REPOWERING WIND FARMS

Maximizing Energy Yield From Existing Site Layouts

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Abbreviations

BEE	: Bureau of Energy Efficiency
CDM	: Clean Development Mechanism
CEA	: Central Electricity Authority
CERC	: Central Electricity Regulatory Commission
COP26	: 26th session of the Conference of Parties
CSE	: Centre for Science and Environment
CUF	: Capacity Utilization Factor
DISCOM	: Electricity distribution company
FDI	: Foreign Direct Investment
FiT	: Feed-in Tariff
FOR	: Forum of Regulators
GBI	: Generation Based Incentive
GW	: Gigawatt
GWEC	: Global Wind Energy Council
INWEA	: The Indian Wind Energy Association
IREDA	: Indian Renewable Energy Development Agency Limited
ISTS	: Inter-state Transmission System
IWEA	: Indian Wind Energy Association
LC	: Letter of Credit
MNRE	: Ministry of New and Renewable Energy
MSME	: Ministry of Micro, Small & Medium Enterprises
MW	: Megawatt
NAPCC	: National Action Plan on Climate Change
NIWE	: National Institute of Wind Energy
OEM	: Original Equipment Manufacturer
PPA	: Power Purchase Agreement
REC	: Renewable Energy Certificate
RPO	: Renewable Purchase Obligation
SECI	: Solar Energy Corporation of India
SLDC	: State Load Dispatch Centres
TANGEDCO	: Tamil Nadu Generation and Distribution Corporation Limited

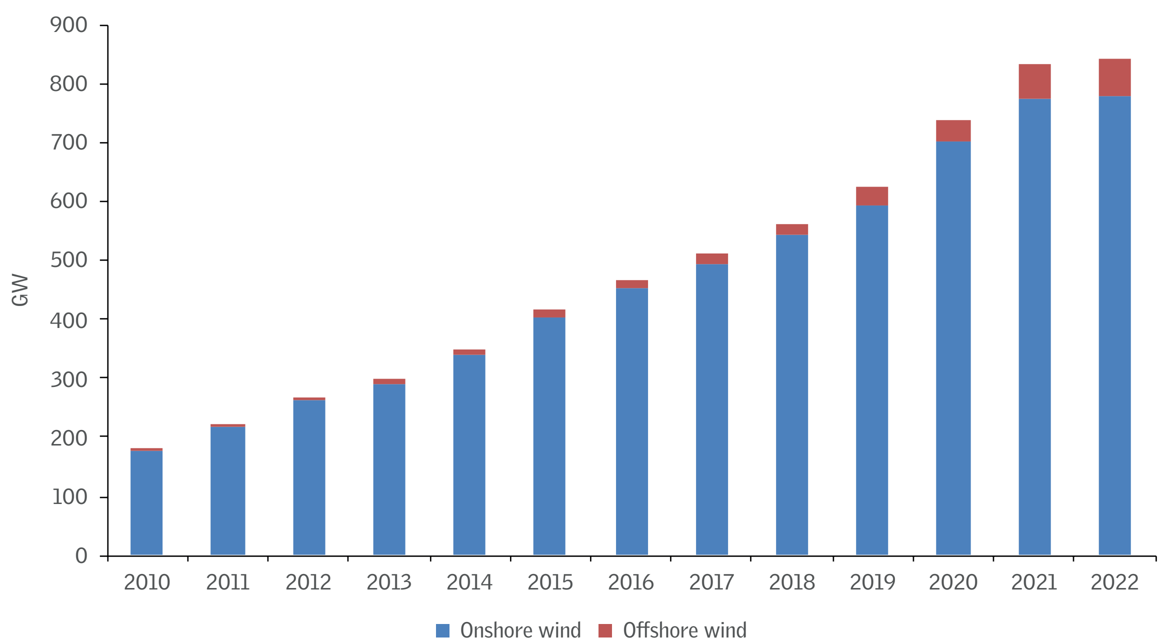
TNEB	: Tamil Nadu Electricity Board
TNERC	: Tamil Nadu Electricity Regulatory Commission
WRPI	: Wind Repowering Project Implementer
WTG	: Wind Turbine Generator

1. Introduction

The world is confronted with pressing energy-related concerns—while fossil fuel combustion is adversely affecting the environment, reliable and secure energy at affordable prices is inaccessible for most. Moreover, fluctuating energy prices and recent geopolitical events have reminded us of the importance of affordable energy for economic development, as well as the vulnerability of the global energy system to supply disruptions. Even as the international community is focused on safeguarding energy supplies, the current pattern of energy consumption carries the threat of severe and irreversible environmental damage, including changes in global climate. A McKinsey report reveals that since the year 2000, the demand for primary energy across the globe has increased at an average rate of 3.7 per cent per year; with the world's population projected to increase to up to 10 billion by 2050, coupled with rising living standards, meeting energy demand would be a major challenge.[1]

While renewables are the only way out of this morass, harnessing the potential of wind energy for grid application is proving to be difficult due to its intermittent nature and the limited number of favourable sites. However, wind is being increasingly used to generate electricity and its application is likely to increase in the future (see *Graph 1: Global wind power capacity in 2022*).

Graph 1: Global wind power capacity in 2022



Source: IEA, 2022

This paper aims to review and analyse the challenges and problems that the wind sector is facing, with the focus on Tamil Nadu. Furthermore, by exploring the issue of repowering in detail, it addresses the ways and means these challenges can be overcome.

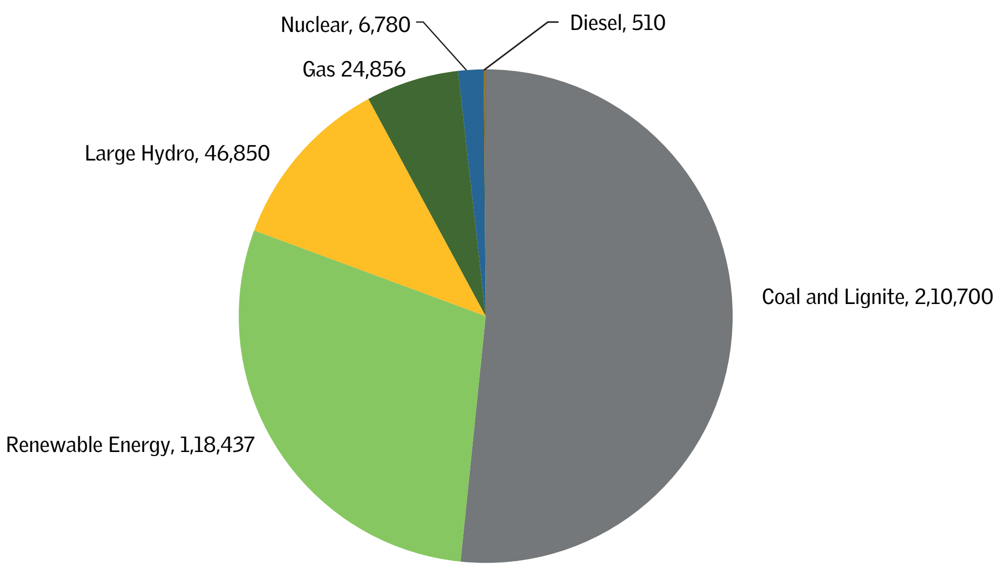
India's renewable energy capacity

As of August 2022, India's installed renewable energy capacity stood at 116 GW, representing 29 per cent of the overall installed power capacity of the country. Power generation from renewable energy sources stood at 171 billion units (BU) in August 2022, just 12 per cent of the overall generation (see *Graph 2: Energy mix of India*).

At COP26, Prime Minister Narendra Modi announced enhanced targets for India to combat climate change. One significant change declared by the PM was that 50 per cent of the installed power capacity target will now be derived from non-fossil sources.

In the following year, on 3 August 2022, the Union Cabinet approved India's updated climate pledge to the Paris Agreement: non-fossil fuel-based energy resources to form 50 per cent of cumulative electric power installed capacity by 2030.

Graph 2: Energy mix of India (MW)

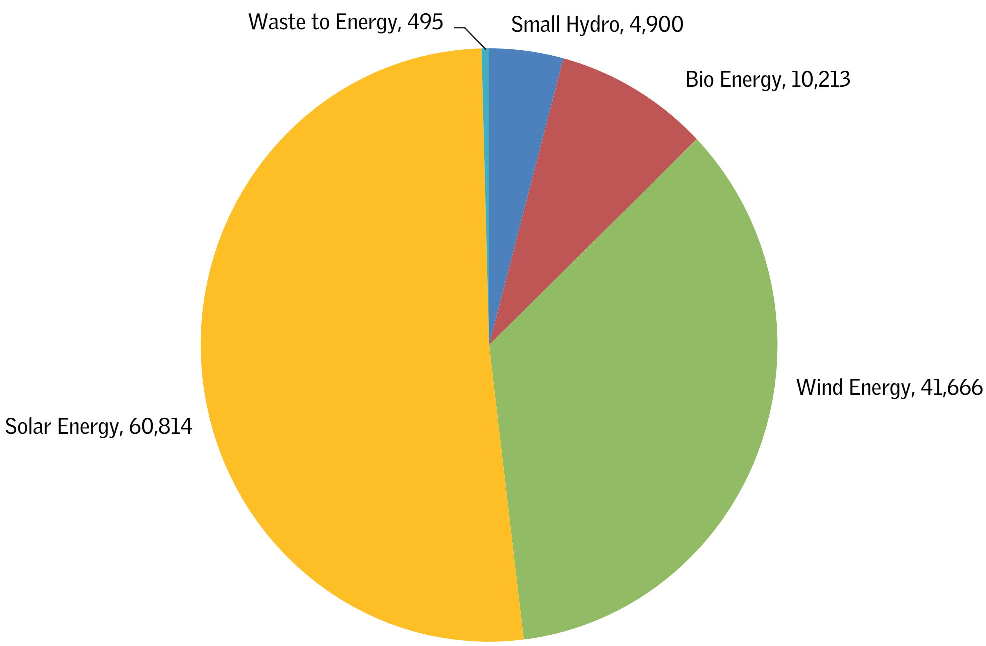


Source: MNRE, Dec 2022

Figure 1: India's low-carbon commitment at COP26

1. Take its non-fossil energy capacity to 500 GW by 2030.
2. 50 per cent of its energy requirements from renewable sources by 2030.
3. Reduce carbon emissions from the total projected emissions by 1 billion tonnes by 2030
4. Bring the economy's carbon intensity down to 45 per cent by 2030
5. Achieve the target of net-zero by 2070

Graph 3: Renewable energy mix of India (MW)



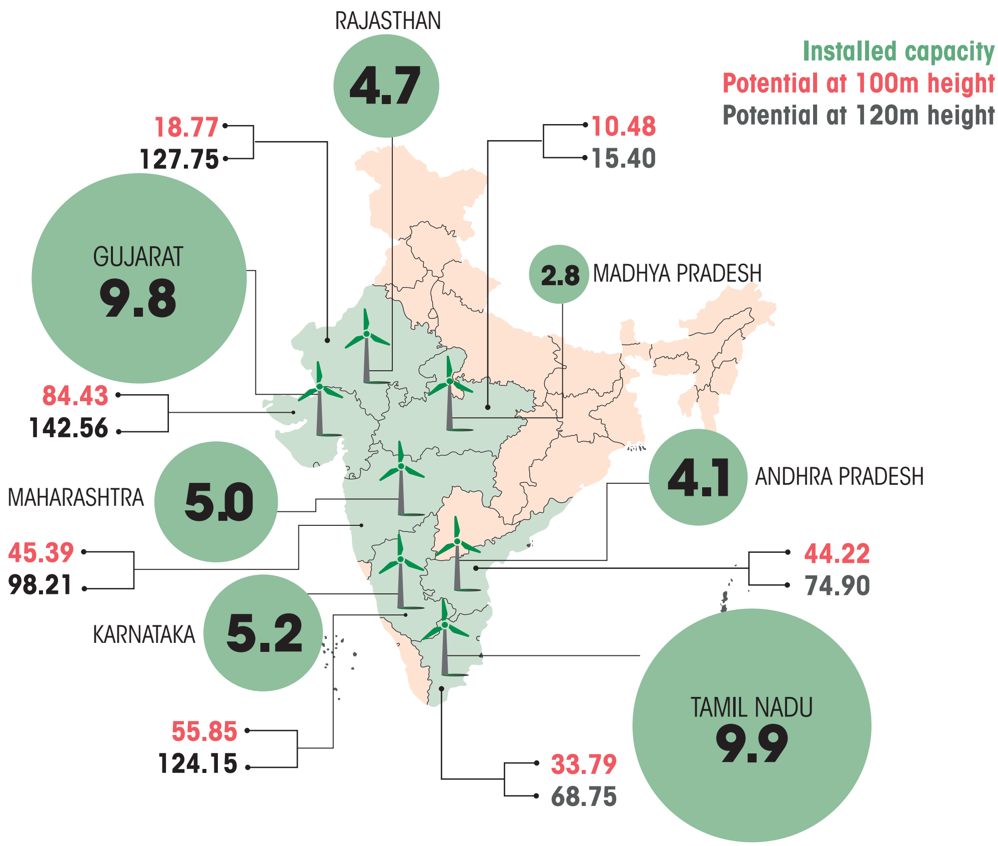
Source: MNRE, Nov 2022

India's wind power capacity

The share of wind power in India's total installed capacity is only 10 per cent. With total power generation at 1,456 BU, wind power accounted for just 5 per cent of electricity generation.

India ranks fourth in the world in terms of installed wind power, with a capacity of 41.6 GW as of November 2022. Tamil Nadu and Gujarat have 25 and 22 per cent of this capacity respectively.

Map 1: Installed capacity and wind potential in seven windy states at a hub height of 100m and 120m (in GW)

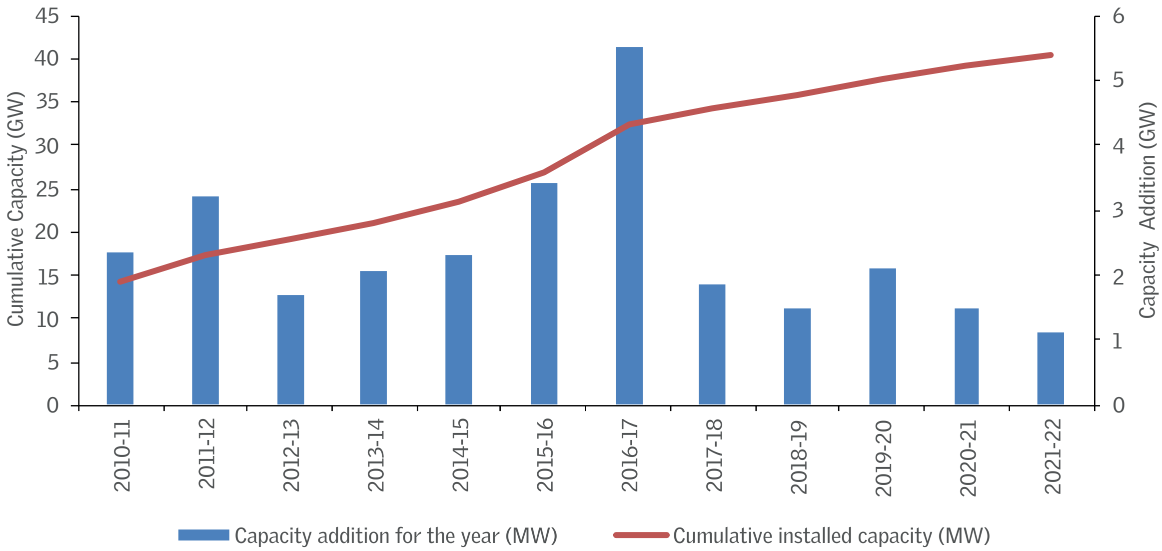


The National Institute of Wind Energy (NIWE) estimates that the country has a wind potential of 302 GW at a hub height of 100 m and 695 GW at a hub height of 120 m above ground level. Most of this potential exists in the seven windy states—Rajasthan, Gujarat, Madhya Pradesh, Maharashtra, Karnataka, Andhra Pradesh and Tamil Nadu.

Installed capacity

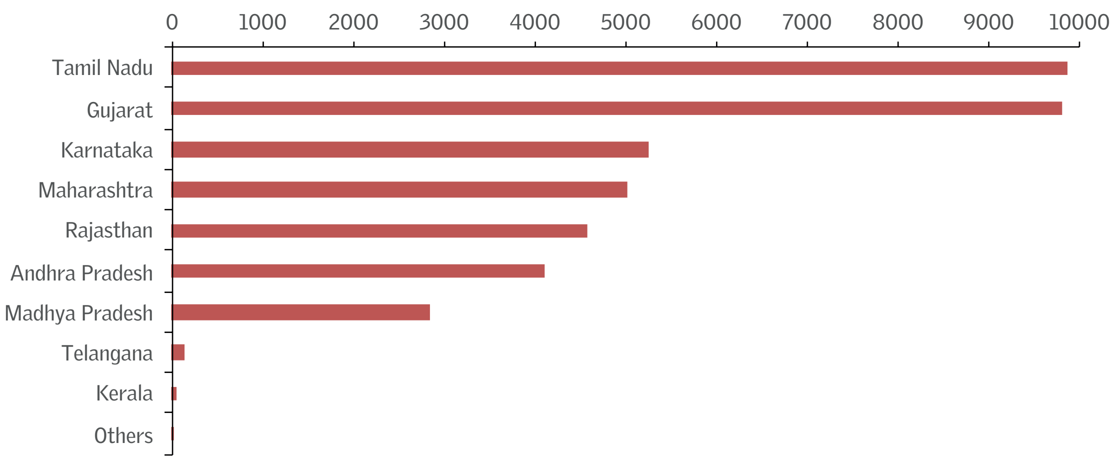
The installed capacity of grid interactive wind power in India in December 2022 was 41.9 GW.

Graph 4: Capacity addition and total installation of wind energy in India



Source: Collated from various reports of the Central Electricity Authority and the Union Ministry of New and Renewable Energy

Graph 5: State-wise installed capacity of wind power (in MW)



Source: MNRE, as on November 2022

INCENTIVES FOR WIND ENERGY SECTOR IN INDIA

The government has initiated several measures to promote renewable energy, including wind energy, in the country. They are:

- Permitting Foreign Direct Investment (FDI) up to 100 per cent under the automatic route
- Waiver of Inter State Transmission Charges for projects commissioned by 30 June 2025
- Declaration of trajectory for Renewable Purchase Obligation (RPO) up to the year 2022
- Assistance to RE developers in setting up ultra-mega renewable energy parks by providing land and transmission services
- Laying of new transmission lines and creating new sub-station capacity for evacuation of renewable energy
- Setting up of project development cells for attracting and facilitating investments
- Standard bidding guidelines for tariff-based competitive bidding, with the aim of procuring power from gird connected solar PV and wind projects
- As per government orders, power shall be dispatched against a letter of credit (LC) or advance payment to ensure timely payment (through distribution licenses) to RE generators
- Organizing development programmes to create a pool of skilled manpower for implementation, operation and maintenance of RE projects

In addition to the above, the following steps have been taken specifically for promoting wind energy:

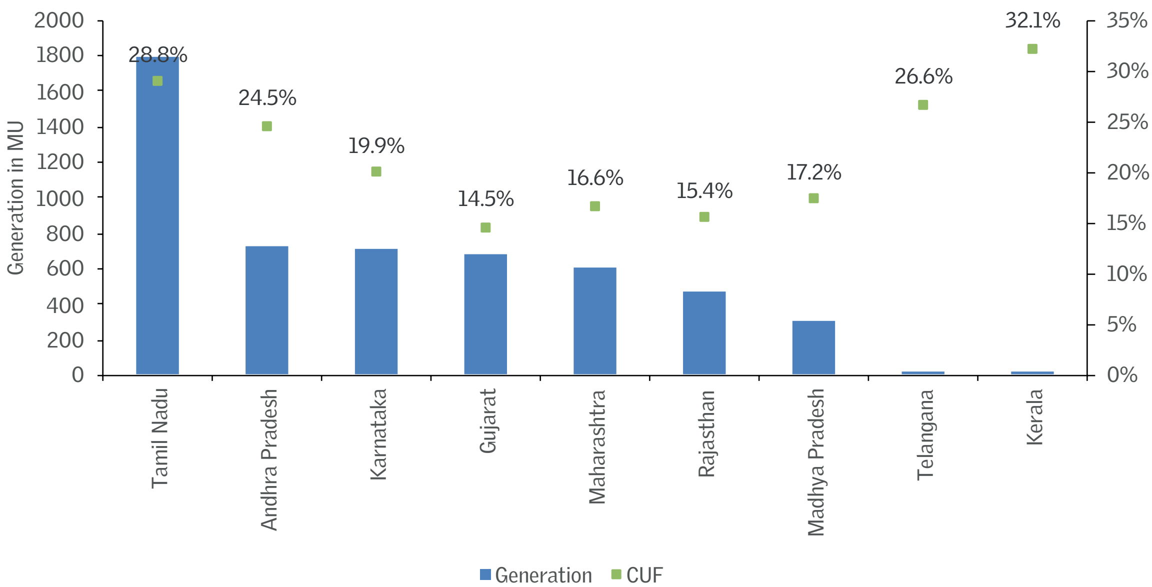
- Concessional custom duty exemption on certain components required for manufacturing wind electric generators
- Generation Based Incentives are being provided to wind projects that were commissioned on or before 31 March 2017
- Technical support, including wind resource assessment and identification of potential sites through the National Institute of Wind Energy, Chennai

Power generation

In September 2022, Kerala had the maximum wind power capacity utilization at 32.1 per cent, followed by Tamil Nadu at 28.8 per cent, Telangana at 26.6 per cent, Andhra Pradesh at 24.5 per cent, Karnataka at 19.9 per cent, Madhya Pradesh at 17.2 per cent, Maharashtra at 16.6 per cent, Rajasthan at 15.4 per cent and Gujarat at 14.5 per cent. An aggregate quantum of 5,315 MU was evacuated, which was 20.5 per cent of the total installed capacity of wind power in the country.

The government set a somewhat modest target for wind energy in India—60 GW by 2022 and 140 GW by 2030. India was unable to fulfil its commitment for 2022—only 41.9 GW was installed by December 2022. For installed wind capacity in the country to increase from 41.9 GW in 2022 to 140 GW by 2030, annual installation of more than 12 GW for the next 8 years would be required. According to CSE's research, the maximum capacity addition over the past decade was 5.5 GW in FY 2016–17 and the last four years have witnessed an average annual capacity addition of about 1.5 GW. Hence, it is essential to revive the growth of India's wind energy industry.

Graph 6: State-wise wind power generation in September 2022



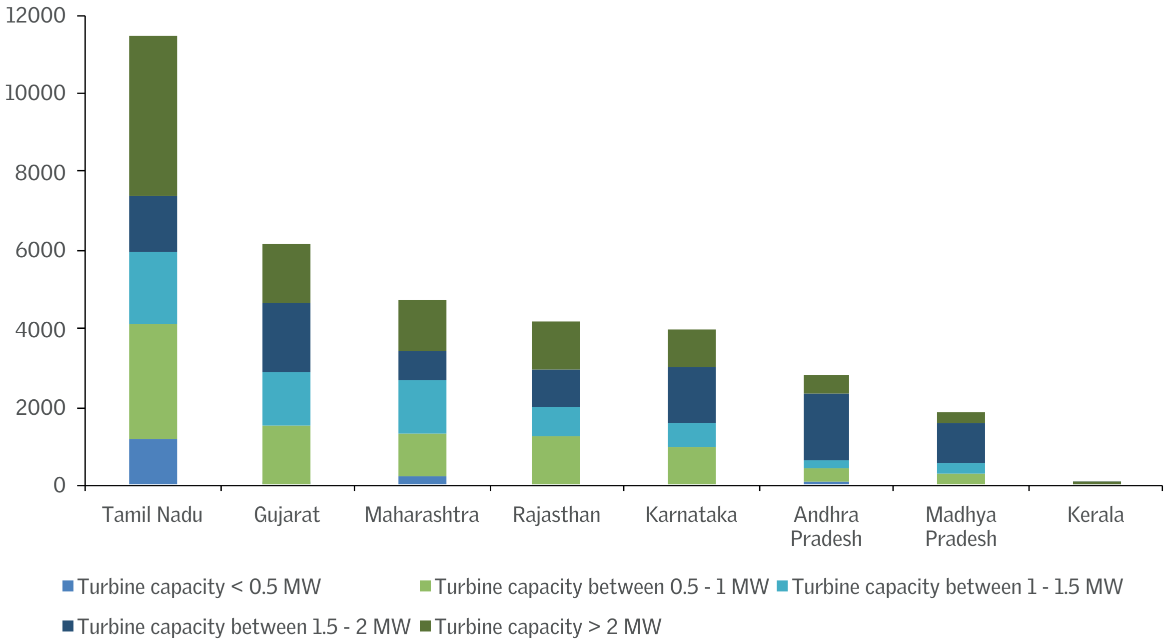
Source: WindPro Issue 10, Vol 10, Indian Wind Power Association

The need for repowering

Wind turbines should be decommissioned once they complete their lifespan, which is about 20 years. If this is not done, they can be hazardous and pose a safety risk. However, there are several old wind farms in India that have completed their 20-year period and continue to run, as they are still profitable to their owners. According to the National Institute of Wind Energy (NIWE), even if only turbines of capacity below 2 MW are considered, the total repowering potential in India is 25.4 GW. States that lead the business opportunity for repowering include Tamil Nadu, Maharashtra and Gujarat (see *Graph 7: Fit for repowering—state-wise break-up of installed wind turbine generators*).

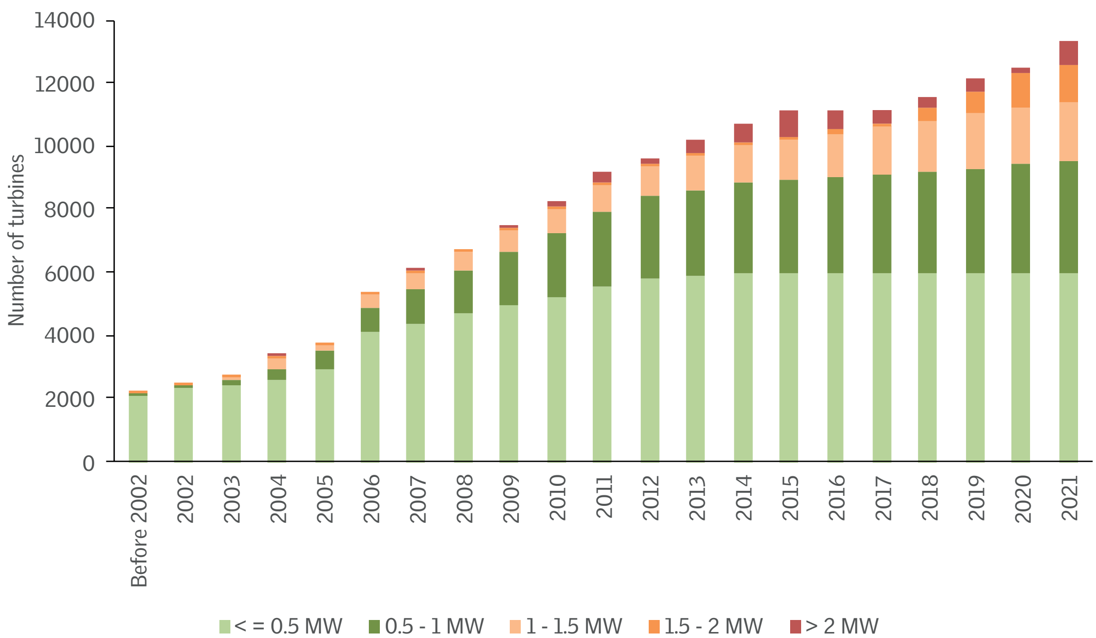
At 9.8 GW, Tamil Nadu has the highest installed wind capacity in the country, which is one-fourth of the total installed wind capacity in the country. With the best wind sites in India, aided by favourable policy by the state government and low off taker risk, Tamil Nadu was one of the earliest states to initiate wind projects. However, most of these projects are still operating with turbines that run on old technology that have low hub height and low capacity. Approximately 3,000 turbines, each of less than 1 MW capacity, and with a cumulative installed capacity of 800 MW, have completed their design life. Therefore, Tamil Nadu is ideally placed to take a lead in the next phase, i.e., repowering. This opportunity in the state is available on a rolling basis (see *Graph 8: Wind turbine profile of Tamil Nadu*).

Graph 7: Fit for repowering—state-wise break-up of installed wind turbine generators (up to Mar 2012)



Source: India Wind Power Directory 2012

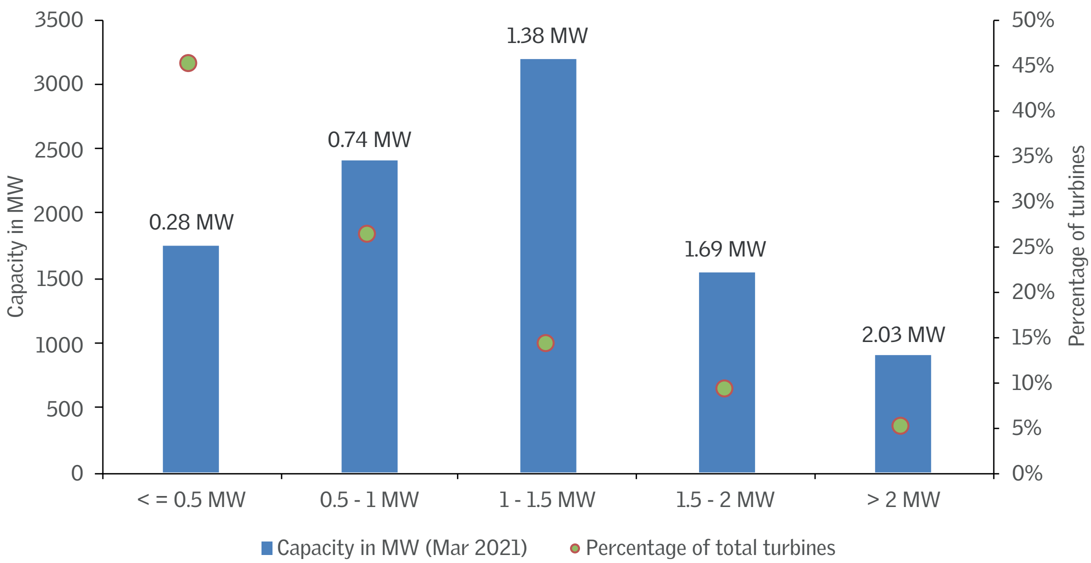
Graph 8: Wind turbine profile of Tamil Nadu (up to Mar 2021)



Source: Indian Wind Power Directory, 2021

In Tamil Nadu, wind turbines have an average capacity of 750 kW. As of March 2021, over 13,000 odd wind turbine generators (45 per cent) were of 500 kW or less in capacity, and another 26 per cent were between 500 kW–1 MW capacities. Together, these smaller turbines account for slightly over half of the total installed capacity (see *Graph 9: Installed wind capacity versus percentage of wind turbines in Tamil Nadu*).

Graph 9: Installed wind capacity versus percentage of wind turbines in Tamil Nadu



Note: Average capacity of each turbine range is mentioned above the bars

Source: CSE analysis

2. Tamil Nadu

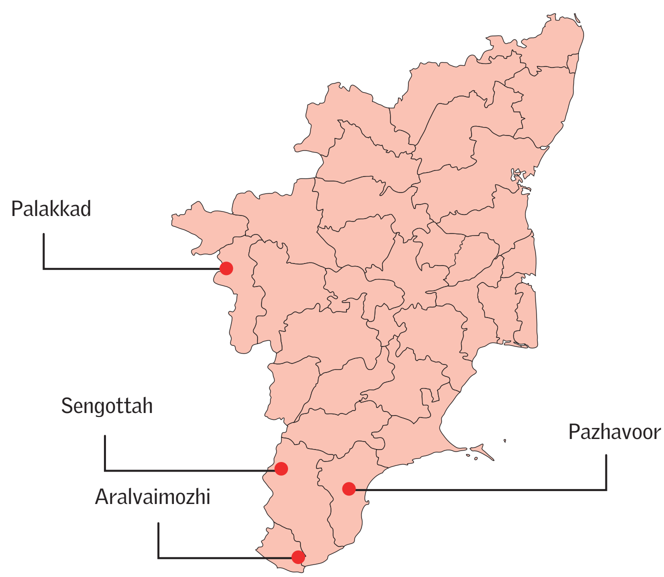
The state of Tamil Nadu has been leading in the renewable energy space from the early 1990s. Two monsoons, accompanied by additional wind power, allow major sites in Tamil Nadu to have higher capacity-utilization compared to other states in the country. Moreover, Tamil Nadu has also made considerable efforts in tapping other renewable energy (RE) resources like small hydro and biomass. Owing to this, the installed RE power capacity in the state has now reached over 46 per cent of the total installed power. Going forward, the contribution is expected to increase over the years as the RE market advances in the state.

Tamil Nadu also has the highest installed wind capacity in India. It is home to 24 per cent of the nation's wind power capacity. Additionally, the state offers some unique characteristics when it comes to wind installations.

Factors influencing wind power in Tamil Nadu

- **Geographical location:** Tamil Nadu has some of the best windy sites in the country. It is situated at the southernmost tip of India. Apart from the Bay of Bengal in the east and the Indian Ocean in the south, it is also surrounded by the Western Ghats (on the western border). The Western Ghats consist of small hills that are low in altitude, but contiguous in nature. Thus, there is a consistent and high flow of wind at the Aralvaimozhi, Pazhavoor, Palakkad and Sengottah passes.

Map 2: Passes in Tamil Nadu with consistent and high wind flow



- **Southwest monsoon:** In the months of May, June and July, the sun travels to the Tropic of Cancer. During summer when the sun is shining brightly over the northern hemisphere, the big land mass of Asia is intensely heated. This creates a low-pressure area. The low-pressure area ultimately becomes so intense that even the south-east trade wind of the southern hemisphere is drawn across the equator by it. Due to the Coriolis effect, the earth's rotation on its axis deflects the wind to the right, causing the south-west monsoon. It is the monsoon wind from the Indian Ocean and Arabian Sea that causes high wind flow to Tamil Nadu.

- **Northeast monsoon:** In August, September, October and November, the sun is in the line of Capricorn. Therefore, the northeast trade wind crosses the equator and becomes the northeast monsoon. Since Tamil Nadu is situated near the equator—especially Muppandal, Kayathar and Poolavadi pass—it experiences abundant wind flow during this monsoon.

- **Proximity to the sea:** Among the passes, the Aralvaimozhi pass is just adjacent to the sea shore. As a result, water gets heated quickly during the day and forms a low-pressure zone. Since the land mass does not heat up immediately, the pressure there remains higher. Consequently, wind from the high-pressure zone flows into low-pressure zones. Thus, during the day, Muppandal region in this pass has a good wind flow. At night, the water cools faster than the land mass. Thus, in the evening and at night, wind flows from the sea to this region.

- **Wind passes in Tamil Nadu:** Furthermore, three passes in the state—Aralvaimozhi, Sengottah and Palakkad—serve as an entry point to a good amount of wind and have a funnel effect, blowing the wind across the entire terrain. Recent studies have also identified Kambam Pass (in Dindigul district), as a potential windy area.[2]

- **Other factors**
  Tamil Nadu tops India's list in harnessing wind power due to the following reasons:
  - The wind power density is high in Tamil Nadu, compared to other states
  - The terrain in Tamil Nadu is almost plain and accessibility to any site is easy compared to the mountainous terrain in other states like Kerala and Karnataka. This has not only helped in quicker erection of wind farms, but also facilitated transmission and distribution lines to the nearby grid
  - Developers have been able to purchase lands for wind farms directly from the owners at mutually agreed rates

- The grid is strong and the infrastructure facilities are better
- Since the industrial tariff is high in Tamil Nadu, wheeling power from the wind farm has resulted in huge savings in the power bill

Challenges faced by the wind sector in Tamil Nadu

The wind sector in Tamil Nadu is beset with many challenges, some generic and others that are unique to the state. These include:

1. Large wind portfolio and curtailment of power

It is estimated that wind power accounts for close to 30 per cent of the total installed capacity of the state. Wind generators have to face frequent back-downs/ cut down of RE power. The curtailment of wind power went up from 1.87 hours per day in 2018 to 3.52 hours per day in 2019.

'Curtailment' describes limiting (denying) off-take (flow) of the generated power, leading to a decrease in the plant's output. 'Must-run' means that utilities, state load dispatch centres (SLDCs) and distribution companies (DISCOMs) must prioritize evacuation of the power generated from renewable energy. If curtailment of wind power is happening, it suggests that the principle of 'must-run' is not being adhered to.

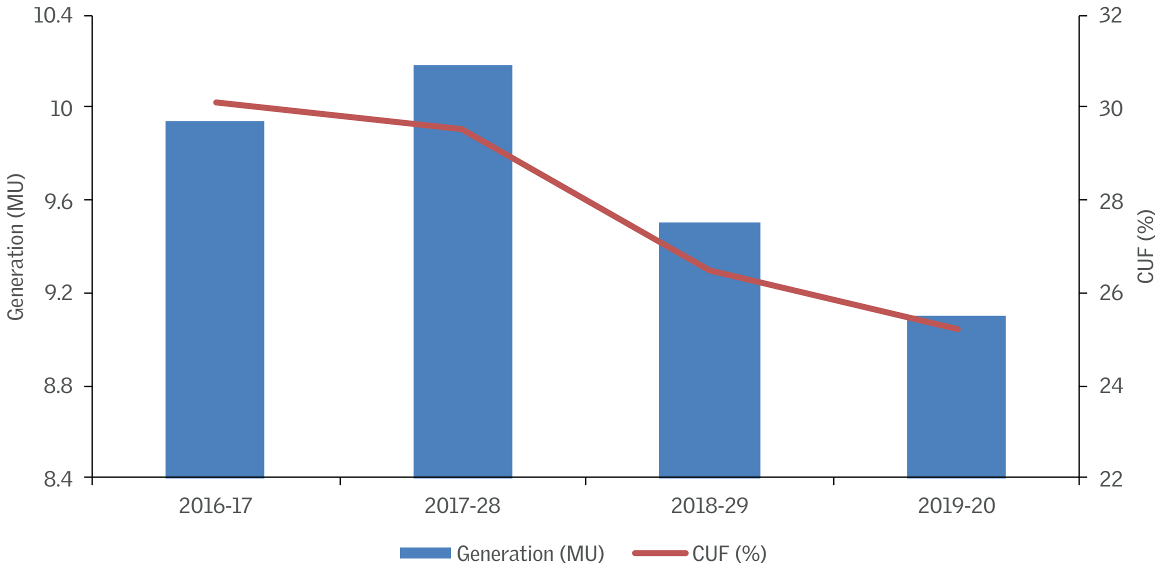
Data on curtailment is not available in the public domain due to a lack of transparency on the part of SLDCs and DISCOMs. In the peak seasons from 2012–15, wind power plants curtailed approximately 30–35 per cent of their output, while it averages 20–25 per cent currently, according to the founder of a wind farm operation and maintenance company based in Mupandal, who chose to be anonymous. By conservative estimates, the back-down amounts to an annual loss of 2,000 to 2,500 million units (MUs).

According to the aggregate wind generation data for Tamil Nadu, during the peak wind generation period of April–September, the capacity utilization factor (CUF) declined for four consecutive years (see *Graph 10: Total generation vs CUF*).

Despite the increase in installed generation capacity, the amount of power actually produced has decreased—indicating a general curtailment.

While CSE's analysis suggests that the reasons for curtailment are both technical and commercial, the primary reasons attributed by SLDC for back down are to maintain grid stability and compliance to new deviation settlement mechanism (DSM) regulations.

Graph 10: Total generation vs CUF



Source: Down to Earth[3]

There have been several changes to the DSM regulations since they were launched in January 2014. In November 2015, the first major update was implemented, wherein a separate deviation structure and pricing structure for renewable generators was introduced. Moreover, the fourth amendment to the 2019 regulations linked deviation charges to the average daily market price discovered on the daily-ahead market (DAM) segment of the power exchanges.

In March 2022, the Central Electricity Regulatory Commission (CERC) notified the new DSM regulations, which link the deviation charges to the time block-wise market prices, including new market segments on the power exchange. Owing to preparatory work on the several changes that have been identified, the regulations have not yet been implemented.

All plants have been subject to the new regulations. For existing wind plants, the cost of deviations or deviation penalties could potentially increase to 5–6 per cent of the total revenue (from current levels of 1–2 per cent).

DSM regulations have changed for wind power plants of 500 MW with a deviation of 125 MW (or 25 per cent) during a particular time block when DAM prices are Rs 5 per kWh. According to the new regulations, the average revenue for over-injection would decline from Rs 2.64 per kWh to Rs 1.05 per kWh. For a wind farm, this is a significant loss of revenue. A similar increase in cost would also occur for under-injection, increasing from Rs 2.86 per kWh to Rs 3.05 per kWh.

2. Long-term power purchase agreements (PPAs) without end dates

Turbine owners in Tamil Nadu have signed long-term PPAs with TANGEDCO. No time limit was specified in the earlier PPA and, hence, wind farms continue to provide power (beyond 20 years).

Wind energy has been generated in Tamil Nadu since 1986 from wind farms with capacities of 200 KW, 225 KW, 250 KW, 410 KW, 500 KW, 550 KW and 600 KW. The spinning systems of older models have limitations—they cannot capture low or high winds and most of them can work only with constant winds. Even though these machines have served their full life period, they continue to ply. Most of them are under *Energy Purchase Agreements* or *Energy Wheeling Agreements* with tariffs of Rs 2.75 and Rs 2.90 per unit.

3. Large numbers of infirm power turbines

TANGEDCO has the humungous task of managing around 10,000 turbines of smaller capacity with different characteristics and reactive power. It is also a well-known fact that the nature of RE sources, especially wind and solar, is infirm, and they are bound to have deviations. Moreover, neither the generator nor the consumer can accurately estimate, exercise control over, or direct the generation of energy from renewable sources. This injected infirm power that does not match the load profile, increases the cost of power and can have a destabilizing effect on load dispatch centres.

4. Reverse bidding, land and CUF issues

Nearly three-fourths of the total wind capacity was installed in the last 10 years under a feed-in-tariff (FiT) regime, at an annual average of 2–3 GW and with installation peaking in 2017. In 2017, India introduced a reverse auction mechanism in addition to FiTs.

This switch from FiT to reverse auctions, even before the industry was prepared for it, caused a disruption. As part of the FiT route, power is procured at a tariff determined by the State Electricity Regulatory Commissions (SERCs), whereas under the bidding route, the market determines what the market participants (developers and procurement companies) have to pay.[4]

It is important to note that the tariff-based competitive bidding process has significantly reduced the tariff of wind power, i.e., from over Rs 4 per unit in the FiT regime to around Rs 2.80 per unit in the reverse auction regime.

Known as a preferential tariff, the determined tariff was notified by SERCs after a thorough hearing and taking all the financial parameters (cost, interest on debt, interest on working capital, margin, etc.) into consideration. During this period, DISCOMs purchased electricity from wind power projects at the determined tariff.

Under the current reverse bidding process, in order to win the bids, the investors are bidding in only the highest CUF states owing to discovery of the lower tariff (below Rs 3.00/kWh).[5] Above this tariff, DISCOMs are not willing to enter into long term power purchase agreements. This scenario has resulted in low-capacity addition (approx. 1.50 GW per annum) in India in the last 5 years.

WHAT IS REVERSE AUCTION?

The reverse auction has significantly increased transparency, but it also faces some major challenges of its own. Basically, reverse auctions are defined as "an approach to procurement in which sellers meeting certain minimum criteria are eligible to submit non-negotiable price bids." Many wind projects are unviable for commissioning due to reverse auctions and unrealistic price discoveries, especially with commodity prices increasing. As a result, a large number of OEMs have been forced into bankruptcy.

When it comes to installations of wind energy projects beyond 1.5 to 2.0 GW per annum in any state, there are constraints due to challenges related to land availability, right-of-way, power evacuation, grid capacity, logistics and infrastructure capability.

Additionally, the concentration of projects causes severe pressure on land, constricts evacuation of power and limits creation of infrastructure, as has been witnessed in Gujarat. This, in turn, has created execution challenges at the state level and, therefore, the inability to generate volumes.

Despite the availability of land and infrastructure in other states, investors tend to avoid Madhya Pradesh, Rajasthan and Maharashtra as the proposed projects cannot compete on the basis of CUF and reverse auction economics, compared to projects in Gujarat and Tamil Nadu.

Due to reverse bidding, India has also not been able to utilize wind power in the seven windy states, even though each state is capable of delivering 2 GW per annum. If the wind generated in all seven windy states could be harnessed, the country would be able to produce 14 GW per annum.

In terms of numbers, around 28.1 GW of capacity bidding has been done from February 2017 to March 2022 (5 years since the auction regime) and approximately 19.7 GW of wind capacity has been allotted. Out of this, only about 4.5 GW of capacity has been commissioned so far.[6]

Currently, the states are trying to avoid captive projects due to loss of their revenue by power intensive industrial customers.

5. GST rate

The GST rate on wind turbines has increased from 5 per cent to 12 per cent w.e.f. 1 October 2021, which means an addition of 7 per cent to the cost of the wind turbine.

Due to decreased returns, prospective bidders/investors are less likely to participate in the upcoming bids. As a result, the manufacturing and capacity additions of wind turbines will slow down over the next 18 months.

6. Wheeling charges and captive use

- Currently, all states with a viable wind resource have different wheeling, transmission and banking policies. In some states, these policies change very frequently, almost on a yearly basis. The Appellate Tribunal for Electricity vide its judgement dated 28 January 2021, directed the Central Electricity Authority (CEA) to come up with a uniform banking procedure which will be followed by all the states.

- The Ministry of Power (MoP) amended an order dated 21 June 2021 for waiver of Inter-state Transmission System (ISTS) charges. This has created more ambiguity, especially for users that are captive or third parties as well as the stakeholders who will be compensated for transmission losses.

- Investors are not opting for the captive option even when third party consumers with > 1 MW projects are allowed, because of the high-cost factor (due to wheeling and transmission costs and losses), banking costs, frequent changes by various states through SERCs and the poor enforcement of Renewable Purchase Obligation (RPO) compliance.

7. Liaisoning charges

Each WTG is connected to a separate service connection in Tamil Nadu, as opposed to other states where group meters are used. Following a breakdown at any WTG, the Tamil Nadu Electricity Board (TNEB) disconnects the meters with a penalty, and then re-connects them with a hefty liaison charge. Unfortunately, this charge has now been increased, causing the high charge to escalate further.

8. Delay in payments by Tamil Nadu Generation and Distribution Corporation (TANGEDCO)

About 20 years ago, in 2002, captive wind generation became popular in the textile industry. Earlier, industry wind generators were connected to the grid and entered into energy purchase agreements (EPAs) with TANGEDCO. However, they have been making delayed payments without interest since the past few years. In some cases, these payments have been delayed for more than one and a half years.[7]

3. Repowering

Wind resources are site-specific. According to NIWE estimates, India has exploitable wind potential of 800 GW at 100–120 meters in height. However, the best Class I wind sites (with high wind speeds and high wind power densities) have already been exhausted during the one-and-half decades of the sector's development (since the 90s). Also, the CUFs of the old wind turbines populating these sites are very low—10 to 15 per cent—compared to more than 35 per cent that modern wind turbines are capable of achieving. Repowering old Class I turbines can increase the project capacity and CUF by two to three times, resulting in a five-fold increase in the annual production of wind energy.

Wind turbines are designed for a lifespan of about 20 years. They need to be decommissioned on the completion of their designed life; otherwise, they can pose a safety risk. However, there are several old wind farms in India that have completed their design life of 20 years and continue to run, as they are still profitable to their owners. This is a national concern when it comes to wasting wind resource and windy sites as these old wind farms run with significantly lower CUF than is currently possible. As per the India Wind Power Directory 2017, over 1.5 GW of installed capacity with turbine sizes of less than 1 MW has completed 20 years of its design life (see *Table 1: Fit for repowering*).

Furthermore, wind farms with a capacity of 2 GW commissioned between 2002 and 2005 will complete their designed life of 20 years in the next two to five years and would provide a continuous sizeable volume for repowering.

Table 1: Fit for repowering

State-wise and turbine size-wise wind installation done prior to 31 March 2002

State	<=500 KW	500 to 1000 KW	Total (KW)
Tamil Nadu	775,780	58,250	834,030
Maharashtra	241,795	159,150	400,945
Gujarat	151,795	2,200	153,995
Andhra Pradesh	84,890	1,500	86,390
Karnataka	30,075	36,900	66,975
Madhya Pradesh	21,100	0	21,100
Rajasthan	14,040	0	14,040
Kerala	225	0	225
Total	1,319,475	258,000	1,577,475

Source: Indian Wind Power Directory

Table 2: Installed wind capacity completing 10 to 20 years of design life by 2022 (MW)

The use of resources can be maximized with long-term continuous repowering

State	Tamil Nadu	Andhra Pradesh	Gujarat	Karnataka	Kerala	Madhya Pradesh	Rajasthan	West Bengal	Maharashtra	Others	Total
Up to March 2002	877.0	93.2	181.4	69.3	2.0	23.2	16.1	1.1	400.3	3.2	1,666.8
2002-03	133.6	0.0	6.2	55.6	0.0	0.0	44.6	0.0	2.0	0.0	242.0
2003-04	371.2	6.2	28.9	84.9	0.0	0.0	117.8	0.0	6.2	0.0	615.2
2004-05	675.5	21.8	51.5	201.5	0.0	6.3	106.3	0.0	48.8	0.0	1,111.7
2005-06	857.55	0.45	84.6	143.80	0.0	11.4	73.27	0.0	545.10	0.0	1,716.17
2006-07	577.90	0.80	283.95	265.95	0.0	16.4	111.90	0.0	485.30	0.0	1,742.05
2007-08	380.67	0.0	616.36	190.30	8.5	130.39	68.95	0.0	268.15	0.0	1,663.32
2008-09	431.1	0.0	313.6	316.0	16.5	25.1	199.6	0.0	183.0	0.0	1,484.9
2009-10	602.2	13.6	197.1	145.4	0.8	16.6	350.0	0.0	138.9	0.0	1,564.6
2010-11	997.4	55.4	312.8	254.1	7.4	46.5	436.7	0.0	239.1	0.0	2,349.2
2011-12	1083.5	54.1	789.9	206.7	0.0	100.5	545.7	0.0	416.5	0.0	3,196.7
Total	6,987.6	245.5	2,966.3	1,933.5	35.1	376.40	2,070.7	1.1	2,733.3	3.2	17,351.5

Source: NIWE

According to the NIWE, all windmills with a CUF of <15 per cent are technically ready for repowering—and with this, the CUF can at least be doubled, or in wind intensive sites, tripled. The NIWE is now estimating wind energy potential in India at a hub height of 150 metres for accommodating future technology in the planning phase. Wind turbine models that are currently available in the Indian market are suitable mainly for Class III and IV sites; they cannot be used for Class I sites of older wind farms. Wind turbine technology has significantly improved since the harnessing of Class I sites in early 2000; it is possible now to design a new, more suitable wind turbine model for maximum capacity utilization.

With fewer turbines, collisions or disruptions to bird migration are less likely. Further, modern turbine designs are sophisticated and technologically advanced, resulting in lesser noise pollution.

Figure 2: Potential benefits of repowering

Technical • Efficient utilization of potential wind sites producing higher quantum of energy • Improved CUF at given wind farm site • Higher efficiency	**Operational** • Reduced operation and maintenance (O&M) costs • Modern wind turbines/farms offer better integration with grid • Better management of grid parameters and provision of higher operational flexibility for the system operators
Environmental • Reduced impact on movement of birds • Reduced noise pollution	**Financial** • Achieve better LCOE • Reduction in land area per MW of wind farm • Additional energy generation can yield higher profits including more Renewable Energy Certificate (REC) offerings • Clean Development Mechanism (CDM) benefits

Why is repowering not taking off?

Even though the Government of India (GoI) released the repowering policy in 2016, it has not had any impact in terms of enabling repowering of older wind farms. This, as per CSE's analysis, is due to the following reasons:

• Fragmented ownership structure of wind farms

The tremendous growth of wind energy in Tamil Nadu has been driven by sales tax benefits and accelerated depreciation, introduced in the state in 1992. Consequently, the state has attracted sizeable private investment, supported by turnkey suppliers. Each private player owns one or a few windmills and this has led to fragmented ownership. Fragmented ownership means that there needs to be a distance between two projects, and within the project there has to be a distance between the turbines—owing to this, earlier attempts at repowering have failed in Tamil Nadu and Gujarat.

For example, in a wind farm, 10 turbines each of capacity 250 kW would be removed for the installation of 3 turbines each of 2 MW capacity. Hence, it complicates the ownership issues of the three new turbines.

• Loss of captive status if captive generators opt for repowering

The Electricity Rules, 2005 of the Indian Ministry of Power state that to qualify as a captive generator, a consumer must own at least 26 per cent equity stake in the generating company and it shall consume at least 51 per cent of the aggregate generation. With such rules in place, if a captive power generator seeks to opt for repowering, the aggregate generation may increase up to three times. Therefore, in cases where the captive consumption has remained unchanged, the generator will lose its captive status since the user is consuming a lower percentage of actual generation by the repowered captive generating plant. In the present legal framework, such captive generators would not take up repowering due to the minimum consumption criteria. Moreover, all the project owners may or may not participate in a repowering project. Repowering could reduce the number of turbines, but it may not be possible to evolve an exact replacement.

Further, it is possible that a repowering project is undertaken by one dominant investor, while the rest of the existing captive project owners may be small/ minority stake holders. As a result, the repowered project may or may not be able to meet the criteria of 26 per cent ownership.

• Evacuation infrastructure upgradation

In Tamil Nadu, most of the wind farms that house projects with a completed lifespan of more than 15 years are connected to 11 kV lines for the evacuation of power. However, post repowering, the capacity and aggregate generation may increase by two and three times respectively. Hence, there is a need to upgrade the existing infrastructure such that all the energy generated can be evacuated properly and without any congestion. This will also ensure evacuation of wind power without any forced generation curtailment.

• Challenges in micro-siting

Micro-siting refers to the placement of wind turbine generators in the wind farm area that maximizes energy production, taking into account all physical constraints of that area. The 7D x 5D spacing for placing wind turbines has been relaxed for repowering projects vide TANGEDCO Proceedings (Per) (CMD) No. 469, dt: 09.11.2018 to 3D x 5D criteria. However, in some areas of Muppandal and Poolavadi, the 3D x 5D criteria is insufficient ever since new habitations came up.

• Valuation of existing assets

Certain financial aspects are associated with projects that need repowering. Apart from the cost of new assets, there are certain other costs such as that of decommissioning old assets, revenue foregone for the remaining life of the existing projects, revenue loss during the construction period, salvage value of the old assets, etc. All these (cost) components should be considered for valuation of the existing wind power project. As of now, no benchmark cost has been set for these components in India.

• Lack of financial interest by owners

The owners of wind turbines (that have completed their life, but continue to be operational even at very low plant load factors), are not willing to do away with their assets. These wind projects have already provided them with ample returns on investment and owners continue to earn without any initiative to repower.

• Loss of generation during construction

The dismantling of old assets and installation of new ones requires a minimum time to complete. This entails a loss of generation during the construction period and could be an issue for the wind turbine owners.

• Transport challenges of longer blades and taller towers

The Muppandal wind farm began operating in 2007 and has a capacity of 1500 MW. In the last 15 years, several dwellings have mushroomed in the area. Owing to this factor, transportation of larger turbines and longer blades through bends, narrow passages and taller towers will be more difficult.

Policy for repowering in India

The wind power sector in India has for some time been exploring the possibility of repowering older wind farms, a move that can accelerate capacity addition. In August 2016, the MNRE released its policy on repowering (see *Box: After service life continuation*). However, a Right to Information (RTI) query addressed to the Indian Renewable Energy Development Agency (IREDA), a government body entrusted with financing repowering projects, has revealed that not a single project has availed an additional interest rate rebate for wind repowering under the 'Repowering of Wind Power Projects 2016' between 2016 and 2020. This proves a complete lack of interest in such projects among developers.

AFTER SERVICE LIFE CONTINUATION: A SCHEME STILL ON PAPER

There is no regulation in India for older wind turbines regarding continuation of operation after their service life of 20 years. As per the Union Ministry of New and Renewable Energy's (MNRE) draft Indian Wind Turbine Certification Scheme of November 2018, it is mandatory to conduct a safety and performance assessment of all turbines that are connected to the grid and that have been in operation for more than 80 per cent of their designed life. Based on the assessment, the turbine would be allowed to operate for another two years, after which it will be assessed again.

Apart from developers who have not shown any interest, the earlier policy on repowering lacked focus on core issues such as the development model, incentive requirements, repowering mandate, and a programmatic approach towards dealing with wind power equipment that has completed its lifespan.

In August 2022, a revised policy was drafted after considering representations received from various stakeholders in the wind energy sector and subsequent deliberations. It offered the following provisions:

1. The policy will cover (a) all turbines with a capacity of < 2 MW (b) projects that have completed their design life, (c) turbines identified by quality control, (d) set of wind turbines from a project, provided such turbines are connected to a single pooling sub-station with > 90 per cent of completed design life.
2. A repowered project can be (1) standalone or (2) an aggregate project, each having a different implementation arrangement.
3. A Wind Repowering Committee (WRC) will be set up by the MNRE to help the latter implement the policy.
4. Power from such projects will continue to be purchased by the procurer based on the average dispatch of last three years of the PPA tenure (25 years). If the PPA tenure is less than 25 years, the same will be extended to 25 years (from the original date when the commercial operations began).
5. The developer shall be allowed to sell any excess power to the market which the DISCOM refuses to buy.
6. The wind project undergoing repowering would be exempted from supplying power to the DISCOM during the execution period. The timespan of the period (in which the repowering is executed) can be a maximum of 2 years.
7. In case of repowering of a captive/third party wind power project, the consumer shall be allowed to purchase power from the grid during the period in which repowering is executed.
8. IREDA will provide an additional rebate of 0.25 per cent over and above the interest rate available to the new wind projects for repowering.
9. The central/state government may consider initiating a scheme wherein additional financial incentives are provided to projects that involve repowering.
10. The wind RPO compliance by the states in which the repowering project is situated, shall be exempted for the remaining period (till the time that the project is commissioned).
11. An enhanced RPO multiplier shall be provided to the project that involves repowering for the remaining period of the PPA.
12. Developers and aggregators suffering revenue losses and having to decommission expenses will be compensated through a repowering siters preparation cost. This will include the terminal value and decommissioning cost. A part of this cost can be compensated through the sale of scrap materials.

Tamil Nadu and Gujarat, which have the highest potential for repowering, have made some progress as far as policies in their respective states are concerned.

State-wise policy interventions for repowering

Tamil Nadu

- At the time of commissioning of the repowered wind farm, the feed-in-tariff will be Rs 2.80 per unit or the latest tender discovered rate, whichever is less.
- Under wheeling agreements, wind farms bank one month with unutilized energy encashed at a tariff of 75 per cent at the end of the month.
- Developers must erect and augment transmission infrastructure up to TANGEDCO sub-stations at their own cost.

Gujarat[8]

- Repowering of plants with a capacity of 1 MW or less is allowed under the policy.
- Incentives will be granted in accordance with the repowering policy issued by MNRE.
- State Nodal Agency – Gujarat Energy Development Agency (GEDA).

Karnataka

- ESCOMs will continue to procure power (average of the last 3 years) based on the terms of the PPA in force. The remaining additional generation may be purchased by them at a discovered tariff that is a result of competitive bidding.
- Captive users shall be allowed to purchase power from the grid during the period when repowering is being executed.
- It is the project developer's responsibility to assess the feasibility of evacuation (of repowering) through the STU and the CTU.

Rajasthan

- Repowering is allowed for wind projects older than 10 years.
- Repowering will require RVPN/DISCOMs to provide a power evacuation facility based on load flow studies—for a new pooling station or augmentation of an existing sub-station.

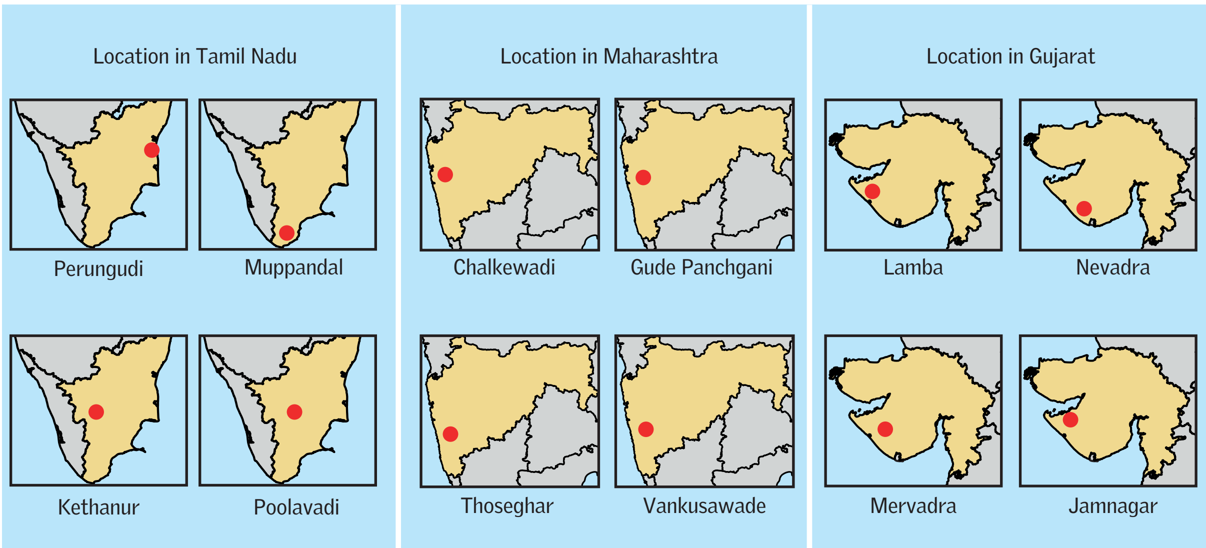
Maharashtra

- Repowering the existing wind turbine generator using micro-siting and improved technologies.
- The repowering of projects will be carried out in accordance with the MNRE's guidelines.

Andhra Pradesh

- Wind projects older than 15 years are allowed to be repowered.
- A PPA amendment will be granted in the event of repowering, with a 25-year extension of the terms.
- Tariffs for additional capacity shall be determined based on competitive bidding or the lowest tariff discovered during the most recent competitive bidding process or by selling the capacity to distribution companies at APPC under the REC mechanism.

Map 3: Sites with high potential for repowering

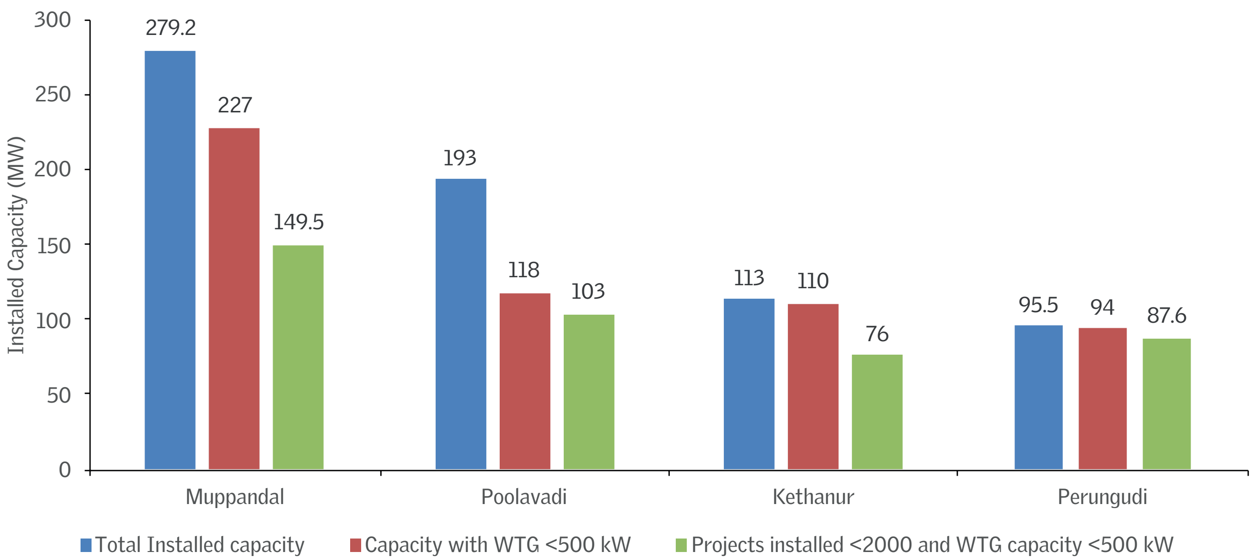


Some of the locations in the states of Tamil Nadu, Maharashtra and Gujarat that have the best windy sites with installations older than 15 years and a capacity of <= 1 MW.

Repowering In Tamil Nadu

Sites such as Muppandal and Poolavadi have immense potential for repowering. It is estimated that Muppandal alone has a capacity of 279 MW, of which approximately 227 MW has been installed using turbines of capacities 500 kW or below. When projects that were commissioned before 2002, with WTG capacities of 500 kW or less, are considered, sites such as Muppandal still have an installed capacity of 149.5 MW. These projects present an immediate potential for repowering.

Graph 11: Wind resource rich sites in Tamil Nadu with the highest potential for repowering



Source: Indian Wind Power Directory, 2017

Repowering: The way ahead

While the potential to augment wind energy from the same resources is enormous—using modern wind turbines helps increase energy generation by more than six times—repowering requires a high level of investment.

Repowering of wind resources is in the national interest. Stakeholders, including central and state governments, need to engage in a positive way for repowering to become a reality. A well-designed policy framework and regulatory support for repowering should be in place, to enable the private sector develop viable business models for the sector. Also, safety standards should be prepared and implemented. Additionally, strengthening the infrastructure for power evacuation will ensure prevention of large-scale curtailment of power, which is a challenge for the sector at present. Finally, a futuristic approach to repowering, wherein space is created for other technologies like solar and storage, will make it more convenient for utilities and this, in turn, will hasten the adoption of renewables. Power producers will be able to deliver firmer and cleaner energy, matching the demand with better predictability.

With so many advantages, repowering is the future of wind energy and needs to be furthered. Tamil Nadu must take the lead in repowering so that other states can follow its example.

CASE STUDY: MAHARASHTRA

Micro-siting at Vankusawade Wind Park

Vankusawade Wind Park is located on a high mountain plateau at 1,150 m above the Koyana Reservoir, around 40 km from the town of Satara in Satara district of Maharashtra.

Wind power is generated from Suzlon turbines of 350 kW each, resulting in a total power output of 243 MW.

A study to identify the repowering potential of the wind park, *Wind Repowering in India: Potential, Opportunities, and Challenges,* was carried out by USAID in 2022 under the South Asia Regional Energy Partnership (SAREP) programme.[9] Technical parameters of turbines like rotor turbulence, fatigue spectrum and machine design, input data like site details, climatic conditions, transmission and substation details, topography, wind characteristics, wind trends, orographic parameter and wind frequency distribution were collected from key stakeholders. Additionally, evacuation limitations and the availability of land, including the orientation of land and contour layout, were examined as well.

Four micro-siting layout combinations—3DX5D, 4DX5D, 6DX5D, and 7DX5D—were studied to see the differences in energy yield, CUF, wake loss and energy yield ratio.

For each arrangement, the total energy output from the machine were calculated, considering all losses such as wake losses, turbine availability losses and grid availability losses.

Table 1: Micro-siting results for Vankusawade, Maharashtra

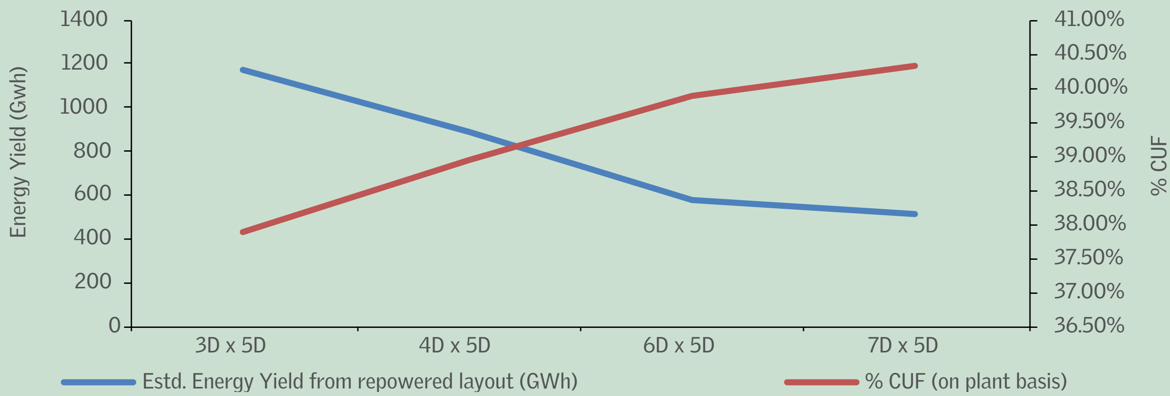
Site Existing Details				Repowering with 2.7MW (130 m) Turbine							Repowering with 3.6 MW (140 m) Turbines						
Layout	Capacity of <1 MW WTG's (MW)	Area of Site (Sq km)	Estd. Energy Yield from Existing site (GWh)	Capacity of re-powered layout (MW)	Re-powering ratio	Estd. Energy Yield from re-powered layout (GWh)	% CUF (on plant basis)	Average Wake loss (in %)	Land usage Ratio (MW/ Sqkm)	Energy Yield Ratio	Capa-city of re-powe-red layout (MW)	Re-powe-ring ratio	Estd. Energy Yield from re-powered layout (GWh)	% CUF (on plant basis)	Average Wake loss (in %)	Land usage Ratio (MW/ Sqkm)	Energy Yield Ratio
3D x 5D	243	26.27	261	353.7	1.46	1173	37.88	8.12	13.46	4.48	313.2	1.29	1110	40.47%	6.25	11.92	4.24
4D x 5D	243	26.27	261	259.2	1.07	884	38.94	5.58	9.87	3.38	244.8	1.01	883	41.19%	4.45	9.32	3.37
6D x 5D	243	26.27	261	164.7	0.68	575	39.89	3.02	6.27	2.20	180	0.74	660	41.90%	2.93	6.85	2.52
7D x 5D	243	26.27	261	145.8	0.60	514	40.32	2.45	5.55	1.97	162	0.67	594	41.91%	2.67	6.17	2.27

It is important to note that higher wind power can be generated from the same land parcel. In the 4-layout combination, we can see that the capacity of repowered layout keeps on increasing. Also, with a compact arrangement of turbines and with less spacing in between, the CUF decreases (with sparsely placed turbines, there is a decrease in wake loss). This observation seems valid when the capacity of both the turbines—2.7 MW at 130 m and 3.6 MW at 140 m—is considered.

Based on the table above, it can be concluded that the energy yield ratio increased by two times with a slight decrease (2 per cent) in CUF at 3DX5D.

This relation has an impact on the tariffs—if the CUF starts decreasing, the tariff will start increasing. However, the overall impact on the tariff, moving from 7DX5D to 3DX5D, is less than 10 per cent. Thus, with a more than fourfold increase in energy generation, the impact on the tariff is less than ten per cent. This comes to a few paise and can be ignored.

Graph 1: Capacity utilization factor and energy yield with different layouts



Graph 2: Energy yield and capacities with different layouts

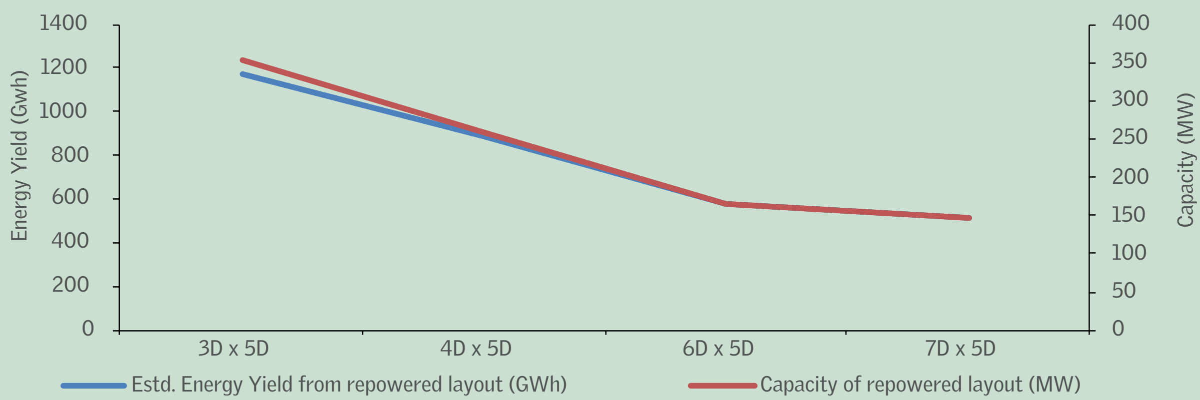


Table 2: Options analysis based on micro-siting

Impact / Repowering basis	Land Usage	Wind Resource Usage	Impact on Wake loss	Impact on Evacuation Infrastructure	Impact on Existing PPA	Revenue generation after Repowering
Maximum CUF	Minimum	Minimum	Less	No Impact	Can be extended	Low
Maximum Energy Generation/Yield	Maximum	Maximum	High	Need upgradation	Can be extended. Extra generation can be sold through open access	Marginally Increase
Maximum capacity addition after repowering	Maximum	Maximum	High	Need upgradation	Can be extended. Extra generation can be sold through open access	Marginally Increase

After a comparative analysis based on the three categories of repowering, it has been observed that:

- Capacity addition and energy generation will ensure maximum land usage.
- Maximum energy generation (MWh/sq km) will ensure maximum resource utilization of old sites, which is the main aim of repowering.

Source: Wind Repowering in India: Potential, Opportunities, and Challenges; USAID

4. Recommendations

The issue of a wind farm having multiple owners is the biggest commercial impediment when it comes to repowering old turbines. It is important that this concern be addressed since repowering may not necessarily replace every low-capacity turbine by a higher one. It is also quite likely that a wind repowering project implementer, who is expected to acquire the existing wind projects and develop the new project, would receive the consent of the existing turbine owners in the following ways:

- Giving stakes of the (new) repowering project to the existing turbine owners in the ratio of their equity contribution. This equity contribution can be adjusted after the valuation of their existing projects.
- For existing owners who are not willing to invest, but are interested in being a part of the new project, the Wind Repowering Project Implementer (WRPI) shall give the existing turbine owners stakes in the new project as per the value of the dismantled assets and the revenue foregone.
- For existing owners who are not willing to be a part of the new repowering project, the WRPI shall offer a complete buyout of the existing turbines with the land rights as per the standard method of valuation.
- All existing stakeholders willing to repower, can be made partners in the WRPI promoted SPV, and subsequently, the profits can be shared in the ratio of equity shareholding in the SPV.

General recommendations

- Wind power plants exhibit changing dynamics, non-linearities and uncertainties. Thus, smart grids require advanced control strategies to be able to solve these problems effectively. Through the use of more efficient control techniques, not only would these systems perform better, but they would also operate for longer periods of time, resulting in cheaper generation.
- Due to the intermittent nature of wind, its behaviour changes on a daily and seasonal basis. Since levels of wind energy vary within a 10-minute to 1-hour time frame, it should be used as an aggregate resource with other renewable energy sources in a power grid, in order to avoid the same kinds of interruption a large base-load generator may experience.
- Research in the technology is still ongoing. Hence, existing generation and delivery infrastructure (i.e., legacy) of RE systems must be future-proofed to work with new technologies.
- Being flexible to changing technologies requires identifying the vital interface between the technology that is being used and its components.

ENVIRONMENTAL IMPACTS

- Most of the wind turbines contain SF6 gas—a greenhouse gas which is 23,500 times more potent a than carbon dioxide and remains in the atmosphere for at least 1,000 years. SF6 is a cheap, non-flammable, colourless, synthetic gas. It makes for very effective insulating material for medium- and high-voltage electrical installations and is widely used across the industry, from large power stations to wind turbines to electrical sub-stations in towns and cities. Turbines leak a small amount of this gas during normal operation and the emission is not significant for small scale projects, but something that must be monitored for larger wind farms.
- The blades of a wind turbine are made from fibreglass which has an average life of 20 to 25 years and there is currently no market for recycling these old blades. Since the blades are hollow, they occupy a large volume of space compared to their mass in landfills.

- Achieving an association across service providers, end-users and technology suppliers is difficult, particularly in a growing international market place. Inter-operability can be attempted by connecting multiple parties and systems through exchange of knowledge, but it will be difficult to achieve.
- Strategies need to account for various policy objectives (affordability, sustainability, growth and cultural values).
- Assigning value to externalities, such as environmental impacts, is difficult, but necessary for balanced decision-making.
- Understanding needs to be developed and accounting needs to be done for the beneficial aspects of smart grid investments as a mechanism for job creation and advancing a technically skilled workforce.
- There needs to be greater awareness about the capabilities of smart grids and their benefits in order to improve energy efficiency and policies that involve integration of renewable resources.
- Forecasting wind power generation will help TANGEDCO exploit wind potential to the maximum while reducing losses due to backing down of wind mills.

Recommendations for repowering

- It is mandatory to conduct a safety and performance assessment of all turbines that are connected to the grid and have been in operation for more than 20 years. For any lifetime extension, wind turbines must have sufficient structural life remaining so that their safety level is not compromised.
- Replacement repowering can be an option. A simple replacement of older turbines with newer ones of the same capacity will not only improve the CUF, but will also result in lower generation loss due to the cut-out phenomenon in class I & II sites as compared to MW scale turbines. Though such losses do

not affect large-scale IPP developers, businesses that own small-scale or retail generators are a concerned lot.

- Under the Wind Parks/Wind-Solar Hybrid Park Development Scheme, the government can identify a few tranches for repowering and should develop/enhance transmission infrastructure.
- In parts of the country where wind power projects have been built on revenue land, states can take up repowering on their own as there is no uniformity among the projects or their sites. In Maharashtra and Karnataka, power purchase agreements are limited to 13 years. Hence, it is possible to take up repowering early in the life cycle of the projects without impacting the contracts and adding complexities.
- Creating a group of companies like Ramco, TVS, and Chettinad Cement (since they have large unused Class I wind farms) is a viable option. This will help replace their older turbines (that have a capacity of less than 500 kW) with newer ones and establish confidence in the sector. Transportability through bends and narrow passages of densely populated regions can be avoided since they have enough land.
- A Direct Drive Wind Turbine (Gearless) of at least 1 MW would be a better solution since not only are their sizes smaller and weight lesser, but the efficiency is also higher. This will eliminate gearbox failures as well as transmission losses. Moreover, 100-ton hydraulic boom crawler cranes used to support the lifting mechanism are hugely advantageous as well.
- Considering the complications and the challenges involved, repowering development in India can be initiated through an original equipment manufacturer (OEM)-driven business model.
- States must facilitate easy termination of PPAs without penalties.

The solution can be three-fold, considering the interests of retail generators, IPPs, TANGEDCO, and large corporations.

i. Replacing a WTG that has the same capacity.
ii. Creating a multi-kW client group to convert it into a single MW.
iii. Installing multi-MW series of WTGs based on the wind class of the site.

Table 3: Repowering development models

PARAMETERS	PROJECT BASIS REPOWERING	SITE BASIS REPOWERING
Ownership	Owner will continue to own it	The acquisition of assets will be undertaken by one of the entities designated, identified, determined or discovered by MNRE
Contractual process	The PPA can be terminated and compensated easily since there's only one owner	As the new owner will have to deal with several owners, it will be challenging to acquire assets and terminate PPAs
Micro-siting	Having each project micro-sited poses problems because there has to be a minimum distance between them, so project configuration is inefficient	• No need to maintain distance between projects • Optimize turbine sizes and total capacity at the site • Minimize losses, maximize energy yield and ensure maximum utilization of land resources
Evacuation	There's no need to upgrade the evacuation since the capacity will not increase. Individual owners will get more power with better turbines of the same capacity.	• Capacity will increase by 1.5–2 times—hence, there is a need to upgrade the evacuation. A separate arrangement for creating this capacity will have to be made
Energy yield	There aren't many opportunities to increase the turbine's capacity or height	Energy yield can be maximized with minimal wake loss and compact layout
Transport infrastructure	Transport can be a challenge for two reasons: a. adjoining operating projects b. the cost of mobilizing heavy cranes and building roads would be prohibitive	• Transport can be managed, as the entire site is going to be repowered • Infrastructure development costs would be spread across a larger capacity base

Annexures

Annexure 1: Global initiatives

Denmark

In Denmark, repowering was undertaken in different stages. The first repowering scheme was initiated from 2001 till the end of 2003, targeting turbines up to a capacity of 150 kW. For decommissioning these small turbines, the owners received a ‘Repowering Certificate’—this was equivalent to an additional tariff of 2.3 cents/kWh, two to three times the scrapped capacity, for 12,000 full-load hours. Since these certificates could be traded, the scheme enabled the installation of larger turbines. During the lifetime of the scheme, around 1,480 lower capacity old turbines with a combined capacity of 122 MW were replaced by 272 new turbines with a combined capacity of 324 MW. The scheme was most effective for turbines in the capacity range of 55 kW to 95 kW in which more than 80 per cent of the turbines were decommissioned, whereas only 25 per cent of the 150 kW turbines were decommissioned.

In the second stage, bigger turbines, the ones that had a capacity of up to 450 kW, were removed and received the same treatment. The scheme was announced in 2004 and lasted for four years, from 2005 to 2009. In this scheme, the wind turbine owners received repowering certificates equivalent to 1.6 cents/kWh for two times the decommissioned capacity (for 12,000 full load hours). Apart from the repowering certificate, the wind turbine was given a general subsidy of 1.3 cents/kWh and a balancing fee of 0.3 cents/kWh. The subsidy was restricted so that the sum of the repowering subsidy, the general subsidy (of 1.3 cents/kWh) and the spot price did not exceed 6.4 cents/kWh. In fact, the repowering certificate system enabled successful repowering of old wind turbines in Denmark.

Certificate holders are entitled to higher prices for electricity, up to a maximum of two or three times the replaced capacity. The incentive is regulated according to the market price of electricity.

The Danish FiT framework is listed below:

- **Old wind turbines connected to the grid before 2000**: Turbines connected to the grid prior to 2002 received a general price guarantee of €80/MWh for a 10-year production period.

- **Wind turbines connected between 2000 and 2002**: Turbines connected to the grid between 2000 and 2002 received a FiT of €58/MWh up to a production limit of 22,000 full-load hours.

- **New wind installations connected to the grid after 01 January 2003**: Turbines connected to the grid after 01 January 2003 had to sell electricity at the market price. In addition, turbines received a subsidy of 16/MWh for 20 years.

Germany

Nearly 50 per cent of the current wind power capacity in Germany was installed after 2000. In fact, the Renewable Energy Sources Act (Erneuerbare-Energien-Gesetz [EEG]) was a key enabler for the wind capacity addition achieved by Germany.

The implications of EEG on repowering from the year 2000 to 2017 were as follows:

- **EEG 2000:** The EEG Law complied with the EU criteria by setting time limits on compensation; establishing cost-oriented rates; differentiating according to the energy source, plant size and location; introducing a digressive structure; and insisting on regular reviews. The Law, however, was silent on any incentives for repowering.

- **EEG 2004:** Amendment to the Renewable Energy Sources Act (EEG) in 2004 offered an additional financial incentive to repower wind projects that were installed before 1995. In the years prior to 2004, Germany encouraged wind repowering by granting higher FiTs to new wind projects rather than the existing projects that were already in operation. With the introduction of the FiTs in 2004, projects that were built prior to December 1995 were replaced with those that delivered longer and higher incomes and were at least three times more powerful than the older ones. Owing to the spacing requirements and limitations on height, the repowering incentives offered by the EEG did not have the desired effect as far as tripling of the installed nominal capacity was concerned.

- **EEG 2009:** FiT for onshore wind farms was increased from 8.03 to 9.2 cents/kWh for the first five years of operation, and decreased to 5.02 cents/kWh thereafter. It was decided that this tariff would be decreased annually for new installations by 1 per cent, as opposed to the previously decided 2 per cent. Similarly, it was agreed that the new policy would increase repowering incentives so as to aid the replacement of old turbines with new ones. Also, there would be an increase in remuneration of 0.5 cents/kWh. According to the policy decision in 2009, replaced turbines must be in the same administrative district and must be at least 10 years old. Additionally, the new turbine must have at least twice, but no more than five times, the capacity of the original turbine.

- **EEG 2012:** The EEG amendments in 2012 retained the incentives on repowering projects. FiT for onshore wind projects remained at 8.93 cents/kWh for the initial five years, with a base tariff of 4.87 cents/kWh for the rest of the project's life. An annual depreciation of 1.5 per cent was applied to this FiT. An incentive of 0.5 cents/kWh was retained in the amendment. However, the law stated that the incentive amount shall be reduced by 0.01 cents/kWh annually. Also, some conditions were laid out for the applicability of incentives. This entailed that:
  - The repowered capacity must be at least twice the earlier capacity.
  - The onshore plants must be the ones that were commissioned prior to 2002.

- **EEG 2014:** The revised version of EEG 2014 gave an additional impetus to the repowering of older wind turbines as the financial incentives meant for repowering were granted only for projects which could be completed by the end of the year. Due to this, the operators of older wind turbines were given the opportunity to take advantage of the repowering incentive---this they could do by dismantling an old turbine and installing a new one in the same region. After the EEG revision became effective in August 2014, repowering gained more ground for the German wind energy market. The Federal Network Agency (Bundesnetzagentur) established a register of all new renewable energy plants commissioned and decommissioned. The obligation to report is a pre-requisite for claiming the EEG remuneration, and therefore since August 2014, a clearly improved database for repowering became available.

- **EEG 2017:** This reform introduced public tender procedures for wind, solar and biomass projects in order to support the country's efforts to shift from FiT renewable energy deployment to a market orientated price finding mechanism. This means that projects will no longer qualify for statutory FiT compensation, but will have to bid on it through a public auction organized and monitored by the Federal Network Agency (BNetzA). After the auction, the successful projects will receive contracts for a period of 20 years and this will be based on the sale of electricity generated at the bid price. Repowering incentives continued to be abolished in this law as well.

Spain

A few large operators own most of the wind turbines in Spain. This has significantly impacted the lifetime extension strategy as larger operators have more operational data available. However, presently, no political repowering subsidies exist. Even though repowering bonuses were announced in the Renewable Energy Plan 2011–2020, they have not materialized owing to the subsequent suspension of the plan.

Despite these setbacks, Nordex, one of the largest wind turbine manufacturers, won its first repowering project. The said project aimed at removing 22 old turbines at Acciona Energia's 30 MW El Cabrito project in Andalucía, southern Spain. The plan was that the site's 330 kW turbines would be replaced with eight N100 3 MW and four AW 70 1.5 MW machines. The lower number of turbines, it was hoped, would reduce the operating costs for El Cabrito, and the lower nominal capacity would result in an increased energy yield.

Meanwhile, in December 2017, the Spanish wind energy association (Asociación Empresarial Eólica, AEE) published a growth plan in which it said that the country should reach 40 GW of installed capacity by 2030. Repowering of ageing wind farms and new installations are considered imperative to Spain, therefore, meeting this target was envisaged in the growth plan.

Netherlands

The installation of wind power in the country began in the mid-80s, around the year 1985. Most of the old wind farms in Netherlands consist of smaller turbines compared to those that are typically deployed today. This provides sufficient scope for repowering of old wind installations in the country. Broad estimates set the repowering potential in the country to be around 1,000 MW.

Therefore, despite having a small market for wind, Netherlands is seen as a country which has immense scope for growth and provides an opportunity for wind repowering.

The Noordoostpolder wind farm on Lake IJsselmeer has 86 turbines installed by RWE Energy and several partners—they were the original equipment manufacturers in 2016. This farm will be powered by 48 Siemens 3 MW offshore turbines and 38 huge Enercon 7.5 MW E-126 turbines. At this site, RWE will remove its 50 WindMaster 300kW turbines once installation of the first 12 Enercon E-126 models is complete. With a hub height of 30 m and a rotor diameter of 25 m, WindMaster is dwarfed by Enercon, which has a hub height of 135 m and a rotor diameter of 127 m.

Simultaneously, investments to the tune of more than 200 million Euros were being discussed by the end of 2017, to repower Wieringermeer, one of the oldest wind farms in the country. By the year 2019, the project was expected to repower older wind turbines with updated technology and a capacity of 180 MW.[10]

Annexure 2: Draft policy for repowering of the wind power projects

No. 238/9/2018-Wind
Ministry of New and Renewable Energy
Atal Akshyay Urja Bhawan, Lodhi Road, New Delhi- 110003

Dated: 17th October, 2022

<u>Circular</u>

Subject: Draft 'National Repowering Policy for Wind Power Projects, 2022'– Reg.

A Policy for Repowering of the Wind Power Projects was issued on 5th August, 2016 by this ministry. Based on the feedback from stakeholders on the same the policy has been modified and a draft 'National Repowering Policy for Wind Power Projects, 2022' has been prepared.

2. The revised draft is attached as **Annexure** for stakeholders consultation.

3. It is requested that the comments on the draft may be provided to this ministry within 15 days, i.e. latest by 01.11.2022, to the undersigned through email at **rishikesh.mnre@gov.in.**

Rishi 17/10/22

Rishikesh Vaishnav
Scientist 'B', MNRE
Email: rishikesh.mnre@gov.in

To,
All Concerned.

Copy To:
1. PSO to Secretary, MNRE
2. PPS to JS (Wind)
3. Sci-D (PKD)

Annexure

DRAFT POLICY FOR REPOWERING OF THE WIND POWER PROJECTS

1. Introduction

India started harnessing Wind power in the late eighties and as on 31st August 2022 the total Wind power capacity installed in the country has reached 41.4 GW. India's Wind power sector is led by indigenous Wind power manufacturing industry which has shown consistent progress since its inception. The share of Wind power in the total installed capacity mix in the country has also increased from 21.1 GW in March, 2014 to 40.3 GW in March, 2022

The Wind turbine generator technology has evolved over and individual rated capacities of Wind turbines have increased from sub MW scale to multi MW scale. Most of the Wind-turbines installed in India up to the year 2000 are of sub MW capacity and are at sites having high Wind energy potential. Some of the old Wind turbines have already completed their design life while some are approaching the end of their design life. These Wind turbines are not only inefficient in comparison to the latest technology but also have lower hub heights (in the range of 30- 60m) in comparison to hub heights of 120-140 m range being installed these days. The lower hub height Wind turbines are not able to harness the higher Wind speeds available at higher hub heights. Therefore, it is essential to repower these older, smaller Wind turbines with higher capacity and higher efficiency turbines, in order to optimally utilize the Wind energy resource available at the respective site.

The Ministry of New and Renewable Energy had issued 'Policy for Repowering of the Wind Power Projects' on 5th August 2016 in order to create a facilitative framework for repowering. However, the majority of old Wind power projects with sub MW scale Wind turbines are yet to be repowered. Therefore, a revised policy has been drafted taking into account representations received from various stakeholders and subsequent deliberations.

2. Repowering Potential

National Institute of Wind Energy has estimated repowering potential of the country to be 25.406 GW considering Wind turbines below capacity 2 MW. The state wise details of repowering potential is as under:

States	Total Capacity below 0.5 MW	Total Capacity between 0.5-1 MW	Total Capacity between 1-1.5 MW	Total Capacity between 1.5-2 MW	Total Capacity below 02 MW
Tamil Nadu	1181	2919	1813	1473.5	4100
Maharashtra	243	1068	1389	731.35	1311

Karnataka	0.3	954	652	1417.05	954.3
Gujarat	51	1457	1352	1805.35	1508
Rajasthan	39	1192	788	914.9	1231
Madhya Pradesh	0	290	260	1012	290
Kerala	0	18	0	10	18
Andhra Pradesh	92	378	195	1701.2	470
Total	**1610**	**8280**	**6449**	**9067**	**25406**

Since the latest Wind turbine technology of 3+ MW capacity is being manufactured in the country, the repowering of Wind turbine of below 2 MW capacity must be considered. National Institute of Wind Energy will issue a repowering potential map of the country considering below 2 MW capacity Wind turbines.

3. Title and Enforcement

This policy will be known as the 'National Repowering Policy for Wind Power Projects – 2022'. The policy is being issued in supersession of 'Policy for Repowering of the Wind Power Projects' issued on 5th August 2016 and will be effective from the date of issuance.

4. Objective

The objectives of the Repowering Policy are optimum utilization of Wind energy resource by maximizing energy (kWh) yield per sq.km of the project area and utilizing the latest state-of-the art onshore Wind turbine technologies.

5. Eligibility

This policy lays out conditions for developers to go for repowering of their old Wind turbines. The following Wind turbines are eligible for repowering under the policy:

i. All Wind turbines as identified in accordance with the quality control order issued by this ministry under the relevant BIS Act ;

ii. The Wind turbines of rated capacity below 2 MW;

iii. Wind turbines which have completed their design life; and

iv. A set of existing Wind turbines over an area shall also be eligible for Repowering provided:

- Project area is a geographically contiguous land area
- All turbines considered for repowering are connected to a single Polling Sub Station (PSS)

- More than 90% of total capacity of the project should have completed its design life.

Note: These conditions shall not apply to such Wind turbines which are replaced or repowered within its design life due to malfunctioning, issues in workmanship, safety issues etc.

6. Repowering Project

A Repowering Project is a project which satisfies one or more of the eligibility conditions mentioned at clause 5 above and the capacity of the repowered Wind turbines is enhanced by at least 1.5 times of its aggregate capacity of old turbines.

A repowering project can be classified into two types:

i. Standalone Project – A Wind power project having a single or group of Wind turbines owned by a single entity

ii. Aggregation Project – A Wind power project having a group of Wind turbines owned by multiple owners with shared common infrastructure.

7. Implementation Arrangements

The repowering projects would be implemented through the respective State Nodal Agency/Organization involved in promotion of Wind energy in the State or the Central Nodal Agency appointed by the Central Government as detailed under:

(i) Standalone Project

a. State Nodal Agencies (SNAs)/Central Nodal Agency (CNA) shall identify the potential turbines for repowering and elicit interest from the potential Project Owner.

b. Project Owner may submit the Detailed Project Report (DPR) for repowering the old project to concerned SNA/CNA for verification.

c. Based on the DPR, the SNA/CNA will coordinate with the respective STU/ CTU for availability/ augmentation of the transmission capacity, if required.

d. On scrutiny of the project and transmission capacity availability, SNA/CNA may provide consent letter to Project Owner/Developer after obtaining in principle consent of the incumbent DISCOM.

(ii) Aggregation Project

In case of aggregation projects, the following modalities shall be adopted for development of the repowering projects;

a. SNAs/CNA may identify the potential turbines for repowering. In such cases SNAs/CNA either nominate any State/Central PSEs as Wind Repowering Project Aggregators (WRPA) to repower the project or elicit interest from private developers for the same. The selection of the private developer as WRPA shall be transparent based on minimum technical criteria and submission of consent letters from all the identified turbine owners.
b. A private developer may identify potential turbines for repowering and submit a proposal to the SNAs/CNA along with consent letters from all the identified turbine owners. In such cases the SNAs/CNA shall nominate the private developer as the WRPA.

- **Responsibilities of WRPA**:

  a. Preparation of a detailed project report (DPR) for land acquisition and development of the site for repowering project.
  b. Acquisition/ leasing/ purchase of additional land, if required.
  c. Acquisition of all assets at the site including Wind turbine and associated equipment, internal transmission infrastructure, land and power evacuation rights, compensate asset owners for their future loss of revenue for the balance life of the project, if any. The valuation of such functional/non-functional projects assets shall be done in accordance with the standard market practices. In this regard an indicative methodology for valuation of assets is annexed.
  d. WRPA shall also be responsible for decommissioning of the existing assets, removal and lawful disposal of all scrap from the site, including disposal of the Wind turbine blades. The turbine blades to be disposed as per the applicable norms of MoEFCC and CPCB/ SPCB and a certificate from appropriate authority need to be produced to that effect.
  e. Prepare the site without any encumbrances for development of Wind project as if it is a Greenfield project.

Procedure followed shall be as follows:

- WRPA shall submit the Detailed Project Report to concerned SNA.
- Based on the DPR, the SNA/CNA shall coordinate with the respective STU/CTU for availability/ augmentation of the transmission capacity, if required, and facilitate the acquisition of additional land, if required.
- On scrutiny of the project and transmission capacity availability, SNA/CNA shall provide consent letter to Project Owner/Developer after obtaining in principle consent of the incumbent DISCOM.

Note:

1. In case of In-STS connected Wind turbines, SNA shall identify the potential turbines for repowering and carry out required activities as mentioned.

2. In case of ISTS connected Wind turbines, CNA shall identify the potential turbines for repowering and carry out required activities as mentioned.

8. Repowering Implementation Framework

Within one month of announcement of this policy, MNRE shall appoint a monitoring and advisory committee (named as “Wind Repowering Committee (WRC)”) in accordance with the provisions of this policy to assist MNRE in implementation of the Repowering Policy.

The Members of the Committee shall include:

Joint Secretary (Wind), MNRE - Chairman
Representatives of IREDA, SECI – Member
Representative of Central Transmission Utility – Member
Representative of respective SNAs – Member
Three independent experts from Wind sector –Member (nominated by MNRE)
Representative of NIWE – Member Secretary

9. Arrangement for Power Purchase

a. The power generated corresponding to average of last three years’ generation prior to repowering would continue to be procured as per the terms of PPA in-force till the PPA tenure. In the case the PPA tenure is less than the standard PPA tenure i.e. 25 Years, the concerned DISCOM shall make arrangements to extend the tenure of the PPA for a period of 25 Years from the date of COD of the original project & continue to procure the quantum of power generated (average of last three years generation) for the remaining tenure of the PPA

b. The project developer(s) shall be at liberty to sell additional Wind power capacity (MW)/ generation to the incumbent DISCOMs or to any other entity through Open Access subject to refusal of concerned DISCOM. The power off take by concerned DISCOM shall be at the discovered tariff of the project.

c. A Wind farm/turbine undergoing repowering would be exempted from supplying Power to the Purchasing entity (DISCOM) during the period of execution of repowering, subject to that repowering period shall not exceed 2 years from the date of commencement of execution of re-powering.

d. The project developer(s) shall be at liberty to seek early termination by mutual consent of both the parties.

e. Incumbent DISCOM shall neither have any right over the additional power generated nor shall have any obligation to purchase the additional power generated after repowering.

f. In case of repowering of captive/ third party sale Wind power project, the consumer shall be allowed to purchase power from grid (through DISCOMs or any other available source) during the period of execution of repowering, as per relevant rules & regulation. SNA/CNA may coordinate with DISCOMs for facilitating such connection/ load for temporary period, as per existing provisions of DISCOMs.

10. Incentive

i. For repowering projects Indian Renewable Energy Development Agency (IREDA) will provide an additional interest rate rebate of 0.25% over and above the interest rate available to the new Wind projects being financed by IREDA.
ii. All fiscal and financial benefits available to the new Wind projects shall be available to the repowering project as per applicable conditions.
iii. Central or State Government may consider a scheme to provide additional financial incentives to the repowering projects, in order to support the additional investment required for repowering project (for decommissioning and acquisition of existing asset) in comparison with the greenfield projects. Repowering sites can also be considered under other relevant schemes available such as RE park scheme and avail the benefits under the same.
iv. The Wind RPO compliance of concerned states in which the repowering project is situated shall be exempted for the remaining period till the commissioning of repowered project. (For the purpose of calculations PLF from such projects shall be the average PLF's over the last three years before which the project was taken for Re-powering).
v. An enhanced RPO multiplier shall be provided to the repowered project for remaining period of PPA.

$$\text{RPO Multiplier} = \frac{X + Y}{Y}$$

Where

'X" is the average of last three years generation before repowering and

'Y' is the yearly generation of repowered project for the particular year for which RPO is calculated.

11. Data Management

i. NIWE shall create and maintain a project data base of all old projects with relevant information about the project such as ownership, technology, turbine details, connected PSS, land ownership etc.
ii. NIWE shall also collect performance related data for all the sites and analyse to identify poor performing sites for repowering in accordance with the IWTCQ
iii. SNAs/CNA along with SLDCs shall provide necessary cooperation to NIWE to collate

this data.

iv. NIWE shall coordinate with SNAs/CNA and maintain data of decommissioned projects which shall be updated on quarterly basis.

12. Power to amend and review

MNRE reserves the right to amend and review the policy from time to time to ensure effective implementation of this policy.

Annexure-I

It is noted that the PPAs for Wind power projects are generally signed for long time period (20/25 years) or renewed up to 25 years on short term basis (1 or 2 years). In such cases, the existing owners deciding to go for repowering may be losing the future revenue from their projects. Such potential financial loss needs to be compensated. In addition, Wind Repowering Project Aggregator (WRPA) would incur cost on decommissioning and disposal of the old Wind assets. The said cost may be partly compensated by the income from sale of scrap material. Accordingly, following equations may be considered for 'Repowering Site Preparation Cost (RSPC)'.

RSPC = Terminal Valuation + Decommissioning Cost – Income from sale of scrap material

Where:

Terminal Valuation = PPA Value + PPA Termination Incentive

"PPA value" can be estimated as an amount equal to the Net Present Value (NPV) of net revenue from the anticipated generation in the remaining years (as per PPA).

$$\text{PPA value} = NPV\ of\ \sum_{k=0}^{n}[(t * G_k) - (OM_k)]$$

wherein;

t = Tariff as per PPA in case of sale to DISCOM or third party. In case of captive consumption, tariff as per tariff order(s) of the appropriate commission for the year commissioning of project may be considered. In case of absence of both PPA and tariff order, a nominal tariff such as APPC of the concerned state for the project may be considered.

G= Average annual generation which may be calculated using the energy delivered at the delivery point (as defined in the PPA) or the PSS level data for the last 3 years.

OM= Annual O& M cost (OM) may be considered as per SERC/CERC tariff Orders. In case of absence of the appropriate SERC/CERC tariff orders O&M expenses for the first year of the control period shall be 2% of the wind turbine original capital cost (CAPEX) and shall be escalated at the rate of 5% per annum over the tariff period.

n = No of remaining years for completion of PPA

k= 1,2,3…….n

PPA Termination Incentive means the incentive provided to the asset owner over and above the PPA value. The incentive will be maximum upto 5% of PPA Value.

Decommissioning cost would include costs associated with dismantling Wind turbines, site clearance and disposal of blades.

Decommissioning cost = DS +SC+ DB

Wherein;

DS = Cost incurred for dismantling Wind turbine

SC = Cost incurred for clearing the site

DB = Cost incurred for disposal of blades.

Income from sale of scrap material may be considered on the basis of SERC/CERC tariff orders. In case of absence of appropriate order, the income shall be assumed to be 10% of the capital cost.

Indicative Valuation Model

(Model, Costs and calculations given below are indicative only and may not be considered as benchmark.)

Assumptions:

Project Type: Sale to Utility

Type of Turbine: 1000 KW

PLF: 12.3%

Annual Generation: 1077480 kWh

O & M Expense: 9 Lakhs

O & M Escalation: 5%

PPA Tariff (t): 3.00 (INR/kWh)

Escalation rate for Decommissioning Cost: 3%

Discount Rate for NPV: 10%

PPA Termination Incentive: 5% of (NPV of PPA Value)

Expected revenue (For last 10 year of PPA)		16th YEAR	17th YEAR	18th YEAR	19th YEAR	20th YEAR	21st YEAR	22nd YEAR	23rd YEAR	24th YEAR	25th YEAR
Annual Generation in MWh	**A**	1077.4	1077.4	1077.4	1077.4	1077.4	1077.4	1077.4	1077.4	1077.4	1077.4
O&M (INR Lakhs)	**B**	18.71	19.65	20.63	21.66	22.74	23.88	25.07	26.33	27.64	29.03
Revenue (INR Lakhs)	**C=t*A**	32.32	32.32	32.32	32.32	32.32	32.32	32.32	32.32	32.32	32.32
PPA Value (INR Lakhs)	**D=C-B**	13.61	12.68	11.70	10.66	9.58	8.44	7.25	6.00	4.68	3.30
No. of year left in PPA		10	9	8	7	6	5	4	3	2	1
NPV of PPA Value @ 10% discount rate (INR Lakhs)	**E**	59.42	51.75	44.24	36.97	30.00	23.42	17.32	11.80	6.98	3.00
PPA Termination Inc. (INR	**F**	2.97	2.59	2.21	1.85	1.50	1.17	0.87	0.59	0.35	0.15

Lakhs)											
NPV + PPA Termination Incentive (INR Lakhs)	**G=E+F**	**62.39**	**54.33**	**46.45**	**38.82**	**31.50**	**24.59**	**18.18**	**12.39**	**7.33**	**3.15**

Decommissioning cost (INR Lakhs)	**H**	25.00	25.75	26.52	27.32	28.14	28.98	29.85	30.75	31.67	32.62
Income from sale of scrap (INR Lakhs)	**I**	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00
Terminal value (INR Lakhs)= NPV + Termination Inc. + Income from Scrap - Decommissioning cost	**J=G+I-H**	87.39	78.58	69.93	61.50	53.36	45.61	38.33	31.64	25.66	20.53

Valuation in Rs Lakh/MW		87.39	78.58	69.93	61.50	53.36	45.61	38.33	31.64	25.66	20.53

References

1 Namit Sharma, Bram Smeets, and Christer Tryggestad 2019. *The decoupling of GDP and energy growth: A CEO guide*, McKinsey Quarterly. Accessed at https://www.mckinsey.com/industries/electric-power-and-natural-gas/our-insights/the-decoupling-of-gdp-and-energy-growth-a-ceo-guide on 12 January 2023.

2 T. Palaneeswari 2018. "Wind Power Development in Tamil Nadu," *International Journal of Research in Social Sciences* 8(3). Accessed at https://www.ijmra.us/project%20doc/2018/IJRSS_MARCH2018/IJMRA-13494.pdf on 12 January 2023

3 Pratha Jhawar 2020. *Renewable energy: Curtailment is a bane*, Down To Earth. Accessed at https://www.downtoearth.org.in/blog/energy/renewable-energy-curtailment-is-a-bane-68857 on 12 January 2023

4 Anon 2020. *Consultative Paper for procurement of wind power and related issues*, Tamil Nadu Electricity Regulatory Commission (TNERC). Accessed at http://www.tnerc.gov.in/PressRelease/files/PR-120320211500Eng.pdf on 12 January 2023

5 Anon (n.d.). *Published Tenders,* Solar Energy Corporation of India Limited (SECI). Accessed at https://www.seci.co.in/view/publish/tender?tender=all on 12 January 2023.

6 Manoj Kumar Upadhyay 2022. *Reviving the Wind Sector: Challenges & Suggestions*, The Financial Express. Accessed at https://www.financialexpress.com/opinion/reviving-the-wind-sector-challenges-suggestions/2454196/ on 12 January 2023.

7 Vasudevan Sridharan 2021. *In Tamil Nadu, rusting turbines showcase India's challenge in generating more wind power*, Scroll.in. Accessed at https://scroll.in/article/1012923/in-tamil-nadu-rusting-turbines-showcase-indias-challenge-in-generating-more-wind-power on 12 January 2023.

8 Anon (n.d.). *Gujarat Wind Power Policy*, GEDA. Accessed at https://geda.gujarat.gov.in/Gallery/Media_Gallery/Gujarat_Wind_Power_Policy-2016.pdf on 12 January 2023.

9 Anon 2022. *Wind Repowering in India: Potential, Opportunities, and Challenges*, USAID. Accessed at https://sarepenergy.net/wp-content/uploads/2022/11/USAID-SAREP-Presentation-Wind-Repowering-in-India-Potential-Opportunities-and-Challenges.pdf on 12 January 2023

10 Balwant Joshi et al 2018. *Repowering of old wind turbines in India*, Idam Infrastructure. Accessed at https://www.idaminfra.com/wp-content/uploads/2018/10/Repowering-of-Old-Wind-Turbines-in-India.pdf on 12 January 2023.

While renewables are the only way out of the energy-related concerns the world is currently caught in, harnessing the potential of wind energy is proving to be difficult for India due to a variety of reasons.

This paper aims to review and analyse the challenges and problems that the wind sector is facing in India, with a special focus on Tamil Nadu. Furthermore, by exploring the issue of repowering in detail, it addresses the ways and means these challenges can be overcome.

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