities: Adding solar capacity to wind repowering projects offers strong financial solutions to standalone wind project challenges. Hybrid projects can increase overall capacity utilization to 40 per cent or more, improving economics and appeal to developers and lenders. Shared evacuation infrastructure lowers transmission costs per megawatt, while storage enables power supply during peak demand periods at higher prices.

Leverage public-private partnerships: Encourage collaboration between government agencies, transmission utilities, turbine manufacturers, and developers through PPPs to streamline project implementation. Such partnerships can pool technical expertise, share financial burdens, and ensure coordinated upgrades in manufacturing, turbine deployment, and grid infrastructure.

Enable institutional reform: Involve Navaratna Public Sector Undertakings as key players to build market confidence. Their financial strength and public mandate can lead pilot projects demonstrating successful repowering financing models. Allow owners of older PPAs to sign new agreements at reasonable tariffs, with a cap of about 5 MW for feed-in tariffs, giving smaller investors excluded from competitive bidding a pathway to repower their assets.

Annexure

Wind turbine models included in the revised list of models and manufacturers (RLMM) after declaration of new procedure as on 1 May, 2025

S. No.	Manufacturing company	Model name	Rotor Dia (m)	Hub height (m)	Tower type	Capacity (kW)	According to (standards)
1	M/s. Adani New Industries Limited	MWL-160–5.2MW	160	120	Tubular tower	5,200	IECRE Class S, IEC 61400-1 Edition 4.0 2019-02
2	M/s. Adani New Industries Limited	WD147–3000	145.9	100	Steel tubular tower	3,000	IEC 61400-22 Ed. 1.0 & IS/IEC 61400-22 2018-06, Class S, IEC 61400-1:2005+AMD1:2010
3	M/s. Adani New Industries Limited	WD164–3300	163.95	139.73	Tubular steel	3,300	IEC 61400-22 Ed. 1.0 Class S, IEC 61400-1:2005+AMD1:2010
4	M/s. Adani New Industries Limited	MWL-160–5.2MW HYT-140 m	160	140	Hybrid tower	5,200	IECRE Class S, IEC 61400-1 Edition 4.0 2019-02
5	Envision Energy India Private Limited	EN-156/3.3 MW	156	140 / 143	Tubular steel	3,300	IEC 61400-22:2010 Class S
6	Envision Energy India Private Limited	EN-156/3.3 (LM76.5 P and EN 76.5 A V2)	156	120/123/140/143	Tubular steel	3,300	IEC 61400-22:2010 Class S
7	Envision Energy India Private Limited	EN-182-5.0–50 Hz TC	181	105.56	Tubular steel	5,000	IEC 61400-22:2010 Class S
8	GE India Industrial Private Limited	GE 2.7–132	132	130 / 94	Tubular steel	2,730	IEC 61400-22:2010 and IEC 61400-1:2005+AMD1:2010 Class S
9	Suzlon Energy Limited	S111 DFIG 2.1 MW (50 Hz)	111.8	90/120/140	Hybrid lattice/ tubular steel	2100	IEC Class IIIA/ IEC S (IEC 61400-22:2010)
10	Suzlon Energy Limited	S120 DFIG 2.1 MW (50 Hz)	120	105/120/140	Hybrid lattice/ concrete/ tubular	2100	IEC Class S (IEC 61400-22:2010) and IEC 61400-1:2005+AMD1:2010
11	Suzlon Energy Limited	S144-3.0 / 3.15 MW	144	105/140/160	Hybrid lattice/ tubular steel	3000/3150	IS/IEC 61400-22 and IEC 61400-22 WT Class S
12	Suzlon Energy Limited	S133 2.6 MW/ 2.8 MW / 3.0 MW	133	105/140/160	Hybrid lattice/ tubular steel	2600/2800/ 3000	IS/IEC 61400-22 and IEC 61400-22 WT Class S

S. No.	Manufacturing company	Model name	Rotor Dia (m)	Hub height (m)	Tower type	Capacity (kW)	According to (standards)
13	Vestas Wind Technology India Private Limited	V100-2MW 50 Hz VCS Mk10	100	75/80/ 95/100	Tubular steel	2000	IEC Class S (IEC 61400-22:2010)
14	Vestas Wind Technology India Private Limited	V155-3.6 MW	155	102.5/105/ 118/ 120/ 136/137	Conical steel	3600	IS/IEC 61400-22:2010 Class S
15	Inox Wind Limited Inox Towers	DF/2000/113	113	92	Tubular steel	2000	GL 2010, GL Class III A
16	Inox Wind Limited Inox Towers	DF/3000/145	145	100/122.5 /140	Tubular steel	3000 (3300 Power Boost)	IS/IEC 61400-22:2010 Class IIIB
17	Senvion Wind Technology Private Limited	2.3M120–2300kW	120	120	Tubular steel	2300	IEC 61400-22:2010 and IEC 61400-1:2005+AMD1:2010 Class IIIB
18	Senvion Wind Technology Private Limited	2.3M130/2.7MW	130	120/130 /140	Tubular steel	2700	IEC 61400-22:2010 and IEC 61400-1:2005+AMD1:2010 Class S
19	Senvion Wind Technology Private Limited	3.1M130	130	130	Tubular Steel	3100	IS/IEC 61400-22 and IEC 61400-22 Class S
20	Siva Wind Turbine India Private Limited	SIVA 250/50	50	30	4-Legged Lattice Steel Tower	250	IS/IEC 61400-22:2010 Class S
21	Siva Wind Turbine India Private Limited	SIVA 225/40	50	30	4-Legged Lattice Steel Tower	225	IS/IEC 61400-22:2010 Class S
22	Siemens Gamesa Renewable Power Private Limited	G114–2.0MW	114	106/110	Tubular Steel	2000	IEC Class S (IEC 61400-1:2005+AMD1:2010)
23	Siemens Gamesa Renewable Power Private Limited Limited	SG 2.2–122	122	127	Tubular Steel	2200	IEC 61400-22 IEC WT Class S
24	Siemens Gamesa Renewable Power Private Limited	SG 3.4–145	145	127.5/133.5	Tubular Steel	3465	IECRE Class S, IEC 61400-1/A1, 2010
25	Siemens Gamesa Renewable Power Private Limited	SG 3.4–145 (LM 71.0 P2)	145	127.5	Tubular Steel	3465	IECRE Class S, IEC 61400-1/A1, 2010
26	Siemens Gamesa Renewable Power Private Limited	SG 3.6-145	145	127.5/133.5	Tubular Steel	3600	IECRE Class S, IEC 61400-1/A1, 2010
27	Siemens Gamesa Renewable Power Private Limited	SG 3.6–145 (LM 71.0 P2)	145	127.5	Tubular Steel	3600	IECRE Class S, IEC 61400-1/A1, 2010

S. No.	Manufacturing company	Model name	Rotor Dia (m)	Hub height (m)	Tower type	Capacity (kW)	According to (standards)
28	Pioneer Wincon Energy Systems Pvt. Ltd.	PW 750/49/24–61.1m	49	61.1 / 75.3	Lattice Steel Tower	750	IEC 61400-22:2010 and IEC 61400-1:2005+AMD1:2010 Class IIIA
29	Pioneer Wincon Energy Systems Pvt. Ltd.	PW 750/49/24–75m	49.17	61.5 / 75	4-Legged Lattice Steel Tower	750	IS/IEC 61400-22 and IEC 61400-1:2005 Ed. 3 + AMD1:2010 Class IIIB
30	Pioneer Wincon Energy Systems Pvt. Ltd.	PW 750/57–75m-TC	57	75	4-Legged Lattice Steel Tower	750	IEC 61400-22:2010 and IEC 61400-1:2005+AMD1:2010 Class IIIA
31	Pioneer Wincon Energy Systems Pvt. Ltd.	PW750/57-90m–TC	57	90	4-Legged Lattice Steel Tower	750	IEC 61400-22:2010 and IEC 61400-1:2005+AMD1:2010 Class IIIA
32	Sany Wind Energy India Private Limited	SI–16840	166.8	139	Tubular Steel Tower	4000	IS/IEC 61400-22:2010 Class S
33	WEG Industries (India) Pvt Ltd	AGW 147/4.2	147	120	Tubular Steel Tower	4200	Class IIIB, IECRE 61400-1:2019
34	Southern Wind Farms Limited	GWL 225	29.8	48.7	Tubular steel tower (Folded Bolted)	225	IS/IEC 61400-22:2010 and IEC 61400-1 Edition 3.1 dated 2014-04 Class S
35	Powerwind Limited	Power wind 56	56	71	Tubular steel tower (3 Sections)	900	IS/IEC 61400-22 & IEC 61400-1 Ed. 3.1 2014-04, Class IIB

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India's wind energy sector is at a crossroads. Once a global pioneer, the country now faces the pressing challenge of ageing wind infrastructure that limits efficiency and output. From *Facilitating Wind Repowering* explores the urgent need for repowering, replacing old, low-capacity turbines with modern, high-capacity ones, to unlock vast untapped potential in wind-rich states like Tamil Nadu and Gujarat. The report highlights structural barriers that hinder repowering, from fragmented ownership to outdated evacuation systems, and calls for a coordinated, policy-backed response.

This document offers a roadmap to transition from incremental progress to sectoral transformation. With focused recommendations across regulation, finance, manufacturing, and grid planning, it urges decision-makers to treat repowering not just as a technical fix but as a strategic imperative for India's clean energy leadership. By revitalizing its legacy wind assets, India has the opportunity to lead the global south in climate action through a bold, just energy transition.

Centre for Science and Environment
41, Tughlakabad Institutional Area, New Delhi 110 062
Phones: 91-11-40616000 Fax: 91-11-29955879
E-mail: cseindia@cseindia.org Website: www.cseindia.org