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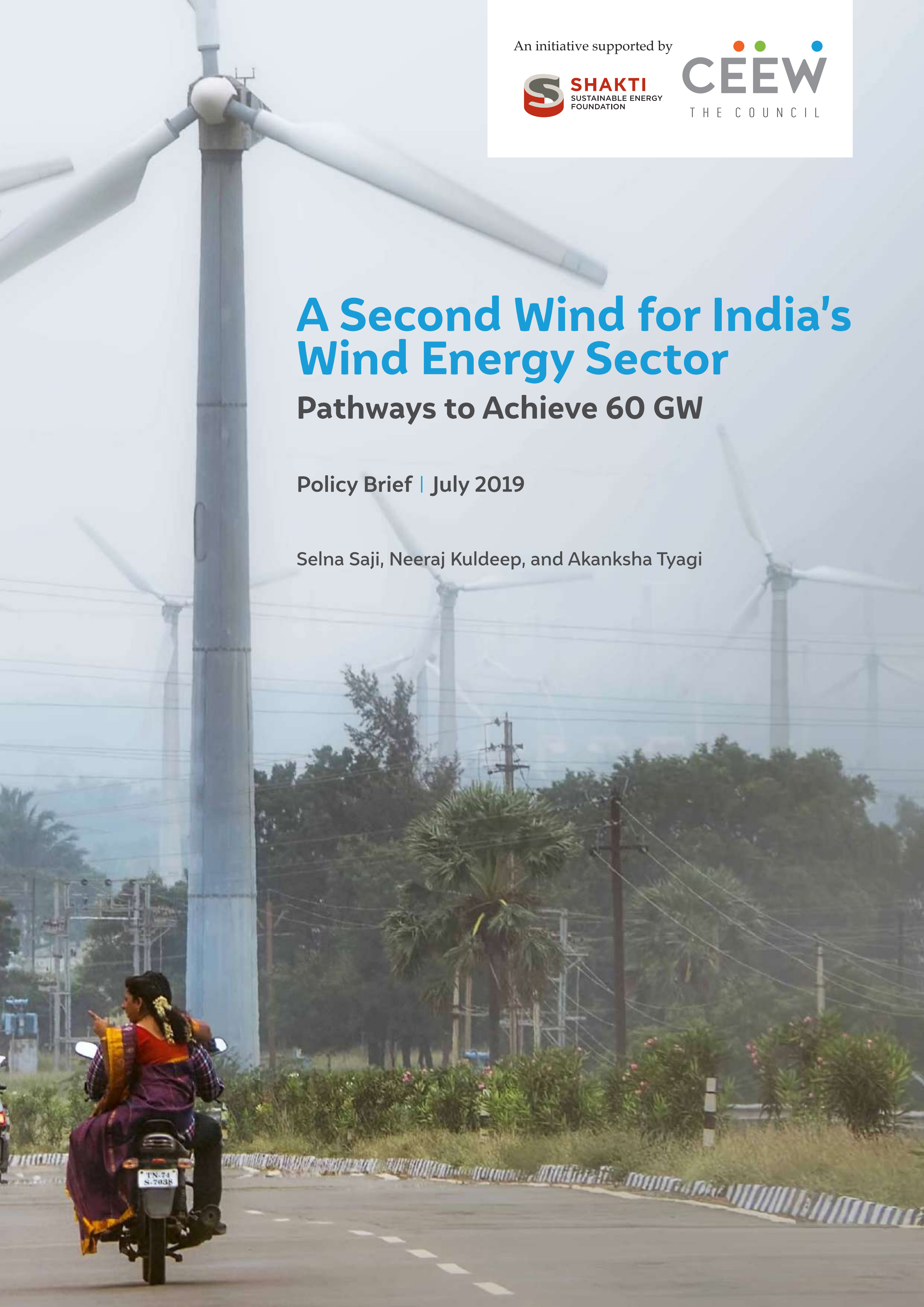

A Second Wind for India's Wind Energy Sector

Pathways to Achieve 60 GW

Policy Brief | July 2019

Selna Saji, Neeraj Kuldeep, and Akanksha Tyagi

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Selna Saji, Neeraj Kuldeep, and Akanksha Tyagi

Policy Brief
July 2019
ceew.in

Suggested citation: Saji, Selna, Neeraj Kuldeep, and Akanksha Tyagi. 2019. *A Second Wind for India's Wind Energy Sector: Pathways to Achieve 60 GW.* New Delhi: Council on Energy, Environment and Water..

Cover image: iStock

Peer reviewers: Rahul Tongia, Fellow, Energy and Sustainability, Brookings India; V. Subramanian, Independent expert; Industry reviewer (anonymity requested); and Abhishek Jain, Senior Programme Lead, CEEW.

Publication team: Alina Sen (CEEW), Mihir Shah (CEEW), The Clean Copy, Twig Designs, and Friends Digital.

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In 2019, CEEW once again featured extensively across nine categories in the '2018 Global Go To Think Tank Index Report', including being ranked as South Asia's top think tank (15^{th} globally) with an annual operating budget of less than USD 5 million for the sixth year in a row. CEEW has also been ranked as South Asia's top energy and resource policy think tank in the latest rankings. In 2016, CEEW was ranked 2^{nd} in India, 4^{th} outside Europe and North America, and 20^{th} globally out of 240 think tanks as per the ICCG Climate Think Tank's standardised rankings.

In over eight years of operations, The Council has engaged in over 210 research projects, published nearly 150 peer-reviewed books, policy reports and papers, advised governments around the world nearly 500 times, engaged with industry to encourage investments in clean technologies and improve efficiency in resource use, promoted bilateral and multilateral initiatives between governments on more than 60 occasions, helped state governments with water and irrigation reforms, and organised over 260 seminars and conferences.

The Council's major projects on energy policy include India's largest multidimensional energy access survey (ACCESS); the first independent assessment of India's solar mission; the Clean Energy Access Network (CLEAN) of hundreds of decentralised clean energy firms; India's green industrial policy; the USD 125 million India-U.S. Joint Clean Energy R&D Centers; developing the strategy for and supporting activities related to the International Solar Alliance; designing the Common Risk Mitigation Mechanism (CRMM); modelling long-term energy scenarios; energy subsidies reform; energy storage technologies; India's 2030 Renewable Energy Roadmap; energy efficiency measures for MSMEs; clean energy subsidies (for the Rio+20 Summit); clean energy innovations for rural economies; community energy; scaling up rooftop solar; and renewable energy jobs, finance and skills.

The Council's major projects on climate, environment and resource security include advising and contributing to climate negotiations (COP-24) in Katowice, especially on the formulating guidelines of the Paris Agreement rule-book; pathways for achieving NDCs and Mid-century Strategy for decarbonisation; assessing global climate risks; heat-health action plans for Indian cities; assessing India's adaptation gap; low-carbon rural development; environmental clearances; modelling HFC emissions; the business case for phasing down HFCs; assessing India's critical minerals; geoengineering governance; climate finance; nuclear power and low-carbon pathways; electric rail transport; monitoring air quality; the business case for energy efficiency and emissions reductions; India's first report on global governance, submitted to the National Security Adviser; foreign policy implications for resource security; India's power sector reforms; zero budget natural farming; resource nexus, and strategic industries and technologies; and the Maharashtra-Guangdong partnership on sustainability.

The Council's major projects on water governance and security include the 584-page National Water Resources Framework Study for India's 12^{th} Five-Year Plan; irrigation reform for Bihar; Swachh Bharat; supporting India's National Water Mission; collective action for water security; mapping India's traditional water bodies; modelling water-energy nexus; circular economy of water; participatory irrigation management in South Asia; domestic water conflicts; modelling decision-making at the basin-level; rainwater harvesting; and multi-stakeholder initiatives for urban water management.

About the authors

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Selna is an energy and environmental analyst who focusses on renewable energy technologies. At CEEW, she is working on developing business models and tools to facilitate the adoption of rooftop solar in India. Selna holds a dual postgraduate degree in Management and Engineering of Environment and Energy from Queen's University Belfast and Universidad Politécnica de Madrid.

"Interactions with the stakeholders in the industry give a bleak picture of the current state of affairs in the sector. Timely corrective actions are needed to revitalise the sector."

Neeraj Kuldeep
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Neeraj Kuldeep has worked and published extensively on renewable energy markets. He is currently leading the rooftop solar programme at The Council and piloting new utility-led business models to accelerate rooftop solar deployment. Neeraj holds an undergraduate degree in Energy Science and Engineering, and an M.Tech in Energy Systems from the Indian Institute of Technology (IIT), Bombay.

"Wind was a dominant renewable energy technology till recently; however, the focus has now shifted to solar considering the sharp decline in generation tariffs. It is distorting the existing strong domestic wind manufacturing industry as well. India must address the issues pertaining to the reverse auction mechanism and transmission and evacuation infrastructure. Provisions such as wind RPOs, site-specific reverse auctions, and wind generation within state boundaries for low wind states could provide the required impetus to revive the sector."

Akanksha Tyagi
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An experimental chemist by training, Akanksha contributes to the ongoing work on rooftop solar at The Council. Currently, she is developing a tool to assess the monetary value of grid-connected rooftop solar for the discoms. Before joining The Council, she was a postdoctoral researcher at ESICB, Kyoto University, and holds a doctorate in Human and Environmental Studies from Kyoto University.

"The wind energy sector is one of the greatest success stories of India's renewable energy programme. A clear understanding of the sector's current downfall will not only help in reinvigorating the sector but will also prevent recurrence in other emerging technologies."

Image: Emotivelens

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Abbreviations

AD	accelerated depreciation
ARR	aggregated revenue requirement
CCD	concessional custom duty
CDM	clean development mechanism
CEA	Central Electricity Authority
CEEW	Council on Energy, Environment and Water
CERC	Central Electricity Regulatory Commission
CPP	captive power projects
CSTEP	Centre for Study of Science, Technology and Policy
CTU	central transmission utility
CUF	capacity utilisation factor
C-WET	Centre for Wind Energy Technology
Discom	distribution companies
DNES	Department of Non-conventional Energy Sources
FiT	feed-in-tariff
GBI	generation-based incentive
gencos	generation companies
GIG	Grid Integration Guarantee
IPP	independent power producers
IREDA	Indian Renewable Energy Development Agency
ISTS	inter-state transmission system
KERC	Karnataka Electricity Regulatory Commission
LCOE	levelised cost of electricity
MNES	Ministry of Non-Conventional Energy Sources
MNRE	Ministry of New and Renewable Energy
MOP	Ministry of Power
MSME	micro, small, and medium enterprises
MW	megawatt
NEP	National Electricity Policy
NPA	non-performing asset
NTP	National Tariff Policy
NTPC	National Thermal Power Corporation
O&M	operations and maintenance
OEM	original equipment manufacturers
PGCIL	Power Grid Corporation of India Limited
PLF	plant load factor
PPA	power purchase agreement
PPP	public-private partnerships
PRAPTI	Payment Ratification and Analysis in Power procurement for bringing Transparency in Invoicing of generators
PV	photovoltaic
R&D	research and development
RE	renewable energy
REC	Renewable Energy Certificates
REMC	Renewable Energy Management Centres
RPO	renewable purchase obligation
RPS	renewable purchase specification
SAD	special additional duty
SECI	Solar Energy Corporation of India
SERC	State Electricity Regulatory Commission
SME	small and medium enterprises
STU	state transmission utility
TNEB	Tamil Nadu Electricity Board
TNERC	Tamil Nadu Electricity Regulatory Commission
TNSMA	Tamil Nadu Spinning Mills Association
TPS	third party sales
UT	union territories
VAT	value-added tax
VGF	viability gap funding
WPD	wind power density
WEGs	wind energy generators

With a cumulative capacity of around 35 GW, India is the fourth largest market globally for wind energy.

Image: iStock

Executive summary

Wind energy contributes 60 gigawatts (GW) to India's target of achieving 175 GW of renewable energy by 2022.[1] However, in the last few years, the sector has witnessed an immense slowdown. The annual capacity addition of wind energy was below 2 GW for the last two consecutive years—a drastic 60 per cent decrease from the financial year 2016–17.[2] Frequent policy changes, infrastructural unpreparedness, and a lack of consensus among stakeholders have crippled the growth of the sector, thereby jeopardising the possibility of achieving national targets in time.

The annual capacity addition of wind energy was below 2 GW for the last two years—a drastic 60 per cent decrease from the financial year 2016–17

In order to revitalise the sector and achieve the 60 GW target by 2022, this study examines the wind energy sector—its evolution over three decades and current challenges—and develops three scenarios that illustrate different pathways to achieve the minimum capacity required to reach 60 GW goal by 2022.

Evolution of the wind energy sector

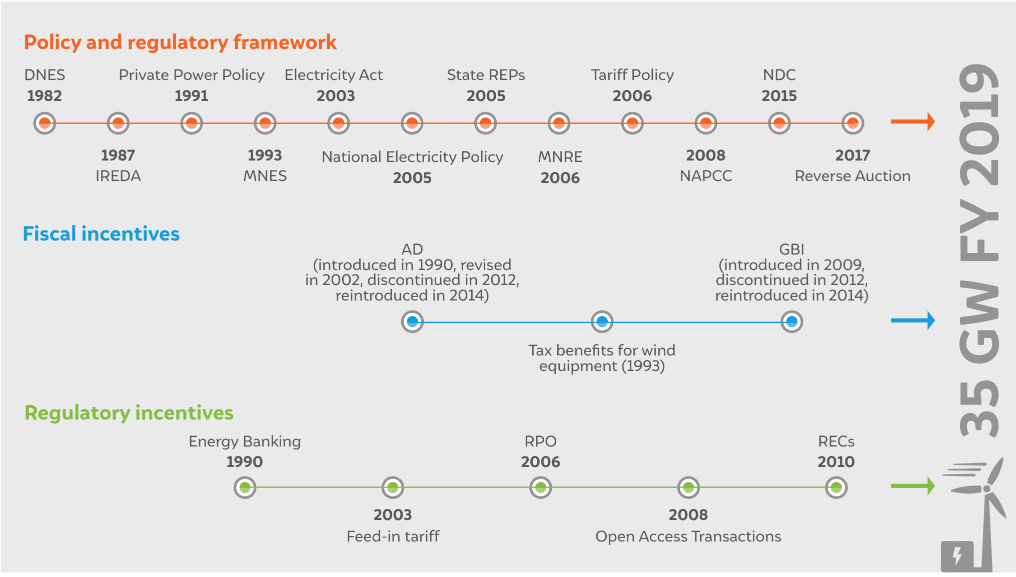
Over the last three decades, the wind energy sector has grown steadily to achieve a cumulative capacity of 35 GW,[3] making India the fourth-largest market globally. The first development in the sector dates back to the 1983, when a detailed wind resource assessment was conducted by the Indian Institute of Tropical Metrology.[4] Various regulatory interventions and fiscal incentives encouraged the private sector to actively invest in the area, resulting in its rapid growth. Figure ES1 illustrates the policy and regulatory framework that has shaped the wind energy sector since 1982.

1 Ministry of New and Renewable Energy (MNRE), Annual Report 2015–2016, (New Delhi: MNRE, 2016).

2 Nitin V. Raikar, Indian Wind Industry Analytical Report - FY 2017–18, (New Delhi, 2018).

3 Ministry of New and Renewable Energy (MNRE), "Physical progress (Achievements)," //www.mnre.gov.in/physical-progress-achievements, (May 31, 2019).

4 Anna Mani and D. A. Mooley, Wind Energy Data for India, (New Delhi: Allied Publishers Private Limited, 1983).



ES1:
Timeline of policy interventions and incentives

Source: Authors' analysis

One of the major milestones for the sector was the transition to reverse auction from the feed-in-tariff (FiT) regime. This transition also revealed some of the systemic issues that the sector faces, which were exacerbated under the new market design and have led to low annual capacity addition.

Impediments to growth

Wind resources in India are concentrated in the southern and western parts of the country, with the highest wind speeds being recorded in just three states. As reverse auction became the norm, the low ceiling tariffs set for the auctions led developers to set up plants in the windiest states; most the developers who won the bids have been looking to set up plants in Gujarat. This has put severe pressure on the available land and evacuation infrastructure in the region, leading to project delays. Reverse auctions with unfeasible ceiling tariffs coupled with the concentration of wind resources in certain regions have resulted in the following challenges that are impeding the growth of the sector:

a) **Land and evacuation infrastructure availability:** With the announcement of several solar and wind mega tenders, competition for suitable land with high wind speeds and grid connectivity has grown intense, making land acquisition in a timely manner an arduous task for developers. Most of the land in the high wind regions with access to grid connections have been used up. Hence, augmenting existing substations or building new ones is essential to setting up new wind power plants, which would further delay the commissioning of plants.

b) **Transmission infrastructure availability:** During the Twelfth Five-Year Plan period (2012–17), India's power generation capacity grew by 91 per cent whereas its transmission capacity (lines) increased by only 43 per cent.[5] There is a need to rapidly

One of the major milestones for the sector was the transition to reverse auction from the feed-in-tariff (FiT) regime

5 Central Electricity Authority (CEA), National Electricity Plan (Volume II) Transmission, (New Delhi: CEA, 2018).

expand the transmission network to keep up with the deployment of new capacity. Additionally, most of the windy sites are located in remote locations, far from demand centres. An adequate transmission network will ensure effective evacuation of the energy generated by wind power plants, minimising curtailment.

c) **Mechanism for regional cooperation:** One major reason for the simultaneous creation of power surplus and power-deficit regions is the lack of an effective mechanism for regional cooperation that would enable the seamless exchange of power. There is no effective framework that facilitates the inter-regional and inter-state exchange of electricity. Thus, wind energy is generated in concentrated regions without robust markets or regulatory mechanisms to transfer the power to power-deficit regions; this can lead to surplus wind energy in concentrated regions and hamper the demand for wind power from distribution companies (discoms) in the region.

d) **Discom financial health:** The poor financial condition of discoms has resulted in payments to wind power producers being delayed, thus creating cash flow problems for power producers which are at risk of being classified as non-performing assets (NPAs). The delays vary between 12–24 months between states, with most renewable energy (RE)-rich states having overdue bills from over 600 days.[6]

e) **Market design: transition to reverse bidding:** Wind power developers are facing serious challenges in implementing the reverse auction process. The low ceiling tariffs (below INR 2.85/kWh) set for the auctions are not feasible and can only be achieved at the highest wind speeds. Developers are facing delays in procuring land and gaining connectivity to the inter-state transmission system (ISTS) network—all within the same region—which is putting stress on the land and connectivity in the region.

Pathways to achieve 60 GW by 2022

There are two approaches to address the problem of concentrated wind energy resources. The first option is to have the generation plants concentrated in wind-rich or high wind power density (WPD) regions and have robust physical and market regulatory mechanisms to enable the effective transfer of the energy generated. The second option is to distribute the capacity from high to medium and low wind power density (WPD) regions. Repowering old wind plants is another potential approach to increase the overall capacity.

There are two approaches to address the problem of concentrated wind energy resources – to have generation plants concentrated in high WPD regions or to distribute the capacity from high to medium and low WPD regions

This study aims to conduct a preliminary assessment of the different approaches by developing three short-term state-wise scenarios and comparing them based on multiple aspects. The scenarios developed represent three pathways aimed at achieving the 60 GW target by 2022. They are termed as follows:

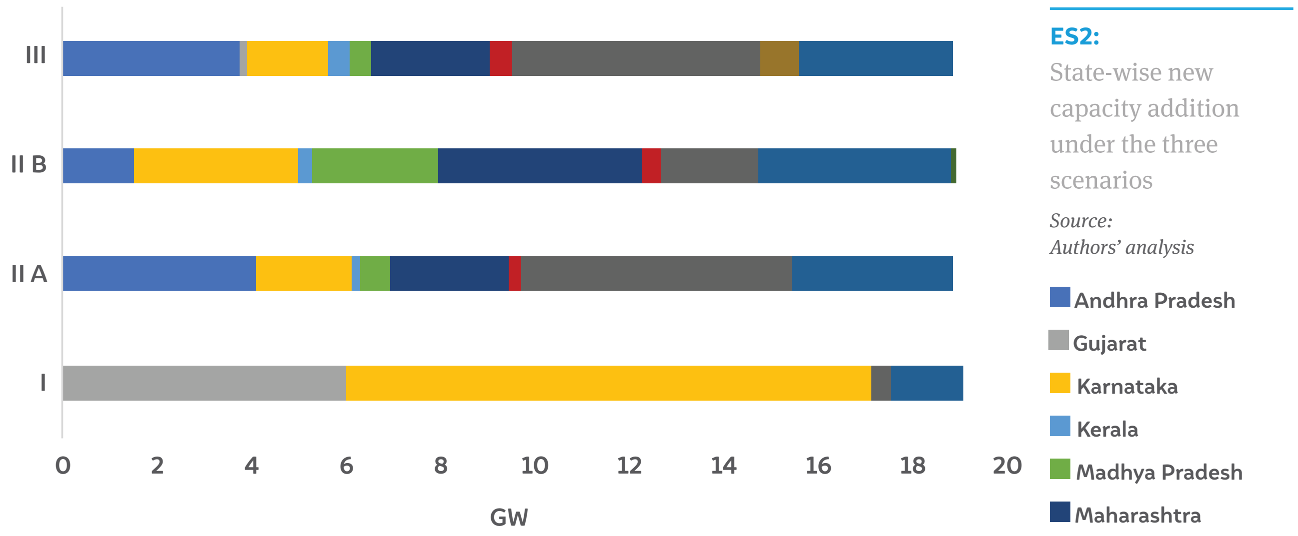
I. Base case scenario

II A. Medium-low WPD sites – fallow land only

II B. Medium-low WPD sites – fallow and agricultural land

III. Medium-low WPD sites – with repowering of old power plants

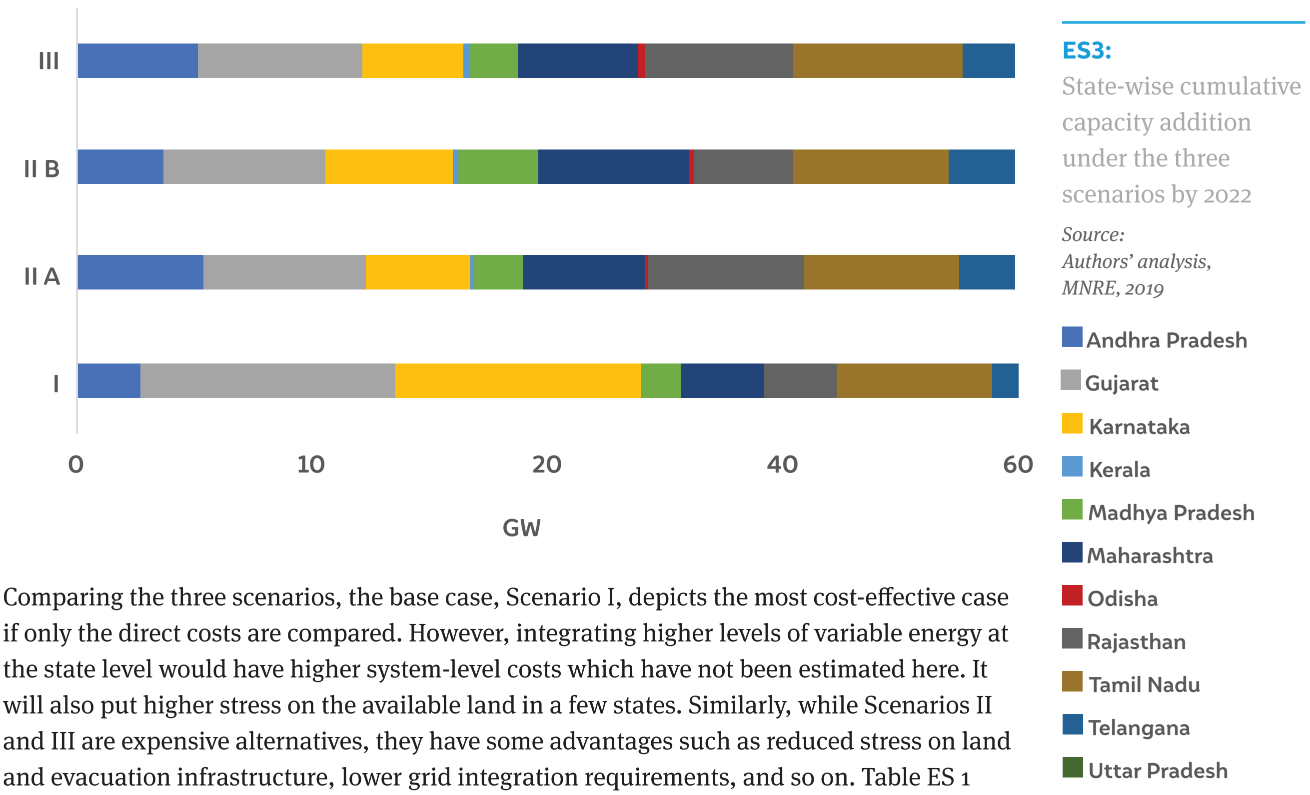
6 Ministry of Power, "Praapti," //www.praapti.in, (March 31, 2019).



ES2: State-wise new capacity addition under the three scenarios

Source: Authors' analysis

Scenario I depicts the base case where continuous deployment in high WPD states would occur with marginal deployment (2000 MW) in medium WPD states. Scenario II explores the potential to locate more capacity in the medium-low WPD sites. Scenario II A is developed assuming the use of only fallow land. Scenario II B assumes the use of fallow and agricultural land. In Scenario III, the repowering of 1.6 GW of capacity, which is located in some of the windiest sites, is considered. Additional deployment is assumed in medium-low WPD regions.



ES3: State-wise cumulative capacity addition under the three scenarios by 2022

Source: Authors' analysis, MNRE, 2019

Comparing the three scenarios, the base case, Scenario I, depicts the most cost-effective case if only the direct costs are compared. However, integrating higher levels of variable energy at the state level would have higher system-level costs which have not been estimated here. It will also put higher stress on the available land in a few states. Similarly, while Scenarios II and III are expensive alternatives, they have some advantages such as reduced stress on land and evacuation infrastructure, lower grid integration requirements, and so on. Table ES 1 compares the merits and demerits of the three scenarios.

Scenarios	Merits	Demerits
I	+ Lowest possible levelised cost of electricity (LCOE) as installations will be in the sites with the highest wind speeds only + Higher energy generation	– High stress on land and evacuation facilities in the windiest regions – Higher grid integration costs – Underutilisation of transmission infrastructure
II	+ Capacity is more distributed, leading to reduced stress on land and evacuation infrastructure + Lower transmission investment requirements as installations will be closer to demand centres + Reduced underutilisation of the ISTS network with a higher proportion of installations connected to state grids	– Increased cost sassociated with power generation from less windy sites, which would be costlier than solar energy generation from the same sites – Lower energy generation compared to other scenarios
III	+ More efficient use of land and resources by repowering old power plants + Higher energy generation than Scenario II	– Repowering old power plants may involve several implementation challenges – No incentives for existing power plant owners to repower plants

TABLE ES1: Comparison of merits and demerits of scenarios

Source:
Source: Authors' analysis

Short-term policy roadmap to achieve 60 GW target

A comprehensive policy roadmap is needed for the timely revival of the wind energy sector. A clear policy objective backed by a robust policy framework to support the new capacity addition as well as address sectoral challenges is required to revive the wind energy sector. Some key policy approaches that can increase capacity deployment in the sector in the short term are summarised below:

1. Define a clear policy objective after carefully choosing from the multiple approaches available to deploy new capacity
2. Streamline the reverse auction process to deploy new capacity at the central and state level
3. Provide regulatory support to create and sustain demand in the sector
4. Develop regulatory and financial mechanisms to address the high off-taker risk in the sector
5. Develop a regulatory framework to implement optimum grid integration practices

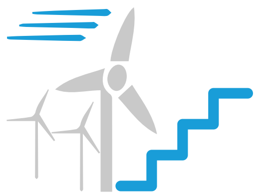
A comprehensive policy roadmap is needed for the timely revival of the wind energy sector

While the timeframe to commission a wind power plant is 18 months, commissioning new substations – from application to approval and then construction – usually takes around three years. Therefore, it is important to identify sites with available evacuation infrastructure for timely commissioning of the plant.

Image: iStock

1. Introduction

Aiming to capitalise on its vast renewable energy (RE) sources, India has set an ambitious target of achieving 175 GW by 2022.[7] Wind energy, one of the country's oldest and best developed RE technologies, is meant to contribute a significant 60 GW to this target.[8] Over the past three decades, the sector has steadily grown to achieve a cumulative capacity of 35.62 GW,[9] making India the fourth-largest market globally.[10] States with high WPD like Tamil Nadu, Gujarat, Karnataka, Maharashtra, Rajasthan, and Andhra Pradesh take the lead with a cumulative installed capacity that accounts for more than 90 per cent of the total wind capacity in the country.[11] This achievement was made possible by the fiscal incentives provided by the central and state governments and the active response of the private sector.[12] The exceptional growth of the sector has supported the country's transition from fossil to clean and sustainable fuels. The sector has also created a new domestic manufacturing industry, resulting in significant employment opportunities.[13]



Over the past three decades, the sector has steadily grown to achieve a cumulative capacity of 35.62 GW, making India the fourth-largest market globally

However, current trends suggest a rather grim future for the sector. Frequent policy changes, infrastructural unpreparedness, and a lack of consensus among stakeholders have crippled the growth of the sector, thereby jeopardising the possibility of achieving national targets in time. In the financial year 2017–18, there was a steep decline in annual capacity additions, with a mere 1.78 GW capacity being added as compared to 5.5 GW in the financial year 2016–17.[14] Decelerated growth continued in FY 2018–19, when the Solar Energy Corporation of India's (SECI) ambitious 1.2 GW wind tender went 50 per cent undersubscribed.[15] Although the sudden shift from FiT to reverse auction bidding was a major challenge, other persisting issues are equally detrimental. These include the scarcity of high WPD sites, lack of evacuation infrastructure, and poor inter-state cooperation that results in states with high WPD having surplus power and states with low WPD having unfulfilled renewable purchase obligation (RPO) targets. The weak financial health of distribution utilities adds to the

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7 Ministry of New and Renewable Energy (MNRE), Annual report 2015–2016,(New Delhi: MNRE, 2016).

8 MNRE, Annual report 2015–2016.

9 Realistic technical potential for rooftop solar PV in urban settlements.

10 TERI (2014) Reaching the Sun with Rooftop Solar, New Delhi: The Energy and Resource Institute, p. 62.

11 Bridge to India (2018) "India Solar Rooftop Map 2018," available at https://bridgetoindia.com/reports/, accessed on 12 February 2019.

12 TERI (2014) Reaching the Sun with Rooftop Solar, New Delhi: The Energy and Resource Institute, p. 62.

13 Prayas (Energy Group) (2016) Residential Electricity Consumption in India: What Do We Know?, Pune: Prays (Energy Group).

14 Authors' analysis.

15 Authors' analysis, ARR 2018-19 BSES Yamuna Private Limited (BYPL).

woes of the sector, as they continue to be reluctant to buy wind power and often default on payments to wind generators.

These challenges have limited the deployment of new wind projects and negatively influence the financial viability of existing wind projects. Since most of the high WPD sites have already been utilised, developers are unable to find viable sites within the project timeline. Project delays further exacerbate the financial struggles of investors who do not realise the expected returns. This is leading to a dampening of industry and investor interest as well as confidence in the sector. However, with some policy support and attention, the sector can be revitalised. This policy brief makes recommendations to that end.

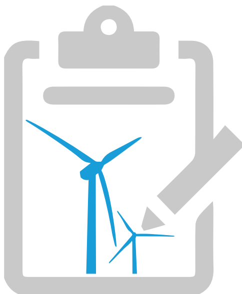
This policy brief discusses the issues that impede the development of wind energy in India and undertakes a systematic analysis to propose pathways and interventions to achieve the national target of 60 GW of wind capacity by 2022. Chapter 2 presents the current state of the sector in terms of capacity additions and lists policy changes and other factors that have led to the current scenario. Chapter 3 discusses the challenges obstructing the sectoral growth. Chapter 4 provides a detailed assessment of different approaches to achieve the national target. The various state-specific scenarios considered in the study compare these pathways on multiple grounds and highlight the associated challenges. Chapter 5 proposes some optimum approaches based on the results of the assessment.

2. Evolution of the wind sector in India

India has a vast potential for renewable energy; it contains several viable sites for constructing wind farms to harness an estimated potential of 302 GW at 100 m height.[16] The following section tracks the key regulatory actions taken in India and the incentives that have been provided by the government over the years to encourage the development of the wind sector.

1980–1990

The wind energy sector emerged in India in the early 1980s following a detailed assessment of wind resources by the Indian Institute of Tropical Metrology in 1983.[17] The resulting information helped the then newly established Department of Non-Conventional Energy Sources (DNES) decide how best to support the construction of the first grid-connected wind turbine in Gujarat in 1985. The project also marked the first collaboration between the government and the private sector. Technical guidance and financial aid from foreign agencies like the Danish aid agency (DANIDA) and World Bank's Renewable Resources Development Project contributed heavily to develop the wind market in India in these early years. The policy coherence and financial support led to the addition of 37 MW of wind capacity during the Seventh Five-Year Plan (1985–1990).[18]



The wind energy sector emerged in India in the early 1980s following a detailed assessment of wind resources by the Indian Institute of Tropical Metrology in 1983

1990–2000

With the intention of liberalising the power sector, the government formulated the Private Power Policy in 1991. This enabled private investors to generate or distribute power. With the nation's huge renewable energy potential in mind, the government established a public sector financing firm called the Indian Renewable Energy Development Agency (IREDA)

16 National Institute of Wind Energy, "Wind Power Potential at 100m agl,"https://niwe.res.in/department_wra_100m%20agl.php, (January 31, 2018).

17 Anna Mani and D. A. Mooley, Wind Energy Data for India, (New Delhi: Allied Publishers Private Limited, 1983).

18 Down to Earth, "Wind power: up, up and down," http://www.indiaenvironmentportal.org.in/content/10758/wind-power-up-up-and-down/, (July 30, 1992).

in 1987. IREDA provides loans for renewable energy projects around the country at interest rates lower than commercial rates. In 1993, the DNES was upgraded to a dedicated ministry, the Ministry of Non-Conventional Energy Sources (MNES). These were landmark policy interventions in the energy sector. The MNES laid down financial incentives to promote private-sector participation in the wind energy sector. Further, it also legislated attractive fiscal benefits like 100 per cent accelerated depreciation (AD) on capital investment (revised to 80 per cent in 2002); a five-year tax holiday on the revenue from wind energy; banking and wheeling facilities; tariff allocation for the sale of wind power; mandatory power purchases to be made by state electricity boards; industry status for manufacturing SMEs, making them eligible for various industry-related benefits like relief from customs and excise duties; and revised foreign investment norms.[19] Supported by these incentives, private-sector participation in the wind energy sector increased manifold, with the cumulative capacity reaching 576 MW during the mid-90s.

However, the sector could not sustain this sudden and unregulated growth. Research and development (R&D) was still in the nascent stages. There were no technical standards or regulatory frameworks in place, which led to poor governance practices. These, along with delays in land allocation and reduced tax benefits by the government, decelerated the growth of the sector in the late 90s.[20] Consequently, the annual capacity addition fell to 72 MW in 2000, 80 per cent less than that in 1995.

2000–2012

To revitalise the power sector, government introduced the Electricity Act in 2003. It proved pivotal for the wind energy sector as well. The enactment introduced feed-in-tariffs for the sale of wind power and directed the state electricity authorities (SERCs) to procure a fixed component of their power requirements from renewable sources under the Renewable Purchase Specification (RPS). Later, amendments to the National Electricity Policy (NEP) in 2005 and the National Tariff Policy (NTP) in 2006 also focused on the development of the wind energy sector. Building upon these, the SERCs designed policies to promote wind energy in their respective territories, introduced RPOs, and conducted tariff determination. The Centre for Wind Energy Technology (C-WET) in Tamil Nadu and its National Wind Resource Assessment Programme provided the necessary data on potential windy sites around the country, standardisation, certifications for equipment, and the technological improvements required to boost the wind energy sector. These reforms accelerated wind capacity addition; the annual capacity addition rose to 1,836 MW in 2006, a 2,400 per cent increase from 2000. These capacity additions boosted the growth of the manufacturing industry as well. Both Indian and foreign companies invested to set up local manufacturing units for turbines and other components. The government supported it by exempting specific parts like the rotor, tower, blades, nacelle, wind power controller, etc. from excise duty, concessional custom duty (CCD), and special additional duty (SAD).[21]

Aiming to maintain growth in the sector, the government shifted its focus from sanctioning additional capacity to improving the quality of wind farms in 2009

19 Emi Mizuno, Enabling Environment and Policy Principles for Replicable Technology Transfer: Lessons from Wind Energy in India (Cambridge: Climate Strategies, July 2015), 1–24.

20 B. Rajsekhar, F. Van Hulle, and J. C. Jansen, "Indian Wind Energy Programme: Performance and Future Directions," Energy Policy 27, no. 11 (1999): 669–678.

21 J. K. Jethani, "Wind Power Policy in India," (presentation, Conference on Wind Power in India, New Delhi, November 21, 2017).

Aiming to maintain this growth, the government shifted its focus from sanctioning additional capacity to improving the quality of wind farms. To encourage energy generation via efficient wind farms, in 2009, the Ministry of New and Renewable Energy (MNRE - renamed from MNES to MNRE in 2006) introduced a generation-based incentive (GBI) that was applicable to all grid-connected wind projects sanctioned before 2012. The scheme also aimed to facilitate the participation of independent power producers (IPPs) and to promote foreign direct investments in the wind energy sector. This was in lieu of the existent 80 per cent accelerated depreciation (AD) incentive, and could be availed by those IPPs who were not able to avail the AD benefit due to the non-availability of a depreciation appetite. Hence, the GBI and AD benefits were available in an either or basis. Under this, wind energy producers were paid INR 0.50 for every unit that was fed into the grid between 4 to 10 years of functioning. The scheme was applicable to plants of capacities less than 4 GW and the maximum receivables were capped at INR 10 million. GBI was a direct incentive for states with high WPD and the utilities there met their RPO targets comfortably. However, states with low WPD lagged behind, and it was difficult for utilities in these regions to meet their RPO targets. To overcome the issue of wind resources being concentrated in a few states and to ensure that all states meet their RPO targets, the government introduced renewable energy certificates (RECs) in 2010. It is a market-based instrument wherein state nodal agencies issue RECs to RE generators, who can later sell them at Power Exchanges. One REC equals 1 MWh of RE. As the minimum eligibility for a RE generator to be eligible for RECs was 1 MWh, the REC mechanism also encouraged higher energy generation from wind projects. These different generation-related benefits helped add a cumulative capacity of more than 3,000 MW in 2012.

2012–present

The AD benefits accorded to wind energy provided a huge impetus for the sector, but the lack of performance-linked monitoring led to poor practices. The AD benefit focused on the initial cost of the project, and there was no provision to correct the under performance of these projects. The investors and developers availed of the benefits without facing any penalisation for low generation. Thus, to curtail such consequences, the government discontinued the

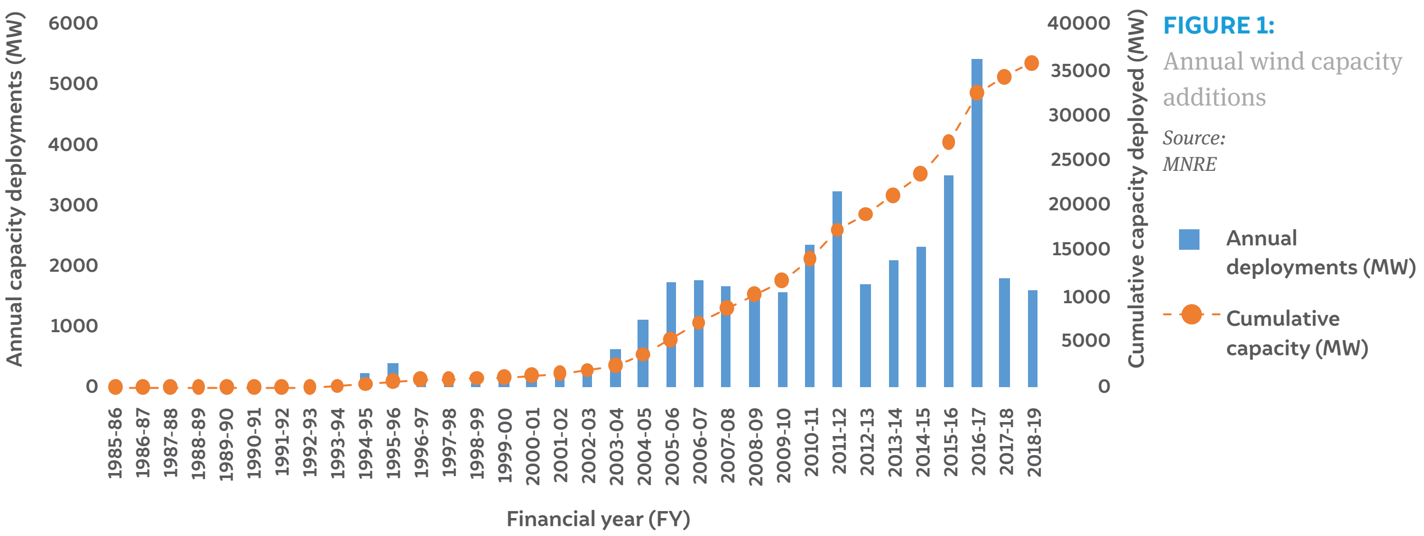
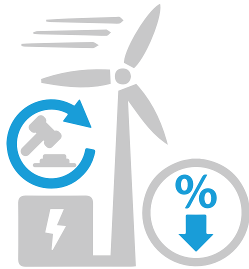


FIGURE 1: Annual wind capacity additions

Source: MNRE

incentive in 2012. Further, it did not renew the GBI after its expiry in 2012. The sudden removal of these two incentives led to a sharp decline in the annual wind capacity installed in 2013, with a mere 1,200 MW capacity being added. In response, the government re-introduced both incentives in 2014, which contributed to a 2,080 MW capacity addition.[22] The sector continued to grow steadily in the following years and the national cumulative capacity reached 26,777 MW in 2015. Anticipating continuous growth in the years to come, the government set the target of 175 GW of RE capacity by 2022, of which 60 GW would come from wind energy.[23]



The year 2016 was decisive for the future of the wind energy sector; with the aim of achieving low tariffs for wind energy, the government suggested a reverse auction bidding scheme for wind projects

The year 2016 was decisive for the future of the wind energy sector. At first, it witnessed a superlative capacity addition of 5,503 MW, reaching a cumulative capacity of 32,280 MW. Secondly, with the aim of achieving low tariffs for wind energy, the government suggested a reverse auction bidding scheme for wind projects.[24] Reverse bidding was fairly common in the solar energy sector and had resulted in record low tariffs, but it was a first for wind energy. The objective was to shift from a FiT mechanism to a uniform and transparent mechanism for expanding wind capacity. This was expected to induce a competitive market for wind energy. The auctions were delayed twice due to a lack of clarity among the developers on the topic.[25] In February 2017, when the SECI finally conducted the first-ever auction for setting up 1 GW of grid-connected wind power projects, the tariff discovered was a low INR 3.46 per unit. Although this served the primary aim of achieving competitive tariffs, other consequences surfaced soon. The sudden shift from the existing FiT mechanism to reverse auction had an adverse impact on both ongoing and new wind projects. Some of these developers were yet to sign a power purchase agreement (PPA) with utilities at fixed feed-in-tariffs now faced a growing demand for lower tariffs, similar to those from the auction. So, the developers had to negotiate with the original equipment manufacturers (OEMs) for cheaper turbines and identify favourable windy sites to compensate for the decreased revenue. The lack of clarity on the reverse auction scheme, poor land availability in windy states like Gujarat, and grid connectivity issues stalled the growth of the wind energy sector and resulted in a steep decline in annual wind capacity additions in 2017 and 2018, which stood at a mere 1,766 MW and 1,520 MW, respectively.

22 J. K. Jethani, "Wind Power Development in India: An Overview," Akshya Urja (August–October 2017): 11 (1&2), 20–25.

23 MNRE, Annual Report 2015–2016.

24 MNRE,"Sanction for the Scheme for Setting up of 1000 MW CTU-connected Wind Power Projects," https://mnre.gov.in/sites/default/files/schemes/Wind-1000-MW-CTU-Scheme.pdf, (June 14, 2016).

25 Newsbase, "India's First Wind Auctions Postponed," https://newsbase.com/topstories/india%E2%80%99s-first-wind-auctions-postponed, (December 22, 2016).

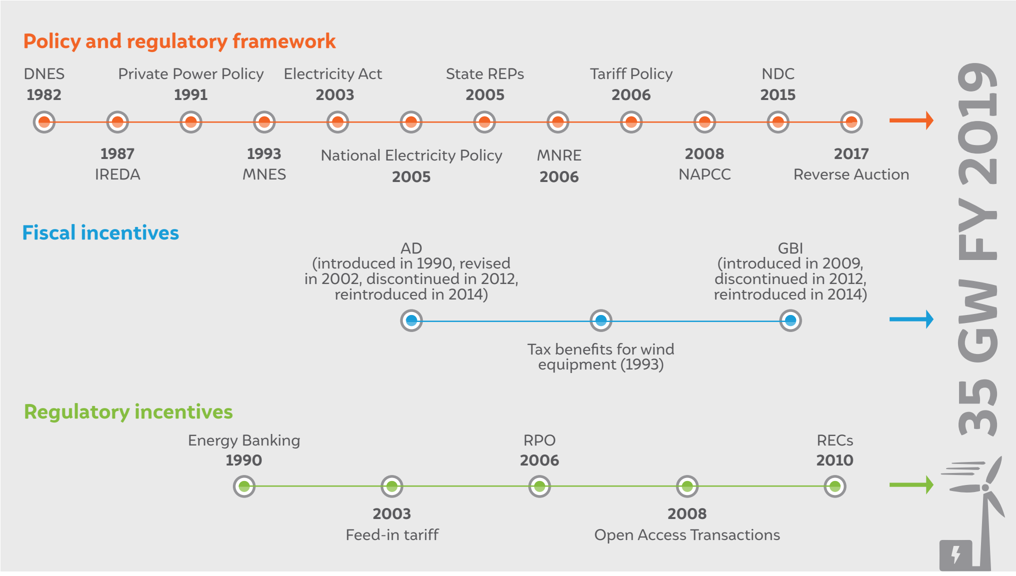


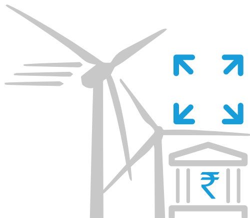
FIGURE 2: Timeline of policy interventions and incentives

Source: Ministry of Power, MNRE

2.1 State context

The following section mentions state-specific initiatives that supplemented the national-level policies and supported the development of the wind sector. The incentives can be categorised into financial and tax incentives that ensure increased investments and the smooth functioning of projects.

The primary requirement for setting up a wind project is securing viable land with wind potential. States like Maharashtra,[26] Madhya Pradesh,[27] and Andhra Pradesh[28] facilitate land acquisition by providing government lands at concessional rates for developing wind projects. In addition, states like Rajasthan[29] and Gujarat[30] permit the use of private land for industrial purposes at nominal charges. Once the land has been acquired, developers need financial incentives and infrastructural support for the construction and smooth operation of plants. At the construction stage, states like Madhya Pradesh and Rajasthan give industry status to wind MSMEs to make them eligible for various schemes and incentives administered by the state industry department. For example, under its Industrial Promotion Policy, the Madhya Pradesh government establishes land banks to manage future land requirements for industries and skill development institutes,[31] both of which are crucial for the development of the wind energy sector. States also impose a low value-added tax (VAT), in the range of 5 to 5.5 per cent, and exempt wind energy equipment from the entry tax that is



Smooth plant operation requires access to evacuation, transmission, and banking infrastructure to overcome the intermittency of wind energy. State governments have set concessional transmission and wheeling charges to evacuate wind electricity

26 Maharashtra Energy Development Agency, "Policy for Renewable Energy sources 2015," https://www.mahaurja.com/meda/data/grid_wind_power/state_policy/Policy%202015_2.pdf, (July 20, 2015).

27 Government of Madhya Pradesh , "Wind Power Project Policy of Madhya Pradesh -2012," http://www.mpnred.com/Images/pdf/Wind-Policy_ENGLISH.pdf, (February, 2015).

28 Government of Andhra Pradesh, "Andhra Pradesh Wind Power Policy," http://apedb.gov.in/downloads/wind-power-policy.pdf, (February 13, 2015).

29 Energy Department, Government of Rajasthan, "Policy for Promoting Generation of Electricity from Wind 2012," http://energy.rajasthan.gov.in/content/dam/raj/energy/common/Policy%20for%20promoting%20generation%20of%20electricity%20from%20Wind%20-2012.pdf, (July 18, 2012).

30 Energy and Petrochemicals Department, Government of Gujarat, "Gujarat Wind Power Policy, 2016," https://guj-epd.gujarat.gov.in/uploads/guj-wind-Power-Policy-2016.pdf, (August 2, 2016).

31 Department of Commerce, Industry & Employment, Government of Madhya Pradesh, "Industrial Promotion Policy, 2014, and Action Plan," http://www.dit.mp.gov.in/documents/10180/e13533ae-5c3e-433f-bba8-2809da8824bd, (October 2014).

usually levied on goods entering a state from outside its boundary. These tax benefits ensure greater ease in doing business and promote technology exchange.

Smooth plant operation requires access to evacuation, transmission, and banking infrastructure to overcome the intermittency of wind energy. State governments have set concessional transmission and wheeling charges to evacuate wind electricity. For example, Rajasthan charges 50 per cent, Tamil Nadu 40 per cent, and Andhra Pradesh 5 per cent of the normal tariffs for transmission and wheeling. In Gujarat, normal open-access charges are used for third-party sale projects, while voltage-specific tariffs exist for captive plants. Madhya Pradesh exempts captive and open-access consumers from open-access charges. Thus, although the extent and type of incentives vary across the country, all states have taken initiatives to facilitate plant operation.

Energy banking is crucial for ensuring the continuous supply of energy to the consumer.[32] It allows the generators to supply energy at times when wind energy is unavailable. Maharashtra (has slot-wise settlement), Andhra Pradesh (charges at 2 per cent of energy injected), Karnataka (charges at 2 per cent of the input energy, which is carried forward on a monthly basis), and Madhya Pradesh (has a banking fee of 2 per cent of the banked energy) have no conditions on projects or duration and provide banking throughout the year.[33] Andhra Pradesh follows this approach (has a fee of 2 per cent of the injected energy) with restrictions on withdrawal during peak hours. Further, Maharashtra provides a slot-wise year-round banking facility for self-use and sale to third parties. The utility will purchase a maximum of 10 per cent of the net energy delivered to the grid by the developer at the lowest time-of-day slab rate for the high tension (HT) energy tariff of the financial year in which the power was generated. Rajasthan, on the other hand, provides banking throughout the year except between December and February. In Gujarat, the facility is unavailable for third-party sale and captive power projects (CPP) opting for REC, while a one-month slot-wise facility is available for CPPs not opting for REC.

32 National Renewable Energy Laboratory, "Wheeling and Banking Strategies for Optimal Renewable Energy Deployment: International Experiences," https://www.nrel.gov/docs/fy16osti/65660.pdf,(March 2016).

33 Consultation on National Wind Energy Mission, "Existing Wind Power Policies and Incentives," https://mnre.gov.in/file-manager/UserFiles/Presentations-NWM-09012014/Dilip-Nigam.pdf, (January, 2014).

TABLE 1: Summary of banking charges set by states for renewable energy

Source: Compiled by the authors

State	Banking charges	Other conditions
Tamil Nadu	INR 0.94/unit	Allowed for 1 FY (April–March) for non-REC projects. REC projects can bank for one month and the surplus beyond this would be considered lapsed
Gujarat	No information on exact charges	Monthly settlement available for CPPs unaffiliated to REC Projects under third-party sale and CPPs under REC cannot avail banking facilities
Karnataka	@2% of input energy	Carried forward on a monthly basis throughout the year
Maharashtra	Lowest time-of-day slab rate of FY of generation	Annual settlement
Rajasthan	No information on exact charges	Allowed on a half-yearly basis for the FY (April–September and October–March); prohibited from December to March
Andhra Pradesh	@2% of input energy	No withdrawal during peak months (Jan–June) and hours (0600–0900 and 1800–2100)

TABLE 2: Summary of wheeling and transmission charges set by states for renewable energy

Source: Compiled by the authors

State	Wheeling and transmission charges
Tamil Nadu	40% of normal transmission and wheeling charges
Gujarat	**CPP:** Voltage > 66 kV: normal transmission charges as applicable to open-access consumers Voltage < 66 kV: transmission charges are same as normal open-access consumer charges; wheeling charges are 50% of normal open-access consumer charges **TPS:** all charges are the same as open-access consumer charges; if wheeling is at more than one location, INR 0.05/unit on energy fed to the recipient's discom in addition to the applicable open access charges.
Karnataka	5% of injected energy (in kind)
Maharashtra	Normal open-access charges
Rajasthan	50% of normal charges
Andhra Pradesh	Total wheeling and transmission charges in kind at 5% of electricity delivered to the grid
Madhya Pradesh	CPP and open-access consumers are exempted from open-access charges; 4% wheeling charge grant to the discom for TPS within the state

TABLE 3: Summary of government incentives

Source: Compiled by author

Direct incentive	• Generation-based incentive • Sales tax benefit • Exemption on income tax on earnings from wind projects for 10 years
Indirect incentive	• Accelerated depreciation • Reduced excise duty on wind energy generator • Concessions on custom duty for certain wind turbine components

In addition to the above incentives, leading wind energy producing states like Tamil Nadu,[34] Maharashtra, and Gujarat have taken additional steps to reach the present capacity levels (Box 1).

34 Tamil Nadu Energy Development Agency, "Wind Energy," https://www.ireda.in/writereaddata/CompendiumStatePolicyRE/P%20Original/Tamil%20w.pdf, (2009).

Box 1 - List of additional incentives taken by states with high installed wind energy capacity

Tamil Nadu: In Tamil Nadu, the local textile and cement industries invested extensively in wind energy. Tamil Nadu's Spinning Mills Association (TASMA) was an early adopter of grid-connected wind energy projects, or the 'bundled wind project' model. The Ministry of Textiles provided capital loans for setting up CPPs or third-party sales under the Technology Upgradation Fund (TUF) scheme. The state has also mandated repowering all WEGs (Wind Energy Generators) with low plant load factor (PLF). It also encourages public-private partnerships (PPP) for the development of infrastructure like roads to access the plants.

Maharashtra: Like Tamil Nadu, Maharashtra also promoted CPPs by introducing sales tax benefits and levying off electricity duty for the first five years after the date of commissioning the project. In addition, it has imposed a Green Cess to collect funds for the development of the renewable energy sector and to develop the required infrastructure for the evacuation of wind energy. A similar tax is also planned in Karnataka. Maharashtra is also the only state that has set feed-in-tariffs based on the WPD, contrary to other states that use a fixed feed-in-tariff.

Gujarat: In Gujarat, the benefits from the Clean Development Mechanism (CDM) are shared between power producers and procurers. Starting with the power producer being the sole beneficiary, the procurer gets 10 per cent of the benefits every year until it is equally distributed.

The government and private sector have worked together to bring the wind energy sector to its current stage. However, the lack of vision in the implemented policies and infrastructural unpreparedness, inter alia, have jeopardised the sector. Therefore, the sector needs prudent solutions to achieve the ambitious 60 GW target in a timely manner and create market depth to increase wind deployment beyond the target capacity as well.

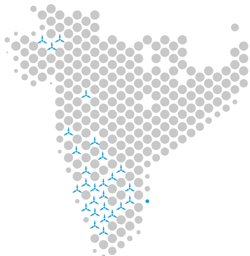
3. Impediments to growth in the sector

Image: iStock

The wind energy sector in India is facing a grim future. Due to the stagnation in its very promising growth trajectory, the sector has virtually come to a standstill, with an annual installation of less than 1,500 MW in 2018.[35] While the transition from the 15-year-old FiT to an auction-based regime has coincided with this stagnation, the real impediments to its growth area number of systemic problems.

As described in the previous chapter, wind resources in India are concentrated in the southern and western regions, with 93 per cent of all installations being located in seven states in the country. These regions also hold vast potential for solar power.[36] This has led to extensive wind and solar deployments in the region, which have put pressure on the availability of land and transmission infrastructure. The absence of an effective mechanism for inter-regional cooperation on electricity exchange has led to the problem of plenty, with discoms having surplus power leading to frequent cases of back down of thermal power plants and curtailment of renewable power.[37,38] Further, wind power producers are burdened by the poor financial health and operational inefficiencies of their off-takers, the discoms.[39] Payment delays, delays in signing PPAs, and PPA renegotiations and cancellations have created an atmosphere of uncertainty in the sector.

The impact of these sectoral challenges increased once the wind sector moved to the auction regime. The sector will continue to struggle without timely corrective actions and sufficient policy support. To worsen the situation, recent issues have increased the perceived risk in the sector and has made affordable debt more inaccessible.[40]



Wind resources in India are concentrated in the southern and western regions, with 93 per cent of all installations being located in seven states in the country

35 MNRE, "Physical Progress (Achievements)," https://mnre.gov.in/physical-progress-achievements, (May 31, 2019).

36 MNRE, "State-wise Estimated Solar Power Potential in the Country," (February 2, 2014).

37 Prayas (Energy Group), The Price of Plenty: Insights from 'Surplus' Power in Indian States, (Pune: Prayas [Energy Group], 2017).

38 Council on Energy, Environment and Water (CEEW), Curtailing Renewable Energy Curtailment, (New Delhi: CEEW, 2018).

39 Manu Aggarwal and Arjun Dutt, State of the Indian Renewable Energy Sector: Drivers, Risks, and Opportunities, (New Delhi: CEEW, 2018).

40 Industry sources.

The following section describes, in detail, the growth impediments that the wind energy sector in India is currently facing.

3.1 Land and evacuation infrastructure availability

Wind energy production is land intensive. On average, a 2MW turbine model usually requires 1 hectare of land, in addition to the land needed for roads and maintenance and evacuation infrastructure.[41] In most SECI tenders, developers are free to choose the site. However, with the announcement of several solar and wind mega tenders, acquiring suitable land with high wind speeds and grid connectivity in a timely manner has proven to be an arduous task for developers. The recent SECI tender for 1,200 MW ISTS-connected wind power under Tranche - VII (announced in February 2019) went undersubscribed by 50 per cent due to the unavailability of good sites with existing evacuation facilities.[42]

Timely procurement of land is a major challenge for developers. Land, being a state subject, has different governing regulations across states. The process for procurement also varies depending on the type of land and the procurement model – land leasing or purchase. Revenue land – usually fallow and unutilised land – has to be leased from the state government on the recommendation of the state nodal agency. Private land has to be either leased or purchased. However, utilising private land, which is mostly agricultural land, would require it to be converted to non-agricultural land.

While identifying land, developers also need to apply for connectivity to the transmission grid. If there are grid substations available nearby, approvals from the relevant state transmission utility (STU) would be required. If sufficient capacity is not available in the existing infrastructure, the existing substation needs to be augmented or new substations need to be built. In that case, there will be a delay of 18–22 months in the project execution timeline. While the timeframe for wind power plant commissioning is 18 months, commissioning new substations – from application to approval and then construction – usually takes around three years.

Timely procurement of land is a major challenge for developers. Land, being a state subject, has different governing regulations across states

Another worrying issue is the underutilisation of connectivity bays granted for wind and solar generation projects. As per the Connectivity Regulations, the Central Transmission Utility (CTU) can grant connectivity to pooling substations to RE generators with plant capacities between 50 and 250 MW. As the connectivity applicant is not obligated to sign any agreement, submit any bank guarantee, or fulfil any other financial obligation, there have been multiple instances of grantees making no use of the connection, thus blocking other entities from using the connection facility and, therefore, the land nearby.[43,44]

41 Amit Kumar and Sapan Tapar, Addressing Land Issues for Utility Scale Renewable Energy Deployment in India, (New Delhi: TERI School of Advanced Studies, 2017).

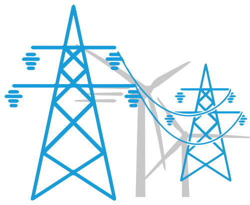
42 Saumy Prateek, "SECI's 1.2 GIGAWATTS Wind Tender Undersubscribed by 50% Owing to Tariff Cap and Land Woes," Mercom India, https://mercomindia.com/secis-1-2-gigawatts -wind-tender-undersubscribed/, (April 17, 2019).

43 Central Electricity Regulatory Commission (CERC), "Petition No. 145/MP/2017," http://www.cercind.gov.in/2017/orders/145_MP.pdf, September 29, 2017.

44 Industry sources.

3.2 Transmission infrastructure

More than 9 GW of wind capacity is planned to be deployed between 2019 and 2020 and an additional 15 GW of capacity needs to be commissioned to achieve the 60 GW target. According to the National Electricity Plan by the Central Electricity Authority (CEA), the current plan for transmission system expansion (2017–2022), which includes the Green Energy Corridor, is sufficient to absorb the planned capacity addition until 2022, including the expected 175 GW of renewables.[45] However, the progress of the project has been dismal. The Green Energy Corridor aims to establish substations with an aggregate capacity of 19,000 mega volt amperes (MVA) and install 8,500 circuit kilometres of transmission lines in eight states by March 2020. According to the report by the Parliamentary Standing Committee on Energy, a mere 13 per cent of the targeted transmission lines were installed with commissioning still pending, as of 31 December, 2017.[46] This means that the remaining 77 per cent of the work needs to be completed within two years to meet the target by March 2020. Considering the underlying challenges, it seems highly unlikely that the required transmission capacity will be built within this timeframe.



The growing installed capacity with sluggish expansion of transmission facilities can lead to the non-commissioning of awarded projects and curtailment of renewable power

The growing installed capacity with sluggish expansion of transmission facilities can lead to the non-commissioning of awarded projects and curtailment of renewable power. Currently, several instances of grid curtailment due to congestion have been reported in the industry. According to CEEW analysis, monthly curtailment at the substation level has gone as high as 35 percent in Gujarat with an annual average of 5 per cent. Curtailment of even 5 per cent a year would lead to a 17 per cent decrease in the project's returns on equity.[47,48]

Conversely, seasonal variations in wind energy generation also result in the underutilisation of transmission infrastructure dedicated for wind. According to CEEW analysis, 51 per cent of the wind energy generated in Gujarat in 2015 was generated in only 34 per cent of the days in the year.[49] The average monthly wind generation over the rest of the year was 67 per cent lower than the highest monthly generation, which was in the month of July.[50] This indicates that transmission infrastructure dedicated to evacuating wind energy over long distances, such as the Green Energy Corridor, would remain underutilised for most of the year.

3.3 Mechanism for regional cooperation

Large wind energy capacity additions in a few regions have led to the problem of surplus power and frequent back down of thermal power plants. Studies suggest that even if states meet 60 per cent of their renewable capacity targets by 2022, distribution companies will be burdened by surplus power, which will lead to a large number of stranded assets.[51] Most

45 CEA, National Electricity Plan (Volume II) Transmission, (New Delhi: CEA, 2018).

46 Standing Committee on Energy, "39th Report MNRE Demands for Grants," (presentation, Lok Sabha, March 13, 2018).

47 Anjali Viswamohanan and Manu Aggarwal, Curtailing Renewable Energy Curtailment, (New Delhi: CEEW, 2018).

48 Authors' analysis.

49 Authors' analysis; data from Gujarat SLDC.

50 Authors' analysis; data from Gujarat SLDC.

51 Prayas (Energy Group), The Price of Plenty: Insights from 'Surplus' Power in Indian States.

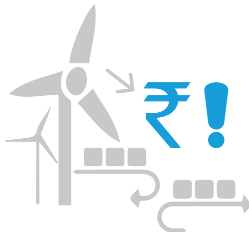
recently, Karnataka Electricity Regulatory Commission (KERC) has asked the state nodal agency to halt solar auctions as power generation in the state exceeds the demand.[52] The lack of an effective mechanism for regional cooperation that would enable the seamless exchange of power is one of the major reasons for the existence of power surplus and power-deficit regions at the same time. This could further hamper the demand for wind power from discoms in the country.

The RPO, which was created to act as a mechanism to compel discoms to procure renewable power, has not been very effective. This is because the current regulatory framework does not mandate compliance to RPOs. As many as 27 of the states and union territories (UTs) met less than 60 per cent of their RPOs and 25 out of these 27 are non-RE-rich states and UTs.[53] While the ISTS-connected auctions conducted by SECI and NTPC are one way for the non-RE-rich states to procure large-scale renewable energy, there is no effective framework for electricity exchange between states.

3.4 Discom financial health

Discoms in India have traditionally been the weakest link in the electricity value chain due to the burgeoning losses they incur from continuously deferring tariff hikes and due to delayed subsidy reimbursements. The financial woes of discoms are now spilling over to the rest of the value chain. As of March 2019, state discoms owe over INR 41,000 crores in power procurement charges to generation companies (gencos) according to the data available on the PRAAPTI tification and Analysis in Power procurement for bringing Transparency in Invoicing of generators) portal.[54] More than half of the power generation companies are IPPs that are private companies. IPPs with wind power assets listed in the portal, along with other wind IPPs who face the same dilemma, are at risk of being classified as NPAs due to the working capital issues caused by delays in payment from discoms. The delays vary from 12–24 months between states, with most of the RE-rich states having overdue bills from over 600 days.

Discoms across states have also attempted making wind PPA renegotiations.[55] This could have serious adverse effects such as irreversibly dampening investor confidence in the sector. While it is encouraging that the respective regulatory commissions have consistently denied such requests, such action from the discoms create uncertainties over the sanctity of PPAs.



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52 Saumy Prateek, "KERC Asks State Agencies to Halt New Solar Tenders and Auctions in Karnataka," Mercom India, https://mercomindia.com/karnataka-halt-solar-auctions-for-now/, (April 29, 2019).

53 Saumy Prateek, "Most States Fail to Meet RPO Targets with 27 Achieving Less Than 60%," Mercom India, https://mercomindia.com/most-states-fail-rpo-targets/, (January 11, 2019).

54 Ministry of Power, "Praapti," http://www.praapti.in, (March 31, 2019).

55 Aggarwal and Dutt, State of the Indian Renewable Energy Sector: Drivers, Risks, and Opportunities, (New Delhi: CEEW, 2018)

3.5 Market design: Transition to reverse bidding

The slowdown in capacity addition can also be attributed to the implementation challenges faced by developers under the reverse auction regime. The low ceiling tariffs (below INR 2.85/kWh) are not feasible and can only be achieved at the highest wind speeds.[56] Most sites with high wind speeds are located in Tamil Nadu and Gujarat, with Tamil Nadu already having utilised most of the available revenue land. Developers are facing delays in procuring land and accessing connectivity to the ISTS network – as the majority are concentrated within the same region– which is putting stress on the land and the connectivity in the region.

Since 2017, a cumulative capacity of around 18GW has been auctioned off by the SECI and the states.[57] However, the annual capacity addition has remained lower than 2 GW for the last two years.[58] The low annual capacity addition means that the turbine manufacturers are operating below 20 per cent of their maximum capacity, which severely affects their cash flow.[59] The wind industry also comprises around 4,000 domestic small and medium enterprises (SMEs) along its supply chain. They are engaged in parts manufacturing for specialised services such as transportation, resource assessment, design and consultancy, and construction and civil works; they are now pivoting their businesses as it is impossible to sustain their businesses at such a low demand level.[60]

56 Authors' analysis.

57 Industry sources and tender data compiled by CEEW.

58 MNRE, "Physical Progress (Achievements)".

59 Twesh Mishra, "Lower Capacity Utilisation Hits Wind Turbine Manufacturers," Hindu Business Line, https://www.thehindubusinessline.com/economy/lower-capacity-utilisation-hits-wind-turbine-manufacturers/article26808643.ece, (April 11, 2019).

60 Industry sources.

Currently, almost all the projects being commissioned under the reverse auction process are in Tamil Nadu and Gujarat.

Image: iStock

4. Pathways to achieve 60 GW by 2022

Historically, wind installations have been concentrated in a few states. Currently, almost all the projects being commissioned under the reverse auction process are in Tamil Nadu and Gujarat. This is because the high mean wind speeds required to achieve tariffs below the current ceiling tariffs are available only in sites in these two states. This has put lot of stress on the existing land and evacuation facilities in these states delaying plant commissioning.

As described in Chapter 3, the underlying reason for the current challenges in the wind energy sector boils down to the issue of concentrated wind energy resources. In this situation, scaling up the variable wind energy capacity without a long-term comprehensive plan can lead to higher grid integration costs, higher investment costs, project delays, etc. There is a need for a long-term strategy to plan the scaling up of the sector as well as for consistent policy measures to see it through.

Broadly, there can be two approaches to address the problem of concentrated wind resources. One option is to have generation plants concentrated in wind-rich or high WPD regions and have robust physical and market or regulatory mechanisms to enable the effective transfer of the energy generated. The second option to distribute the capacity from high to medium and low WPD regions. Repowering old wind plants is also an option to increase capacity.

Each approach has its merits and demerits. There is a need to quantify the trade-offs between the different approaches, develop a long-term strategy, and back it up with policy, regulatory, and budgetary support. This is essential to enable sustainable growth in the sector and achieve the country's short- and long-term decarbonisation goals.

There is a need to quantify the trade-offs between the different approaches, develop a long-term strategy, and back it up with policy, regulatory, and budgetary support

Therefore, this study aims to conduct a preliminary assessment of the different approaches by developing three short-term state-wise scenarios and comparing them based on multiple aspects. The scenarios developed are three pathways to achieve the 60 GW target by 2022 and are termed as follows:

I. Base case scenario

II A. Medium-low WPD sites – fallow land only

II B. Medium-low WPD sites– fallow and agricultural land

III. Medium-low WPD sites – with repowering of old power plants

4.1 Methodology for building the scenarios

As discussed in the previous section, the objective of the study is to conduct a preliminary assessment of the different approaches that can be followed to deploy the remaining capacity of wind power to achieve the 60 GW target for 2022. The principle behind each of the approaches is to address the root cause of the sector's natural limitation – concentrated wind energy resources. Therefore, the scenarios have been built with the aim of maximising the distribution of generation plants as much as possible.

The three scenarios have been built for around 18.8–19 GW of capacity addition and have been normalised for comparison. This capacity has been estimated after subtracting the capacity of installed projects and those under construction or in the pipeline from the 60 GW target. However, there is no information available on the location of about 3.5 GW of auctioned capacity. Therefore, this has been added to the remaining capacity required while building the scenarios by allocating it to various states.

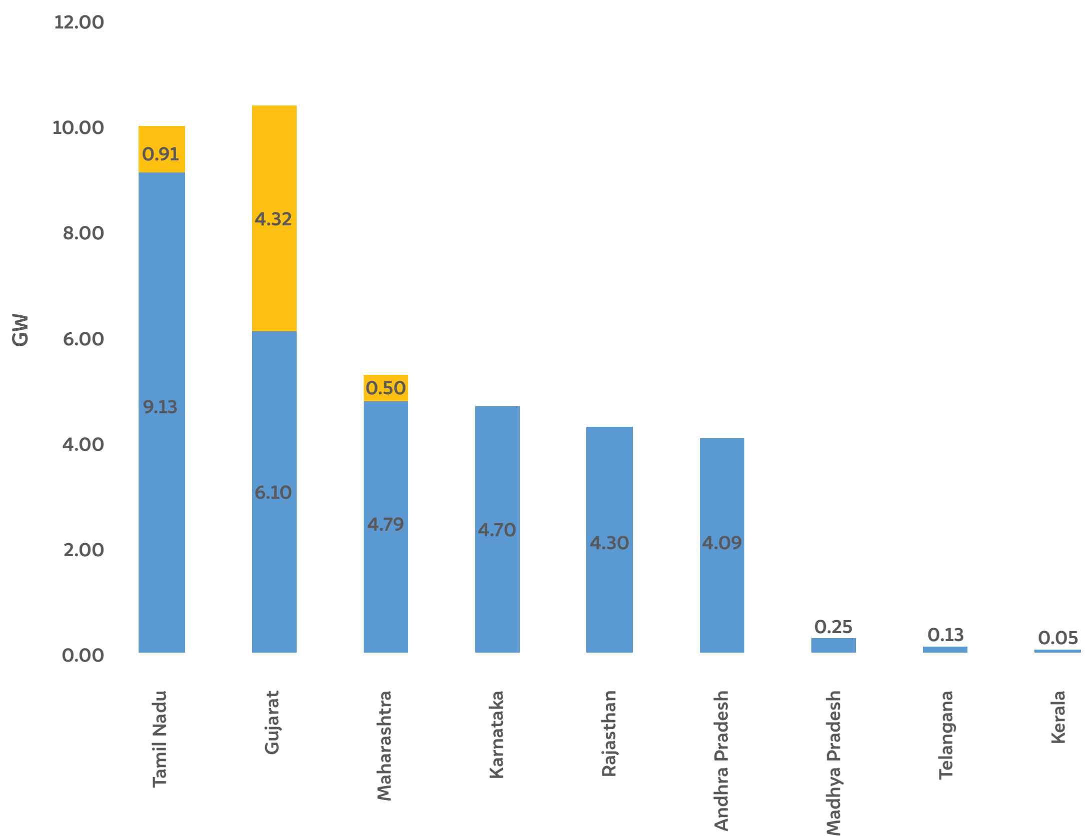


FIGURE 3: Installed and pipeline capacity as of 31 May 2019

Source: MNRE (2019)[61]*, CEEW-IEA database*

61 MNRE, "Physical Progress (Achievements)".

The wind potential data used in this study is from an independent study conducted by the Centre for Study of Science, Technology and Policy (CSTEP) and WinDForce Management Services Limited.[62] Current estimates by the National Institute of Wind Energy (NIWE) pegs the total wind potential at 100 metres hub height at 302 GW.[63] However, multiple independent studies have estimated this potential to be over 2,000 GW.[64] The separate studies undertaken by CSTEP and WinDForce, as part of a committee formed by MNRE, have estimated a total potential of 2,760 GW and 2,161 GW, respectively, at 100 metres hub height with a 5D x 7D array configuration. Since the findings are similar to those of other independent reassessment studies, the CEEW study has chosen the state-wise wind power potential from the CSTEP-WinDForce study. Data on suitable state-wise land has also been adopted from the same.

Assumptions on state-wise new capacity installations are derived in such a way that each scenario achieves the remaining capacity required to reach 60 GW – around 19 GW

The wind speed data at 100 metres hub height was used to estimate the capacity utilisation factor (CUF) for each state.[65] CUFs are calculated at the mean wind speed for 30 per cent of the windiest areas in the state with minor adjustments for terrain and elevation. Specifications for a standard turbine in the market with a hub height of 120 metres, rotor diameter of 120 metres, and rated capacity 2.1 MW is used to estimate the CUF. The detailed calculations are given in Annexure B.

Based on the CUF thus estimated, the states are divided into low, medium, and high WPD (Table 4).

TABLE 4: WPD classification

High WPD states	Mean CUF	Medium WPD states	Mean CUF	Low WPD states	Mean CUF
Tamil Nadu	44%	Maharashtra	36%	Chhattisgarh	31%
Gujarat	43%	Rajasthan	36%	Kerala	31%
Karnataka	40%	Andhra Pradesh	35%	Madhya Pradesh	31%
		Telangana	35%	Odisha	31%
				Uttar Pradesh	31%
				West Bengal	31%

Source: Author's analysis, Global Wind Atlas (2018)[66]

Assumptions on state-wise new capacity installations are derived in such a way that each scenario achieves the remaining capacity required to reach 60 GW – around 19 GW.

62 Jami Hossain et al. "Report on India's Wind Power Potential," WinDForce - MNRE - Shakti Foundation - C-STEP 2–15,doi: 10.13140/RG.2.1.2193.0967, (2015)

63 National Institute of Wind Energy, "Wind Resource Assessment," https://niwe.res.in/, (2019).

64 Amol Phadke, Ranjit Bharvikar, and Jagmeet Khangura, Reassessing Wind Potential Estimates for India: Economic and Policy Implications, (Berkeley, 2012).

65 Technical University of Denmark (DTU), "Global Wind Atlas," https://globalwindatlas.info/area/India, (2018).

66 Technical University of Denmark (DTU), "Global Wind Atlas."

In **Scenario I,** which follows the base case, the installations are concentrated in three high WPD states– Tamil Nadu, Gujarat, and Karnataka – with marginal deployment in medium WPD states. The base case is developed under the assumption that the current reverse auction process will continue, in which ISTS-connected projects will be predominant and the auctions will not be site specific. Given these circumstances, developers will be keen to build plants in the windiest sites first. Therefore, in the base case scenario, 20 per cent of the suitable fallow land in the three high WPD states is considered for total capacity deployment along with 4 per cent of fallow land in medium WPD states. Since Tamil Nadu has an installed capacity equivalent to more than 30 per cent of the suitable fallow land, there is no new capacity addition in the state. After considering the existing installations in the medium WPD sites, only Telangana and Rajasthan have been assigned new capacity additions. Also, following the current trend, it is assumed that most of the new installations will be ISTS network connected, as a higher proportion of new deployments will be from ISTS-connected SECI auctions.

Scenario II has two sub parts – one, deployment only in fallow land (II A) and two, deployment in fallow and agricultural land (II B). Scenario II A is built in such a way that wind power will not take up more than 8.5 per cent of the suitable fallow land in the medium WPD states (Andhra Pradesh, Karnataka, Madhya Pradesh, Maharashtra, Rajasthan, and Telangana) and 4 per cent in the low WPD states (Kerala and Odisha). Gujarat and Tamil Nadu have already exceeded this 8.5 per cent mark of land use (Rank 1 land), with the current installations occupying 12.6 per cent and 31.8 per cent, respectively, of the total fallow land in the states. Hence, Scenario II A assigns zero new installations to both the states. However, Karnataka is assigned new capacity based on the same criteria as for medium WPD states. Scenario II B achieves the required capacity by considering 3 per cent of the suitable fallow and agricultural land in medium WPD states (same as II A) and 2 per cent in the low WPD states (Chhattisgarh, Uttar Pradesh, and West Bengal are to add nominal capacity in addition to Kerala and Odisha). Gujarat and Tamil Nadu will not have additional capacity in this scenario either.

The sub categories under Scenario II compare the use of fallow land and agricultural land. While use of agricultural land will permit the deployment of wind energy plants in a greater number of low WPD states, the change in land use patterns might have a larger impact on the local environment and long-term food security.

Scenario III considers the potential for repowering old wind power plants. The repowering potential in India is around 1.58 GW between seven states.[67] Assuming a 100 per cent increase in installed capacity with repowering, in Scenario III, 1.58 GW of new capacity is added from repowering.[68] The rest of the capacity is to be deployed in medium to low wind speed states, where only 8 per cent of the fallow land is to be used for the installations.

In Scenarios II and III, a higher share of the new installations is assumed to be connected to intra-state networks as state agencies will be better placed to drive the new capacity addition in these scenarios. The distributed capacity addition might also result in the new capacities being closer to demand centres compared to the base case and hence can be utilised within state or regional boundaries.

67 Idam Infrastructure Advisory Private Limited, Repowering of Old Wind Turbines in India, (New Delhi: Idam Infra, 2018).

68 Vishal Agarwal, "Re-powering of Old Wind Turbines in India", Energetica India, http://www.energetica-india.net, (December, 2013).

TABLE 5: Pathways to achieve 60 GW by 2022

Source: Authors' analysis

States	Base case	Medium-low WPD sites		Repowering		
	I GW	II A GW	II B GW	Repowered GW	New GW	III GW
Andhra Pradesh		4.1	1.5	0.09	3.64	3.7
Chhattisgarh			0.02			
Gujarat	6.0			0.15		0.2
Karnataka	11.0	2.0	3.5	0.07	1.66	1.7
Kerala		0.2	0.3		0.43	0.4
Madhya Pradesh		0.6	2.7	0.02	0.46	0.5
Maharashtra		2.5	4.3	0.40	2.11	2.5
Odisha		0.2	0.4		0.48	0.5
Rajasthan	0.4	5.7	2.1	0.01	5.20	5.2
Tamil Nadu				0.83		0.8
Telangana	1.6	3.4	4.1		3.25	3.3
Uttar Pradesh			0.13			
West Bengal			0.02			
Total	**19.1**	**18.8**	**18.9**			**18.8**

The following section describes in detail each of the scenarios and compares them in terms of multiple aspects.

4.2 Scenario I: base case

Scenario I depicts the base case in which continuous deployment in high WPD states would occur with marginal deployment (2,000 MW) in medium WPD states. Figure 4 illustrates the capacity distribution between states in Scenario I.

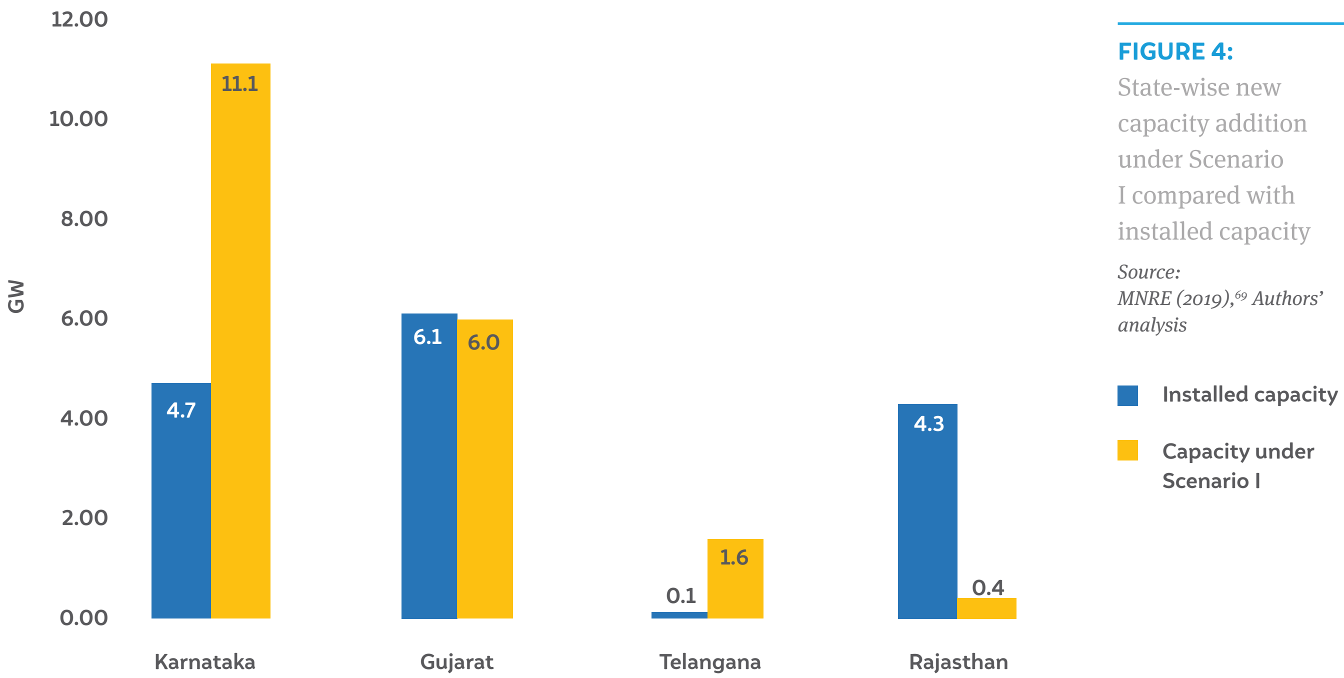


FIGURE 4: State-wise new capacity addition under Scenario I compared with installed capacity

Source: MNRE (2019),[69] Authors' analysis

69 MNRE, "Physical Progress (Achievements)".

This scenario considers only the three states with the highest wind speeds and two medium WPD states. This would result in lower tariffs and higher energy production. Figure 5 shows the average LCOE of wind power generation in each of the states under Scenario I.

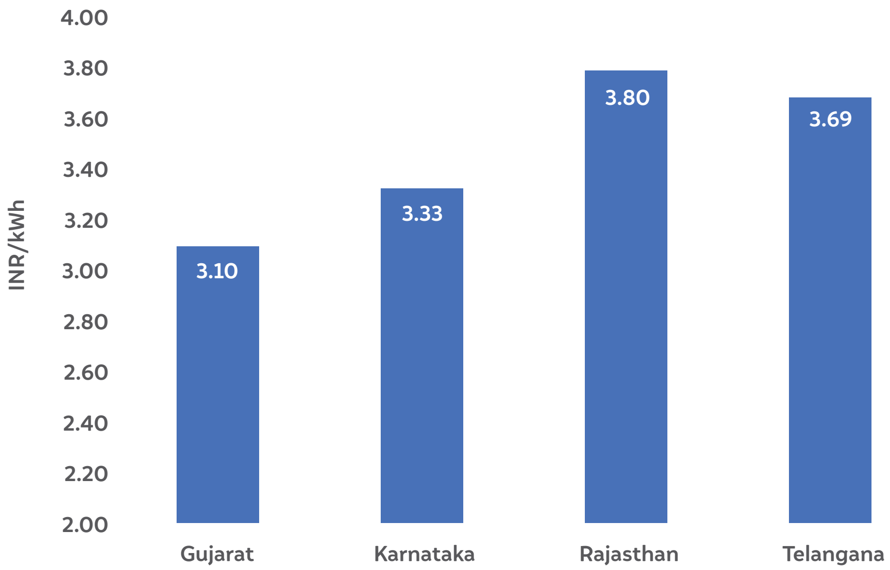


FIGURE 5: Average LCOE under Scenario I

Source: Authors' analysis[70]

The LCOE for each state is calculated using standard assumptions collected from industry stakeholders. The assumptions can be found in the annexure. It is interesting to note that the LCOE estimated for Gujarat, which has one of the highest wind speeds in India, is higher than the current ceiling tariffs set for SECI auctions. As per our analysis, such low rates can only be obtained by fixing very low margins for investors and would not be sustainable in the long run.

Wind-rich states such as Tamil Nadu, Karnataka, and Gujarat already have high wind penetration. This will necessitate an increased spinning reserve, thus increasing the cost of energy generation

Challenges in implementing Scenario I

The addition of 19.1 GW to the existing capacity will result in approximately 60.6 GW being deployed between the eight states in the southern and western regions. Therefore, this scenario will have several challenges such as:

1. **Grid integration:** Power generation from wind is intermittent in nature. Thus, integrating wind power in large-scale into the grid could cause voltage and frequency fluctuations, due to which the grid gets destabilised, power quality degrades, and the power system may breakdown.[71] Wind-rich states such as Tamil Nadu, Karnataka, and Gujarat already have high wind penetration. This will necessitate an increased spinning reserve, thus increasing the cost of energy generation.[72] Also, to avoid technical breakdowns of the grid, wind power is curtailed.[73]

70 Assumptions given in the Annexure.

71 Temitope Raphael Ayodele, Abdul-Ganiyu Jimoh, and J. L. Munda, "Challenges of Grid Integration of Wind Power on Power System Grid Integrity: A Review," International Journal of Renewable Energy Research2, No. 4, (2013), accessed April 28, 2019, https://www.ijrer.org/ijrer/index.php/ijrer/article/view/317 .

72 John Kabouris and Fotis D. Kanellos, "Impacts of Large-Scale Wind Penetration on Energy Supply Industry", Energies 2, No.4, (2009), accessed April 28, 2019, https://www.researchgate.net/publication/38112016_Impacts_of_Large_Scale_Wind_Penetration_on_Energy_Supply_Industry

73 CEEW, Curtailing Renewable Energy Curtailment.

2. **Grid access:** The development of transmission infrastructure for renewable electricity transmission is not in line with the development of the renewable sector, which is why land with abundant amounts of wind resource remains unexploited. In the Twelfth Five-Year Plan period, power generation capacity grew by 91 per cent whereas transmission capacity (circuit-kilometres) increased only by 43 per cent.[74] Moreover, the existing transmission infrastructure also needs to be strengthened to handle the variable and intermittent nature of wind energy.

3. **Land availability and acquisition:** The foremost issue with wind power projects is difficulties in identifying suitable land. Most high wind potential sites that are close to existing transmission infrastructure have already been exhausted in wind-rich states.

Policy, regulatory, and market interventions required

To address the challenges involved in implementing Scenario 1, various kinds of policy support are necessary. This section describes the policy measures that would facilitate realisation of this scenario.

1. **Ancillary services framework for effective grid balancing:** With the increased wind power capacity addition at the regional level, there is an urgent need to introduce robust grid balancing mechanisms. To ensure grid stability and reliability, Scenario I necessitates a framework of ancillary services that will achieve nationally coordinated dispatch, increased coal flexibility, and other grid balancing techniques that can facilitate grid integration of high levels of RE.[75]

2. **Long-term transmission and evacuation plan:** To ensure the effective transfer of the generated power, the expansion of transmission and evacuation facilities need to be in sync with the capacity deployment. A long-term inter-state plan in coordination with the SECI, CERC, and Power Grid Corporation of India Limited (PGCIL) as well as intra-state plans involving the SECI, state energy development agencies, and STUs need to be developed. Conducting state-and regional-level power flow modelling using accurate forecasting techniques, establishing the proposed renewable energy management centres (REMCs), and promoting private investments in transmission infrastructure are some of the measures that will help expedite transmission planning and expansion.

A long-term inter-state plan in coordination with the SECI, CERC, and Power Grid Corporation of India Limited (PGCIL) as well as intra-state plans involving the SECI, state energy development agencies, and STUs need to be developed

3. **Stricter RPO compliance and robust inter-regional/inter-state energy trading mechanisms:** While the RPO targets are meant to increase the demand for renewable power and facilitate the inter-state and inter-regional transfer of renewable power, actual compliance has been dismal. There is a need to design an effective compliance mechanism for state discoms. Having a separate wind RPO might also be beneficial to increase the procurement of wind energy by non-wind-rich states.

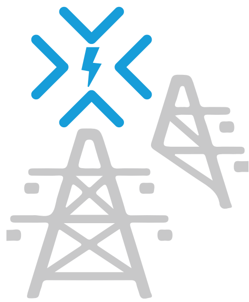
4. **Wind and hybrid parks:** To facilitate the procurement of suitable land with connectivity to the grid, development of designated wind parks would be essential. This would ensure timely access to land, evacuation infrastructure, and other facilities needed to construct and operate a wind power plant. In areas where solar and wind generation complement each other, optimum utilisation of the transmission network can be devised. Unlike solar

74 CEA, National Electricity Plan (Volume II) Transmission.

75 David Palchak et al., Greening the grid: Pathways to Integrate 175 Gigawatts of Renewable Energy into India's Electric Grid, Vol. I—National Study (NREL - POSOCO - Berkeley Lab, 2017).

park development, wind parks require an advanced wind resource assessment for at least a year before the land is procured. This would only be possible with advance planning and coordinated efforts among state and central entities. A thorough assessment with simulations and on-the-ground data is necessary to optimise the deployment of large-scale wind turbines.

5. **Grid integration guarantee:** To mitigate the risk of grid curtailment, which is relatively high when there is a higher penetration of variable power in a region, CEEW has proposed an innovative instrument called the Grid Integration Guarantee (GIG).[76] Measured against scheduled energy, GIG offers developers a minimum compensation for curtailed units at the substation level on paying a premium. Implementing de-risking mechanisms such as the GIG would facilitate sustainable growth in the wind sector.



To mitigate the risk of grid curtailment, which is relatively high when there is a higher penetration of variable power in a region, CEEW has proposed an innovative instrument called the Grid Integration Guarantee (GIG)

4.3 Scenario II: low-medium WPD sites

Scenario II explores the potential to locate more capacity in medium-low WPD sites. Scenario II A has been developed assuming the use of only fallow land. Scenario II B assumes the use of fallow and agricultural land for wind energy generation. Under Scenario II, there is no new capacity assigned to Gujarat and Tamil Nadu. In II A, additional capacity is distributed between five medium WPD and three low WPD states, while in II B, new capacity in distributed between six low WPD states, with the highest in Madhya Pradesh. Figure 6 illustrates the state-wise capacity addition under Scenario II by 2022.

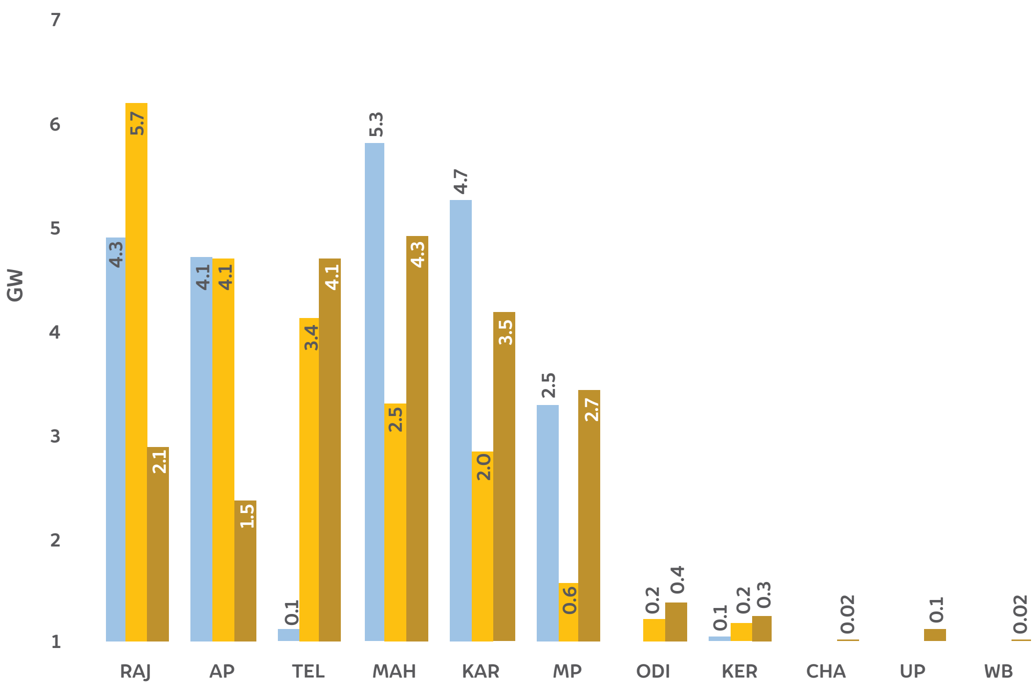


FIGURE 6: State-wise new capacity addition under Scenario II compared with installed and pipeline capacity

Source: MNRE (2019),[77] Author's analysis

Installed/pipeline capacity
II A
II B

RAJ: Rajasthan
AP: Andhra Pradesh
TEL: Telangana
MAH: Maharashtra
KAR: Karnataka
MP: Madhya Pradesh
ODI: Odisha
KER: Kerala
CHA: Chhattisgarh
UP: Uttar Pradesh
WB: West Begal

76 CEEW, Grid Integration Guarantee.

77 MNRE, "Physical Progress (Achievements)".

The higher capacity in medium-low WPD sites will result in a higher LCOE and lower energy production. Figure 7 shows the state-wise average LCOE for wind power plants and the average cost of non-RE power.

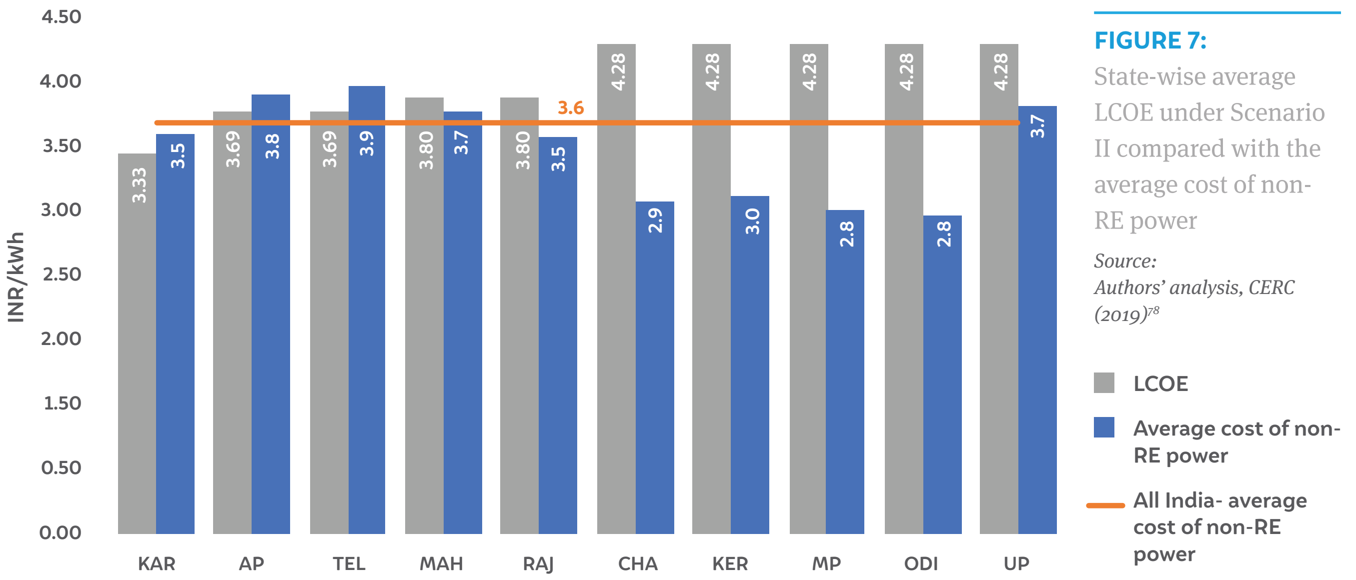


FIGURE 7:
State-wise average LCOE under Scenario II compared with the average cost of non-RE power

Source: Authors' analysis, CERC (2019)[78]

KAR: Karnataka
AP: Andhra Pradesh
TEL: Telangana
MAH: Maharashtra
RAJ: Rajasthan
CHA: Chhattisgarh
KER: Kerala
MP: Madhya Pradesh
ODI: Odisha
UP: Uttar Pradesh

Challenges to implement Scenario II

While the challenges described under Scenario I are applicable for this scenario (but to a lesser degree), this section describes the specific challenges that will arise under Scenario II. These are:

1. **Technological challenges in harnessing low wind sites:** To harness energy from low-speed wind in a cost-effective way, there is a need to use advanced turbine technology, such as turbines with a higher rotor diameter and hub heights as well as low cut-in and rated speeds. There are several large turbines designed for low wind speeds (Class III C and IES) that are being deployed in the Indian market. However, for scaling up deployment in low WPD sites, there is a need to incentivise the procurement of turbines designed for low wind speeds.

2. **Competition with cheaper solar and conventional energy:** In Scenario II, there is higher deployment in states such as Maharashtra and Madhya Pradesh, where there is high solar potential and the LCOE of solar is lower compared to wind energy.[79] These states will not have any incentive to allocate land to produce costlier wind energy. As seen from Figure 5, the LCOE of wind power in some of the states in this scenario is higher than the average cost of non-RE power.

78 Central Electricity Regulatory Commission (CERC), "Petition No. 05/SM/2019," http://www.cercind.gov.in/2019/orders/05-SM-2019.pdf, May7, 2019.

79 Authors' analysis.

Policy, regulatory, and market interventions required

To address the challenges involved in implementing Scenario 2, various policy supports are necessary. This section describes the policy measures that would facilitate the realisation of this scenario.

1. **Site-specific auctions:** Site-specific auctions are a prerequisite for capacity installations in medium-low WPD sites under the reverse auction regime. Identifying and classifying regions based on accurate wind speed data and estimating a tariff upper limit based on the available wind resources is essential to ensuring competitive tariffs.

2. **Incentives to promote advanced turbine technology:** The largest turbines currently being deployed in the Indian market have rotor diameters in the range of 120–130 m and rated power less than 3 MW. However, there are higher capacity turbines (rotor diameter greater than 130 m with lower cut-in/cut-out and rated speeds) which can generate more energy from low WPD sites. To incentivise their procurement and deployment, viability hap funding (VGF), which covers differences in investment resulting from using advanced turbine technology, or tax exemptions could be introduced. The additional cost of deploying the advanced turbines currently available in the Indian market is around INR 1 crore per MW capacity.[80]

3. **Budgetary support in the form of GBIs:** Deploying new capacity in medium-low WPD sites would lead to higher tariffs for the energy generated compared to the current ceiling tariffs and solar photovoltaic (PV) tariffs. Budgetary support in the form of GBIs is needed to address the tariff difference arising from lower CUFs.

4. **Hybrid parks:** Given the possible competition with solar PV in states under Scenario II, the development of hybrid parks can ensure the optimum use of land and connectivity while improving the overall variability. Hybrid parks with storage could also be considered to build dispatchable RE power. This will become more relevant as the penetration of renewable power increases at the regional level.

5. **Effective open-access regulation:** The higher LCOE of wind energy from medium-low WPD states will be still be competitive if sold via open access. However, to facilitate increased wind open access, there is a need for regulations across states that will address the existing challenges in operationalising open access.

Site-specific auctions are a prerequisite for capacity installations in medium-low WPD sites under the reverse auction regime

80 Industry sources.

4.4 Scenario III: repowering of old power plants

Given the long history of wind power plants in India, there are plenty of ageing turbines that are over 15 years old. Most of the turbines installed prior to 2002 are below 1000 kW with CUF less than 25 per cent. There is at least 1.6 GW of repowering potential between five states – Tamil Nadu, Maharashtra, Gujarat, Andhra Pradesh, and Karnataka – if the turbines installed before 2002 are considered for repowering.[81] Under Scenario III, repowering of this capacity, which is located in some of the windiest sites, is considered. Additional deployment is in the medium-low WPD regions. Figure 8 depicts the state-wise distribution of repowering and new capacity addition under Scenario III.

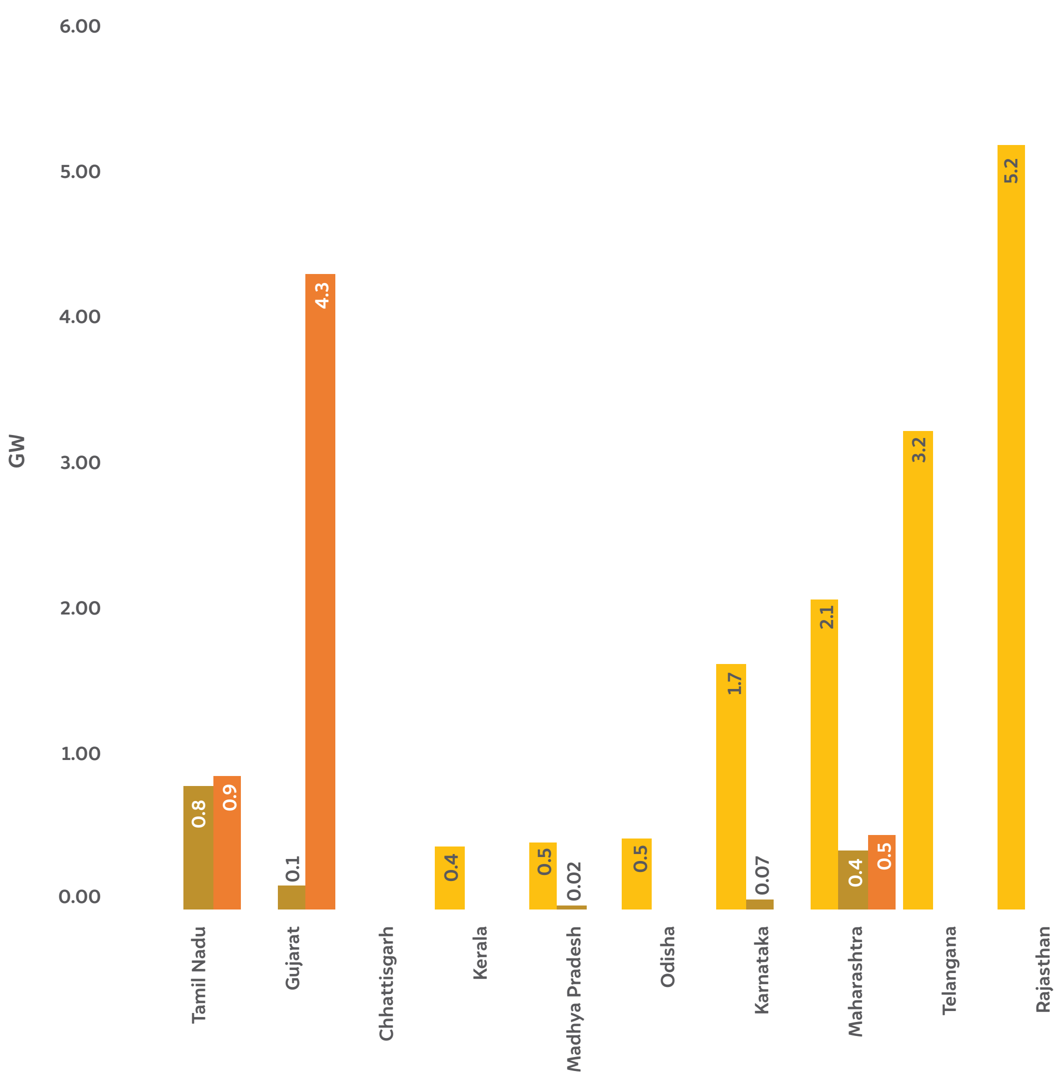


FIGURE 8: State-wise new capacity addition under Scenario III compared with installed and pipeline capacity

Source: MNRE (2019), Authors' analysis[82]

82 MNRE, "Physical Progress (Achievements)".

Figure 9 shows the average LCOE of the new capacity added across different states. LCOE is estimated only for new capacity as the LCOE of the repowered capacity would vary significantly based on its age, location, ownership, etc.

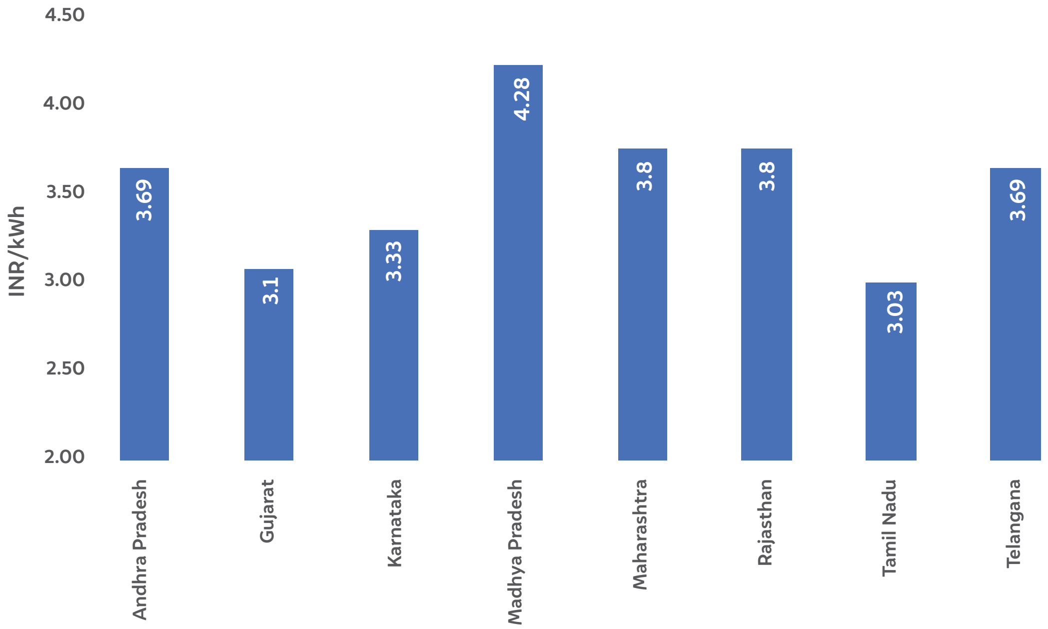


FIGURE 9: LCOE of new capacity and total generation under Scenario III

Source: Authors' analysis

Challenges to implement Scenario III

The main challenge for repowering would be to ensure the plant's profitability under the new tariff regime. Hence, there is a need for new business models and tariff designs to incentivise existing developers and CPP owners to repower old plants. The challenges for capacity addition in this scenario are similar to the ones for Scenario II, as this scenario also considers medium-low WPD sites.

The main challenge for repowering would be to ensure the plant's profitability under the new tariff regime

Policy, regulatory, and market interventions required

To address the challenges involved in implementing Scenario III, various kinds of policy support are necessary. One of the main steps would be to design a new tariff mechanism for the repowered power plants so that the developers are compensated for the lost generation from the old power plants, which would be under a higher FiT rate. Box 2 illustrates a two-part tariff mechanism for repowering old wind power plants. The data and assumptions used to illustrate the mechanism are given in Annexure E.

Box 2: Repowering example: a wind power plant in Tamil Nadu with 1 MW installed capacity commissioned in 2002–03 and repowered in 2019–20

It is assumed that after repowering, the installed capacity doubles. Additionally, the CUF goes up from 17 per cent to 43 per cent.

The cost of refurbishing an existing power plant has been taken to be equal to the cost of building a new power plant less the land cost and scrap value of the existing power plant. Thus, the cost of the project is equal to the cost of refurbishment, the operations and maintenance (O&M) costs that would be incurred, the loss of revenue for the refurbishment period, and the net value of the existing power plant for its remaining lifetime. The last component is calculated by finding the difference between the receivables (product of FiT and the generation of the old plant) and O&M expenses for the old plant for its remaining lifetime and discounting it to the present year.

A straight-line depreciation of 90 per cent over 25 years has been assumed for the repowered power plant. The levelised tariff for the new plant is determined by adding the aforementioned cost components of the project, the mandated equity returns, and interest payments. Finally, the two-part tariff has been determined by nominally dividing the generation of the refurbished plant into two parts:

i) **Generation that would have come from the existing power plant**

ii) **Increase in generation due to repowering**

The two-part tariff has been calculated such that the net present value of the receivables from both parts of the generation is the same as that obtained had the entire generation been sold at the levelised tariff calculated for the repowered plant.

Several models were tried out for the tariff that would be applicable to the additional generation (equal to the total generation after the existing plant's scheduled lifetime) from the repowered plant. The only condition common to all the models was that the net present value of the receivables was the same as what the plant would have received had there been a single-part tariff equal to the LCOE. Imposing this constraint in each model description gives the complete tariff structure for the additional generation from repowering.

Thus, the tariff for the additional part is INR 2.76/kWh with an annual decrease of 2.5 per cent.

Levelised tariff for generation from the repowered plant	**INR 2.91/kWh**
Net present value of the existing plant that would be lost	**INR 3.59 crore**
Generation lost in the year of refurbishment of the plant	**1.43 million units**
Ratio of new annual generation to old annual generation	**5.3**
Payback period	**11 years after completion of repowering**

Year	Repowered generation (kWh)	Scheduled generation from old plant (kWh)	FiT (INR/kWh)	Additional generation (kWh)	Tariff for additional generation (INR/kWh)
2019–20	0	14,27,159	2.70	(14,27,159)	-
2020–21	75,33,600	14,23,591	2.70	61,10,009	2.77
2021–22	75,14,766	14,20,032	2.70	60,94,734	2.70
2022–23	74,95,979	14,16,482	4.91	60,79,497	2.63
2023–24	74,77,239	14,12,941	4.91	60,64,298	2.56
2024–25	74,58,546	14,09,409	4.91	60,49,137	2.50
2025–26	74,39,900	14,05,885	4.91	60,34,015	2.44
2026–27	74,21,300	14,02,370	4.91	60,18,930	2.38
2027–28	74,02,747	0	-	74,02,747	2.32

As observed, the payback period is currently very high, which may dissuade wind turbine owners from going ahead with it. This can be solved by suitable policy measures, one of which is providing generation-based incentives on the additional generation for a limited time frame. It is assumed that the incentive is provided at the end of the year of generation.

Timeframe	Incentive	New payback period	Present value of GBI on state exchequer for the project
First 5 years of generation	INR 0.75/kWh	4 years after completion of repowering	INR 1.72 crore
	INR 1/kWh	3 years after completion of repowering	INR 2.31 crore

Source: Authors' analysis

4.5 Comparison of three scenarios

Figure 10 and Figure 11 illustrate the new capacity addition and cumulative capacity addition under the three scenarios respectively.

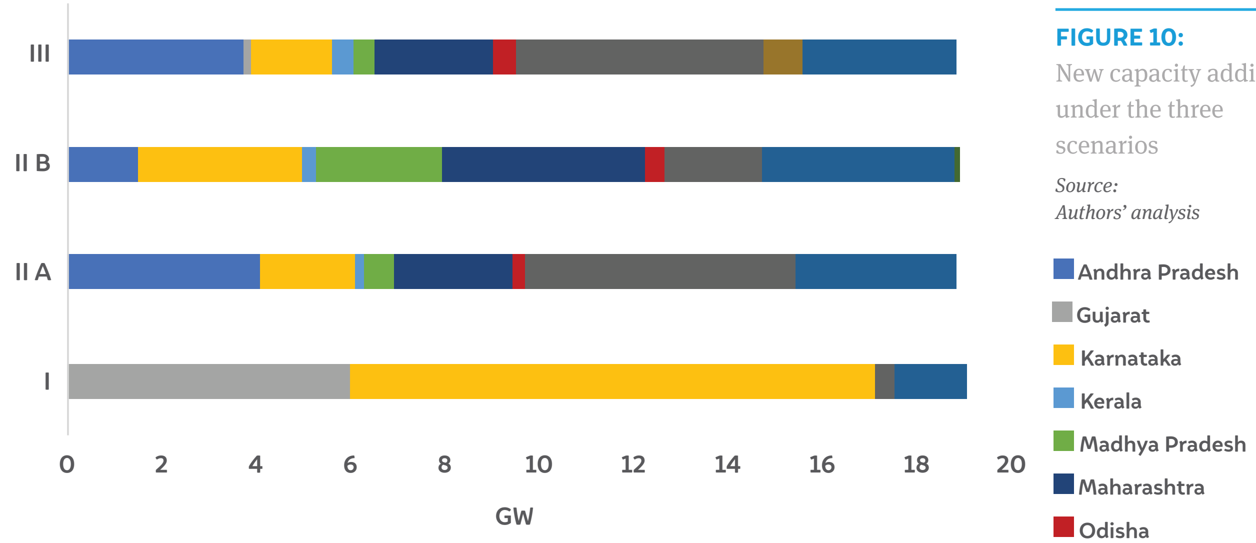


FIGURE 10: New capacity addition under the three scenarios

Source: Authors' analysis

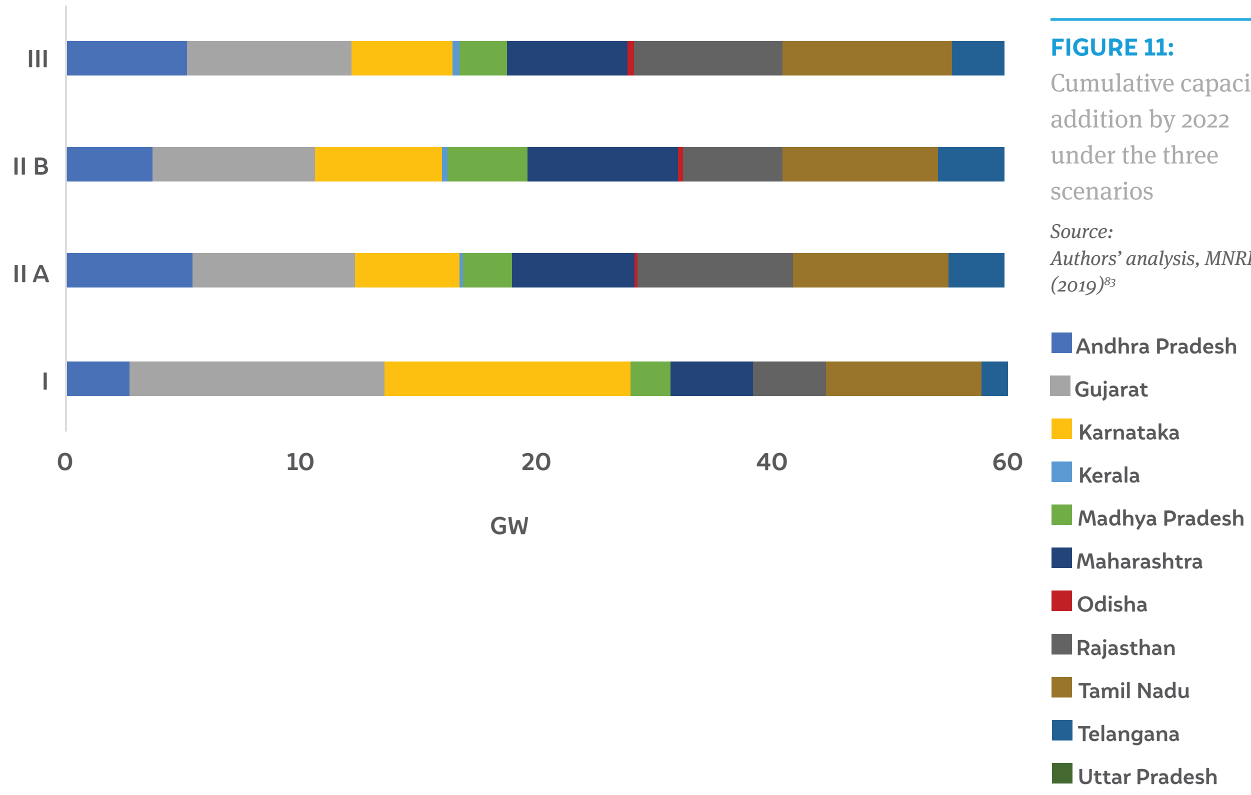


FIGURE 11: Cumulative capacity addition by 2022 under the three scenarios

Source: Authors' analysis, MNRE (2019)[83]

Comparing the three scenarios, the base case Scenario I depicts the most cost-effective case if only the direct costs are compared. However, integrating higher levels of variable energy at a state level would have higher system-level costs, which have not been estimated here. It will also increase the stress on the available land in a few states. Similarly, **while Scenarios II and III are expensive alternatives, they have some advantages such as reduced stress on land and evacuation, lower grid integration requirements, and so on.** Table 6 compares the merits and demerits of the three scenarios.

TABLE 6: Comparison of the merits and demerits of the three scenarios

Scenarios	Merits	Demerits
I	+ Lowest possible levelised cost of electricity (LCOE) as installations will be in the sites with the highest wind speeds only + Higher energy generation	– High stress on land and evacuation facilities in the windiest regions – Higher grid integration costs – Underutilisation of transmission infrastructure
II	+ Capacity is more distributed, leading to reduced stress on land and evacuation infrastructure + Lower transmission investment requirements as installations will be closer to demand centres + Reduced underutilisation of the ISTS network with a higher proportion of installations connected to state grids	– Increased cost sassociated with power generation from less windy sites, which would be costlier than solar energy generation from the same sites – Lower energy generation compared to other scenarios
III	+ More efficient use of land and resources by repowering old power plants + Higher energy generation than Scenario II	– Repowering old power plants may involve several implementation challenges – No incentives for existing power plant owners to repower plants

Source: Authors' analysis

In terms of energy generation, higher capacity deployment in higher WPD sites would result in higher generation. On an average, Scenario I would lead to 15 per cent more energy generation than the other two scenarios when estimated based onplant life time (Figure 12).

83 MNRE, "Physical Progress (Achievements)".

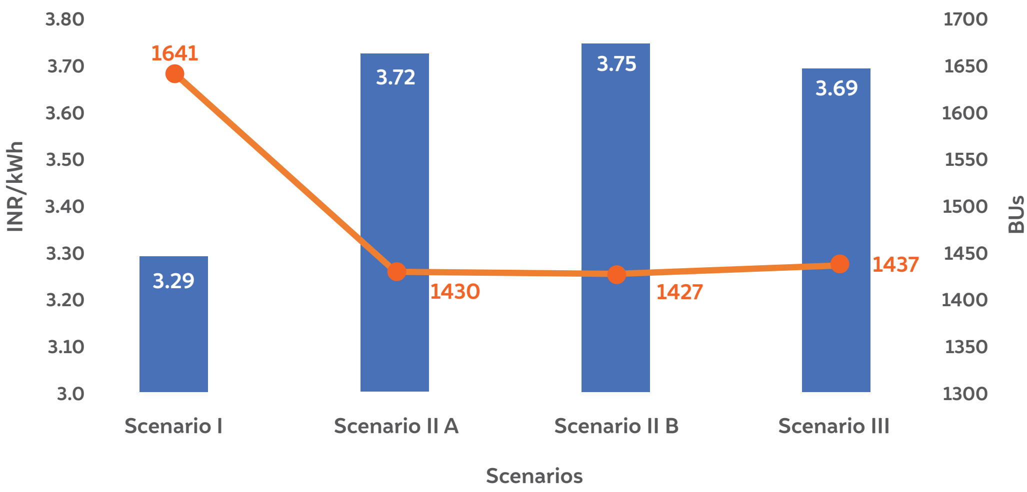


FIGURE 12:
Weighted average LCOE and total energy generated over the lifetime for the three scenarios

Source: Authors' analysis

Weighted average LCOE

Total energy generated over lifetime

Additionally, budgetary support requirements are estimated for deployment in low WPD states. **Budgetary support in the form of GBIs or VGF would be necessary to obtain comparable tariffs in these sites.** The support is estimated from a base tariff of INR 3.33/kWh, which is the average LCOE for a plant located in Karnataka – the third-windiest state.[84] As seen in Figure 13, Scenario II B requires the highest support and Scenario I the least. Support in the form of VGF would require less funds than GBIs. However, VGF would be an upfront outflow while GBI would be spread over years. Scenario III would require additional support for the repowering projects; this would depend on the age of the plants being repowered and their business model, which are not considered here.

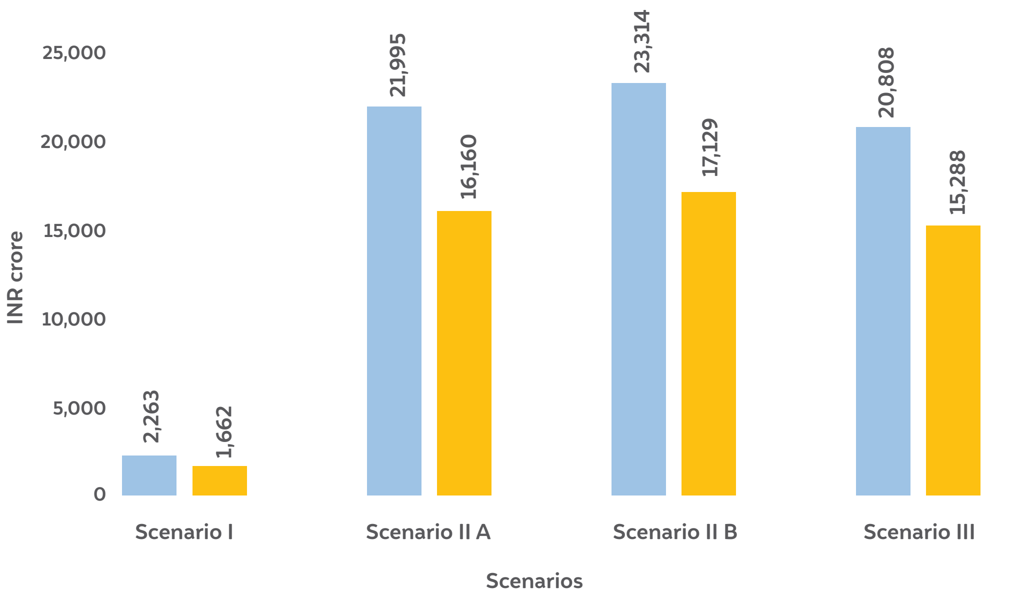


FIGURE 13:
Energy generated and budgetary support needed over lifetime

Source: Authors' analysis

Budgetary outlay for GBI support

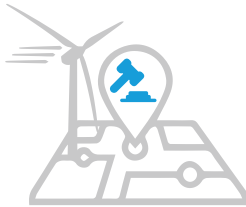
Budgetary outlay for VGF support

84 The LCOE for Karnataka is taken as a benchmark because our analysis shows that the current ceiling tariffs are not viable under standard assumptions.

However, when comparing the scenarios in terms of the penetration of variable energy in the state-level electricity mix by 2022, we see that in Scenario I, some states have disproportionate amounts of variable energy capacity (Figure 14). In this scenario, the highest wind energy penetration in a state, in Karnataka in this case, is higher than the highest penetration level under the other scenarios by around 27 per cent. In terms of wind penetration, Scenario II B has the most uniform distribution of deployment. Comparing this scenario with the base case, Karnataka and Gujarat have higher wind capacity penetration by 50 and 41 per cent, respectively in the base case.

However, most of the new capacity additions since 2017 have been ISTS network connected, which means that the variability of the wind energy will not have a direct impact on the local network. Scenario I depicts this situation, as a higher proportion of the future capacity is expected to be ISTS-connected following the current trend. This necessitates huge investments in transmission infrastructure to transmit the energy generated in the south and west to demand centres in the north. The Green Energy Corridor has an estimated project cost of INR 10,141 crores. However, more than 50 per cent of the wind energy in India is generated over a few months due to prevalent weather patterns. Therefore, a high proportion of the transmission capacity built for wind energy will remain unutilised for most of the year. Scenario I, in which there is higher capacity concentrated in few states, will lead to this situation; hence, it may not be the most optimum approach to follow.

On the other hand, there is better distribution of capacities in the other two scenarios. Site-specific auctions can also lead to a higher proportion of new capacity being added to the respective state networks, which will reduce the need for investments in dedicated inter-state transmission infrastructure that will remain underutilised for most of the year.



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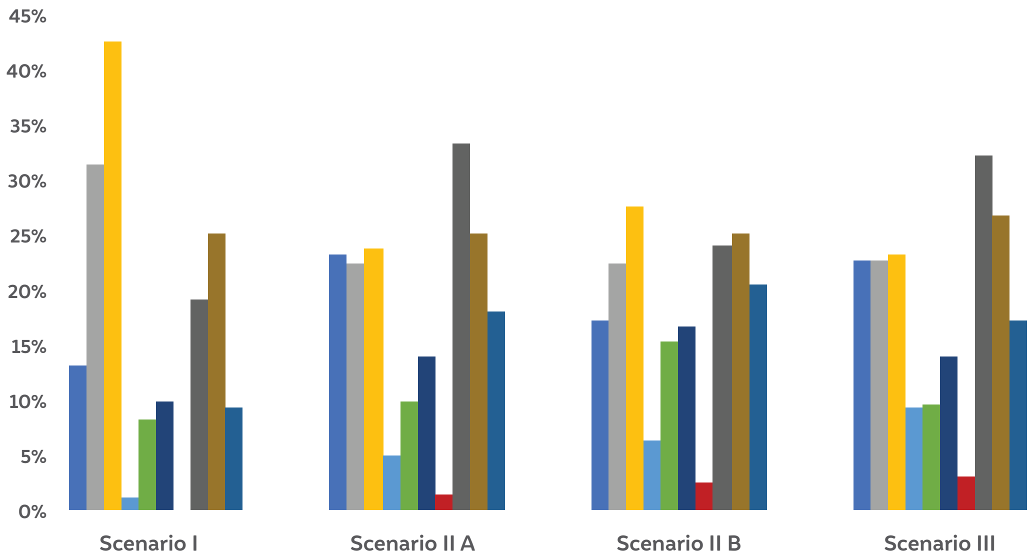


FIGURE 14:
State-wise wind penetration in the electricity capacity mix by 2022

Source: CEA (2018),[85] Authors' analysis

- Andhra Pradesh
- Gujarat
- Karnataka
- Kerala
- Madhya Pradesh
- Maharashtra
- Odisha
- Rajasthan
- Tamil Nadu
- Telangana

Higher deployment in a few states might also lead to additional indirect costs due to the higher demand for land and the greater socio-economic and environmental impacts of deploying large-scale wind power plants. Another aspect to be explored is the impact of large-scale wind power deployments on the local weather.

85 CEA, National Electricity Plan (Volume II) Transmission.

5. Short-term policy roadmap to achieve 60 GW target

Image: Emotivelens

The wind energy industry in India is going through a turbulent time. Timely corrective actions are required to increase capacity addition and reach the 60 GW target by 2022. The current challenges are the result of systemic issues such as concentrated wind energy resources, poor discom financial health, and lack of regional cooperation for energy transfer. There is a need for a comprehensive policy roadmap that will address these issues and give policy certainty in the short- and medium-term.

Each of the scenarios described in the previous section have certain merits and demerits. As is evident, Scenario I will lead to the lowest tariffs and highest energy generation but will have higher grid integration costs and other indirect costs, which will need to be borne by the exchequer. There are also other factors such as the socio-economic and environmental impact that need to be considered. Additionally, states do not have any incentives to allocate land for generating electricity that will be consumed outside the state borders.

Scenario II A and B feature higher capacity addition in medium-low WPD states. This will result in higher tariffs and lower energy generation. However, the distributed capacity addition would ensure lower grid integration costs. Between Scenario II A and B, land use priorities need to be considered while making a choice. While II A only considers fallow land available in the selected states, II B also considers agricultural land. Scenario II B has a better distribution of capacity between states than II A.

Repowering old power plants in high WPD sites may help increase energy generation while deploying a higher capacity in medium-low wind sites. However, given the low potential for repowering (1.5 GW), the increase in energy generation as compared to Scenarios II A and B is not very significant. It would also need additional support to incentivise existing proprietors to opt for repowering. However, repowering ensures better utilisation of the available resources, which is an important factor to consider.

There is a need for a comprehensive policy roadmap that will address these issues and give policy certainty in the short- and medium-term

A clear objective backed by a robust policy framework to support the new capacity addition as well as address the sectoral challenges is required to revive the wind energy sector. This section describes some of the key policy approaches that can facilitate the implementation of the scenarios.

1. Define a clear policy objective after carefully choosing from the multiple approaches to deploy new capacity

The study offers a glimpse of the possible approaches that can be adopted to add new capacity. There needs to be a policy decision on which approach to follow based on joint priorities set by all the central and state-level stakeholders involved. The next steps could be as follows:

a. Undertake an accurate assessment of the overall cost of adopting each of the approaches. The cost of building transmission and evacuation infrastructure, developing robust grid balancing mechanisms, additional monetary support requirements, and other indirect costs need to be factored in.

b. Choose an approach based on the assessment and define policy objectives.

c. Formulate a supporting policy plan to achieve the objectives defined and address the challenges in implementing the chosen approach for the short- and long-term.

2. Streamline the reverse auction process for deploying new capacity at the central and state level

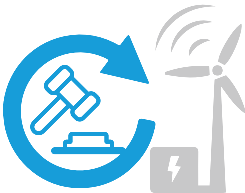
By focusing on new capacity deployment, the central and state governments can ensure smoother and faster deployment as well as optimise the scaling up of the wind energy sector so that it offers the maximum economy-wide benefits. MNRE can plan and execute new capacity deployment with a streamlined reverse auction process with greater involvement from the state nodal agencies in the stages leading up to the auction itself. The processes that could streamline the reverse auction are as follows:

a. Based on the chosen policy approach, conduct a detailed resource assessment for the selected states and identify the wind energy zones in those states.

b. Identify and catalogue suitable revenue land in wind energy zones to create land databases or land banks. Create a single-window portal for applying, processing, and approving land procurements by developers. Wind parks and hybrid parks in identified sites could also be developed. Databases can also be created for private land identified in the zones, with the required approvals being processed through the single-window portal.

c. Coordinate with the central and state transmission utilities and transmission planning committees to develop timely transmission infrastructure that is required to execute the planned deployment strategy in the identified zones.

d. Conduct site-specific auctions in the identified zones with benchmark tariffs estimated for the respective sites. Provide additional support in the form of a VGF or GBIs if the projects are being executed in medium-low WPD sites to ensure parity.



MNRE can plan and execute new capacity deployment with a streamlined reverse auction process with greater involvement from the state nodal agencies in the stages leading up to the auction itself

Establish dedicated wind RPO targets for the states to create demand for wind energy

3. Provide regulatory support to create and sustain demand in the sector

An important and immediate issue that the government needs to address is the continued low annual capacity addition. Having a steady demand for wind energy can help ensure a minimum annual capacity addition. Some of the regulatory measures that could create this demand are as follows:

a. Create a stringent RPO compliance mechanism to ensure uniform compliance across states and a binding penalty for non-compliance. Strengthen the RPO compliance cell within the MNRE by clearly defining its roles and powers in coordinating with state agencies.

b. Establish dedicated wind RPO targets for the states to create demand for wind energy. This is required to help create additional demand for wind energy, which otherwise might lose out to cheaper solar power.

c. Revise open-access regulations across states to streamline the application process and prevent additional charges from reducing the competitiveness of wind energy. Open access and captive power plants can increase the demand for smaller wind power plants in the country.

4. Develop regulatory and financial mechanisms to address the high off-taker risk in the sector

There is a high off-taker risk for wind energy projects where the off-taker is a state discom. This is due to discoms delaying payments and attempting to renegotiate PPAs. However, land procurement and site-specific auctions would be more streamlined if state agencies undertake a greater role in the wind capacity deployment process. Therefore, there is a need to mitigate the off-taker risk in the sector. Some of the mechanisms to achieve this are as follows:

a. Develop a payment security mechanism to address delays in payments to wind power plant owners. This could be developed under the SECI.

b. Deploy innovative financial mechanisms such as green bonds, which can be issued by the states and used to finance working capital loans to meet the RPO obligations of discoms. According to a framework developed by the CEEW, discoms with long payment delays but relatively high credit ratings are most ideal to issue the green bonds; this would reduce payment delays to RE power producers.[86]

5. Develop a regulatory framework to implement optimum grid integration practices

In case of increasing addition of variable energy to the grid, better grid integration of the energy generated becomes crucial. The ramp rate of conventional coal power plants increases with capacity additions of wind and solar energy to compensate for the diurnal variability.

86 Arjun Dutt et al. Financing India's Energy Transition: A Guide on Green Bonds for Renewable Energy and Electric Transport (New Delhi: CEEW, 2019).

A regulatory framework with the following objectives could facilitate better grid integration of the variable renewable power generated:

a. Create a robust ancillary services market with innovative market designs that can facilitate better integration of RE while minimising the impact of grid balancing on the efficiency of conventional plants.

b. Fast track the operationalisation of REMCs with state-of-the-art technology across states to undertake accurate scheduling and forecasting of renewable power and improved balancing of the grid.

c. Deploy financial de-risking mechanisms such as GIGs to reduce the wind curtailment risk.[87]

87 CEEW, Curtailing Renewable Energy Curtailment

Annexures

A. State-wise wind potential at 100 m

S No.	STATES / UTs	Wind potential –WindDForce 100m –5Dx7D			
		Rank I –fallow land GW	Rank II –agricultural land GW	Rank III –forest land GW	Total GW
1	Andhra Pradesh	96	90	49	235
5	Chhattisgarh	0	1	1	2
7	Gujarat	82	166	27	275
12	Karnataka	79	194	70	343
13	Kerala	6	11	30	47
14	Madhya Pradesh	37	236	21	294
15	Maharashtra	92	228	63	383
20	Odisha	6	16	5	27
22	Rajasthan	118	94	26	238
24	Tamil Nadu	31	78	34	143
25	Telangana	42	98	21	161
27	Uttar Pradesh	0	7	1	8
29	West Bengal	0	1	0	1

TABLE 7:
State-wise wind potential at 100 m

Source:
Jami Hossain et al. (2015)[88]

B. Calculation of the CUF of a wind turbine

For Suzlon S120 model –specifications

Wind class IIIA
Rated power = 2,100 kW
Cut-in speed = 3 m/s (uc)
Cut-out speed = 18 m/s (uf)
Rated speed = 9.5 m/s (ur)
Rotor diameter = 120 m
Hub height = 120 m

Assumptions

Location = Karnataka
average wind speed = 6 m/s (at 100 m)
k = 2 (shape parameter)
CUF = 0.087* average wind speed – Rated power/ (Rotor diameter) ^2
Putting all the values above
CUF = 0.40

Source: Y. Ditkovich and A. Kuperman[89]

88 Hossain et al., Report on India's Wind Power Potential

89 Y. Ditkovich, and A. Kuperman, "Comparison of Three Methods for Wind Turbine Capacity Factor Estimation," Scientific World Journal 2014, (2014).

C. Mean wind speed data

States		Mean wind speed at agl 100 m (m/s)		
	Roughness factor	10% windiest	20% windiest	30% windiest
Gujarat	0.15	6.37	6.13	5.95
Karnataka	0.15	6.31	6.07	5.93
Maharashtra	0.15	6.03	5.62	5.41
Andhra Pradesh	0.15	6.06	5.76	5.57
Tamil Nadu	0.15	7.53	6.82	6.44
Rajasthan	0.15	5.87	5.59	5.42
Madhya Pradesh	0.15	5.23	5.06	5
Telangana	0.15			
Odisha	0.15	4.98	4.72	5
Kerala	0.15	7.02	6.22	5
Puducherry	0.15	5.53	5.48	5.44
Chhattisgarh	0.15	4.91	4.7	4.54
Andaman & Nicobar	0.15	5.75	5.55	5.42
Lakshadweep	0.15	4.59	4.53	4.47
Arunachal Pradesh	0.15	4.2	3.67	3.34
Assam	0.15	4.11	3.76	3.58
Bihar	0.15	4.01	3.94	3.91
Diu & Daman	0.15	6.62	6.53	6.48
Haryana	0.15	4.61	4.45	4.35
Himachal Pradesh	0.15	9.48	8.29	7.48
Jharkhand	0.15	4.41	4.25	4.16
Jammu & Kashmir	0.15			
Manipur	0.15	5.42	4.91	4.58
Meghalaya	0.15	4.68	4.42	4.27
Nagaland	0.15	4.16	3.81	3.6
Sikkim	0.15	8.92	7.51	6.56
Uttarakhand	0.15	7.36	6.06	5.37
Uttar Pradesh	0.15	5.27	4.73	5
West Bengal	0.15	4.5	4.27	5

TABLE 8:
State-wise mean wind speed data

Source: Global Wind Atlas[90]

90 Technical University of Denmark (DTU), "Global Wind Atlas," https://globalwindatlas.info/area/India, (2018).

D. Assumptions for LCOE calculation

Input	Unit	CEEW assumption
Useful life	Years	25
Power plant cost	INR Lacs	750.00
Debt	%	70%
Equity	%	30%
Total debt amount	INR Lacs	455.00
Total equity amount	INR Lacs	195.00
Total cost	INR Lacs	650.00
Loan amount	INR Lacs	455.00
Moratorium period	Years	0
Repayment period (including moratorium)	Years	13
Interest rate	%	9.50%
Equity amount	INR Lacs	195.00
Post-tax weighted average of ROE	% p.a	16%
Discount rate (post-tax WACC)	%	9.15%
Income tax	%	34.61%
Depreciation rate for the first 12 years	%	5.28%
Depreciation rate from the 13th year onwards	%	1.78%
O&M charges	Months	1
Maintenance spare (% of O&M expenses)	%	15%
Receivables from debtors	Months	2
Interest on working capital	%	12.26%
O&M charges	INR Lacs/MW	10.00
O&M expense escalation	%	5.00%

TABLE 9: Assumption for LCOE calculations

Source: Authors' analysis

E. Calculation for repowering

Calculating the cost of the new power plant

Based on the available literature, it was estimated that 7 per cent of the total cost of a new power plant goes towards land acquisition and the construction of peripheral roads. Thus, for the repowered plant, this part was deducted from the total cost of a new plant. Additionally, the recovered scrap value of the old power plant, assumed to be 10 per cent of the original capital cost and discounted to current terms, was also deducted from the upfront capital cost.

Calculation of the LCOE

The calculation of the LCOE for the repowered plant is similar to that of a new power plant with one difference. The (levelised) present value of the lost revenue due to the premature decommissioning of the existing power plant was also added to the other LCOE components. The LCOE came to INR 2.43/kWh.

Calculation of the lost revenue

This was calculated by finding the net revenue that would have accrued to the developer in the remaining lifetime of the existing power plant. The tariffs used for the calculation were as per the Tamil Nadu Electricity Regulatory Commission (TNERC) policies for wind power plants commissioned between 1998 and 2003. According to the regulation, the FiT is to remain at INR 2.70/kWh for 20 years of the plant's lifetime following which the energy would be sold at the average power purchase cost. From the latest Aggregated Revenue Requirement (ARR) for Tamil Nadu Electricity Board (TNEB), this cost has been estimated at INR 4.91/kWh and is assumed to be constant for the remaining five years.

Calculation of the two-part tariff

Several models were tried out for the tariff that would be applicable to the additional generation (equal to the total generation after the existing plant's scheduled lifetime) from the repowered plant. The only condition common to all the models was that the net present value of the receivables was the same as what the plant would have received had there been a single-part tariff equal to the LCOE. Imposing this constraint in each model description gives the complete tariff structure for the additional generation from repowering.

Model description	Tariff structure*	Payback period
1. Balancing cashflows for each year separately such that the cashflow each year is same as what would have been for single-part tariff equal to LCOE	INR 2.37/kWh for the first two years, INR 1.86/kWh for the next five years, and INR 2.43/kWh thereafter	13 years
2. Constant tariff	INR 2.25/kWh for the lifetime of the repowered plant	13 years
3. Starting with INR 2.43/kWh, reduce the tariffs at a constant rate	Annual de-escalation of 0.89 per cent starting with INR 2.43/kWh in the first year	12 years
4. Annual de-escalation of 2.5%	Starting with INR 2.77/kWh in the first year, an annual de-escalation of 2.5%	11 years
5. Matches the FiT (i.e., tariff for the first part) and is constant thereafter	INR 2.70/kWh for the first two years, INR 4.91/kWh for the next five years, and INR 0.73/kWh thereafter	3 years
6. Constant decrease of INR 0.08/kWh every year	Starting with INR 2.94/kWh every year, decreasing it by 8p/kWh every year	8 years

TABLE 10: Comparison of different tariff designs for repowered power plants

Source: Authors' analysis

Model 4 was selected with suitable generation-based incentives to decrease the payback period. It was preferred over Model 6 as the difference between the maximum and minimum tariffs was over 60 paise higher in the latter.

Generally, land is procured in patches to set up wind power plants, unlike solar where it needs to be a continuous patch of land.

Image: Emotivelens

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