INDIA'S RENEWABLE ENERGY GOALS

FACTS ABOUT PROGRESS MADE TILL 2022

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CENTRE FOR SCIENCE AND ENVIRONMENT

Authors: Jasleen Bhatti and Binit Das

Editors: Sunita Narain, Aditya Batra and Akshat Jain

Cover design: Ajit Bajaj and Ritika Bohra

Design: Ajit Bajaj and Chaitanya Chandan

Infographics: Mukesh Kumar Singh and Sanjit Kumar

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41, Tughlakabad Institutional Area
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Phones: 91-11-40616000
Fax: 91-11-29955879
E-mail: sales@cseinida.org
Website: www.cseindia.org

CONTENTS

Overview 7

Utility-scale solar 21

Wind energy 33

Rooftop solar 55

Biomass 65

Mini-grids 73

Hydrogen energy 85

Manufacturing and recycling 93

OVERVIEW

GOAL 1

500 GW OF NON-FOSSIL FUEL ENERGY CAPACITY BY 2030

INDIA'S LOW-CARBON COMMITMENT:

Renewable energy will be key for energy transition

At COP26, Prime Minister Narendra Modi put out enhanced targets for India to combat climate change. These are as follows:

1. India will increase its non-fossil energy capacity to 500 GW by 2030.
2. India will meet 50 per cent of its energy requirements from renewable energy by 2030.
3. India will reduce the total projected carbon emissions by one billion tonnes from now onwards till 2030.
4. By 2030, India will reduce the carbon intensity of its economy to less than 45 per cent.
5. India will achieve the target of Net Zero by 2070.

A. INDIA'S ENERGY TRAJECTORY TILL 2030: ROLE OF RENEWABLES

GOAL 1: 500 GW OF NON-FOSSIL FUEL ENERGY CAPACITY BY 2030

India's Central Electricity Authority (CEA) has done a projection for the country's energy mix for 2030. As per this, India's installed capacity of non-fossil energy—solar, wind, hydel and nuclear—for electricity generation in 2019 was 134 GW and by 2030 it will be 522 GW. This will require installed capacity of solar and wind energy to rise to 280 GW and 140 GW respectively.

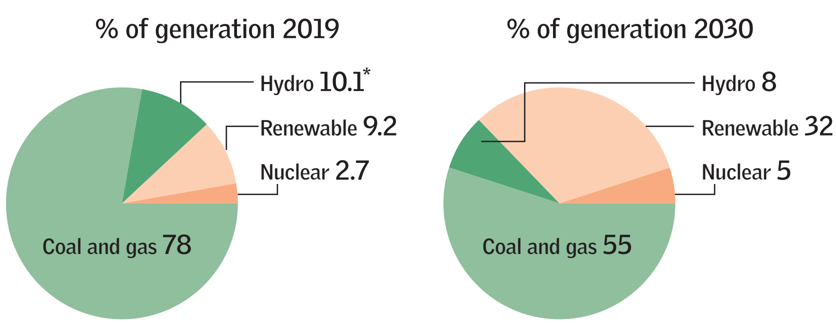
Total installed capacity will be 817 GW and power generation will be 2,518 billion units in 2030. The contribution of coal and gas to total electricity generation will go down from 78 per cent in 2019 to

Table I: Current and future energy mix for India: CEA

	Installed capacity (GW) 2019	% of installed capacity 2019	Generation (Billion Units) 2019	% of generation 2019	Installed capacity (GW) 2030	% of installed capacity 2030	Generation (Billion Units) 2030	% of generation 2030
Coal and gas	228	63	1,072	78	282	36	1,393	55
Hydel	45	12.5	139	10.1*	61	7.5	206	8
Renewable	82.5	22.7	126	9.2	455	54.5	805	32
Nuclear	6.7	1.9	378	2.7	19	2.3	113	5
	362		**1,376**		**817**		**2,518**	

*Including import from Bhutan; Source: Report on Optimal Generation Capacity Mix for 2029–2030. Central Electricity Authority, Ministry of Power

Graph I: Current and future energy mix for India: CEA



*Including import from Bhutan
Source: Report on Optimal Generation Capacity Mix for 2029–2030. Central Electricity Authority

55 per cent in 2030. The share of renewable energy will increase from 9.2 per cent to 32 per cent. This will require the installed capacity of renewable energy to be scaled up from 82.5 GW in 2019 to 455 GW in 2030.

GOAL 2: INDIA WILL MEET 50 PER CENT OF ELECTRICITY REQUIREMENTS FROM RENEWABLES

As per CEA, India was generating 9.2 per cent of its electricity in 2019 from renewables. By 2021, with an increase in renewable energy capacity to 102 GW,

GOAL 2
INDIA WILL MEET 50% OF ELECTRICITY REQUIREMENTS FROM RENEWABLES

the share of renewables in generation increased to roughly 12 per cent.

India's power requirement in 2030 is projected to be 2,518 BU and if India aims to meet 50 per cent of its requirements from renewables, then the installed capacity will have to increase from the planned 450 GW to 700 GW. If India considers hydroelectricity as part of renewables—as it is considered globally—then India will need to increase new renewable capacity to 630 GW.

India's target and energy plan for 2030 also implies that India will restrict its coal-based energy. Currently, roughly 60 GW of coal thermal power is under construction and in the pipeline. According to CEA, India's coal capacity will be 266 GW by 2030—an addition of 38 GW (which is roughly what is under construction currently). This means India has stated that it will not invest in new coal thermal power beyond this.

GOAL 3: INDIA WILL REDUCE PROJECTED CARBON EMISSIONS BY 1 BILLION TONNES FROM 2021 TO 2030

India's CO_2 emissions in 2021 were 2.88 Gt/year. In the business-as-usual (BAU) scenario, India's CO_2 emissions will be 36.28 Gt between 2020 and 2030. In other words, India has committed to emit 1 billion tonnes less, or 35.28 Gt in this period.

GOAL 3
INDIA WILL REDUCE PROJECTED CARBON EMISSIONS BY 1 GT FROM 2021 TO 2030

In terms of per capita: India would be emitting 2.98 tonnes of CO_2 per capita in 2030. If you compare this to the world, US will be emitting 9.42, EU will be emitting 4.12, UK will be emitting 2.7 and China will be emitting 8.88 tonnes of CO_2 per capita in 2030.

According to Intergovernmental Panel on Climate Change (IPCC), global CO_2 emissions must be 18.22 Gt in 2030 for the world to stay below 1.5°C rise in temperature. If we take global population in 2030 and divide this amount, it would mean that the entire world should be emitting lesser than 2.14 tonnes of CO_2 per capita in 2030.

In terms of the carbon budget: With the new NDC announcement (2 November 2021), India will occupy 9.5 per cent of remaining IPCC 400 Gt carbon budget for 1.5°C by 2030 and 4.4 per cent of world emissions between 1870–2030.

GOAL 4: CARBON INTENSITY REDUCTION BY 45 PER CENT

Carbon intensity is a measure of CO_2 emissions from different sectors of the economy. It should be reduced as the economy grows. As per CSE's observations, India has reduced emission intensity of its GDP by 25 per cent between 2005–2016, and is on the path to achieve more than 40 per cent reduction by 2030. But this means that India will have to take up enhanced measures to reduce emissions from the transport sector and the energy-intensive industrial sector, especially cement, iron and steel, non-metallic minerals and chemicals. It would also require India to reinvent its mobility systems so that we can move people, not vehicles—augment public transport in our cities and improve thermal efficiency of our housing. All this is in our best interests.

GOAL 4
CARBON INTENSITY REDUCTION BY 45%

GOAL 5
NET ZERO BY 2070

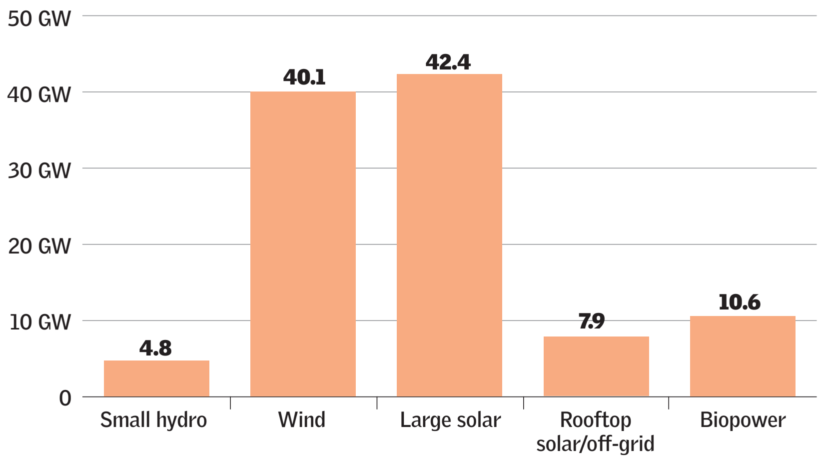
GOAL 5: NET ZERO BY 2070

According to IPCC, global emissions must be halved by 2030 and reach net zero by 2050 (see CSE's factsheet on net zero). Given the enormous inequity in emissions in the world, the OECD countries must reach net zero by 2030, China by 2040 and India and the rest of the world by 2050. However, the targets for net zero are both inequitable and unambitious. OECD countries have declared net zero target for 2050 and China has declared net zero target for 2060. Therefore, India's net zero target of 2070 is an extension of this and cannot be argued against. However, this combined net zero goal will not keep the world below 1.5ºC temperature rise and it means that OECD countries must frontload their emission reductions by 2030. Most importantly, China, which will occupy 33 per cent of the remaining budget, must be asked to reduce its emissions drastically by 2030. China alone will add 126 Gt in this decade.

Renewables will play a critical role in India's energy future and reach anywhere between 455–630 GW by 2030.

The cost of this energy will have to be affordable so that it can meet the needs of the poor in the country; for whom even the cheapest electricity sourced from dirty coal is expensive and who continue to use non-monetized sources of fuel like firewood and cow dung for their needs. Energy poverty is unacceptable and even as India ramps up renewable power, access to energy must also be secured.

Graph 2: RE installed by 31 January 2022



Source: MNRE

B. IS INDIA ON TRACK TO MEET THE TARGET?

To be on track to meet its renewable energy goal of 450 GW by 2030, India needs to add about 35 GW of renewable power each year in this decade.

There is no doubt that the government is committed to scaling up renewable energy in the country. As of 31 January 2022, India had installed 105.8 GW of renewable power. Between April and December 2021, India installed 10 GW of new renewable power—below what it needs to do to achieve its 2030 goal—but still commendable.

C. CHALLENGES TO AND OPTIONS FOR SCALING UP

1. The future of renewables is linked to the health of electricity distribution companies (DISCOMS): Currently, distribution companies are in deep debt; they cannot pay for power or they delay the payment, which in turn puts pressure on renewable power developers and adds to their financial risks. In July

BETWEEN APRIL AND DECEMBER 2021, INDIA INSTALLED 10 GW OF NEW RENEWABLE POWER

2019, roughly Rs 10,000 crore was owed to renewable energy generators. And in spite of the government's efforts to improve this situation, the debt had increased to roughly Rs 20,000 crore by 2022.

This matter of outstanding dues of over Rs 1 lakh crore reached the Supreme Court in early 2022. The Supreme Court warned DISCOMS that if the situation is not remedied fast, then power generation companies will have to shut down.

DISCOMS are the spine of the electricity supply system and so the future of renewable power is intrinsically linked to their functioning. This will remain the Achilles' heel for this sector's growth.

This is also why the government has, in its hydrogen policy, sidestepped the need for DISCOMS—letting renewable energy developers sell power directly to green hydrogen manufacturers.

The same is true for commercial and institutional scale rooftop solar, in which captive clean power is generated by consumers. This impinges on the sustainability of DISCOMS as they lose paying customers. But DISCOMS will be needed to supply electricity when the sun is not shining—at night or in other periods. They are the backups for captive clean power—unless there is expensive storage included in the project.

HEALTH OF DISCOMS IS KEY TO THE SUCCESS OF THE RE SCHEME IN THE COUNTRY

It is for this reason that the health of DISCOMS—their viability, functioning and operations—is the bedrock for the success of the grand renewable energy scheme of the country.

2. Curtailment of power adds to risk of investment: Curtailment of power generated by wind and solar projects is a persistent problem for renewable energy developers in India despite a 'must run' assurance in regulations. There is no official data on this 'curtailment' because of the lack of transparency on the part of state load dispatch centres (SLDCs) and distribution companies.

CURTAILMENT OF POWER IS A PERSISTENT PROBLEM FOR RENEWABLE ENERGY DEVELOPERS

The industry says curtailment is between 1–5 per cent for solar power; wind, particularly in Tamil Nadu, sees much higher curtailment, pegged at 30–35 per cent. But all these numbers are seen to be underestimates. This is clear from the fact that capacity utilization in the wind sector of Tamil Nadu has dropped from 30 per cent in 2016–17 to 25 per cent in 2019–20. This is happening even though the Indian Electricity Grid Code 2010 asks SLDCs to prioritize scheduling of renewable power over other generators/sources to incentivize green energy projects unless there are technical constraints such as congestion in the grid or unavailability of renewable energy.

This illegal curtailment is also pegged with the price of power. DISCOMS ask older plants, with higher tariffs in the power purchase agreements, to cut back on generation—that is, to not feed to the grid.

In Andhra Pradesh, when the state government failed to re-negotiate the 'expensive' wind and solar projects, it started using curtailment as its best option. In October 2019, the National Solar Energy Federation of India (NSEFI)—the association of large solar generators—wrote to the Union Ministry of Power asking for its intervention as solar projects in the state were suffering from continuous curtailment of 60–70 per cent since July 2019. On 20 December 2019, the CEA took cognizance of this matter and convened a meeting to discuss 'curtailment of power from renewable energy-based generating stations.' Its notice said that 'it has been observed during high RE season of April–October 2019 that growth of energy generation from RE sources was less compared to previous years'—even after addition of new RE capacity. One possible reason is curtailment instructions issued by the SLDCs, as brought to the CEA's notice by the Indian Wind Power Association (IWPA), instances of which increased in 2019. Estimated average curtailment of wind power in Tamil Nadu in 2019 was 3.52 hours/day, while it was 1.87 hours/day in 2018. The CEA also planned to set up a mechanism to collect curtailment data on a monthly basis—but not much is known about the status of this.

3. State governments want to renegotiate or cancel power purchase agreements with higher tariffs: Solar and wind energy developers sign a contract with a power purchaser, mostly DISCOMS, for a prescribed period (usually 25 years) on a particular tariff rate per unit—based on the then discovered best rate. But then as prices of renewable energy fall and subsequent power purchase is at lower rates, DISCOMS start pushing for re-negotiation. In Andhra Pradesh, the government wanted to renegotiate energy tariffs with developers for some 140 power plants to Rs 2.43 per unit for wind and Rs 2.44 per unit for solar from higher legacy levels. It wanted to do this retrospectively, and threatened to cancel the projects in case this was not done. In this case, the High Court

STATE GOVERNMENTS ARE TRYING TO RENEGOTIATE OR CANCEL PPAs WITH HIGHER TARIFFS

stepped in. But tensions on tariffs continue to simmer. Now Punjab has legislated that it wants to do the same. If this goes through, then many first generation projects could face an uncertain future and this would also spook investors.

RS 24,000 CRORE
HAVE BEEN PROVIDED AS PLI FOR HIGH-EFFICIENCY SOLAR MODULES

4. Uncertainty because of hike in GST rates and import duty on solar components, which will increase cost of projects: Developers can exercise the 'change in law' provision to claim higher tariffs because of the changed GST regime (the Karnataka High Court has also upheld this in a recent case). However, this increased taxation, combined with the 20–40 per cent duty on imported solar cells and modules, will impact the viability of projects. The government is working to increase domestic manufacturing and has provided Rs 24,000 crore as production linked incentives for high-efficiency solar modules. But there is concern if domestic manufacturing can keep pace with the need for growth in this sunrise sector.

5. Renewables are intermittent power sources and will require planning and balancing of the grid for supply, storage and backup: Solar energy is generated when the sun is shining and this means that any plan for ramping up this source of power will need storage systems. This could be done through the mix of power generation in the grid, which includes hydel or coal; or it could be done by setting up battery storage in every solar installation; or by 'exporting' solar energy generated in the daytime to parts of the world where it is night.

OVERVIEW

The Central Electricity Regulatory Commission (CERC) has in its 2017 review, *Introduction of Electricity Storage System in India*, detailed out various options for balancing the grid to take into account the intermittent nature of renewable systems. It finds that higher penetration of renewable generation will require higher capacity of load generating stations—coal, hydel and gas-based power plants. But it also says that regulating output of coal-based thermal generation stations to address the variability of renewable generation is not recommended as it is both uneconomical and difficult to implement. It says that the country needs a strategy for electricity storage systems to improve the operations of the grid.

These electricity storage systems would involve various options and technologies—including pump-storage hydroelectricity, in which electricity is used to pump water to upper-reaches, and then, when required, it is converted back to electricity by running water through a turbine. It would also include electrochemical battery cells and other emerging technologies. CERC's review listed 6.8 GW of different storage systems that were operational or in implementation stage. Clearly, this will be a big part of the future story of renewables.

AFFORDABLE POWER IS NECESSARY TO MEET THE NEEDS OF MILLIONS OF POOR

6. The need for affordable power to meet the needs of millions of poor: It is not enough to electrify villages; it is not even enough to provide subsidies on LPG cylinders that will be used by women to cook food. The fact is that energy, when supplied to households, has to be both affordable and reliable. Currently, even the cheapest and dirtiest raw material (coal) used to generate electricity is expensive for households. This is evident from the fact that while the grid has reached almost every village in the country, electricity has not.

It is also a fact that part of the problem lies with the distribution companies, which buy power relatively cheaply (between Rs 1.50–3.00/unit) and supply it at much more expensive rates (between Rs 6–11/unit). It is partly because of the built-in inefficiencies in the system, but also because there continue to be huge leakages, which make DISCOMS unviable. Renewables must not add to this energy poverty, but find ways of enabling the poor to leapfrog from darkness to light using clean power. A strategy is needed to pay the difference between 'affordable' rates and the cost of generation. A feed-in-tariff regime is needed that works to address energy poverty.

7. Exploring options for scaling up of clean energy to meet the twin challenges of energy access and clean power: The current rate of addition in capacity (roughly 10 GW in 2021) will need to be scaled up to meet the 2030 target of 50 per cent electricity from renewables. This needs new thrust areas for the future and would include:

i. Repowering wind projects: The potential is enormous as past wind installations are inefficient but occupy the best windy sites. Replacing these with modern windmills will increase power generation manifold. This requires a policy which is able to consolidate the fragmented sites, plan comprehensively for the upgrade and make sure the owners are incentivized.

TARGET FOR 2030

50%

ELECTRICITY FROM RENEWABLES

INDIA NEEDS TO ADD ABOUT 35 GW OF RENEWABLE POWER EACH YEAR IN THIS DECADE

ii. Offshore wind: India's long coastline can be the new energy corridor, but the cost of these projects is high. India needs a strategy to raise international finance to pay the difference for offshore wind projects—that will allow it to scale-up and still have affordable power.

iii. Biomass to replace coal in power production: The 2022 directions mandating the use of 5–10 per cent biomass in thermal projects, however welcome, are too small an intervention. India's ageing fleet of thermal power plants can be cleaned up by large-scale transition to biomass and other such fuels. This is a win-win strategy for circularity, as farmers will earn from agricultural residues and it will also help combat local air pollution as this fuel will be burnt in controlled environments where it is possible to install abatement measures.

iv. Decentralized grids based on modern clean energy to meet local needs and address energy poverty, including needs for cooking: This is a potential gamechanger in the energy map of countries like India. But strategies are needed that recognize the potential of clean energy mini-grids. Issues of cost and affordability also need to be addressed so this locally generated and supplied energy can be used by households to power not just essential needs but also meet livelihood and economic needs.

In this way, renewable energy will not only help safeguard the world from an increasingly warming planet, but also help to leapfrog the poorest, who are outside the fossil fuel energy system, directly to the cleanest and most modern energy system in the world.

1

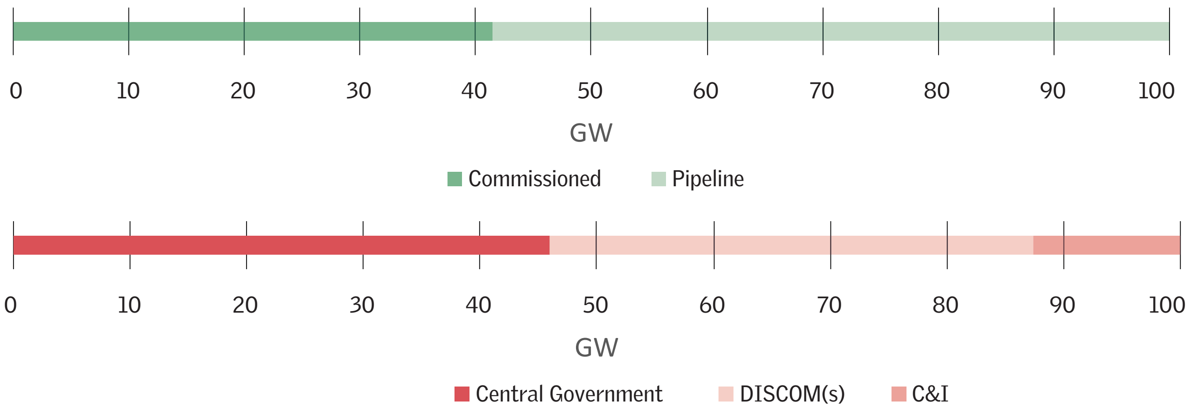
UTILITY SCALE SOLAR

UTILITY-SCALE SOLAR

WHERE DO WE STAND TODAY?

Out of the 100 GW target for solar renewable energy by 2022, as much as 60 GW is to come from utility-scale solar. By December 2021, more than 42.4 GW of utility-scale solar had been installed in the country and around 58.5 GW was at various stages of development. So, this sector has been growing and it is poised to exceed its target of 60 GW—touching 100 GW of installations soon.

Graph 1: Status of utility-scale solar as on December 2021



Source: CSE analysis

STATES AND PROGRESS IN LARGE-SCALE (GROUND-MOUNTED) SOLAR

Rajasthan was the top state for utility-scale solar projects with a cumulative installed capacity of 8.9 GW as of December 2021. This represents about 22 per cent of the country's total installed solar power capacity. Upcoming projects in Rajasthan could face delays in light of the Supreme Court ruling on the need to protect the endangered Great Indian Bustard, whose habitat lies in some of the project areas (*see Box: Bustard vs solar*). The state also houses Bhadla Solar Park, the largest solar park in the world.

Karnataka came in second for large-scale solar projects with a total installed capacity of 7.5 GW at the end of 2021. This amounts to about 18 per cent of the country's total installed solar power capacity. The state reissued the 'Draft Karnataka Renewable Energy Policy 2021–2026' to develop 10 GW of renewable energy projects with and without energy storage.

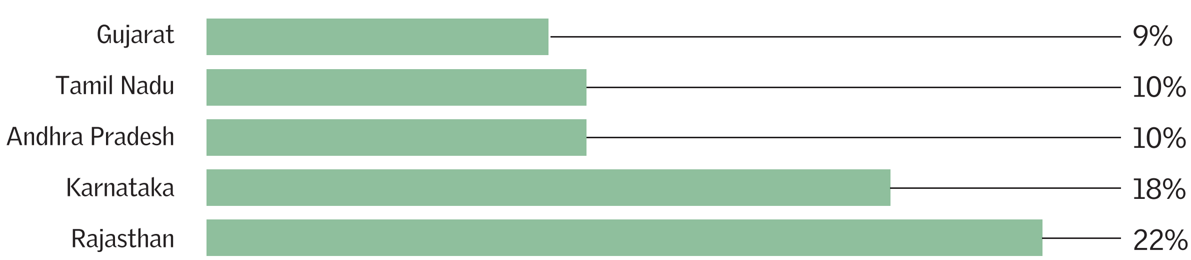
Andhra Pradesh is the third-largest state for solar with cumulative installed capacity of 4.3 GW. This makes for over 10 per cent of the country's total installed solar power capacity. In November 2021, DISCOMs in Andhra Pradesh received regulatory approval to procure 7,000 MW of solar power from the Solar Energy Corporation of India (SECI).

In fourth place is Tamil Nadu with 4 GW, accounting for close to 10 per cent of the country's total installed solar power capacity. The state aims to install 8,971 MW by the end of 2022.

Gujarat was the fifth-largest state for utility-scale solar projects with 3.9 GW, amounting to 9 per cent of the country's total installed solar power capacity.

RAJASTHAN WAS THE TOP STATE FOR UTILITY-SCALE SOLAR PROJECTS WITH A CUMULATIVE INSTALLED CAPACITY OF 8.9 GW AS OF DECEMBER 2021

Graph 2: Total installed capacity in top five states of India as of December 2021

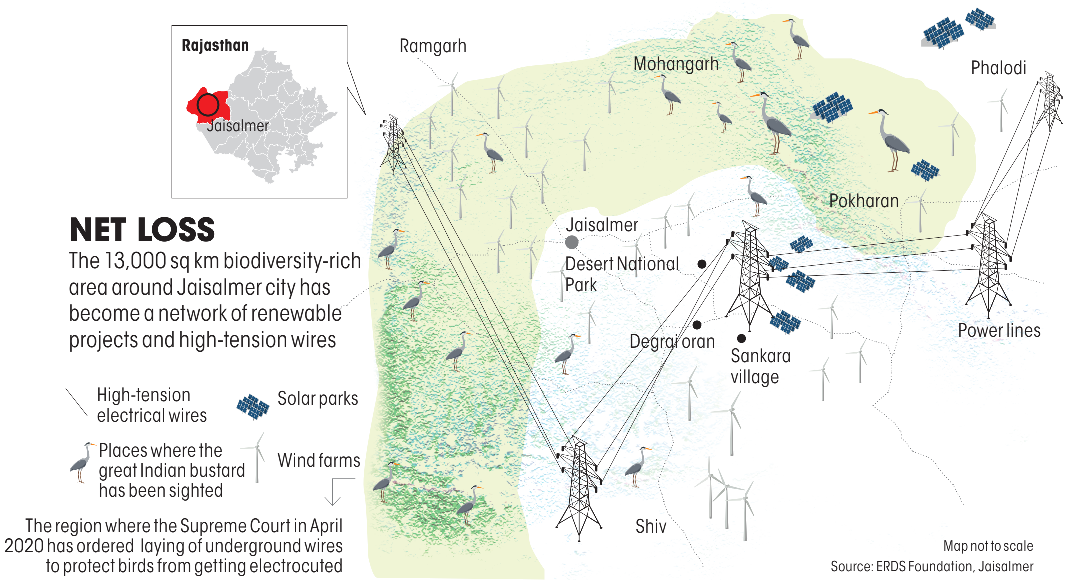


Source: CSE analysis

BUSTARD VS SOLAR

In 2019, M K Ranjitsinh Jhala, a wildlife conservationist, filed a petition in the Supreme Court urging power companies to lay underground wiring in the areas where the Great Indian Bustard dwells in Jaisalmer. In April 2021, the apex court ordered power firms in Rajasthan to lay underground wiring for all projects and install diverters on existing lines in the region. In October 2021, Jhala and other environmentalists filed another petition in the apex court, stating that its April orders were being flouted by the power companies who continued the construction of overhead power lines in the area. The verdict is awaited. 'The solar companies have taken up our *oran*, uprooting native trees and grasses that have not even been documented properly. We know that India is committed to achieving ambitious solar and wind energy capacity by this year. But what we are losing in the process is irreplaceable,' says Sumer Singh Bhati, a conservationist from Sanwata.

In response to the April 2021 SC verdict, MNRE filed an interlocutory application where it alleged underground transmission will make renewable projects untenable. It says the project costs will increase by 4 to 20 times and, as a result, derail the country from realizing its renewable energy goals. 'So far, only a miniscule 3 per cent of the estimated potential of around 263 GW of renewable energy in this area has been tapped. If the remaining potential stays untapped, we will need an additional 93,000 MW of coal-fired capacity to replace the unutilized renewable energy in the future,' reads the application. Admitting that 65 GW of solar and wind energy projects lie in the Great Indian Bustard habitats in Rajasthan and Gujarat, it says no company globally manufactures underground cables for 765 KV that are ideally needed for transmitting electricity from the plants. Additionally, pushing the wiring underground may lead to disputes over 'right of way' to lay the cables under privately owned land, risking land acquisition litigation and causing delays in the projects. There are also safety issues as faults may cause electrocutions in the area. The Centre has set up a three-member committee, as directed by the SC in its April 2021 verdict, to look into the possibility and technical aspects of undergrounding the high-tension power lines.



NET LOSS

The 13,000 sq km biodiversity-rich area around Jaisalmer city has become a network of renewable projects and high-tension wires

SOLAR PARKS

The Indian government introduced a solar park scheme in 2014 to promote solar power. Under this scheme, solar projects with capacities of over 500 MW will be considered as solar parks, also referred to as ultra-mega solar parks (UMSP). It is estimated that India has 467,000 square meters of wasteland available which could be utilized to install such large solar parks with total capacity of 28.8 GW.

In spite of policy and project-implementation issues, India's utility-scale solar park model has held firm. Till June 2018, 45 such solar parks with cumulative capacity of 26.4 GW in 22 Indian states had been approved by the Ministry of New and Renewable Energy (MNRE).

According to the scheme, solar parks would be managed by Solar Power Project Developers (SPPD) who would facilitate the bidding, erection, commissioning and operationalization of UMSPs and feed all generated power to the grid. The scheme prefers non-agricultural barren contiguous land between 4,000–6,000 acres.

India has also pioneered the concept of the ultra-mega power plant (UMPP) in a single solar industrial park. The UMPP concept involves a state government or local distribution company facilitating a single central grid connection and taking on the procurement and time delay risks relating to land acquisition. This approach has been instrumental in driving economies of scale and attracting global capital into India's renewable energy sector over the last five years.

SOLAR PROJECTS WITH CAPACITIES OF OVER
500 MW
WILL BE CONSIDERED AS SOLAR PARKS

NTPC SIMHADRI IS THE LARGEST FSPV IN THE COUNTRY THUS FAR

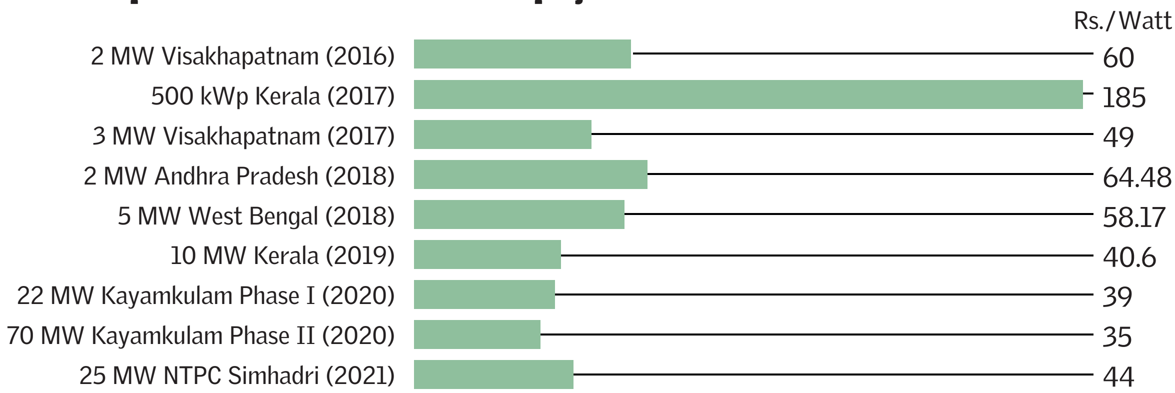
FLOATING SOLAR PV

In August 2021, NTPC Simhadri in Andhra Pradesh commissioned the 25 MW floating solar PV (FSPV)-based project, the largest FSPV plant in the country thus far.

The FSPV sector is now getting a lot of attention in the country. The number of tenders released has increased in the past 2 years. At the moment, there are more than 2500 MW worth of projects which are in various stages of development. The overall 280 GW potential is a strong indication of the extent of the surface area than can be made available for setting up these projects. However, very little knowhow is available at the moment thus posing many challenges, which need to be addressed:

- Unavailability of FSPV-specific standards and technical guidelines
- Unavailability of waterbody data
- Safety of FSPV plant components and their long-term reliability
- Absence of local manufacturing
- Unavailability of bathymetry and other studies on water

Graph 3: Investment cost for FSPV projects in India



Source: CSE's analysis based on a compilation of publicly available data

SOLAR-WIND HYBRID (WITHOUT STORAGE) AND ROUND-THE-CLOCK (WITH STORAGE) POWER

MNRE released a solar-wind hybrid (SWH) policy in 2018. This provides a framework to promote grid-connected hybrid energy that would use land and transmission infrastructure optimally and also manage the variability of renewable resources to some extent.

As per the tenders allotted under various central and state schemes, about 11.6 GW of SWH power is likely to come up over the next three years, riding on strong support from SECI and several state governments. In August 2021, SECI tenders for SWH without storage have attracted low tariffs to the tune of Rs 2.34/kWh which are comparable to solar tariffs. NTPC, Ayana and NLC quoted Rs 2.34/kWh each and won 450 MW, 450 MW and 150 MW respectively. Azure won 150 MW at Rs 2.35/kWh.

In August 2021, ReNew Power signed a PPA with SECI for the country's first 400 MW round-the-clock renewable energy project. It will result in deployment of 1,300 MW SWH capacity supplemented by battery storage. The quoted tariff was Rs 2.90/kWh (for the first year) for the 400 MW capacity in the reverse auctions held in May 2020. Though the tariff under this tender will increase by 3 per cent annually for 15 years, the levelized tariff would be around Rs 3.60/kWh, which is lower than the current average power purchase cost of Rs 3.85/unit from non-renewable sources in the country. The project will be designed to operate at an 80 per cent average annual plant load factor (PLF) and will have a minimum capacity utilization factor (CUF) of 70 per cent monthly.

ABOUT
11.6 GW
OF SWH POWER IS LIKELY TO COME UP OVER THE NEXT 3 YEARS

CURTAILMENT STILL PLAGUES THE INDUSTRY

Developers allege that while curtailment is rampant and affects all projects, older wind and solar projects with higher tariffs are curtailed more than the new ones supplying power at lower tariffs. The RE sector in Andhra Pradesh had been in flux since the state government announced its decision to renegotiate 'expensive' wind and solar power purchase agreements. Following this, the state load dispatch centre (SLDC) had been indiscriminately curtailing power generation.

Curtailment of renewables is now a major concern for investors as well as existing players. At NSEFI, curtailment of both solar and wind in India is being tracked since the lockdown in April 2020. According to their data, at least 73.9 million units of solar and wind power has been curtailed in the last one year with at least 1.5–2 GW of solar curtailed every day. This curtailment majorly happens in Tamil Nadu, Andhra Pradesh and Telangana. The need of the hour is to have a mechanism in place that will prevent undue and rampant curtailment of solar and wind in India without respecting the 'Must Run' status.

Meanwhile, there has been limited acknowledgement from central and state governments about the commercial motives behind curtailment. Developers have increasingly voiced their concerns through associations and approached regulators and courts, which has yielded some results. The challenge is directly related to the financial weakness of the DISCOMS, which requires strong structural reforms.

However, there are technical challenges in integrating both wind and solar with the grid on the DC side. As per the MNRE policy, till the time the DC metering framework is not in place, only AC integration is permitted. This reduces the cost benefits associated with DC integration in terms of utilization of the balance-of-system (BOS).

IMPEDIMENTS TO GROWTH

1. Access to land for installations: Utility-scale solar projects require a large amount of land and present a resource availability challenge in a densely populated country.

2. Need for interventions for grid stability: Large-scale power input from utility-scale generators is more difficult for grid stability management from the grid operator's perspective because it must deal with large voltage and frequency fluctuations.

3. Risk to investment because of non-payment of dues by DISCOMS: Investment risk has increased as DISCOMS are unable to pay their dues to solar power generators. According to the Central Electricity Authority (CEA), the dues towards 342 RE projects amounted to about Rs 9,400 crore by the end of November 2019, affecting 14.56 GW of capacity. States with the bulk of RE projects—Andhra Pradesh, Tamil Nadu, Telangana and Karnataka—account for 78 per cent of the dues; these four also account for 54 per cent of the installed capacity of large-scale solar. Even with the government's bail-out package for DISCOMS, such risks are expected to persist.

According to the Praapti (payment ratification and analysis in power procurement for transparency in invoicing of generators) Portal of the government, the total dues of DISCOMS to power companies had increased to Rs 1,01,714 crore by February 2022. Of this, some 20 per cent, or Rs 20,000 crore, was due to renewable energy projects.

4. Increasing cost of components could hit viability of projects: The average cost of large-scale solar projects in the first quarter of 2021 was about Rs 33.6/Wp. The cost increased by 29 per cent when compared to the same period last year (Rs 26/Wp). The government recently increased GST on critical components such as photovoltaic cells and modules from 5 to 12 per cent with effect from February 2022. Under the existing regime,

DISCOMS OWE
RS 20,000 CRORE
TO RENEWABLE ENERGY PROJECTS

DISCOMS—PAYMENT ISSUES AND DELAYS

Total outstanding dues owed by electricity DISCOMS to power producers rose 4.4 per cent year-on-year to Rs 1,21,030 crore in January 2022. DISCOMS owed a total of Rs 1,15,904 crore to power generation firms in January 2021.

In January 2022, the total overdue amount, which was not cleared even after 45 days of grace period offered by generators, stood at Rs 1,01,357 crore as against Rs 99,650 crore in the same month a year ago. The overdue amount stood at Rs 99,981 crore in December 2021.

Power producers give 45 days to DISCOMS to pay bills for electricity supply. After that, outstanding dues become overdue and generators charge penal interest on that in most cases. To give relief to power generation companies, the Centre enforced a payment security mechanism from 1 August 2019. Under this mechanism, DISCOMS are required to open lines of credit for getting power supply.

The Centre had also given some breathers to DISCOMS for paying dues to power generation companies in view of the COVID-19-induced lockdown. The government had also waived penal charges for the late payment of dues. DISCOMS in Rajasthan, Uttar Pradesh, Jammu & Kashmir, Telangana, Andhra Pradesh, Karnataka, Madhya Pradesh, Maharashtra, Jharkhand and Tamil Nadu account for the major portion of dues to power generation companies.

Overdue of independent power producers amounted to 54.56 per cent of the total overdue of Rs 1,01,357 crore of DISCOMS in January 2022. The overdue of non-conventional energy producers like solar and wind stood at Rs 19,651.15 crore in January 2022.

70 per cent of the gross value of the contract was considered for the supply of goods, attracting a 5 per cent rate—which is now 12 per cent. And then, the rest of the components will also have their respective GST rates—inverters at 18 per cent, cables at 28 per cent, and so on.

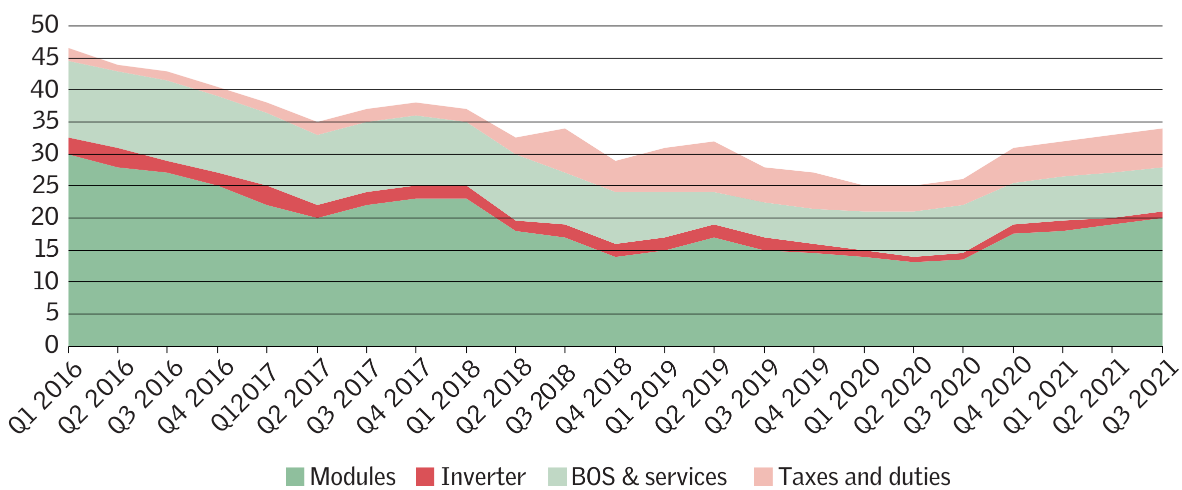
MNRE has announced the basic customs duty (BCD) on imported solar cells and modules starting 1 April 2022. The BCD on solar modules with HSN Code 85414012 will be 40 per cent, and on solar cells (85414011) will be 25 per cent.

This has increased the total taxation on a solar project from 8–9 per cent to 12–13 per cent, which will more than double to 30 per cent when customs duty of 40 per cent on imported solar modules kicks in from April 2022.

Increase in the GST rate will affect the economic feasibility of renewable energy projects and will have a detrimental effect on ongoing and upcoming projects. Though developers can always claim compensation under the 'Change in Law' clause, they don't want to get into a legal quagmire as GST claims have taken years to get resolved in the past.

However, the Karnataka Electricity Regulatory Commission (KERC), in a recent order, ruled in favour of a solar developer i.e., Adani Green Energy (UP) and directed four DISCOMs of the state to compensate the developer for the additional cost incurred due to the imposition of the GST laws under the 'Change in Law' clause.

Graph 4: Trend of Engineering, procurement and construction cost



Source: Bridge to India

PUNJAB LEGISLATES FOR RENEGOTIATION

The Punjab Renewable Energy Security, Reform, Termination and Re-Determination of Power Tariff Bill, 2021 seeks to redetermine tariffs under concluded power purchase agreements for a total of 983.5 MW of renewable energy capacity (886 MW solar and 97.5 MW biomass). The bill was introduced and passed in the Punjab State Assembly on 11 November 2021. After sending it to the Governor, the bill has been further referred to the President of India for his final assent.

Punjab has around 900 MW of operating solar power projects at an investment of close to Rs 7,000 crore. The return for this investment is in the form of long-term power purchase agreements with a fixed tariff approved by the Punjab State Electricity Regulatory Commission.

As per the provisions of the bill, '...all the clauses impacting tariff directly or indirectly in the Agreements shall stand terminated. Further, the agreements between power generators and Punjab Corporation, including the implementation agreements with the Punjab Energy Development Authority, shall be referred to the Punjab State Electricity Regulatory Commission for redetermination of tariff.' To ensure continuity in the electricity supply and energy security of the state, the Punjab State Electricity Regulatory Commission shall also determine a temporary tariff rate that will be applicable until the tariff is finally re-determined by the regulatory commission.

According to National Solar Energy Federation of India (NSEFI), the promulgation of the bill into law will be detrimental to the interests of all solar power developers operating in the state of Punjab. A move to re-negotiate tariffs for the already operating projects will affect the viability of the projects and power producers will find it difficult to repay their loans and pay their vendors and staff.

5. Renegotiation of PPAs: The Andhra Pradesh government's effort to re-negotiate the terms of the solar power purchase agreements on the ground that these have a high cost, have also spooked investors. Many other states are now demanding re-negotiated rates (see *Box: Punjab legislates for renegotiation*).

This sunrise sector—which uses the power of the sun to energize economies—will weather these storms. It must. It is clear that the imperative of renewable energy is even more in today's climate risked times than before.

2
WIND ENERGY

WIND ENERGY

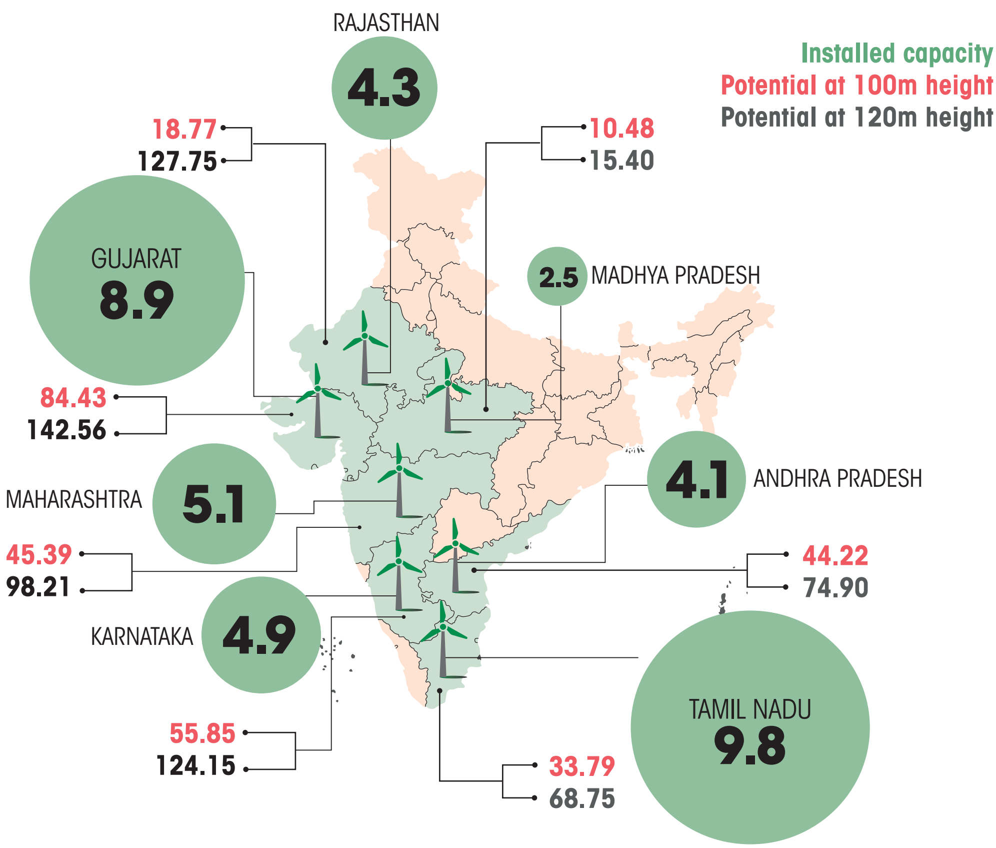
INDIA RANKS
FOURTH
IN THE WORLD IN TERMS OF INSTALLED WIND POWER

WHERE DO WE STAND TODAY?

India ranks fourth in the world in terms of installed wind power, with a capacity of 40 GW as of January 2022. Tamil Nadu and Gujarat have 25 and 22 per cent of this capacity respectively.

The National Institute of Wind Energy (NIWE) estimates that the country has a wind potential of 302 GW at a hub height of 100 m and 695 GW at a hub height of 120 m above ground level. Most of this potential exists in the seven windy states (*see Map 1*).

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



WHAT ARE INDIA'S TARGETS FOR THE FUTURE?

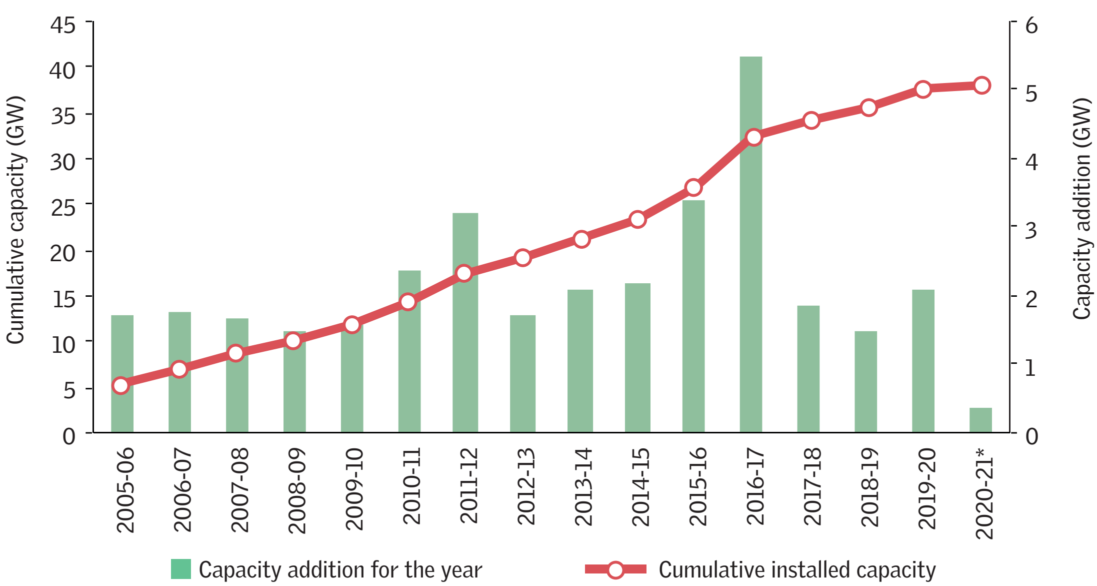
The government has set a somewhat modest wind target of 60 GW by 2022 and 140 GW by 2030. With 39.7 GW installed, another 9.9 GW in different stages of tendering and development, and 11 GW to be tendered, the government remains confident of meeting the wind target by the end of 2022.

39.7 GW INSTALLED, ANOTHER 9.9 GW IN DIFFERENT STAGES OF TENDERING AND DEVELOPMENT

The industry is less confident about the ability to meet targets. According to Mumbai-based analytical company CRISIL, wind power installations may reach only 45 GW by March 2022.

The fact that the country is off-track in terms of meeting its wind energy targets is corroborated by the CEA's January 2020 report on optimal generation capacity mix. For installed wind capacity in the

Graph 1: Capacity addition and total installation of wind energy in India



* Till September 2020
Source: Collated from various reports of the Central Electricity Authority and the Union Ministry of New and Renewable Energy

ANNUAL WIND INSTALLATION HAS CROSSED **5 GW** ONLY ONCE

country to increase from 40 GW in December 2021 to 140 GW by March 2030, annual installation of more than 10 GW for the next 10 years would be required.

However, annual wind installation in India has crossed the 5 GW mark only once—in 2016–17. In all other years, it has been less than 2 GW (see *Graph 1*). Given this scenario, how achievable is the target that India has set for itself?

WHY IS WIND POWER LAGGING BEHIND THE TARGETS?

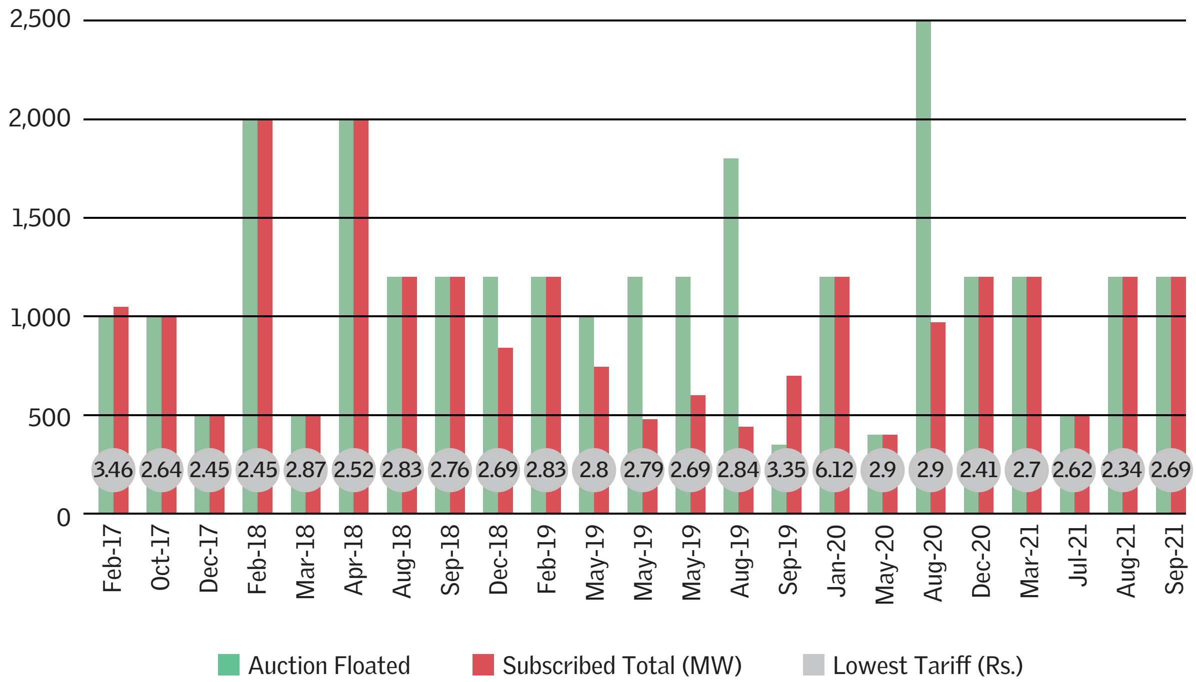
LACK OF FINANCIAL VIABILITY IN PROJECTS

In March 2017, the policy of generation-based incentives was discontinued and competitive bidding was instituted with tariff caps. The first auction of the Solar Energy Corporation of India (SECI) for 1,050 MW in February 2017 brought a record bid of Rs 3.46/unit against the lowest operating price of Rs 4.16 in Tamil Nadu. The tariff cap was revised in 2019 to Rs 2.93/unit, but the industry says it is still not viable. The auctions for 2019–20 are all undersubscribed, with a total response of 45 per cent (see *Graph 2*).

LAND AVAILABILITY AND ACCESSIBILITY TO WINDY SITES

Only two states—Gujarat and Tamil Nadu—have sites where projects can achieve the tariffs under the cap. But these states are not ready to give up land for wind projects to be developed under the Inter-state Transmission System (ISTS) model, where energy can be exported through the grid.

Graph 2: Wind energy project auctions and minimum discovered tariffs



Land acquisition is becoming a huge constraint for new projects all over the country. Unavailability of land is a major cause of the delays in projects allocated through central auctions. Greenfield wind projects require large amounts of land and are location-specific to high wind areas.

TRANSMISSION NETWORK

The gestation period for renewable energy projects is two years, but planning and development of transmission lines in India typically take four to five years. Several mega schemes, like Green Energy Corridors (GEC)-1 and GEC-2 (for 66.5 GW of renewable energy capacity) are underway, but are facing delays in their commissioning. In addition, short-term grid unavailability serves as a bottleneck for businesses participating in new auctions.

INDIA HAS EXPLOITABLE WIND POTENTIAL OF **800 GW** AT 100–120 METRES IN HEIGHT

WHAT ARE SOME OPTIONS TO CLOSE THE GAP BETWEEN TARGETED AND ACTUAL CAPACITY?

1. REPOWERING WIND PROJECTS: POTENTIAL TO INCREASE GENERATION BY 4 TIMES

Wind resources are site-specific. According to NIWE estimates, India has exploitable wind potential of 800 GW at 100–120 meters in height. But the best class I wind sites (with high wind speeds and high wind power densities) have already been exhausted during the one-and-half decades of the sector's development since 1990s. And the plant load factors (PLFs) of the old wind turbines populating these sites are very low, at 10–15 per cent, compared to more than 30 per cent achievable by modern wind turbines. The repowering of old Class I turbines can increase the project capacity and PLF by two to three times, resulting in a fivefold increase in annual energy production.

Wind turbines are designed for a lifespan of about 20 years. These are required to be decommissioned on the completion of their designed life; otherwise, they can pose a safety risk. However, there are several old wind farms in India that have completed their design life of 20 years and continue to run, as they are still profitable to their owners. As per the India Wind Power Directory 2014, over 1 GW of installed capacity with turbine sizes of less than 1 MW has completed 20 years of its design life (*see Table 1*).

Furthermore, wind farms with a capacity of 1.67 GW, commissioned before March 2002 will complete 20 years of design soon; these can be immediately repowered to 5 GW with modern wind turbines. Another 2 GW commissioned between 2002 and 2005

Table 1: Fit for repowering: State-wise and turbine size-wise wind installation done prior to 31 March 2000

This is the wind power capacity that is fit for repowering in the country (most of it is in Tamil Nadu and Gujarat)

States	<=0.5 MW	0.5-1.0 MW	Total
Tamil Nadu	717.05	37.9	754.95
Gujarat	143.75	1.6	145.35
Andhra Pradesh	84.39		84.39
Maharashtra	63.72	2.25	65.97
Karnataka	24.53		24.53
Madhya Pradesh	21.1		21.1
Rajasthan	2.9		2.9
Total installed capacity	1,057.43	41.75	1,099.18

Source: Indian Wind Power Magazine 1:2, Feb-Mar 2015

will complete their designed life of 20 years in the next two to five years: these would provide a continuous sizeable volume for repowering (see *Table 2*).

According to NIWE, all windmills with a CUF of <15 per cent are technically ready for repowering—and with this the CUF can be at least doubled, or in wind-

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

A long-term continuous repowering programme can help utilize resources optimally

State	Tamil Nadu	Andhra Pradesh	Gujarat	Karna-taka	Kerala	Madhya Pradesh	Rajast-han	West Bengal	Mahar-ashtra	Others	Total
Up to March 2002	877.0	93.2	181.4	69.3	2.0	23.2	16.1	1.1	400.3	3.2	1,666.8
2002-03	133.6	0.0	6.2	55.6	0.0	0.0	44.6	0.0	2.0	0.0	242.0
2003-04	371.2	6.2	28.9	84.9	0.0	0.0	117.8	0.0	6.2	0.0	615.2
2004-05	675.5	21.8	51.5	201.5	0.0	6.3	106.3	0.0	48.8	0.0	1,111.7
2005-06	857.55	0.45	84.60	143.80	0.0	11.40	73.27	0.0	545.10	0.0	1,7161.17
2006-07	577.90	0.80	283.95	265.95	0.0	16.40	111.90	0.0	485.30	0.0	1,742.05
2007-08	380.67	0.0	616.36	190.30	8.50	130.39	68.95	0.0	268.15	0.0	1,663.32
2008-09	431.1	0.0	313.6	316.0	16.5	25.1	199.6	0.0	183.0	0.0	1,484.9
2009-10	602.2	13.6	197.1	145.4	0.8	16.6	350.0	0.0	138.9	0.0	1,564.6
2010-11	997.4	55.4	312.8	254.1	7.4	46.5	436.7	0.0	239.1	0.0	2,349.2
2011-12	1,083.5	54.1	789.9	206.7	0.0	100.5	545.7	0.0	416.5	0.0	3,196.7
Total	6,987.6	245.5	2,966.3	1,933.5	35.1	376.40	2070.7	1.1	2,733.3	3.2	17,351.5

Source: NIWE

intensive sites, tripled. NIWE is now estimating wind energy potential in India at a hub height of 150 m for accommodating future technology in the planning phase. Wind turbine models currently available in the Indian market are suitable mainly for class III and IV sites; they cannot be used for class I sites of older wind farms. Wind turbine technology has significantly improved since the harnessing of class I sites in early 2000; it is possible now to design a new, more suitable wind turbine model for maximum capacity utilization.

POLICIES ON REPOWERING

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

AFTER SERVICE LIFE CONTINUATION: A SCHEME STILL ON PAPER

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

indicates the lack of interest in such projects among developers under the current policy regime.

The MNRE released its Repowering Policy in August 2016. The policy allowed repowering for wind turbine generators (WTG) of 1 MW and less. It offered the following provisions:

- The IREDA will provide an additional interest rate rebate of 0.25 per cent.
- Any augmentation of transmission system from pooling station onwards would be carried out by respective state transmission utilities.
- In case of power being procured by state DISCOMS through power purchase agreements (PPAs), the power generated corresponding to the average of last three years' generation prior to repowering would continue to be procured on the terms of the PPA in force; the remaining additional generation would either be purchased by DISCOMS at feed-in-tariffs applicable in the state at the time of commissioning of the repowering project, and/or allowed for third party sale.
- A wind farm/turbine undergoing repowering would be exempted from not honouring the PPA for the non-availability of generation during the period of execution of repowering. Similarly, in case of repowering by a captive user, they will be allowed to purchase power from the grid during the period of execution of repowering, on payment of charges as determined by the regulator.

The two states of Tamil Nadu and Gujarat, which have the highest potential for repowering, have made some progress with respect to their own state policies.

TILL MARCH 2017, GUJARAT HAD **1,494 MW** OF WIND CAPACITY WITH TURBINE SIZES OF LESS THAN **1 MW**

Tamil Nadu

The Tamil Nadu Generation and Distribution Corporation Limited (TANGEDCO) has sought approval from the Tamil Nadu Electricity Regulatory Commission (TNERC) for the procedure to be adopted for repowering of existing wind farms within the state, as well as for the tariff proposed for the repowered wind farms.

TANGEDCO has proposed the following for repowering:

- The feed-in-tariff of Rs 2.80 per unit or the latest tender discovered rate at the time of commissioning of the repowered wind farm, whichever is less.
- For wind farms under wheeling agreement, banking of one month with encashment of unutilized energy at 75 per cent of the tariff at the end of the month.
- Developers to erect/augment transmission infrastructure up to TANGEDCO sub-stations at their own cost.

Gujarat

Till March 2017, Gujarat had 1,494 MW of wind capacity with turbine sizes of less than 1 MW; out of this, 894 MW was under PPP model and the remaining 600 MW was under wheeling mode (captive/third party). In May 2018, the state released its policy on repowering of wind projects. It has the following provisions:

- Any augmentation in transmission system up to a Gujarat Energy Transmission Company (GETCO) sub-station would be undertaken by the developer.

- The average generation during the last three years prior to repowering will continue to be paid as per the existing PPA. The additional generation shall be procured by the state DISCOM, taking into account the renewable purchase obligation requirements and tariffs discovered through a competitive bidding process. However, it is not binding on state DISCOMS to purchase additional power.
- In case of wheeling agreement, the wheeling charges would be applicable on the entire repowered capacity.

WHY IS REPOWERING OF WIND NOT TAKING OFF?

The repowering policy has not made any impact in terms of enabling repowering of older wind farms. The reasons for it, as per CSE's analysis, are as follows:

- In Tamil Nadu, no time limit has been mentioned in the earlier PPA and hence, wind farms can continue to provide power beyond 20 years.
- In Gujarat, the PPA has a provision of multiple extensions.
- The earlier wind turbine models had high design margins (meaning having a design acceptability which is more than the value prescribed in operation). The renewable energy sector in the country is of the opinion that the relatively benign environmental conditions in India allow many of the older wind turbines to operate even after 20 years of service.
- Old wind farms have minimal O&M (operation and maintenance) requirements. Given the tariff of Rs 2.75 or Rs 2.90 before 2009 in Tamil Nadu, running older wind farms, therefore, has been profitable

REPOWERING POLICY HAS MADE **NO IMPACT** THUS FAR

CASE STUDY: REPOWERING THE ANANTHPUR BHEL 6.5 MW WIND POWER PROJECT

Historic CUF
8.5%

Land available
220 ACRES

Repowered with
16 MW
of new wind capacity and 25 MW of solar capacity at the cost of Rs 2.5-3 crore/MW and Rs 5-5.5 crore/MW, respectively

Post-repowering CUF
35%

Post-repowering capacity
41 MW

With investment of
₹143 CR
the generation increased by almost 10 times

with minimum interventions.

- Around 90 per cent of the older wind farms in Tamil Nadu have been under a captive scheme, where banking of power is allowed for a period of 12 months. However, for repowered wind farms, the banking facility is provided only for one month.

REPOWERING: WAY AHEAD

What is clear is that the potential to augment wind energy from the same resources is enormous. But it requires high order of investment (*see box on case study on the Ananthpur BHEL project*). Repowering has the potential to increase energy generation by more than six times by using modern wind turbines.

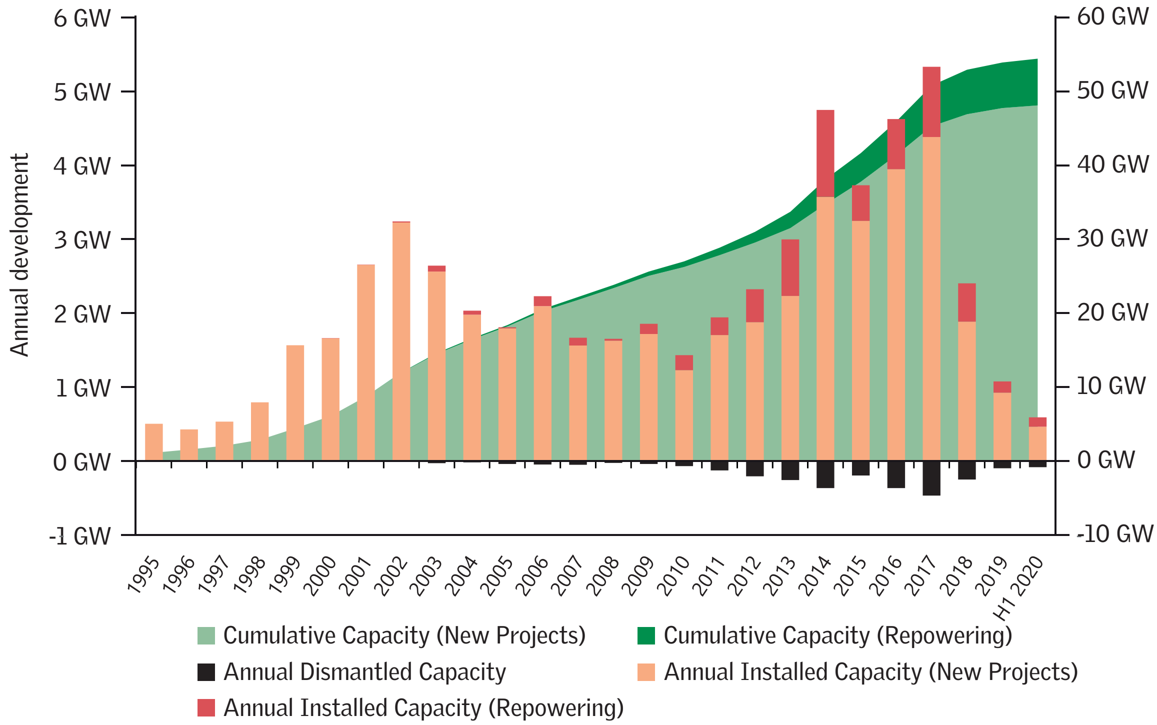
GLOBAL EXPERIENCES IN REPOWERING

Germany

The Renewable Energy Act (EEG) is the key legislation responsible for wind turbine development in Germany. It was enacted in 2000 and subsequently amended in 2004, 2009, 2012, 2014 and 2017. The Act of 2000 provisioned for subsidies for 20 years in the form of feed-in-tariffs (FiTs); a higher tariff indirectly supported repowering of older turbines. The 2004 amendment first offered an incentive for repowering installed before 2015 and for new capacity of at least three times the older capacity. However, the stringent requirements on height limits and spacing made it almost impossible to fulfil all the criteria to receive the incentive.

The 2009 amendment increased the repowering incentive and relaxed the criteria where it required for the replaced turbines to have at least twice

Graph 3: Development of repowering in Germany



Source: Deutsche WindGuard 2020, Status of Onshore Wind Energy Development in Germany First Half of 2020

the original turbine capacity. The amendment in 2014 was the last one that continued to provide the financial incentive for repowering. The 2017 amendment moved to public tender procedures where the price would be decided through public auctions. Today, repowering which had started in Germany in early 2000 constitutes a sizeable portion of the new capacity addition (*see Graph 3*).

Repowering is currently tendered in Germany through reverse bidding. The recently commissioned Beckum Wind Farm was repowered with two

TAMIL NADU: CASE STUDY ON POTENTIAL OF REPOWERING

Wind profile of Tamil Nadu

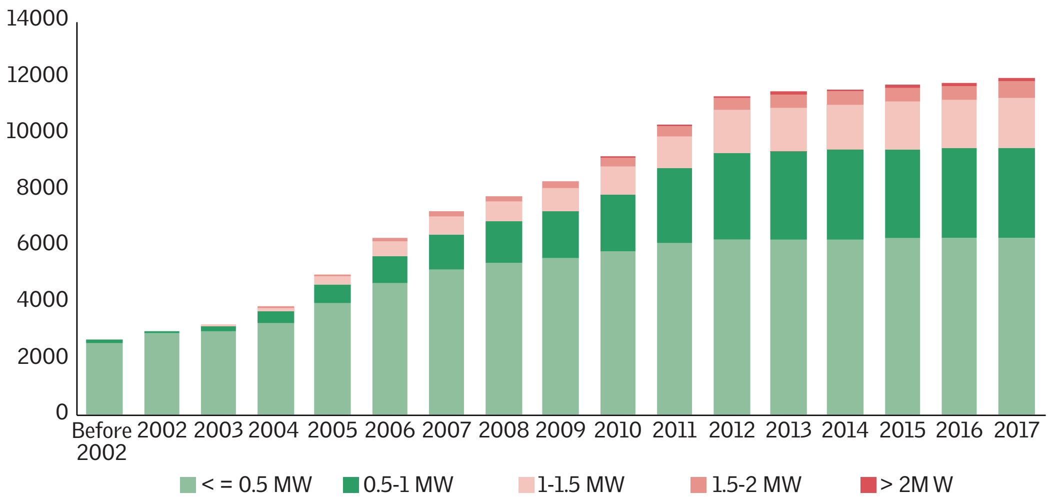
The state offers some unique characteristics with respect to wind installations.

It holds the highest wind portfolio of about 9.5 GW, which is one-fourth of the total installed wind capacity in the country. It was one of the earliest to start wind projects. Therefore, it is ideally placed to take a lead in the next phase, i.e., repowering

It has the best wind sites in the country, most of which are occupied by turbines running on old technology with low capacity. Approximately 3,000 turbines, each of less than 1 MW capacity, and with a cumulative installed capacity of 800 MW, have completed their design life

The repowering opportunity in the state is available on a rolling basis (*see Graph 1*).

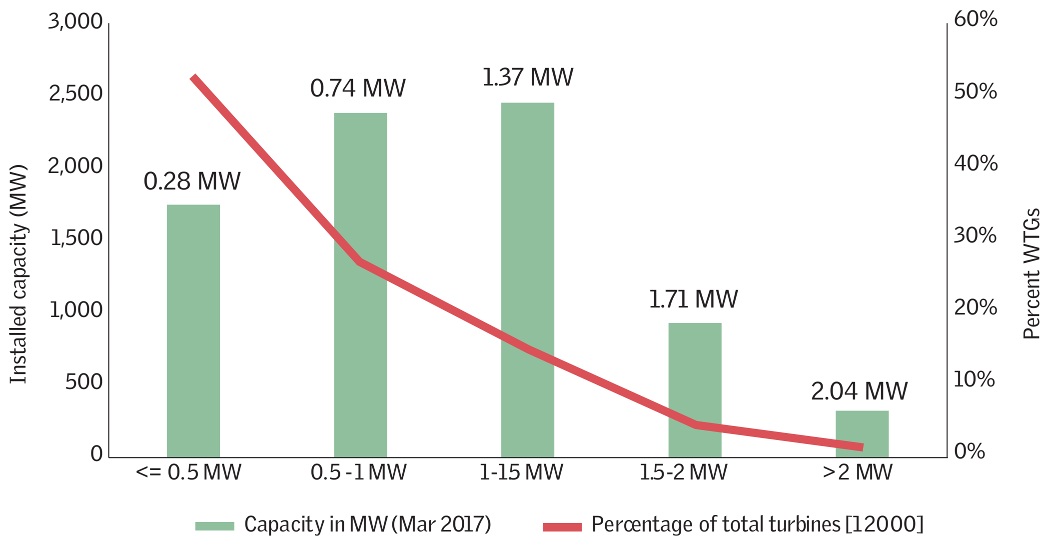
Graph 1: Wind turbine profile of Tamil Nadu



Source: Indian Wind Power Directory, 2017

Average wind turbine capacity in Tamil Nadu is only 650 kW. As of March 2017, of the 12,000 odd wind turbine generators, 52 per cent are of 500 kW or less in capacity, and another 27 per cent have between 500 kW–1 MW capacities. Together, these smaller turbines account for slightly over half of the total installed capacity (*see Graph 2*).

Graph 2: Installed wind capacity vis-à-vis number of wind turbines in Tamil Nadu



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

They can easily be upgraded. If solar power is added to these calculations, leading to hybrid renewable energy projects, annual energy production can go up by more than six times. Solar+wind hybrid projects, in synergy with battery storage, are technically and financially a viable option over new coal plants in the state.

Wind sector's unique challenges in Tamil Nadu

Wind sector in Tamil Nadu is beset with many challenges, some generic and other unique to the state. They are also hampering repowering in the state. These include:

1. Large wind portfolio and curtailment of power: Wind accounts for close to 30 per cent of the total installed capacity of the state. Wind generators have to face frequent back-downs. Curtailment for wind power plants averaged around 30–35 per cent of generation during the peak season between 2012 and 2015. The curtailment of wind power in 2019 went up to 3.52 hours per day from 1.87 hours per day in 2018. CSE's analysis suggests that the reasons for curtailment are both technical and commercial.

2. Long-term PPAs without end-dates: Turbine owners have signed long-term PPAs with TANGEDCO. Most potential repowering projects in the coming decade will be under the Feed-in-Tariff (FiT) regime. While determining the tariff, the design life of the plant should be taken into consideration.

3. Highly fragmented ownership: The tremendous growth of wind energy in Tamil Nadu has been driven by accelerated depreciation, introduced in the state in 1992. Consequently, the state has attracted sizeable private investment, supported by turnkey suppliers. Each private player owns one or a few windmills. This has led to fragmented ownership which makes repowering complicated.

4. Lack of financial interest of owners to repower their projects: Owners of wind turbines that have completed their design life

but continue to be operational even at very low plant load factors are not willing to do away with their assets. These wind projects have already provided them ample returns on investment and owners continue to earn with no incentive to repower.

5. Large numbers of infirm power turbines: TANGEDCO has the humungous task of managing some 10,000 turbines of smaller capacity that have different characteristics and reactive power. These plants inject infirm power that does not match the load profile and can have a destabilizing effect on load dispatch centres. This increases the cost of power.

Current situation and possible solutions

It is clear that there is a huge opportunity to rework wind projects in Tamil Nadu for increased efficiency and output. The appropriate turbine technologies for Class I sites are available and manufacturers are confident of delivering such turbines. Micro-siting of the projects for high output is also easier with improvements in technology—for instance, Computational Fluid Dynamics (CFD)-based software is capable of emulating any combination of windmills at the site.

What is needed is as follows:

1. Mandatory dismantling of wind turbines and suitable incentives for the affected owners.
2. The PPAs with wind power plants that have passed their design life should be stopped.
3. Start the repowering process in Tamil Nadu in the high-density regions—with over 5,400 wind turbines of less than 500 kW capacity each, amounting to 1,472 MW in total. To do this, consolidate the wind turbine owners on a common platform through a cooperative and collaborative project approach.

GERMANY'S RENEWABLE ENERGY ACT OF 2000 PROVISIONED FOR SUBSIDIES FOR **20 YEARS** IN THE FORM OF FEED-IN-TARIFFS

turbines of 4.5 MW each by replacing six turbines of total 5.2 MW capacity. In a recent tender (June 2020) for repowering of Krusemark Wind Farm, 15 older turbines will be replaced with six N-131 models of 3.3 MW each. Vestas, the Denmark-based wind turbine manufacturer, will be repowering the Brest Wind Farm by replacing 11 old Nordex turbines (with a cumulative capacity of 14.30 MW) with five turbines of V150-5.6 MW to take the capacity to 28 MW.

The federal incentives for the first batch of wind farms of 4,000 MW, developed with 20 years of FiT under EEG 2000, are ending soon. Around 16 GW of wind power capacity will lose the support of federal incentives by 2025, after 20 years of FiT provision. Hence, from 2021 and onwards, Germany will see massive large-scale dismantling and replacement of old turbines as these would not be sustainable without subsidies.

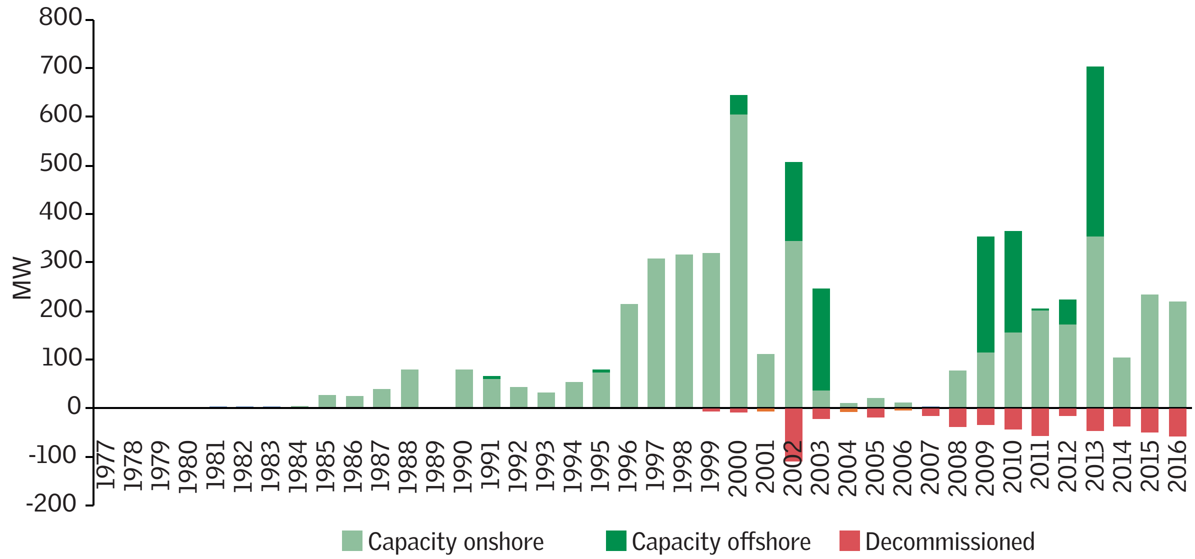
Denmark

Wind turbine installation in Denmark started before 1980. By 2000, almost 2,500 MW capacity was installed, accounting for 12 per cent of the total electricity generation (*see Graph 4*). Repowering of older turbines also started before 2000.

Two repowering schemes have been implemented in Denmark. The first one is for wind turbines with capacities up to 150 kW, decommissioned between 3 March 1999 and 31 December 2003. The second scheme is for wind turbines with capacities up to 450 kW, decommissioned between 15 December 2004 and 15 December 2011.

Graph 4: Development of the wind energy sector in Denmark

Wind energy constitutes a major part of the energy mix



Source: World Wind Energy Association Policy Paper Series, Denmark, April 2018

Wind turbine owners with repowering certificates have the right to receive a price supplement. Under the first repowering scheme, turbine owners were entitled to receive the price supplement for triple the decommissioned capacity if decommissioned wind turbines had an installed capacity of less than 100 kW. The capacity constraint was removed in the second repowering scheme, and the owners could receive the price supplement for double the decommissioned capacity.

2. OFFSHORE WIND: OPPORTUNITY TO UPSCALE BUT NEEDS FINANCIAL SUPPORT

In India, where land is limited and the population is increasing, large wind farms positioned over water bodies will be vital. According to the MNRE, India can generate 127 GW of offshore wind energy with its 7,600 km of coastline. According to NIWE, the

MNRE HAS SET A TARGET OF INSTALLING **5 GW** OF OFFSHORE CAPACITY BY END OF 2022 AND **30 GW** BY 2030

total offshore wind energy potential is 302 GW at a 100-meter hub height.

Offshore wind energy refers to the deployment of wind farms inside water bodies. They utilize the sea winds to generate electricity. These wind farms either use fixed-foundation turbines or floating wind turbines. Offshore wind farms must be at least 200 nautical miles from the shore and 50 feet deep in the ocean. Offshore wind turbines produce electricity which is returned to shore through cables buried in the ocean floor.

It is proven that offshore wind turbines are more efficient compared to onshore ones. Wind speed over water bodies is high and is consistent in direction. As a result, offshore wind farms generate more electricity per installed capacity. Also, fewer offshore turbines are required to produce the same capacity of energy as compared to onshore ones. Offshore wind farms have a higher CUF than onshore wind farms. Therefore, offshore wind power allows for longer operating hours.

India has yet to develop its offshore wind energy. To date, the country has not begun any offshore wind projects. MNRE has set a target of installing 5 GW of offshore capacity by end of 2022 and 30 GW by 2030.

In the past, high capital expenditures (CAPEX) have been major deterrents. To facilitate offshore wind siting, MNRE intends to conduct an offshore wind measurement campaign for a minimum of 10 GW of accurate on-site measurements. NIWE plans to install five LiDARs (Light Detection and Ranging) by 2021 to gather precise bankable data that will be critical to developing offshore wind projects of up to 7.4 GW indicative installable capacity. A tender has already been floated for the design, fabrication, delivery, and installation of support structures for four offshore LiDARs.

Offshore wind turbines require stronger structures and foundations than onshore wind farms. This can lead to higher installation costs. Consequently, offshore wind tariffs in India are expected to range between Rs 7–9 per unit, compared to Rs 2.8–2.9 per unit for onshore wind.

To be able to reduce the tariff, MNRE is seeking feasible cost interventions from stakeholders for offshore wind. Offshore wind PPAs and auction designs are being examined by government authorities. MNRE, NIWE and the Danish Energy Agency have entered into a partnership for financial modelling of offshore wind farms in India or FIMOI 2019–2021.

Offshore wind is taking off globally. Top cost-reduction strategies in the UK include upscaling wind turbine ratings, increasing competition within the turbine manufacturing industry and reducing equity costs.

3. WIND-SOLAR HYBRID (WSH)

In 2018, the MNRE announced its national wind-solar hybrid policy, stating that a project

MORE THAN **4,500 MW** OF WSH PROJECTS HAVE BEEN ANNOUNCED, BUT LESS THAN ONE-THIRD OF THE CAPACITY IS UNDER IMPLEMENTATION

Table 2: Wind-solar hybrid projects awarded by SECI

Developer	Project capacity (MW)	Scheduled commissioning date	Tariff (Rs/ kWh)
Mahoba Solar (UP) Private Limited	390	10 July 2021	2.69
SBE Renewables Ten Private Limited	450	10 July 2021	2.67
Adani Renewable Energy (Park) Gujarat Ltd	600	15 December 2021	2.69
Greenko Energies Private Limited	900	03 January 2022	Peak tariff—6.12; off-peak tariff—2.88
Renew Solar Power Private Limited	300	03 January 2022	Peak tariff—6.12; off-peak tariff—2.88
AMP Energy Green Private Limited	130	31 September 2022	2.41
ABC Renewable Energy Private Limited	380	31 September 2022	2.41
Greenko Energies Private Limited	900	03 January 2022	Peak tariff—6.12; off-peak tariff—2.88
ACME Solar Holdings Pvt. Ltd	90	31 September 2023	2.42
Total	3,540		

Source: MNRE

must have a minimum 25 per cent share of one of the two technologies to be defined as a wind-solar hybrid.

SECI purchases the electricity generated from the wind-solar hybrid power projects on a build-own-operate (BOO) basis. More than 4,500 MW of projects have been announced, but less than one-third of the capacity is under implementation. These projects face both wind and solar sector problems (*see Table 2*).

3

ROOPTOP SOLAR

CASE FOR ROOFTOP SOLAR

Installing solar on rooftops is seemingly an attractive and relatively easy proposition. It does not need new land; it can be built on existing rooftops; it is built in a modular fashion; it provides electricity to the consumer directly; it can be done quickly and is scalable; and the aggregate of the rooftops can add up to build a new energy grid. In spite of these advantages, and government policy support, this sector is still struggling to take off.

WHERE DO WE STAND IN TERMS OF ROOFTOP INSTALLATIONS?

India has set itself a relatively ambitious goal for what it refers to as subsidized grid-connected solar rooftop—40 GW by 2022.

According to the Ministry of New and Renewable Energy (MNRE)'s physical progress database, the country had installed 4.4 GW of rooftop solar by 31 March 2021. In the nine months of 2021, an additional 2 GW was installed—taking total rooftop installation to 6.4 GW by December of 2021. This sector, even though it is not close to meeting the set target, is clearly seeing accelerated growth.

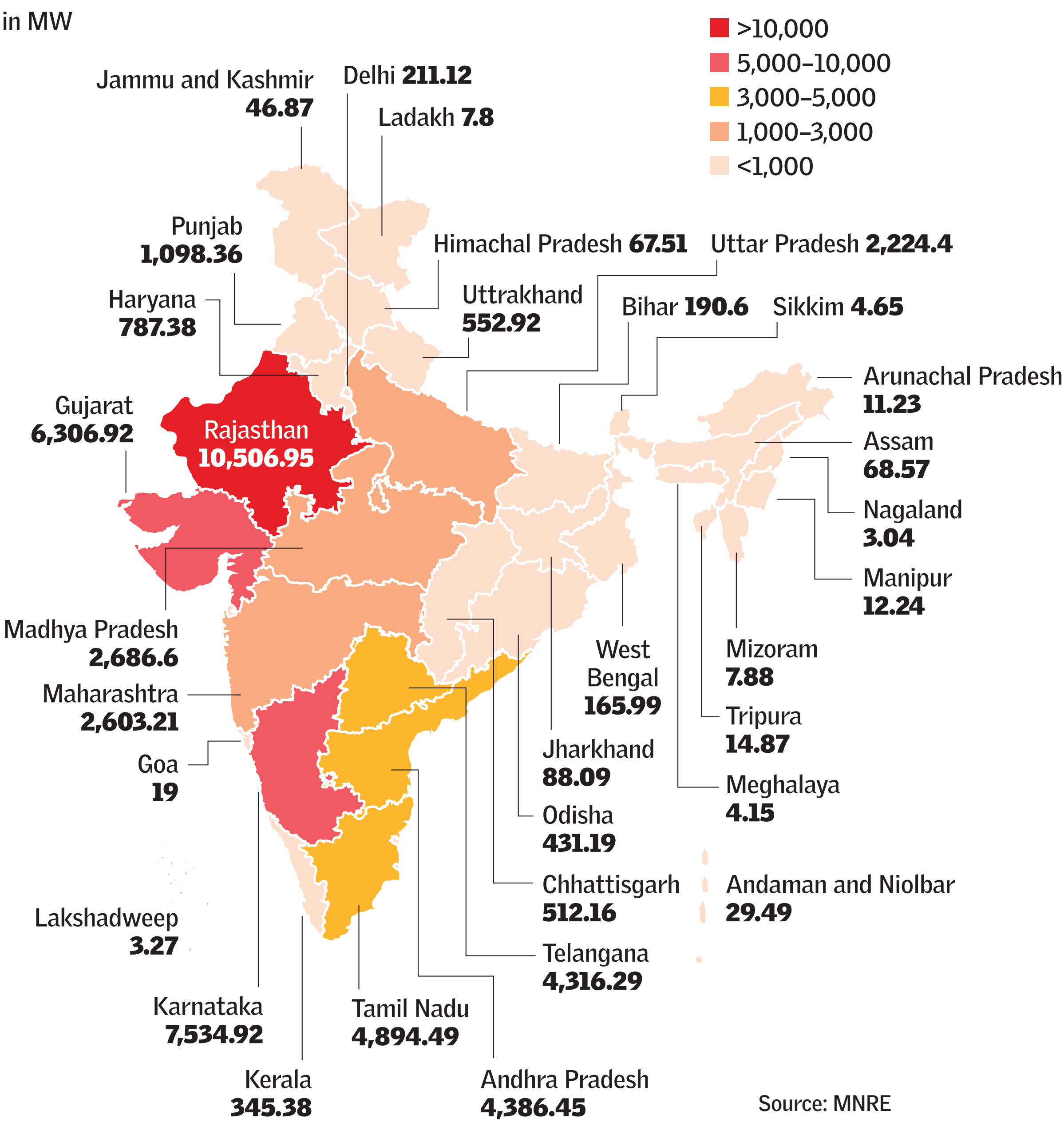
The energy analyst Mercom's report on India's rooftop solar market puts the total cumulative installations at 6.7 GW by December 2021.

INDIA AIMS TO INSTALL **40 GW** OF GRID-CONNECTED ROOFTOP SOLAR BY 2022

POLICIES, FINANCING MODELS AND SUBSIDIES

Two common types of business models are available for rooftop solar in India.

Map 1: State-wise rooftop solar cumulative installations



Source: MNRE

In the CAPEX model, the user of the rooftop owns the solar installation and the upfront cost must be paid entirely by the user. The owner then uses the solar electricity generated for their own use or can earn by 'selling' it to the distribution company (DISCOM) through net-metering.

In the RESCO or OPEX model, the assets are owned by developers or investors but installed at the customer's premises. The customer pays a pre-determined price per unit generated as defined in a power purchase agreement (PPA) over a specified period, normally 15 to 20 years.

CAPEX or self-financing models are most common, especially for non-commercial and non-industrial users such as the residential sector, due to lack of debt financing. The share of the RESCO or OPEX model, however, has been increasing. It went from 13 per cent in 2016 to about 40 per cent in 2020.

Policies for residential and commercial/institutional segments for rooftop solar projects have evolved over time and are distinct. The current system provides subsidy for small-scale residential projects (below 10 kW) while larger sized projects and those installed in commercial and institutional areas are expected to be financed through loans or other instruments.

THE SHARE OF THE OPEX MODEL INCREASED FROM 13% IN 2016 TO 40% IN 2020

In Phase II of the rooftop programme, MNRE has made DISCOMS the nodal points for implementation of these projects. DISCOMS now don't just disburse the subsidy, but also take on vendor management and empanelment.

The policy is working towards 4 GW solar rooftop installations. The Central government pays a 30–40 per cent subsidy for grid connected solar systems in residential areas (even higher to special status states). But this subsidy amount is linked to the size of the system and benchmark costs: for 1–3 kW, subsidy is 40 per cent; for 4–10 kW, it is 20 per cent. Under this scheme, the householder has to go through the DISCOM to get the system set up and the subsidy realized.

10 KW SOLAR SYSTEM WITH SUBSIDY WOULD COST BETWEEN RS 4–6 LAKH

The system costs have been benchmarked by MNRE—and they range from Rs 51.10/watt for a 1 kW system to Rs 44.64/watt for systems between 3–10 kW. The price drops as the systems get larger; so solar grid systems between 10–100 kW cost Rs 41.64 and above 100–500 kW cost Rs 39.08/watt.

On an average, based on this benchmark costing, the grid-based solar system without subsidy would cost roughly Rs 60,000 per kW—including product and installation, servicing for 5 years and net metering. A 10 kw system with subsidy would cost between Rs 4–6 lakh, which would need to be paid upfront and would be high for most consumers.

So, given this cost, solar companies are raising capital to provide loans to households to set up the systems. For instance, Orb is a company, based out of Bengaluru, that has set up over 100,000 solar systems for residential houses in the country—it does this by providing service and financing.

NET METERING

In June 2021, the Ministry of Power issued the amendment to the Electricity (Rights of Consumers) 2020 rules on net-metering. As per this amendment, net metering is allowed for loads of 500 kW or the sanctioned load, whichever is lower. Gross metering, under which a rooftop solar generator can sell power to the DISCOMS, is allowed for loads above 500 kW.

Before this amendment came into force in 2021, net metering was capped at 1 MW and the government had planned to reduce this to 10 kW—which would have destroyed the rooftop business.

It is also expected that the state electricity regulatory commission will introduce time of the day tariffs, which would in turn incentivize rooftop owners to set up storage systems so that they 'export' energy at peak hours.

States in India have come up with rooftop solar policies indicating modalities of installing a grid-connected rooftop solar project and to determine how consumers are compensated for the electricity produced.

States are also using `mandates'—directions—which make it compulsory to install rooftop solar. Chandigarh has made it mandatory to install solar energy in residential housing measuring over 500 square yards; Haryana has introduced a similar policy.

STATES ARE USING MANDATES TO MAKE INSTALLATION OF ROOFTOP SOLAR COMPULSORY

According to Mercom, as a result of these two policy changes—subsidy for residential systems and net-metering—there has been renewed interest in rooftop solar from DISCOMS. In the third quarter of 2021, tenders were floated for 200 MW of rooftop solar by state DISCOMS—Gujarat topped the list with the highest installations in this quarter, followed by Maharashtra and Haryana.

CHALLENGES IN ROOFTOP SOLAR

In spite of these efforts, the programme has still not reached its full potential.

The key problem remains the lack of incentive for electricity distribution companies to install rooftop solar in institutional and commercial sectors. DISCOMS are already cash strapped and they contend that while the residential and farming sectors are subsidized, it is the institutional and commercial sectors that cross-subsidize and provide the necessary finances for their operations. Their concern is that if these high electricity tariff paying sectors move to solar rooftop, they will become even more financially unviable.

So, even though in the current phase of rooftop solar, DISCOMS have been made partners—with the aim to bring them on board and to remove inefficiencies in the system—this is not working as well as it was planned. In many cases, DISCOMS are creating a maze of stringent and sometimes impossible conditions for tendering for the projects. In other cases, the projects are being given out to companies that do not have the necessary expertise to build or operate the projects.

Rooftop solar project developers also say that the current policy to cap the prices that can be paid for solar installations is leading to problems—the

INCENTIVIZING DISCOMS FOR ROOFTOP SOLAR IS A CHALLENGE

prices of solar modules are volatile and depend on international market conditions.

The other problem is that the cost of electricity to the residential sector is subsidized and often even waived completely (up to 200 units); so, there is no incentive for households to install rooftop solar.

It is also for this reason that by and large the growth in this segment has been in the commercial and industrial sectors, which currently pay high electricity bills: for these consumers, installing solar reduces their monthly power bills.

The average cost of electricity for commercial and industrial consumers ranges from Rs 8–11 per unit and is even higher in some states. Under the RESCO model, these consumers can pay developers between Rs 3–5 per unit, which is a huge saving—especially if the system can 'sell' the surplus daytime power to the DISCOM under net-metering.

The payback on the system at the current high commercial tariffs is between 5–7 years. The Cochin airport installed a 40 MW system to power all its operations, and expects that it will pay back the cost in 4–5 years.

THE AVERAGE COST OF ELECTRICITY FOR COMMERCIAL AND INDUSTRIAL CONSUMERS RANGES FROM RS 8–11 PER UNIT

Commercial institutions are more credit-worthy, which makes it easier for them to get loans. The Reserve Bank of India (RBI) has now notified grid-connected solar rooftop systems under priority sector lending and public sector banks are advised

SOLAR ENERGIZES SCHOOLS IN DELHI

In 2020, the Delhi government set up rooftop solar projects in 150 school buildings under a central government scheme. The government aims to generate 2,000 MW of solar energy by 2025. The developers were identified through competitive bidding. Zero-investment RESCO model, which provides energy to consumers from renewable energy sources, was adopted for the project.

A quarter of the total project cost was borne by the Central government upon completion. Schools in Delhi procure electricity at Rs 3.13/kWh from RESCO developers, which is 65 per cent cheaper than DISCOMS. These schools can sell the electricity at Rs 5.65/kWh to the DISCOMS for any surplus generation during non-working days.

Oakridge Energy Pvt Ltd, a RESCO developer for 15 such schools, said that the Delhi government floating a pre-approved bid helped it install solar rooftops in the middle of the COVID-19 pandemic. The government is 'critically monitoring the assets and their daily generations remotely so that the developer and schools don't lose any opportunity in revenue generation.' The developers stated that the project can help save approximately 26,412 tonnes of carbon dioxide annually by generating 21.5 MW capacity. Most of these schools have an unused shadow-free terrace ideal for rooftop solar installations which can meet their daytime electrical loads.

accordingly. To increase the economic viability of solar rooftops, the World Bank is providing financial assistance of US$ 625 million. It has also developed a product with the State Bank of India under which interest rates on debts for solar rooftops have been slashed from 16 per cent to 8–9 per cent.

There is also a concern that the increased price of solar systems—partly because of the imposition of basic custom duty on cells and modules—could form an impediment to future projects. Therefore, the question arises if the role of DISCOMS in the rooftop solar business should be reviewed.

It could be argued that the subsidy should be availed

SUSTAINABILITY OF DISCOMS IS KEY IN THIS DISTRIBUTED ENERGY SYSTEM

by the consumer; who in turn would be able to contract authorized and empanelled agencies for installing the system at competitive rates. The role of the DISCOM would be to ensure the integrity of the net-metering system. In this way, DISCOMS would be 'buying' surplus power from the rooftop owner and 'selling' them electricity during night time, when the system does not generate power. But the question of this working as desired still remains, given the dire financial health of the distribution companies.

They would continue to lose paying customers and this would make their situation even more untenable. Without the DISCOMS to provide power at night-time and when the sun is not shining, the solar rooftop systems would need battery storage and this would increase costs and make the system unviable. Therefore, the sustainability of DISCOMS is key in this distributed energy system.

The distributed and modular solar system provides energy where it is needed and it builds a movement for change—consumers become the generators of clean energy. So, we need to work on this further and find ways to achieve its full potential.

4

BIOMASS

BIOMASS

WHAT IS THE PRESENT STATE OF BIOMASS IN INDIA?

Burning biomass for energy is not a new phenomenon—large numbers of poor women continue to use biomass as cooking fuel to the detriment of their health. But what is new is the process of burning biomass/bagasse in controlled environments to make fuel. This is a win-win option—farmers get value for their residue, the biomass is not burnt in the open to add to air pollution, and it provides energy (coal is replaced in boilers leading to reduced greenhouse gas emissions).

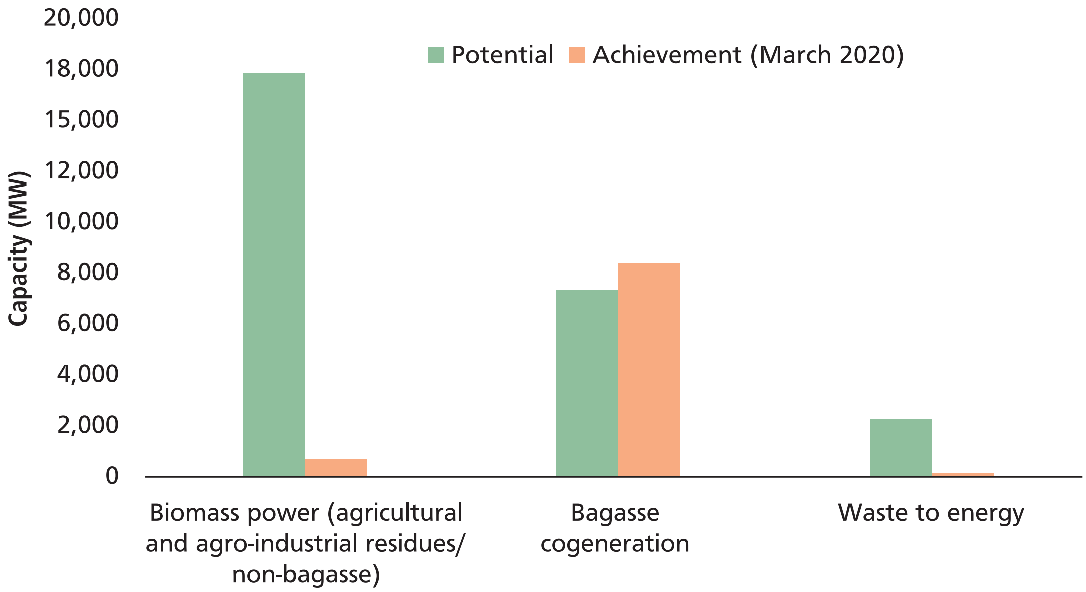
The fact is that biomass—from crop residues to kitchen waste—is a key cause of air pollution and adds to the enormous challenge of waste management in the country. Therefore, any efforts to use this so-called waste for gasification and energy generation would go a long way to combat pollution and turn waste into a resource.

The current availability of biomass in India is estimated at about 500 million metric tonnes (MMT) per year. Studies sponsored by the MNRE have estimated surplus biomass availability at about 120–150 MMT per annum covering agricultural and forestry residues corresponding to a potential of about 18,000 MW. In addition, the potential of bagasse cogeneration is estimated at around 8,000 MW based on full utilization by 550 sugar mills in the country (*see Graph 1*).

THE CURRENT AVAILABILITY OF BIOMASS IN INDIA IS ESTIMATED AT ABOUT 500 MMT PER YEAR

There is no estimation of the organic household waste that is generated in the country in terms of its energy

Graph 1: Biomass energy: Potential vs Achievement



Source: MNRE reports

potential. Also, the estimates of surplus vary between the Union government's biomass portal (250 million tonnes) and NITI Aayog (620 million tonnes). But what is clear is that the potential is enormous.

CSE has also estimated the pollution abatement from the use of agro-residues for combustion. It finds that, as against the baseline, emissions will decrease by 50–70 per cent if coal is replaced by biomass in controlled boilers—as in the case of thermal power plants.

Given this possibility, a rather unambitious target of 10,000 MW of biomass energy has been included in India's total renewable energy target by 2022. This target was achieved in December 2019. Now, there are new efforts afoot to increase the use of biomass in the power sector.

EMISSIONS WILL DECREASE BY 50–70% IF COAL IS REPLACED BY BIOMASS IN CONTROLLED BOILERS

CO-GENERATION

The MNRE incentivizes biomass through its biomass-based cogeneration scheme for sugar mills and other industries. Under this, it provides central financial assistance at the rate of Rs 25 lakh per MW of surplus exportable capacity fed into the grid. In addition, this energy source gets a tax holiday for 10 years and other concessions on customs and excise for equipment. Also, state electricity regulatory commissions (SERCs) provide preferential tariffs and this source of energy is also included in the `must run' category—but only for plants which are 10 MW and below (*see Table 1*).

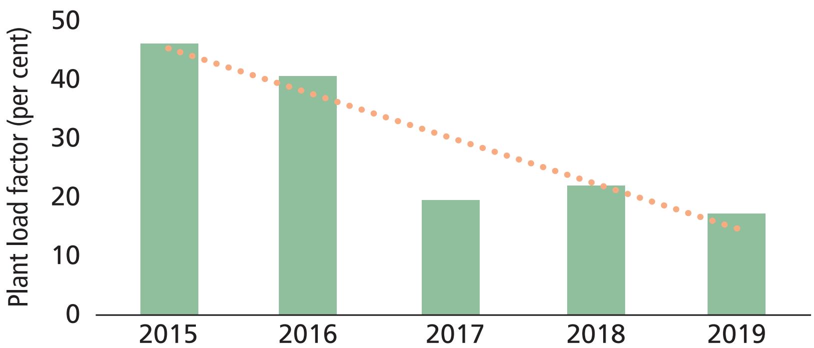
What is inexplicable is that there is also a drastic decrease in the plant load factor (PLF) of biomass plants—from 46 per cent in 2015 to 17.1 per cent in

Table 1: Net levelized tariff (upon adjusting for accelerated depreciation benefit), in Rs/kWh

	Biomass power projects [other than rice straw and Juliflora (plantation) based project]						Biomass power projects [Rice straw and Juliflora (plantation) based project]		
State	Water Cooled Condenser and travelling grate boiler	Air Cooled Condenser and travelling grate boiler	Water Cooled Condenser and travelling grate boiler	Air Cooled Condenser and travelling grate boiler	Water Cooled Condenser and AFBC boiler	Air Cooled Condenser and AFBC boiler	Water Cooled Condenser and AFBC boiler	Air Cooled Condenser and AFBC boiler	Bagasse Based Co-generation Project
AP	7.53	7.78	7.63	7.89	7.44	7.69	7.54	7.8	6.19
Haryana	8.25	8.52	8.35	8.63	8.15	8.41	8.25	8.52	7.19
Maharashtra	8.39	8.66	8.49	8.77	8.28	8.55	8.38	8.66	6.85
Punjab	8.53	8.8	8.63	8.91	8.41	8.69	8.51	8.8	6.61
Rajasthan	7.5	7.75	7.6	7.86	7.4	7.65	7.5	7.76	
Tamil Nadu	7.45	7.7	7.55	7.81	7.35	7.6	7.45	7.71	5.75
UP	7.62	7.88	7.72	7.99	7.53	7.78	7.63	7.89	6.58
Others	7.89	8.16	7.99	8.27	7.79	8.05	7.89	8.16	6.48

Source: Central Electricity Regulatory Commission (CERC) RE Tariff Order 2019-20

Graph 2: Plant Load Factor (PLF) of biomass plants



Source: Analysis by CSE based on CEA data

2019 as per the data from CEA (*see Graph 2*). This is happening even though the Central Electricity Regulatory Commission (CERC) recommends that the PLF of biomass plants should range from 60–80 per cent. This would suggest gross under-utilization of the existing plants.

This industry is dependent on the cyclical availability of raw material—seasonal harvesting of sugarcane and other crops. It is estimated that by and large, a 1 MW power plant requires 7,000–10,000 metric tonnes of biomass per year. The industry says there is a shortage of biomass and costs of raw materials are increasing—it costs roughly Rs 6 to generate one unit of power. This is inexplicable and needs to be investigated: Why is there a shortage of agricultural residues when agricultural production is high?

POWER PLANT OF
1 MW
REQUIRES
7,000–
10,000 MT
OF BIOMASS
PER YEAR

The CERC puts the capital cost of these plants between Rs 5.6 crore and Rs 6.5 crore per MW for a biomass plant, and Rs 5 crore per MW for a co-generation plant. This, coupled with the cost of fuel and other operational spending, means that the cost of energy is high—Rs 7.35 to Rs 8.91 per unit (with bagasse it is between Rs 5.75 and Rs 7.19 per unit).

This tariff makes the industry unviable, particularly at a time when there is surplus cheap energy in the grid, and DISCOMS are in the red and cannot pay. This is perhaps the reason why the biomass sector is flagging.

On 17 January 2020, the CEA drew attention to the reduction in generation from bagasse. It found a significant decrease in generation from bagasse-based energy in November 2019, as compared to the previous year (2018) and this happened in spite of the increased capacity of 71 MW in just this period. The agency had asked for an explanation from biomass producers. It has received responses from only two states—Maharashtra and Uttar Pradesh; both have cited delays in harvesting and reduction in bagasse generation as the reasons.

BIOMASS USE IN THE POWER SECTOR

In Punjab and Haryana, rice straw burning has become a major cause for concern because of its contribution to winter air pollution. Currently, in Punjab, only 3 per cent of the paddy stubble is used for generating power. The use of biomass as fuel in coal-based power plants will reduce coal usage and air pollution and can help utilize the existing power capacity. The NTPC estimates that 5 per cent co-firing will need roughly 200 tonnes of biomass per MW–if this is calculated for India's present coal-based power generation capacity, it would require some 40 MMT of biomass every year.

5% CO-FIRING WILL NEED ROUGHLY 200 TONNES OF BIOMASS PER MW

HUSK POWER'S SOLAR-BIOMASS HYBRID PLANT LIGHTING THE LIVES OF PEOPLE IN CHANPATIA, BIHAR

With the solar revolution, an optimum combination of solar-biomass storage is turning out to be an effective mini-grid based solution and an alternative to diesel-based generators in some small areas or villages in the country that often face electricity outages or load-shedding.

Centre for Science and Environment (CSE), in its study, found that one such solution has been provided by Husk Power Energies in Chanpatia village in West Champaran district of Bihar through its biomass-cum-solar storage plant located in the village. Husk Power commissioned the plant in April 2017. The current installed capacity is 40 kW solar and 25 kW biogas. Since its inception, there has been a gradual rise in customers. Husk has around 100 customers in Chanpatia, which comprises 30 per cent domestic, 10 per cent industrial and 60 per cent commercial connections. All the commercial connections are on the 5 kW load connection.

The power generated during the daytime (from 10 am to 4 pm) from solar has been rated 20 per cent less. The biomass part kicks in for supply of power during the evening and night—periods when there are outages and peak-shaving. The biomass feed is supplied by local threshers. The price ranges anywhere between Re 1 to Rs 4 depending upon the season and availability of rice husk. Rice is harvested twice a year in the region; therefore, husk is easily available throughout the year. Dry feed like rice husk maintains the moisture and avoids corrosion. The biomass plant can provide reliable power as it gives a stable output whenever required; it can play a balancing role and reduces the requirement for costly storage.

Such decentralized solutions play a big role in bridging the gap between government's supply of electricity and customer demand.

The Union Ministry of Power has mandated 5–10 per cent co-firing at every thermal power plant in the country. While presenting the Union Budget on 01 February 2022, Finance Minister Nirmala Sitharaman said 5–7 per cent of biomass pellets will be co-fired in thermal power plants. Only 13 National Thermal Power Corporation (NTPC) plants have been retrofitted completely to run this scheme at the moment, according to the data collected by the Centre for Science and Environment.

NATIONAL MISSION ON BIOMASS USE IN POWER PLANTS: REPLACING COAL AND IMPROVING CARBON FOOTPRINT

The national mission on biomass use in thermal power plants will have the following objectives:

- To increase the level of co-firing from the present 5 per cent to higher levels to have a larger share of carbon-neutral power generation from the thermal power plants.
- To take up research & development (R&D) activity in boiler design to handle the higher amounts of silica and alkalis in biomass pellets.
- To facilitate overcoming of constraints in supply chains of biomass pellets and agro-residue.
- To consider regulatory issues in biomass co-firing.
- Biomass co-firing can help in cutting emissions from the thermal power sector by 90–180 million tonnes by 2030, replacing 50–100 million tonnes of coal. It has been accepted as the most economical method to reduce carbon footprints of coal power plants.

BIOMASS CO-FIRING CAN HELP IN CUTTING EMISSIONS FROM THE THERMAL POWER SECTOR BY 90–180 MT BY 2030

To implement this, thermal power plants may also need to improve their backend fuel-processing, including the use of biomass briquettes and pellets.

The potential is enormous. Biomass co-firing can help in cutting emissions from the thermal power sector by 90–180 million tonnes by 2030, replacing 50–100 million tonnes of coal. It has been accepted as the most economical method to reduce the carbon footprint of coal power plants.

As per this scheme, central financial assistance will be provided at the rate of Rs 25 lakh per MW of surplus exportable capacity fed into the grid. In addition, this energy source gets a tax holiday for 10 years and other concessions on customs and excise for equipment.

5

MINI-GRIDS

MINI-GRIDS

TOTAL INSTALLED CAPACITY OF MINI-GRIDS HAS REACHED

1,467 MW

MINI-GRIDS: DECENTRALIZED POWER

As of 31 March 2021, some 216 MW capacity of standalone power plants (off-grid power plants) had been set up. In addition, there are 10 million off-grid solar-based lighting systems (street lights, home lights and solar lanterns) and 286,830 solar water pumps in the country. All these totaled to 1,467 MW of installed capacity by 31 January 2022, according to the Ministry of New and Renewable Energy (MNRE).

A mini-grid refers to decentralized electricity generation systems with capacities above 10 kW to a few MW, serving residential, commercial, institutional and small industrial loads. As opposed to this, micro-grids are systems with capacities less than 10 kW.

Currently, households use diesel or biomass as sources of decentralized energy. These fuels are polluting, but convenient. The aim is to shift households from direct use of diesel and biomass to electricity produced from solar, biomass and wind. This can then become the key source for last-mile connectivity, reaching households that still do not have access to electricity; or, and most critically, can become the supply for cooking energy needs of households. It will then displace all the dirty fuels which are used today, and can be a win-win proposition for the world's energy-insecure poor.

In the past decade, there was interest in setting up mini-grids till policy focus shifted to all-India grid-connectivity. Mini-grids were promoted by MNRE

Table 1: State mini-grid policies and their features

States	Salient feature of mini-grid policy
Uttar Pradesh (Uttar Pradesh Mini-grid Policy, 2016)	• To ensure power supply to 20 million households of the state for minimum need (daily three hours in the morning and five hours in the evening with a total of at least eight hours) • To create a conducive environment for stimulating private sector participation through 30 per cent subsidy. Developers to establish projects on Build Own Operate & Maintain (BOOM) basis and guarantee 10 years of Operation and Management (O&M) services. • To enhance skills and create employment opportunities at the local level. • To promote establishment of local manufacturing facilities and socio-economic development of backward areas.
Odisha (A component under Odisha Renewable Energy Policy, 2016)	• The Odisha Electricity Regulatory Commission notified the Mini-grid Renewable Energy Generation and Supply Regulations in June 2019. • Two models for business operations are discussed - one each for where the grid pre-exists and the grid is non-existent.
Bihar (A component under Policy of Promotion of Bihar New and Renewable Energy Sources, 2017)	• Promotion of mini-grids as a solution to provide 24x7 reliable energy to all by FY 18-19. • State government targets to achieve deployment of 100 MW of RE capacity equivalent through mini-grids. • Projects to be constructed on the BOOM model. • The government to facilitate the development of mechanisms to streamline project aspects such as single window clearance.

as components of the `Off-grid and Decentralised Applications Programme', implemented under the National Solar Mission with a provision of Central Financial Assistance. In 2016, the Indian government came up with a Draft National Policy on Mini and Micro-grids with a target of deploying at least 10,000 renewable energy-based micro/mini-grids with minimum capacities of 500 MW within five years in under-served and un-served locations of the country. But this policy has not been finalized yet.

The draft policy encouraged states to use the enlisted guidelines to prepare their own policies. Uttar Pradesh, following this, has framed its own mini-grid policy, while states like Odisha and Bihar have included the component of mini-grids in their wider renewable energy policies (*see Table 1*).

GRID HAS REACHED RURAL AREAS BUT ELECTRICITY IS NEITHER RELIABLE NOR AFFORDABLE

By 2017, the government's focus had shifted to providing electricity access to all households by extending the grid. The Pradhan Mantri Sahaj Bijli Har Ghar Yojana—also known as the `Saubhagya' scheme—was launched with the aim to electrify the whole country. As of 2019, there were some 19,679 villages that remained to be electrified. As of 2022, even these have been reached with the grid. India, therefore, can claim 100 per cent electrification, says the government. This is no mean achievement.

However, the definition of `electrified households' remains problematic. Till recently, `electrification' meant that there was more than just a single wire in the village connected to the grid. The new definition says a village can be called `electrified' if at least 10 per cent of the households are connected.

There is also a lack of data to show if this electrification has led to electricity reaching households, if it is reliable, and if electricity supply is continuous given that distribution companies are mostly cash-strapped and households are often unable to pay. In such a situation, mini-grids, which can generate and supply energy close to the households, could well be the answer.

ACCORDING TO THE GOVERNMENT, INDIA CAN CLAIM 100% ELECTRIFICATION

The 2019 report called *Rural Electrification in India – Customer Behaviour and Demand*, published by Smart Power India, a subsidiary of The Rockefeller Foundation and the Initiative for Sustainable Energy Policy (ISEP), had found households mixing and matching both grid and off-grid energy sources for their needs. The study, based on data collected from 10,000 households and 2,000 rural enterprises in Bihar, Uttar Pradesh, Odisha and Rajasthan, found that 16 per cent of the households and 40 per cent of the enterprises used non-grid sources—diesel generators, but also solar home systems. It also found that one in two grid-users faced a power cut at least eight hours daily. Besides the inconvenience, an undependable electricity supply forced customers to bear additional expenses on power back-ups.

THE POTENTIAL OF MINI-GRIDS IN INDIA HAS BEEN ESTIMATED AT ABOUT 4 GW

Therefore, the requirement of mini-grids cannot be ruled out—particularly for energy access to meet the needs of the poorest. The country is still facing a major challenge in providing reliable and quality electricity supply. The supply during the evening peak hours (5–11 pm) is a serious issue, especially in villages. According to Prayas (Energy Group)'s Electricity Supply Monitoring Initiative, 27 per cent of the monitored locations experienced an average daily outage of 30 min or more during evening hours in September 2019. For the same month, only 7 per cent of rural areas received the entire six hours of evening supply.

These frequent interruptions and variability in voltage strengthen the case of mini-grids. Localized mini-grids are efficient and have high accountability. Supplying 24x7 electricity through a centralized grid is both costly and technically challenging. The transmission and distribution losses are also high as the distance from the generation end increases. Therefore, mini-grids can play a grid-balancing role. These are also helpful in generating employment in rural areas.

RELEVANT FOR CLEAN ENERGY ACCESS

The CEA acknowledges the importance of mini-grids in meeting the target of 175 GW of renewable energy by 2022. The potential of mini-grids in India has been estimated at about 4 GW in the villages which have an inadequate power supply. It is also clear that energy is critical for economic and livelihood growth. This energy access would ensure that not only are domestic needs taken care of but that it is used to make small businesses sustainable and make villages viable for economic growth.

The key will be to develop mini-grid systems and policies that integrate with the grid, so that the surplus power generated can be exported out; and in times of need also imported into the system for supply. The modern mini-grid must be as easy to install as the local distributor for other supplies—it should provide last-mile connectivity.

COOKING FOOD WITH ELECTRICITY

The advantage is that the solar energy distributor knows the customer and this means that there can be on-demand energy available at low cost. It is a sustainable business model and if it can be made affordable, it can allow households to meet basic livelihood and economic needs.

OVER **70%** OF INDIAN HOUSEHOLDS IN RURAL INDIA CONTINUE TO COOK FOOD ON BIOMASS-BASED FUELS

Energy access is still a key issue. In addition, over 70 per cent of Indian households in rural India continue to cook food on biomass-based fuels (cowdung, wood, twigs), which are polluting and harmful for health, particularly of women working the stoves. The Central government's

Ujjwala programme—which provides subsidized LPG to meet cooking needs—has reached over 80 million households. But what is now well recognized is that affordability remains the key issue and even the refills of LPG are 50 per cent below full utilization.

ELECTRICITY IS A VIABLE OPTION TO REPLACE BIOMASS FOR COOKING

It is also clear that electricity could be a viable option for meeting the needs of cooking in households. It is cheaper than LPG—even at the cost of Rs 8/unit—and efficiency is higher. The problem is that cooking energy costs remain unmonetized in households—the time taken by women to collect fuelwood or cowdung is discounted. And therefore, households do not want to pay for this energy—even though now there is a better understanding of the health impacts of using dirty fuel. Then there is the cultural problem of using electricity for cooking—as it would require changes in utensils and may be even certain culinary practices.

The potential of this leapfrog—moving the poor in the world to clean energy—without going through the fossil fuel trajectory is enormous and powerful.

ECONOMICS OF THE SMALL

The problem with this decentralized source of energy is that it remains more expensive than the conventional grid-based energy supply. This is partly to do with the scale of operations as setting up solar systems, particularly with battery back-ups to meet night time usage, is expensive—more so than solar energy supplied through grid-based large systems. It is also because the system operator has to set up the entire distribution

Table 2: Case study of mini-grids: where, what and costs

Based on field visits and documentation by CSE

Project location	Technology used	Implemented by	Year	Capacity	Cost-CAPEX (Rs)	Cost-OPEX (Rs)	Tariff	No. of consumers
Raimongol Kumirmari Island, Sundarbans, West Bengal 2021 case study update	Solar PV with storage	WWF India, IndusInd Bank Schneider Electric India Foundation	2016 and completion 2021	22.5 kW: Marichjhapi 23.6 kW: Raimongol	80 lakh for each plant	85,000/ month	Up to 3 kWh: Rs 50/month Above Rs 12/ kWh	400 households
Madavchandra Satjelia Island, Sundarbans, West Bengal 2021 case study update	Solar PV with storage	WWF, Tata Power Solar and CAT international	2010	9.6 kW	80 lakh	40,000/ month	Fixed charge of Rs 50/ month for usage up to 3 kWh Above this Rs 12/kWh	70 households With grid coming to village, usage has dropped
Jargatoli Gumla, Jharkhand 2021 case study update	Solar PV with storage	Mlinda Sustainable Environment Pvt Ltd (India)	2016 Completion by 2018	23.5 kW	91 lakh Fee of Rs 1700–2700 paid for connection		Pre-paid meter for Rs 100 for 2 LED bulbs and 1 mobile charger for 28 days Rs 20/hour for ½ Hp pump Rs 78/hour for 5 HP pump	124 households 19 small pumps, 3 rice hullers, 2 flour mills and 2 shops
Basua, Gumla Jharkhand Grid in village 2021 case study update	Solar PV with lithium-ion batteries for storage Grid connected	Mlinda Sustainable Environment Private Limited (India)	2018	33.3 kW	1.2 crore Fee of Rs 1700–2700 paid for connection		Domestic consumers: Rs 20–30/kWh Commercial: Rs 40–50/ kWh Rs 20/ hour for ½ -HP water pump; Rs 78/hour for a 5-HP water pump	230 households 20 small pumps, 1 rice huller, and 1 welding workshop
Chopan, Amravati, Maharashtra Grid in village 2021 case study update	Solar PV with storage	Maharashtra Energy Development Agency (MEDA)	2019	24 kW	42.5 lakh Deposit of Rs 60 for electricity meter		Rs 7/kWh	124 households
Fughala and Anghanwadi, Thane district, Maharashtra 2016 case study, published in CSE report, Minigrids for All	Solar PV with storage	Solarisis and Grand Lodge of India (GLI)		3.6 kW x2	5 lakh x 2		Nil	80 households x2

Project location	Technology used	Implemented by	Year	Capacity	Cost-CAPEX (Rs)	Cost-OPEX (Rs)	Tariff	No. of consumers
5 villages in Kandhara Reserve Forest, Dhenkanal, Odisha 2016 case study, published in CSE report, Minigrids for All	Solar PV with storage AC/DC system	The Energy and Resources Institute (TERI) and Institute for Research and Action on Development Alternatives (IRADA), funded by Off-Grid Access System for South Asia (OASYS)	2014	13.8 kWp Rajanga (6 kWp) Kanaka (5 kWp) Baguli (2.4kWp) Rajanga hamlet (400 Wp) Chadoi (400 Wp)	60 lakh for 5 plants		Rs 50/month	140 households
Darewada, Pune, Maharashtra 2016 case study, published in CSE report, Minigrids for All	Solar PV with storage	Gram Oorja, with CSE fund from Bosch Solar	2012	9.36 kW	30 lakh (land was donated by village)		Fixed Rs 90/ month per connection Rs 20/unit (prepaid meter)	36 households + street lights and pumps
Neechli Babhan, Pali district, Rajasthan 2016 case study, published in CSE report, Minigrids for All	Solar PV with pre-paid smart meters	Gram Power With funding from MNRE	2013	5.5 kW	25 lakh Connection fee of Rs 2.8 collected from households		Rs 31.25/unit (pre-paid meter)	80 households
Chanpatia, West Champaran, district, Bihar CSE field report 2020	Biomass (husk)-solar with battery storage plant	Husk Power Energies	2017	40 kW solar and 25 kW biomass (for evening and night time)				100 customers, of which 30 per cent domestic, 10 per cent industrial and 60 per cent commercial
Odanthurai Tamil Nadu CSE field report 2021	Wind energy	Panchayat with partial funding from Central Bank of India	2006	350 kW Suzlon windmill	1.55 crore Rs 40 lakh from villagers and rest as commercial bank loan		6.75 lakh units generated each year Self-use is 4–5 lakh units/year. Remaining 2.25 lakh units sold at Rs 2.90/unit to TN Electricity Board, generating Rs 19.6 lakh/year which is used to pay back bank loan.	

COST OF GENERATION FROM MINI-GRIDS COULD RANGE FROM **RS 6–28 KWH**

network to reach each household and this comes at a high cost. It is also a fact that while many of these costs are underwritten in conventional electricity projects as development charges, the developer of the standalone clean energy system has to bear these charges.

A survey done by CSE of the different models of mini-grids in the country found that the cost of generation per unit could range from Rs 6–28 depending on the size of the system and its configuration. The supplied energy costs are high and unaffordable for general use in many cases. But it has been observed that people 'buy' higher cost energy for productive purposes—village-based industry or even to power their irrigation pumps. It is important that the cost of energy is reduced so that it can be used for all purposes, including cooking, in households. Only then will we address the issue of energy poverty.

MODELS OF MINI-GRIDS

A CSE study of solar-biomass hybrid-based mini-grid model at Chanpatia village in Pashchim Champaran district in Bihar found that the system is effectively handling the load during power outages as well as ensuring stable and uninterrupted supply for customers. Customers have a higher willingness to pay to the mini-grid-based energy suppliers for their service steadfastness, operational efficiency and tailored solutions, despite the power being costlier than that from grid-based supply. Small commercial customers were found to shift from diesel generators to mini-grid connections.

Some private sector firms—including TP Renewable Micro-grid, a joint venture of Tata Power, The Rockefeller Foundation and Husk Power Systems—are installing mini-grids to provide quality energy in rural areas.

Tata Power (mini-grid), for instance, has a growing programme as it finds that as a power utility it can provide an integrated service of 24x7 power to all. In this case, mini-grids can be an option even in those places where power supply has reached but is not reliable.

CSE is documenting case studies of mini-grids to review functioning, costs and possible models for scaling up. What is emerging is that while the potential exists, it will be the affordability of energy that will make or break this decentralized clean source of power.

WAY AHEAD

Mini-grids are still needed in spite of grid connections; either because of unreliable power or high cost. People today have to use kerosene or other dirty sources of power which have high health costs. It would be important to find ways to leapfrog households using dirty energy to cleanest energy.

India needs policy to support the growth of mini-grids (standalone clean energy systems)

In February 2022, MNRE released a draft policy framework for Decentralised Renewable Energy (DRE) livelihood applications. The ministry says this is intended to achieve its objective of decentralized and distributed renewable energy supply in the country, particularly for rural populations with little or no access to power.

MINI-GRIDS ARE USEFUL IN THOSE PLACES WHERE POWER SUPPLY HAS REACHED BUT IS NOT RELIABLE

DRAFT MINI-GRID POLICY HAS TO BE FINALIZED FOR POLICY COHERENCE AND DIRECTION

The main objectives outlined in the new framework are:

- Enabling a market-oriented ecosystem
- Increasing the adoption of DRE-based livelihood solutions by enabling easy finance for the end-user
- Encouraging development and management of high-quality products
- Developing effective DRE livelihood applications through innovation as well as research and development
- Establishing energy-efficiency standards for high-potential livelihood products
- Using applications powered by mini/micro-grids operating in hybrid mode along with the main grid

This will not be enough. The draft mini-grid policy needs to be finalized and issued so that there is policy coherence and direction on how these standalone systems can be scaled up. The Rwandan government's policy on mini-grids provides for interaction between grid and mini-grids and transfer when grid is available; it standardizes tariffs and provides funding for capital investment.

Financial support is essential

This source of energy must be seen as killing two birds with one stone—poverty reduction and meeting the climate goals of the world. It needs financial support to meet the needs of the poorest—those who are unconnected to conventional energy systems. A scheme needs to be made which underwrites capital investment to reduce energy costs or subsidizes every unit of energy supplied to households for domestic and livelihood purposes. If the government gives subsidy on tariff, then mini-grids could be more affordable for households to use and would displace the consumption of biomass or diesel.

6

HYDROGEN ENERGY

GREEN HYDROGEN

Green hydrogen fuel is the promise of tomorrow. It will displace oil in vehicles and can be used as fuel in many industries which are hard to decarbonize. But there are issues that need to be understood in terms of its environmental impact and financial viability. It all depends on what is the source of hydrogen. This is why colourless and invisible hydrogen has been colour-coded by the energy industry to differentiate it based on the source or process by which it is produced (*see Table 1*).

Green hydrogen is hydrogen produced using renewable energy—wind or solar or biomass. The renewable energy sourced electricity is used to generate an electric current to separate hydrogen from oxygen in water. So, green hydrogen is about using renewable power for electrolysis in water.

This hydrogen produced from water using renewable energy can be stored for later and burnt as fuel in all industrial applications. This is why there is huge expectation from this technology to be a game-changer as it has the potential to replace conventional fossil fuels like coal, oil and gas. Hydrogen produced through this route can be combined with nitrogen to produce ammonia.

GREEN HYDROGEN IS HYDROGEN PRODUCED USING **RENEWABLE ENERGY**

However, for this hydrogen to be 'green' it cannot use fossil fuels—coal or gas—as raw material. This is why the colour coding of hydrogen based on the production pathways matters.

Currently, oil refineries and fertilizer and steel manufacturers use hydrogen in their processes—but this is 'grey hydrogen' as it is produced using natural gas or naptha as the raw material. These companies would be the first movers to green hydrogen—if they can source renewable power at affordable rates. These companies are also looking to continue to generate 'grey hydrogen' but then to use carbon capture, utilization and storage technologies to clean up the CO_2 emissions generated from this production of hydrogen.

THE WORLD PRODUCED **90 MT** OF HYDROGEN IN 2020, BUT ONLY A SMALL FRACTION OF THIS WAS FROM RENEWABLES

According to the International Energy Agency's (IEA) Global Hydrogen Review 2021, the world produced some 90 million tonnes of hydrogen in 2020—though all but a small fraction was produced from fossil fuels. This production of hydrogen from fossil fuels added 900 million tonnes of CO_2 emissions—equivalent to the emissions of Indonesia and UK combined.

IEA projects that with the growing interest in hydrogen from electrolysers, the world will be in a position to produce more than 8 million tonnes of green hydrogen by 2030—but this is still vastly below the 80 million tonnes that would be required by 2030 in the IEA pathway to net zero emissions.

Table 1: Colour coding of hydrogen on the basis of production pathways

Colour	Production pathway
Brown	Gasification of brown coal (lignite)
White	A by-product of industrial processes
Grey or Black	Natural gas reforming without CCUS
Pink/Purple or Red	Electrolysis powered through nuclear energy
Blue	Natural gas reforming with CCUS
Yellow	Electrolysis powered by grid electricity
Turquoise	Through thermal splitting of methane-producing solid carbon
Green	Electrolysis powered through renewable electricity

COST WILL DETERMINE UPTAKE OF THIS NEW FUEL

According to IEA's 2021 review, the key barrier for this green fuel remains the cost—and its competitiveness with other fuels. As per this review, 'depending on regional gas prices, the levelized cost of hydrogen production from natural gas ranges from US$ 0.5 to US$ 1.7 per kilogramme (kg). If Carbon Capture, Utilisation and Storage technologies (CCUS) are used to reduce the CO_2 emissions from hydrogen production, this doubles the levelized cost of production – from US$ 1 to US$ 2 per kg. But when renewable power is used to produce hydrogen the costs range between US$ 3 to US$ 8 per kg.'

However, IEA projects that this situation will change by 2030. The price of green hydrogen will come down drastically because of increased deployment of renewables and reduced costs. It estimates that by 2030, green hydrogen prices would fall to US$ 1 per kg (range is between US$ 1–3) and it could compete with hydrogen produced from fossil fuels (natural gas) but with carbon capture, utilisation and storage technologies.

ACCORDING TO THE GLOBAL HYDROGEN COUNCIL, INDIA WILL BECOME A NET EXPORTER OF GREEN HYDROGEN BY 2030

In India, the current price is said to be close to Rs 500 per kg—which clearly makes it unaffordable for use as a fuel. However, there is optimism that this cost will come down by 2030. According to the Global Hydrogen Council, India will become a net exporter of green hydrogen by 2030 due to its cheap renewable energy tariffs.

The improved electrolyser efficiencies and increased solar plant load factors will also play a crucial role in bringing down the price of green hydrogen. Electrolyser stacks account for up to 70 per cent of the hydrogen production cost.

TRANSPORTING HYDROGEN IS A CHALLENGE

Hydrogen is an expensive fuel to store and transport. A technical study was carried out by the National Renewable Energy Laboratory (NREL) for blending hydrogen into the existing natural gas pipeline network. If implemented with relatively low concentrations—less than 5–15 per cent hydrogen by volume—this strategy of delivering green hydrogen energy to markets appears to be viable

Trucks can also transport hydrogen in lower volumes. High-pressure compressed gas tankers can be used or liquid hydrogen can be transported in cryogenic tankers. Since trucks can only transport small quantities, this distribution model would be limited to smaller end-users (such as hydrogen refuelling stations) or industrial demonstration projects.

BIG INVESTMENTS IN GREEN HYDROGEN

Reliance Industries Ltd (RIL) has recently announced its plans to become a net zero carbon firm by 2035. RIL has plans to invest Rs 600 billion to build a 5000-acre green energy complex in Jamnagar, Gujarat. The complex will house an electrolyser plant to produce green hydrogen. RIL head, industrialist, Mukesh

RELIANCE INDUSTRIES LTD HAS RECENTLY ANNOUNCED ITS PLANS TO BECOME A NET ZERO CARBON FIRM BY 2035

Ambani has set the objective to bring down the price from US$ 3/kg currently to just US$ 1kg.

US-based renewable energy company Ohmium International has started India's first green hydrogen electrolyser factory in Bengaluru through its Indian subsidiary. In its current capacity, the factory can manufacture approximately 0.5 GW per year.

GAIL (India) is looking at locations to finalize a 10 MW plant for manufacturing electrolysers, one of the biggest plants announced so far. GAIL has already started mixing hydrogen in natural gas on a trial basis.

National Thermal Power Corporation (NTPC) has announced its plans to produce green hydrogen in its 4.75 GW park at the Rann of Kutch. Presently, the company is running a pilot in their Vindhyanchal unit. The company also has plans to set up green hydrogen fuelling station in Leh, Ladakh. They have invited Expression of Interests (EOIs) for 10 hydrogen fuel cell buses and cars.

Indian Oil Corporation Limited (IOCL) is going to setup a green hydrogen plant at its Mathura refinery in Uttar Pradesh with a capacity of around 160,000 barrels per day. IOCL also has plans to setup a hydrogen manufacturing unit in Kochi, which is targeted to draw energy from the solar facility at the Kochi international airport. Additionally, IOCL floated a tender for 15 hydrogen PEM fuel cell electric buses.

Larsen and Toubro (L&T) are looking to venture into the green hydrogen sector. In addition to exploring the possibility of manufacturing electrolysers, they are setting up a green hydrogen plant at their Hazira complex, which is scheduled to be completed withing this financial year.

THE GOVERNMENT AIMS TO PRODUCE **5 MT** OF GREEN HYDROGEN BY 2030

Both Hindustan Petroleum Corporation Limited (HPCL) and Bharat Petroleum Corporation Limited (BPCL) are planning to use hydrogen for their refineries. Solar Energy Corporation Limited (SECI), is looking to invite bids to build green hydrogen plants using renewable energy sources. The corporation recently released a Notice Inviting Tenders (NIT) for setting up a green hydrogen based pilot project at SNM hospital in Leh, Ladakh.

GOVERNMENT POLICY ON GREEN HYDROGEN

The Prime Minister launched the Green Hydrogen Mission on India's 75th Independence Day on 15 August 2021. On 17 February 2022, the Union government announced its green hydrogen and green ammonia policy, with the objective to produce 5 million tonnes of the product by 2030—making India a commercial hub for this fuel.

The policy has waived off the inter-state transmission costs on renewable power for 25 years—which means that if renewable power is generated in Rajasthan, then it can be transmitted, without additional costs, to another state for hydrogen production. It has said that hydrogen/ammonia manufacturers can purchase renewable power from the power exchange or set up this capacity or work through any other developer to do

INTER-STATE TRANSMISSION COSTS ON RENEWABLE POWER HAVE BEEN WAIVED FOR 25 YEARS

so. In other words, the hydrogen producer would be able to have captive renewable power production, which if set up in another state, will not attract inter-state transmission costs. This open access policy is expected to bring down the costs.

The manufacturers of green hydrogen can also 'bank' renewable power with a distribution company for 30 days.

As India is hoping to build an export economy from this clean fuel of green hydrogen, the policy also lets manufacturers set up bunkers near ports for storage.

The promise of green hydrogen has many challenges—the cost of renewable power has to reduce and then the system has to be worked out to 'utilize' hydrogen—and to displace oil—in vehicles and other industries. It is for this reason that IEA's 2021 Global Review of Hydrogen remains sanguine about the potential of this fuel, saying that 'hydrogen is an important part of the net-zero emissions scenario, but it is only one piece of this puzzle.'

7

MANUFACTURING AND RECYCLING

WHAT ARE INDIA'S TARGETS?

India has set an ambitious goal of establishing 280 GW solar energy, 140 GW wind energy and 27 GW (4 hrs) battery storage capacity by 2030. Roughly 28 GW of solar and 12 GW of wind energy capacity must be built annually to reach these targets.

MANUFACTURING

SOLAR

At the moment, the country's solar cell and module production capacity is only 3 GW and 13 GW, respectively, which is insufficient to meet the country's current demand. Furthermore, the existing Indian landscape lacks manufacturing capacity for upstream stages of polysilicon, ingot and wafer, owing to high production costs. Imports from neighbouring Asian nations such as China and Malaysia have fulfilled more than 80 per cent of India's domestic demand for solar modules. Because of the high reliance on imports, pricing and module supply are unpredictable.

ROUGHLY **28 GW** OF SOLAR AND **12 GW** OF WIND ENERGY CAPACITY MUST BE BUILT ANNUALLY FOR INDIA TO REACH ITS AIM

As of April 2022, the Indian government has imposed a 40 per cent basic customs duty (BCD) on solar modules and a 25 per cent BCD on solar cells to minimize dependency on imports and develop the country's PV manufacturing base. In 2021, MNRE decided to implement a National Program on Solar PV Manufacturing involving production linked incentives (PLI) to increase domestic manufacturing capacity of High Efficiency Solar PV Modules, for which the Cabinet gave approval on 11 November 2020 and allocated an amount of Rs 4,500 crore to be spent over a five-year period. The PLI plan for the solar PV industry was a huge success, attracting proposals from 18 companies totalling about 54 GW of integrated production. Through phase 1 of this PLI scheme, domestic manufacturing capacity for integrated solar PV manufacturing is planned to be expanded up to 10 GW (from wafer-ingot to high efficiency modules) by Q4 of 2022–23.

OVER THE PAST TWO YEARS, YEARLY CAPACITY ADDITIONS IN WIND HAVE BEEN LESS THAN
2 GW

WIND

Over the past two years, yearly capacity additions have been less than 2 GW. Because of the low yearly capacity increase, turbine makers are operating at less than 20 per cent of their full capacity, which has a significant impact on their cash flow. Along its supply chain, the wind sector employs roughly 4,000 domestic small and medium businesses (SMEs). They manufacture parts for specialized services such as transportation, resource evaluation, design and consultation, and construction and civil works; they are presently pivoting their companies as low demand makes it hard to support them. India needs to solve the reverse auction procedure as well as transmission and evacuation infrastructure. Wind RPOs, site-specific reverse auctions, and wind generating inside state boundaries for low-wind states might offer the necessary push to resurrect the industry.

BATTERY

Despite India's comparatively low starting position in the global battery production industry, the size of the market is piquing the interest of prominent firms in India and throughout the world. If manufacturers are optimistic about the future, India's battery output might soon go up.

The government has approved a Rs 18,100 crore PLI programme that incorporates advanced chemistry cell (ACC) manufacturing to boost domestic storage battery manufacturing. In March 2019, India established a "National Mission on Transformative Mobility and Battery Storage" to boost electric car adoption and support 50 GWh of local ACC manufacture. The PLI scheme has the following features:

- Cash subsidy offered on output, or the volume of cells manufactured and sold
- Cells with higher performance specifications are eligible for incentives
- Benchmarks for subsidy programmes to assess the quality or performance of cells

Battery swapping is a cost-effective option for the space-constrained charging infrastructure segment, as well as expanded fleet electrification for "last mile" connection. Given that EVs would account for 90 per cent of India's annual lithium-ion battery (LiB) consumption by 2030, EV adoption also paves the path for battery adoption.

RECYCLING

SOLAR

GLOBAL PHOTOVOLTAIC WASTE IS EXPECTED TO REACH **78 MT** BY 2050

India is ramping up its solar power installations, but it lacks a clear policy on how to deal with waste that results from the use of solar panels or from their manufacturing. Global photovoltaic waste is expected to reach 78 million tonnes by 2050, according to the International Renewable Energy Agency. India is expected to be among the top five countries producing this waste.

According to a report released jointly by the National Solar Energy Federation of India, SolarPower Europe, and PVCycle, India might create 34,600 metric tonnes of PV trash by 2030. Given India's ambitious renewable energy plans, this figure is expected to rise by at least 4–5 times in the next decade.

INDIA MIGHT CREATE 34,600 METRIC TONNES OF PV TRASH BY 2030

Solar trash is now treated as part of electronic waste in India, and it is not tracked separately. A committee has been formed to submit an action plan for developing a "circular economy" in solar panels through reuse/recycling.

In India, there is no commercial raw material recovery plant for solar e-waste, but a private business has built up a pilot facility for solar panel recycling and material recovery in Gummidipoondi, Chennai, Tamil Nadu.

WIND

For every kilowatt of new capacity, 10 kilograms of blade material is required. Approximately 75 tonne of blade material is needed for a standard 7.5 MW wind turbine.

Wind turbines have a 25-year average lifespan in terms of durability. The blades of these wind turbines are scrapped or recycled after they are retired. In certain cases, blades are even discarded when wind farms are repowered. A University of Cambridge study estimates that windmill blades will account for 43 million tonnes of waste in 2050, with most of them ending up in landfills now that recycling them is difficult.

MANUFACTURERS MUST FILE A STATEMENT OF THEIR SALES AND BUYBACKS WITH THE STATE BOARD BY THE END OF EACH YEAR

Although the blades can be chopped into a few pieces on site, transporting them for recycling or disposal becomes complicated and expensive. Cutting the incredibly strong blades also necessitates massive machinery, such as vehicle-mounted wire saws or diamond-wire saws similar to those used in quarries. Around 85 per cent of their compositional materials can be recycled or reused, including steel, copper wire, electronics and gearing.

BATTERIES

The Ministry of Environment, Forest and Climate Change (MoEF&CC) published the draft Battery Waste Management Rules, 2020, on 20 February 2020. These rules are set to supersede Batteries (Management and Handling) Rules, 2001. This amendment aims to ensure safe and formalized recycling of batteries that are under use, with a particular focus on tracking discarded batteries through online records and data management.

The amendment also explicitly states the responsibilities of manufacturers, importers, assemblers, reconditioners, consumers, exporters, dismantlers, collection centres, and state and central pollution control boards, and emphasizes awareness of the hazards of lead, cadmium and mercury, as well as the safety precautions that must be taken when they are handled.

Furthermore, manufacturers must file a statement of their sales and buybacks with the state board by the end of each year.

India has set ambitious renewable energy targets for itself. The achievement of these targets is necessary from the viewpoints of climate and energy security, pollution abatement, and also to secure clean energy for all, including the poor. This book is an update on the facts about the progress we have made thus far. It is meant as a resource to help us step into the future on a surer footing.

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