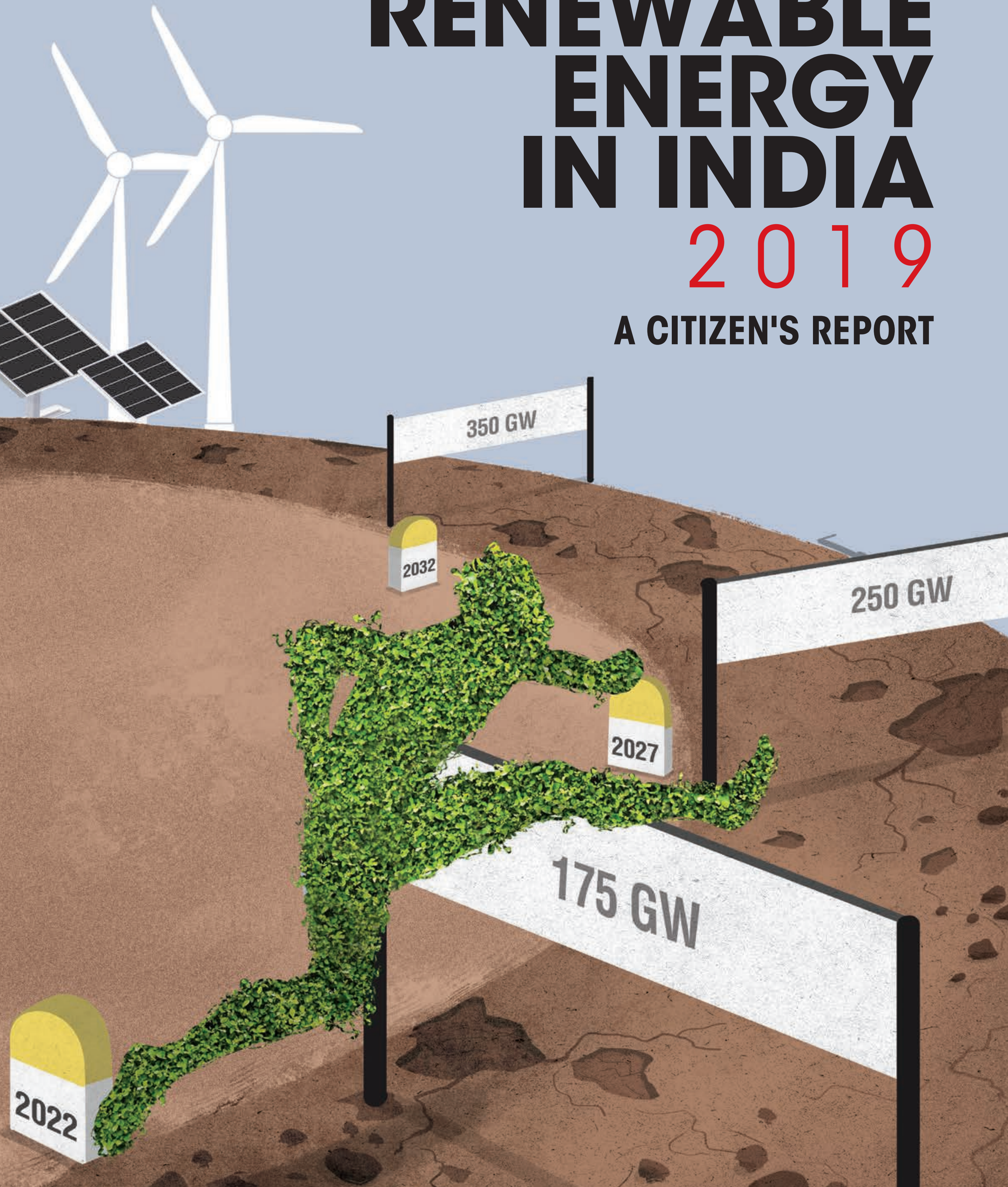
THE STATE OF RENEWABLE ENERGY IN INDIA 2019

A CITIZEN'S REPORT



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A CITIZEN'S REPORT

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CSE

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Key abbreviations

ABT: availability-based tariff
ACS: average cost of supply
AGC: Automatic Generation Control
AMI: automatic meter infrastructure
APERC: Andhra Pradesh Electricity Regulatory Council
APPC: annual pooled purchase cost
ARR: average revenue realised
AT&C: aggregate technical and commercial
BU: billion units
CEA: Central Electricity Authority
CEMS: Continuous Emission Monitoring Systems
CEQMS: Continuous Effluent Quality Monitoring Systems
CERC: Central Electricity Regulatory Commission
ckm: circuit km
CPCB: Central Pollution Control Board
CSS: cross-subsidy surcharge
CUF: capacity utilisation factor
DCR: domestic content requirement
DDG: decentralised distributed generation
DDUGJY: Deen Dayal Upadhyaya Gram Jyoti Yojana
DHBVNL: Dakshin Haryana Bijli Vitaran Nigam Ltd
discom: distribution company
DRE: distributed renewable generation
DSM: Deviation Settlement Mechanism
EDC: electrification distribution circle
EDD: electrification distribution division
EIA: environment impact assessment
EOI: expression of interest
EPC: Engineering Procurement and Construction
ESMI: Electricity Supply and Monitoring Initiative
F&S: Forecasting & Scheduling
FiT: feed-in tariff
FoR: Forum of Regulators
FY: financial year
GBI: generation-based incentives
GEC: Green Energy Corridor
GST: Goods and Services Tax
GW: gigawatt
GWEC: Global Wind Energy Council
HAREDA: Haryana Renewable Energy Development Agency
HERC: Haryana Electricity Regulatory Commission
HUDA: Haryana Urban Development Authority
HVDC: high voltage direct current
IEA: International Energy Agency
IEGC: Indian Electricity Grid Code
INDC: Intended Nationally Determined Contribution
IPDS: Integrated Power Development Scheme
IPP: independent power producer
IREDA: Indian Renewable Energy Development Agency
ISMA: Indian Solar Manufacturers Association
ISTS: Inter-state Transmission System
IT: information technology
JAREDA: Jharkhand Renewable Energy Development Agency
JNNSM: Jawaharlal Nehru National Solar Mission
KERC: Karnataka Electricity Regulatory Commission
KUSUM: Kisan Urja Suraksha Evam Utthan Mahabhiyan
kW: kilowatt
kWh: kilowatt hour
LDC: load dispatch centre
MGO: mini-grid operator
MGP: Mera Gaon Power
MNRE: Ministry of New and Renewable Energy
MoEF&CC: Ministry of Environment, Forests & Climate Change
MoP: Ministry of Power
MoUD: Ministry of Urban Development
MPUVNL: Madhya Pradesh Urja Vikas Nigam Ltd
MSW: municipal solid waste
MU: million units
MVA: mega volt ampere
MW: megawatt
NBFC: non-banking financial corporation
NCEF: National Clean Energy Fund
NEP: National Electricity Plan
NGT: National Green Tribunal
NIWE: National Institute of Wind Energy
NPA: non-performing asset
NREL: National Renewable Energy Lab
NSEFI: National Solar Energy Federation of India
NSM: National Solar Mission
NTP: National Tariff Policy
NVVN: NTPC Vidyut Vyapar Nigam
OA: open access
OMC: oil marketing company
OMS: outage management system
PE: private equity
PGCIL: Power Grid Corporation of India Ltd
PLF: plant load factor
PLM: peak load management
PMU: phasor measurement unit
PMUY: Pradhan Mantri Ujjwala Yojana
POSOCO: Power System Operation Corporation
PPA: power purchase agreement
PPP: public-private partnership, public-private participation
PQM: power quality management
PSA: power sale agreement
PSHP: Pumped Storage Hydro Plants
PSM: Payment Security Mechanism
R-APDRP: Restructured Accelerated Power Development and Reforms Programme
RDF: refuse-derived fuel
REC: Renewable Energy Certificate / Rural Energy Corporation
REMC: Renewable Energy Management Centre
RE-OA: renewable energy-based open access
RESCO: Renewable Energy Service Company
RGGVY: Rajiv Gandhi Grameen Vidyutikaran Yojana
RPO: renewable purchase obligation
RRAS: Reserves Regulation Ancillary Services
RRF: Renewable Regulatory Fund
SAUBHAGYA: Sahaj Bijli Har Ghar Yojana
SBM: Swachh Bharat Mission
SECI: Solar Energy Corporation of India
SERC: State Electricity Regulatory Commission
SPIS: Solar Pumping Irrigation System
SRISTI: Sustainable Rooftop Implementation for Solar Transfiguration of India
SRT: solar rooftop
SVC: static var compensator
SWM: solid waste management
SWP: solar water pump
T&D: transmission and distribution
TANGEDCO: Tamil Nadu Generation and Distribution Company
TASMA: Tamil Nadu Spinning Mills Association
TNERC: Tamil Nadu Electricity Regulation Commission
TPD: tonne per day
TSP: total suspended particles
UDAY: Ujjwal Discom Assurance Yojana
UI: unscheduled interchange
UPNEDA: Uttar Pradesh New and Renewable Energy Development Agency
URTDSM: United Real Time Dynamic State Measurement
VCPE: venture capital and private equity
VGF: viability gap funding
WAMS: Wide Area Management System
WECI: Waste to Energy Corporation of India
WSAT: Wind Security Assessment Tools
WTE: waste to energy
WTG: wind turbine generator
WTO: World Trade Organization

Foreword

Five years ago, when Centre for Science and Environment (CSE) published its first State of Renewable Energy report, the sector was just taking wings. We were part of its cheerleaders — an environmental research and advocacy group which believed strongly that the world needs to move out of fossil fuels because of the growing risks of climate change. Renewable energy (RE) is the ticket to get the world out of its addiction to oil and gas. We were its proponents, but we had our fears.

We believed that India needed a RE policy that would be less about industry and more about supply to meet the needs of the poorest in the country. For us, renewable energy was (and is) a means to both decarbonise our economy and provide access to large numbers of people who were (and still are) energy-deprived.

Five years later, when we publish the 2019 State of Renewable Energy report, much has changed, and yet much remains the same. The government of India has an ambitious target for RE — 175 gigawatt (GW) by 2022. There is no question now that RE has arrived. Nobody argues about its imperative or feasibility. The industry has matured. There are RE companies that can bid and out-bid each other for the supply of panels, solar power plants or wind turbines. RE is an industry with sparkling offices, new age companies and flamboyant leaders. It is no longer restricted to the musty world of scientists or activist NGOs. It has certainly grown out of the world of community groups working in villages on small projects. It is real. It is big. RE plants compete with coal-based energy. Renewables are now under the Ministry of Power — RE is no longer a peripheral scientific sector, struggling to compete with the big boys.

The testimony to this growth lies in its numbers. Today, the Ministry of New and Renewable Energy (MNRE) says that the country has hit 73,000 megawatt (MW) of installed RE power, which is some 20 per cent of the country's installed capacity for power generation. On good days, when the sun is shining and the wind is blowing, RE meets some 12.5 per cent of the country's electricity demand. On other days, it is over 7 per cent. This is not small. But it is not big either.

This, therefore, is not the time to be complacent or to pat our backs for work done. Even as RE has grown, the challenges that confront India have also grown — in fact, they have become even more troublesome and crippling. This is what we must discuss.

First, there is the challenge of electricity supply. The government has an aggressive plan to reach every household with electricity. But the fact is that even as the grid reaches everywhere, the light does not. This is either because people are too poor to pay for electricity, or the distribution company is too poor to supply the electricity, or the market has no way of working in the cashless energy segment. Whatever the reason, millions in the country are still in darkness. Energy poverty is still crippling vast numbers of Indians, who cannot use this crucial enabler to progress — from education to employment. This is our challenge.

Second, there is the challenge of clean cooking energy. This is the world's wicked, wicked problem. Women across the developing world — including in China and India — are exposed to toxic emissions because of the biomass they burn to fuel their cooking stoves. Globally, it is estimated that 2.6 billion people still rely on biomass for cooking food, with 80 per cent of Sub-Saharan Africans and 66 per cent of Indian's using this inefficient and polluting fuel. This adds up to roughly half the developing world and 40 per cent of the entire world. The International Energy Agency estimates that even in 2030, 43 per cent of the developing world (33 per cent of the world's people) will continue to cook on biomass.

In India, the Census of 2011 revealed that 75 per cent of rural households used biomass and dung to cook, as against 21 per cent of urban Indian households. In addition, data from the National Sample Survey Organisation (NSSO) on energy sources of Indian households for cooking and lighting reveals that nothing changed in the two decades of 1990s and 2000. In 1993-94, as many as 78 per cent households in rural India used biomass as a cooking fuel and in 2009-10, 76 per cent used this fuel. Therefore, in this period, when urban India moved to LPG (from 30 per cent to 64 per cent), rural India remained where it was, cooking on highly inefficient and dirty stoves. This shift to cleaner energy in urban areas was not incidental. It happened because government provided subsidised LPG cylinders to the middle classes — people like you and me. The subsidy ran out because the government could not provide it to all. The poor, particularly poor women, remained where they were; first expending vast energy to collect firewood, and then inhaling toxins.

This has changed to some extent in the last five years. The Indian government's aggressive and much-needed push to provide LPG to poor households has made a dent in the cooking energy sector. The national Ujjwala programme, which provides cheaper cooking energy to households below poverty line aims to correct an historical injustice by transferring the subsidy from the rich to the poor. It does not focus on the cooking appliance — cleaner stoves — but on providing vast amounts of LPG, a fossil fuel, but cleaner and one that most urban Indians use, to the rural masses and to the poor. This is all very good.

But it is also a fact that in spite of this, households are still using dirty biomass fuel, ranging from firewood, leaves and cowdung, for cooking food. This is because it is free — the labour of women is always discounted as is their health. There is a definite correlation between income and cooking fuel. So, households do not get the refill of their cylinder as frequently as they must. The data on this is patchy, but what is clear from any visit to rural India is that smoke still fills the air. So, the 'other' energy crisis still exists, RE or not.

The third challenge is air pollution. Almost every city in the country is reeling under choking air, which is literally making us ill. There are deep connections to energy in the air we breathe. There is the belch from our every growing fleet of petrol- and diesel-powered vehicles. This is a big part of the pollution problem. Then there is the fact that industries use (in this age of RE) the dirtiest of fuels — everything from the bottom-of-the-barrel pet coke to anything (literally anything) that they can get which is cheap and so, sadly, also dirty. Industry is competing to reduce costs; it says electricity (which is where RE is fed through the grid) is either too expensive or too unreliable. So, it continues to use polluting fuels and continues to pollute.

Worse, air pollution knows no boundaries. So the use of emissions from biomass cooking fuel of the poor ends up in the same air-stew as the diesel SUV of the rich. The health impact of the foul air is now so big that even governments cannot deny the problem. Clean combustion, in other words RE, has a big role to play in clearing the air of toxins. But it is just not there.

Fourth, without any doubt, is the climate conundrum — the world and India remain addicted to fossil fuels. This is when we are definitely running out of time to combat climate change by drastically reinventing our energy system. According to the Intergovernmental Panel on Climate Change (IPCC) 2018 report on 1.5°C, the world is in serious jeopardy. IPCC has revised its previous findings; it says now that the impacts of global warming will be greater than previously anticipated at a temperature increase of 1.5°C. To stay below this temperature guardrail, the world has to cut net anthropogenic CO_2 emissions by 45 per cent, over 2010 levels and reach net zero around 2050.

This means serious energy transformation. It means that renewable energy must supply 70-85 per cent of all electricity by 2050. Currently, renewables supply some 20 per cent of global electricity, the bulk coming from hydropower plants. So, the challenge is enormous. It also means that coal use must be close to zero per cent by 2050. This is huge — the world is still addicted to coal for its electricity use, in its rich as well as poor parts. The developing world needs to provide affordable energy to large numbers of its people. How can it replace coal and yet provide this energy security? This is the question. This is where RE must matter.

I would argue, given these challenges, it is time that we began an altogether different discourse about RE. It is not about industry; its market imperatives; its predictable policy environment. This is not to say we don't need industry in RE. But we need to reinvent its imperatives. We need to redefine its objectives (and certainly its language) so that it can meet societal needs. It cannot be enough to meet targets. It must meet the poor's energy, clean air and climate change needs. Frankly, this RE market needs to be embedded in societal principles. It needs it to be emboldened and driven so that it is the change.

This is where the opportunity is enormous. Indeed, it is mind-blogging. This sector can provide the answers to growth and climate change. But the path ahead is also extremely difficult. No government has gone there before. No energy company has walked this path till now.

How will it happen? The fact is that energy security for vast numbers of the poor requires an energy delivery system that is different. It will require reaching energy, which costs less but is advanced and cleaner, into households that cannot even afford to buy the basic fuel or light. It will require cutting length of supply lines, leakages and losses and everything else that makes energy cost more, so that it is affordable. There is no clear idea what will work. But what is clear is that we have to push the envelope so that RE becomes transformational — not because it is produced, but because it is an agent of transformation of society and environment.

As yet, our track record (as the 2019 State of Renewable Energy report shows) on these fronts is not commendable. RE is like all energy sources — it could be coal or gas — it is produced and pushed into the grid. It is supplied through the conventional (and broken) distribution network. It is limited by its environment and its imagination.

This is also why efforts to do the energy business differently, through mini-micro grids or rooftop solar, are still not taking off. This work is patchy and, frankly, disheartening. It seems like we don't believe in it. We cannot make it work. I am not saying that this is the only pathway to energy access and clean energy. But we need to give it a hard try before we give up.

What is clear is that we need to do ask deliberately what it would take to put clean energy, RE, into the hands of the poor. For this, we will need to do everything to make the transition to clean power — not a few light bulbs, but the whole shindig of this new business. Similarly, we need to ask how RE can work to clean up local air in our cities. It is not just about battery vehicles, but clean power to power the batteries. It is not about shifting the source of pollution, but about really cleaning it up. Every house needs to generate this clean power; every vehicle — ideally a bus or cycle — and every industry needs to be powered from this source. This is where we need to go.

The same is the case with the wicked problem of cooking energy of the poor woman. We need RE to be the basis of the electricity that powers the cookstove — from solar and wind to biogas and all other ways in which it can be supplied into the hearth. It can do this if it is available; if it is convenient, affordable and clean. The basis for this transition has to be the health of the last person, in this case the woman behind the cookstove.

This is the course correction we must seek in 2019 and beyond. This is also important for the future of RE in India. This is the dialogue we must have so that we can seek new policies and methods. RE has to be the moral and economic imperative for a cleaner and more inclusive world. Anything less is selling us short. Anything else must be unacceptable.

Sunita Narain

Executive summary

It has been five years since we published our inaugural *State of Renewable Energy in India (the SO-RE 2014)*, in January 2014. These five years have proven to be transformational for the renewable energy industry in the country. In 2014, the industry had barely taken roots. Making a timely intervention, our *SO-RE 2014* offered several recommendations to encourage and nurture a sustainable growth for the sector. It called for pursuing a predictable, consistent policy course; developing an integrated policy and plan for 2050; and setting up ambitious goals, especially in view of the fact that the growth in capacity had exceeded official targets. It urged policymakers to pay more attention to distributed generation such as mini-grids to efficiently provide energy access to unconnected households; reduce subsidies and promote reverse bidding to push the sector to reach grid parity. It also advocated rationalisation and enforcement of RPOs (renewable purchase obligations) to stimulate demand from discoms.

Some of these recommendations, we are happy to note, have found a place in the country's policies. Meanwhile, the renewable sector has made tremendous strides — according to the Union Ministry of New and Renewable Energy (MNRE), renewable capacity has reached 73 gigawatt (GW), accounting for over 20 per cent of the country's total. Solar has performed particularly well: in 2017-18 alone, around 10 GW of solar was installed equaling the entire installed base. The capacity growth was driven by a sharp fall in tariffs, with both solar and wind auctions attracting bids that were lower than the cost of power from coal-based plants.

Generation of renewable energy has also increased sharply. Its share in total electricity supply had stalled at around 5.5 per cent during 2011-16. But in 2017-18, its share jumped to 7.8 per cent; in June 2018, when wind generation is strong, it was around 12.5 per cent. The growth was supported by a favorable policy environment offering low import duties, a payment security mechanism and efficient auction processes, combined with a dip in PV prices.

While 2017 left us with a sense of success, a lot still needs to be done to maintain the momentum

While 2017 left us with a sense of success, a lot still needs to be done to maintain the momentum. Indeed, 2018 has seen a reversal of some of the positive trends. Installations dropped to ~6.6 GW in the months between January to September. Tariffs went up as the government introduced a safeguard duty on imported PV modules. Solar auctions were cancelled or retendered for a lower size due to lack of developer interest and discoms' demand for lower tariffs. The wind sector was disrupted by the auction regime introduced in June 2016 which impacted installation — though, auction volumes climbed up in 2018 following the release of auction guidelines in December 2017.

Issues and challenges

Some of this slowdown is a temporary phenomenon, since longer term trends — such as declining PV module costs — remain in place. But there are also some policy and implementation hiccups that need to be addressed to ensure the sector continues to grow strongly.

Unpredictability in policy

Nothing can be more disruptive for an emerging sector that seeks to attract global investors, than *ad hoc* and abrupt policy changes. In the case of renewable energy, the most recent example has been the introduction of a safeguard duty on imported PV modules — this has resulted in an uncertainty about project costs, increase in tariffs and, consequently, a drop in installations.

So far, the growth in India's solar capacity has been built on an overwhelming (almost 90 per cent) share of imported PV modules because their costs are up to 30 per cent lower. In fact, the government has encouraged imports by keeping duties low — as a result, domestic manufacturing units have suffered financial distress and have experienced capacity utilisation of only around 50 per cent. The recently injected safeguard duty points to the fact that the government has not resolved its dilemma between its professed goal to 'Make in India' and the need for cheap electricity based on imported panels and equipments.

The growth in India's solar capacity has been built on an overwhelming share of imported PV modules because their costs are up to 30 per cent lower

The sector's growth has been marred in the past as well by several ill-considered steps. Auctions with 'domestic content requirement' have been introduced to support local manufacturers, but the World Trade Organization (WTO) has contended that the move violated international trade rules. The government announced a safeguard duty of 70 per cent, withdrew it, and reintroduced a 25 per cent duty in June 2018. Import duties were increased to up to 10 per cent in late 2017 and subsequently removed. In early 2018, the Solar Energy Corporation of India (SECI) announced an exclusive auction of 10 GW linked to new manufacturing capacity — the move flopped. After multiple modifications and several rounds of auctions, only one company made an offer to install 600 MW.

The wind industry has been caught unawares, similarly, by the introduction in June 2016 of an auction-based regime to award bids from the feed-in tariff (FiT) process. The transition has resulted in a dip in installations. Auctions too declined sharply and recovered only after detailed guidelines to address policy gaps were issued in December 2017.

Hiccups in auctions and PPAs

Over the last year, there have been a number of incidents that have proved to be damaging to the auction process. Several auctions have been cancelled after the winning bids were announced because the buyers felt the rates were not low enough; in some cases, discoms refused or delayed signing the power purchase agreements (PPAs). In a few others, arbitrary tariff caps were introduced resulting in auction failures.

There have been media reports as well about regulators and discoms clamouring to renegotiate PPAs. In 2017, Karnataka's Electricity Regulatory Commission (ERC) rejected PPAs that had been approved, forcing the state government to step in and overrule its decision using a rarely used provision. It is important to maintain the sanctity of the auction process and the PPAs to ensure sustained investor interest in this sector.

Power procurement policies need to be more sophisticated, with a lower share of long-term PPAs combined with peaking power and low marginal cost renewable energy

The trouble with discoms

- ***Curtailment and payment delays:*** Renewable power enjoys a 'must run' status, which means it should be scheduled first by the discoms unless there are technical constraints such as grid congestion or unavailability. However, there have been reports and court cases of "illegal" curtailment. State Load Dispatch Centres (SLDCs), in collusion with discoms, have reportedly asked developers to shut down the supply for commercial reasons. Some developers have alleged curtailment in excess of 25 per cent, which severely reduces their revenues.

  To add to this, discoms have reportedly been delaying payments to developers by several months. These problems are directly related to the financial weakness of the discoms. Renewable companies operate with thin margins and small capital, and will have difficulty remaining viable if these issues are allowed to fester.

- ***Procurement policies***: Most discoms have a sizable share of contracted capacity under long-term, two-part tariff PPAs, which provide the back-up supply to intermittent renewable power. However, an excessive share of thermal PPAs amounts to an inefficient process — it will prevent discoms from contracting renewable energy and will result in higher consumer tariffs. Yet, the Union Ministry of Power (MoP) has been encouraging discoms to sign more PPAs with thermal power plants.

  Power procurement policies need to be more sophisticated, with a lower share of long-term PPAs combined with peaking power and low marginal cost renewable energy. This would require developing a real-time electricity market. In addition, regulators may need to modify the tariff structure of both thermal power plants and renewables and the principles governing dispatch of power.

- ***Non-implementation of policies***: New regulations that have been introduced to open the electricity market or to promote renewable energy can result in potential revenue losses for discoms. Therefore, many discoms appear to have withheld support for implementation of such policies. For example, open access regulations, which allow large consumers to choose their power suppliers, have encouraged them to contract the lower-cost renewable power producers (waiver of transmission and distribution charges makes them even more attractive). Also, the bulk of open access is short term, which imposes additional costs on discoms to balance the grid and maintain back-up supply.

Similarly, rooftop installations may lead to revenue losses for discoms. Migration of large, profitable customers will leave the discoms with an increasing share of subsidised customers. Regulators need to ensure that discoms are not burdened with unfair costs on account of open access consumers. Additionally, discoms need to explore innovative business models, such as partnering with renewable companies in the rooftop sector, to offset revenue losses.

Decentralised distribution: Not yet in vogue

- ***Mini-grids ignored***: The government's focus on grid-based power supply to ensure universal access, a long-standing goal, seems misplaced. The failure to provide universal access is not only a measure of the challenge; it also underscores the inadequacy of various policies over the decades. The two latest iterations — extending the grid to all villages (through the Deen Dayal Upadhyaya Gram Jyoti Yojana, or DDUGJY) and providing electricity connection to all households (through the SAUBHAGYA scheme) are also unlikely to succeed.

  One reason for the likely failure is that the burden of ensuring 24-hour, affordable supply will rest primarily on financially-stressed discoms. Historically, the discoms have been reluctant to provide power supply to poor households given their small consumption, subsidised tariffs and poor collection. Our survey reveals that households that were recently connected do not enjoy regular power supply. Furthermore, the cost of the power is prohibitive for most poor families. Mini-grids can be a more efficient and quicker route to providing access to a sizable number of consumers, point out energy experts as well as state regulators — but is the Central government listening?

Mini-grids can be a more efficient and quicker route to providing access to a sizable number of consumers

- ***Solar rooftop's untapped potential***: In a similar vein, the potential of solar rooftop has not been exploited — the growth in renewables has been powered almost entirely by utility-scale projects. Solar rooftop has garnered a major share in many developed markets and it can be a key contributor to India's renewable ambitions as well. Residential solar rooftop offers a unique set of benefits: lower electricity bills, reduced T&D losses and a sizable number of retail investor-consumers; additionally, consumers can do away with polluting diesel generating sets for their back-up supply. But the lack of awareness about solar PV technology — their performance and maintenance — and high up-front costs dissuade retail consumers. Although India has set itself a massive goal of 40 GW of solar rooftop by 2022, only 3.4 GW had been installed till September 2018 — most of it by commercial and industrial customers, as the government has not promoted it with the right set of policies.

Wind: In the sun's shadow

Wind power, which still has a leading share of renewable capacity, has received little attention from policymakers. Wind provides valuable daily and seasonal balancing to solar generation. It also provides an additional benefit of supporting local manufacturing. Yet, the sector has suffered from periodic policy flip-flops such as abrupt changes in accelerated benefits, unexpected introduction of auctions etc. Moreover, various policy initiatives such as repowering, offshore or hybrid have been introduced with little details, which has resulted in their failure. Repowering is a very cost-effective approach to increase wind capacity of old projects (many of which are located in prime wind sites) that have a capacity utilisation factor (CUF) of as low as 10 per cent; in comparison, the latest turbines can reach CUF of over 40 per cent.

The wind industry — both the turbine manufacturing segment and wind developers — is a mature sector with significant installations over the years. The government's modest long-term goals for it, and its lack of policy support, are therefore inexplicable.

The way forward

The energy sector is at a critical juncture. Climate change and its accompanying risks have meant the world needs to plan for a decarbonised power sector. The falling cost of renewable power and grid-scale storage point us to the fact that a 100 per cent renewable-based electricity supply is technically and economically feasible in not too distant a future.

Furthermore, renewable-based distributed generation offers advantages over supply from a centralised infrastructure. A new supply model will need to ensure viability of various providers, competitive price discovery and new policies to determine tariffs and schedule power. Meanwhile, electric vehicles and super-efficient, internet-connected devices, combined with demand-side management tools, will modify demand patterns. These changes will require redesigning the grid. In short, a new energy architecture would be needed.

Energy decarbonisation

To begin with, the country needs an ambitious low-carbon growth pathway. India's INDC (Intended Nationally Determined Contributions) goal for 2030 — building up a non-fossil fuel capacity of 40 per cent of the total — is not ambitious enough and would be easily surpassed. The Niti Aayog's draft National Energy Policy, 2017 assumes a largely centralised, conventional fuel-based supply. It projects 570 GW of renewable capacity by 2040, less than half of the total capacity of 1,200 GW, while the share in electricity supply is projected to be only 28 per cent by 2040, with fossil fuels contributing over 60 per cent. The country needs to have an ambitious goal to generate 100 per cent power from non-fossil fuel sources by 2050-2060.

Secondly, while the 175-GW goal has led to investor interest and boosted the sector, there is no clarity about the assumptions behind the target. The rationale for various sub-sectors — 40 GW for solar rooftop or 60 GW for wind — is even less convincing. Going forward, there should be an integrated renewable strategy which would include balanced targets for the various sub-sectors.

The energy sector is at a critical juncture. Climate change and its accompanying risks have meant the world needs to plan for a decarbonised power sector

Thirdly, there should be a clear plan for fossil-fuel based capacity — its role will steadily transition from being central to the country's energy mix to becoming the back-up supply for renewables. The National Electricity Plan (NEP), 2018 prepared by the Central Electricity Authority (CEA) is based on questionable assumptions such as a deceleration in renewable growth (100 GW during 2022-27 compared to 117 GW in 2017-22). Consequently, it has concluded that a huge 93 GW of additional coal capacity was required during 2017-27. As a result, 70 GW of thermal power plants are under construction as of September 2018. But some of these plants in the pipeline are already stalled or stressed. In this scenario, no more new coal-based plants should be approved. In fact, old, inefficient and expensive plants should be shut down.

Distributed generation

The second major trend that policymakers need to plan for is the increase in the share of distributed renewable generation (DRE). This is already contributing a major share in several parts of the world, given its falling costs compared to grid-based supply. However, DRE has received little policy support in India.

SOUPARO BANERJEE/ CSE

Solar rooftop: So far, to promote solar rooftop, the government has relied on subsidies to residential households. This approach does not address the main bottlenecks: high up-front costs and lack of financing; discoms' reluctance to support installations; low comfort with technology; and bureaucratic hurdles. The government's latest proposed policy, Sustainable Rooftop Implementation for Solar Transfiguration of India (SRISTI), appears misguided and is essentially a short-term approach — it compensates discoms for potential revenue losses from rooftop installation, instead of encouraging sustainable and innovative business models.

The problem of high up-front cost and doubts about technology can be addressed by RESCOs (Renewable Energy Service Companies) that can offer long-term supply contracts to households. A multi-pronged effort would be needed to build the RESCO industry for the residential sector: ensuring sanctity of PPAs, making repossession of defaulters' assets easy, and encouraging discoms to partner with RESCOs in customer sourcing, installation and bill collection.

Mini-grids: Mini-grids have the potential to efficiently provide energy to households in regions that might not be satisfactorily served by discoms. In fact, mini-grids also thrive in areas that are connected to the grid. The government needs to introduce a comprehensive policy that requires mini-grids to provide a certain standard of supply (for example, total hours of supply and a minimum supply during peak hours) and incentivise mini-grids to ensure tariffs are in line with those of grid-based supply. Secondly, the policy should provide for a viable business model for mini-grids, which means mini-grids should have reasonable and well-defined exit options (sale price of mini-grids' assets, tariff for sale of power to discoms etc), once the grid supply does become reliable in their markets. For this, the mini-grids' network should comply with the grid codes so that they can be seamlessly integrated with the grid, which in turn would require capital support for additional investment in distribution network.

There are other models as well that are emerging. The government is planning to distribute around 1.8 million solar water pumps, which can be linked together in a mini-grid and supply to the grid when they are not needed to draw water. This would prevent wasteful extraction of water and provide an alternate source of income. In many developed markets, groups of residential blocks are establishing micro-grids, a market that is essentially similar to rooftop solar in residential societies. Policies need to both anticipate and plan for these developments.

Grid of the future

Integrating 175 GW of renewable by 2022, which translates into around 20 per cent share of renewables in total energy, will not be a challenge. A recent report by the NREL estimates this can be achieved with curtailment of only 1.4 per cent by using the inherent flexibility of the country's coal-based fleet. Importantly, current grid expansion plans, if executed on schedule, would be sufficient. Regulations such as forecasting and scheduling, deviation settlement mechanism and ancillary services mechanism are being implemented across states, which will help in efficient integration.

The future electricity scenario — which is expected to include very high penetration of variable renewable energy, sizable distributed supply, more volatile demand and internet of things — will require 'smart grids' that use communications infrastructure, control systems and information technology for efficient delivery. The National Smart Grid Mission was a good start, but its ambition and outlay (Rs 990 crore for 2017-20) are extremely limited in the context of a rapid increase in renewables.

A multi-pronged effort would be needed to build the RESCO industry for the residential sector

Smart grids have real-time awareness of the grid, which can enable efficient dispatch and balancing when power dynamically flows in multiple directions. Distributed energy resources (including EV batteries) can be linked in micro-grids and balanced through flexible resources (such as batteries) leading to lower cost of operations. Micro-grids can also provide ancillary services and improve grid resiliency. Advanced metering infrastructure and smart appliances will allow automated demand management; data analytics can identify meter tampering. Remote sensing and control systems and machine learning can accurately locate faults and quickly resolve outages.

While some of the scenarios presented above are still in the future, a number of countries are already in advanced stages of smart grid implementation to assist in efficient integration of distributed renewal energy and demand side management using market signals.

Reforming discoms

The country's ability to reach the target of 175 GW by 2022 will depend on the health of discoms, which are at the heart of the electricity market. Most discoms in India incur significant losses due to a combination of high aggregate technical and commercial (AT&C) losses, inadequate tariff increases, cross-subsidies and poor billing. The renewable energy market is already witnessing problems such as muted demand for new capacity, attempts to renegotiate PPAs or cancellation of auctions, curtailment of power for commercial reasons and delays in payments to developers. Some of the problems stem from poor governance/political difficulty of raising tariffs. Others are on account of misguided strategies — for example, excessive long-term capacity contracts. New policies to promote renewables, if ill-considered, may result in revenue losses and higher costs for discoms, exacerbating their financial distress.

The government's latest effort to reform the discoms, the Ujjwal Discom Assurance Yojana (UDAY) scheme, has translated into shifting their substantial debt load on to the states. However, UDAY does not appear to be succeeding in resolving the fundamental challenges to discoms' sustainability — cutting AT&C losses and rationalising tariffs.

The discom model needs to be rethought of. A separation of carriage and content, which implies customer choice and competition among suppliers, is required. However, it will lead to migration of high-tariff paying customers, leaving the discoms with an unprofitable and subsidised consumer base. Policies should ensure that open access consumers pay an equitable amount for network access and back-up supply; in the initial years, there should also be a provision for a cross-subsidy. Legacy discoms need to be compensated to service remaining customers through explicit budgetary support.

Discoms also need to explore newer revenue sources such as supporting DER, enabling retail exchange for producer-consumers, energy efficiency and demand response, and ancillary services to/from retail customers

The country's ability to reach the target of 175 GW by 2022 will depend on the health of discoms, which are at the heart of the electricity market

Building storage ecosystems

Inexpensive energy storage is critical to achieving a high penetration of variable renewable energy. The levelised cost of lithium-ion battery, which has become the dominant technology, has fallen to US $0.2/kWh for grid-scale storage (similar to a gas peaking plant). A rapid dip in prices has resulted in grid-scale storage being deployed to balance the grid. Industry experts predict battery pack costs will halve to US $100/kWh in five years, at which point there would be a quantum shift in its value addition.

Bloomberg predicts 1,000 GWh of storage by 2040, which will require US $620 billion of investment. Countries such as China, the US, Korea and Japan are building huge capacities to dominate this market, with their governments providing significant funding for R&D. India runs the risk of becoming an importer of Chinese batteries, similar to what happened in the case of solar cells.

However, the future of storage is not only about lithium-ion — India has some time to establish a competitive industry. The use of the battery will

For the first time, decarbonised electricity appears feasible in the foreseeable future. Can this vision be translated into reality?

be varied and so should be the storage types — from pumped hydro and compressed air to batteries using different materials. Varied battery types reduce reliance exposure to few materials. Indigenous research can improve upon existing technology in terms of cost and performance. Policy support for EVs, DRE etc — potentially a very large domestic market — can drive scale for the battery industry. The country should also consider providing seed capital or subsidised financing to support industries of the future. Finally, policies should promote a wide storage ecosystem — for example mobile storage, leasing, conversion of IC engines to electric etc — to expand the market.

The first word

As pointed out earlier in this chapter, we stand at the cusp of a momentous shift in the energy sector. For the first time, decarbonised electricity appears feasible in the foreseeable future; it is not an abstract vision. The question is, whether India will reach peak coal and 100 per cent renewable quickly and efficiently, or whether it will be a delayed process, merely egged on by global momentum.

Secondly, will the transition bring about innovations in the electricity market, or will it result in undesirable disruption in delivery of electricity and in the well-functioning segment of the market? Thirdly, will we be able to use this opportunity to develop indigenous research and manufacturing to service both the domestic and the vast global markets, or will we become an importing client? Only the right strategy, policies and incentives can help us get the right answers.

CHAPTER 1

The road to 175 gigawatt

The renewable energy sector in India has come into its own in the last few years, with the country now home to some of the largest solar and wind installations in the world. The sector received a major boost after 2015 following the government's decision to create 175 gigawatt (GW) of renewable energy capacity in the country by 2022. The new target redefined the scale and scope of the sector, especially for wind and solar which comprise 60 GW and 100 GW (the original goal for solar was 20 GW), respectively, of the goal. Over the last few years, the government has launched a series of supportive policies and schemes to encourage the building up of renewable capacity in the country. The dramatic fall in prices of Chinese-made solar PV modules (by over 35 per cent between 2015 and 2017) has helped further boost the sector.

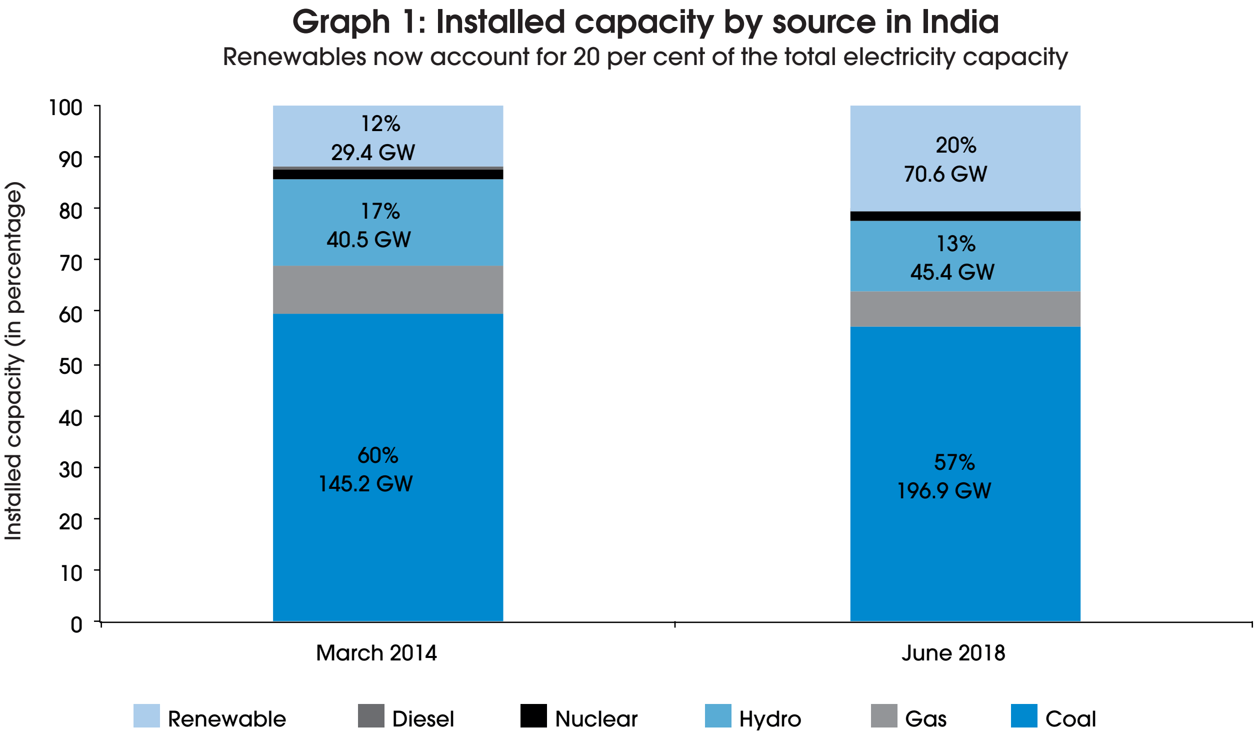
As a result of all this, renewable capacity in India has registered a sharp growth, and stands at 74.8 GW as of November 2018, up from 36.5 GW in March 2014; it now contributes 20 per cent of the country's total electricity capacity (*see Graph 1: Installed capacity by source*). India currently has the world's third and sixth largest wind and solar installed capacities, respectively.[1]

However, renewable energy still makes up only a small portion of the total generation mix — the low capacity utilisation factors (CUF) of wind and solar plants have meant the share of generation from renewables has remained very small. This share has increased from 5.6 per cent of the total generation in 2014 to a mere 7.8 per cent in 2018 (*see Graph 2: Generation mix over the years*). Coal-fired power plants continue to dominate the country's energy mix with a 57 per cent share of the capacity; since these plants run at high capacity utilisation, the share of thermal generation is a very high 80 per cent.[2]

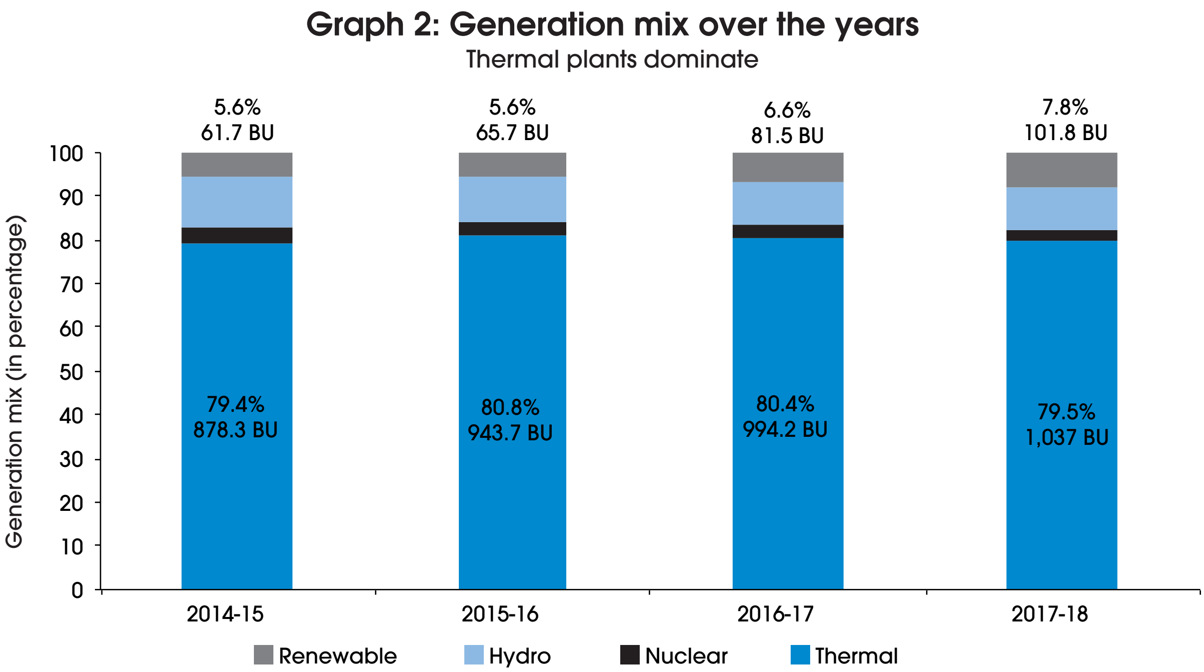
Renewable capacity in India has registered a sharp growth, and stands at 74.8 GW as of November 2018, up from 36.5 GW in March 2014

Reaching the 175-GW target

The 175-GW renewable capacity target by 2021-22 is an ambitious goal. It implies increasing the share of the capacity from around 20 per cent currently to over one-third by March 2022 — as per the estimates of the National Electricity Plan (NEP) 2018, prepared by the Central Electricity



Source: Compiled from Central Electricity Authority's installed capacity reports, http://www.cea.nic.in/monthlyarchive.html



Source: Compiled from Central Electricity Authority's generation reports, http://www.cea.nic.in/monthlyarchive.html

The geographical concentration

While the push to expand renewable capacity has come from Central government-driven policies, the sector's growth has been unevenly distributed among various states, with the southern and western states home to most of the wind and solar assets (*see: Renewable capacity in various states — July 2018*). The states in these parts of the country also have higher targets since they hold greater solar and wind potential.

Remarkably, these states have outperformed other states in terms of two key measures: the share of their installations mostly exceeds their share of the country's total potential, and several states such as Karnataka, Tamil Nadu, Andhra Pradesh-Telangana (combined) and Rajasthan have already achieved a significant share of their overall targets.

Renewable capacity in various states — July 2018

Southern and western states dominate

State	Wind target (MW)	Installed wind capacity (MW)	Solar target (MW)	Installed solar capacity (MW)	Percentage of combined wind and solar targets (%)	Percentage of total wind and solar installed capacities (%)	Percentage of state RE target achieved (%)
Karnataka	6,200	4,713	5,697	5,172	7	18	83
Tamil Nadu	11,900	7,969	8,884	1,819	13	17	47
Gujarat	8,800	5,537	8,020	1,344	11	12	41
Rajasthan	8,600	4,281	5,762	2,310	9	12	46
Andhra Pradesh	8,100	4,009	9,834	2,517	11	12	36
Maharashtra	7,600	4,777	11,926	763	12	10	28
Madhya Pradesh	6,200	2,497	5,675	1,210	7	7	31
Telangana	2,000	100	0	2,990	1	5	155
Other states	600	55	43,735	4,201	28	8	10

Source: Based on information from MNRE and state nodal agencies

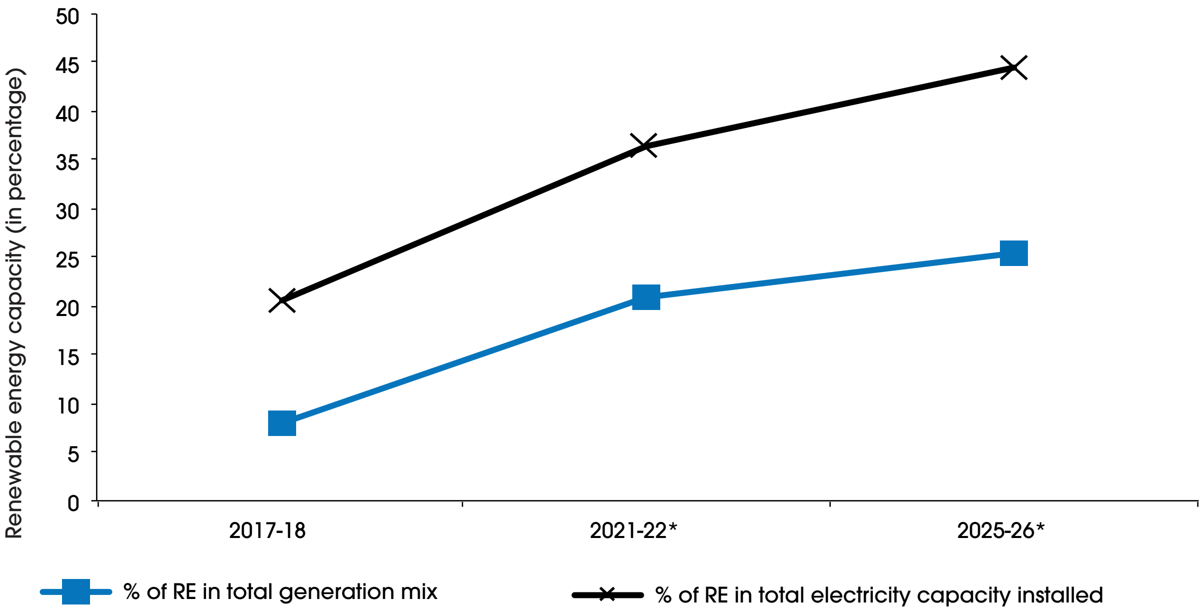
Authority (CEA). The NEP projects that renewable energy capacity will increase to 275 GW by March 2027 with a share of almost 45 per cent; its share of generation is projected to be 25 per cent in 2026-27 (*see Graph 3: Share of renewable energy capacity in total capacity and generation mix*).[3]

Trends in renewable capacity addition

Are the NEP's projections supported by past trends? The growth of renewable energy capacity in India between 2014 and 2018 is attributed to grid-connected solar and, to a lesser extent, wind. While the annual renewable capacity additions have been impressive, especially between 2015 and 2017, the shortfall has increased since 2017-18 as annual targets have also climbed up (*see Graph 4: Annual renewable capacity addition*).[4]

Graph 3: Share in total capacity and generation mix

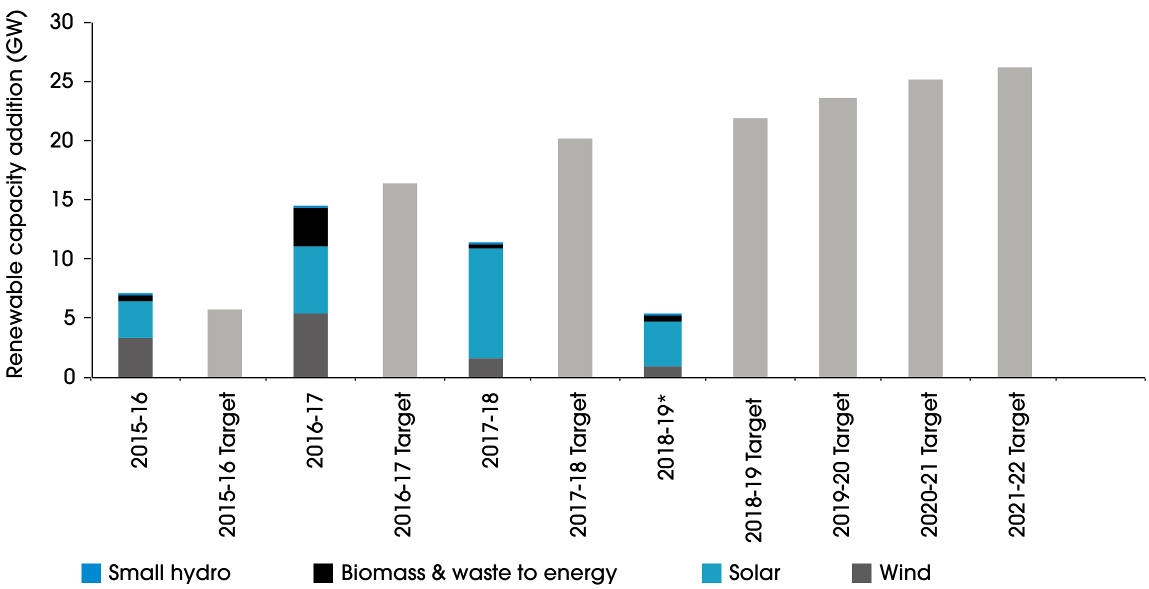
The National Electricity Plan projects substantial jumps in share of renewable energy capacity



Source: National Electricity Plan, CEA, http://erpc.gov.in/wp-content/uploads/2017/03/NEP_slides_200418.pdf

Graph 4: Annual renewable capacity addition vs yearly targets

Higher targets have meant more shortfalls



Source: MNRE* as of November 2018, https://mnre.gov.in/physical-progress-achievements

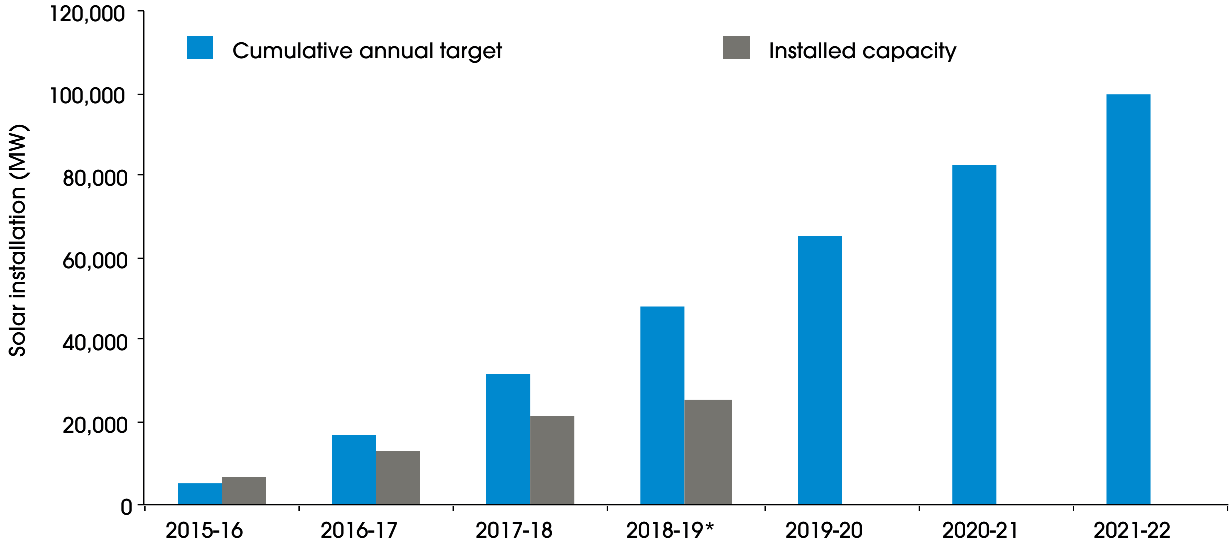
Solar capacity has increased sharply from 3 to 22 GW between 2015 and 2018 and is expected to contribute the bulk of the capacity addition. However, till July 2018, it had achieved less than 50 per cent of the March 2019 target of 48 GW (*see Graph 5: Solar installation — achievements vs targets*). The rooftop PV sector has been faring particularly badly, with only 2.1 GW installed by December 2018 against a target of 40 GW.[5] As the targets in the next few years climb further, annual new capacity additions have to grow even more to reach 100 GW. Based on the performance so far and the outlook, it seems unlikely that they will.

One of the main impediments to utility-scale solar is the poor health of the discoms. Many discoms appear to be slowing down on new purchase commitments — the better ones may have already sourced sufficient renewable capacity. Meanwhile, solar rooftop continues to struggle due to lack of financing available to households and because developers find the residential and small business sector unattractive.

The wind sector presents a better picture. As of July 2018, wind capacity totaled 34.4 GW against the March 2019 target of 40 GW (*see Graph 6: Wind installation — achievements vs targets*).[6] In fact, the likely shortfall would be partly due to the sudden introduction of an auction scheme for wind projects, which slowed down installations in 2017. After December 2017, the sector has been picking up again with auctions totaling 6.9 GW, according to data compiled by CSE. It is, therefore, conceivable that the wind sector might achieve a significant share of the 60-GW goal by 2022, especially if the government manages to jump-start repowering and hybrid projects.

Graph 5: Solar installation — achievements vs targets

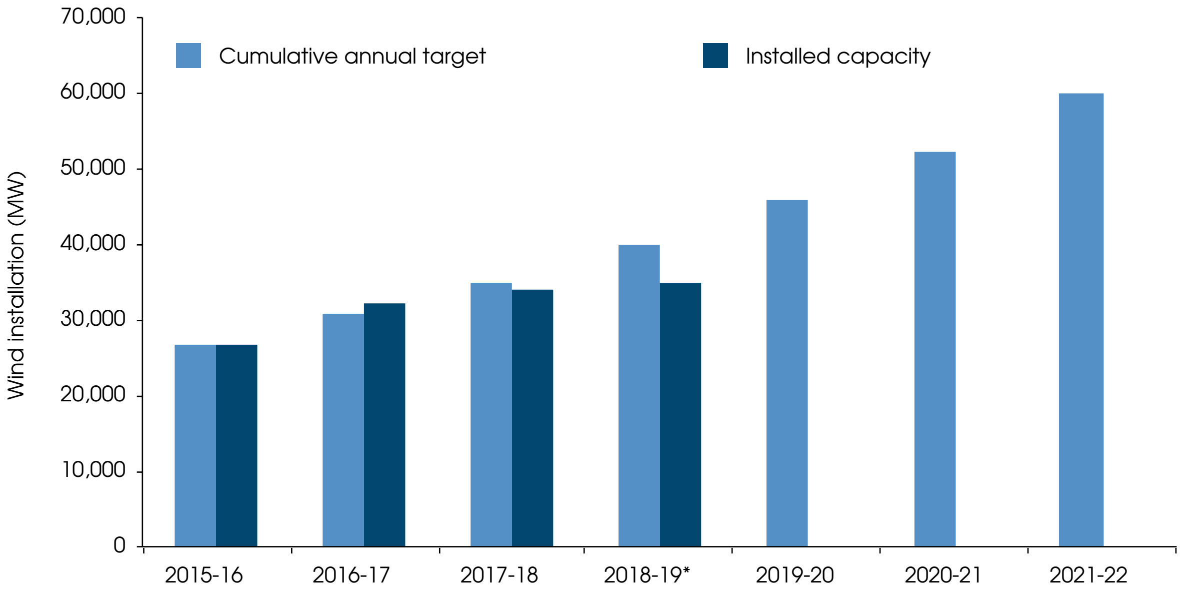
Capacity has increased, but targets remain out of reach



Source: Compiled from MNRE Annual Reports, https://mnre.gov.in/annual-report*, November 2018

Graph 6: Wind installation — achievements versus vs targets (MW)

The sector looks set to achieve a significant portion of its target



Sources: Compiled from MNRE reports; annual targets obtained from Prayas, http://www.prayaspune.org/peg/publications/item/download/813_72f650b395383a796d4b5b898a61a10e.html*, November 2018

Auctions with reverse bidding — the driving mechanism

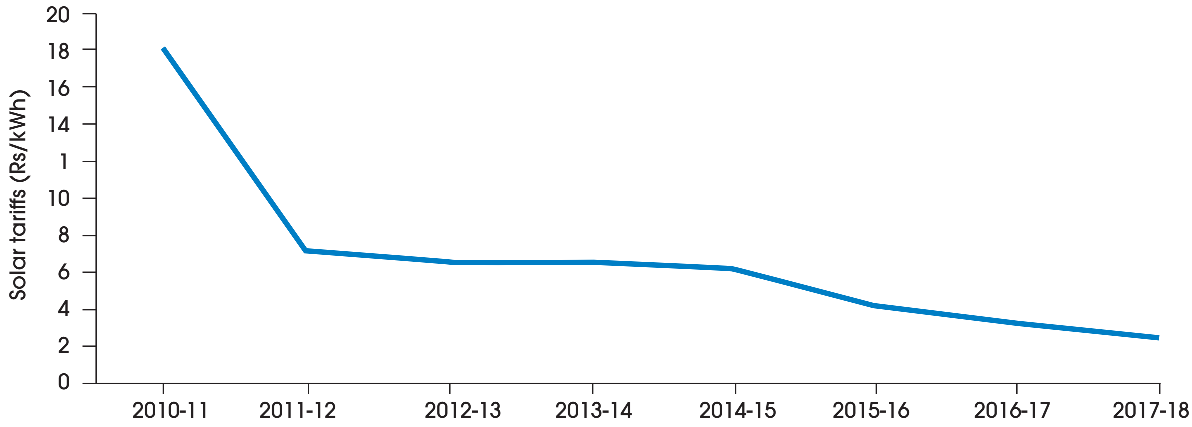
One of the notable drivers of renewable success in the country has been the introduction of auctions with reverse bidding. In these, bids which offer the lowest tariffs are declared the winners. The success of these auctions can be measured by the fact that the bids made in them by developers have been consistently below the tariff benchmarks set by the Central Electricity Regulatory Commission (CERC) — in fact, by 2017, this allowed the CERC to stop publishing its benchmark tariffs altogether.

The mechanism has helped foster competition by driving down prices which, in turn, has incentivised discoms to sign up for ever increasing capacity contracts. In the last few years, wind and solar have gone from being expensive sources of power that needed subsidy support to becoming cheaper than conventional power (*see Graph 7: Lowest solar tariffs achieved in FY 2010-18*).

In the initial years, wind tariffs were determined by feed-in tariffs (FiTs), with price demarcation across zones based on favourable wind conditions. The FiT was reviewed over the years by the State Electricity Regulatory Commissions (SERCs). Occasionally, it showed an upward trend, ranging between Rs 4 to 6.5 per kilowatt-hour (kWh). However, the success of the solar auctions led to the adoption of the same mechanism for wind from 2016 onwards. This ended the wind developers' complacency with regard to tariffs — the auctions began receiving bids that were at par with those in solar. While the transition created a short-term disruption that resulted in a dip in the number of new installations, the last few auctions held in 2018 have seen successful project allocations, with the lowest tariff achieved being Rs 2.44 per kWh, significantly below the tariffs previously offered in the most favourable zone. (*see Graph 8: Benchmark CERC wind tariffs in 2014-16*).[7]

Graph 7: Lowest solar tariffs achieved in FY 2010-18

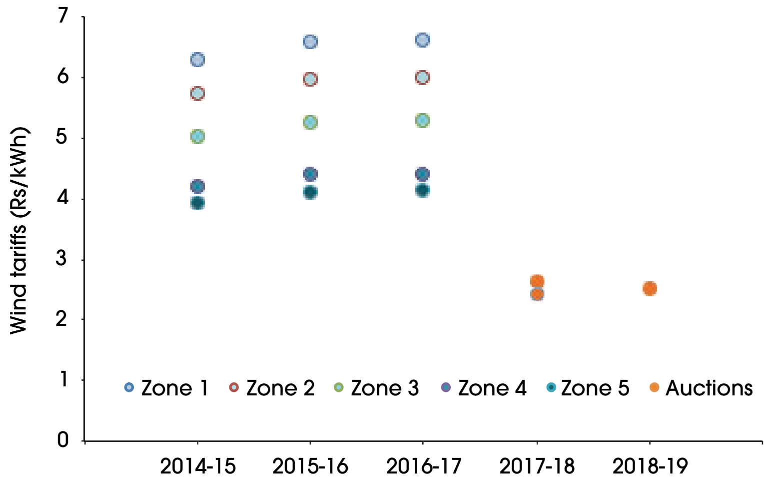
Solar has become cheaper than conventional sources of power



Source: Based on data from MNRE and various news reports

Graph 8: Benchmark CERC wind tariffs in 2014-16

Wind auctions got tariffs significantly lower than the benchmarks



Source: Compiled from CERC tariff orders

Investment in renewable energy in India

As of November 2018, close to 100 GW of capacity installation goal was pending, which would require capital investment of over Rs 600,000 crore (*see Table 1: Investment required to meet the 175-GW target*). This translates to approximately US $28 billion (Rs 200,000 crore) a year. In comparison, the average annual investment in the sector has been significantly less, with the highest amount clocked at US $13.8 billion (*see Graph 9: Annual investment in renewable energy in India*).[8]

Table 1: Investment required to meet the 175-GW target

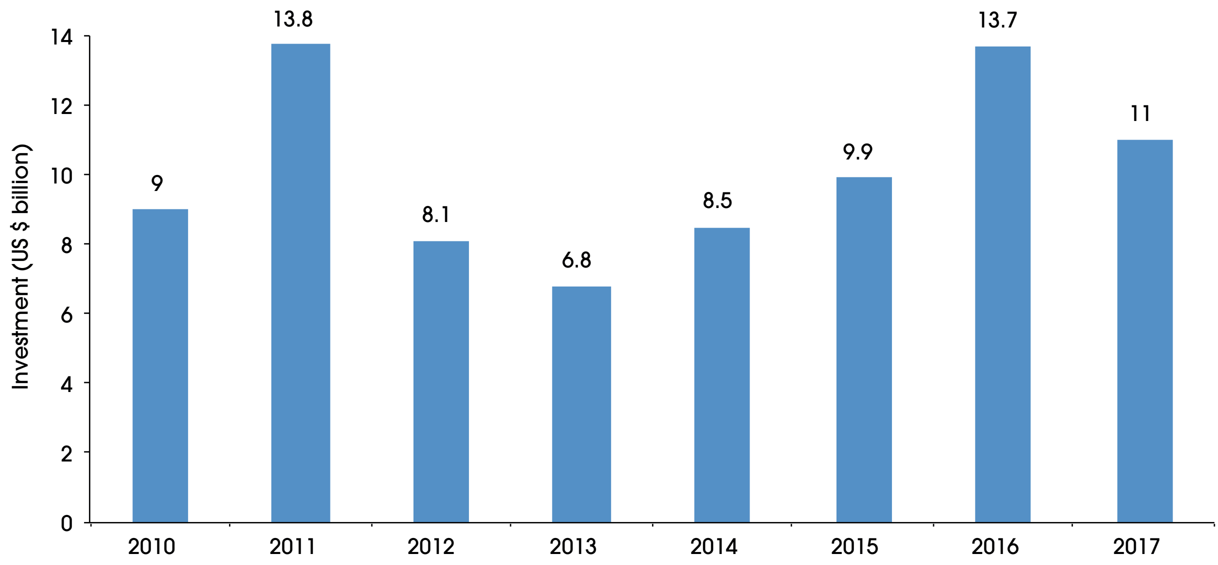
100 GW of capacity yet to be installed, at over Rs 600,000 crore

Technology	Capacity needed to meet 2022 target (MW) as of November 2018	Cost per MW (in INR crore)	Investment required (in INR crore)
Utility-scale solar	36,800	4.5	165,600
Solar rooftop	37,861	5.5	208,235
Wind	25,000	5	125,000
Evacuation infrastructure	–	1	100,000
Total	–	–	598,835

Source: CSE estimates

Graph 9: Annual investment in renewable energy in India

While on the rise, the investment is still below required levels



Source: Bloomberg New Energy Financehttps://data.bloomberglp.com/bnef/sites/14/2018/01/BNEF-Clean-Energy-Investment-Investment-Trends-2017.pdf

Table 2: Financing sanctioned for RE projects (March 2016)

Commercial banks and non-banking financial corporations have chipped in

Bank/NBFC	Capacity (MW)	Amount sanctioned (Rs crore)	Shares
Public banks	12,620	19,639	SBI (28%)
Private banks	6,905	18,660	Yes Bank (13%)
Public NBFC	6,122	20,802	IREDA (41%)
Private NBFC	5,337	19,728	L&T Infra Financing (75%)

Source: The Economic Times, https://economictimes.indiatimes.com/industry/energy/power/banks-financial-institutions-provide-over-rs-78k-crore-for-clean-energy-projects/articleshow/53265652.cms

However, due to the fall in capital costs per MW of both wind and solar (the latter by 45 per cent during 2011-17), the investments in 2015-17 have translated into a higher volume of installations, according to CSE estimates (*see Table 1: Investment required to meet the 175-GW target*).[9]

Sources of finance

Wind and solar developers have been financed, to a significant extent, by Indian commercial banks and non-banking financial corporations (NBFCs). As of March 2016, banks and NBFCs had together sanctioned Rs 78,830 crore (of which Rs 33,483 crore was disbursed)[10] (*see Table 2: Financing sanctioned for RE projects*). The trend held steady in 2017 as well, with SBI, L&T, Yes Bank, IREDA, IDFC and PTC continuing to be the largest financiers of new capacity in renewable energy in India.[11] In 2016, the Reserve Bank of India (RBI) mandated that renewable energy be added to the list of 'priority sectors' — this ensured the flow of credit to this industry.[12]

The high dependency on Indian banks, especially public sector ones, carries several risks. A significant number of independent power producers are highly leveraged. The drop in tariffs has led to developers operating on thin margins and falling equity returns for the developers. This leaves little room to maneuver in case of unexpected problems such as payment delays, defaults by discoms or curtailment, which can quickly overwhelm developers. A rise in the banks' non-performing assets (NPAs) on account of renewable projects could dry up the flow of credit to the sector.

Wind and solar developers have been financed by Indian commercial banks and non-banking financial corporations

Private equity

Many IPP (independent power producers) projects are financed through bank loans midway through the construction process or after commissioning. Relatively well established, larger IPPs have also secured capital via bonds, and equity investment. However, access to financing poses challenges, especially for smaller companies to grow, hence most IPPs have relied on private equity (PE) financing. In fact, the flow of PE into the renewable energy sector has been considerable. According to PricewaterhouseCoopers (PwC), the year 2017 had seen PE investments worth US $1.5 billion in the sector.[13] In the first three quarters of 2017, the solar sector in India received 59 per cent of the total global venture capital and private equity (VCPE) financing in the sector.[14]

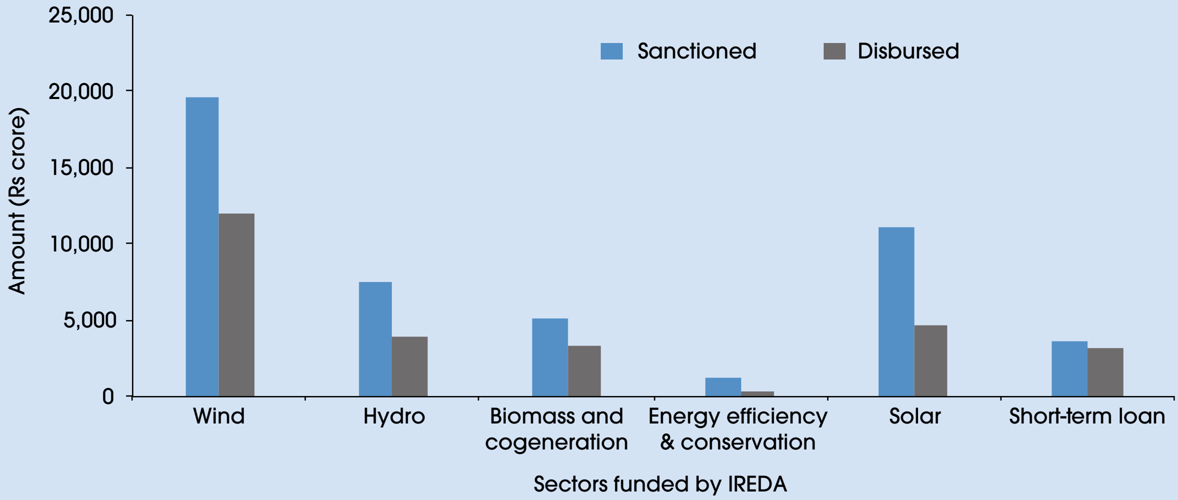
The Indian Renewable Energy Development Agency (IREDA)

The IREDA, established in 1987, is a wholly government-owned NBFC. Its primary function is the financing of renewable energy, and it was once the largest source of financing for the sector. Aside from budgetary allocations from the MNRE, IREDA raises funds from domestic and multilateral banks.[1]

The agency is currently facing scrutiny, particularly on account of its poor disbursement rates and questions over its loan sanctioning process. IREDA has also been experiencing high NPAs (net NPA was 3.84 per cent as of March 2018, up from 3.77 per cent in the previous financial year. This does not account for the loans that were written off.)[2]

The agency plans to sanction Rs 13,000 crore in FY2018-19, which would be 20 per cent of the total credit for the renewable sector.[3] It is an ambitious target, and IREDA would have to improve its credit approval processes and transparency to meet it.

IREDA's sanctioned vs disbursed amounts (1987-2017)



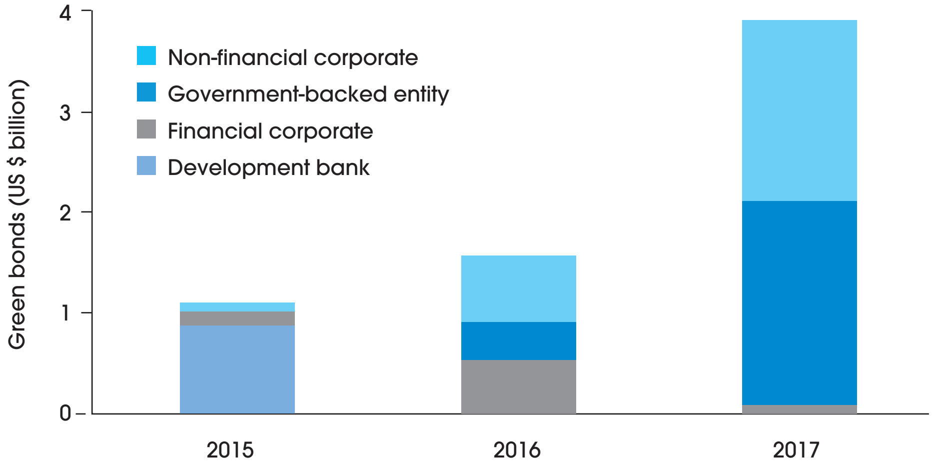
Source: Compiled from IREDA's Annual Reports

However, this source of financing would be adversely impacted if the project returns become volatile, or are artificially capped. Having a policy environment that is market-friendly and consistent is, therefore, critical for encouraging participation by private equity investors.

Foreign direct investment (FDI)

In response to the policy push in the country, foreign direct investment (FDI) in renewables has gone up. Of the total Rs 40,280 crore (US $6.8 billion) FDI directed at the sector in India since 2000, 54 per cent was made between March 2014 and June 2018.[15] However, when viewed in the context of the

Graph 10: Green bonds issued by Indian entities
Developers and government-backed entities have embraced green bonds



Source: Climate Bond Initiative, https://www.climatebonds.net/resources/reports/india-country-briefing-july-2018

US $35 plus billion invested in the sector between 2015 and 2018, the FDI component of US $3.217 billion in the same period is relatively small.[16]

Green bonds

'Climate' or 'green' bond refers to bonds issued for projects that are considered environmentally friendly. A fairly recent concept, pioneered by the European Investment Bank in 2008[17], global green bond issuance (i.e. the total debt raised by bonds globally where the use of proceeds have been solely for "green" projects), currently stands at US $389 billion.[18] The first green bond was issued in India in 2015 by the EXIM Bank for US $500 million. So far, US $6.5 billion worth of climate/green bonds have been issued by banks, renewable IPPs and government agencies in India (*see Graph 10: Green bonds issued by Indian entities*). A majority of these bonds were issued for financing renewable projects.[19]

The road ahead

The 175-GW target has been a driving force for the sector and is in no small part responsible for the introduction of supportive policies, market mechanisms and investor confidence in renewable energy in India. Overall, the phenomenal growth in capacity as a result of reverse bidding auctions, that resulted in grid parity of wind and solar, underscores the fact that renewable energy has been a success story, 2015 onwards.

But this success has come about predominantly on the back of large-scale solar. The wind industry, historically the largest source of renewable generation in the electricity mix in India, is continuing to face headwinds. Distributed generation — solar rooftop and renewable-based mini-grids — has performed poorly.

The success of renewable energy has come about predominantly on the back of large-scale solar

The clarity around the end goal of 175-GW needs to be supported by ensuring continuity and longevity of successful policy measures and regulations

As of mid-2017, cracks in the large-scale solar sector have begun to appear, as market conditions turned unfavourable and entrenched problems in the electricity procurement market reared their head. Wind is, likewise, yet to gain momentum.

While the sector has managed to obtain financing for its growth thus far, the journey forward might prove to be arduous. The banking sector has been plagued with NPAs, with the thermal power assets proving to particularly culpable. The relatively new renewable sector is also financed, to a large extent, by Indian banks and any newfound reluctance in lending to the power sector might slow down growth. With FDI inflows insufficient to pick up the slack at the moment and the fluctuating rupee causing difficulties in raising foreign capital and in the bond market, there is cause to be concerned about whether finances will be as readily available in the near future.

One of the most successful interventions by the government in the sector are those that mitigate the risks posed by off-takers that have poor credit ratings — payment security mechanisms that guarantee that the developer gets paid even if the discoms cause delays. It is a measure that will need to be carried forward and sustained to ensure that banks continue to finance wind and solar projects. The sancity of the auction process needs to be upheld, leaving no room for cancellation at the whim of nodal agencies and discoms. Likewise, power procurement agreements should be enforced and not be subject to the uncertainty of renegotiations.

Finally, policy consistency is of the essence. Return on equity is already squeezed due to aggressive bidding in the auctions and private equity investors will need the reassurance of continuity of those regulations that have de-risked the sector, to an extent, post-2015.

The clarity around the end goal of 175-GW needs to be supported by ensuring continuity and longevity of successful policy measures and regulations. It is imperative that renewable energy growth is sustained and integral to the country's energy mix, up to and beyond 2022.

CHAPTER 2

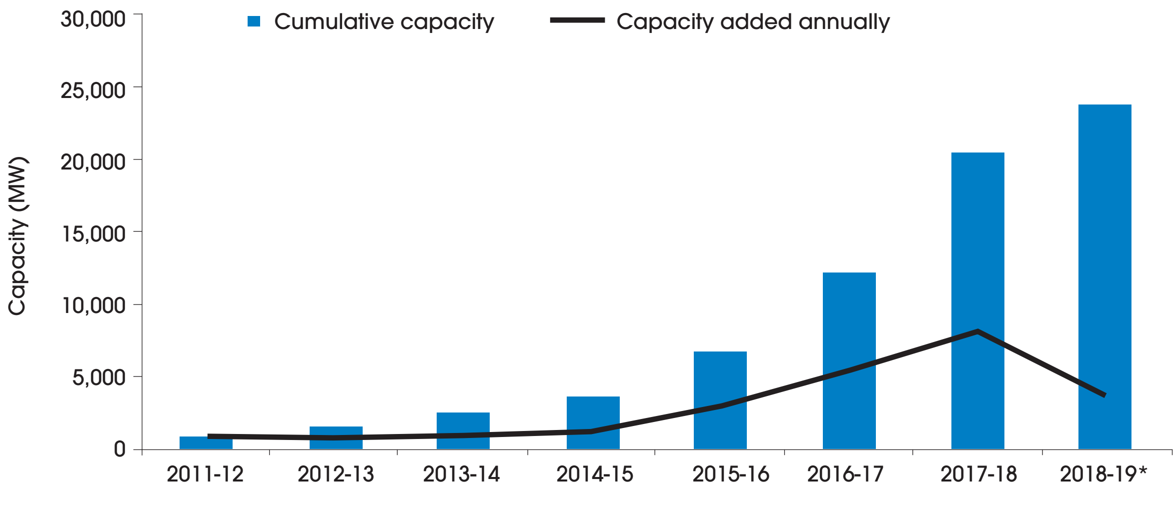
Utility-scale solar: Charting a new course

India's ambitious renewable energy goal of developing 175 GW capacity by 2022 leans heavily on the Jawaharlal Nehru National Solar Mission (JNNSM), the country's key solar programme, which targets to install 100 GW of solar energy, 60 GW of which would comprise large or utility-scale solar capacity and 40 GW, rooftop solar.

Over the last four years, the utility-scale solar sector's performance has been exceptional, with an average annual growth rate of over 70 per cent. The installed solar capacity has increased from 2.6 GW in March 2014 to 26 GW as of December 2018, of which utility-scale solar comprises over 91 per cent.[1] In 2017-18, 8.3 GW of utility solar capacity was installed, a 50 per cent growth over the previous year (*see Graph 1: Utility-scale solar capacity*). The outlook has remained healthy with 9.5 GW of capacity in the pipeline at the end of August 2018.[2] During January to July 2018, over 10 GW of solar projects were

Graph 1: Utility-scale solar capacity

The average annual growth has clocked an impressive 70 per cent



Source: Information compiled from MNRE Annual Reports, 2011-18, https://mnre.gov.in/annual-report *as of December 2018 auctioned. Although some auctions were cancelled recently because discoms felt the bids were too high, these hiccups do not change the fact that the long-term fundamentals of the utility-scale solar sector remain strong.

A number of factors have come together over the last few years to provide a boost to this sector: the sharp increase in the JNNSM goal from its original target of 20 GW; continually falling cost of solar PV driven by overcapacity in China; supportive Central government policies and schemes such as the establishment of solar parks and the Solar Energy Corporation of India (SECI); introduction of competitive auctions and payment security mechanisms to offset discom risks; easy financing from banks, private equity and other investors. These factors have led to the entry and growth of numerous solar developers, and tariffs have now reached below that of coal-based power, which in turn has persuaded discoms to sign up for large long-term capacity.

However, this rapid growth has exposed some risks. First, the sector's growth is overly reliant on Central government support. SECI-run auctions dominate the sector with their payment guarantees that protect developers from payment delays by discoms. Corporate procurement of renewable energy has failed to take off due to inconsistent implementation of open access. Projects face curtailment of power, given the lack of clear regulations to forecast and schedule variable renewable power, combined with "illegal" direction by the load dispatch centres that are driven by commercial reasons. Discoms' existing two-part tariff PPAs (power purchase agreements) with coal power plants have provided back-up capacity for renewable energy — however, excessive coal power PPAs are now inhibiting discoms from signing solar PPAs. Most of these issues require policy interventions to open up the market further, which will increase competition and help it mature.

India's solar potential

India's southern states — Karnataka, Andhra Pradesh, Tamil Nadu and Telangana — are together home to almost 50 per cent of the installed capacity in the country, though their collective potential is only 8 per cent of the country's total.[3] They have pushed supportive policies to help grow solar capacity. The western states — Rajasthan, Gujarat, Maharashtra and Madhya Pradesh — have some of the highest potential in the country. Of these, Rajasthan and Gujarat have installed significant capacities; the other two are not far behind (*see Table 1: States — the targets and achievements*).

Utility solar comprises over 91 per cent of the installed solar capacity in India

The market and its evolution: Auctions

So far, the National Solar Mission (NSM) can be deemed to be a success with regard to installed capacity: over the last eight years, the NSM has gone through various experiments and policy refinements that have progressively helped the solar market grow. The first stage, represented by auctions run by NTPC's Vidyut Vyapar Nigam (NVVN), the power-trading arm of the National Thermal Power Corporation (NTPC), was marked by high feed-in tariffs (FiTs) that was considered necessary to attract investors in this new

Table 1: States — the targets and achievements

Four southern states account for 50 per cent of the installed capacity

State	Potential (GW)	Installed capacity (MW)	State potential (% of total)	Installed capacity (% of total)
Andhra Pradesh	38.4	2,165	5	13
Karnataka	24.7	4,100	3	24
Tamil Nadu	17.6	1,819	2	11
Telangana	20.4	2,990	3	17.5
Punjab	2.8	905	0	5
Gujarat	35.7	1,344	5	8
Madhya Pradesh	61.6	1,210	8	7
Rajasthan	142.3	2,310	19	14
Uttar Pradesh	22.8	550	3	3
Maharashtra	64.3	763	9	4
Total	748.9	17,027	-	2

Source: Union Ministry of New and Renewable Energy

sector — it saw NVVN auctioning 470 MW of solar PV and 200 MW of solar thermal during 2010-13.[4]

In later auctions, NVVN introduced bundling (solar power was bundled with cheaper coal power and sold to discoms) to reduce the cost of power. While the scheme was basically an accounting exercise in coal cross-subsidy, it did help solar developers sell power to a good buyer.

SECI: In the next stage, the Solar Energy Corporation of India, a public sector undertaking, was given the charge of administering auctions. SECI would act as the off-taker, sign PPAs with developers and sell the power to the state distribution companies (discoms). This mechanism protected developers from the financially stressed discoms. The benchmark tariff was aggressively reduced to Rs 5.45/unit with a provision for viability gap funding (VGF)[5]; the auction winners were chosen based on the lowest VGF requirement (reverse bidding).

Solar parks: In 2014, new initiatives were introduced to scale up the programme, with the most important being solar parks (*see more on them later in this chapter*).

100-GW solar: In 2015, the target for solar power was upped to 100 GW from 20 GW. This meant a change of scale in the auctions — from as low as 20 MW to 500 MW in the very first bundling auction held in Kurnool. Further, the auctions saw a narrow range of winning bids (less than Rs 0.02/kWh), indicating that a competitive market had developed.

SECI-run auctions: Between 2013 and 2017, a host of auctions were

In 2015, the target for solar power was upped to 100 GW from 20 GW. This meant a change of scale in the auctions

held, mediated by the SECI, with the mechanism of reverse bids for VGF against a benchmark tariff (*see Table 2: Major National Mission phases and schemes*). As global module prices continued to fall resulting in lower capex, developers began bidding negative VGFs by mid-2017, the winning bids fell below the benchmark, reaching Rs 2.43/unit.[6]

Inter-state Transmission System (ISTS): The ISTS scheme heralds the further opening up of the sector. Previous auctions relied on a sponsoring state that was a major off-taker and the installations were, typically, in a certain solar park. The ISTS scheme is an 'open auction' that does away with both of these provisions. A developer can install anywhere and sell to

Table 2: Major National Mission phases and schemes

The NSM schemes evolved with the prevailing market conditions

Phase or scheme	Time period	Target (MW)	Capacity under construction/operational (Dec 31, 2017)(MW)	Means of achieving target
National Solar Mission target set at 20 GW, to be achieved by 2022				
Phase I NVVN batch I	2010-13	150	140	Allocated capacity by reverse bidding off high FiT
NVVN batch I solar thermal		470	200	
NVVN batch II		350	330	
Phase II batch I	2013	750	680	Implemented by SECI through support from National Clean Energy Fund (NCEF); reverse auction of VGF; tariff set at Rs 5.45/kW
National Solar Mission Target increased to 100 GW, to be achieved by 2022				
Batch II tranche I	2015-18	3,000	PPA: 2,750 MW Commissioned: 2,050 MW	Solar parks through state-specific bundling scheme; NVVN the implementing agency. Capacity allocated by reverse bidding of tariffs
Batch III	2015-19	2,000	PPA: 2,295 MW PSA: 2,425 MW Commissioned:300 MW	Implemented by SECI; state-specific projects auctioned by reverse bidding of VGF with benchmark tariff of Rs 4.43/kWh
Batch IV	2017-19	5,000	PPA: 970 MW PSA: 1,720 MW Commissioned: 250 MW	Implemented by SECI; projects auctioned by reverse bidding of VGF with benchmark tariff of Rs 4.43/kWh; negative VGF allowed reflected by tariffs lower than the benchmark.
ISTS	2018-2019	7,000	Auctioned: 2,000 (NTPC) 3,000 (SECI)	Implemented by SECI and NTPC; open auction; projects can be located anywhere and power sold to any buyer
CPSU	2017	1,000	Sanctioned: 986 Commissioned: 765	PSUs granted VGF of Rs 1 crore/MW to develop capacity; projects expected to use indigenous cells/modules. If imported cells, VGF reduced by half.

*Proposed schemes/targets of 12,000 MW under Phase II batch II were cancelled in 2018.

(1) 375 MW: DCR, 375 MW: open category)

Sources: Compiled from MNRE Annual Reports, https://solarrooftop.gov.in/notification/Notification-09012017.pdf and various news reports any discom (SECI/NTPC remain the intermediaries, though). Till July 2018, 7 GW had been auctioned under the scheme. However, SECI cancelled the allotment of 2.4 GW solar power capacity out of 3 GW auctioned in July 2018 on the grounds of high tariff rates (all bids above Rs 2.44/kWh).[7] The somewhat higher rates might have been due to the risk of land acquisition and construction of power evacuation infrastructure.

Utility-scale solar auctions by states seem to do better when SECI is not in the market

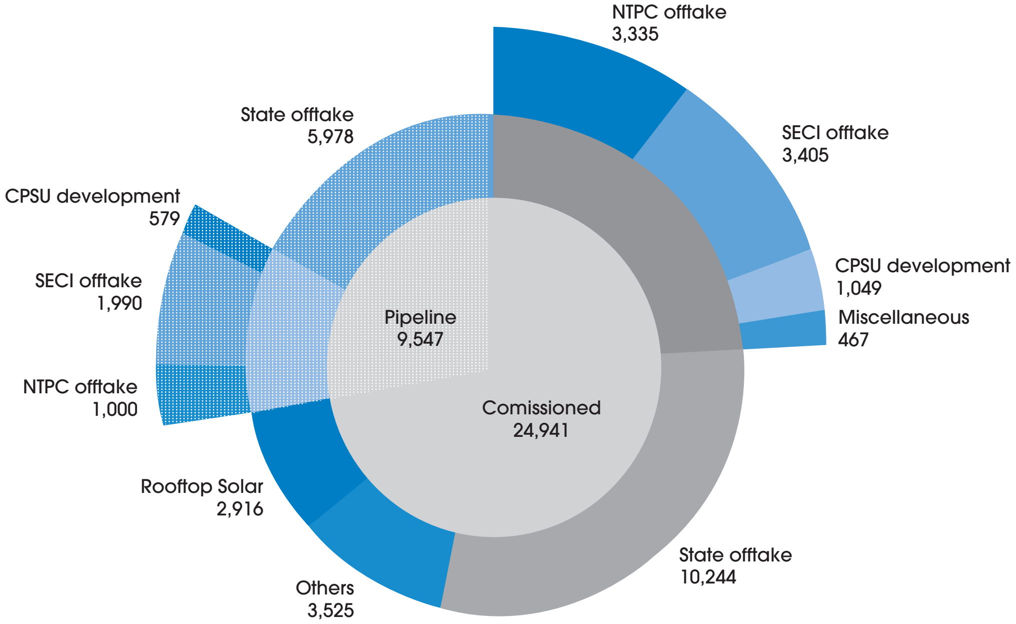
The state auctions

Over the last two years, all the attention has been focused on SECI (Central government-backed) auctions. Historically, however, that was not the case. The state sector auctions had a share of almost half of the installed capacity and over 60 per cent of the pipeline (*see Graph 2: Utility-scale solar capacity*). As of August 2018, states had commissioned a total of 10.2 GW, and another 6 GW was in the pipeline.[8]

In the past, state auctions did well only when SECI was not in the market. This suggests an imbalanced scenario (*see Graph 3: Auctions categorised by scheme*). The NSM's Central government auctions in 2013 were followed by a period when the solar market was driven almost entirely by states, with PPAs signed directly between the developers and state discoms. State auctions slowed down in 2016 after the SECI took the lead with several auctions under batches 3 and 4. Indeed, Tamil Nadu and other states failed to hold successful auctions in 2016. In late 2017, auctions were held by Tamil Nadu and Gujarat in a background of dwindling NSM auctions. But as the SECI-driven auctions struggled to make headway in 2018, state auctions

Graph 2: Utility-scale solar capacity (MW)

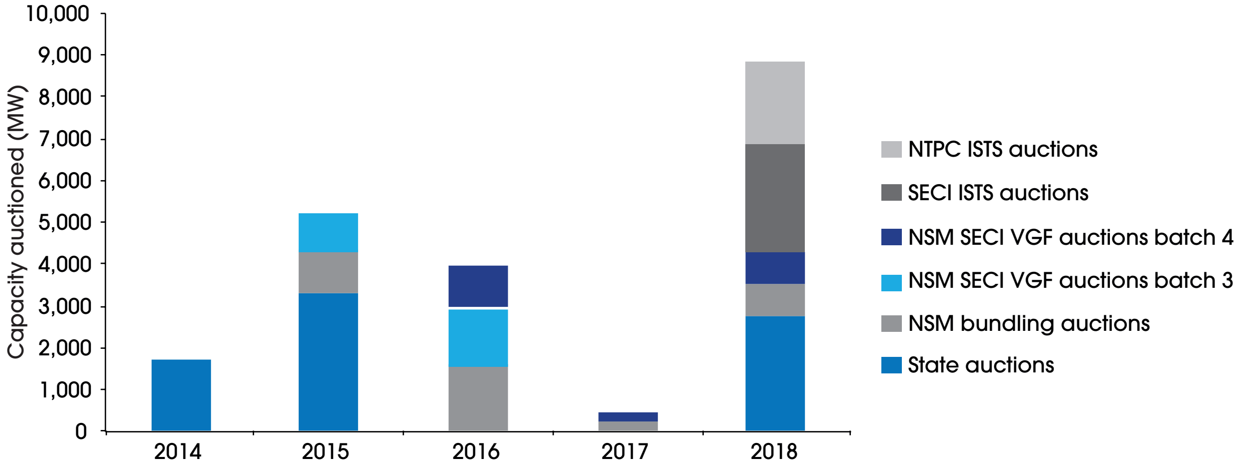
Operational and pipeline capacity from state auctions is significant



Source: Bridge to India, https://bridgetoindia.com/reports/india-solar-compass-q2-2018-august-2018/

Graph 3: Auctions categorised by scheme

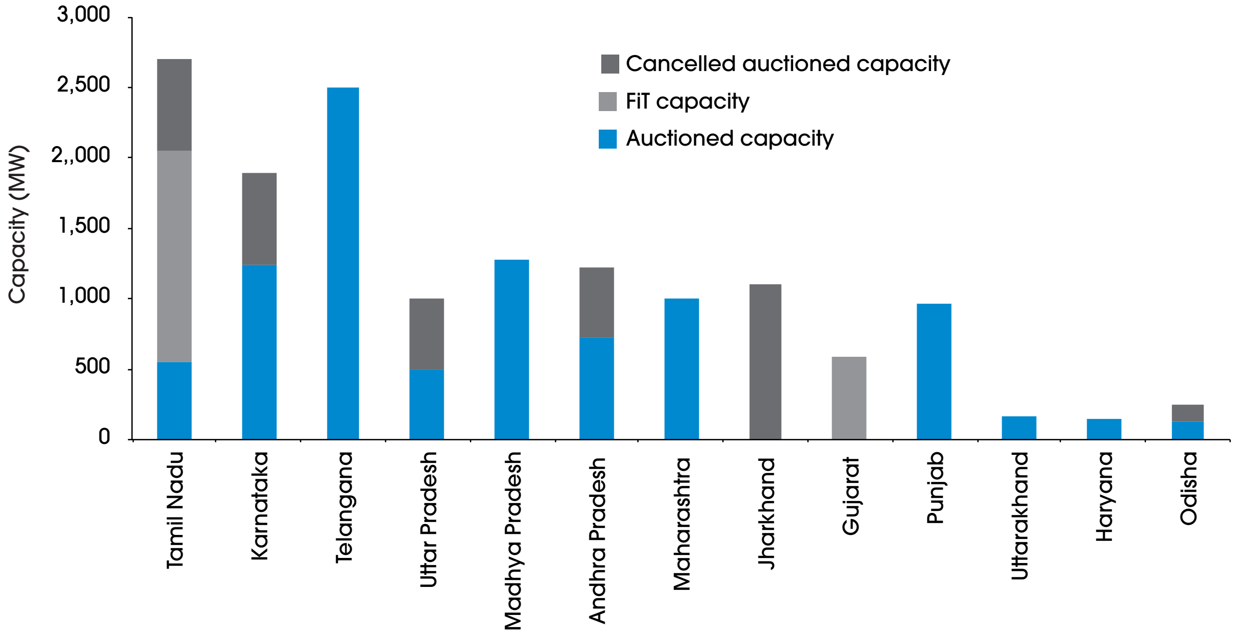
State auctions are making a comeback after losing ground to SECI in 2016



Sources: Compiled from SECI notifications, Lok Sabha Unstarred Question No-1740, and various news reports

Graph 4: State-driven solar auctions from 2012 to 2018

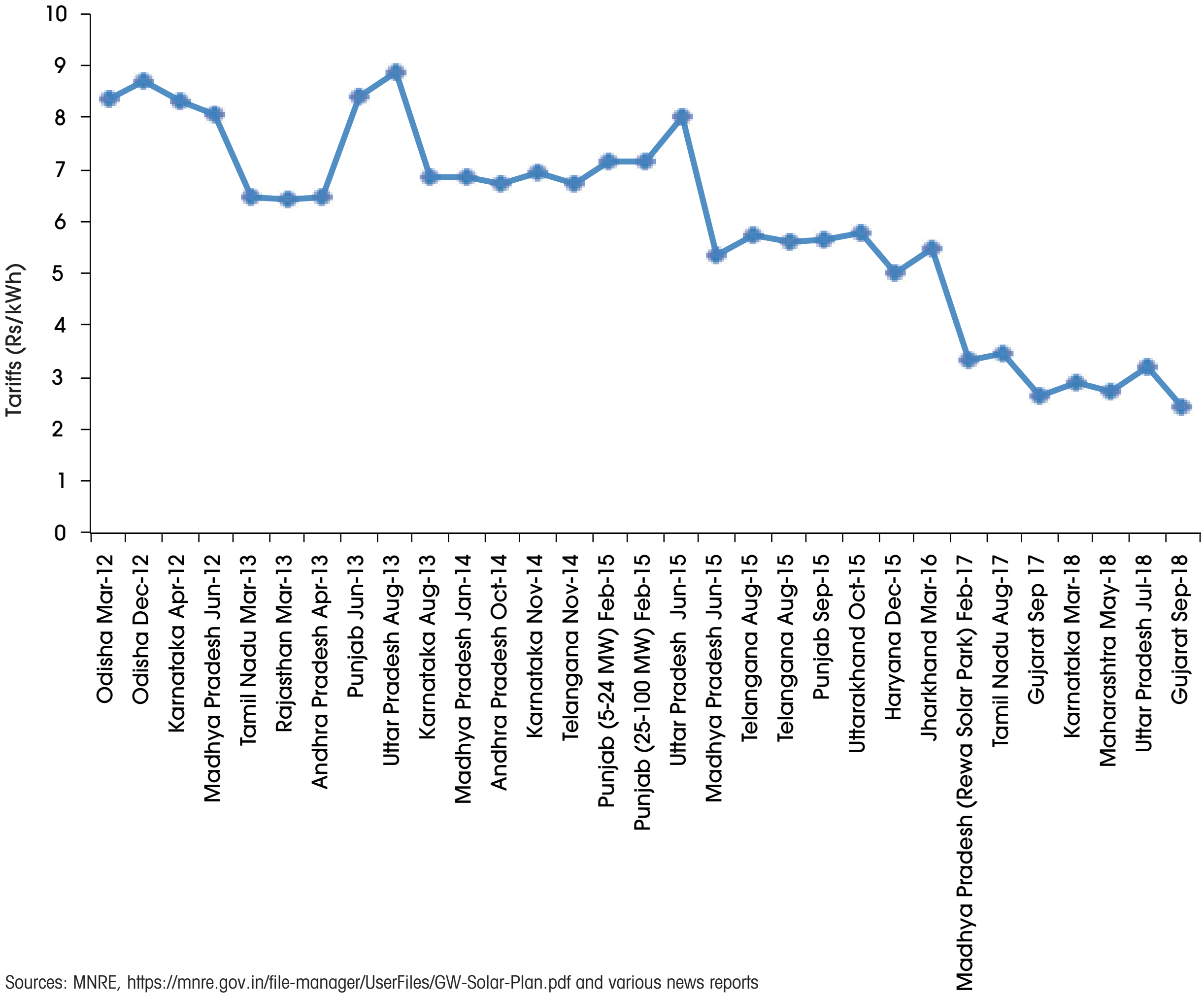
Auctions held by most states have been fairly successful



Source: Compiled from State Nodal Agency notifications and various news reports

Graph 5: Tariffs (weighted average) for state-run auctions

Tariffs have mirrored the national trends, but varied among states



Sources: MNRE, https://mnre.gov.in/file-manager/UserFiles/GW-Solar-Plan.pdf and various news reports

in Gujarat, Karnataka, Uttar Pradesh and Maharashtra have once again begun to dominate the scene.

States have used different schemes to install solar capacity (*see Graph 4: State-driven solar auctions*). Telangana, with one of the largest installed solar networks in the country, drew its entire capacity from its own auctions. On the other hand, Rajasthan built all of its solar capacities under NSM schemes.

The tariffs obtained by the states mirrored the national ones with a similar downward trajectory, though they were higher than the bids received in NSM projects auctioned at the same time. Also, there was a marked difference in the tariffs obtained by various states reflecting the financial health of discoms and the state's governance (*see Graph 5: Tariffs for state-run auctions*).

NSM and its policy successes

SECI — a vital intermediary

SECI operationalises various schemes of the Union Ministry of New and Renewable Energy (MNRE), administers auctions, and develops solar parks. In 2013, the company was appointed as the power purchaser under the Solar Park Scheme. SECI signs long-term power sale agreements (PSAs) with the state distribution companies, earning a margin of Rs 0.05-0.07/kWh. Having SECI as the counter-party against financially stressed discoms is a safety net for developers — this has played a vital role in the solar sector's growth.

However, SECI is becoming the dominant buyer in both solar and wind sectors, hobbling the development of a diversified market where independent power producers sell directly to various buyers (mainly discoms) and tariffs are determined by, among other things, the risk profile of buyers. State auctions that are not backed by the SECI are not garnering sufficient interest from developers; some auctions have failed and states are now demanding bids in line with SECI auctions (along with the protections entailed in them), which is an unreasonable expectation.

A potentially serious concern is that while payment delays by discoms have been manageable so far, the issue could compound in the future; Having SECI insulate developers from the discoms' risk is a good idea, but having the Corporation back-stop almost the entire renewable sector is a debatable policy — it will inhibit the industry from standing on its own feet and may saddle taxpayers with a situation where they have to bail out SECI.

Payment Security Mechanism (PSM)

To give additional confidence to developers about SECI's capability to honour its obligations vis-à-vis payment delays by discoms, the government has established the PSM with an initial corpus of Rs 500 crore. This scheme is applicable for the 7.75 GW of capacity where SECI has signed PPAs, and will be upsized as the Corporation signs more PPAs. The PSM assures developers that payments will be processed quickly by SECI without the need for a lengthy resolution process.

Solar parks — infrastructure support

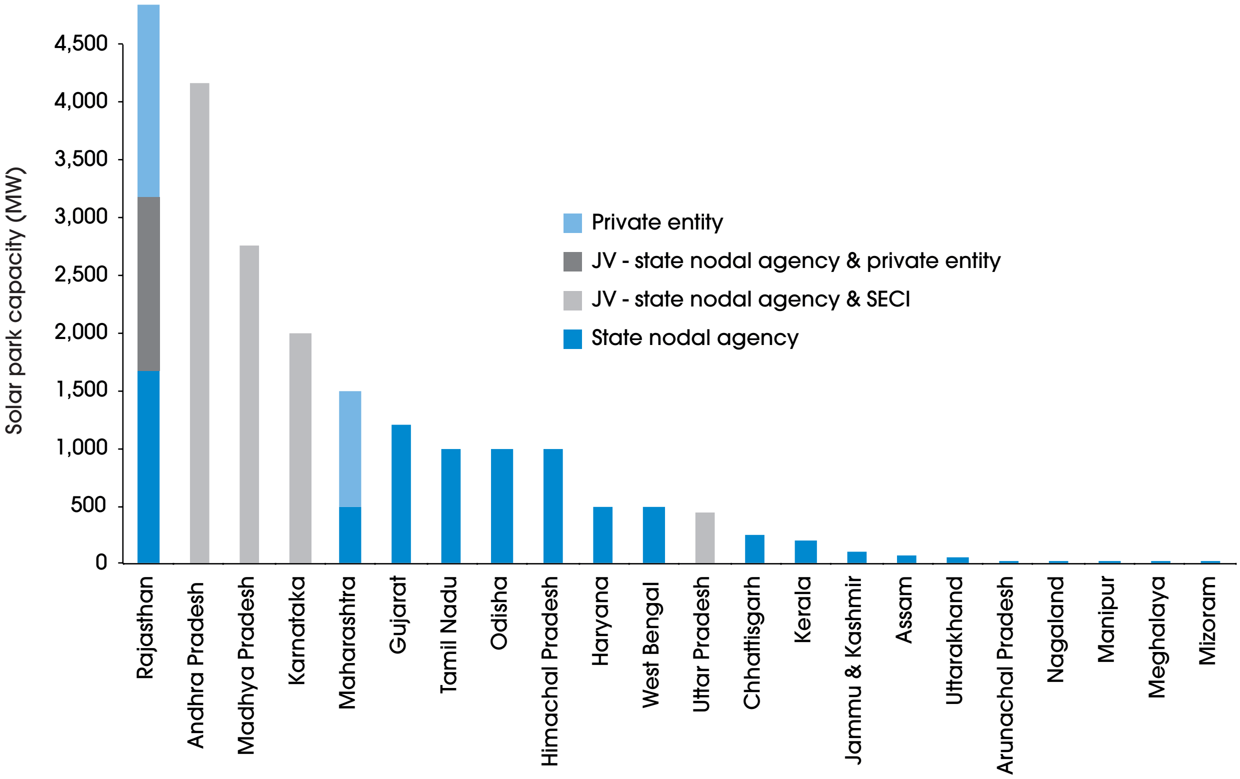
So far, 45 solar parks have been approved, with a total capacity of 26,449 MW

In 2014, the MNRE issued a mandate for the development of 'solar parks', a plug-and-play concept where the risks of land acquisition and evacuation is covered. These parks acquire large tracts of land and equip them with basic infrastructure. These parks were designed especially to attract overseas investors. The parks have been developed using different models, with a dominant portion developed by SECI and state nodal agencies (*see Graph 6: Breakdown of solar parks by ownership type, across states*). In 2017, the solar park target was increased to 40,000 MW.

So far, 45 solar parks have been approved, with a total capacity of 26,449 MW (*see Graph 7: Total capacity of sanctioned solar parks by state*), of which Gujarat, Rajasthan, Andhra Pradesh and Madhya Pradesh command significant shares (*also see case study on Bhadla Solar Park in this chapter*).

Graph 6: Breakdown of solar park by ownership-type, across states

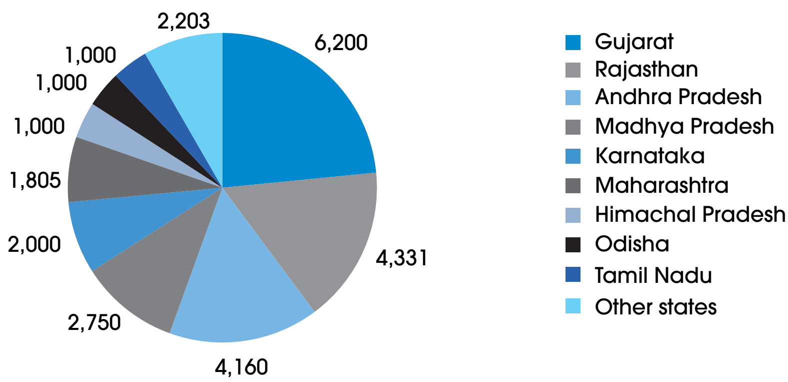
Park ownership is mostly concentrated in the hands of state nodal agencies and SECI



Source: https://mnre.gov.in/file-manager/annual-report/2017-2018/EN/pdf/chapter-4.pdf

Graph 7: Total capacity* of sanctioned solar parks by state

Gujarat, Rajasthan and Andhra Pradesh have the largest capacities



*In megawatt

Source: https://mnre.gov.in/file-manager/UserFiles/List-of-approved-Solar-Parks-Phase-wise.pdf

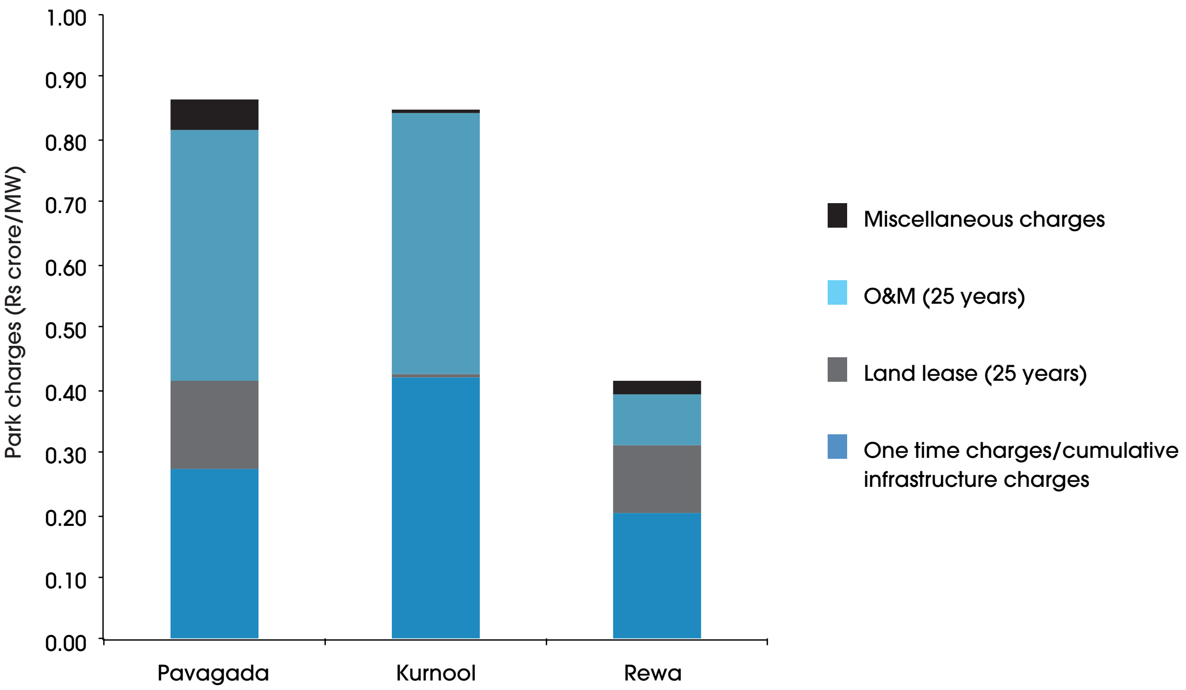
The cost of solar parks

The main funding support for solar parks comes from the Central Finance Assistance (CFA) of the MNRE, which has budgeted Rs 8,100 crore for solar park development. This includes a subsidy of Rs 20 lakh per MW (or 30 per cent of the total capital cost, whichever is lower) and Rs 25 lakh per park to prepare a Detailed Project Report (DPR). Park owners charge solar developers a one-time down payment and annual recurring costs per MW. The charges vary widely since land prices and evacuation costs are highly variable (*see Graph 8: Park charges over a project's lifetime*). Solar companies claim that park charges are actually higher than what the government incurs on developing them.

Notwithstanding claims made by solar companies that park charges are not subsidised, the parks clearly offer several benefits, especially to foreign investors. First, solar parks remove the serious challenge of acquiring large tracts of contiguous land. In some cases, the government has allocated its own land which may be below the market price. Second, power evacuation facilities, built in tandem, reduce the risk (12-15 months in parks *vs* two to 2.5 years for stand-alone projects) for developers. Given that bids in solar parks are among the lowest, the implicit benefits to developers are undeniable.

Graph 8: Park charges over the project's lifetime

Park charges vary across different locations



Sources: Based on data obtained from park authorities at Rewa and Kurnool; Pavagada park charges from http://kspdcl.in/SP_DOCS/solarparks/Charges%20to%20be%20paid%20by%20SPDs%20to%20KSPDCL%20for%20Pavagada%20Solar%20Park.pdf,

DMRC and Rewa — a successful marriage

The 750-MW Rewa Solar Park was commissioned in July 2018 by a 50:50 joint venture between the Madhya Pradesh Urja Vikas Nigam Limited (MPUVNL) and SECI. The land was made available by the state government, and the evacuation infrastructure was built by the Power Grid Corporation of India Ltd (PGCIL).

The bids achieved first year tariffs of under Rs 3/kWh and levelised the tariff over the projects' lifetime at Rs 3.30/kWh in February 2017. However, the Rewa Park is unusual in terms of various guarantees and safeguards undertaken by the Madhya Pradesh state government, that enabled low bids:

- Tier 1: One-month letter of credit by offtakers to cover payment to the park
- Tier 2: PSM (payment security mechanism) for a three-month guarantee
- Tier 3: State government guarantee to pay the difference or the pending amount to developers in case of further delays
- Tier 4: State government guarantee to pay the costs incurred if transmission outage lasts over 50 hours

The Rewa Solar Park is the first of its kind facility in which solar power will be supplied to an interstate commercial entity — the Delhi Metro Rail Corp (DMRC). The PPA for 345 million units is expected to meet 80 per cent of the DMRC's needs. Given that DMRC pays Rs 6.1/kWh to the discom, the levelised tariff of Rs 3.30/kWh will result in annual savings of Rs 96.6 core.

Emerging risks

While the sector has made tremendous progress in terms of capacity installation and the pipeline is strong with large auctions over the last few months, it is also facing challenges that have a potential to disrupt it. Many of the sector's risks relate to the financial weakness of its main buyers, the discoms. Other concerns are inconsistent implementation of policies and lack of enforcement of regulations, and the casual attitude of regulators and discoms towards honouring contracts. To address these emerging risks and to ensure that the sector's momentum is not lost, regulators need to establish clear policies and strictly enforce them.

Market turbulence

The year 2017-18 has been a record year for solar installations in India, with more solar capacity coming on-line than ever before.[9] However, the industry also started facing problems: rising module prices exacerbated by international trade disputes; policy flip-flops in India on import duties; and confusion over GST slabs and their impacts. These resulted in a smaller number of NSM auctions in the second half of 2017.

The slowdown continued into 2018 — several auctions in Gujarat, Maharashtra, UP and Karnataka were either unsuccessful and required to be retendered multiple times or cancelled altogether. The 3,000-GW ISTS auctions held by SECI were also cancelled for similar reasons. Discoms have added to the market problems by saying they will not accept tariffs above a certain level, throwing the auction processes' credibility into doubt. More

recently, they have cited their inability to sign any new solar PPAs since they already have excess supply tied in from existing coal power PPAs.

Curtailment

Curtailment of power means that the load dispatch centre (LDC) asks the solar plant not to inject power into the grid, resulting in loss of revenues for the developer. It may be for legitimate technical reasons such as grid unavailability or/and demand-supply mismatch (for example, when demand is lower than forecast, or there is a spike in renewable energy supply).

Curtailment for commercial reasons means that LDCs or discoms have asked solar plants to shut down because cheaper power is available (this request, however, is against the law). Often, older projects with high FiT are subject to curtailment. However, even newer projects at low tariffs face this problem. Since fixed costs for coal power have been paid under the two-part PPAs, the discoms compare coal's variable cost with the solar tariff to schedule power.

Industry observers say curtailment in the solar sector is in the range of 1-3 per cent. SLDCs/discoms claim that a surge in supply compels them to issue back down orders to maintain grid stability. However, developers say that curtailment has often been due to commercial reasons.

In 2016, the National Solar Energy Federation of India (NSEFI) filed a petition before the Tamil Nadu Electricity Regulation Commission (TNERC) saying that the Tamil Nadu Generation and Distribution Company (TANGEDCO) has been backing down solar power.[10] In 2017, a similar petition was filed by solar power plant developers arguing that backing down instructions from the TNSLDC violates the 'must-run' status. The case is now at the Madras High Court, stuck in a protracted legal process.

The New Guidelines for Tariff-Based Competitive Bidding Process 2017 have attempted to address some of the risks associated with curtailment.[11] The discom/buyer has to procure power over three years in excess of the PPA contract if there is curtailment due to transmission constraints or grid unavailability. In case of a back-down, the generators will be compensated for 50 per cent of the generation that is backed down.

In addition, Forecasting and Scheduling (F&S) as well as Deviation Settlement Mechanism (DSM) need to be enacted by states and implemented to limit variability and curtailment.

Payment delays

Payment delays by discoms seem to be a widespread problem, as reported by developers surveyed by CSE, affecting even states with well-performing discoms (*see Table 3: Payment delays in states*). Most solar developers do not have a large capital cushion or cash reserves and can get financially stressed if faced by payment delays. The projects that reported payment delays have several characteristics: they were auctioned under state schemes, most have high tariffs, and most of the states have large capacities (see *Table 4: State auction capacities and tariffs*). While PPAs have penalty clauses in case of delays, developers are unable to enforce them, given discoms' strong bargaining position.

Table 3: Payment delays in states

Payment delays can put developers in serious financial stress

Surveyed developers	Solar portfolio size in India	Reported states with payment delays	Delay period
A	>2,000 MW	Karnataka, Andhra Pradesh, Punjab, Tamil Nadu	6-7 months
B	>200 MW	Andhra Pradesh, Karnataka, Telangana	Up to 4 months
C	>1,200 MW	Andhra Pradesh, Rajasthan, Madhya Pradesh	6-12 months
D	<1000 MW	Telangana, Andhra Pradesh	1.5-2 months

Source: Data obtained and compiled by CSE from surveys conducted with developers

Table 4: State auction capacities and tariffs

Significant capacity was auctioned by states before 2016

State	Capacity auctioned in older state-run auctions between 2013 to 2015 (MW)	Tariff range (Rs/ kWh)
Andhra Pradesh	690	5.5-8.34
Telangana	726	6.45-6.75
Karnataka	2,500	5.17-6.72
Punjab	970	5.09-8.75
Madhya Pradesh	525	5.05-12.45

Sources: Compiled from state nodal agencies' notifications and various news reports

Quantifying the discom risk

Based on discussions with developers, CSE believes the risk of dealing directly with state discoms compared to the SECI is around 5 per cent premium in terms of tariff, or around Rs 0.16/kWh. If we compare two recent auctions held in Uttar Pradesh — one by the state nodal agency Uttar Pradesh New and Renewable Energy Development Agency (UPNEDA) (July 2018) and the other by SECI (June 2018) — the difference in tariffs was Rs 0.16-0.23/kWh. Developers expect around 2 per cent higher IRR (internal rate of return) for projects where the state discoms are the direct procurers.

The UPNEDA auctions were ultimately cancelled after the completion of the auctions, fulfilling the prophesied risk[1] — 500 MW was retendered in August 2018, this time carrying concessions in case safeguard duties were imposed on PV panels. The leeway given in response to a difficult market condition resulted in successful round of auctions in which tariffs fell as low as Rs 3.17/kWh.[2] This case highlighted the need for state auctions to have more in the way of incentives to attract low bids to compensate for discom risks.

Price difference in SECI and state nodal agency auctions in Uttar Pradesh

SECI auctions command cheaper tariffs

Uttar Pradesh SECI (Jalaun) auction tariff	**Rs 3.32/kWh**
Uttar Pradesh New Energy Development Agency (UPNEDA) 1-GW auction tariff (cancelled)	Rs 3.48-3.55/kWh
Uttar Pradesh New Energy Development Agency (UPNEDA) 500-MW auction tariff	Rs 3.17-3.23/kWh

Sources: https://www.eqmagpro.com/upneda-1000-mw-solar-tender-bidder-list/, https://mercomindia.com/upneda-solar-auction-500-mw-l1-tariff-3-17/ , https://www.business-standard.com/article/pti-stories/acme-bags-75-mw-solar-project-in-up-at-rs-3-32-unit-118060800735_1.html

Contract enforcement

The rapidly falling tariffs in this sector are now creating some unexpected complications. There have been media reports about state discoms (Uttar Pradesh, for one) approaching renewable energy developers to renegotiate signed PPAs that were signed previously at higher rates.[12] In some cases, the ERCs refused to approve PPAs that had been signed. In September 2017, the Karnataka Electricity Regulatory Commission (KERC) decided to reduce the tariff the state discom would pay for wind energy projects for which PPAs were signed before March 2017. The state government had to intervene to overrule the KERC's order to ensure the PPAs were honoured.[13]

In the case of Jharkhand, tariff renegotiations were held twice in March 2016 and August 2017 for the auctioned 1,200-MW capacity. In April 2018, the Jharkhand State Electricity Regulatory Commission rejected JAREDA's (Jharkhand Renewable Energy Development Agency) petition to sign PPAs citing several reasons; these included the facts that the auction process did not follow the MNRE's guidelines and that the final tariff was arrived at through negotiations. This particular case highlighted the need for transparent processes to ensure contract enforcement.[14]

Regulators need to ensure that auction processes are transparent, auctions are not cancelled for arbitrary reasons, and the sanctity of contracts is maintained.

The way ahead

The deployment of large-scale solar in India has been a success so far. But the fundamental reason for the success has been the outsized role played by the Central government. While the sector no longer receives direct subsidies (high FiTs or VGF), it continues to receive assistance in myriad ways — making large tracts of land available for parks, waivers of transmission and distribution charges and evacuation infrastructure built with large multilateral loans. The SECI has played a very significant role in helping the sector grow by protecting solar developers from the risks posed by financially-stressed discoms.

Central government support has also created some distortions in the market. The price discovery process, especially of state discoms, is not working well, as highlighted by the arbitrary cancellation of auctions. This points to an insufficient appreciation of market conditions and risks which can sow doubts about the auction process itself. Similarly, delays in signing PPAs, attempts to renegotiate them or their rejection by regulators undermines investor confidence in the sanctity of contracts.

While the supportive tools and policies were vital for the sunrise industry's growth and some may still be required, over the longer term, regulators need to ensure the development of an independent, competitive market.

PRIYA SREENIVASAN / CSE

The utility-scale solar has reached a stage were government has to open the sector for more private risks and competition

So far, attempts to open up the sector have been half-hearted, with open access regulations poorly implemented; as a result, procurement of renewables by the corporate sector has not taken off despite the substantial economic benefits it poses.

Finally, the excessive focus on tariffs has led to concerns about the quality of panels being used. Since most projects are financed by substantial loans from scheduled banks, a poorly performing project will have a cascading impact on the banking sector.

Going ahead, the following policy interventions would be critical to sustain the growth of this sector:

- SECI's role as the intermediary off-taker needs to be gradually diluted. Auctions, with sale of power directly to end-consumers (utilities or a third party), should come to the forefront. This will help in the creation of a mature market.
- The private sector should be engaged in solar park development to ensure 'park charges are not subsidised and are reflective of the market value of land, a precious resource in India, and the evacuation network.
- Having the public sector guarantee payments to insulate developers from discom risk is neither a desirable nor a sustainable solution. Alternative mechanisms to protect against discom risks include creating an insurance fund by pooling industry contributions.
- The current auction mechanism (pay-as-bid) may result in unviable bids for the lowest bidders. Government should also experiment with other models like the uniform pricing auction where every winning bidder gets the same tariff. This model is also likley to obtain a better average tariff compared to the pay-as-bid model.
- Corporate entities cannot procure power from ISTS auctions as it would mean the SECI underwriting the risks of the private sector. Auctions need to be completely competitive allowing for projects to be built anywhere and accessible to all end-users, creating a truly open, market-driven sector.

CASE STUDY: A 'BLUE SEA' IN THE DESERT
Bhadla Solar Park, Jodhpur, Rajasthan

RRECL

The sight of the Bhadla Solar Park is awe inspiring: rows of panels, glinting against the barren land, stretch over a 45 square kilometer area all the way into the horizon, a dark, blue sea in the middle of the sun-scorched desert.

The Bhadla Solar Park epitomises the success of the National Solar Mission. Here, all the policy initiatives have come together in a massive 2,255-MW capacity installation that has regularly produced the lowest tariffs in the country from 2015 onward (including the current record at Rs 2.44/kWh). Bhadla receives the highest solar irradiation amongst all the solar parks in the country — 5.71 kWh/m^2/day, compared to the national average of 5 kWh/ m^2/day. The solar irradiation is high throughout the year, which translates to consistent solar output.

Built in four phases, the park's developer for the first two was the Rajasthan Solar Development Corporation Ltd (RSDCL), wholly owned by the Rajasthan Renewable Energy Corporation Ltd. Phases III and IV were developed in partnership with private entities, IL&FS and Adani Green Power.

The land has been leased to the park developers at approximately Rs

Table 5: Ownership and associated capacity in the Bhadla Solar Park

Private sector participation in park development has been successful in Bhadla

Phase	Capacity (MW)	Park owner/administrator	Status as of September 2018
I	75	RSDCL	Operational
II	260+420	RSDCL	Operational
III	1000	Saurya Urja Company of Rajasthan Ltd (JV between IL&FS and Rajasthan government)	Under construction
IV	500	Adani Green Power	Under construction

Source: Government of Rajasthan, https://d2oc0ihd6a5bt.cloudfront.net/wp-content/uploads/sites/837/2018/06/Basant-Dosi-Rajasthan-The-Solar-Destination-and-Development-of-Bhadla-Solar-Park.pdf

2 lakh per hectare, with a 5 per cent annual escalation. The evacuation infrastructure has been financed through the Green Energy Corridor Project, funded by the German development bank KfW and the Asian Development Bank (ADB).

Bhadla is the first park to have been developed in partnership with private entities and serves as a model for weaning the sector away from dependency on the public sector. It is also the first one to have signed an agreement to supply power across state boundaries with a 750-MW PPA with discoms in Uttar Pradesh (*see Table 5: Ownership and associated capacity in the Bhadla Solar Park*).

Given the fact that the park is located in the arid Thar desert, water for cleaning panels and maintenance is scarce; this has prompted innovative solutions. For instance, solar developer Rising Sun's plant makes use of a home-grown semi-mechanical cleaning device with an efficient spray nozzle, which is hoisted on an improvised tractor. The device uses significantly less water than the average plant. Some of the newer plants in Phases III and IV have opted for fully automated, water-less cleaning devices supplied by an Israeli company named Ecoppia, which is expected to cut water consumption to zero.

The park is also equipped with state-of-the-art SCADA systems, with on-site engineers constantly monitoring the plant output. It is technically ready to respond to new forecasting and scheduling regulations to ensure maximum injection of power.

The Bhadla Solar Park realises the vision of using waste land to tap into the country's vast solar resources for generating renewable power.

CHAPTER 3

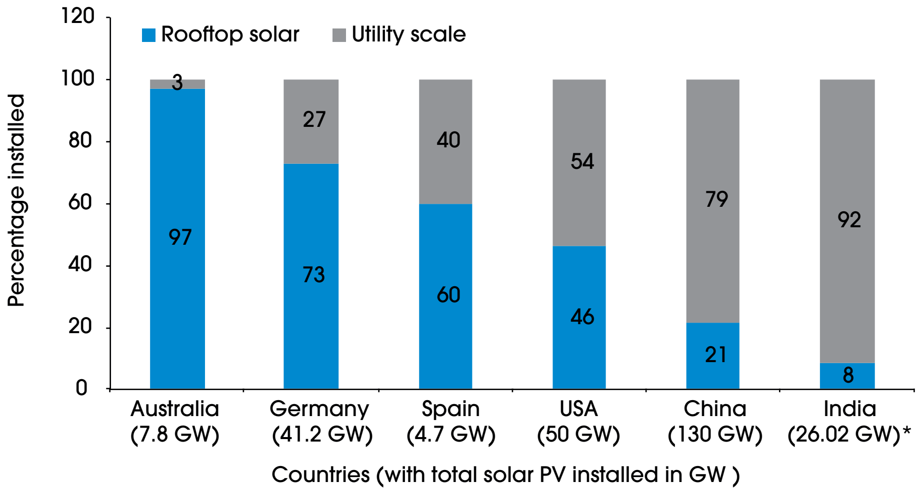
Solar rooftop: Overshadowed

Most developed economies started their solar programmes by targeting household rooftops; as a result, they now have a sizable share of installations in the residential rooftop segment (*see Graph 1: Rooftop and utility-scale solar in different countries*). China and India, on the other hand, have used large-scale solar installations in an effort to quickly achieve scale and — simultaneously — push down costs. In the case of India, this focus on large utility-scale solar seems to have become an unintended obstruction in the development of the rooftop segment.

India, though, does have an ambitious plan for solar rooftop or SRT, as it is called: a target of 40 gigawatt (GW) capacity by 2022. But so far, the

Graph 1: Rooftop and utility-scale solar in different countries

Developed countries have focused on residential rooftop



*Indian capacity up to December 2018, others till December 2017.
Source: Compiled by CSE from various sources

achievement has fallen short of the goal. According to the Union Ministry of New and Renewable Energy (MNRE), only 2,158 megawatt (MW) of SRT systems had been installed in the country till December 2018.[1] Gurugram (Haryana)-based solar consulting company Bridge to India reports 3,400 MW of SRT systems till September 2018.[2]

The shortfall in capacity is compounded by the fact that a large proportion — 70 per cent — of the installed rooftop systems is for commercial and industrial (C&I) customers; residential consumers account for less than 20 per cent of the total installed capacity[3] (*see Map: SRT installation in India*). Of the states with sizable SRT systems — Maharashtra, Tamil Nadu, Karnataka, Rajasthan, Uttar Pradesh, Gujarat, Haryana and Delhi — the industrial segment has the largest share in all except Delhi. Public sector undertakings (PSUs) have been the largest rooftop driver in Delhi.

There are clear economic considerations behind industrial and commercial consumers' preference for rooftop systems: solar rooftop power is cheaper than grid-supplied electricity. These consumers have the financial resources to make the necessary investments, which are sizable, to install SRT systems. Moreover, they also have access to the Renewable Energy Service Company (RESCO) model (in which developers install the system on the consumers' premises and sign a long-term contract to sell them electricity), under which they do not need to make any investments.

The dominance of 'large-scale' rooftop installations by commercial-industrial, institutional and government/PSU segments has meant that attention to the residential solar rooftop segment has lagged behind. Distributed solar rooftop systems, installed on individual residences, offer many advantages. They help minimise transmission and distribution losses, as the generated power is consumed locally. In large cities, they can act as a back-up, replacing polluting diesel generator sets. Solar rooftop can be harnessed for demand-side management (for example, time-of-day pricing to match household demand with solar generation). With falling solar prices and steadily increasing discom tariffs, SRT systems are being seen as financially attractive.

Instead of policy initiatives and administrative interventions, government has largely relied on subsidies to drive SRT installation

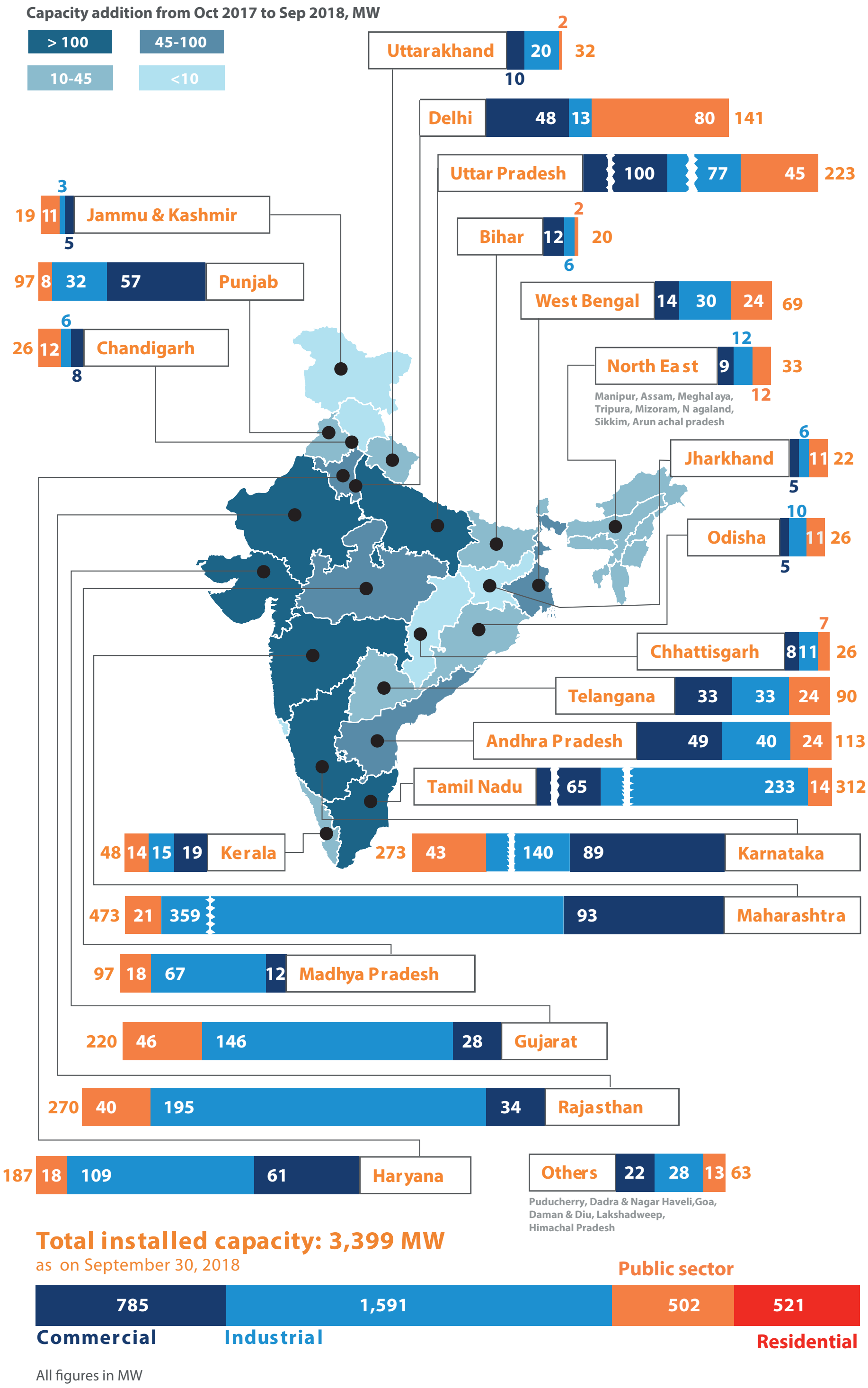
The policy environment: A subsidy-driven strategy

Achieving significant capacity addition in rooftop solar would require close engagement with numerous small consumers, which is a challenging task in itself. Concerted effort would be needed for raising consumer awareness about the benefits of SRT systems and PV technology and their installation. Processes for approving net metering applications and disbursing subsidies will need to be efficient and painless to motivate consumers to invest in this new technology. Loans need to be made available, which requires significant capacity building of retail bank branches. Instead of these much-needed policy initiatives and administrative interventions, the government has largely relied on subsidies (70 per cent for hill and north-eastern states and 30 per cent for other states) to drive SRT installation.

There have been a few half-hearted efforts to break this mould. One such effort was the Solar City Programme initiated in 2008 — but it has not been

Map: SRT installation in India

Industrial-commercial consumers account for 70 per cent of installations



Source: Bridge to India, India Solar Rooftop Map December 2018; https://bridgetoindia.com/wp-content/uploads/2018/12/BRIDGE-TO-INDIA-India-Solar-Rooftop-Map-December-2018-1.pdf

Table 1: State policies on solar rooftop

Most state policies put limits on the installation of SRT

Parameters	Regulation range
Limit on SRT capacity (at customer level)	30-150% of sanctioned load
Limit on total SRT capacity (at distribution transformer level)	15-90%
Cap on system size	No cap up to 1 MW
Metering — both net and gross	10 states (net-metering in others)
Feed-in tariff, Rs/unit	Rs 0-9.5
Annual power purchase cost (national average)*, Rs/unit	Rs 2.5-3.9 (national average — Rs. 3.5)

*Excludes RE, while APPC includes it; they are similar.
Source: Union Ministry of New and Renewable Energy, 'Grid Connected Solar Rooftop — State Policies and SERCs Regulatory/Tariff Order', available at https://mnre.gov.in/grid-connected-solar-rooftop-states-policies-and-sercs-regulatory-tariff-order
See Statistics section for details.

backed by any concrete steps. Similarly, the Environment Impact Assessment (EIA) Notification, 2006 requiring buildings with an area over 5,000 square metre to have at least 1 per cent of their connected load through SRT[4], has not had much impact due to non-existent monitoring and enforcement.

Policies at the state level

Several states and Union territories (UTs) have announced regulations governing SRT installation (*see Table 1: State policies on solar rooftop*). These regulations focus primarily on clarifying the limits on capacity that a consumer can install. In addition, they define the terms of metering (net or gross) and the purchase cost. However, policies of most states have not done anything yet to encourage installations.

So far, 30 states and UTs have defined their net metering guidelines. Feed-in tariff (FiT) for SRT systems are decided by the state tariff regulators. Most regulators allow payment to SRT systems based on the annual pooled purchase cost (APPC) of the discom. A few states and UTs, such as Rajasthan, Chandigarh, Uttarakhand and Karnataka, allow FiTs that are higher than the APPC. Some states have introduced other measures to boost the SRT market:

Additional state subsides: Gujarat provides as much subsidy as the Centre; this means the cost of solar rooftop systems for homeowners in the state becomes Rs 30,000 per kilowatt (kW).[5] Uttar Pradesh is disbursing up to Rs 30,000 as incentive to residential customers, while Maharashtra provides 100 per cent subsidy to government and semi-government offices and 15 per cent to private offices.[6]

30 states and UTs have defined their net metering guidelines

SRT mandates: In May 2016, the Chandigarh Renewable Energy and Science and Technology Promotion Society (CREST) made installation of rooftop solar systems in the city mandatory within two years in residential houses measuring over 500 square yards as well as in group housing societies.[7] Karnataka has decided that 40 per cent of the state's solar energy target (2,300 MW) should be met through rooftop solar, with a cap of 200 MW per *taluk* to ensure widespread installation by 2021-22.[8] Delhi, on the other hand, has mandated that all government-owned buildings must have a rooftop solar plant within the next five years.[9]

Some states have introduced measures to boost the SRT market, but these have had little impact

Expanding the target base: Karnataka has tried a new approach: land-owning farmers are offered additional incentives to put up solar installations of 1-3 MW capacity under the land owners' category. Till November 2018, the state had already triggered installation of 290 MW under this scheme against the allotted 314 MW.[10] Delhi has recently introduced a scheme under which private companies can install SRT systems in one-third of a farmer's land; the farmer receives a rent.[11] However, it is still too early to assess the success of these schemes.

Overall, the measures put forth by the states are not backed by concrete efforts to raise awareness, remove bureaucratic bottlenecks or even monitor the progress — as a result, they have had very little impact.

SRISTI — a misguided approach

The MNRE believes that discoms are a bottleneck in the spread of rooftop solar — they are seen to be slow in approving and installing net meters because they fear losing revenues from their most prized customers. To address this, the ministry launched the draft Sustainable Rooftop Implementation for Solar Transfiguration of India (SRISTI) scheme in December 2017. The scheme proposes Rs 23,450 crore of incentives for discoms and consumers (*see Figure 1: Subsidy break-up in SRISTI*).

The scheme has a number of flaws, though. To begin with, the subsidy itself: it may incentivise discoms to encourage rooftop installations, but it is designed to benefit them only over the shorter term while magnifying their revenue problems over the longer term. Instead of helping discoms tide over revenue losses, the subsidy should be targeted to improve their long-term

Figure 1: Subsidy break-up in SRISTI

A short-sighted solution to a multi-dimensional problem?

RESIDENTS	• Rs 18,000/kW (upto 5 kW); benchmark cost Rs. 65,000/kW • Total Rs 9,000 crore for 5 GW
DISCOMS (for industrial and commercial installations)	• Rs 5,500/kW (based on estimated targets achieved annually by discoms); benchmark cost Rs 55,000/kW • Total Rs 14,450 crore for 35 GW

Source: 2017, Union Ministry of New and Renewable Energy Concept Note on SRISTI, available at https://mnre.gov.in/file-manager/UserFiles/comments-on_RTS.pdf

Table 2: Non-agricultural sales with variable tariff

In most states SRT is cheaper than commercial and industrial tariff

State	Sales in MUs with variable tariff > Rs 5/kWh	Percentage of non-agriculture sales with variable tariff > Rs 5/kWh
Maharashtra	52,485	75
Punjab	26,403	80
Madhya Pradesh	14,294	49
Haryana	22,061	72
Rajasthan	28,625	91
Andhra Pradesh	25,906	67
Telangana	12,602	61
Gujarat	40,774	68
Bihar	12,114	77

Source: Prayas (Energy Group), 'India's journey towards 175 GW renewables by 2022'

viability — for example, by pushing them into newer business models such as partnering with rooftop installers to collect their bills.

Another concern with the scheme is the fact that it reduces residential consumers' share of the rooftop target to just 5,000 MW out of the total target of 40,000 MW. This points to both a failure of existing policies and wrong direction, given the fact that small-scale distributed generation offers a unique set of benefits. Further, India's large number of middle-class consumers can be a vital source of financing for solar rooftop. The scheme offers a narrow solution to a problem which requires addressing the following issues:

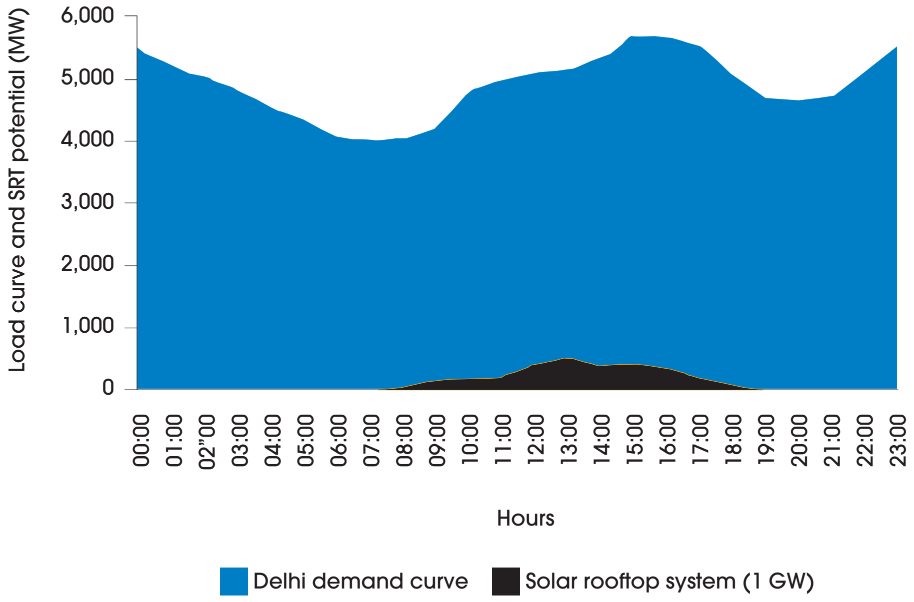
Customer migration: It is true that discoms face a problem of potentially losing a share of their residential, commercial, industrial, and institutional customers — especially the ones whose tariffs are the highest— to cheaper renewable power. Customer migration on account of solar rooftop can worsen a discom's already precarious financial health, which is why they may not be keen to streamline the net metering process. An analysis by Prayas shows that almost half to over 90 per cent of non-agricultural sales by discoms in various states were at a tariff of more than Rs 5 per unit, which is broadly the cost of rooftop solar[12] (*see Table 2: Non-agricultural sales with variable tariff*).

Customer migration on account of solar rooftop can worsen a discom's already precarious financial health

Power procurement: Solar rooftop may only partially help in reducing the peak demand from the grid, which is widely assumed to be in the afternoon for most cities when solar generation is also the highest. Delhi's load curve shows a second peak around midnight when most households turn on their air conditioning (*see Graph 2: Daily load curve of Delhi and the solar rooftop potential*). Discoms' procurement strategy entails having the vast majority of the demand met through long-term power purchase agreements (PPAs). In this scenario, they incur a cost for providing the balancing power

Graph 2: Daily load curve of Delhi and SRT potential

Solar rooftop does not help in reducing the night peak demand



Sources: Compiled by CSE 2018. Delhi State Load Despatch Center, https://www.delhisldc.org/; SMA Sunny Portal, https://www.sunnyportal.com/Templates/Start.aspx?ReturnUrl=%2f

to rooftop consumers. Discoms will need to develop sophisticated power procurement processes that rely on a combination of peaking supply, short-term purchases, demand management etc, in addition to long-term contracts.

The challenges

Financing

The total funding requirement for installing 40 GW of SRT systems by 2022 is estimated to be over Rs 2.8 lakh crore (US $40 billion).[13] A 30 per cent capital subsidy support from the government does cover a portion of this cost. However, most prospective customers either do not have the savings to cover the upfront costs, or are simply unwilling to invest given the relatively large amount. Also, most customers do not have access to bank financing.

In recent years, the government has taken steps to improve the availability of loans for SRT projects. The Reserve Bank of India has identified solar rooftop as a priority sector for lending. Eight public sector banks have included SRT systems under their housing or housing improvement loans. Multilateral banks are providing concessional loans against sovereign guarantee to public sector banks to support subsidised lending to the segment. Despite this, collective lending from them till 2017 for solar rooftop financing was only to the tune of US $1.4 billion, just 3.5 per cent of the total required funding.[14]

Some of the possible ways of breaking the financing logjam could be:

The RESCO model: In this, developers install the SRT and sign long-term PPAs with the customer. Almost exclusively targeted currently at industrial, commercial and institutional consumers, this model can give a big boost to household segment installations, since developers will no longer need to make a sizable investment in the installation. Currently, RESCOs are not keen on the household market because they are unable to assess homeowner risk and are wary of the cumbersome legal process in case of payment delays or defaults by the homeowner.

A neat solution could be for discoms to partner with RESCOs to install SRT systems. Another alternative could be that discoms collect a monthly PPA amount on behalf of the RESCO, along with the electricity bills — this mechanism would protect RESCOs from homeowners' credit risk, while discoms could earn a fee. Furthermore, this arrangement will allow RESCOs to raise financing from banks and other investors, which would otherwise be reluctant to extend funding to RESCOs targeting households.

***Securitisation**:* Bundling a number of individual SRT loans and raising finance against them can be explored as an alternate source of funds. However, this would require measures to develop the relatively underdeveloped debt market. It would require strengthening repossession of defaulting assets, assignment of collateral and targeting new investors such as IREDA (Indian Renewable Energy Development Agency).

***Municipal bonds**:* Another idea is to have municipal authorities issue bonds that are backed by house or other taxes and use the proceeds to finance rooftop installation or to extend loans to rooftop developers.

Consumer apathy

Residential consumers have been, largely, staying away from SRTs for a number of reasons. They are not familiar with the solar PV technology, its performance and its life. They are wary of claims that it is reliable and worry about its maintenance needs, especially when confronted by the fact that it has to be in operation for at least 25 years. The rooftop installers who are tasked with the maintenance are small new companies, and hence do not arouse any confidence.

Only a policy that integrates the interests of discoms with SRT will succeed

The financial benefits — in terms of monthly deductions in the billed amounts — tend to be relatively small for many middle class consumers whose tariffs are low (in fact, rich households which pay higher tariffs stand to gain much more).

Finally, the process of installing solar rooftop on one's own can be a daunting prospect. The larger and better known companies do not operate in this market. There is no reliable source of market information. Most consumers do not even know about the government subsidies, and those who do, fear the bureaucratic process of obtaining the subsidy. Consumers, typically, have a poor opinion of discoms' customer services and believe that obtaining approvals for the SRT system would be an exhausting process.

Policymakers should focus their efforts on cities and involve city, town and district authorities

The way ahead

It is clear that SRT systems provide multiple benefits — to households, to the grid and even to discoms. Promoting them, therefore, is a desirable policy goal. SRT systems can offer reduced power bills for households; the gains may increase as tariffs are likely to keep going up. They provide environmentally friendly, inexpensive back-up supply of power (compared to DG sets), a big advantage given the persistent supply interruptions in most places. They can result in lower T&D losses and improved grid management, since the generation is close to the point of consumption. Solar rooftops, however, also face several challenges, as indicated in the preceding section: lacklustre growth, little consumer awareness, lack of innovative government policies or attention, bureaucratic hassles, and limited support from discoms. Sustained and broad-based efforts are required to promote SRTs.

Refine the SRISTI scheme: SRISTI needs to focus on strengthening the long-term viability of discoms, which should ideally play a central role in the SRT market. Discoms need to explore innovative business models to not just avoid revenue losses, but also profit from the emerging SRT sector. For instance, discoms have valuable customer data and can assist solar developers in identifying clients, sizing up SRT systems etc. They can act as a franchise to bill and collect for a range of entities, and take a fee for providing this service. Since residential customers are unlikely to default on bills, discoms can help banks collect the EMIs for individual SRT systems, thereby expanding the available financing. They can also act as intermediaries in structuring loans for large numbers of customers in an area.

City-wide concerted efforts: Policymakers should focus their efforts on cities and involve city administrations and town and district authorities. An ideal beginning could be the development of a city-wide long-term plan and targets. The SRT sector involves the participation of a large number of small consumers — accordingly, raising awareness about the financial benefits of SRT, the durability and performance of solar PV, and about government subsidies is very important. These efforts need to be intensive and down to the town/housing colony level. Subsidy approvals need to be processed efficiently. Nodal offices should be set up to monitor city-wide goals as well as performance of various authorities which are responsible for promoting SRT.

Streamlining processes: Discoms need to deploy more resources to encourage SRT installation. This will involve both hiring people and training staff about net metering processes. Discoms must also enforce tight timelines to approve applications and install net meters and ensure they are meeting those performance standards.

CASE STUDY: IMPLEMENTATION OF SRT POLICY

CSE analysis of implementation of SRT regulations in Gurugram

Solar rooftop is largely an urban phenomenon in India, with cities being at the forefront of interventions to promote it. Large towns and cities have significant power demand as well as solar rooftop potential, and their residents have the resources to afford installation of SRT systems. A comprehensive analysis of SRT implementation in a city, therefore, can provide insights about challenges, bottlenecks and solutions on the ground which might be relevant to other cities as well. Gurugram, one of the fastest growing urban centres in India, has been chosen for this analysis by CSE.

Gurugram's electricity demand

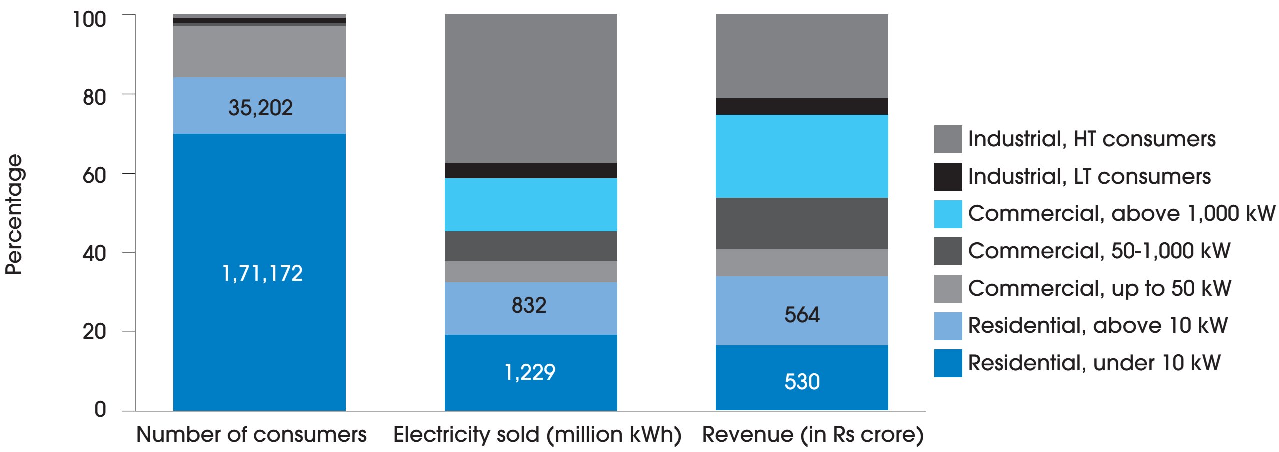
With sizeable commercial and industrial activity and a large consumer population, Gurugram's per capita consumption of electricity stands at 4,000 kWh per person per annum; this is expected to increase to 6,400 kWh per person per annum by 2022.[15] The Dakshin Haryana Bijli Vitaran Nigam (DHBVNL), the discom supplying to Gurugram, has almost 250,000 customers in the city who consume 6.4 billion units (BU) (*see Graph 3: Load-wise category of consumers*). According to the DHBVNL, the average demand for electricity in Gurugram is around 1,125 MW per day; during peak summers, this reaches around 1,700 MW.[16]

Solar rooftop in Gurugram

Gurugram district has installed a total of 24 MW of SRT systems. Of this, 8 MW is grid-connected and 16 MW is off-grid. The commercial and industrial sectors dominate rooftop installations because of the clear financial

Graph 3: Load-wise category of consumers

Two-thirds of the power is consumed by a small number of commercial and industrial customers

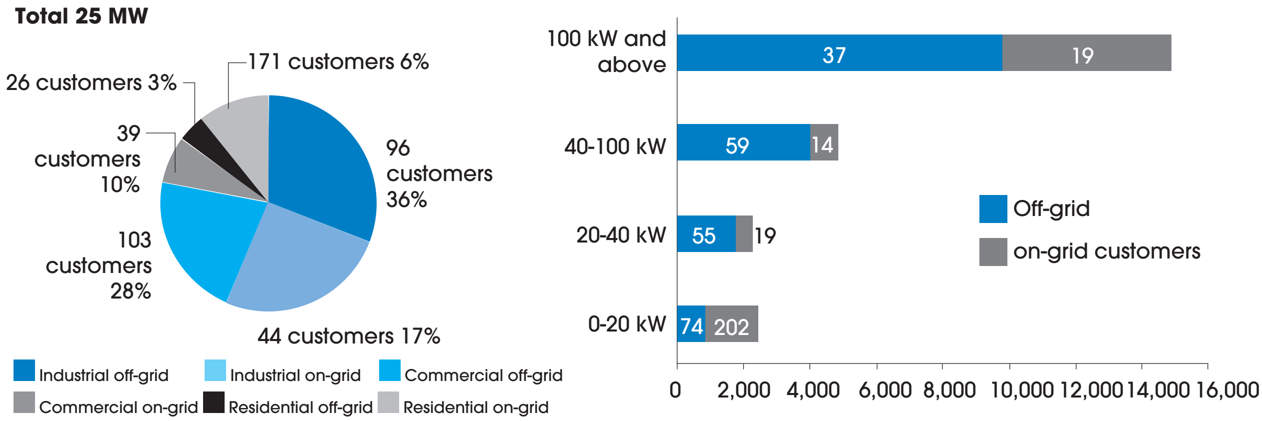


Revenue Rs 3,249 crore • Electricity 6,303 MU • Customers 2,44,518

Source: Dakshin Haryana Bijli Vitran Nigam (DHBVNL), 2018

Graph 4: Solar rooftop installations

Despite a sizable number of retail consumers, SRT holds a small share of the total capacity



Source: Dakshin Haryana Bijli Vitaran Nigam (DHBVNL), 2018

benefits to these customers, who are charged Rs 8-10 per unit by DHBVNL. More than 14 MW of the total capacity comprises of installations larger than 100 kW[17] (*see Graph 4: Solar rooftop installations*). These installations do not really fall under the 'rooftop' category from the perspective of 'distributed generation'.

Power supply

The DHBVNL claims that there is virtually no load-shedding in Gurugram. It defines load-shedding as "four hours per power cut per day for four continuous days" to come up with this rather unbelievable statistic. The Nigam refers to sporadic power outages as "regular maintenance or line

Table 3: Solar rooftop mandates for Gurugram

Large consumers have been been mandated to install SRT

	Connected load (kW)	Total load (MW)	No. of customers	Rooftop potential (MW)	Electricity consumed (MU)	Electricity generated — rooftop (MU)
Commercial	50—1000	334.4	3,957	21	458	30.9
	Above 1000	434.7	207	14	854	21.1
Industrial	50—1000	265	1,769	21	477	31.5
	Above 1000	156.5	69	5	2,018	7.5
Educational institutes	Above 30	14.6	146	0.7	NA	1.1
Government buildings	Above 30	8.5	106	0.4	NA	0.6
			6,254	62.1	3,807	92.7

Source: Dakshin Haryana Bijli Vitaran Nigam (DHBVNL), 2018

faults". A survey by CSE done in December 2016 showed that power cuts in housing societies ranged from 30-60 minutes per day[18]. Another survey done in January 2018 also confirmed approximately 30 minutes of power cuts every day in winter and an average of 60 minutes per day in summers[19].

State policies

Haryana allows customers to install grid-connected solar rooftop systems of a capacity equal to the sanctioned load. Average power purchase cost is set as feed-in-tariff by the Haryana Electricity Regulatory Commission (HERC).

In 2016, the Haryana Renewable Energy Development Agency (HAREDA) issued an order mandating certain customers to install solar rooftop (*see Table 3: Solar rooftop mandates for Gurugram*). The order was applicable to only around 6,200 non-residential customers, including less than half of the industrial and 15 per cent of the commercial segment customers.[20] CSE researchers estimate that around 62 MW of solar rooftop installation can potentially emerge from the order. Industrial and commercial customers with loads between 10-50 kW could easily add a sizable capacity. Further, an estimated 200 MW of solar rooftop can be installed on the buildings planned to be constructed under Gurugram's Master Plan 2031.

But till the time of going to press, less than 300 customers had complied with the HAREDA order. Agencies such as the Town and Country Planning Department, the Haryana Urban Development Authority (HUDA), the municipal corporation and various government departments (police, PWD etc) are responsible for ensuring compliance. They were required to incorporate relevant provisions in their departmental bye-laws to facilitate the implementation of the order, but many of them have not done so yet. Most have not even informed their consumers about the requirement. None of the agencies are monitoring progress either.

One of the stumbling blocks is the perception that SRT is a threat to discom viability. While it might be termed a long-term risk, currently, most cities continue to have very low level penetration of SRT. If the HAREDA order was implemented, the installed solar rooftop in Gurugram will generate a mere 2 per cent of the electricity consumption of those customers.

CASE STUDY: POTENTIAL OF SRT TO REDUCE POLLUTION

A study to estimate the pollution load from DG sets in Gurugram

GREENTECH PROJECT

A large number of residents in Gurugram rely on diesel generator (DG) sets for back-up power.[21] CSE conducted a study to assess the impact of operating these DG sets on pollution levels inside residential societies.[22]

Five such societies (DLF Phase 1, DLF Phase 2, Devinder Vihar, New Colony and Time Residency) located across Gurugram were selected, with varying sizes of DG sets and building configurations (*see Table 4: Societies surveyed by CSE*). The sites were selected carefully, and did not have any other significant sources of pollution (construction, traffic congestion etc) near the buildings, which might have corrupted the data.

CSE installed automatic air pollution monitoring equipment at these

Table 4: Societies surveyed by CSE

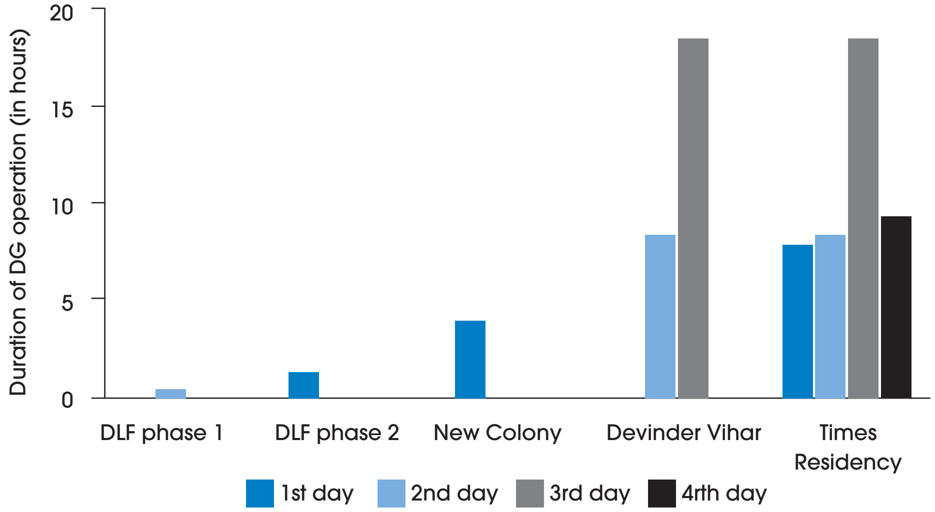
Sites were carefully selected to understand the impacts of DG sets

Location	Devinder Vihar	New Colony	Time Residency
Details	450 flats in 9 buildings	3 houses and a commercial entity	875 flats in 7 buildings
DG capacity	325 kVA	64 kVA	500 kVA
Monitoring period	17th to 21st May 2018	23rd to 27th May 2018	22nd to 26th May 2018
DG operation	18th May between 02:34 and 06:44 hrs (for 4 hours)	23rd May between 04:07-07:30 hours (more than 3 hours)	24th May, from 03:00-10:01, 11:09 - 22:42 (longest operation span within a day).

Note: The DLF residential societies did not suffer from extended power cuts, and hence are not featured in this table.

Graph 5: Duration of power cuts

The societies faced a number of power cuts during the monitoring period



Note: There was no power cut on the fifth day of monitoring at any location.

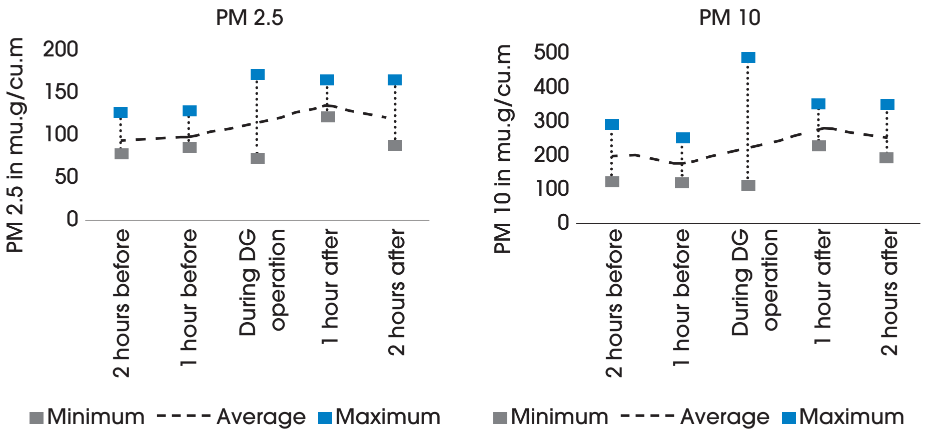
sites to collect PM1, PM2.5, PM4, PM10 and total suspended particles (TSP) data at intervals of 10 minutes for five consecutive days. The operational hours for the DG sets were noted separately. The societies faced a number of power cuts over the monitoring period, both in terms of days as well as hours of cuts per day (*see Graph 5: Duration of power cuts*). Since the DLF societies experienced minimal power cuts, CSE researchers studied the impacts of DG sets only in the remaining three societies.

The three case studies in Table 4 include one residential society with moderate levels of power cuts and ambient pollution levels (Devinder Vihar) (*see Graph 6: Pollution levels in Devinder Vihar*); one with very high ambient pollution (New Colony) (*see Graph 7: Pollution levels in New Colony*); and one with long power cuts and DG operation timings (Time Residency) (*see Graph 8: Pollution levels in Time Residency*). In all of them, PM2.5 and PM10 levels were found to be spiking when the DG sets were operated. Since pollution keeps on accumulating during the period a DG set is in operation, the average pollution levels in the hour after a generator was shut down were found to be even higher.

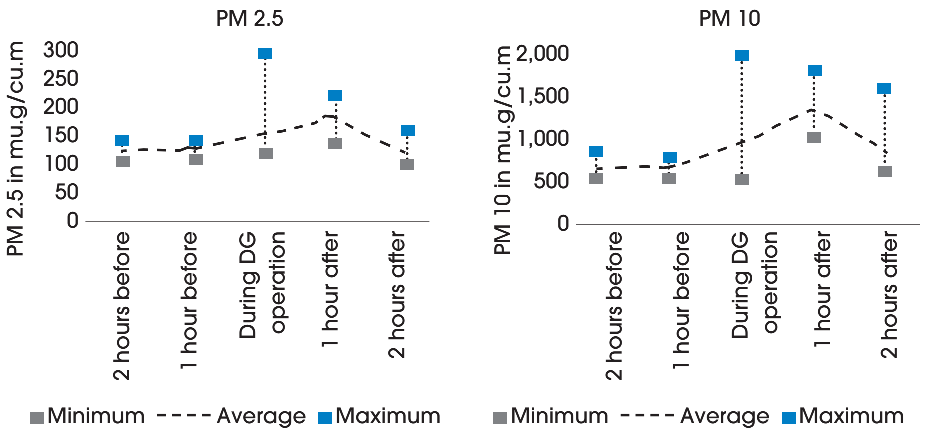
The average PM2.5 levels increased by 30-40 per cent after three to four hours of DG set operations — the levels remained high even after one hour of shutting down the generator. Similarly, average PM10 levels increased by 20-50 per cent during DG operations and the levels remained high for an hour after. Maximum levels of both PM2.5 and PM10 were also found to be extremely high in two of the societies.

Societies with exceptionally high duration of DG operations experienced sustained high levels of PM — longer the DG use, higher the ambient levels. On the other hand, there was a barely discernible impact on air pollution in societies with limited power cuts (15-30 minutes) and DG use.

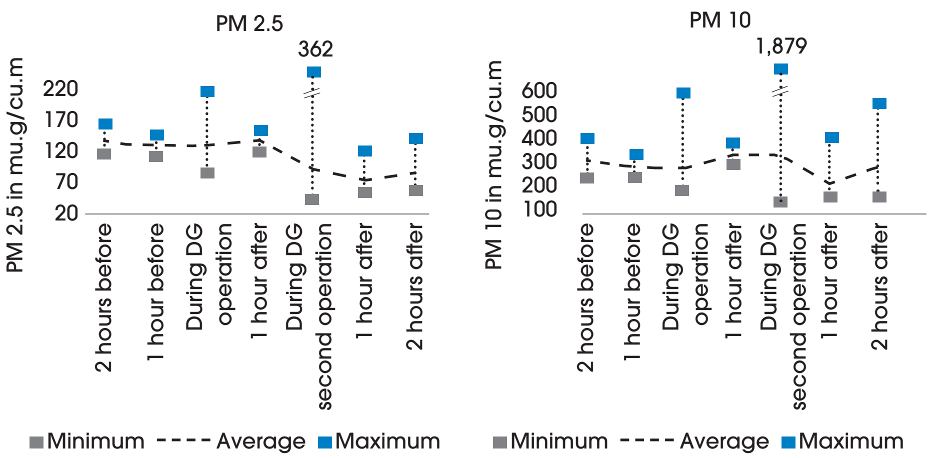
Graph 6: Pollution levels in Devinder Vihar



Graph 7: Pollution levels in New Colony



Graph 8: Pollution levels in Time Residency



CASE STUDY: THE ECONOMICS OF SRT VS DG SETS

The viability of replacing DG sets with SRT in Delhi NCR

Urban households largely opt for DG sets as a default option for back-up power when grid power is unavailable. In 2017, CSE conducted a study in residential societies located in Delhi, Haryana, Uttar Pradesh, and Rajasthan to assess the cost of power from solar rooftop compared to the cost of power from DG sets. The study tried to estimate actual costs for households in different societies based on power cuts, back-up DG capacity, roof space and DG set use.[23]

The societies selected for the study covered a wide range in terms of number of apartments, society type (upper or middle income), DG back-up level (full, partial or only for common services) etc. In addition, these societies experienced power cuts, which drove DG usage (*see Table 5: An overview of the societies*).

The study assessed the cost of tariffs for two scenarios. The first one sized up the total demand based on a 300-W load per household and battery

Table 5: An overview of the societies

Sample reflects a wide range of societies

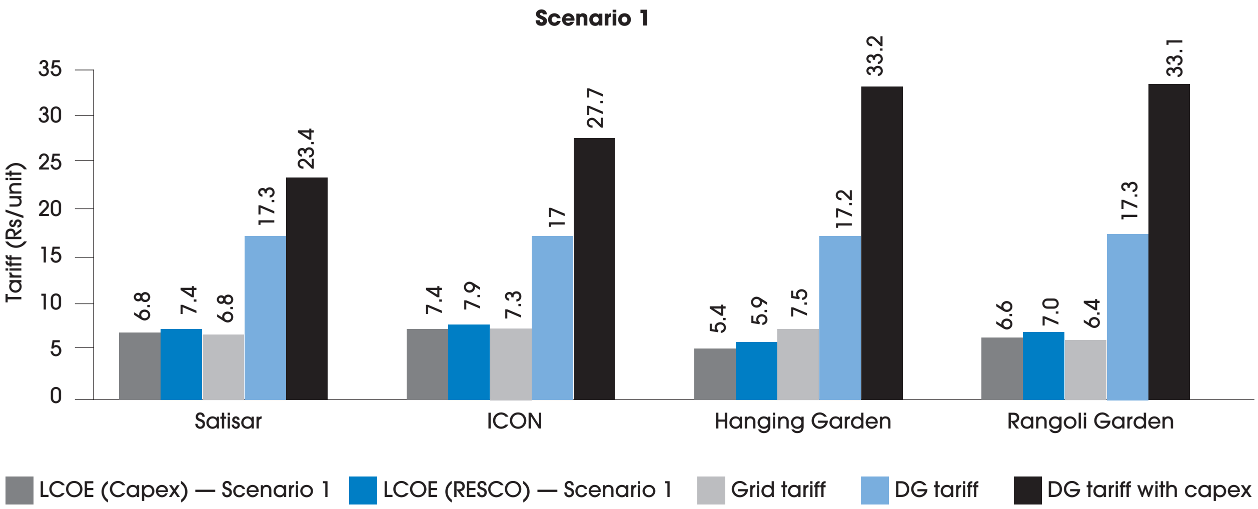
Society	No. of flats	Connected load (kW)	Common area load (kW)	"Stated" back-up	DG size (kW)	Annual grid electricity consumption (kWh)
Satisar, Dwarka (Delhi)	245	1,924	180	Partial (common area load + 800 watt to each apartment	112	1,510,550
ICON, Gurugram (Haryana)	344	1,998	550	Full back-up for all loads	1,112	4,005,450
Hanging Garden, Jaipur (Rajasthan)	400	4,218	183	Back-up only to common loads	180	304,512
Rangoli Garden, Jaipur (Rajasthan)	1,300	10,635	555	Partial (common area load + 750 watt to each appartment)	1,712	2,390,625
Amgel Mercury, Gjazianad (Uttar Pradesh)	280	363	142	Common area load + 1 kW and 3 kW back-up provided to apartment	256	1,146,627

Source: CSE survey

to cover average outage hours in the building. The second added common area demand to the total demand and provided for battery for up to twice the time of average outage. The rooftop system was limited by available space in both the scenarios. Under the first scenario, the cost of SRT power was one-fourth the cost of supply by DG (including capital cost of DG). In the second case, the cost of SRT power was between one-third and half of the cost of supply through DG sets (*see Graph 9 – Scenarios 1 and 2: Tariff*

Graph 9: Tariff comparisons

Solar tariff is half of the DG tariff in all societies



Scenario 2 on next page

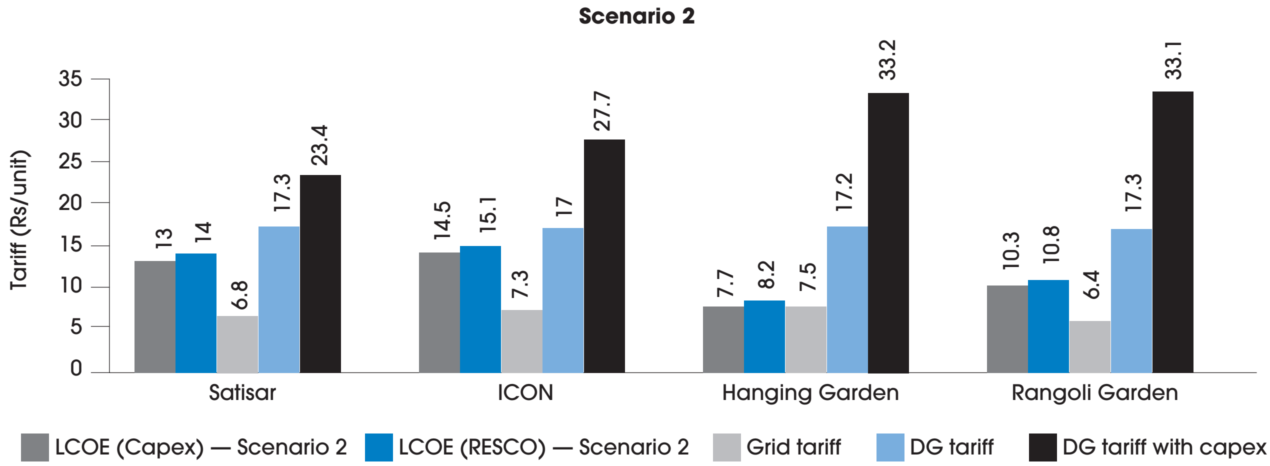


Table 6: Demand met by SRT systems

Solar rooftop can meet significant amount of partial load in most societies

Society	Percentage of partial load*	Percentage of partial load* (0.3 KW/flat)	Percentage of DG capacity
Satisar	54	100	100
**ICON	24	69	6.5
Hanging Garden	100	100	100
Rangoli Garden	36	87	20

*Partial load — 0.3 kW/flat + common area load
**For ICON, 10 per cent of the connected load is considered as common area load
Source: CSE analysis

comparisons). Even if we ignore the capital cost of DG, power generated by it cost much higher (over twice than that under the first scenario) because of the high cost of diesel.

In addition to the cost benefit, the study confirmed that most societies have sufficient rooftop space for installing SRT systems that could reliably meet the basic load for individual flats (assumed to be around 300 W), plus the common area loads, assuming power cuts of up to one hour per day (*see Table 6: Demand met by SRT systems*). But an SRT system may not be able to fully replace DG sets in upscale societies that provide "full back-up" — which typically means the facility to operate air conditioners in addition to the usual household needs.

CHAPTER 4

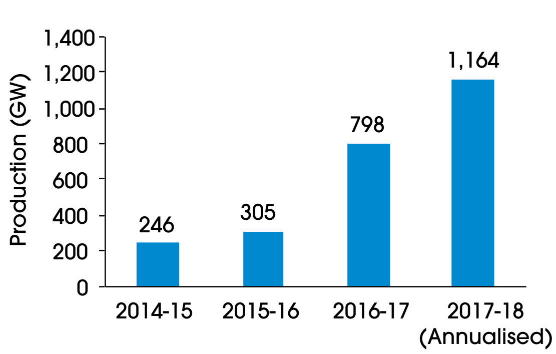
Solar manufacturing: Moving out of the doldrums

While solar installations have grown in number and spread in India, they have largely done so on the back of imports — domestic manufacturers of solar modules and panels have fared badly and have had little role to play in this growth. During the period 2014-17, local manufacturers in India had ramped up their capacities, as both targets and installation of solar PV saw a rise. According to the Union Ministry of New and Renewable Energy (MNRE), manufacturing capacity of cells and modules jumped by 160 per cent and 258 per cent to 3.1 GW and 8.4 GW respectively.

But production has failed to keep pace with this hike (*see Graph 1: Indigenous solar cell production*) resulting in the under-utilisation of the installed capacity (*see Graph 2: Capacity utilisation*). To add to that,

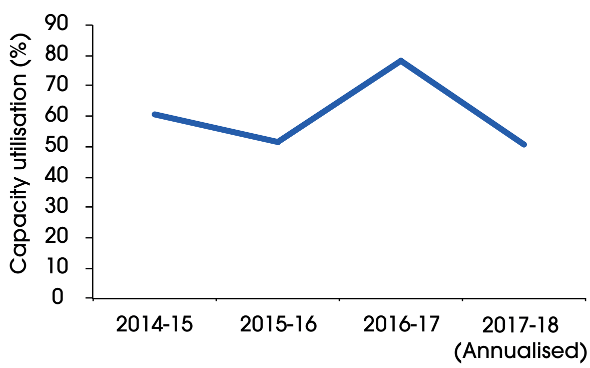
Graph 1: Indigenous solar cell production

Does not match capacity



Graph 2: Capacity utilisation*

Under-utilised

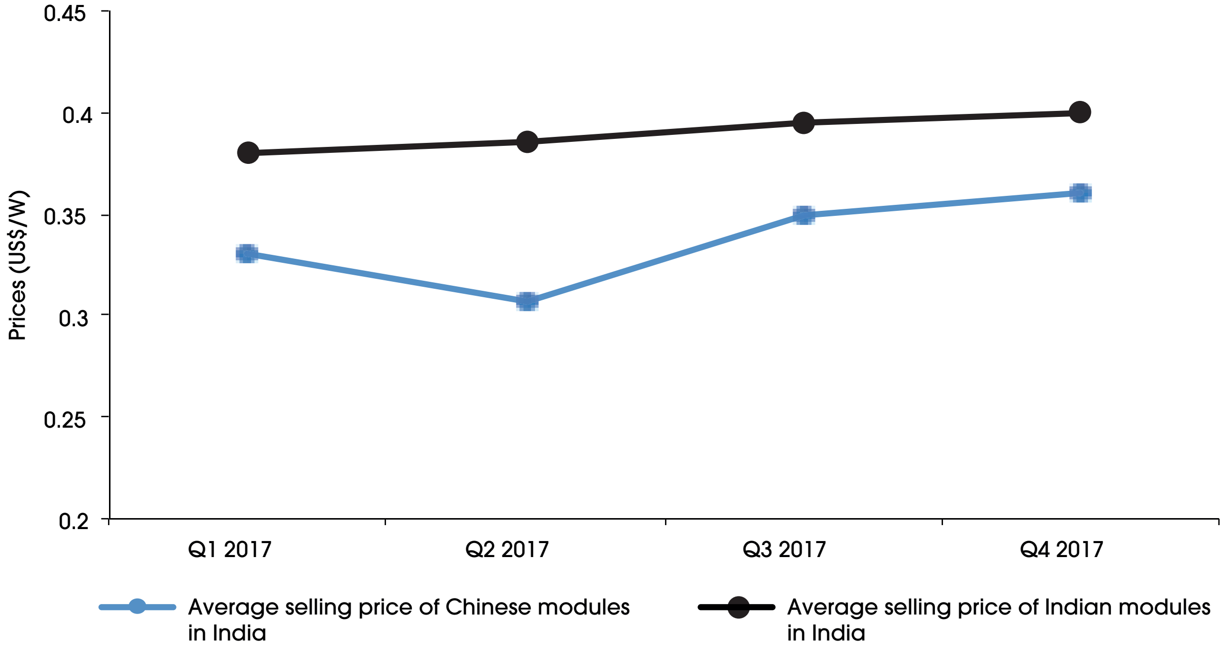


*Five major manufacturers who have 72% share in total installed capacity in 2017-18.

Source: 2018, Directorate General of Safeguards Duties, http://dgsafeguards.gov.in/DataFiles/Tender/NWM77Preliminary%20Findings%20Solar%20Cells%2005.01.18-Final.pdf

Graph 3: Landed import prices vs domestic sales prices

The price difference ranges between 10-25 per cent



Source: Mercom India and CSE estimates

cheap imports, mainly from China, have put domestic manufacturers at a severe disadvantage. Compared to Chinese manufacturers, Indian firms suffer from smaller scale, operations that are not fully integrated, and high costs of energy and finance. The price difference between domestic and imported modules is, broadly, 10-25 per cent (*see Graph 3: Landed import prices vs domestic sales prices*). Unable to compete on the price, domestic manufacturers' capacity utilisation has remained quite low.

An import-driven market has its own pitfalls. The question before India, therefore, is whether to continue to rely on a cheap-imports and low-tariff model, or to create conditions in which domestic manufacturers might grow and prosper.

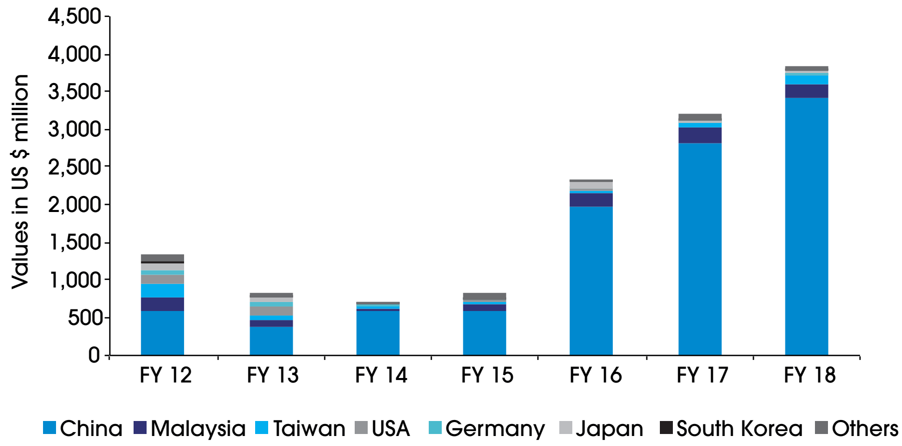
The import conundrum

India's dependence on imported, especially Chinese, modules has existed since the days of the National Solar Mission's first phase. This dependence has magnified over the years, and imports have grown faster than the rate of solar installations. In 2017, the share of domestic manufacturers in the Indian market stood just at 10 per cent (*see Graph 4: Imports — solar cells and PV modules*).

The cheap imports have propelled a relentless fall in tariffs and triggered a rise in solar capacity. The phenomenon of falling prices was disrupted in 2017 — spot prices went up due to a spike in demand from USA in

Graph 4: Imports — solar cells and PV modules

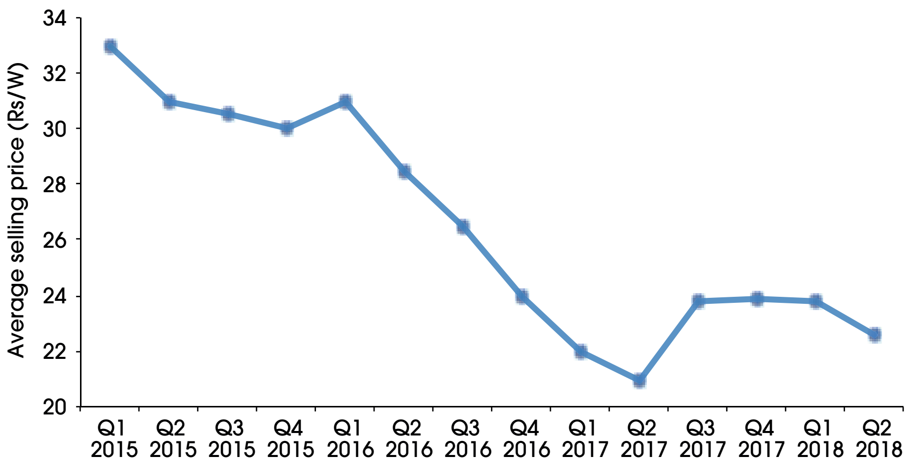
India's solar manufacturing business is almost wholly dependent on imports



Source: Union Ministry of Commerce and Industry, http://commerce-app.gov.in/eidb/Icomq.asp?hs=85414011

Graph 5: Average selling price of Chinese modules in India

Prices have largely been in a free fall



Sources: Bridge to India; Mercom; PV Magazine; CSE estimates

anticipation of safeguard tariffs by the US administration (*see Box: The changing Chinese dynamics*). But the disruption was brief (*see Graph 5: Average selling price of Chinese modules in India).*

There are legitimate concerns about India's almost total dependence on imported components — supplies can be affected by changes in the exporting countries' strategic priorities or due to international trade disputes. Imports are also vulnerable to abrupt changes in domestic trade policies and exchange rate risks. Recently, imports were disrupted on account of 'new' import duties. Solar PV components have been exempt from customs

The changing Chinese dynamics

India's dependency on imported, especially Chinese modules, is not a new phenomenon. More than 90 per cent of the total demand from the Indian solar industry was taken care of by imports in the last three financial years. Of this, China accounted for 82 per cent of the total modules installed in 2016-17 and 88 per cent of the total import mix in 2017. Solar cells and PV module imports from China have increased by over six times — to US $3.84 billion in 2017-18 from US $596.73 million in 2013-14.[1]

But this dependence on imports brings with it inherent pricing risks. In 2017, Chinese manufacturers saw a spike in demand from the US in anticipation of the safeguard tariffs that were expected to be levied on China by the incumbent US administration. As a result, spot prices went up and manufacturers were no longer keen on supplying at the low prices drawn up on contracts with solar developers in India. Chinese manufacturers began demanding a higher price — US $0.35-0.37/watt, up from US $0.30-0.32/watt.[2] Developers who had bid under Rs 3/kWh in anticipation of further declines in module prices were suddenly faced with potentially unviable projects. Given the short 12-15 month deadline to complete a project, there was no option of waiting it out till the market stabilised.

This incident highlights the risks from over-reliance on imports, as well as the impact (on supplies) of international trade disputes and changes in exporting countries' strategic priorities.

China is now entering a new phase of solar installation, by terminating any approvals for new subsidised utility-scale PV power stations. It is capping the construction of distributed project size at 10 GW — down from 19 GW — mandating auctions for utility-scale projects and reducing feed-intariffs (FiTs). These internal developments will reduce the demand within China leading to oversupply in global markets, and may trigger a one-third reduction in prices of solar modules.[3]

At the same time, the Chinese government has started reforming its solar sector by reducing the intensity of subsidies. If this move is extended to the manufacturing sector, Chinese companies will not be in a position to supply PV modules at such low rates.

These changing dynamics within China keep the Indian solar market on tenterhooks. The glaring lack of growth in India's local/domestic manufacturing industry has left most developers with very little alternatives. India needs to support its manufacturing for self-reliance in the near future.

duty since 2010. However, in September 2016, the Central Board of Indirect Taxes and Customs (CBIC) issued a notification saying solar PV components are electricity generation components and should attract a custom duty of 7.5 to 10 per cent.[1] The ruling, enforced in mid-2017, held up trade in PV components worth millions of dollars. In April 2018, the CBIC finally issued a clarification that solar panels can be classified as diodes and will not be charged a duty.[2]

India needs to nurture its domestic manufacturing sector, growth in which is desirable for many reasons — for employment generation, encouragement to indigenous R&D, earning foreign exchange and ensuring long-term stable supply. However, the country's policies to support the domestic sector have been *ad hoc* (for example, introduction of a safeguard duty that will provide only temporary relief) and muddled (such as the hike in import duty that was later withdrawn). A strategic vision is required that can carefully balance the benefits of cheap electricity from imports against the costs of supporting local manufacturers.

A strategic vision is required that can balance the benefits of cheap electricity from imports against the costs of supporting local manufacturers

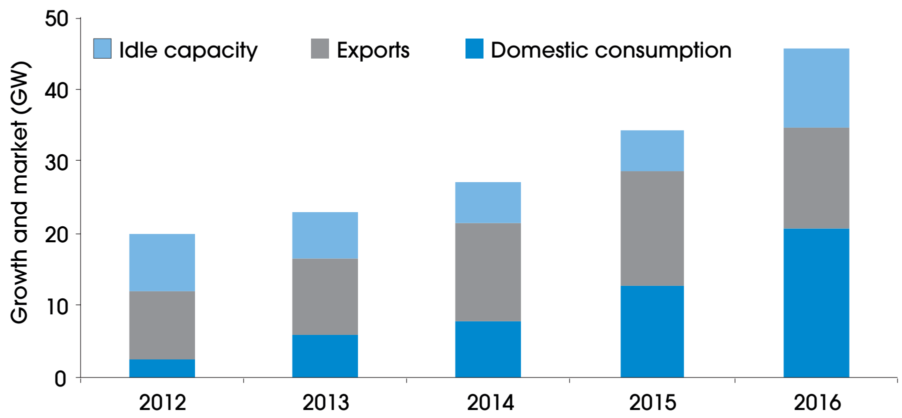
Policy moves

To be fair to it, the government has taken some tentative steps. In the initial phase of the NSM, a substantial portion of the auction capacity was reserved for domestic manufacturers under domestic content requirement (DCR). The DCR auctions were supported by a higher level of capital subsidisation by commanding higher viability gap funding (VGF). In 2013, the US complained to the World Trade Organization (WTO) that the DCR scheme was a violation of the WTO's rules. In 2016, the WTO ruled against India and asked it to stop DCR allocations by September 2017 (see *Statistics section*). However, the ruling permitted a loophole — entities that were generating power for their own consumption were not bound by it.[3] This has allowed the Indian government to continue with DCR auctions for PSUs and government offices.

There has been action on anti-dumping as well. Faced with the domestic manufacturers' precarious condition, the Indian Solar Manufacturers Association (ISMA) had filed a petition with the Directorate General of Anti-Dumping & Allied Duties (DGAD) in July 2017, alleging dumping of PV cells and modules by China, Taiwan and Malaysia.[4] China's solar module manufacturing capacity has increased sharply over the years (*see Graph 6: Growth and market of Chinese modules*), and prices have consistently climbed down. India is particularly vulnerable, having replaced Europe as

Graph 6: Growth and market of Chinese modules

China's domestic demand is about half of its manufacturing capacity



Source: United States International Trade Commission, November 2017, https://www.usitc.gov/publications/safeguards/pub4739-vol_i.pdf

GST and its impact on the sector

Earlier, solar plant components were largely exempt from taxes in most states. The new GST (Goods and Services Tax) regime has changed that. While all the components (PV modules, inverters, etc) have been clubbed under `solar power generating system', which is taxed at 5 per cent, there is no clarity on the tax on Engineering Procurement and Construction (EPC) services.

Different states have variously interpreted the taxes on solar power systems. Maharashtra, for instance, has declared that EPC services for setting up a plant would be levied an 18 per cent tax. On the other hand, Karnataka has ruled that a specific type of EPC contract (including component sourcing and maintenance after installation) should be taxed at 5 per cent. The industry contends that GST has resulted in raising the cost of projects by 10-12 per cent.

Recently, the Central Electricity Regulatory Commission (CERC) has ruled that the enactment of GST laws is covered under the Change in Law provision. Under this, any increase in costs as a consequence of transitioning to the new GST mechanism would be passed on to buyers. The ruling may result in disputes if developers demand higher tariffs, because the argument for GST has been that it should not increase costs but merely apportion them through the supply chain.

In December 2018, the GST Council clarified that renewable devices and EPC services will attract tax at the rate of 5 per cent and 18 per cent, respectively. But more clarity is required on the implementation of these rates. The industry, on the other hand, is demanding a constant rate of 5 per cent.

the largest market for Chinese PV. In July 2018, therefore, the Union Ministry of Finance imposed a safeguard duty of 25 per cent on solar panels from China and Malaysia, followed by 20 per cent for the next six months and 15 per cent for another six. Developers, however, have claimed the duty would increase tariffs and jeopardise the 100-GW solar target.

In December 2017, the MNRE rolled out a new scheme to support fully backward integrated manufacturing capacity for solar PV modules, cells, wafers/ingots and poly-silicon. The scheme proposes a financial assistance of Rs 11,000 crore along with several incentives — a 12,000-MW CPSU (Central Public Sector Unit) scheme with an assured DCR component, capital subsidy for capacity addition, and interest subvention for upgradation or expansion.[5]

Separately, the government has announced an expression of interest (EOI) for a scheme that would auction 20,000 MW of solar capacity to integrated manufacturers[6] — however, no further public information is available on its progress. In May 2018, the Solar Energy Corporation of India (SECI) floated an RfS for the development of 5 GW of solar manufacturing capacity and 10 GW of solar projects under the ISTS scheme.[7] This has now been reduced to 3 GW (per annum) of solar manufacturing capacity. The tender has been floated four times till November 2018, with each iteration

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containing changes to attract manufacturers — but it has failed to attract even a single bid.

The solar market is still perceived as a high risk sector and needs huge investments to execute such programmes. Therefore, not many manufacturers are enthusiastic about building the facilities. The SECI must take note of this and come up with clarifications to queries from manufacturers about the challenges they face.

Innovation and technology

India is emerging as a world leader in installing solar power. But the growth has little to show in terms of manufacturing expertise, development of new technology or innovative ideas. If India is to benefit from the global demand for solar installation, it needs to offer state-of-the-art solutions.

Look beyond land and roof
Utility-scale solar power is land-intensive, while rooftop plants use up valuable space in cities. It is time, therefore, to look beyond the conventional. Floating solar power plants are already a reality in India. Some countries like France, the Netherlands and China have experimented with solar roads or highways. The US is testing a new solar technology for pavements. All this may revolutionise the way we build and design our roads, which can now have lots of functionalities — for instance signages, emergency warning systems, and charging stations to plug in electric cars, which are poised to be the future of transportation.

Building Integrated Photovoltaics (BIPV) is an innovation in solar cell development. Companies are experimenting with products like solar-skin that enhances or personalises the look of buildings and roofs without interfering in the efficiency of the solar panels. Another innovative product is the frameless panel with strong adhesives at back that can be installed on roofs in a few hours with minimal effort.

Space solar, another out-of-the-box idea, has the potential to replace all other sources of power. Japan is developing a system for capturing solar energy from space in the form of laser beams or microwaves. The US National Aeronautics and Space Administration (NASA) is also researching a similar system, and hopes to have a prototype ready by 2025.

Look beyond silicon
India has been largely dependent on imported silicon-based solar PV components. Currently, crystalline silicon technology is the backbone of the solar industry. But it has a fundamental limitation: it has an efficiency of only 32 per cent. Therefore, researchers are working on next generation solar cells that would be more efficient.

Examples include gallium arsenide-based solar PV developed at London's Imperial College, which will be nearly three times more efficient than existing products. The US-based Massachusetts Institute of Technology (MIT) is developing an advanced thermo-photovoltaic energy device (which first converts sunlight into heat and then converts heat back into light with the focus on the spectrum), which will be able to absorb

The way forward

So far, the government has employed short-term ideas — a combination of incentives and protections (import duties) — to support the sector. But if the cost gap in domestic manufacturing is not narrowed, India will have no option but to continue relying on cheap imports that drive low tariffs. The longer term solution lies in making Indian manufacturers globally competitive. This would require a broad range of initiatives:

Policy support: Concerted efforts are required to address the apprehensions of manufacturers and make the sector lucrative for them. There is a sizable market in India and new entrepreneurs will be willing to be part of it — but more solar energy than the traditional silicon.

Perovskite (hybrid organic-inorganichalide-based material) solar cells could be the next generation disruptive technology: they are cheap and simple to manufacture. Light-sensitive nanoparticles called colloidal quantum dots and polymer-based thin films are being developed as solar paints. These technologies have the potential to change the market.

Apart from solar cells, storage solutions are also receiving a lot of attention. High capacity, long-lasting and cost-effective batteries will play a big role in the future of renewable energy. In early 2018, the MIT discovered a low-cost, effective way of reviving an old battery through a steel mesh technique to make it more durable. The US-based company NantEnergy has developed a rechargeable battery operating on zinc and air that can store power at a lower cost compared to lithium-ion batteries.

An R&D challenge for India

India seems to be almost absent in this innovation race. Even India's 'Mission Innovation' in clean energy does not capture solar PV adequately. The reasons behind this dearth in R&D could be summarised under three heads — budget crunch, lack of vision and lack of research partnerships.

The MNRE's budget for R&D in solar averaged less than Rs 70 crore (about US $10 million) per annum for the period 2012-16.[1] A company like First Solar invested more — about US $130 million per year — in the same period.[2] The US spent $1.5 billion on solar-dominated renewable energy R&D projects in 2015-16. The Office of Energy Efficiency and Renewable Energy in the US budgeted $134 million for FY18 — this covered research on renewable generation and manufacturing technologies.[3]

Unlike China, which has clear Solar Innovation Goals in its Five-Year Plans, India lacks strategic planning. The Clean Energy Research Initiative set up by the government is supporting solar-oriented fundamental research on an ad hoc basis. Other research institutions are not keeping up with global developments — in fact, very few of them (such as the Indian Space Research Organisation and a few IITs) are driving innovation in solar. India requires more collaborations with global leaders of technologies: there is a huge scope for learning from the best institutions worldwide.

India needs an ecosystem in which academics can lead innovation from the front, while the government acts as a facilitator. Participation by industry in R&D for business innovation in private or public-private partnership mode is a dire need at this hour.

only if they get sufficient support from policies that are conducive to the growth of market and that can enable them to sell.

Scaling up: Economies of scale will play a big role in making the solar manufacturing industry competitive. Hence, large-scale manufacturing should be supported by the government through stable policy. Cheap finance is required to support and nurture a new industry till market forces take over. Also, availability of raw material for ingots and power for wafer production has to be guaranteed for long-term viability of solar manufacturing in India. In parallel, increasing the number of testing facilities is required to ensure the quality and reliability of the products.

Vertically integrated operations: Backward integration up till the manufacturing of ingots should also be backed up with a parallel industry that produces machines for photovoltaic manufacturing. It may require further analysis on viability. The Indian manufacturing sector should explore technological ties with countries like Germany, Italy, China and USA to leverage from their experiences.

Research and development: The time has come to invest in R&D for storage solutions. The solar manufacturing sector provides unique opportunities to cut down on material costs and take a leap into the next phase of the technology. Domestic R&D can be developed in association with research institutes — this will help narrow the gaps in technology and scale.

Developing skilled human-power: Skill development in solar module repairing can help create jobs; additionally, this kind of auxiliary service can support an already existing market with millions of modules deployed each year. It will save on the material costs for manufacturing, and reduce the quantum of waste created by discarding old and malfunctioning modules.

CHAPTER 5

Wind energy: Braving the headwinds

Wind energy found its bearings in India in the 1980s, with the country's first wind energy demonstration project of 1.15 MW established in 1986 in Tuticorin, Tamil Nadu. But the sector's growth trajectory did not pick up pace till the mid-2000s.

Over the last decade, wind has become the largest contributor to renewable energy capacity additions in India. It has reached a sizable 35 GW and now accounts for 50 per cent of all renewable energy capacity and 10 per cent of the total installed power capacity in India.[1] The sector's growth has come on the back of a favourable policy environment, including a host of subsidies and incentives. At the end of 2017, India was in fourth spot globally for cumulative installed capacity — behind USA, China and Germany — and fifth for annual capacity installations.[2]

This growth, however, has been turbulent, with the government erratically introducing and withdrawing incentives. In the past, the government has announced incentives that were subsequently reduced and when faced with a sudden drop in the market, it has reintroduced incentives. The latest abrupt change in policy occurred in 2016[3] when the government introduced competitive auctions to determine tariffs and award contracts; the change stalled the market for around a year as the industry was unclear about certain provisions and protections in the auction mechanism. However over the last year the new regime did result in a sharp fall in tariffs.

The wind energy sector in India stands at a crossroads today. Although its tariffs are similar to that of solar, there are questions about their sustainability. Over the longer term, its competitive position vis-à-vis solar may worsen if costs of solar drop faster and as the best wind sites are taken up. Indeed, the country's plans call for a far smaller capacity of wind compared to solar.

Nevertheless, the industry is a mature one, with a large installed capacity and years of operating experience along with a large manufacturing base and skilled human power. This makes it important for the country's energy security and diversification. The sector needs to explore alternatives such as repowering, hybrid and offshore to remain relevant and to expand its scope, in addition to improving efficiencies and cutting costs to retain its competitive edge.

Wind accounts for 10 per cent of the country's total installed capacity and half of its renewable capacity

Evolution of the wind power industry

The potential

The latest wind energy potential study carried out by the Chennai-based National Institute of Wind Energy (NIWE) estimated 302 GW at 100 metre above ground level (agl).[4] With 35 GW installed so far, the country has a sizable untapped potential. However, almost 90 per cent of this potential is concentrated in just five states (*see Graph 1: Wind potential and installations*). Given the high variability of wind energy, this has important implications on the evacuation infrastructure needed and grid integration measures adopted.

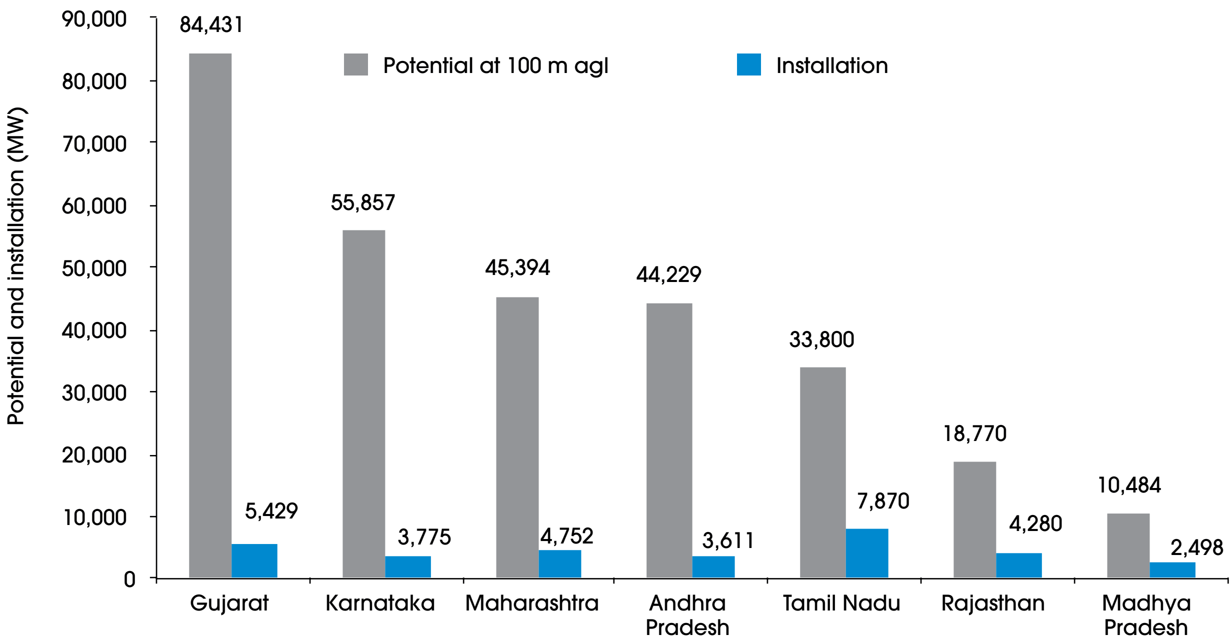
The growth

In 2015, the Ministry of New and Renewable Energy (MNRE) set a target for 60 GW of wind installations by 2022. While the capacity additions in FY 2016-17 were a sizable 5.4 GW, the pace slowed down considerably in FY 2017-18, with only 1.7 GW of projects commissioned, against a target of 4.1 GW. Most of these installations (~1.2 GW) came online only after December 2017.[5] The industry blamed the abrupt introduction of reverse auctions and bidding — moves that it felt were not fully thought through — in addition to the untimely withdrawal of support mechanisms. In contrast, the MNRE called the move a necessary "course correction" to develop a competitive market (*see Graph 2: Wind energy development in India*).

Lately, the industry's performance has been mixed. Running January to September 2018, a sizable 5.2 GW of auctions were planned: these included the three tranches of auctions led by the SECI Tranche-III of 2 GW,

Graph 1: Wind potential and installations

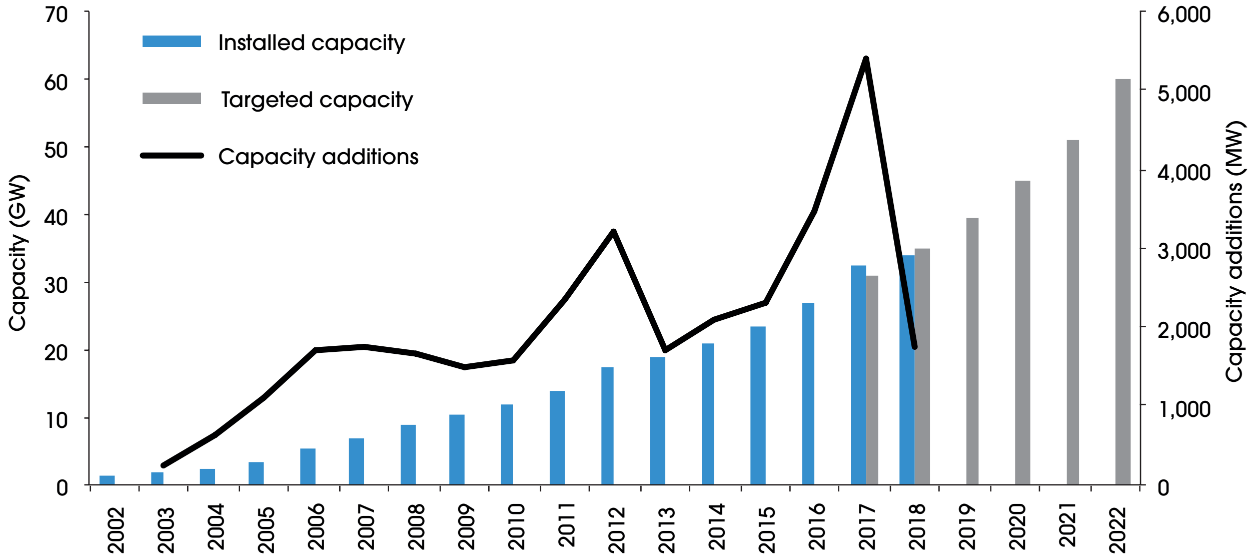
Against a potential of 302 GW, only 35 GW has been installed



Sources: Compiled from National Institute of Wind Energy (NIWE) and Ministry of New and Renewable Energy (MNRE) reports

Graph 2: Wind energy development in India

The pace slowed down in 2017-18, due to the introduction of auctions



Source: Compiled from various MNRE annual reports

Tranche-IV of 2 GW and Tranche-V of 1.2 GW and 1.2 GW of NTPC auctions. However, some of the auctions were reduced or cancelled on account of concerns about lack of evacuation capacity.[6] If the wind energy industry is planning to meet the target of 60 GW by 2022, it must auction 20 GW of capacity within the next two years, considering the two to three years needed to commission wind projects.

Historically, the growth in wind energy capacity has followed a pattern, with individual states dominating for a few years before the focus shifts to another state. In the first phase, before 2004-05, Tamil Nadu was responsible for a majority of the capacity addition: in March 2005, its share of the country's total wind energy capacity was around 56 per cent. Subsequently, Maharashtra, Gujarat and Karnataka began making sizable investments in wind energy. Rajasthan was the next state to show rapid growth beginning in 2009-10, followed by Andhra Pradesh whose installations increased sharply post 2012-2013. During 2014-16, Madhya Pradesh was the clear leader (*see Statistics section*).[7]

The policy on wind energy

The sector has been marked by the introduction of large incentives and sudden withdrawals that has, alternately, boosted installations and disrupted the market. Growth began with the introduction of high feed-in tariffs (FiTs), which ensured long-term guaranteed sale of power at attractive tariffs. At the same time, accelerated depreciation (AD) and generation-based incentives (GBI) were employed to draw in investors. But these policies were periodically withdrawn or reduced and, subsequently, reintroduced when installations slowed down.

Accelerated depreciation (AD)

The AD scheme, introduced in 1992, was particularly attractive for investors who had large taxable incomes: they benefitted from the scheme's tax benefits.[8] Wind projects no longer needed to rely on traditional funding sources such as banks, but could access a large number of private investors. The tremendous growth of wind energy in Tamil Nadu was driven by AD benefits.[9]

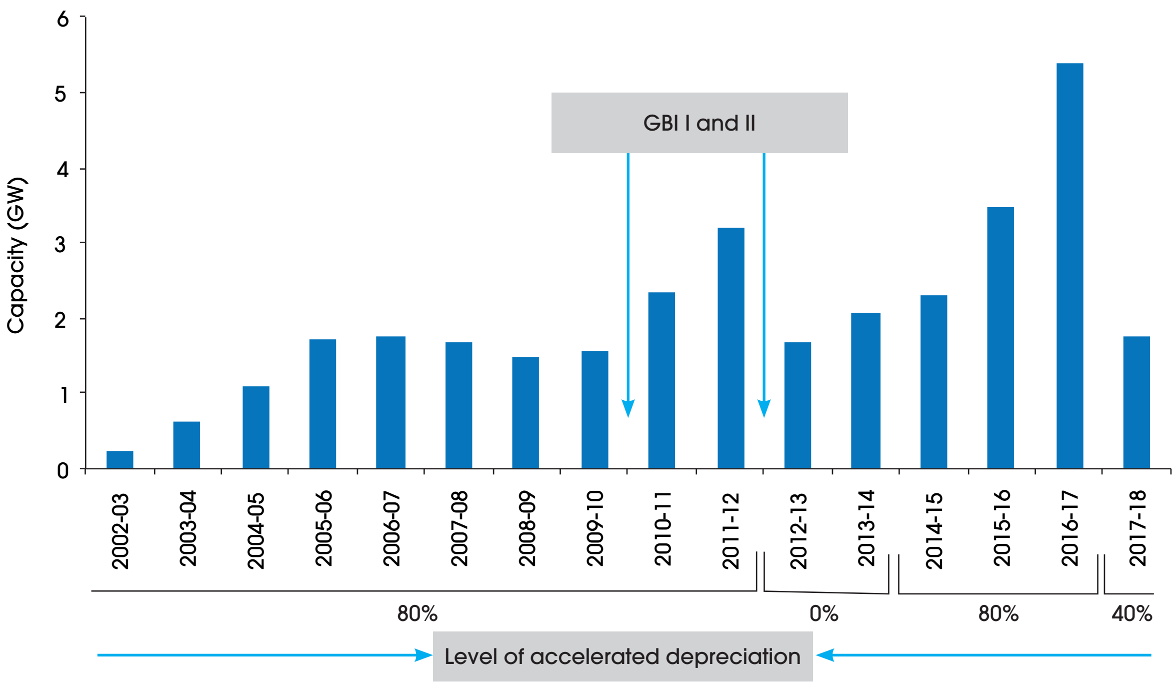
In 2002, the AD applicable to wind projects was reduced from 100 per cent to 80 per cent, and was finally withdrawn in 2012. Capacity additions immediately dropped from 3.2 GW in 2011 to 1.7 GW in 2012. The scheme was reinstated in 2014, which resulted in a rebound during 2015-16 and 2016-17; AD benefits were used by nearly 70 per cent of all wind installations in 2016. In 2017, AD benefits were reduced again to 40 per cent (*see Graph 3: Impact of incentives on capacity addition*).[10]

Generation-based incentives (GBI)

The GBI scheme was introduced in 2009 to incentivise generation, rather than just installations. It offered an incentive of Re 0.50 for every unit (kWh) of electricity fed into the grid. The scheme was attractive for independent power producers and foreign investors, who had little to benefit from AD. The GBI scheme was discontinued in 2012, but lobbying by the industry led to its reinstatement in 2013. It was again discontinued in March 2017.

Graph 3: Impact of incentives on capacity addition

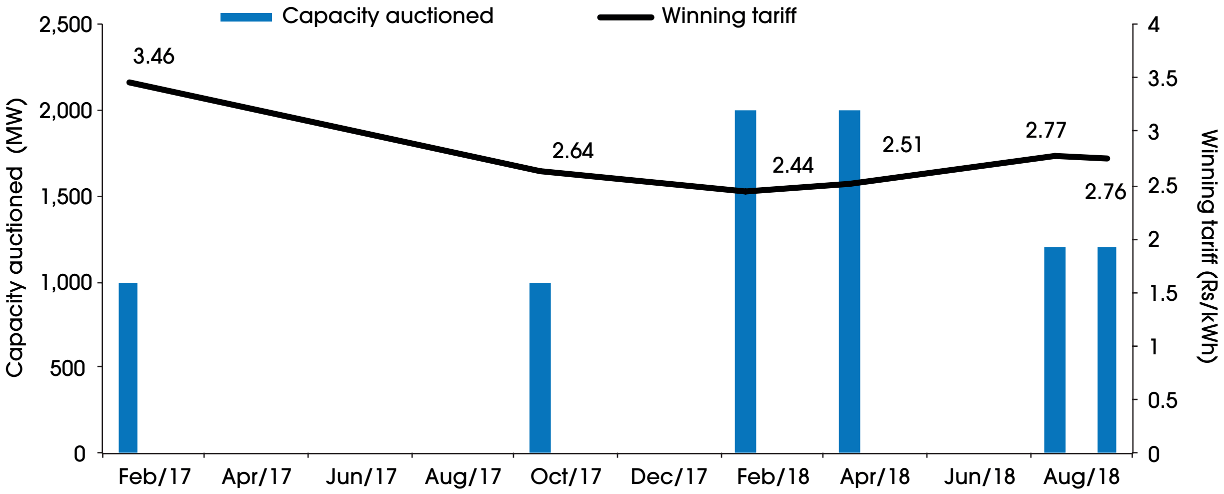
Fluctuations in AD and GBI policies have impacted the sector



Source: Compiled from MNRE annual reports and PIB notifications

Graph 4: Winning bids from wind auctions in India

Almost 8.4 GW have been auctioned by SECI and NTPC combined



Source: Compiled from various MERCOM press releases

The shift to competitive bidding

The government felt that the FiT mechanism was leading to high tariffs and an uncompetitive market. In the light of the success of the auctions in the solar power market, the government decided in June 2016 to introduce a competitive bidding process for the wind sector. The first 1,050-MW auction held by SECI in February 2017 achieved a then-record low tariff of Rs 3.46 per unit. The state discoms of Uttar Pradesh, Bihar, Jharkhand, Delhi, Odisha and Assam signed a 25-year PPA under the auction. Although the auction was considered a success, the sudden introduction of the new policy, lack of clarity about certain critical issues and the sharp fall in tariffs disrupted the sector. Some discoms and ERCs added to the confusion by trying to renegotiate terms of already-signed old PPAs at higher FiTs, stalling installation.

The government finally released the new guidelines for the competitive bidding process in December 2017 to address the policy gaps.[11] Since then, close to 6.4 GW has been auctioned (*see Graph 4: Winning bids from wind auctions in India*). The tariffs have fallen steadily, reaching Rs 2.44 per unit, making wind cost-competitive with solar. In addition to the auctions held by SECI and NTPC, the states of Tamil Nadu, Gujarat and Maharashtra have conducted auctions totaling 2.9 GW between August 2017 and March 2018.

Introduction of new policies

The Indian government has released several new policies over the last three years to expand the potential of wind energy deployment in India. But almost all of them are poorly conceived, and lack innovative ideas and adequate support. The result: the expected development has not happened.

India is embarking on offshore wind without any experience from demonstration projects or detailed data

National Offshore Wind Policy, 2015

Offshore wind energy has seen tremendous success across the world, with close to 19 GW installed.[12] The United Kingdom and Europe have been the pioneers, followed closely by China. The economics of offshore projects is now compelling — in 2017, the Netherlands held the world's first subsidy-free tender for an offshore project. Auctions in Germany and Denmark have yielded tariffs comparable to those attained for onshore wind in India.[13]

In the light of the growing global offshore sector, India released its 'National Offshore Wind Policy' in 2015 to realise its vast offshore potential. The country set itself a target of 30 GW from the sector by 2030. But offshore wind comes with its own set of challenges — resource characterisation, sub-sea cabling, turbine foundation, and installation including logistics and development of the transmission infrastructure.[14] India is ill-prepared to meet these challenges. It lacks sufficient wind data, oceanographic and EIA studies along with basic resource assessment, and preliminary feasibility studies.

The NIWE, the agency in charge, has turned to the Global Wind Energy Council (GWEC) to build on the European experience. But the challenges will remain. In Demark, developers were made to conduct their own metocean data and geological condition studies. Germany spent close to eight-ten years collecting and correlating data from the proposed plant site before the first offshore project was set up. India's target for 5 GW by 2022 might be too short a timeline and in need of a drastic revision.

Demonstration projects provide invaluable inputs when working on a new technology. Although the first offshore wind project in India was set up purely for this purpose, the government has decided that India would start out with a tender and skip the demonstration project part altogether.[15]

The National Offshore Wind Policy lays the onus of development of infrastructure (till the sub-station on land) on the developer. Large investments in offshore structures and transmission facilities (sea-bed structures, foundations and submarine cables, array layout and grid connection) can perhaps be best addressed by delinking the responsibilities for transmission and generation — similar to the UK's offshore transmission owner model. Otherwise, offshore wind projects will be uncompetitive due to high tariffs.

Ports close to the offshore farm are essential to reducing the costs of installation. They could also help in O&M, repowering and decommissioning. The policy does not discuss upgrading or redesigning existing facilities of ports to meet the needs of offshore projects. If India is serious about offshore wind, it must set up dedicated ports — Europe, for example, has 10 such ports.

Recently, the MNRE issued an expression of interest (EOI) for India's first commercial offshore wind farm auction: 34 global and domestic wind energy companies responded. The official auctioning process is awaiting results from the surveys and studies conducted by the NIWE.

Table 1: State-wise installed WTGs for repowering

Large capacities for repowering lie in the states of Tamil Nadu and Gujarat

State	Repowering capacity (kW)-COD prior to March 2000		
	< = 500 kW	500-1,000 kW	Total capacity (kW)
Tamil Nadu	717,050	37,900	754,950
Gujarat	143,745	1,600	145,345
Andhra Pradesh	84,390		84,390
Karnataka	24,525		24,525
Maharashtra	63,715	2,250	65,965
Madhya Pradesh	21,100		21,100
Rajasthan	2,900		2,900

Source: Wind Power Directory 2014

Policy for Repowering Wind Power Projects, 2016

In 2016, the MNRE released the 'Policy for Repowering of Wind Power Projects', which merely offers the bare outlines rather than a comprehensive strategy to promote repowering.[16] The policy has failed since it does not address the fundamental issue — how to quantify the cost of repowering wind projects and compensate the developer.

Repowering entails replacing ageing wind turbine generators (WTGs) with modern infrastructure and technology. Another option is 'partial' repowering, which means reusing components such as the foundation, towers and electrical infrastructure and replacing worn-out components such as blades, grid connections etc. Under both these options, the result is higher efficiency of WTGs and increased generation.

According to the MNRE, of the total wind power capacity in India, there is a need to repower 3 GW of capacity; Wind Power Directory 2014 provides visibility of around 1.1 GW of capacity installed till March 2000 (*see Table 1: State-wise installed WTGs for repowering*).[17] Furthermore, according to the NIWE, two-thirds of the 'repowerable' WTGs in the country are located in prime wind sites.[18] Neither does the national policy address the commercial, technical and regulatory challenges associated with repowering, nor does it incentivise upgradation of the Indian fleet (*also see section on repowering*).

Policy for repowering of wind power projects needs more clarity and detailing before it can take off

National Wind-Solar Hybrid Policy, 2018

Locating solar and wind energy projects at the same site offers multiple benefits. The generation patterns of wind and solar technologies are complementary: wind generation is high in monsoon when solar generation dips, and could be stronger at night, which helps reduce variability and eases integration with the grid. India's wind and solar potential maps show significant overlaps: co-location can result in efficient utilisation of available land and evacuation infrastructure. ICRA, the Delhi-NCR-based credit rating agency, reports[19] that capital costs for a hybrid project are 5-7 per cent lower in comparison to a single technology plant.

Further, the convergence of O&M activities and reduced storage requirements could result in additional savings. There is also some evidence that wind turbine activity close to solar panels helps in reducing the temperature of the panels, thereby increasing efficiency and lowering the rate of degradation.[20]

In May 2018, the MNRE announced the ‘National Wind-Solar Hybrid Policy’, two years after the draft was released. Despite a two-year consultation process, the document offers nothing new.[21,22] It merely states the basic rationale for hybrid projects, and provides some rudimentary definitions and configurations. The policy says hybrid projects shall be encouraged by allowing captive use and sale to open access consumers and discoms; the sale to discoms can happen through an auction process or at average power purchase cost to earn RECs. Power procured from these projects qualifies for RPO compliance.

These provisions, however, are standard terms and can hardly be considered incentives if the government’s aim is indeed to push hybrid projects. The policy has met with little success. In January 2018, the SECI invited bids to set up a 160-MW storage-backed wind-solar hybrid plant in Andhra Pradesh.[23] In May 2018, it issued a tender for ISTS-connected 2.5 GW hybrid plants to be set up anywhere in India. However, the latter was reduced to 1.2 GW, and the tendering process has been subsequently postponed five times. The tender was recently reintroduced with a higher ceiling tariff and an increased bidding capacity, in the hopes of drawing more participatio. However, it remained under-subscribed by 150 MW, with the Rs 2.70/kWh ceiling tariff: Adani and SB Energy were awarded capacities worth 600 MW and 450 MW, respectively.[24]

The key challenges

Wind energy has been associated with a string of ecological issues — impact on land and biodiversity, shadow flicker and noise pollution

Environmental issues

Despite its many benefits as a renewable energy source, wind energy has been associated with a string of ecological issues — impact on land and biodiversity, shadow flicker and noise pollution. The requirement of land for wind energy is large, and is a point of contention in a densely populated country like India. Wind-rich regions tend to overlap hilly forested areas, abundant in biodiversity — Western and Eastern Ghats are key examples. In addition to the loss of habitat and animal life, infrastructure development for wind projects may lead to suppression of native vegetation, large-scale erosion and landslides.

Birds have been a major casualty — collisions with windmills and electrocution has had a particularly severe impact, with the critically endangered Great India Bustard’s fate drawing the most attention. In March 2018, the Union Ministry of Environment, Forests & Climate Change’s Forest Advisory Committee discussed guidelines to help prevent bird loss in this sector.[25]

Noise from wind turbines has been a concern in settlements surrounding wind farms. Though technology has reduced the intensity of the sound, it continues to be a problem. Another pressing issue is that of WTG disposal. Reconditioning and reusing them for captive usage or exports has been the practice in some countries. European countries have reused WTGs as structures in children's parks and as public infrastructure. Germany has tied up with its cement industry to reuse the blades in cement production. Though India has not taken any specific policy steps in this direction, it does have a considerable WTG reconditioning capacity.

Wind technology has witnessed an increase in average CUFs because of increasing hub heights, larger rotor diameters and improved electronics

Technology

A number of the old turbines set up in India were refurbished, second-hand purchases from the developed markets. These turbines were considerably cheaper, but of relatively smaller capacity. Though these installations made sense in the initial years, today, an aging fleet of WTGs of capacities less than 500 kW and low CUF is occupying some of the best wind sites in India. Close to 4,000 of the installed WTGs, primarily located in Tamil Nadu, are of 1,000 kW or lesser capacity (*see Table 2: Number of WTG installations by size and location*). There are another 8,000 odd WTGs of capacities between 500-1,000 kW dispersed primarily across Tamil Nadu, Gujarat, Karnataka, Rajasthan and Maharashtra. More than 30 per cent of the installed WTGs can and should be discarded and replaced by newer, more efficient technology.[26]

Wind technology has witnessed an increase in average CUFs primarily because of the increasing hub heights (to reach stronger wind at higher heights), larger rotor diameters (to increase the swept area) and improved electronics. For example, in the US, the average capacity factor of WTGs installed before 2011 was 31 per cent; of those installed between 2014 and 2016 was 42 per cent.[27] At the same time, the costs per MW have fallen. In India, the improvements in technology have been slow. The average rated capacity of WTGs manufactured before 2000 was below 500 kW. Today, the largest WTG manufactured in India has a maximum rated capacity of 2.8 MW, with the first prototype installed in 2018.[28]

Another challenge is that India-specific turbines need to optimise potential from the low to medium wind speeds of 5.5-7.5 meter per second (m/s)[29],

Table 2: Number of WTG installations by size and location

More than 30 per cent of the installed base is obsolete

	Gujarat	Karnataka	Maharashtra	Andhra Pradesh	Tamil Nadu	Rajasthan	Madhya Pradesh	Telangana	Kerala
<500	202	63	302	94	1,744	53	27		0
501-1,000	1,475	1,312	1,000	301	2,375	1,287	311		34
1,000-1,500	1,255	795	1,877	194	2,445	1,023	604		0
1,501-2,000	1,329	1425	931	1,479	925	948	1,320		16
>2,000	1,106	230	538	1,467	321	989	238	101	8

Note: As on March 2017

Source: 2018, Repowering of old wind turbines in India, IDAM, New Delhi

The old and the new

NEPC's SRC31 and Suzlon's S111

To understand the benefits of repowering, CSE has compared an old turbine with the current technology leaders in the market. In 1986, NEPC India Ltd, one of the earliest players in the Indian wind industry, set up Asia's first wind farm of 1.1 MW capacity in Gujarat. The most advanced of NEPC turbines, SRC31, has a rated power of 250 kW, a maximum hub height of 45 m, and rotor diameter of 31 m.

In comparison, a recent turbine by Suzlon, S111, has a rated power of 2,100 kW. With a hub height of 120 m and rotor diameter of 111.8 m, it is capable of extracting the increased potential available at these heights. A demonstration prototype in Kutch, Gujarat achieved a CUF of 42 per cent in its first 12 months of operation.

Sources: NEPC and Suzlon

as well as cope with turbulent, strong gusts of wind. Most manufacturers in India have obtained proprietary technology (for India: Class II and Class III optimal wind profile) through licensing, joint ventures or mergers and acquisitions (M&A), but investing in R&D to develop proprietary technology would be a big competitive advantage. Also, manufacturers will need to streamline operations and cut costs to remain profitable since their buyers, the wind project developers, are bidding at very aggressive rates.

Problems with discoms

Most discoms are financially weak, which has negatively affected the wind sector. Renewable energy, including wind, enjoys a 'must-run' status according to Indian regulations — energy generated by wind projects is evacuated by the grid on a priority basis and must be purchased by discoms. The only exception is if the grid is unavailable, or if evacuating the renewable power is creating grid instability.

Wind project owners claim that the load dispatch centres, in connivance with the discoms, curtail wind power under the excuse of grid congestion/imbalance. However, the real reason is the discoms are not keen to buy wind power, especially from older projects, because they were contracted at relatively high FiT rates. Wind projects also face delays in receiving payments from discoms. Wind developers claim that the banking commitments (energy fed into the grid is permitted to be used at a later date) are often not honoured by discoms (*see Case Study: TASMA's textile cooperative and wind farms*).

Moreover, since the introduction of auctions there have been media reports of discoms seeking to renegotiate terms of older PPAs that were signed at higher tariffs. In Karnataka, the Karnataka Electricity Regulatory Commission (KERC) refused to accept signed PPAs, jeopardising 599 MW of signed PPAs pending with it. Eventually, the Karnataka state government had to step in and overrule the KERC to uphold the sanctity of the signed PPAs. In Andhra Pradesh, the state discom requested the return of 41 PPAs that were with the Andhra Pradesh Electricity Regulatory Commission (APERC) for final approval, so that it could renegotiate them.[30]

Repowering

Repowering is defined as replacing old turbines with much larger ones. The majority of MNRE-listed repowering capacity lies in Tamil Nadu and Gujarat (*see Table 1: State-wise installed WTGs for repowering*), the early adopters of wind energy. These turbines are small — most of them under 500 kW, with some between 500 kW and 1 MW — and were typically established before the year 2000. Their capacity utilisation factors (CUF) are as low as 10 per cent, whereas the PLF of new, larger turbines can go up to 40 per cent.[31] As many of the old turbines are located in very good wind sites, repowering can increase generation from wind projects exponentially.

Moreover, new turbines are more specific to India's wind profile, meet grid code requirements and consume less reactive power. The new technology is adaptable to ancillary services and other electronic components required for efficient integration with the grid. To add to this, capital costs have fallen, making economic benefits of repowering even more compelling.

However, repowering also faces some challenges.

The economics of repowering

Repowering entails decommissioning an existing plant, which may have a PPA with a number of years of remaining term and a salvage value at the end of the PPA term. Since dismantling an existing project would result in a loss to owners, they need to be compensated. A compounding problem is that several of the older wind projects are owned by multiple investors in wind farms with turbines of differing sizes, age, commercial terms (tariffs, project lifetimes etc) and land ownership models (leased, owned etc). The owners of these projects may have varying goals, with some not keen on making any additional investments in repowering.

These projects with fragmented ownership will need to be consolidated to enable repowering — the first step in the repowering process should be to consolidate ownership. Private developers may be able to consolidate ownership only for large-sized projects with multiple owners but one or two buyers. It will not work in a wind farm that has many owners, varying turbine types and several commercial contracts. One option could be to mandate repowering where existing owners are required to sell to the 'consolidator' at a pre-defined value if they do not wish to participate in repowering.

A more efficient alternative would be for the government, perhaps through SECI, to acquire wind assets. These sites/assets can then be auctioned off to developers who will repower the projects. This could be managed through a reverse auction with a targeted capacity and a ceiling price.

Repowering will result in loss for original investors from lost revenues over the remaining life of PPA and the salvage value of the project. They have to be compensated for the loss. The compensation may be in the form of a lump sum (similar to the VGF) or a per unit amount in addition to the tariff that could be spread over a new PPA term of 25 years.

Repowering is economically viable. What is required is for the government to compensate the old owner and auction the site

An economic analysis of repowering

Assumptions

- Remaining life of the project/PPA: 10 years
- Tariff for old project: Rs 5.75/kWh
- Tariff for new project: Rs 2.7/kWh
- O&M costs: Rs 2.3 million/MW per annum, inflated at 5 per cent every year
- Wheeling and transmission charges have been ignored to simplify simulation. Also, they vary across the country with many states partly waiving them.

	Old project	New project	
Capacity	500 kW x 2 turbines	2 MW	4 MW
CUF (%)	10	40	45
NPV	Rs 2.7 crore		
Expected increase in tariff		Rs 0.2/kWh	Rs 0.08/kWh

The above analysis clearly shows that repowering is economically lucrative. The compensation that needs to paid to the old turbine owners will be just about 3-7 per cent of the tariff of the new turbine, depending on the size of the new turbines.

If it is assumed that two WTGs of 500-kW capacity each, commissioned in 2003, are replaced with new WTGs, the owners of the old project will need to be compensated for the remaining 10 years of the plant life. A simplified model shows a VGF of Rs 2.7 crore that needs to be paid to the old project. Alternatively, the tariff of the new project will increase by 20 paisa/unit and 8 paisa/unit as compared to an "unsubsidised" tariff, assuming the replacement WTGs have capacities of 2 MW and 4 MW, respectively. This will be 3-7 per cent of the tariff of the new turbine. (*see Box: An economic analysis of repowering).*

Captive wind projects

Captive consumers enjoy several benefits such as concessional wheeling, banking provisions etc. However, such consumers need to own a minimum of 26 per cent equity in the project and must consume at least 51 per cent of the generated electricity.[32] If a project is repowered, the captive owner's share of consumption or equity may fall below the threshold in which case it will lose the benefits. Therefore, these provisions need to be loosened to enable repowering of captive projects.

Disposal of WTGs

Disposal of wind assets in the process of repowering is a major environmental challenge. Countries which have taken up repowering at a large scale have adopted some innovative concepts. For example, some have repurposed the scrap to serve as utilitarian public infrastructure. Germany has established a recycling unit that reduces scrap to fuel raw material to be used in cement factories.[33]

Repowering also throws up opportunities. Old turbines can be refurbished for exports. For this, the government needs to seed the refurbishment industry and provide export incentives. The target could be those developing nations that are keen to expand their renewable energy capacity, but have low demand and, therefore, would prefer small turbines.

Eligibility

Any repowering policy must have a comprehensive target for repowering. Age and size are the basic screening criteria. In addition, the policy should look at turbines with poor performance and low efficiency. Good wind sites should have a higher standard of performance. The policy should assess repowering eligibility and needs based on the long term evolution of the WTG fleet.

So where does the sector stand today?

Although a significant amount of capacity has been auctioned since January 2018, cracks are appearing in the wind sector. Auctions have witnessed hiccups, with investors citing insufficient evacuation infrastructure. The SECI Tranche-V auction, initially for 2 GW, was re-auctioned for a lower capacity of 1.2 GW. The subsequent SECI Tranche-IV auction, initially for 2.5 GW, was cancelled temporarily. Wind developers assert that the widespread problems of curtailment, delays in payments and the lack of recourse in case of defaults under old PPAs need to be resolved for the sector to bounce back.

The sector's slow but steady loss of momentum has other reasons as well. First, the government's policies have been haphazard, with several changes in incentives and subsidies and sudden introduction of auctions, which have led to frequent disruptions in the market. Also, the sharp fall in solar tariffs over the last few years has shifted the focus of the government, developers and buyers to large-scale solar projects. Although recent wind auctions have achieved tariffs that are competitive with that of solar, there are increasing questions about their long-term sustainability.

Second, compared to solar, wind installations have a higher dependence on peripheral costs — primarily transportation and civil construction — that are less amenable to technology improvement and manufacturing cost-cuts. Economically, it makes more sense to develop local manufacturing capabilities; however, policymakers have not offered a long term strategy to promote it. Local manufacturers have relied on imports of components, as there is inadequate investment in R&D. The FiT regime has created complacency, which is why the sector is not cost-competitive. The manufacturing sector now faces the twin problem of excess capacity and uncompetitive products.

Wind developers assert that the widespread problems of curtailment, delays in payments and the lack of recourse in case of defaults under old PPAs need to be resolved

There should be an urgent effort to upgrade the evacuation network, which has been cited as the reason for the tepid response to new auctions

Third, the low tariffs in wind auctions are being attributed to manufacturers offering WTG components at unsustainable prices to dispose of the piled-up inventory. With continued innovations in technology, solar costs are expected to drop consistently in the coming years. While wind manufacturers predict that prices will fall and turbine efficiencies will improve, experts expect solar's cost advantages to widen over the longer term.

Fourth, solar energy presents a far larger potential across a wider area. Wind is more variable and less predictable than solar — these characteristics increase the cost of its integration with the grid. Moreover, the best sites have been used up already or are a rapidly diminishing number. The sector is also grappling with a host of environmental concerns.

The way ahead

Despite all this, the wind sector is likely to play a role — albeit a secondary one to solar — in India's energy future. The country's wind industry is relatively mature, with a large installed capacity that has been operational for several years. Unlike solar, the wind sector is supplied by a large, technically adept local manufacturing industry. The industry may become more competitive, with the coming of larger turbines with increased efficiency. However, it means manufacturers must invest in R&D.

At the level of the government, a consistent and predictable policy environment is needed. There should be an urgent effort to upgrade the evacuation network, which has been cited as the reason for the tepid response to new auctions. Repowering the aging, small turbines is an efficient way to expand wind generation, especially since some of the best wind power sites house many low-efficiency turbines. For this, the government needs to come up with a comprehensive policy that addresses the key concerns — consolidation of fragmented ownership of wind projects, compensation to old projects for the loss of value, loosening ownership, and consumption provisions for captive projects.

The government should also encourage growth of hybrid and offshore projects to fully exploit the wind sector's potential. Hybrid projects have been stymied by arbitrary ceiling rates: the best course would be for auctions to discover the lowest tariff. A slightly higher tariff will be offset by the balancing benefits as well as lower evacuation costs. Approvals for offshore projects need to be streamlined — currently, clearances need to be obtained from, among others, departments of defense, space and telecommunications. Offshore wind farms may further benefit from separating evacuation and generation projects.

CASE STUDY: POWER SPINNING

TASMA — textile cooperative and wind farms

A 2018 report lists Tamil Nadu as one of the top nine renewable energy markets in the world.[34] Today, 14.3 per cent of all energy demand in the state is met by renewable energy, primarily solar and wind. Wind power capacity in Tamil Nadu increased from a meager 877 MW in 2002 to 7,652 MW in 2017 (*see Graph 5: Capacity addition in Tamil Nadu*).[35]

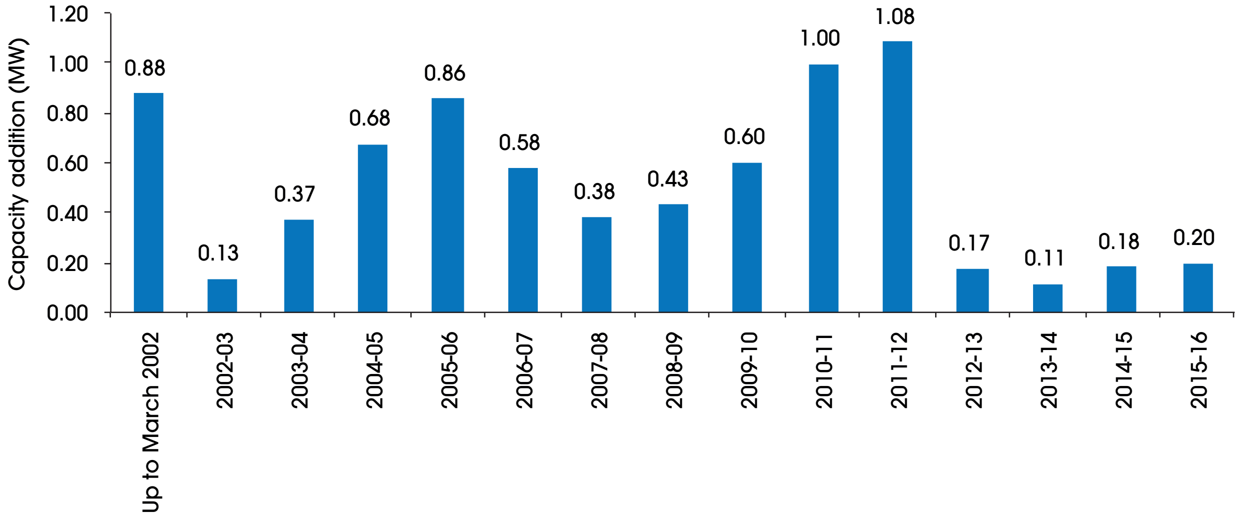
Persistent load shedding by the Tamil Nadu Generation and Distribution Corporation Limited (TANGEDCO) has been a huge problem for the local industry. The policies and incentives offered by the government — bundling of wind power projects, accelerated depreciation, a Technology Upgradation Fund etc — has driven the state's power-intensive industries to invest in captive wind power plants. Of the total capacity today, nearly 5,500 MW[36] of captive plants have been set up by textile mills and cement industries.

The Tamil Nadu Spinning Mills Association (TASMA) was an early adopter of the 'bundled wind project' model — several small power consumers formed cooperatives to invest in wind turbines. Today, TASMA cooperatives own a total of 3,500 MW of wind energy capacity, 45 per cent of the state's wind-generation capacity.[37]

But the wind generating capacity in the state has stagnated since 2012.

Graph 5: Capacity addition in Tamil Nadu

Annual capacity addition has taken a hit post-2012



Source: Compiled from various MNRE annual reports

Even the reintroduction of accelerated depreciation could not revive the regional wind market. This can be attributed to evacuation problems, history of curtailment and payment delays, all of which are acute in Tamil Nadu because of the large shares of RE in its power mix. A TASMA official said, "The curtailment averaged around 30-35 per cent of the generation in the peak season during 2012-15 and averages at 20-25 per cent today. A conservative figure of 15 per cent back down translates to an annual loss of 2,000 to 2,500 million units." TASMA has filed a case to ensure compliance of a must-run provision for windmills. The Association claims that the older wind turbine generators with higher tariffs were curtailed more compared to the newer, more efficient ones and payments continue to be delayed by 12-18 months.

Wind generation peaks during the southwest and northeast monsoon months, followed by below average generation for the remaining months. The state introduced banking of energy, which allows the cooperatives to supply to the grid when there is excess generation, in exchange for free supply during low generation periods. According to TASMA, TANGEDCO seldom honours these banking obligations since power purchase costs are high during the low generation period.[38]

Addressing these challenges should be the priority; if that is not done, they can wreak havoc in the renewable energy industry. While these issues are more serious in Tamil Nadu, they are slowly creeping into the other high potential states of India as well, since discoms across the country are struggling with poor financial health.

CHAPTER 6

Energy access: Bridging the gaps

Despite the implementation of several dedicated electrification schemes, India's struggle with ensuring universal electricity access persists. The country declared 100 per cent of its villages as electrified in April 2018 — as per a Government of India (GoI) definition, this required 10 per cent of households and all public facilities in the 5.9 lakh inhabited villages to be connected to the grid.

This was followed (rightly so) by a scheme to provide connections to all individual households (*SAUBHAGYA — see section in this chapter for details*). As of October 2018, 95 per cent of all households in India were reportedly electrified — this included 100 per cent of urban and 94 per cent of rural households.

Even if this claim were true, quality power supply to every urban and rural household in India remains out of reach. Many rural households still get only a few hours of power supply which is typically absent during peak hours. Ensuring universal energy access — uninterrupted, affordable power — would require comprehensive reforms, including distribution sector reforms — a challenge that the government has been struggling with for decades.

Given this scenario, mini-grid systems based on renewable energy sources can play a significant role in shouldering the government's rural electrification responsibility. There are thousands of mini- and micro-grid systems operating in the country to supply electricity to remote and rural settlements, but the government considers them merely as a stop-gap solution till the grid arrives. Only a more comprehensive policy can help realise the true potential of these systems in ensuring universal electrification.

Ensuring universal energy access — uninterrupted, affordable power — would require comprehensive distribution sector reforms

Policy inadequacies: Central schemes struggle to deliver

Over the last decade, the Indian government has launched a string of policies and schemes to enhance energy access. To understand the scale of the problem, it might be worthwhile to approach it through the prism of the GoI's efforts at providing a solution.

In 2005, the Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) was conceived to electrify all villages/habitations, and provide access to all households, especially those below the poverty line (BPL). It laid emphasis on infrastructure for distribution of rural electricity and use of decentralised distributed generation (DDG) for settlements where supply was not feasible or cost-effective. Implemented through the Rural Electrification Corporation, the scheme received 90 per cent of its funds to meet the overall project cost from the Centre and 10 per cent from the state. At its close in 2014, RGGVY had reportedly reached 97 per cent of the un-electrified villages under its purview.[1]

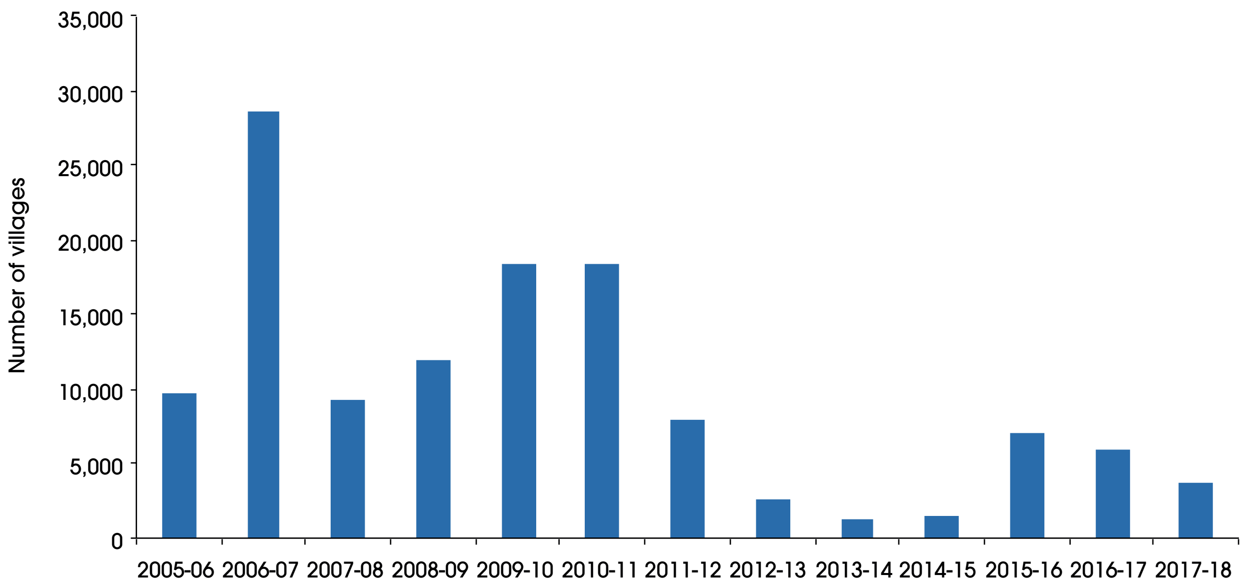
The Deen Dayal Upadhyaya Gram Jyoti Yojana (DDUGJY), launched in 2014, aimed to take the work forward under a different title. Its Rs 75,893-crore outlay was directed at improving rural power infrastructure through feeder separation; and strengthening sub-transmission and distribution systems and metering at various stages — transformers, feeders and consumers. It subsumed the RGGVY scheme and took on the responsibility of electrifying the remaining 18,452 villages. In April 2018, the government declared that 100 per cent of the villages had been electrified under DDUGJY.[2] (*see Graph 1: Rate of village electrification*).

But this was a misleading claim. Both these schemes considered a village as 'electrified' if a mere 10 per cent of its households and all its public facilities (such as schools, health centres etc) were connected to the grid. Therefore, though the power infrastructure extended to reach all villages, most households remained unelectrified. In any event, most of the electrified villages did not receive a regular supply.

In October 2017 came another scheme — the Pradhan Mantri Sahaj Bijli Har Ghar Yojana (SAUBHAGYA) — to provide electricity connections to

Graph 1: Rate of village electrification

As per government records, 100 per cent of the villages have been electrified



Source: Compiled from various Rural Electrification Corporation (REC) annual reports, https://www.recindia.nic.in/annual-reports

Decentralised systems for access

In the late `90s, the Union Ministry of New and Renewable Energy (MNRE) initiated the Remote Village Electrification Programme, an off-grid scheme, to cover villages located in remote areas. The scheme offered distributed renewable energy solutions to meet basic lighting needs. Abysmal after-sales services and widespread corruption led to the termination of this scheme in 2012.

In 2009, the government made another similar effort — the Decentralised Distributed Generation scheme was launched under RGGVY. Plagued by lack of accountability and monitoring, this scheme was reduced to just another target to be met by the Rural Energy Corporation (REC). The Off-grid and Decentralised Application Programme, launched under Jawaharlal Nehru National Solar Mission (JNNSM), is yet another attempt at deploying decentralised (solar) renewable energy (DRE) in the country. The programme included providing solar-powered lights, study lamps, pumps, SPV power plants and even mini-grids to increase energy access (*see Cumulative installation of SPV systems — December 2017*).[1]

Cumulative installation of SPV systems — December 2017

Total installed capacity of solar PV off-grid systems/power plants is 182 megawatt peak (MWp)

Lanterns and lamps (No)	Home lights (No)	Street lights (No)	Pumps (No)	Stand-alone power plants (MWp)
2,328,865	1,477,189	471,220	147,527	181,901.36

Source: Ministry of New and Renewable Energy (MNRE) Annual Report 2017-2018, https://mnre.gov.in/file-manager/annual-report/2017-2018/EN/pdf/chapter-4.pdf

all households, rural and urban. The scheme, when it began, identified 4 crore un-electrified households. However, this number has kept changing. As per the latest data put out by the government only 2.48 crore households were willing to take up connections; the remaining refused to get connected.[3]

India's electrification gap

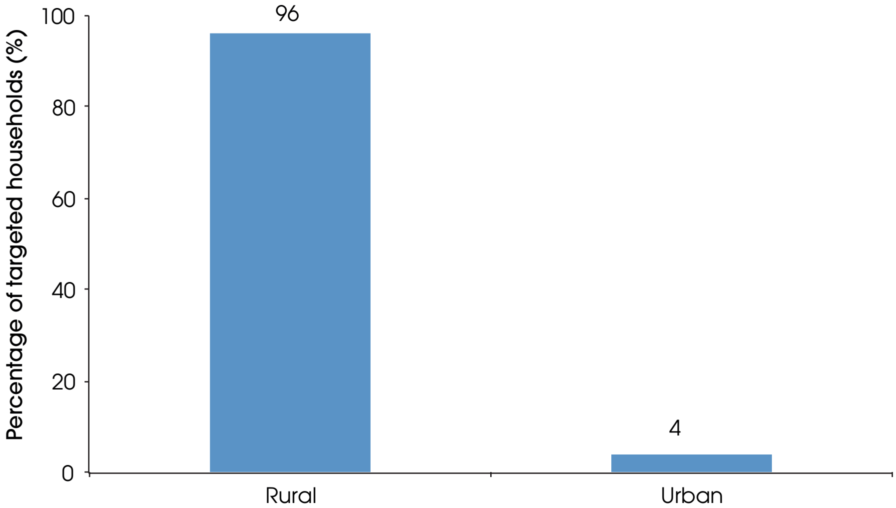
India's rural areas bear the brunt of its energy access problem. Though the divide between electrification of rural and urban areas has reduced over time, it still remains considerable. As per SAUBHAGYA, 96 per cent of the un-electrified households were in rural areas, only 4 per cent were in the urban areas[4] (*see Graph 2: Households targeted to be electrified under SAUBHAGYA*).

Further, a vast majority of the un-electrified households is concentrated in just a few states — Uttar Pradesh, Bihar, Odisha, Assam, Madhya Pradesh and Jharkhand (*see Graph 3: State-wise distribution of un-electrified households*).

In theory, India has sufficient installed capacity to meet its discom demand. According to the Central Electricity Authority of India (CEA), power supply is in surplus in the country (*see Graph 4: Trends in energy deficit*). For example, the peak demand in October 2018 was 172.9 GW against a national power supply position of 346 GW, at a time when thermal power plants operated at less than 60 per cent capacity.[6]

Graph 2: Households targeted to be electrified under SAUBHAGYA

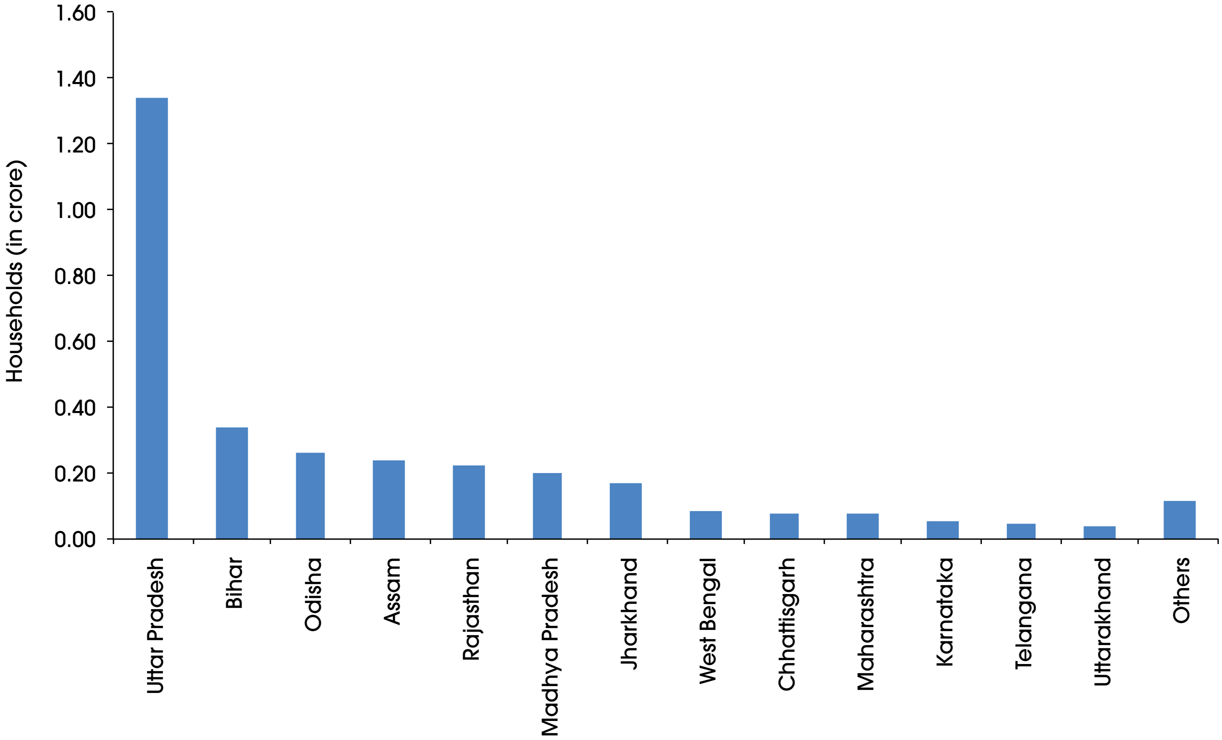
96 per cent of the targeted households are in rural areas



Source: SAUBHAGYA dashboard, accessed in January 2019, http://saubhagya.gov.in/

Graph 3: State-wise distribution of un-electrified households as of October 2018

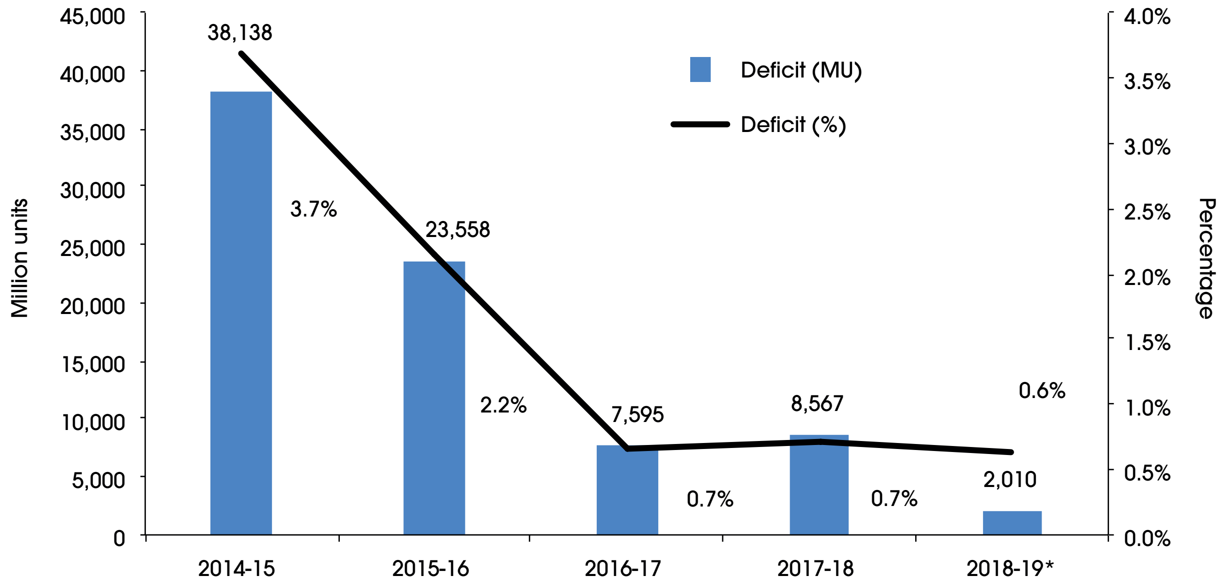
A vast majority of these households is concentrated in just six states



Source: SAUBHAGYA dashboard, accessed in October 2018, http://saubhagya.gov.in/

Graph 4: Trends in energy deficit

National energy deficits are decreasing, but quality supply remains a mirage



Notes: *as of July 2018; MU = million units
Sources: Compiled from various Central Electricity Authority (CEA) annual reports, http://www.cea.nic.in/annualreports.html

However, the deficits presented by the CEA do not reflect the true picture: they are merely the mathematical difference between energy demanded by the distribution companies and supplied by the generating companies, which understates the real deficit. Since many distribution companies are financially stressed, their electricity off-take is driven by their ability to pay — the discom demand does not reflect the expected end-consumer demand. Besides this, the potential demand of households that are not connected to the grid is not accounted for. Essentially, the relatively small energy deficits reported by the CEA are largely on account of grid congestion.

SAUBHAGYA: Sufficient for universal access?

SAUBHAGYA is the government's latest attempt to connect households to the grid. To electrify the four crore households (as identified under Census 2011), an outlay of Rs 16,320 crore has been sanctioned, which includes a budgetary support of Rs 12,320 crore from the Government of India. SAUBHAGYA incentivises discoms to set up the infrastructure — service line cables, poles, single point wiring, meters (including prepaid meters)etc — for last mile connectivity of all unconnected households.

The funding (at Rs 4,500 per household), however, appears to be inadequate. Installing meters could cost anywhere between Rs 1,000 to Rs 2,000 per household (Rs 7,000-Rs 9,000 for prepaid meters). The low tension service line connecting a house to a pole itself could cost between Rs 1,800 to Rs 3,000 per household for a single phase and Rs 5,000 to Rs 9,000 per household for a three-phase connection. Further, as per the

Table 1: SAUBHAGYA's funding fault lines

Allocation falls short of cost estimations made by UPPPCL

For rural households	No of households (in millions)	Cost (Rs crore)	Budgetary support (Rs crore)
Cost of service connection @ Rs 3,000 per household	25	7,500	5,625
Cost to provide last mile connectivity @ Rs 1,500 per household	25	3,750	2,812
SPV-based stand-alone systems for remote households @ Rs 50,000 per household	0.5	2,500	1,875
For urban households		2,295	1,732
Grand total		16,320	12,320

Source: Guidelines for Saubhagya scheme, https://powermin.nic.in/sites/default/files/webform/notices/Guidelines_of_SAUBHAGYA.pdf

UPPPCL's schedule for 2017-18, the cost of installing a low tension (LT) overhead line could vary from Rs 1.5 lakh to Rs 3.1 lakh per km depending on conductor type, conductor size, and span length. This excludes the cost of setting up a new substation or distribution transformer which could cost several lakhs of rupees. As per the cost estimates done by the UPPCL, there is a significant gap between the actual cost and the budgetary support (*see Table 1: SAUBHAGYA's funding fault lines*).[6]

Assuming India does achieve full electrification, ensuring regular and affordable supply will be the next big challenge. Many BPL households may need to be provided subsidised power. Supplying relatively small 30 to 50 units per household per month to the additional 2.4 crore rural households to be electrified under SAUBHAGYA would increase the annual subsidy burden of state discoms by approximately Rs 3,400-5,600 crore (*see Table 2: Potential subsidies due to SAUBHAGYA*).

Assuming India does achieve full electrification, ensuring regular and affordable supply will be the next big challenge

Moreover, the bulk of the subsidy burden will be borne by a few of the poorest states that are home to the largest number of un-electrified households — Uttar Pradesh, Bihar, Odisha and Assam. Also, the provision of subsidised electricity by state-owned discoms may result in households increasing their consumption, thereby inflating the subsidy. This raises the question if grid extension is the most effective approach to improve access.

Discoms: bottlenecks for access

Universal energy access — defined as provision of a minimum level of electricity (around 30-50 units per household per month) for a minimum number of hours a day at an affordable cost — would certainly need subsidy support for a sizable number of people. However, India's policies are not geared to address this.

Indian states have relied on discoms to provide subsidised electricity, which is very politically popular, to people. This policy has had a ruinous

Table 2: Potential subsidies due to SAUBHAGYA

Subsidy burden of discoms may go up by Rs 3,400-5,600 crore

Details	Estimates	
Total number of households to be electrified (crore households)	2.48	
Number of rural households to be electrified (crore households)	2.4	
Assumed electricity consumption per household per month (units)	30	50
Rural consumption (crore units per month)	72	120
Assumed AT&C losses (%)	25	25
Discom procurement demand (crore units per month)	90	150
Discom procurement cost at average cost of supply of Rs 5.51/unit (Rs crore)	495.9	826.5
Tariff for metered rural consumers for the first 100 units	3	3
Revenue from new consumers (Rs crore)	216	360
Revenue shortfall (Rs crore)	279.9	466.5
Increase in annual subsidy burden (Rs crore)	3,358.8	5,598

Notes: AT&C losses and average cost of supply for 2015-16, as per PFC report on utility performance
Sources: 1. Unelectrified households: http://saubhagya.gov.in/, accessed in October 2018
2. AT&C losses -*https://www.financialexpress.com/economy/power-pack-discoms-atc-losses-come-down-at-19-1/1197993/

impact on discoms' financial health, resulting in most of them needing repeated bailouts by the government. In this scenario, discoms will not be able or willing to provide additional subsidised electricity to newly connected customers.

Can mini-grids bridge the electrification gap?

Given the challenges that the SAUBHAGYA scheme faces, mini-grids powered by renewable energy offer an alternative. They are ideal for remote villages where electrification through grid extension is financially unviable, typically due to long distances and a heterogeneous terrain. Interestingly, CSE surveys show that mini-grids are popular even in electrified villages since discom supply is for limited number of hours and frequently not available during peak hours.

Mini-grid systems, typically, are under 1 MW. They generate as well as distribute electricity and are installed close to the point of consumption. The mini-grid market grew after the passage of the Electricity Act, 2003, which allowed private operators to supply electricity in remote/rural areas without licensing requirements or tariff regulations. Currently, India has over 17,000 (primarily hydro and diesel) mini-grid installations with sizes varying from 5 to 1,000 kW.[7] On the official front, however, nothing much has happened — a National Mini-Grid Policy has been in a state of limbo since 2016 (*see Box: The National Mini-Grid Policy*).

Currently, India has over 17,000 (primarily hydro and diesel) mini-grid installations

So what is the future of mini-grids in India?

What is clear is that mini-grids do have a potential over the short to medium term: both consumers and regulators appear to agree on the benefits of the

The National Mini-Grid Policy

Most independent energy policy experts believe mini-grids will fill the energy access gap for a sizable number of consumers. State regulators, too, acknowledge that grid extension may not fully solve energy access issues and mini-grids will continue to be relevant. Given this widely shared view, in 2016, the MNRE released a draft National Mini-Grid Policy for comments.

The document was presented as a broad set of guidelines that states could choose from to frame their own state-specific policies. The draft listed the acceptable configurations of mini-grids and suggested various tariff models as well as the standards and norms for the technologies that were employed. It envisioned 10,000 new, renewable energy-based micro- and mini-grid projects (≈500 MW) by 2022 with an average size of 50 kW. Though it categorised mini-grids based on their sizes, the draft policy favoured larger, clustered systems.

Till date, the final national policy has not seen the light of the day.

system. It remains to be seen whether an environment can be created in which these systems can play their expected role in enhancing energy access. The SAUBHAGYA scheme does not look poised to attain 24x7 electricity for all, and therefore mini-grids might continue to operate in even connected villages which are plagued by irregular supply. The immediate risk is of redundancy when the grid reaches the mini-grid served areas; therefore, states must develop regulatory frameworks for compulsory purchase of power into the grid from these small projects.

The primary aim of both the draft national policy and state policies has been to develop mini-grid systems that can service rural/remote consumers at affordable rates. But mini-grid generators (MGOs) claim that the projects would be unviable at tariffs comparable to discom rates even with the additional state subsidy (30 per cent, in the case of UP). There is also an uncertainty about the terms of exit when the grid starts supplying — the future price at which MGOs can sell either the generated power to discoms or the project assets. MGOs believe they are better off with the flimsy distribution network which helps keep the tariffs low. Investment in a Grid code-compliant distribution network makes sense only if it is integrated with the grid (and not abandoned).

The extension of the national grid into the mini-grid serviced markets is inevitable. In such a scenario, integrating mini-grids into the grid can make them viable over the longer term under varied business models (*see Box: Grid integration — some possible scenarios*). However, a comprehensive national policy needs to be developed that addresses the existing gaps. The comprehensive mini-grid policy should include the following provisions:

- If a mini-grid avails a subsidy, it should mandatorily comply with certain service parameters including minimum number of hours of supply,

supply during peak hours, and a minimum percentage of total supply to the residential segment.

- Tariffs for residential consumers should be in line with discom rates. The subsidy to support this may be best discovered through an auction on viability gap funding. Given the small size of individual projects, an auction may be conducted for a portfolio of projects.
- The network should comply with the grid code to allow integration at a later date. Funding support should be provided for incremental investment in distribution assets.
- Exit options should be clearly laid out. Sale of generation assets to a discom may equal the outstanding debt plus 150 per cent of equity. The cost of supply to the discom or to consumers may be the same as the project's tariff.

The way ahead

The goal of universal energy access — 24-hour, affordable electricity to all — has bedeviled Indian policymakers over the past several decades.

Grid integration of mini-grids — some possible scenarios

- **Tail-end generation for grid or open access consumers:** Mini-grid developers will operate as independent power producers (IPP) after integration with the national grid. The generated power will be sold to the grid under a power purchase agreement (PPA) or to an open access consumer at a mutually agreed upon price. In both cases, the mini-grid distribution network will be abandoned or sold off to the local discom, depending on its condition.
- **Distribution franchisee with a generation asset:** The mini-grid developer will operate as a distribution franchisee, buying power from the local discom and selling it to rural consumers at the prevalent tariff rate. The mini-grid's distribution network will be purchased (and upgraded, if needed) by the discom, and the franchisee will be allowed to access it. The generation asset will continue operations as an IPP feeding power into the grid.
- **Grid integration with net metering:** The mini-grid developer will continue to own and operate generation and distribution assets, while the entire system could be interconnected to the grid with bi-directional metering. The mini-grid system will export power to the grid in case of surplus and import power in case of deficits, with the balance settled on a net metering basis. Thus, the mini-grid continues to generate and supply power while interacting with the grid to balance demand and supply.
- **Back-up power supplier:** Mini-grids will act as a source of back-up when the grid fails to supply (basically, act as a flexible generation source). These generators will be adequately compensated with high per unit generation tariffs for providing these services. The mini-grid operator will retain the generation asset, while the distribution network will be taken over by the discom.

Source: Mini Grids in Uttar Pradesh, CSE 2018, https://www.cseindia.org/mini-grids-in-uttar-pradesh-8826

Mini-grids have a potential — both consumers and regulators appear to agree on its benefits

Grid-based supply has been and will remain the core strategy to expand access to electricity. The SAUBHAGYA scheme, which aims to connect all households to the grid, is a worthy initiative. It will significantly improve energy access; however, it may not be sufficient to ensure regular electricity supply. Discoms remain financially stressed due to their poor operating performance and political interference regarding tariff-setting and subsidies to various interest groups. The government's latest attempt to reform the discom sector, the UDAY scheme, also looks likely to fail. Weak discoms will not supply adequate power to many recently-connected poor consumers who are not profitable for disoms. In fact, SAUBHAGYA will further weaken discoms if it is not accompanied by reforms such as an increase in tariffs for certain consumers and caps on subsidised supply.

A one-size-fit-all strategy will fall short. Mini-grids do have a potential over the short to medium term — both consumers and regulators appear to agree on the benefits of the system. Indeed, mini-grids continue to operate in even connected villages which are plagued by irregular supply. A well-designed set of policies, some of which have been detailed above, can ensure that mini-grids fill the gap by supplying affordable power to energy-deprived households; at the same time, they also have a viable business model when the grid becomes the reliable and predominant source of power in their markets.

CASE STUDY
Providing universal 24x7 electricity access in Uttar Pradesh


JONAS HAMBERG

Uttar Pradesh (UP), with over 14.2 million un-electrified households, presents the biggest challenge in India. District-level data presents a grim picture, with rural electrification ratio of less than 30 per cent in places like Lalitpur, Jalaun, Sonbhadra and Jhansi; and 35 to 40 per cent in Chandauli, Fatehpur, Kanshiram Nagar, Bahraich, Kanpur Dehat, Saharanpur, Kanpur Nagar and Kaushambi.[8]

Households which do get power are plagued by its poor quality — limited hours of supply, frequent outages and fluctuating voltages. The Electricity Supply Monitoring Initiative (ESMI) shows that in May 2018, 68 per cent of the monitored locations in UP experienced outages lasting more than 15 minutes a day, with the urban areas faring better than the rural ones. In fact, UP and Jharkhand were the two states with the highest number of supply interruptions in the country. In UP, urban and rural areas did not get any power supply for an average of 131 hours per month and 328 hours per month, respectively; for Jharkhand the figures were 163 and 257 hours, respectively.

Another report by ESMI for the period between January and March 2018, showcases the true disparities between urban and rural settlements in UP. The number of interruptions in a month are significantly more among the

Table 3: Quality of power supply in Uttar Pradesh (January-March 2018)

Rural areas bear the brunt of poor quality

		Jhansi	Barabanki	Sitapur	Bahraich
Daily supply hours	Urban	22	18	19	20
	Rural	18	17	14	15
Evening supply hours (5-11 pm)	Urban	5	4	4	4
	Rural	4	4	3	3
Interruptions in a month	Urban	32	75	76	59
	Rural	101	75	116	121
Outage hours in a month	Urban	34	151	137	99
	Rural	147	196	283	246

Source: Prayas Summary Analysis on Electricity Supply Monitoring Initiative, May 2018, http://www.watchyourpower.org/uploaded_reports.php

rural as compared to their urban counterparts. In Sitapur, interruptions in a month were 115 in the rural and 76 in the urban areas. Similarly, the outage hours in Sitapur amounted to 283 and 137 in rural and urban settlements, respectively (*see Table 3: Quality of power supply in Uttar Pradesh*). This ESMI study by Prayas — although limited — is the only attempt at monitoring supply in the country, and confirms the widely held view that power supply quality is abysmal in rural areas.[9]

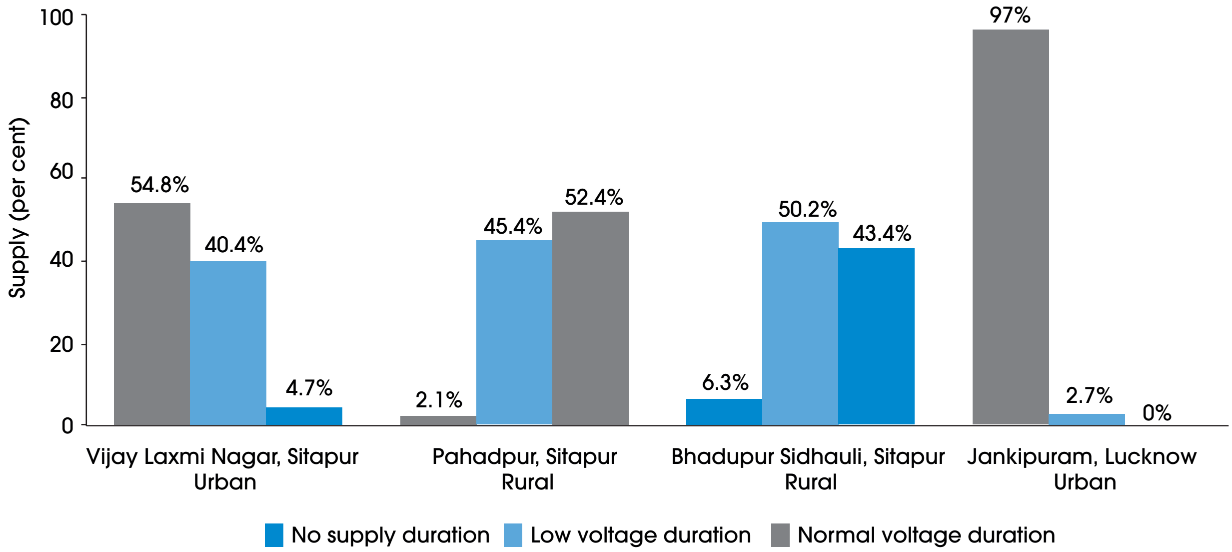
As per Prayas, in Sitapur district, domestic consumers living in the town in the Vijay Laxmi Nagar area received power for 54.8 per cent of the 720 hours in May 2018, while consumers in Paharpur village and Bhadupur Sidhauli block received it for only 2.1 and 6.3 per cent of the time, respectively. Significantly, the low voltage-supply duration in Vijay Laxmi Nagar was only 40.4 per cent, while it was 45.4 and 50.2 per cent in both Paharpur and Bhadupur Sidhauli respectively. In contrast, the Jankipuram area in the state capital of Lucknow received power for 97 per cent of the time in May, all at normal voltage level (*see Graph 5: Power supply to domestic consumers in UP*).[10]

A CSE survey conducted in six villages of the state confirmed the sorry state of rural power supply in UP (*see Table 4: Electricity supply in villages surveyed by CSE*). It found that most villages received less than 16 hours of supply a day. Dhankal Khera village in Unnao received on average 10-12 hours of supply; Tamakuhi Raj village in Kushinagar received 10-14 hours. To add to this, some villages were found to have very low rates of electrification — for instance, only 24 per cent of the households were connected in the largest village in the CSE study sample.

Besides this, the limited hours of supply seldom coincided with 'peak' morning and evening hours. The power supply schedule of the Uttar Pradesh State Load Dispatch Centre (UPSLDC) for the aforementioned villages indicates two- to four-hour gaps during the morning and evening peak-demand periods — even the limited rural supply was not available at times most needed (*see Table 5: Power supply schedule for selected villages*).

Graph 5: Power supply to domestic consumers in Uttar Pradesh

Supply to rural areas is for far fewer hours



Note: Data for 720 hours in May 2018

Source: Watch Your Power portal, Prayas (Energy Group), as viewed on May 2018, watchyourpower.org

Table 4: Electricity supply in villages surveyed by CSE

Average power supply varied from 10 to 16 hours a day

Location	Total households	Rate of electrification (%)	Average duration of grid power supply (hours)
Sanda, Sitapur	737	70.4	15-16
Kamplapur, Sitapur	132	95.5	12-16
Katkutiyan, Kushinagar	819	42.4	15-16
Tamakuhi Raj, Kushinagar	881	66.7	10-14
Para village, Unnao	1212	24.0	12-16
DhankalKhera, Unnao	101	80.2	10-12

Source: CSE survey

Discoms prefer serving urban households over their rural counterparts, since supply to rural areas is associated with higher AT&C losses due to lengthy distribution lines, inadequate size of conductors, long distances between distribution transformers and load centres and over-rated distribution transformers. The primary concern, however, is commercial. Many rural households are poor and consume very little electricity; they may also receive power at subsidised rates. Agricultural consumption is material, but is even more heavily subsidised. Rural areas also have high rates of power theft, but have poor billing and collection rates. All these factors add up to making the rural belt unprofitable for discoms.

Table 5: Power supply schedule in selected villages

No power supply for nearly two to four hours during peak periods

District	Substations	Power unavailable at peak times (29 April–5 May 2018)	Total duration
Sitapur	Muradabad control 1A	7.00–9.15 a.m.	2 hours 15 minutes
	Muradabad control 1B	6.45–8.45 a.m. and 9.30–11.00 p.m	2 hours 30 minutes
Kushinagar	Sarnath control 2A	5.45 –8.15 a.m.	2 hours 15 minutes
	Sarnath control 2B	9.00–11.30 a.m. and 8.00–9.30 p.m.	2 hours 30 minutes
Unnao	Piniki control 2A	5.45–8.15 a.m. and 7.45–9.15 p.m.	3 hours 45 minutes
	Piniki control 2B	8.15–10.45 a.m. and 9.15–10.45 p.m.	2 hours 30 minutes

Note: Peak demand time is 6 a.m.–10 a.m. and 6 p.m.–10 p.m.
Source: Uttar Pradesh State Load Dispatch Centre (UPSLDC) as viewed on May 2018, http://www.upsldc.org/real-time-data

Can SAUBHAGYA fill the gap?

SAUBHAGYA, launched in September 2017, aims at connecting all remaining un-electrified households in the country. As of November 2018, 19 million households have been provided electricity access — 11.3 million households are yet to be electrified. The last few months have witnessed electrification at a rapid rate (two-three million households per month).[11] But the rate is expected to slow down as the scheme tries to connect remote, difficult-to-reach or very poor areas.

At the start of the scheme, Uttar Pradesh had the largest population without access to electricity (15 million out of 40 million households) in India. Despite the 5.5 million households electrified since then, UP's 6.8 million remaining households make up half of the total un-electrified households in India.[12] To understand whether SAUBHAGYA can connect all households quickly and supply quality power on demand, CSE surveyed Shamli, a relatively rich district in north-eastern UP which claims to have 100 per cent electrification, to assess the SAUBHAGYA scheme (*see Table 6: Villages surveyed and Graph 6: Electrification progress in Shamli under SAUBHAGYA*).

UP's 6.8 million households make up half of the total un-electrified households in India

Shamli, home to about 2,13,492 households, had over 25,000-26,000 un-electrified households at the start of the scheme. Today, the district claims it is 100 per cent electrified — but data from the local discom, the Paschimanchal Vidyut Vitaran Nigam Ltd (PVVNL), shows that only 19,486 households have been electrified; over 4,000 odd households have rejected the electricity connections, primarily because of their inability to pay. This is in addition to another 2,415 households that were found to be unoccupied.[13] The latter should have been removed from the target altogether, but the SAUBHAGYA dashboard — in an attempt to show increased numbers — has added them to its list of electrified households.

Table 6: List of villages surveyed

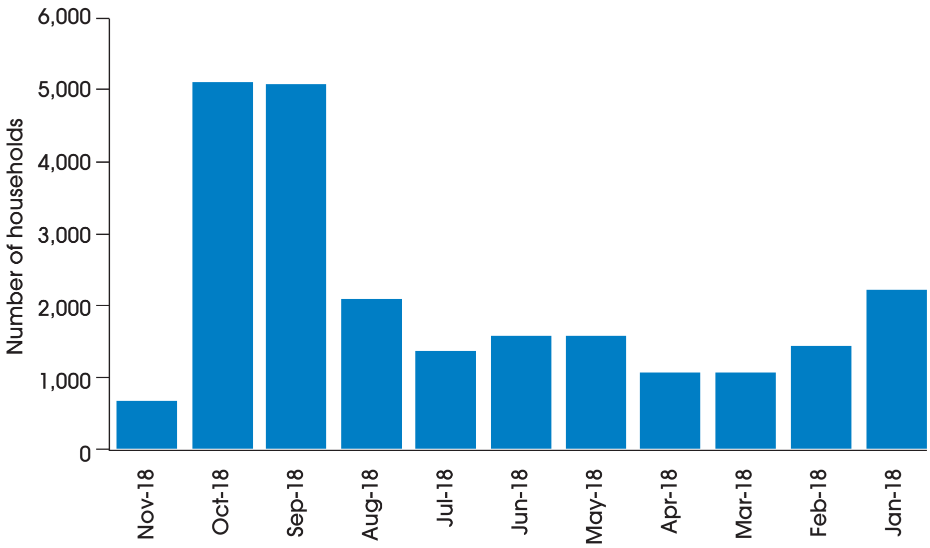
Villages were randomly chosen for the survey

Villages	Total households	Electrified under SAUBHAGYA	Population	Major economic activity
Pindaura	1071	153	11000	Agriculture
Hath Choya	656	159	9000	Agriculture
Poorviyaan Mazra, Gagaur	487	119		Migrant laborers and agriculture
Simbhalka	205	55		Agriculture

Source: CSE survey

Graph 6: Electrification progress in Shamli

Government data shows 100% electrification



Source: SAUBHAGYA dashboard

The SAUBHAGYA scheme has tried to expedite electrification by providing on-the-spot free registration in village electrification camps. However, while focusing on household electrification targets, it appears to have ignored the larger objective — providing electricity access at reasonable cost. Our survey revealed multiple problems.

Tariffs and the ability to pay

Many consumers in Shamli complained about being forced into accepting electricity connections, including instances of large joint families pushed to take separate electricity connections. Economically weak consumers are charged Rs 50 per month over the first 10 months (for the electricity connection), in addition to a flat rate of Rs 80/kW/month over and above their charges for consumption — which can add up to a substantial amount if several connections are forcibly foisted on to them. These consumers are charged anywhere between Rs 3-5.50/kWh, the amount varying based on total consumption in a month.[14]

Most rural consumers in Shamli are either farmers or seasonal labourers. The latter, who do not live in the town for six-nine months in a year, are charged the monthly rental rate for the entire year. The farmers' income is staggered over the year in one or two installments — hence, their monthly bills remain unpaid and attract penalties. Failure to resolve bills on time incurs a penalty of 1.25 per cent of the dues per month for the first three months; after that, every month incurs a 2 per cent penalty on the dues (not including the penalty amount).[15] In several cases, CSE surveyors found bills of individual households to be as high as Rs. 11,000 a year, including penalty.

As per the Socio Economic and Caste Census (SECC) of 2011, in 75 per cent of rural Indian households, the highest earning member earns less than Rs 5,000 a month.[16] Even if they are supported by an additional income, electricity bills for such rural households cannot and should not be costing them one-sixth of their annual salary for the meager electricity they consume. In contrast, many electrified households in Shamli, which are typically richer, do not have meters and are charged a flat rate of Rs 835/month, irrespective of usage. The SAUBHAGYA scheme seems unfair to the new, poorer consumers forcing them to pay more than the wealthier households.

Metering: A long way to go

As of October 2018, 18,236 meters had been installed in Shamli against the 19,486 newly connected households; however, of the installed meters, 420 were pending ledgerisation as per the CSE survey. Claims of 85 per cent billing efficiency under SAUBHAGYA, therefore, seems to have some merit.

The SAUBHAGYA scheme seems unfair to the new, poorer consumers forcing them to pay more than the wealthier households

However, a bigger billing and collections issue pertains to previously connected households. Meter installations for 7,135 unmetered connections have been reportedly undertaken by the PVVNL, which claims to have achieved 38 per cent of its target. The Nigam also claims to have achieved 100 per cent billing in the unmetered households where meters were installed.[17] However, the CSE survey found this to be incorrect. While many houses had meters installed in them, none were connected. Furthermore, the 7,135 unmetered connections where PVVNL has installed meters, account for only 13 per cent of all urban and rural unmetered connections in Shamli district.

The PVVNL also claimed an increase in billing efficiency from 67 per cent in the first two quarters of FY18 to 72 per cent in the corresponding period in FY19, primarily reliant on urban consumers. It has further claimed that these numbers have improved post-SAUBHAGYA, with the first two quarters in FY17 having a 62 per cent billing efficiency.[18]

The quality of power supply

While this is not explicitly stated, SAUBHAGYA should be aiming for ensuring regular electricity supply, not merely connecting households. But regular supply continues to be a problem in these households with frequent power cuts and voltage fluctuations — many consumers have complained about no electricity during the peak evening time. The discom says the villages, on an average, receive supply for 17-18 hours a day, while the agricultural feeders (the few that have been separated) receive eight odd hours of electricity. But villagers contend the supply is far less. To add to it, the discom points out that even this supply quality is unsustainable — supply will take a further hit after the elections in 2019.

Local discom losing out

The PVVNL claims that under SAUBHAGYA, it pays contractors, on an average, Rs 4,400 per connection; it collects only Rs 500 from the APL (above poverty line) households, and nothing from the BPL ones. The government reimburses anywhere between Rs 1,500-4,500 per connection (subject to terms and conditions), but the higher limit is seldom the case for a connection,[19] putting additional pressure on the financially struggling discoms. The amount, according to the PVVNL, averages around Rs 2,000 per connection, which more often than not is insufficient. And though this does not excuse the shoddy work, it does explain the lack of intent. Therefore, not surprisingly, the difference between PVVNL's assessment and realisation amounted to Rs 8,400 lakh in the first two quarters of FY17-18, while it was Rs 4,900 lakh for the same period the year before.[20]

Secondly, collection efficiencies in the rural areas are as low as 20 per cent: this is not expected to rise. Average collection efficiency in Shamli district was 62.4 per cent for the first two quarters of FY19, down from 70 per cent in FY18. This could be attributed to the low collection efficiency (only 44 per cent) at the electrification distribution division (EDD IV) level, a new addition to Shamli's electrification infrastructure.[21]

Thirdly, the AT&C loss was around 55 per cent for the Shamli Electrification Distribution Circle (EDC): surprisingly, it was the highest for the newest EDD IV at 72 per cent in the first two quarters of FY19. These losses are further aggravated in rural settlements. The highest AT&C loss was recorded at an 11-KV feeder in Kudana at 69.4 per cent.

Overall, while SAUBHAGYA and all such electrification programmes must be applauded for their efforts to connect far-flung settlements for which electrification — until recently — was merely a dream, the issues related to supply and discoms mars all the good work.

SAUBHAGYA should be aiming for ensuring regular electricity supply, not merely connecting households. But regular supply continues to be a problem

Can mini-grids bridge the energy access gap in Uttar Pradesh?

UP's acute access issues have seen influx on mini-grids to meet the energy demands of the unconnected. This sector has always drawn in large funding from non-commercial sources — CSR funds, charities, impact investors and international development agencies. For example, of the 1,850 mini-grids in UP, only 16 totaling 2.33 MW fall under the purview of the Uttar Pradesh

Non-Conventional Energy Development Agency (UPNEDA).

Mini-grids in Uttar Pradesh have adopted a wide variety of business models — the anchor-business-community (ABC) model is the most commonplace. It prioritises large 'anchor' loads — commercial and industrial — followed by businesses and households. For example, a 36-kW solar-based mini-grid system by OMC Power, a mini-grid operator, in Sitapur in UP supplies 30-40 units per day to two telecom towers each, while supplying only eight to nine units per day to 70 households. This model works only in villages with considerable commercial/industrial loads. However, mini-grids supplying a vast share of generation to anchor loads while deriving subsidies from the government (30 per cent from the MNRE) is a gross misuse of scarce government resources. The ABC model, thus, does little to further the government's development and access agenda.

The community-based model, on the other hand, deploys smaller systems to serve the basic load requirements for limited hours in a day. The project viability in such a model is heavily reliant on consumer engagement. For example, projects by the mini-grid operator Mera Gaon Power (MGP) are focused on small unconnected settlements with about 50 households, where grid integration is not likely to happen in two to three years; these projects offer basic supply to support lighting and phone charging for six to seven hours. Their customer base primarily includes poor households and micro-enterprises which are billed on a pre-payment basis using community-based collection methods. The business model relies on low capital and operational costs with a projected return of more than 30 per cent at a repayment period of less than three years.

In contrast, projects by TARA, another such mini-grid operator, try to stimulate community demand through micro-enterprise development (Community Engagement, Load Acquisition, and Micro-enterprise Development — CELAMeD), by engaging with the community and encouraging development of local commercial activities.

Mini-grids in Uttar Pradesh have adopted a wide variety of business models — the anchor-business-community (ABC) model is the most commonplace

CSE's survey in UP points to some fundamental problems with the various mini-grid operating models employed. Most mini-grid systems in the state are of 1-kW or less capacity (*see Table 7: Size distribution of mini-grids in Uttar Pradesh*); these small systems with weak distribution grids are incapable of grid integration when the need arises. Even the relatively larger mini-grids set up by UPNEDA can supply only 150 W per household compared to the 500 W per household from the discom grid. Coupled with the nominal amount of power they can provide, mini-grid systems also restrict supply to usually four to six hours a day.

Besides this, the tariffs charged by MGOs (mini-grid operators) are several times higher than those for grid-supplied power — varying across installed systems and consumer categories. The high tariffs are a result of the high fixed cost of the generation plant and distribution system, for a relatively small capacity. Mini-grid operators also fear becoming redundant in the event of the arrival or increased reliability of the grid — they, therefore, tend to charge high tariffs to recover investments over a shorter time period (*see Table 8: Tariffs of mini-grids in Uttar Pradesh*).

Table 7: Size distribution of mini-grids in Uttar Pradesh

Most have small capacity; hence are incapable of grid integration

Range of installed capacity	Number of mini-grids
Less than 1 kWp	1,627
1-30 kWp	30
30-50 kWp	43
50-100 kWp	10
Over 100 kWp	14

Note: The list may not be exhaustive.
Source: Compiled from various sources as part of the CSE survey.

Table 8: Tariffs of mini-grids in Uttar Pradesh

Effective tariff rates are several times higher than that of discoms

Company	Costs of connection	Effective tariff rate (Rs per unit)	Duration of effective usage (hours)
OMC Power	15 watt — Rs 110	40.7	6
Husk Power	34 watt — Rs 230	37.6	6
	50 watt — Rs 300	33.3	
	100 watt — Rs 630	35.0	
Boond Engineering	20 watt — Rs 60	16.7	6
	60 watt — Rs 350	32.4	
Mera Gaon Power	20 watt — Rs 120	28.6	7

Source: Compiled from various sources as part of CSE survey.

In February 2016, in an attempt to address these issues, the UP government released its Renewable Energy Mini-Grid Policy.[22] The Uttar Pradesh Electricity Regulatory Commission (UPERC) followed up the policy with the Mini-Grid Renewable Energy Generation and Supply Regulations in April 2016.[23] The state offers a 30 per cent capital subsidy (based on viability gap funding determined by reverse bidding), in addition to the Central government subsidy. Availing the state subsidy obliges the MGOs to meet certain supply standards — supply residential consumers for a minimum of eight hours and commercial loads for six hours. The policy caps tariff at Rs 60 per month for a 50-W load, and Rs 120 per month for a 100-W load. It allows operators two exit options — to sell either the generation and distribution assets to discoms, or the generated power as an Independent Power Producer (IPP). Unfortunately, the policy has failed to attract any projects since it was announced. Developers claim that even the inclusion of state subsidy did not improve their economics enough to meet the standards set by the policy.

Uttar Pradesh, with its large number of un-electrified villages, offers the largest market for mini-grid operators. This has led it to be an early adopter of a stand-alone mini-grid policy. Further, almost all mini-grid operators across India employ same or similar models. Though the degree of issues might vary, the problems remain same. Therefore, it might be safe to say that the status of mini-grids in UP is reflective of the national sector.

So, what is the next step for mini-grids? It is clear that in a renewable energy world, mini-grids will play a significant role in generating electricity locally, supplying it to the local consumers and feeding the excess to the grid. The government and the mini-grid operators will have to embrace this vision and revive the sector.

CASE STUDY
How sustainable is solar power pumps?

India's agricultural sector consumes nearly 25 per cent of the country's total electricity, largely for its irrigation needs.[24] The sector's demand is met primarily from the 19 million electric and nine million diesel pumps in India.[25] Unfortunately, the use of electric motor pumps is limited by the erratic electricity supply. Diesel pumps, on the other hand, are associated with high fuel prices and dirty emissions. Approximately 60 per cent of farmers in India buy water or rent pumping services at high costs.

Solar Pumping Irrigation Systems (SPIS) have a potential to help reduce dependence on conventional pumping systems and increase farm productivity (*see Table 9: Solar pump deployment models*). Solar water pumps incur zero fuel costs and offer farmers reliability. The falling prices and improving efficiency of technology are an added bonus.

The nine million diesel users can benefit the most from a switch-over to solar pumping systems, given the high fuel cost. A comparison of 10-year lifecycle costs of solar water pumps and diesel water pumps found that the former was 35 per cent cheaper.[26] Several anecdotal studies have shown that farmers cultivate a variety of crops and earn higher incomes when using

Table 9: Solar water pump deployment models

Can reduce dependence on grid power and diesel pumps

Individual ownership	For larger farmers with resources to meet the high upfront costs
Farmer cooperatives	For smaller farmers who co-own the pump; irrigation needs of the farmers can be scheduled by a sole operator or via shared asset model
Service models	Consumers with irregular water needs can rent small portable pumps or buy 'water as a service' from service companies
Rent-to-own/pay-as-you-go	Consumers are charged a fee/rent for the pumps, which are treated as installments towards eventual ownership

Source: Compiled from various company reports

SPIS. However, the capital-intensive nature of solar pumps combined with the low utilisation rate, if used individually by small farmers, reduces their financial viability.

Myriad policies and schemes

States like Maharashtra and Rajasthan offer successful policy examples that incorporate favourable financing mechanisms and deployment models for solar water pump adoption

The high capital cost of SPIS has meant that all government-led initiatives have preferred handing out capital subsidies. Under JNNSM, the Solar Pumping Programme for Irrigation and Drinking Water was introduced in 2014.[27] As of December 2017, 2.4 lakh pumps had been sanctioned under the programme. In the same year, the National Bank for Agricultural and Rural Development (NABARD) introduced a Credit-Linked Capital Subsidy Scheme (CLCSS), which envisaged 30,000 solar water pump systems. The scheme achieved less than 6 per cent of the target and was discontinued.[28]

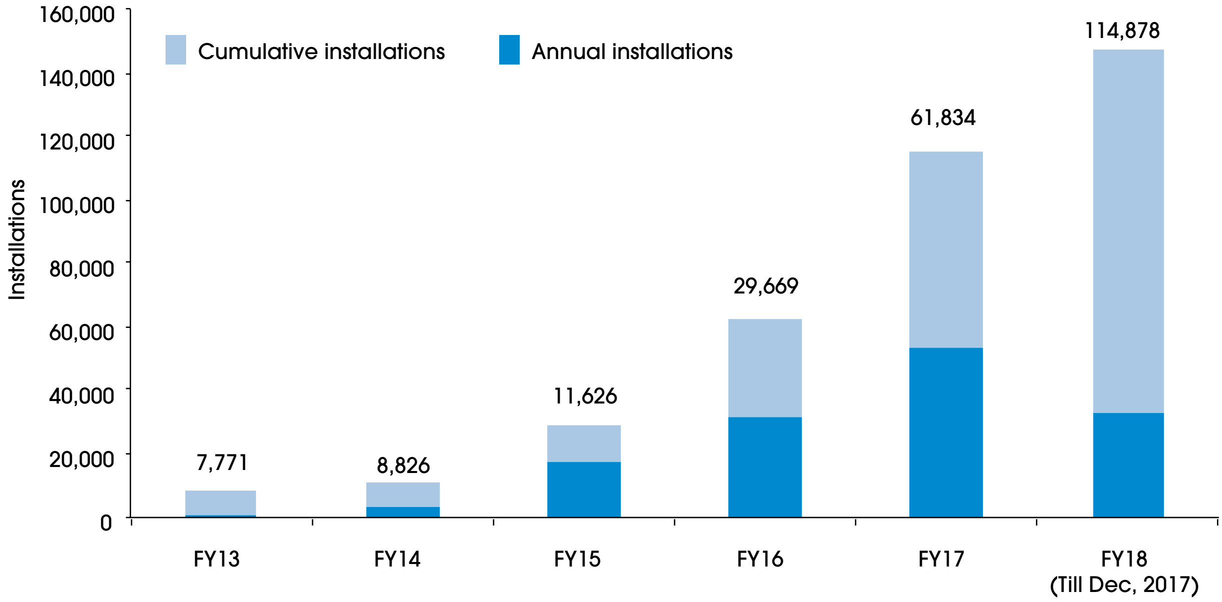
States like Maharashtra and Rajasthan offer successful policy examples that incorporate favourable financing mechanisms and deployment models for solar water pump adoption. Maharashtra has completed a tender to procure 10,000 solar water pumps and is offering a 95 per cent capital subsidy to farmers. A Rajasthan government scheme offered an 86 per cent capital subsidy, including 56 per cent state subsidy (under the Rashtriya Krishi Vikas Yojana) and a Central subsidy of 30 per cent, for certain solar irrigation pumps (2- and 3-HP DC submersible pumps). Overall, 1.14 lakh solar pumps were installed in India till the end of December 2017 (*see Graph 7: Annual installation of solar pumps in India*).[29]

Kisan Urja Suraksha Evam Utthaan Mahabhiyan (KUSUM)

The Kisan Urja Suraksha Evam Utthaan Mahabhiyan (KUSUM) scheme, the Government of India's latest endeavor towards deployment of subsidised solar pumps, will require a total outlay of Rs 140,000 crore over the next 10 years. Under KUSUM, the Centre will provide 60 per cent capital subsidy; 30 per cent will be financed through bank credit and the remaining 10 per cent will be borne by the farmers. KUSUM proposes installation of large solar power plants (28,250 MW), replacement of conventional pumping systems (720 MW) and distribution of SWPs (solar water pumps); and installation

Graph 7: Annual installation of solar pumps in India

Over 1.14 lakh pumps installed till December 2017



Source: Compiled from MNRE annual reports, https://mnre.gov.in/annual-report

of solar-powered tube wells (8,250 MW).[30] Unlike its predecessors, KUSUM promotes a model that allows farmers to sell surplus power to distribution companies, which would get a Rs 0.5/unit incentive to purchase power. This offers farmers a secondary source of income. But the scheme is yet to obtain support from the Union Ministry of Finance and an approval from the Union cabinet.

What is the way ahead?

One of the major concerns in India, however, is water, which has a direct correlation to pumps. India accounts for 25 per cent of the world's extracted groundwater, and the agricultural sector is one of its major users. Declining quality and quantity of surface water and unpredictable rain patterns have pushed farmers to use groundwater more and more. What has compounded the scenario is access to subsidised power — this has led to excessive water withdrawal and unsustainable irrigation practices, aggravating the already dire groundwater scenario in the country. An analysis shows a 13 per cent decline in the water table nation-wide over the past 30 years.[31] In areas receiving free electricity, over-exploitation has been limited solely due to power cuts. Given the fact that solar power's marginal cost is almost zero, indiscriminate SPIS use would be catastrophic for our aquifers.

SPIS deployment should, therefore, be carefully pursued. For example, in the western part of the country where groundwater is scarce, policies should encourage sale of excess power generated by the solar panel (when the pump is not in use) to the grid (instead of incremental water withdrawal).

Reliable electricity, however, might not be an incentive enough for farmers to switch over to SPIS

Secondly, the focus of KUSUM should be on solarisation of conventional electric pumps to reduce the quantum of heavily subsidised grid electricity that the agricultural load draws. Also, water use efficiency (drip irrigation, sprinklers and other water management activities) should be promoted alongside the SPIS schemes. In the Ganga-Brahmaputra basin, on the other hand, where groundwater is aplenty but electricity scarce, solar pumps can displace diesel ones.

Reliable electricity, however, might not be an incentive enough for farmers to switch over to SPIS — especially for those who are enjoying subsidised diesel and/or free grid electricity. A buy-back of the excess electricity generated, as proposed under KUSUM, offers a secondary source of income which could be the added incentive. Pilot examples, like the one in Dhundi, Gujarat can showcase a change in the usage pattern, with its focus on conservation of both electricity and water.

Considering the large size of India's agricultural community, solar water pumps seem to be an obvious choice for electricity generation at the point of consumption — as a decentralised source of energy. As a decentralised solution, SPIS can reduce transmission losses.

Cheap electricity to the agricultural sector is an enormous and continually ballooning problem for discoms. Well-designed SPIS deployment models can limit the subsidy burden on the government by incentivising both appropriate water use and sale of excessive power to the grid. SPIS systems also provide an effective way for discoms to meet their renewable purchase obligations, since discoms can claim credit for all generated power as opposed to only the quantum purchased back from the SPIS.

CASE STUDY

Can induction cooking solve the clean cooking fuel crisis of the country?

VIKAS CHOUDARY / CSE

Clean energy access also encompasses fuel used for cooking: 63 per cent of the Indian population continues to rely on traditional biomass (firewood, crop residues and cowdung cake) which causes indoor pollution and has serious health impacts. Studies have found women and children to be disproportionately affected.

Government schemes and heavy subsidies drove an urban switch to cleaner LPG and PNG. The 2016 Pradhan Mantri Ujjwala Yojana (PMUY) attempts to bring a similar shift in rural areas. Under it, a ‘Give it up’ campaign asked LPG consumers to voluntarily surrender their subsidies that can be redirected to rural consumers. Also under it, ‘PAHAL’ required women of BPL families to open bank accounts, so that direct benefit transfer of LPG subsidies (DBTL) could be facilitated.[32]

Under Ujjwala, beneficiaries are given Rs 1,600 for the LPG connection and the security fee for the cylinder. But this level of subsidy is too low for continued LPG use, a fact that has been corroborated by reports from the ground.[33]

The gaps in Ujjwala

Ujjwala has been pitched as a scheme to encourage affordable, clean cooking fuel uptake — but it seems to be failing at various fronts. The extra costs on the stove or the first cylinder can be covered through a zero-interest loan granted by the oil marketing companies (OMCs). This loan amount can be recovered by withholding the subsidy amount for the four-10 refills that typically follow. Charging beneficiaries the full rate for the first few refills is the first disincentive and to the cause

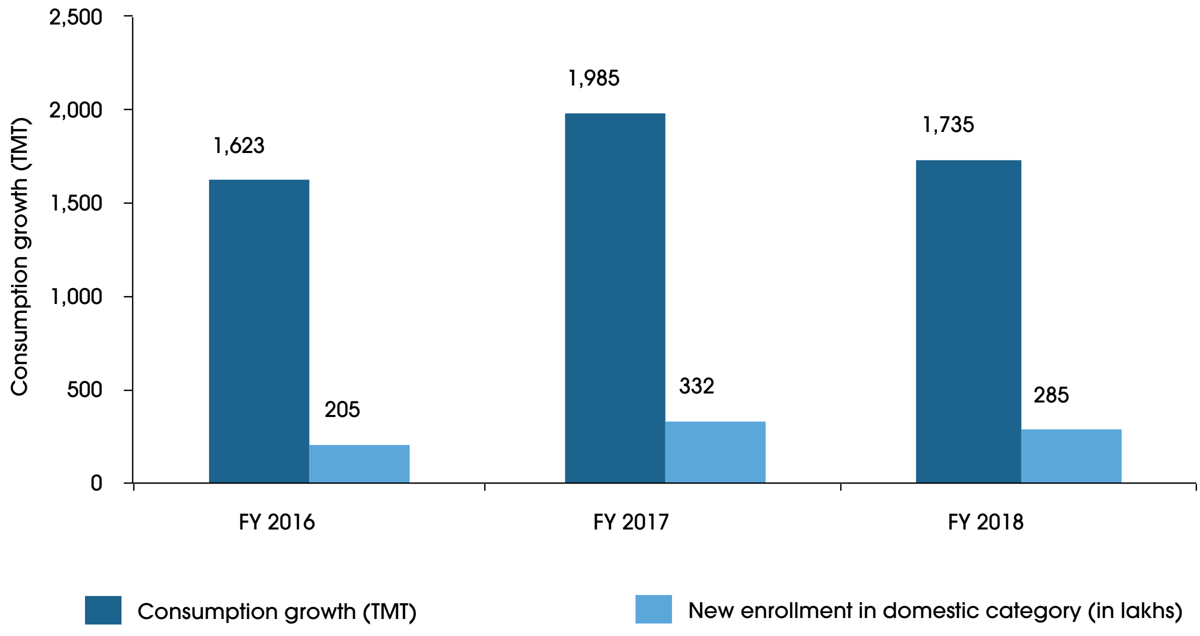
Second, as per Petroleum Planning and Analysis Cell (PPAC) estimates[34], the growth in LPG consumption has actually fallen after Ujjwala entered the picture. It was 10.11 per cent in FY16 — before the introduction of the scheme — as compared to 8 per cent and 9 per cent in the following years. Seen against the increasing number of new LPG consumers (growth rate of 19 per cent in FY2017 and 13 per cent in FY2018), this indicates dampened usage (*see Graph 8: Growth in LPG consumption against new enrollments*).

Third, the national average refill of the 14.2-kg LPG cylinder has fallen from 6.27 cylinders per household in FY2016 to 5.6 in FY2017. Though national averages for refills per connection was 6.9 in FY2018, Ujjwala consumers still averaged only 3.4 refills annually.[35] Therefore, basing the success of the programme purely on the connections provided, and not on refills, might not be accurate.

Fourth, in 2018, the domestic sector accounted for a dominant 88.5 per cent of national LPG consumption;[36] this has been a significant drain

Graph 8: Growth in LPG consumption against new enrollments

Number of new consumers increased against a dip in consumption growth



Source: Compiled from Ministry of Petroleum and Natural Gas (MoPNG) annual reports, http://petroleum.nic.in/documents/reports/annual-reports on foreign exchange, especially given the drop in local production (*see Statistics section*).

To add to this, the government compensation for the subsidy burden borne by OMCs is seldom enough. The companies say that the compensation is based on 2002 prices and should be revised immediately. In fact, the subsidised LPG cylinder has resulted in an exponential increase in the subsidy burden — amounting to Rs 28,067 crore in 2018-19 alone — which is borne by the Central Public Sector Enterprises (CPSE) OMCs.[37] The question is, are such heavy investments on an interim fuel the best way forward for the country?

A government-sponsored report[38] has pointed out the many gaps in Ujjwala: high costs and long waiting times for LPG refills; insufficient distribution network; tedious process for getting new LPG connections etc. These are forcing consumers to slip back to biomass-based cooking, a phenomenon known as 'cooking technology stacking'[39], which defeats the very purpose of the switch to LPG.

An electric stove's increased efficiency can help reduce the amount a family spends on cooking

Onwards to electricity-based cooking

Currently, the share of electricity — the cleanest cooking fuel — in the cooking mix is minimal, especially when compared to the large numbers still dependent on biomass-based cooking. The obvious advantages accrue to the poorest households, which can get rid of indoor pollutants if they switch to electricity-based cooking.

In urban households, the parallel existence of LPG and PNG is being supplemented by electric/induction cookstoves, but this has progressed at a snail's pace. An upper limit assumption says a family's consumption of eight to 10 LPG cylinders (14.2 kg each) per year is equivalent to electricity consumption of nearly 4 kWh per day.[40] The Niti Aayog claims that the additional electricity demand from cooking, approximately 150 to 200 billion units per year, could help alleviate the problems associated with underperforming generation assets.[41]

On efficiency, both electric (74 per cent) and induction (84 per cent) stoves fare far better than gas stoves (40 per cent). An electric stove's increased efficiency can help reduce the amount a family spends on cooking[42, 43]. Combining cooking goals could be an ideal way to use the massive electrification exercise undertaken within the country. It would also obviate the need for building a parallel LPG/PNG infrastructure. To add to this, electricity tariffs tend to be more stable than gas prices — the latter is vulnerable to international events and rupee depreciation.

But it must be kept in mind that electricity-based cooking can only be done in households that are receiving 24x7 electricity without any voltage fluctuations – an important concern in the rural parts of the country. The lack of quality supply can be a deterrent, as has been seen in a TERI study done in Himachal Pradesh.[44] An year after the distribution of 4,000 induction stoves, only 5 per cent households, which had reliable power supply, were still using them.

A true leapfrogging would involve using renewable energy for cooking

Currently, none of the country's energy access plans and policies discuss the utilisation of electricity for cooking

(for example, using solar induction cookers). However, these restrict cooking activities to a few hours unless combined with storage, which adds to the cost. A recent model developed by IIT-Mumbai shows that a solar electric cooker providing 3 kWh of electricity per day (enough for cooking three meals for a family of five) with battery storage, would cost Rs 10,000.[45] Alternatively, remote and/or rural areas that are not connected to the grid may be better served by incentivising mini-grids that support cooking needs as well. The corresponding increase in energy consumption of households could further help improve the economics of mini-grids.

Most developed nations have shifted to using electricity for cooking; India continues to lag behind. Recognising the disproportionate support meted out to transitioning cooking fuels (LPG and PNG), the Niti Aayog suggests extending benefits/subsidies to all cooking fuels, including electricity, through direct benefit transfer. Such a blanket subsidy will give consumers the option to pick and choose. BPL households, with access to reliable, quality electricity, could be provided loans for induction stoves. Consumers in remote regions could be incentivised to adopt electricity as a credible and primary fuel for cooking through grid and off-grid electricity, respectively.

However, any shift to either of the two technologies for cooking will require the government to employ large-scale deployment schemes — such as the distribution of LEDs under Ujjwala by EESL — to help bring down the costs. Additionally, awareness drives must be carried out to bust the myths regarding induction cookstoves' inability to meet Indian cooking needs.

Currently, none of the country's energy access plans and policies discuss the utilisation of electricity for cooking. There is a need to develop an effective, comprehensive policy that follows a multi-pronged approach for adopting clean cooking fuels. As the economics of off-grid solar applications for induction cooking[46] and/or grid power quality improves, electricity is poised to be a strong contender as a cooking fuel.

CHAPTER 7

Discoms: Fundamental reforms required

Discoms (distribution companies) hold the key to the future of renewable energy in India. Mostly state-owned, these companies purchase power from generators and sell them to residential, retail, agricultural, commercial and industrial consumers. Most of the key concerns faced by the wind and solar energy sectors (*these have been discussed in the other chapters in this book*) such as curtailment, payment delays, off-setting discom risks by SECI and NTPC, refusal to sign PPAs with new plants etc are connected to these companies and point to the fact that discoms either drive the growth or can pose crippling problems.

The underlying reason behind this scenario is that most discoms have run huge financial losses and have poor operational performance. Their inability to collect revenues from large sections of their customer base due to power theft and lack of proper billing and collection makes it difficult for them to recover their costs. They are further saddled with unsustainable tariff structures, slabs for different end users and associated cross-subsidies; this makes it unlikely that their business can break even.

Discoms are also bound to large thermal power plants by means of long-term PPAs, with two-part tariffs with a fixed cost component. As a result, there is very little incentive to offset thermal consumption with newer renewable power, even if the latter is cheap. In fact, a large renewable capacity with 'must run' status might be adding more pressure to the distribution sector.

There have been multiple attempts to turn the situation around, with the latest being the Ujjwal Discom Assurance Yojana (UDAY) scheme, introduced in 2015. It, however, remains a work-in-progress.

Ujjwal Discom Assurance Yojana (UDAY)

UDAY was conceived as a plan to rejuvenate discoms in India. By March 2015[1], Indian discoms had collectively accumulated losses of Rs 3.8 lakh crore and an outstanding debt of Rs 4.3 lakh crore. It was clear that all the plans for the electricity sector — 100 per cent electrification, high quality power supply being made available 24x7, and having 175 GW of renewable generation absorbed by the network by 2022 — would suffer setbacks if the discoms continued in this vein.

Discoms either drive the growth or can pose crippling problems

Three years on, the results produced by UDAY remain unclear and questionable

In November 2015, therefore, the Ujjwal Discom Assurance Yojana (UDAY) was introduced: the aim was to restructure the discoms' debt to make them financially stable and hold them accountable for their performance. It was proposed that state governments would take over 75 per cent of the debt of their respective discoms, with bonds issued for the remaining 25 per cent. Aside from the financial restructuring, the discoms were expected to improve their performance along various metrics — most of which are tied to deployment of infrastructure to help curb losses in the system.[2]

The aggregate technical and commercial (AT&C) losses partly reflect the efficiency at the transformer and distribution network level. In addition, the losses go up when theft is endemic, as is the case in large parts of the country. Poor metering and resultant low billing and collection efficiency also contribute to the problem. To cut down on the AT&C losses, the UDAY scheme mandated the installation of smart meters in rural and urban areas, and metering of transformers to track theft and identify leakages and points of low efficiency. UDAY planned that the losses would be cut down to a national average of 15 per cent by FY2018-19. At the revenue end, a total recovery of the cost of supply through various mechanisms, including upward revision of tariffs and reduction in subsidies, was proposed.

Three years on, the results produced by UDAY remain unclear and questionable. A lot of the tasks are running behind schedule — especially smart meter installations. The AT&C losses remain high, with some states indicating losses of over 40 per cent, a far cry from the 15 per cent target. The ACS-ARR gap (the gap between average cost of supply or ACS and the average revenue realised or ARR) continues to be high for most of the states[3] (*see Table 1: The UDAY check-list*).

As per the Union power ministry's annual integrated ratings report[4] which assigns credit ratings to each company with respect to regulatory, operational and financial parameters, 42 discoms are under the scanner. The top tier — 'A+' rated discoms — are concentrated in the state of Gujarat. Among states, Uttarakhand is the only new entrant, while Punjab, formerly a highly rated discom, has deteriorated. At best, more discoms appear to be

Table 1: The UDAY check-list

The scheme has not produced the desired results

Task	Stated deadline	Status as of October 2018
Smart metering for consumers with:		
>200 kWh/month	December 2017	1%
>500 kWh/month	December 2019	3%
LED distribution to achieve savings totaling Rs 40,000 crore	March 2019	100%
Feeder metering	June 2016	100%
Distribution transformer metering	June 2017	Rural 59%/urban 63%
AT&C losses down to 15%	March 2019	National AT&C losses: 23%
ACS-ARR gap down to Rs 0/kWh	March 2019	National gap: Rs 0.27/kWh

Source: https://powermin.nic.in/pdf/Uday_Ujjawal_Scheme_for_Operational_and_financial_Turnaround_of_power_distribution_companies.pdf., as seen in October 2018 concentrated today at the higher end of the average range (B+) as compared to the situation in 2014-15. The number of discoms in the worst performing bracket has quadrupled.

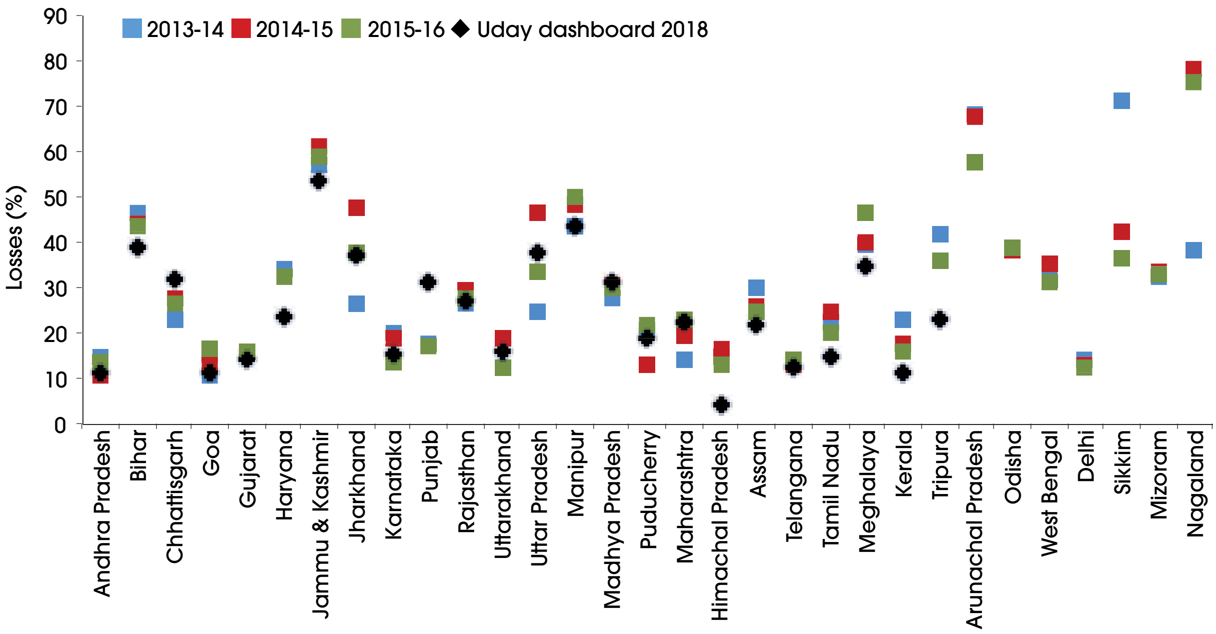
While credit ratings are by no means a foolproof and dependable indicator, it remains an indispensable source of information primarily considered by banks for assessing a discom's credit worthiness. With the rating of most discoms far below the investment grade, the renewable sector will continue to need interventions such as payment guarantees and intercession by SECI to reduce the risks.

Aggregate Technical & Commercial (AT&C) losses

As per the UDAY dashboard in September 2018[5], overall AT&C losses indicate poor outcomes (*see Graph 1: AT&C losses in states from 2013-14 to 2018*). While there have been improvements in some states such as Himachal Pradesh (lowest AT&C loss of 4.33 per cent), Kerala (which has halved its losses in four years to 11.49 per cent) and Haryana (losses have fallen by over 10 per cent, down to 23.8 per cent currently), others appear to have significantly deteriorated. Chhattisgarh (losses have increased to over 30 per cent) and Punjab (losses have almost doubled and currently stand at 31.3 per cent) have recorded some of the biggest losses compared to the previous three years. All other states show fluctuations with no clear

Graph 1: AT&C losses in states from 2013-14 to 2018

Only Himachal Pradesh, Kerala and Haryana have shown improvement



Sources: Compiled from PFC annual reports (2013-14 to 2015-16) available at http://www.pfcindia.com/Home/VS/72 and the UDAY dashboard, as viewed in October 2018 https://www.uday.gov.in/national_parameter_dashboard.php?id=

Many states are unlikely to meet the target which necessitates keeping the losses at 15 per cent by March 2019

improvements. Additionally, these numbers are self-reported by states and the actual performance may be worse.[6]

The outcomes continue to be variable in the case of the smaller universe of renewable-rich states. Karnataka, Gujarat and Andhra Pradesh are the best performers — on an average, they have consistently maintained their losses between 10-15 per cent, with UDAY having had no obvious impact on them. Rajasthan and Madhya Pradesh have also remained more or less static at over 27 per cent. Maharashtra, Uttar Pradesh and Punjab have, in contrast, done significantly worse over the years. Tamil Nadu, a late entrant to the scheme (January 2017) has achieved the target by falling below 15 per cent. Most of these states are unlikely to meet the target which necessitates keeping the losses at 15 per cent by March 2019, a sign that most discoms have not resolved their underlying operational issues.

The ACS-ARR gap

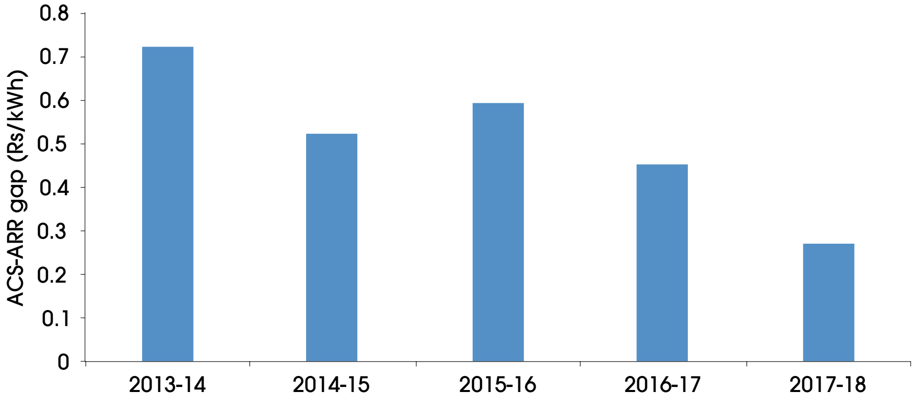
In terms of cost recovery through tariff revenues, most discoms continue to have a significant ACS-ARR gap. It was expected that by March 2019, all the states would be able to close this gap and begin turning profitable. While there is still some way to go before this gap is completely closed, the last four years have seen improvement in terms of the average national performance (*see Graph 2: The ACS-ARR gap through the years*).[7,8]

On closer examination, only four states are, in theory, recovering their costs incurred by supplying power, of which three — Rajasthan, Karnataka and Gujarat — are significant procurers of renewable energy (*see Graph 3: ACS-ARR gap for states with large renewable capacities*). On an average, the states that are recovering their cost have relatively low AT&C losses.

Smart meters are touted as a viable solution to track electricity consumption effectively, reducing losses by theft and improving billing and collection. Rajasthan, the best performing state in terms of the ACS-ARR gap, has 58 per cent smart meter installation rate for large consumers (over

Graph 2: The ACS-ARR gap through the years

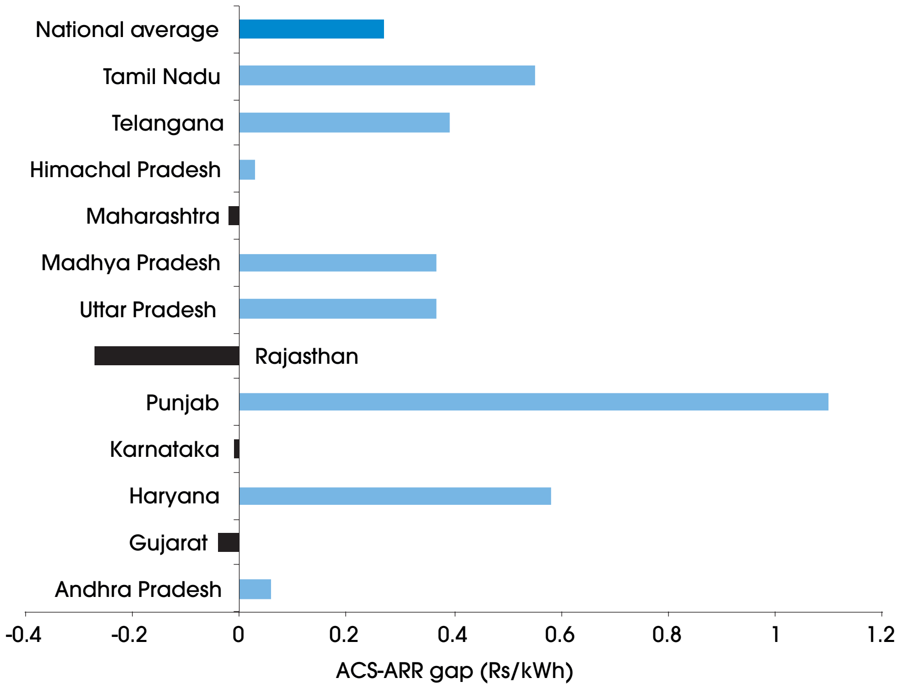
Currently, this is 62.5 per cent lower than in FY-14



Source: Compiled by CSE from PFC reports and KPMG India

Graph 3: ACS-ARR gap for states with large renewable capacities, 2018

States with a negative gap have lower than average AT&C losses



Source: Compiled from the UDAY dashboard in October 2018, https://www.uday.gov.in/national_parameter_dashboard.php?id=5

500 kWh). This sets it apart from most of the other states, which have made practically no headway on smart metering — most of the large states have 0 per cent deployment for both over and under the 500-kWh category[9] (*see Table 2: The status of smart metering*).

Installation of seperate feeders for rural households and agricutural load aims to both provide appropriate power delivery to farmers and reduce misuse of subsidised electricity. However, feeder separation has not had any serious impact on discom financials; states such as Punjab, Haryana and Tamil Nadu, while achieving 95-100 per cent feeder segregation, still have high ACS-ARR gaps, surpassing the national average of Rs 0.27/kWh.[10] Feeder separation and transformer metering has not led to better biling and collection or reduction in thefts.

According to the UDAY dashboard, 25 out of 27 states and Union territories have made tariff revisions.[11] But as per data published by the consultancy firm KPMG India[12], the implementation of tariff increases (the terms of which are agreed to in individual state MoUs signed with the power ministry) is inconsistent. It is also unclear if the marginal increases in tariff have had material impact on the ACS-ARR gap, since costs have gone up.

In the period between FY13 to FY16, the overall expenditure has increased every year — this is reflected in the ACS. The largest component

Table 2: The status of smart metering

No progress on installation

	Feeder segregation (%)	Smart metering (200-500 kWh) (%)	Smart metering (>500 kWh) (%)
Andhra Pradesh	100	0	0
Gujarat	100	0	0
Haryana	100	1	3
Madhya Pradesh	98	1	20
Karnataka	97	1	0
Punjab	95	0	0
Maharashtra	66	0	0
Chhattisgarh	36	0	0
Rajasthan	24	0	58
Uttar Pradesh	15	0	0

Source: UDAY dashboard

(over 60 per cent) built into the expenditure is the power purchase cost, which, historically, has increased annually. The operational costs (including employee salaries and administration expenses) have also seen an annual rise to the tune of 12 per cent in FY 2015-16 and 9 per cent in FY 2016 -17.[13] The average 5 per cent tariff increase which is broadly agreed upon, if at all enforced, would be unlikely to compensate for this.

The reduction in the ACS-ARR gap can be, in large part, attributed to the financial restructuring between FY2016 -17 to FY2017-18. The interest component of the tariff, as estimated by CSE from the tariff breakdown provided in the PFC Annual Reports[14] for the period[15] is 8 per cent of the total expense. With the state government taking over the debt and reducing the discoms' interest payment, the ACS has reduced. At a national level it would appear that the gap closure is attributable to the financial restructuring — this undercuts the notion that the discoms have made any real improvements.

This lack of progress on the operational front is an indictment of the UDAY scheme and on rationalisation of tariffs.

The reduction in the ACS-ARR gap can be attributed to financial restructuring and reduction in debt burden of discoms

Renewable purchase obligations

RPO, or renewable purchase obligation, regulations require that a pre-determined fraction of the electricity procured by utilities and third party (open access) power procurers, comes from renewable sources. The objective is to ensure that renewable energy has a guaranteed market to attract developers and investment.

At the time when RPO was instituted in 2011, wind and solar power were significantly more expensive than coal-powered generation. While this premise has changed, the RPO regulation continues to be important for the growth of renewable energy, since discoms appear to be reluctant to sign additional PPAs.

Table 3: Long-term growth trajectory of RPOs

Mismatch between RPO targets and generation from RE sources

	2016-17 (%)	2017-18 (%)	2018-19 (%)	2019-20 (%)	2020-21 (%)	2021-22 (%)
RPO target	11.5	14.25	17	17.50	19	21
% RE generation	6.33	8.06	-	-	-	16.38 (estimated)

Sources: Ministry of Power, https://powermin.nic.in/sites/default/files/webform/notices/RPO_trajectory_2019-22_Order_dated_14_June_2018.pdf, estimates from CEA generation report 2017-18 http://www.cea.nic.in/reports/annual/generationreview/gen_target-2018.pdf

In line with market growth, the MNRE has issued new long-term annual RPO targets in 2018 for the period up to 2022.[16] However, these targets appear to be inconsistant with capacity installation goals (*see Table 3: Long-term growth trajectory of RPOs*). According to the Niti Aayog's estimates for a scenario where the 175-GW target is met in 2022, renewable energy generation would form only about 16 per cent of the total generation percentage[17], which makes the RPO benchmark targets of 21 per cent unattainable.

State ERCs set their own RPO targets and tend to vary in the scale of their ambitions. This is largely due to the concentration of renewable resources in most western and southern states. The obligated entities in these states have an advantage in being able to directly procure the generation at lower costs. Cross-border power purchase from renewable IPPs comes with many regulatory hurdles and charges which leaves those states with low renewable resources at a disadvantage.

Another factor contributing to the inequality among discoms is their customer base — discoms servicing a higher proportion of subsidised residential and agricultural customers have higher cross-subsidies levied on other segments. These discoms tend to be financially weaker and therefore have less flexibility to procure additional renewable power.

However, most states (including the renewable-rich ones) have comparatively modest RPO targets. Most of the larger states — with the exception of Gujarat, Karnataka and Andhra Pradesh — are yet to pass regulations on their RPO trajectory up to 2022 in alignment with that of the Union Ministry of Power. This is a serious shortcoming, especially in states like Maharashtra and Madhya Pradesh, which have large operational renewable capacity as well as a significant pipeline in the coming years (*see Table 4: RPO regulations of states with largest renewable capacities*).

Most states have not yet passed regulations on RPOs in alignment with that of the Ministry of Power

The RPO regulations also need some fundamental changes. Splitting the RPO requirements into specifically solar and non-solar (mostly wind) made sense earlier, when the former was exorbitant in comparison. But now, with both wind and solar tariffs equally priced at under Rs 3/kWh, this division is meaningless. Having combined targets is likely to allow utilities and other obligated entities more freedom to opt for the technology mix that makes the most sense.

Table 4: RPO regulations of states with largest renewable capacities

State RPO targets are not in alignment with power ministry

	Andhra Pradesh (%)	Karnataka* (%)	Tamil Nadu (%)	Madhya Pradesh (%)	Maharashtra (%)	Gujarat (%)	Rajasthan (%)	MoP (%)	
2015-16		0.25	0.5			1.5			Solar
		5 to 10	9			7.5			Non-solar
2016-17		0.75	2.5	1.25	1	1.75		2.75	Solar
		5.5 to 11	9	6.5	10	8.25		8.75	Non-solar
2017-18	3	2.75	5	1.5	2	1.75	4.75	4.75	Solar
	6	6 to 12	9	7	10.5	8.25	9.5	9.5	Non-solar
2018-19	4	6		1.75	2.75	4.25	6.75	6.75	Solar
	7	7 to 13		7.5	11	8.45	10.25	10.25	Non-solar
2019-20	5				3.5	5.5		7.25	Solar
	8				11.5	8.8		10.25	Non-solar
2020-2021	6					6.75		8.75	Solar
	9					8.9		10.25	Non-solar
2021-2022	7					8		10.5	Solar
	10					9		10.5	Non-solar

*Each of the five discoms in Karnataka have their own RPO targets, and the range is indicative of the lowest and highest assigned.
Source: Compiled from state ERC RPO regulations of 2016 and 2017.

Poor RPO compliance

RPO compliance data is poorly reported. The last detailed audit done by the Comptroller and Auditor General (CAG) in 2014 pointed out that between 2011 and 2014, most states were non-compliant, with Karnataka, Tamil Nadu, Mizoram and Arunachal Pradesh being the only exceptions.[18] The issue was further highlighted by two rulings from the Appellate Tribunal for Electricity[19] and a Supreme Court ruling, which called for stricter enforcement of the regulations issued by the SERCs for all the buyers. However, the state governments remain casual about enforcing RPO regulations. For instance, Madhya Pradesh[20] and Maharashtra[21,22] relaxed or completely waived existing RPO backlogs for state and private utilities.

This non-compliance has continued between 2015 and 2018. The MNRE reported that in FY16, only seven states met and surpassed their RPO targets, of which only three were states with large renewable capacity (Karnataka, Andhra Pradesh and Tamil Nadu).[23] Twenty-one states had a compliance of under 60 per cent.

Additionally, there is no uniformity on the penalties: prior to the CAG audit, quite a few states did not have penalty clauses. The state-imposed penalties vary wildly — some push for total compliance by procuring Renewable Energy Certificates (REC) at forbearance prices to meet the shortfall, with instances of additional fines for delays, while others impose lenient one-time fines.[24]

The need for RPOs

At first glance, RPOs appear to be redundant — cheaper renewable power should be automatically favoured by discoms for procurement. However, that does not appear to be the case.

Discoms are locked into large long-term contracts with thermal power plants by means of a two-part tariff which ensures that thermal plants are paid a fixed component even if their generation is not consumed. This means that solar procurement, however cheap in absolute terms, becomes more expensive when that additional fixed cost is added to the per unit discom expenditure. This makes it difficult for renewable energy to dislodge thermal capacity at the supply end, without having regulations like the RPO imposed on discoms.

Additionally, discoms are grappling with the vast excess supply that has been attributed as the reason why no new long-term PPAs have been signed with thermal plants. It is estimated that 20,000 MW of thermal capacity is currently in limbo because of this.[25,26] In this over-supplied market, therefore, the incentives for signing new PPAs with upcoming solar and wind plants is low.

At the state-level, even with wind and solar power reaching grid parity, RPOs continue to be a driving factor. As recently as a few months ago, renewable energy auctions in Maharashtra, Gujarat and Karnataka were held by the state nodal agencies, primarily to meet their RPO targets.

The REC market

The REC (renewable energy certificate) market was introduced in 2010 to create an alternate means of meeting RPO obligations to incentivise renewable generation procurement.

Projects registered with the REC market can generate certificates. For every 1 MWh generated, one REC is issued, which in turn can be sold to other obligated entities to allow them to meet their RPO compliance. The income from trading the certificates has the benefit of creating a mechanism that incentivises building projects outside the umbrella of the state or Central government policies. These projects, if supplying to discoms, do so at the average power purchase cost (APPC) determined by ERCs. The other categories of projects that can register for RECs are those supplying power under open access (OA) agreements or captive plants.

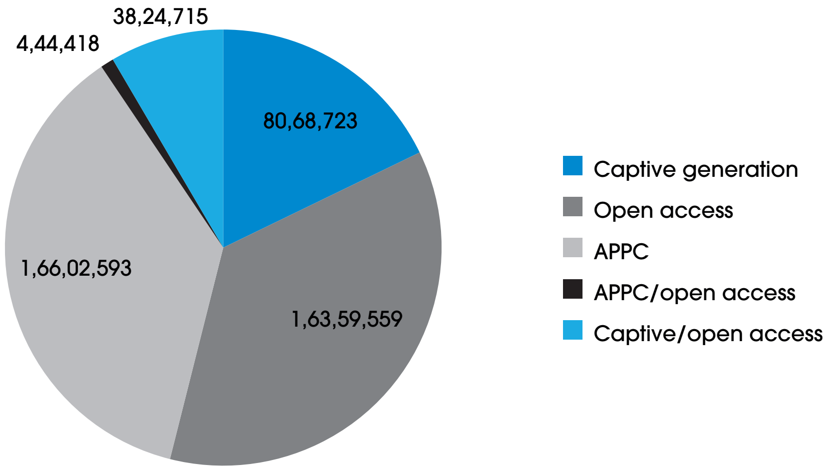
The REC market's largest contributor are those plants that sell power to the discoms at the APPC, followed by OA. The former segment is taking a hit due to the allure of centrally-driven auctions. Although captive plants are the only clear beneficiaries, this category accounts for just over 18 per cent of the RECs issued (*see Graph 4: RECs issued by different categories of projects*).

The price of RECs is determined by market demand between the limits of the floor price and the forbearance price which is set by the CERC; it is reviewed periodically to reflect the average tariffs at which the solar and wind markets are signing PPAs, as seen in the recent revision in April 2017 which brought down the price of solar RECs from Rs 5,800 per MWh to

Even with wind and solar power reaching grid parity, RPOs would still be required to drive growth in renewable energy

Graph 4: RECs issued by different categories of projects

Majority of the projects supply to discoms at APPC or to OA customers



Source: POSOCO, https://recregistryindia.nic.in/flasher_attachment/Report_on_REC_Mechanism.pdf

Table 5: Revised REC floor and forbearance prices

Floor price has reduced in line with reduction in tariffs

	Prices before March 30, 2017		Prices on April 1, 2017	
	Solar REC	Non-solar REC	Solar REC	Non-solar REC
Forbearance price (Rs/MWh)	5,800	3,300	2,400	3,000
Floor price (Rs/MWh)	3,500	1,500	1,000	1,000

Source: CERC, http://www.cercind.gov.in/2017/orders/27.02.2017(R3)_1.pdf

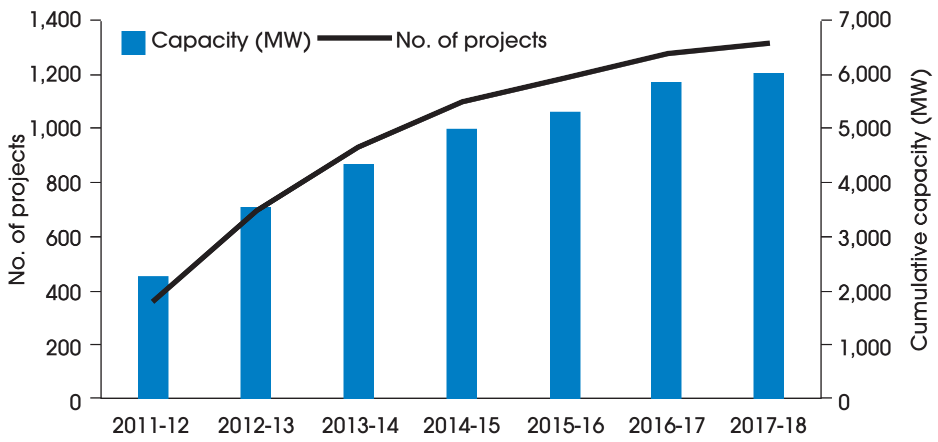
Rs 2,400 (*see Table 5: Revised REC floor and forbearance prices*). Wind comprises 40 per cent of the cumulative capacity of projects registered for participation in the REC market, with solar at 19 per cent.[27]

RECs were the ideal solution for discoms of states that did not have sufficient renewable capacity within their borders for direct procurement of power. They also enabled thermal OA customers to meet their obligations. However, the REC market has lost its appeal for developers, who prefer to construct projects within the auction regime, which has purchase guarantees and payment default protections. There is little incentive and a lot of risk associated with building stand-alone projects and signing PPAs. Between 2015 and 2018, the number of projects registered with the REC market has stagnated (*see Graph 5: Capacity and number of projects registered for RECs*).[28]

It is important to note here that this market has been under-performing right from its inception. It has remained constantly over-supplied: currently, there are 1.86 million non-solar and 2.29 million solar RECs that are lying spare in the system as of September 2018.[29]

Graph 5: Capacity and number of projects registered for RECs

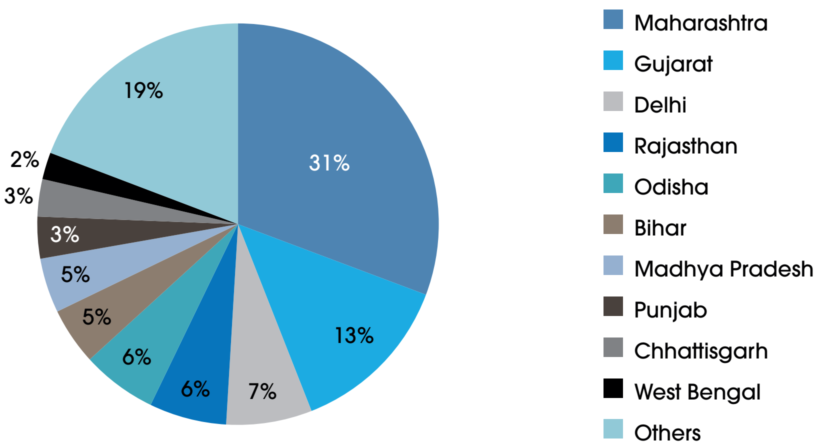
Number of projects registered with the REC market has stagnated



Source: POSOCO, https://recregistryindia.nic.in/flasher_attachment/Report_on_REC_Mechanism.pdf

Graph 6: Percentage of RECs procured by individual states

Maharashtra and Gujarat account for a significant share



Source: POCOSO, https://recregistryindia.nic.in/flasher_attachment/Report_on_REC_Mechanism.pdf

Poor RPO enforcement underlies the failure of the REC market. As of date, many discoms have filed petitions seeking leniency on unmet RPOs that often date back many years. State discoms in Haryana and Telangana have not participated in the REC market, despite the fact that neither met their targets in either solar or non-solar categories. On the other hand, states with better enforcement are more active participants in the REC market — examples are Gujarat and Maharashtra, which have the largest shares of RECs in spite of having large renewable capacity PPAs (*see Graph 6: Percentage of RECs procured by individual states*).

The recent push by various ERCs and the CERC has seen a spike in REC trading, with the largest ever volume of wind RECs (5.2 million) bought in a single month in December 2017. While this is a promising sign for the REC market, it still remains weak and oversupplied. The market clearing price, even in instances of relatively high demand, is only slightly over the floor price, skimming the Rs 1,000/MWh[30] mark — hardly an incentive for developers to opt for the REC route. Going forward, it is unclear what the future of the REC market is likely to be, even when RPO enforcement becomes stringent. The fall in tariffs has made the option of directly procuring renewable energy far more enticing than trading in REC certificates. The wind and solar Inter-State Transmission System auctions, which waive inter-state transmission charges, are likely to further dilute the relevance of the REC market.

Open access customers are likely to be the only consumers of RECs in the coming days, because direct procurement of renewable (or conventional) power is challenging, with most states making OA, especially renewable-based, more demanding. Consequently, it is also likely to keep the pool of REC traders limited.

Renewable energy-based open access (OA)

Following the CERC's lead and considering the mandate of the Electricity Act, 2003, the SERCs started coming up with intra-state and distribution open access regulations from 2004 onwards. OA transactions could either be done bilaterally or collectively (through power exchanges) and for a variety of time frames — short-term (up to one month at a time), medium-term (three months to three years) and long-term OA (12 years and 25 years) (*see Figure 1: Existing framework for OA transactions*).[31]

The fall in tariffs has made the option of directly procuring renewable energy far more enticing than trading in REC certificates

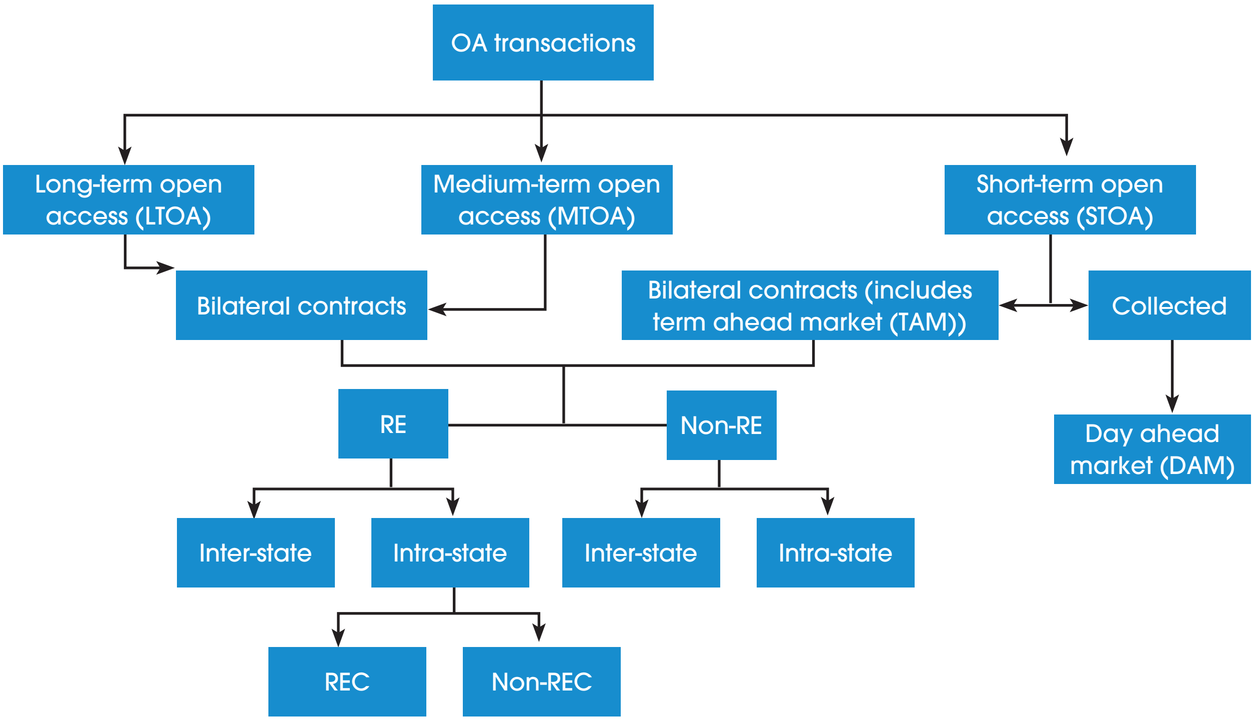
The CERC's monthly market monitoring reports show that from 2010-11 to 2016-17, the absolute volume of power transacted under short-term OA has gone up six times (from 4 BU to 24 BU).[32] The average total number of OA consumers participating in the exchanges has also increased steadily from 608 in 2010-11 to 4,420 in 2016-17. Moreover, the weighted average price of such transactions decreased from Rs 2.74 per kWh in 2010-11 to Rs 2.43 per kWh in 2016-17. This increase in volume and decline in prices are indicative of the growth of OA in the short-term market.

Also, the rapid fall in prices of renewable power, coupled with high industrial/commercial tariffs, have made renewable-based OA viable in the country. Additionally, the concessions and waivers on OA charges that various SERCs have been offering to renewable energy-based open access (RE-OA) consumers have helped their growth. These concessions were introduced for the purpose of promoting RE-OA and boosting investments which helped make RE-OA competitive with conventional open access.

Based on the limited publicly available data from SERCs, State Load Despatch Centres (SLDC) and Regional Load Despatch Centres (RLDC), and the requests filed under the Right to Information Act, 2005, the penetration of RE-OA (open access consumption wheeled through network of the distribution licensees in the state) in few important renewable-rich states

Figure 1: Existing framework for OA transactions

Can be done bilaterally, collectively and for various time frames



Source: Prayas (Energy Group), September 2017, 'Choosing Green: The status and challenges of renewable energy based open access — a working paper'

was estimated by Prayas (Energy Group).[33] The data indicates that RE-OA penetration has increased in the last three years (*see Graph 7: Renewable energy-based OA trends*). Of the total open access consumption in 2016-17, RE-OA consumption stood at around 30 per cent (2,700 MU) in Gujarat, 15 per cent (311 MU) in Madhya Pradesh, 8 per cent (167 MU) in Telangana and 8 per cent (758 MU) in Maharashtra. Also, wind power-based renewable open access dominated in most of the states except Madhya Pradesh, where solar comprised almost 60 per cent of the RE-OA.

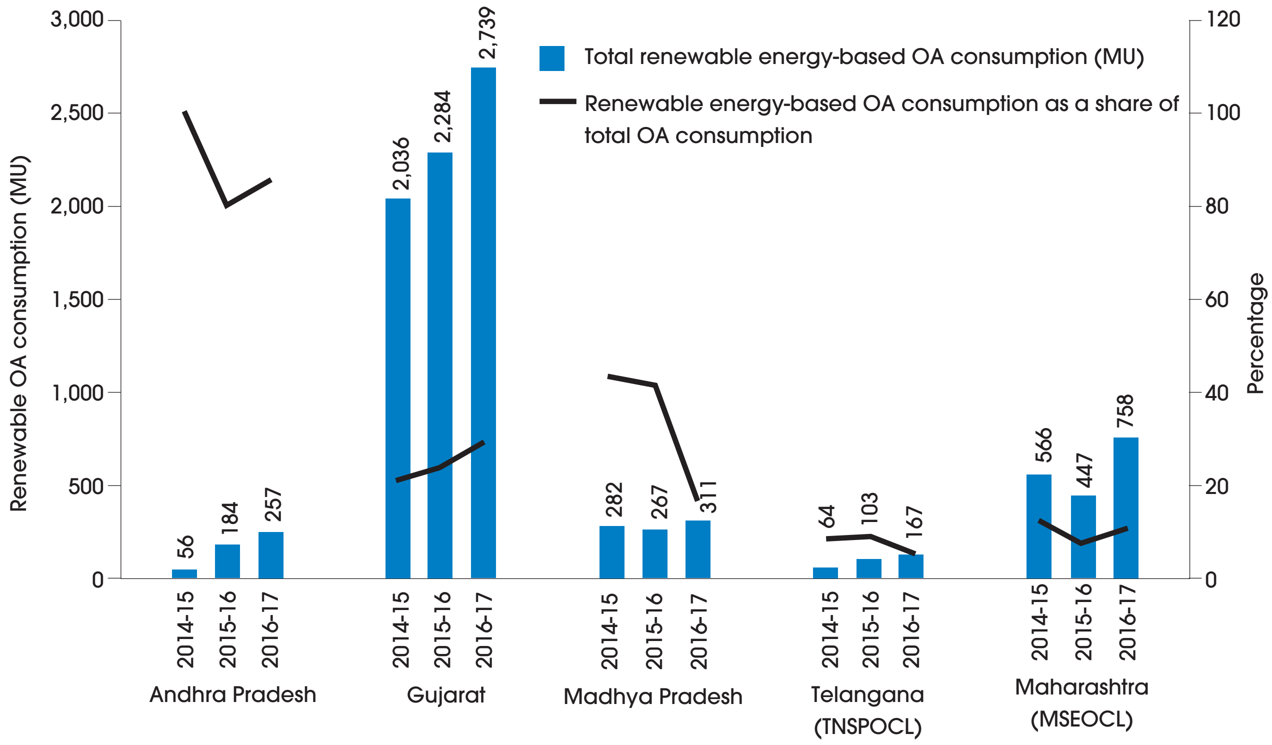
Challenges and difficulties

While data shows that there has been a considerable uptake of OA, the implementation has seen various challenges and operational difficulties. While some of these issues are specific to RE-OA, most affect all OA consumers and generators. These issues include delays in giving of no-objection certificates; overall procedural complexities; lack of independence of SLDCs; frequent switching by OA consumers between the market and the discom supply, leading to inefficiencies in procurement planning and higher cost for discoms; and restrictions imposed by states under Section 11 of the Electricity Act, 2003 to deter export or import of power through open access under deficit or surplus power conditions of the state.

Apart from these operational challenges, there is the vexed issue of

Graph 7: RE-based OA trends

The penetration has increased



Source: Prayas (Energy Group), September 2017, 'Choosing Green: The status and challenges of renewable energy based open access — a working paper'

OA charges. These consist of a variety of fees, charges and surcharges that consumers have to pay in order to avail electricity through OA. These include application fees, network (transmission and distribution) charges and losses, cross-subsidy surcharge (CSS), additional surcharge etc.

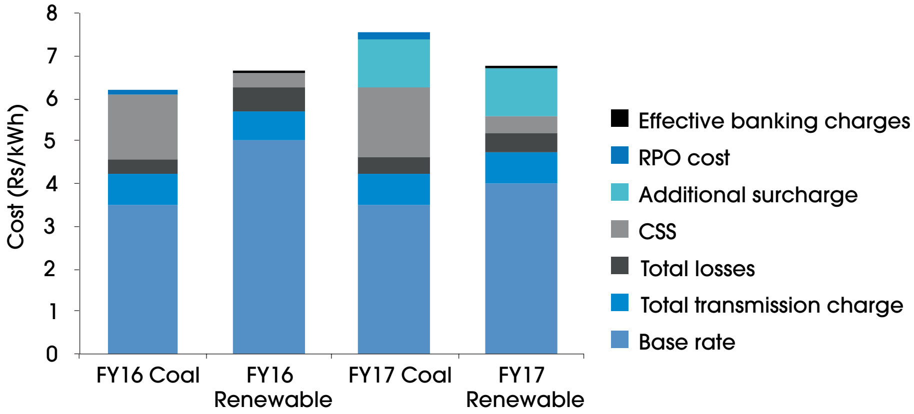
The CSS is levied to compensate the discom for its loss of cross-subsidy needed to provide subsidised power for agriculture and low-income residential segments. In some states, the CSS is as high as Rs 3 per kWh, thus making it the most important charge. While OA consumers perceive the CSS to be too high, it is often insufficient to recover the loss of cross-subsidy to the discom. Also, the SERCs have been capping the CSS at 20 per cent of the respective consumer tariffs, without bringing tariffs for all consumer categories within +/-20 per cent of the average cost of supply, which was recommended by the National Tariff Policy (NTP), 2016.[34]

Additionally, the volatility and uncertainty in the yearly determined CSS undermines a possibility of long-term OA planning. Hence, there needs to be a medium-term certainty of the CSS to encourage consumers, to move to medium-term (MTOA) and long-term open access (LTOA). CSS is also one of those open access charges that many states offer concessions/waivers on for RE-OA.

However, with grid parity being achieved and base price being equivalent

Graph 8: Landed cost of coal and renewable OA

Renewable is cheaper than coal



Source: Prayas (Energy Group), September 2017, 'Choosing Green: The status and challenges of renewable energy based open access — a working paper'

for green and grey sources (*see Graph 8: Landed cost of coal and renewable OA*), the concessions/waivers on these charges can be gradually removed.

Most importantly, if the CSS alone cannot fully compensate the licensee's loss in revenue due to sales migration, some form of additional transitional support from the state and Central government is necessary. Such support can be provided through subsidies or cross-subsidy with the levy of duties on all grid-connected consumers, including captive consumers as suggested in the draft National Energy Policy.

Sales migration from the discom to OA can result in stranded generation capacity. To recover the fixed costs of such capacity, an OA charge known as the additional surcharge is levied. This is enabled by Section 42(4) of the Electricity Act, 2003.[35] The NTP 2016 states that such a surcharge can be charged '*only if it can be conclusively demonstrated that the obligation of a licensee, in terms of existing power purchase commitments, has been and continues to be stranded, or there is an unavoidable obligation and incidence to bear fixed costs consequent to such a contract.*'[36]

Concessions on the additional surcharge are not available widely across states, with the exception of Gujarat, which provides a 50 per cent concession for wind-based OA transactions. A generic problem that the additional surcharge poses to all OA stakeholders is the non-uniformity in the methodology to calculate the surcharge across states. Going forward, there would be a need to identify the principles for such a methodology. The Ministry of Power in its Consultative Paper released in 2017[37] has identified this as a need, and suggested a new methodology that can be followed uniformly by all states. This methodology was also supported by the Forum of Regulator's 'Report on Open Access'.[38]

Renewable energy generation sources (especially wind and solar) have seasonal and diurnal variations. The pattern of renewable energy generation (from wind/solar) may not match with the demand of the RE-OA consumer

A generic problem that the additional surcharge poses to all OA stakeholders is the non-uniformity in the methodology to calculate the surcharge across states

in real time, resulting in excess generation in some time blocks, or excess demand in others. In such cases, the banking mechanism allows for the RE-OA consumer to notionally store or bank the excess generation from its renewable generator with the distribution utility. Such excess energy can be withdrawn when required after payment of a banking charge. In most of the states, the regulators have imposed peak/no peak and seasonal restrictions for injection and withdrawal of the banked power. At the end of the banking period, the excess energy banked with the distribution company is allowed to be purchased by it at a buy-back rate which currently differs from state to state.

At present, the banking charges levied by SERCs vary across the states in magnitude and principle. Most of the SERCs apply the banking charge 'in-kind', i.e. in energy terms. While some apply a 2 per cent in-kind charge on the banked energy, the KERC applies a 2 per cent charge on the total injected energy and the APERC on total drawl of energy. Applying the banking charge on total injected energy and total drawal of energy inherently implies that each consumer, irrespective of his generation source (wind, solar, mini-hydel) and demand profile, would have the same hourly/daily/seasonal pattern of banking energy and have the same impact on the system.

Some of the discoms in Maharashtra, Karnataka and Tamil Nadu are already claiming that the current banking mechanism is unable to recover the difference in power purchase cost of the discom at the time of banking and withdrawal of the banked energy. They have asked for changes in the current design of banking charge.

Current regulations on forecasting and scheduling present a challenge: they do not allow revision of schedules for wind and solar generators selling power under collective transactions

Prayas (Energy Group) analysed banking data provided by MSEDCL in petition 85 of 2017 filed before the MERC.[39] It shows that the monetary value of the current 'in-kind' banking charge (2 per cent of the banked energy), valued at the average lowest variable cost of backed down power per month, works out to a mere Rs 0.04 per kWh of banked energy. Going by the new framework as suggested by MSEDCL, the RE-OA consumer would have to pay an average banking charge of Rs 0.69 per kWh of banked energy for the year 2016-17. This would result in only 3 per cent increase in the landed cost of the RE-OA consumer. Quantifying the banking charge in Rs per kWh and linking it to the power purchase cost of the discom at the time of banking and withdrawal of the banked energy, will help stakeholders like the SERCs, discoms, RE-OA generators and consumers to understand the value and impacts of energy banking.

The current regulations on forecasting and scheduling present another challenge as they do not allow revision of schedules for wind and solar generators selling power under the collective transactions (power exchanges), as it is in line with the present scheduling practices of inter-state OA transactions. Wind and solar generators cannot control their generation close to schedules because of their variable and uncertain nature. Hence, these generators participating in the power exchanges face the risk of higher deviation charges along with the market risk.

Also, the regulations need to be periodically revised in terms of the deviation bands and the corresponding deviation penalties. For example, considering recent the PPA rates of around Rs 3 per kWh for wind and solar power, the deviation penalties are higher for intra-state transactions as compared to inter-state transactions.[40] Hence, deviation penalties for intra-state transactions based on absolute values need careful attention and regular revision in line with the wind and solar market prices. Ideally, the states should quickly move to schedule-based accounting and align the state framework for renewable forecasting and scheduling in line with the CERC framework for regional entities.

These challenges can be dealt with in a more transparent way with better availability of data of RE-OA transactions. This will aid in taking informed regulatory and policy-related decisions, thereby increasing the confidence of stakeholders in making regulatory decisions. To enable this, ideally, the CERC market monitoring report should broaden its scope and include STOA, MTOA and LTOA RE transactions and track the amount of transactions and average price. On similar lines, each SERC should also come up with its own state market monitoring report.

Although RE-OA has seen growth in the recent past, some operational and regulatory challenges persist. With fast declining renewable prices, the need for concessions may decrease in the future. Thus, a gradual removal of the concessions on RE-OA transactions is the way forward. A banking mechanism which addresses the variability in the RE-OA generation needs to be deliberated on and made revenue-neutral for the discom. Finally, given the ever-increasing economic attractiveness of renewable energy-based open access, especially considering the high and rising consumer tariffs, there is a need to critically examine the existing OA framework and work out a set of rules for the near future which would balance the interests of the incumbent discom and potential OA consumers.

With fast declining renewable prices, the need for concessions may decrease in the future. A gradual removal of the concessions on RE-OA transactions is the way forward

The way ahead

It is clear that the various plans and schemes to allow for clean energy penetration at a large scale are hinging on serious power sector reforms. UDAY reforms seem likely to prove inadequate and discoms continue to be plagued by under-performance. What, therefore, is the way ahead?

The discom business needs to be fundamentally restructured. The proposed 2018 Amendement to the Electricity Act is a start but it still has some shortcomings. First, there is a need to increase competition to improve the quality of service provided by the discoms. The proposed seperation of carriage and content does, indeed, allow for greater customer choice. However, it means that rich households, commercial and industrial consumers need to pay equitable costs in order to support poorer consumers during the transition period. This responsibility is likely to fall on legacy discoms and the regulations need to make an allowance for this.

Discom governance needs to be improved fundamentally, with greater resilience to polticial influence. There should be robust mechanisms put in place to ensure tariff rationalisation and follow-through on subsequent increases.

Market-friendly electricity reforms need to be introduced and enforced.

The discom business needs to be fundamentally restructured for a renewable energy future

This includes expanding the role of the short-term markets, as well as strict enforcement of PPAs to assure investors and developers of the legal sanctity of contracts signed with discoms.

Streamlining the open access process, with the fair application of additional surcharges will boost the demand for renewable energy from the commercial and industrial sectors.

Discoms will have to be pushed harder to invest in technical solutions and infrastructure upgrade such as feeder seperation, installing smart meters and undertaking detailed data collection and analysis to root out operational inefficiencies. In order to curb AT&C losses, as per the expectations set out in UDAY, smart meters need to be set up at customer ends to fully evaluate their losses and enforce revenue collection.

RPOs will continue to be indispensable for driving the sector's growth. The MNRE has announced the creation of an RPO compliance cell that is expected to track and report on a monthly basis on compliance by all obligated entities.[40] RPO compliance reporting should be made public and compulsory; an annual audit by the CERC is likely to have more impact.

The bottom-line is that a renewable energy future cannot be built on an outdated discom model. Fundamental changes are required to redefine the role of the discoms.

CHAPTER 8

Integrating RE: Preparing for the future

Integrating renewable energy into existing power grid networks is widely, and mistakenly, perceived to be a major challenge. Since wind and solar energy generation is variable and unpredictable, it is commonly assumed that any efforts to integrate them into the grid — even if their share in the total energy mix is small — would require significant investments in evacuation network and grid management systems.

However, the experience from many countries indicates otherwise: it shows grid networks are capable of accommodating a high share of renewable energy through improvements in power system operations and reforms in regulatory frameworks and markets.[1] Ireland, for instance, is currently managing the world's highest renewable generation penetration of over 35 per cent despite being a small island power system (*see Box: The Irish miracle*). Similarly, countries like Germany, the United Kingdom and Spain are successfully managing RE shares of over 20-25 per cent in their networks.[2]

In India, the Central Electricity Authority (CEA) estimates the share of renewable energy in power grid networks would reach around 17.5 per cent by 2022, based on the 160-GW capacity in solar and wind.[3] Grid integration is far easier at these penetration levels of 15-20 per cent. The International Energy Agency's (IEA) study of best practices in managing RE integration indicates that gradual technical and economic grid management measures are sufficient for reliable and cost-effective operation of power systems in a high renewable scenario.[4] The IEA also estimates only a 15-20 per cent increase in system cost even at a very high RE penetration of 45 per cent.[5]

India's grid is well positioned to efficiently integrate the level of RE share projected for 2022. The planned transmission capacity in the country is adequate. India already has a vast 83 GW of inter-regional transmission capacity which provides grid operators with a wide balancing area. The work on Renewable Energy Management Centres (REMC) for real-time monitoring is in its advanced stages. On the policy front, the Central Electricity Regulatory Commission (CERC) has put regulatory frameworks in place for forecasting and scheduling of RE and flexible operations of thermal power plants and auxiliary services — all of which support higher RE penetration; however, implementation

Global experience shows grid networks can accommodate a high share of RE through improvements in power system operations and regulatory reforms

at the state-level has been unsatisfactory. Discoms, on their part, hold sizable contracted supplies under power purchase agreements (PPAs) with a two-part tariff that pays thermal power plants even when they are not generating, thus ensuring availability of back-up capacity for renewables.

However, achieving a higher level of renewable penetration — beyond 175 GW — would require additional measures such as an increase in the balancing capability of the grid and enhancement of transmission networks. A key area of concern is the limited network augmentation by discoms — which involves smart metering, augmentation in transformer capacity etc — to support distributed renewable energy.

Integration of 175 GW renewables

India's transmission infrastructure has expanded significantly in recent years. Between April 2012 and March 2018, the transmission line length and substation capacity in the country has gone up at an annual average rate of over 7 per cent and 12 per cent, respectively. During this period, the inter-regional transmission capacity has increased nearly three times — from 28 GW to 83 GW.[6]

At the same time, the performance and stability of the national grid has improved due to better forecasting and scheduling mechanisms, introduction of the Deviation Settlement Mechanism (DSM), strengthened incentives/

The Irish miracle

How Ireland is preparing for the world's highest wind power penetration

In 2017, the renewable energy share — dominated by wind power — in Ireland's generation mix was over 35 per cent. The country is aiming to increase this further to 40 per cent by 2020, with instantaneous wind energy penetration reaching 100 per cent of the demand. For maintaining grid security in such circumstances, Ireland — with a small isolated island network — has placed great emphasis on network upgrades, reserve requirements, reliable delivery and performance monitoring of all generating units. Renewable generation has been granted dispatch priority, which is being achieved at low curtailment levels of 2-4 per cent.

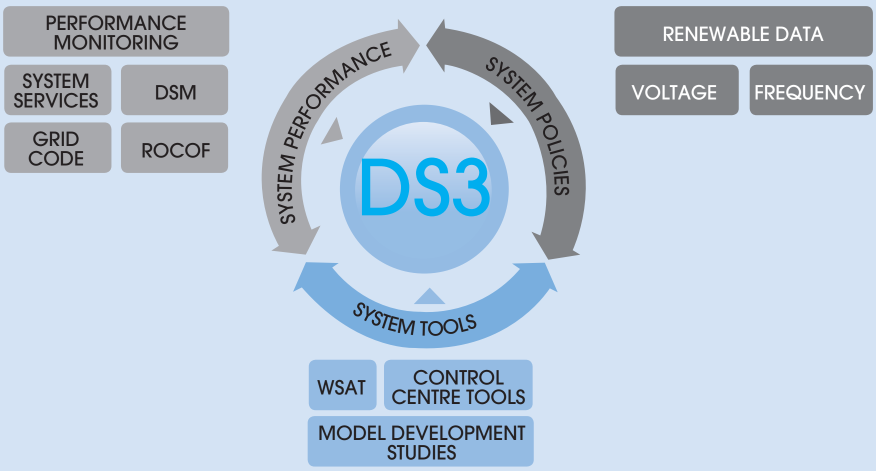
To prepare the national grid for increased renewable penetration, Ireland's national grid operators, EirGrid and SONI, launched the Delivering a Secure Sustainable Electricity System (DS3) programme in 2011. This multi-year, multi-stakeholder programme incorporated a number of technical, economic and regulatory measures required to change system policies, tools and performances to support 75 per cent system non-synchronous penetration in Ireland's grid by 2020, at a targeted annual curtailment of 5 per cent.[1]

Under this programme, grid codes have been strengthened not just for wind power plants but also for conventional generators to ensure discipline from all connected entities. Wind Security Assessment Tools (WSAT) have been installed across the control centres. System service/ancillary service products are being developed to provide financial incentives for improved system performance. Eleven products are already operational, and three others are being introduced.[2]

System operational policies and system tools are being updated to assist voltage and frequency management in the light of increased organisational and system complexity. Ireland is developing a long-term policy for large-scale demand side management and enhanced performance monitoring system. The individual work streams are in various stages of implementation and are set to meet the renewable targets by 2020.

Ireland's system upgrade plan under the DS3 programme

Comprises 11 work-streams categorised across three pillars



Source: Eirgrid Group, 'The DS3 Programme Brochure', http://www.eirgridgroup.com/site-files/library/EirGrid/DS3-Programme-Brochure.pdf disincentives under the availability-based tariff (ABT) mechanism, introduction of ancillary services, and development of short-term markets. The improved grid performance can be seen in substantial tightening in the grid frequency band to 49.5-50.2 Hz under the CERC's 2010 regulations[7] and the lower supply deficits. Maintaining such grid discipline in a 175-GW renewable scenario would, however, require developing additional transmission capacity, forecasting and scheduling systems and regulations, and improving system visibility and flexibility — which are the focus areas in the government's existing efforts.

Detailed system modeling by Power System Operation Corporation (POSOCO) along with the National Renewable Energy Lab (NREL) published in the report *Greening the Grid* concludes that integrating 100 GW of solar and 60 GW of wind can be achieved at a curtailment of only 1.4 per cent without fast-ramping infrastructure such as batteries, pump hydro or gas-based plants etc (*see Table 1: Projected power system and curtailment scenarios*).[8] The model suggests that "inherent flexibility in existing coal-based capacity" will greatly help in integrating variable RE generation. However, the assessment assumes that existing plans of expansion of generation and transmission capacity, which would provide competency

Table 1: Power system and curtailment scenarios, 2022

100 GW of solar and 60 GW of wind can be integrated with minimal curtailment even without fast-ramping infrastructure

Renewable energy scenario	• Share of renewable energy in total generation increases to 22%; nationwide curtailment of renewable energy averages at 1.4% annually; southern region reports highest curtailment of 2.9%; implementation of ongoing regulatory and grid development initiatives — state-level dispatch and 55% minimum generation levels on coal plants
Thermal energy scenario	• Coal generation decreases by 21%; average plant load factor (PLF) of coal-based plants drops to 50%; aggregated nationally, system-wide up-ramps peak at almost 32 GW per hour
Impact of additional measures	**Improved scheduling and dispatch coordination:** Moving from state to regional coordination would lead to 2.8% saving in production cost, and reduce curtailment to 1.3%
	Further increase in flexibility of conventional generators: Curtailment reduces from 1.4% to 0.76% when minimum generation levels are dropped from 55% to 40%; coal ramp rates, start-up costs, and minimum up/down time do not significantly affect RE curtailment or production costs
	Increased integration of energy storage: Negligible benefits of batteries at 2.5 GW aggregate capacity operating at 75% efficiency

Source: National Renewable Energy Laboratory, Lawrence Berkeley National Laboratory, Power System Operation Corporation Limited and US Agency for International Development, 'Greening the Grid, 2017', https://www.nrel.gov/docs/fy17osti/68530.pdf to handle errors in RE forecasts, changes in net load (ramps), and low RE generation, will be executed in time.

Infrastructure development

Expanding the transmission grid network is crucial for both evacuating power from upcoming wind and solar plants and enabling interstate/interregional transfer of surplus power. Inadequate network availability or congestion has led to curtailment of renewable power in renewable-rich states like Tamil Nadu and Rajasthan (*see chapters on wind and solar energy*). A survey of industry leaders reported transmission connectivity of projects as a major challenge in the utility-scale renewable market.[9] Recently, the SECI decided to slash the 2,500 MW Inter-State Transmission System (ISTS) wind tender to 1,200 MW due to investor concerns about evacuation constraints. Industry observers say that the MNRE may need to lower its goal of 10 GW of wind auction in 2018-19 primarily due to transmission concerns.[10]

In the 2017-22 five-year period, India is targeting to increase transmission line length by 105,580 circuit km (ckm) and substation capacity by 292,000 mega volt amp (MVA) based on the projected demand and supply growth (including renewable capacity).[11] Past experience — 110,370 ckm of line length and 331,214 MVA of substation capacity were added during the 12th plan period (2012-17)[12] — indicates that these targets are achievable. Efforts, however, need to be focused on fast-tracking projects dedicated to serving wind and solar projects, given their short gestation periods.

Green Energy Corridor-I: In 2012, the government conceived the Green Energy Corridor (GEC) project (GEC-I) to address evacuation bottlenecks, especially in areas with large wind and solar capacity. GEC-I — concentrated in the seven renewable-rich states of Andhra Pradesh, Gujarat, Himachal Pradesh, Karnataka, Maharashtra, Rajasthan and Tamil Nadu — anticipated a renewable capacity addition of 41 GW during 2012-17.[13]

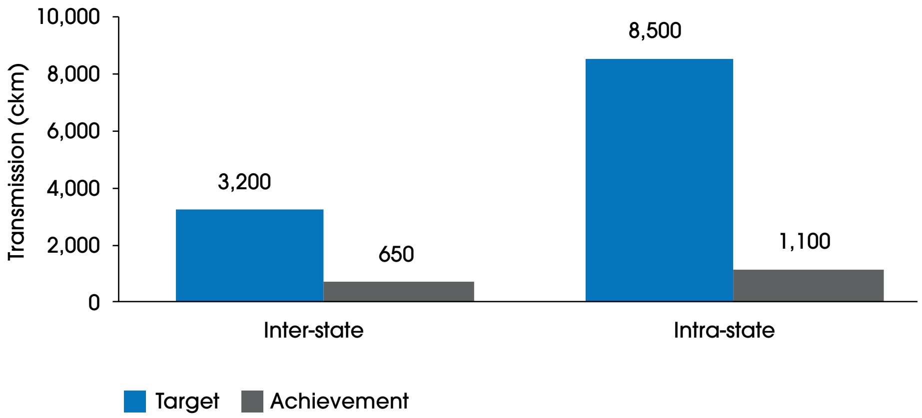
However, the project has faced problems right from the start. The Cabinet Committee on Economic Affairs (CCEA) took almost three years to approve the Rs 10,141-crore investment for the project. So far, GEC-I implementation has made little progress. It is unlikely that its goals — adding an additional 2,550 ckm of interstate lines by June 2019 and 7,400 ckm of intrastate lines by March 2020 — will be met (*see Graph 1: Status of Green Energy Corridor-I*).[14]

Green Energy Corridor-II: The GEC-II project was formulated in 2015 to build transmission infrastructure associated with 20 GW of ultra-mega solar parks, at an investment of around Rs 12,786 crore. So far, transmission infrastructure associated with three solar parks — Kadapa and Kurnool in Andhra Pradesh[15] and Bhadla in Rajasthan — have been commissioned. It is likely that Karnataka's Pavagada Park transmission infrastructure will also be completed soon. Delays in GEC-II would result in financial losses for the plants that are being built inside the park since they would be unable to evacuate power.

Delays in building the Green Energy Corridors is likely to result in financial losses for renewable plants because of curtailments

Graph 1: Status of Green Energy Corridor-I

The project has made little progress



Note: Data till December 2017
Source: Lok Sabha's Standing Committee on Energy, March 2018, http://164.100.47.193/lsscommittee/Energy/16_Energy_39.pdf

Renewable Energy Management Centres (REMCs): Proposed to be installed in load dispatch centres (LDCs), REMCs are at the heart of efficient integration. They are crucial for ensuring optimal forecasting and scheduling, balancing of power (at state LDCs), coordination of the regional grid (at regional LDCs) and maintenance of grid security (at national LDCs). The REMCs will undertake real-time monitoring of renewable generation at the pooling station level, intra-day and day-ahead forecasting, coordination for scheduling and dispatch, and monitoring reserves. This will be enabled by smart technologies such as Supervisory Control and Data Acquisition (SCADA) systems, communication tools such as Wide Area Measurement System (WAMS), and weather forecasting services.

Currently, 11 REMCs are being set up at an estimated cost of Rs 409 crore — including seven of them in the renewable-rich states, three at the regional level and one at the national level[16] (*see Statistics section*). The project, funded by the German development agency GIZ, has experienced delays due to lack of adequate technical expertise, and is now likely to be operationalised in 2019.[17]

Grid technology upgradation

Wide Area Measurement System (WAMS) is crucial for large-scale renewable integration as it enables real-time measurement and monitoring of grid parameters through phasor measurement units (PMU). The Power Grid Corporation of India Limited (PGCIL) is currently implementing a Unified Real Time Dynamic State Measurement (URTDSM) project to install PMUs in all inter and intrastate substations of 400 kV and above, generating stations of 220 kV and above, high voltage direct current (HVDC) terminals and key regional/national connection points. The first phase of the project launched in January 2016 was to be completed in 24 months with installation of 1,184 PMUs at 351 substations and 34 control centers. So far, works have been completed only in the Northern Grid.[18]

Reactive Power Compensation through devices such as static var compensators (SVCs) or static synchronous compensators (STATCOM) are crucial for flexible and dynamic control of power systems and for balancing. So far, one SVCs and four STATCOMs have been commissioned, while 11 more STATCOMs are at various implementation stages.[19]

Regulatory progress

Forecasting and scheduling
Forecasting, scheduling and DSM regulations are key to managing renewable energy injection into the grid. The Indian Electricity Grid Code (IEGC) mandated in 2010 that all wind and solar projects of over 10 MW and 5 MW capacity, respectively, and connected to the transmission network should forecast generation and schedule for dispatch on a day-ahead basis. The Grid Code introduced penalties (for deviations exceeding 30 per cent from schedule) under the Renewable Regulatory Fund (RRF) mechanism, but it was never implemented due to resistance from wind energy generators and insufficient infrastructure availability.

In August 2015, the CERC amended regulations to incorporate forecasting, scheduling and imbalance handling for wind and solar generators that are connected to the interstate network. In November 2015, the Forum of Regulators (FoR) came up with model forecasting and scheduling regulations for states. Several states have now introduced draft/final regulations based on the FoR model — however, Karnataka is the only state to have implemented them.[20]

Forecasting and scheduling regulations are key to managing renewable energy injection into the grid. But Karnataka is the only state to have implemented them

CERC's regulations: These apply to all wind and solar generators connected to the ISTS. A hybrid approach has been adopted, in which both RLDCs and generators (a generator, called a 'qualified coordinating agency' (QCA), may be appointed to coordinate when multiple generators are connected to the ISTS through a common pooling station) forecast independently. Scheduling can be based either on the QCA's or the RLDC's forecast, but the commercial settlement of the deviations is based only on the generator's forecast. Deviations of generation from schedule are calculated and,

- in case of over-injection from schedule, the generator is paid from the regional DSM pool.
- in case of under-injection, the generator pays the regional DSM pool.

State regulations: These are based on the FoR model regulations and apply to wind and solar generators connected to the state network, whether supplying intra or interstate. The forecasting and scheduling process is similar to that of CERC's. However, there are differences in the commercial settlement mechanism — for example, states use a fixed rate for payments

Flexible thermal power plants can easily balance 100 GW of solar and 60 GW of wind in the grid

while the CERC uses an average of power purchase agreement (PPA) rates. Most importantly, generators connected to the state grid are paid as per their actual injection against being paid as per schedule under CERC regulations. Further, state regulations require payment into a pool for both under- or over-injection for intrastate transactions. For generators selling power outside the state, the deviation charges are the same as under the CERC framework (see *Statistics section).*

Emerging issues: The forecasting and scheduling framework in India is at a nascent stage. Implementation is likely to lead to techno-economic implications for various stakeholders which may need fine-tuning of regulations. Some of the emerging issues pertain to:

- Under CERC regulations, renewable generators have clear incentive to under-schedule and take a chance that they may end up over-injecting, since the payoffs are unequal: for under-injection, generators pay a penalty but for over-injection, they merely receive a lower payment.[21] Similarly, in state regulations, estimations by the Prayas Energy Group[22] indicate that loss in revenue is always less for over-injection than under-injection for the same absolute error, which may incentivise generators to under-schedule slightly and over-inject.
- The existing forecasting and scheduling framework puts financial burden on the host state. Deviation settlement of renewable generators is not linked to frequency condition of the grid [in technical terms, renewable generators do not pay unscheduled interchange (UI) charges]. However, the host state will need to pay for deviation charges to the regional UI pool for deviation caused by the renewable generators, bearing penalties.
- Deviation charges under state regulations specified in Rs per kWh terms need to be updated regularly in line with market trends. These penalties will have a higher impact on newer projects with lower tariffs. The target should be to implement availability-based tariff (ABT) across states.

Balancing support from thermal power plants

India's strategy for providing balancing support to accommodate variable generation supply by 2022 relies primarily on flexible operations of thermal power plants. The NREL-POSOCO report (*Greening the Grid*) estimates that at a technical minimum of 55 per cent for thermal plants, the power system would be able to support 100 GW of solar and 60 GW of wind. The report estimates that variability in wind and solar power supply may require thermal power plants to ramp up by 25 GW in one hour only for 56 hours in a year.[23] The inherent flexibility in current coal-based capacity can easily manage these requirements.

The CERC, in April 2016, amended the IEGC to reduce the technical minimum for all central and inter-state plants to 55 per cent, against the previous norm of 70 per cent.[24] However, the states are yet to follow suit: their excuse is technical difficulties, although independent experts claim the states' position has little merit.

Reserve capacity and ancillary markets

To balance variable renewable energy, the reserve capacity needs to be appropriately utilised. It can be broken down into various sub-categories such as primary, secondary, slow tertiary, fast tertiary etc, depending on their response time; these have to be identified in advance, kept available and deployed in real time (*see Table 2: Types of reserves/ancillary services in India*).

Availability of reserves/ancillary services has been ensured in India by regulatory action. The IEGC amendments ensured availability of primary reserves which can respond very quickly — within few seconds to under five minutes — by requiring power plants to keep reserves for system security. The roadmap to implement secondary reserves (with response time of 30 seconds to 15 minutes) and tertiary reserves (5 minutes to 60 minutes) was notified by the CERC in October 2015.[25]

POSOCO has submitted a detailed procedure for implementing secondary control through Automatic Generation Control (AGC). A pilot project on AGC with the Dadri thermal plant stage II of NTPC Limited is currently under implementation.[26] The pilot's test runs have been completed.

With regard to tertiary reserves, the CERC introduced Reserves Regulation Ancillary Services (RRAS) in April 2016; under it, surplus generation from regional entities can be used as part of RRAS on a day-head basis. The CERC is also considering steps like moving away from administered procurement and pre-specified mark-up to auction-based procurement of ancillary services.[27]

Table 2: Types of reserves/ancillary services in India

Availability of reserves is ensured in ISTS by regulatory action

Parameters	Inertia	Primary	Secondary	Fast tertiary	Slow tertiary	Generation rescheduling/ market	Unit commitment
Time	First few seconds	Few seconds-5 minutes	30 seconds-15 minutes	5-30 minutes	> 15-60 minutes	> 60 minutes	Hours/day-ahead
Quantum	~ 10,000 MW/Hz	4,000 MW	~ 4,000 MW	~ 1,000 MW	8,000-9,000 MW	Load generation balance	Load generation balance
Region	Local	Local	NLDC/RLDC	NLDC	NLDC/SLDC	RLDC/SLDC	RLDC/SLDC
Order	IEGC/CEA standard	IEGC/CEA standard	Roadmap on reserves	Ancillary regulations	Ancillary regulations	IEGC	IEGC
Paid/ mandated	Mandated	Mandated	Paid	Paid	Paid	Paid	Paid
Regulated/ market	Regulated	Regulated	Regulated	Regulated	Regulated/ market	Regulated/ market	Regulated/ market
Status	Existing	Partly existing	Yet to start	Yet to start	Existing	Existing	Existing

Source: Central Electricity Regulatory Commission, http://www.cercind.gov.in/2018/draft_reg/DP.pdf

The cost of renewable grid integration

An analysis by the CEA pegs the cost of grid integration of variable renewable energy in India at Rs 1.11 per unit.[1] In the two renewable-rich states of Tamil Nadu and Gujarat, this cost is estimated to be higher at Rs 1.57 per unit and Rs 1.47 per unit, respectively. Analysis of the cost components — balancing cost, stand-by cost, transmission charges and DSM charges — considered by the CEA indicates that actual costs may be much lower *(see: CEA's estimated cost of integrating 175-GW renewable energy by 2022)*.

At the national level, nearly half of the integration cost of Re 0.50 per unit is accounted for by stand-by costs, i.e. the opportunity cost of foregoing cheaper thermal sources for must-run renewables. For this, the CEA study assumes that 25 per cent of the wind and solar generation operating on an average tariff of Rs 4 per unit would replace generation from coal-based stations with a cheaper fuel charge of Rs 2 per unit. This cost component will reduce significantly in the coming years as tariffs discovered through competitive bidding decline further from Rs 2.50 per unit. The gap would further decline with reforms in procurement practices — such as achieving an optimum mix of long- and short-term contracts.

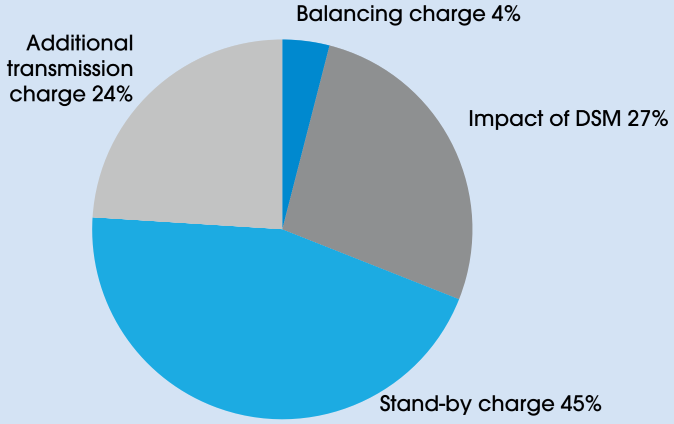
Further, suboptimal utilisation of the transmission system due to lower capacity utilisation factor of renewables is expected to increase transmission charges by Rs 0.26 per unit. This can also be reduced with reforms. Solar power plants use transmission systems only for nine-10 hours, but pay charges based on maximum MW utilisation during a quarter year and 24-hour basis under the existing system. The CEA suggests that this should be changed to a shorter period (monthly or hourly) in line with scheduling of generation to make billing more equitable for renewable sources. The unutilised transmission capacity can be used by open access generators or power exchange players.

The cost arising out of the stand-by balancing capacity is estimated to be minimal at Rs 0.04 per unit — in line with the POSOCO-NREL report. Lastly, the impact of the DSM charge for interstate flow of power is estimated to be Re 0.30 per unit, which can reduce as the forecasting and scheduling framework refines.

While the actual cost of integration may be lower than estimates, even at Rs 1.1 per unit it will be cheaper to add renewable capacities in future — this has been pointed out by the CEA as well. However, remedial measures need to be initiated for sharing of balancing responsibility of renewable energy.

CEA's estimated cost of integrating 175-GW renewable energy by 2022

Cost pegged at Rs 1.11 per unit



Source: Central Electricity Authority, http://www.cea.nic.in/reports/others/planning/resd/resd_comm_reports/report.pdf

Given the fast-expanding pace of renewable energy capacity, implementation of secondary and tertiary reserves needs to be prioritised at the state level. The FoR is in the process of developing a complementary intrastate-level regulatory framework for reserves, but progress on this remains slow.

Looking beyond 2022

The national grid capabilities, combined with ongoing regulatory developments, will be adequate to effectively manage 175 GW of renewable energy capacity. However, additional measures will be needed to prepare the grid for a higher renewable penetration.

India's Intended Nationally Determined Contribution (INDC) goals talk about increasing the share of non-fossil-based power capacity to 40 per cent by 2030.[28] Further, the draft National Energy Policy (NEP) published by the Niti Aayog projects that 597-710 GW of renewable energy capacity is likely to be operational in the country by 2040.[29] This would amount to a 50-56 per cent share in installed capacity and 29-36 per cent share in generation.

Planning for such high levels of renewable penetration must be initiated at the earliest as implementation of technology and policy interventions tends to take longer time compared to setting up wind and solar energy projects.

Global experience indicates that an increase in renewable penetration beyond 15-25 per cent of the total generation requires implementation of sophisticated technical and economic measures (*see Table 3: Strategies for cost-effective renewable integration in increased penetration levels*). A few of these have already been initiated in India; however, additional measures are needed to match higher penetration in the coming years. These additional measures primarily correspond to building balancing capacities through batteries, pump storage hydro plants, and demand response.

In India, pilot projects are being deployed to test various battery chemistries. For instance, the pilot project under implementation in Puducherry by PGCIL is testing three technologies — advanced lead acid, lithium-ion and NaNiCl2/alkaline/flow.[30]

The government is also trying to develop the market through competitive bidding of solar-plus-storage projects. But these have met with limited success. For instance, the tender for auctions held by state-run firm NLC India Limited for 20 MW solar and 28 MWh storage project in the Andaman and Nicobar Islands was cancelled and re-tendered at a far lower battery capacity of 8 MWh. The bids in the cancelled auction varied widely — bids submitted by 10 companies varied from Rs 342 crore to Rs 179 crore, highlighting the under-developed character of the market.[31]

Given the critical role of batteries in India's energy future, the Niti Aayog has released the draft National Energy Storage Mission in August 2018. The draft proposes a three-stage solution — promoting battery manufacturing; scaling supply chain strategies; and scaling of battery cell manufacturing.[32]

Global experience indicates that renewable penetration beyond 25 per cent of the total generation requires sophisticated technical and economic measures

Table 3: Strategies for cost-effective renewable integration in increased penetration levels

Increase in penetration beyond 15-25 per cent of total generation requires implementation of sophisticated technical and economic measures

Measures		Phase I	Phase II	Phase III	Phase VI
Renewable penetration		5%	5-15%	15-25%	Over 25%
Technical	Real-time monitoring and control		√	√	√
	Enhancing capacity of transmission lines		√	√	√
	Power plant flexibility			√	√
	Special protection scheme			√	√
	Advanced variable renewable energy technologies and design			√	√
	System non-synchronous limit				√
	Smart inverter				√
	Advanced pump hydro operation				√
	Inertia-based fast frequency response				√
	Grid level storage				√
Economic	Sophisticated sizing of operating reserves	√	√	√	√
	Integrating forecasting in system operations	√	√	√	√
	Faster scheduling and dispatch		√	√	√
	Incorporating renewable energy in the dispatch		√	√	√
	Coordination across balancing areas			√	√

Source: International Energy Agency, 2017, https://www.iea.org/publications/insights/insightpublications/SystemIntegrationofRenewables.pdf

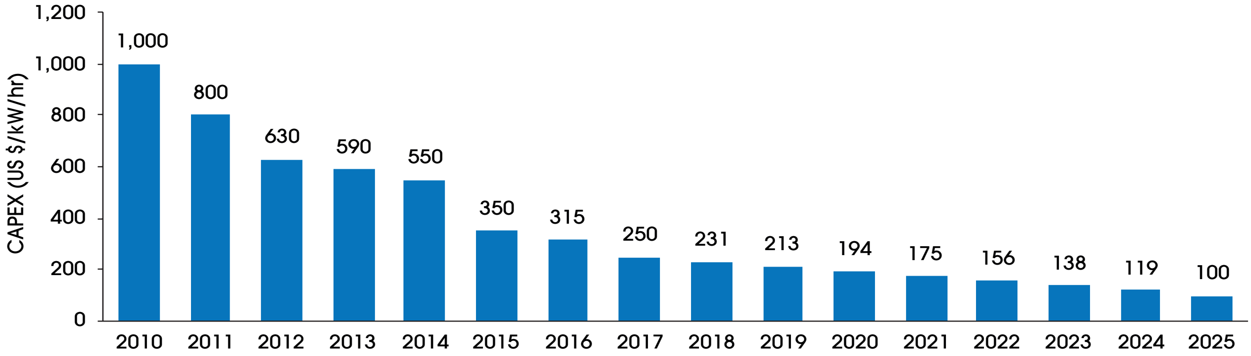
Grid-scale energy storage

Grid-scale energy storage at present remains prohibitively expensive for large-scale deployment; however, its prices have been declining sharply. A Bloomberg New Energy Finance and KPMG[33] study estimates that the cost of lithium-ion battery pack has declined at a compound annual growth rate (CAGR) of 17.5 per cent during 2010-16. It is projected to decline further to US $100 per kW/hr in the next five years (*see Graph 2: Past and projected trends in cost of lithium-ion batteries*).

Pumped Storage Hydro Plants (PSHP)

PSHPs, a cost-efficient and reliable source of storage and balancing support, remain grossly underdeveloped. Against a total estimated potential of 96.5 GW, only 4.8 GW of PSHP capacity has been developed, of which only 2.6 GW is operating in pumping mode.[34]

Graph 2: Past and projected trends in cost of lithium-ion batteries
Battery prices are expected to decline sharply in coming five years



Source: Bloomberg New Energy Finance and KPMG, 'Electric Vehicles: A case for a proactive approach', https://assets.kpmg.com/content/dam/kpmg/in/pdf/2017/11/Electric-Vehicles.pdf

Demand side management

Demand side management techniques can incentivise consumers to match demand patterns with renewable energy generation patterns in a given day. One way of achieving this is through implementation of time-of-day (ToD) tariff. Under this, consumption is billed differently during different time blocks to shift consumption from peak to non-peak hours. Studies in North America demonstrate that ToD tariff motivates behavioural changes resulting in overall energy saving of about 5 per cent with over 10-15 per cent reduction during peak periods.[35] So far, 15 SERCs in India have implemented ToD tariffs for mainly industrial and commercial sectors. Some states (such as Maharashtra and Gujarat) have mandatory ToD structures, while others have optional variants.

The scope of utilising demand side management for grid balancing has increased for India with recent developments. In cities, smart grid distribution technologies can enable introduction of dynamic tariff structures that can induce demand response in line with renewable energy availability. Some utilities in the US have already implemented automated demand response, in which high load equipment such as air conditioners are switched off in response to supply fluctuations.

Further, tariff rates for charging electric vehicles (being introduced in a big way) can be structured to encourage charging during off-peak hours. Conversely, batteries in the EVs can be harnessed to feed into the grid around midnight when the net demand peaks, since there is no solar generation and households turn on air conditioners.

Grid integration of distributed generation

India has an ambitious target of installing 40 GW of solar rooftop (SRT) capacity by 2022 — a tall order, considering existing capacity stands at a mere 2.1 GW. Most discoms, being financially stressed, are reluctant to support SRT as it would lead to decrease in revenues while imposing administrative burdens of installation and metering (*see chapter on solar rooftop*). In addition, grid-related regulatory and technical factors would require investment in the discoms' network.

Regulatory restrictions on deployment based on DT capacity: Most discoms in India have set conservative limits for SRT installation — 15 to 60 per cent of rated/peak capacity of the associated distribution transformer (DT).[36] These restrictions are based on the assumption that higher levels of SRT penetration would lead to voltage problems or overloading, necessitating system upgrades.

However, these assumptions and concerns are misplaced. Detailed simulation studies conducted by GIZ estimate that SRT penetration of 75 per cent of DT capacity can be accommodated by discoms in the urban areas without major system upgrades. Rural networks in India need additional strengthening and can currently accommodate SRT or ground-mounted solar units connected to the 11 kV network, at penetration levels of above 50 per cent. Instead of state-wide limits, it would be optimal for discoms to undertake local area studies to assess DT capabilities.[37]

Technical restrictions due to distribution grid design: Distribution grids in India are not equipped to manage large amounts of variable bi-directional power flow. These systems lack active voltage control measures (currently available only till 66/33 kV step-down transformer level), which are crucial to maintain grid security at high penetration of SRT. Automatic voltage control capability of transformers can be enhanced by deploying WAMS to enable real-time monitoring of voltage at feeders, and by setting automatic taps.

Discoms have set conservative limits on SRT installation. But SRT penetration of 75 per cent of DT capacity can be created in urban areas without major system upgrades

Voltage support can also be enhanced at the consumer-end. Distribution grid codes must mandate reactive power and voltage control from rooftop PV inverters, as well as cap SRT feed-in at 75 per cent of inverter capacity. It must also mandate installation and operation of peak shaving batteries at the customer facility as per the grid requirement.

In India, deployment of advanced and smart technologies for optimising distribution grid and supporting high penetration of distributed renewable energy is yet to take off.

Smart grids in India

Smart distribution grid architecture combines automation, information technology (IT) and communication systems with the traditional electrical grid. It reduces network losses, and improves systems efficiency and reliability by enabling real time monitoring and control of power flow. It increases predictability and flexibility of the system by enabling demand response. Such grid architecture helps seamless and cost-effective integration of distributed generation by supporting bi-directional power flow, demand response and distributed storage.

India started incorporating "smart" elements to the grid under the Restructured Accelerated Power Development and Reforms Programme

(R-APDRP) initiative launched in 2008: the objective was ensuring better utility efficiency by improving metering, indexing and automation. Some of these works remain incomplete even after a decade and are now being undertaken as a part of the Integrated Power Development Scheme (IPDS).

Smart metering yet to take off: Smart metering is the foundation on which utilities can develop their expertise and understanding of data collection, management and use, en route to the eventual transition to managing the larger, more complex apparatus, that is, the smart grid.

Both Ujjwal Discom Assurance Yojana (UDAY) and IPDS schemes have focused on rolling out smart meters for large consumer categories — the progress, however, has been tardy. Against the national target of installing over 184 lakh smart meters for consumers in the 200-500 kWh consumption category, less than 2 lakh meters have been installed so far. Similarly, for consumers in the over-500 kWh category, 1.9 lakh smart meters have been installed against a target of almost 60 lakh.[38]

Smart grid pilots in a limbo: Several pilot projects are under implementation in India with partial grant from the Ministry of Power (MoP) as well as under the NSGM for demonstrating smart grid functionalities. These functionalities include automatic meter infrastructure (AMI), power quality management (PQM), outage management system (OMS), peak load management (PLM), and distributed generation — all aimed at improving efficiency of discoms and reducing distribution losses.

So far, very little progress has been made under these pilots. Out of 14 projects, only three projects (by UHBVNL, HPSEB Limited and CESC) and IIT Kanpur's smart city R&D platform have been completed. Implementation has suffered owing to delays in award of contracts to vendors and finalisation of detailed project reports, as well as implementation challenges. The Lok Sabha's Standing Committee for Energy notes that only Rs 5.5 crore has been provided by the ministry to smart grid projects in past three years — branding it a non-starter.[39]

The MNRE's Solar Cities Programme remains equally uncertain. At present, 60 cities including 13 pilot and five model cities have been approved/sanctioned under the programme. Till date, little progress has been achieved, with only 49 cities preparing master plan, 21 setting up stakeholders committees, and 37 creating solar city cells.[40]

Despite major benefits to the discoms, smart grid projects are in a limbo in the country. Less than 2 per cent of targeted smart meters have been installed so far

The way forward

India can easily integrate 175 GW of renewable energy sources by 2022 without the need for major investment. However, the progress on many critical steps, especially with respect to regulatory reforms, has been fitful. While some key regulations have been implemented nationally, the states have lagged behind.

The key strategies — like GEC, forecasting and scheduling regulations, reduction of technical minimum of thermal plants — are either suffering from delays or remain at a nascent stage. Additional measures need to be initiated

Transmission network for RE evacuation, smart grid technologies, storage infrastructure and demand side management will be the key components of the grid of the future

on priority to prepare the grid for the next level of renewable development — possibly 600-700 GW by 2040. Meanwhile, grid development for distributed generation continues to suffer from legacy issues. Smart grid initiatives, while launched with much fanfare, have remained at pilot stage.

Going ahead, the following will have to prioritised for integrating large penetration of renewable energy into the grid:

- Transmission network development for renewable energy evacuation and transfer must be prioritised. Execution of projects under GEC-I and II must be monitored regularly by the CEA, and the roadblocks must be addressed.
- Deployment plans of smart grid technologies at the transmission grid, like WAMS and control reserve monitoring, should also be scaled up both at inter- and intrastate grids to improve real-time monitoring and response.
- The existing national plans for grid integration must be upgraded, to appropriately reflect the country's long term renewable targets of 597-710 GW by 2040 as per the draft NEP of NITI Aayog.
- Forecasting and scheduling of wind and solar power plants at the state level must be prioritised and implemented within the next year to effectively manage the increasing renewable energy penetration. Standards/guidelines/protocols for forecasting technologies or tools must be notified by the CEA.
- SERCs should reduce the technical minimum for state-owned coal-based power plants in line with the CERC's directions.
- Market mechanisms must be developed to provide incentives to generation plants to participate in balancing support.
- The MNRE must support reduction in cost of utility scale energy storage through measures such as increased R&D on technology or competitive bidding of large tenders.
- Smart grids and policies for demand side management (for example, time-of-day tariff), which can be an efficient tool in grid management, need to be developed
- Interconnection rules for SRT must be revised to accommodate its higher penetration; for instance, discoms should be mandated to undertake load flow studies in relevant areas. Distribution grid codes must specify incorporation of technical solution for voltage management and control at the consumer end.

CHAPTER 9

Waste to energy: Limited scope

Waste to energy, or WTE, is an option of energy recovery from waste that cannot be recycled or composted — simply put, it means the generation of energy from high-calorific value rejects. Energy can be harnessed from municipal solid waste (MSW) either by directly incinerating it (thermal) or by converting it into a fuel (thermo-chemical/biochemical). In several scenarios, given that most WTE plants worldwide run on incineration-based technology, the terms 'incineration' and 'WTE' are used interchangeably.

WTE emerged as a topic of discussion in India way back in the 1980s, at a time when municipal authorities had started grappling with the problem of disposal of the gargantuan mounds of solid waste in cities: as cities continued expanding, huge dumpsites or landfills began making their appearance. Burning this waste seemed the most appropriate way of getting rid of it.

The first WTE plant came up in Timarpur in Delhi in 1987. It was designed to incinerate 300 tonne per day (TPD) of waste and produce 3.75 megawatt (MW) of electricity. The plant failed and was shut down. The commonly cited reason for the failure was a mismatch between the plant's waste input requirements and the quality of waste it received in terms of calorific value, moisture content and physical composition.[1] In 1995, a High Powered Committee Report of the Planning Commission stated that Indian waste has a low calorific value, is usually not suitable[2] for self-sustained combustion, and hence, incineration-based technologies in most cases might be uneconomical for the country.

In June 2013, the Planning Commission appointed a task force to assess the feasibility of WTE technologies. The report of the task force, submitted in May 2014, recommended stand-alone WTE facilities for large cities with populations above two million, and pooled or regional facilities for smaller cities — it estimated that India could support 88 WTE facilities in the next five to seven years, 215 by 2031, and 556 by 2050.[3]

In October 2014, Prime Minister Narendra Modi announced a nationwide campaign to clean India — the Swachh Bharat Mission (SBM). One of the components of this Mission was to improve solid waste management

Waste to energy plants are ideally suited for waste that cannot be recycled or composted

When a comparison between renewable and non-renewable sources is drawn, it is clear that the energy produced by WTE is minuscule and much more costly

capacities and infrastructure in cities. For this, the Mission provides an incentive from the Central government in the form of a 35 per cent grant or viability gap funding (VGF) for each project to encourage public-private partnerships (PPPs) (*see section on policy and regulatory framework in this chapter*).

WTE as a source of renewable energy

WTE, as indicated by evidence from across the world, has been a popular choice of waste disposal in industrialised countries for the last 50 years. It is also considered a renewable source of energy. However, when a comparison between renewable and non-renewable sources of power generation based on various parameters is drawn, it is clear that the energy produced by WTE is minuscule in comparison to other sources, and much more cost-intensive. In fact, the cost of power generation from WTE is the highest among all the renewable sources of electricity. Also, each WTE plant uses around 25-30 per cent of the power generated by it as auxiliary power in-house to run its own machines (*see Table 1: Comparison between renewable and non-renewable sources of power generation*).

Most of India's WTE plants burn mixed waste, and need auxiliary fuel for their operations. This is one of the reasons behind the expensive power they produce. A unit of electricity produced in thermal or coal plants costs Rs 3-4, while that produced in thermal-based WTE plants costs about Rs 7. Also, India will have surplus energy by 2019, and the little contribution from WTE will not add value — WTE, thus, can be considered as a technology for waste management, not for generating energy.

The feasibility of WTE technology

There are three primary criteria for deciding the technology for processing MSW through WTE — waste volume and composition, calorific value, and

Table 1: Comparison between renewable and non-renewable sources of power generation

Energy produced by WTE is most expensive

Parameter	Non-renewable	Renewable	
	Thermal power plants	WTE incineration	Solar
Tarrif costs range	Rs 2.5-6/KWh	Rs 6..39–11/KWh	Rs 2.4-3.5/ KWh
Operation and maintenance cost (variable costs)	O&M cost for coal-based plants will be Rs 1,500–3,500/MWh	O&M cost for MSW-based WTE project is in range of 6.5–9.44 per cent of the project cost (approximately Rs 2–8 lakh per day) for MSW technology and 13.5 per cent of the project cost (approximately Rs 5–10 lakh per day) for RDF	Approxi-mately Rs 1,000-1,600/MWh

Sources: Planning Commission Task Force Report, 2014, Volume 2; prod.sandia.gov, irena.org, http://cornerstonemag.net/coal-based-electricity-generation-in-india, CERC 2016 moisture content. For the volume of waste generated, only if the moisture in the waste feed is low and the calorific value is high, will mass-incineration technologies for waste processing be suitable: this basic premise must be kept in mind before setting up such plants.

In India, the study of waste has repeatedly shown that the proportion of high-calorific value waste is low — most of the fraction is biodegradable in nature, with low calorific value. Countries that are heavily dependent on incineration have high calorific value of waste. A study by the Shriram Institute for Industrial Research[4] on municipal waste in South Delhi found that the net calorific value of the waste was 1,274 kcal/kg and the gross value was 1,324 kcal/kg.

As per an assessment of different Indian cities done by Centre for Science and Environment (CSE), the biodegradable fraction of MSW — which is 40-70 per cent of the total — is much more than its non-biodegradable counterpart: the non-biodegradable fraction (comprising both recyclable and non-recyclable dry waste) varies. It is 27-40 per cent in cities with a population of a million-plus; 20-35 per cent in cities with a population of 0.1-1 million; and 25-40 per cent in cities with a population below 0.1 million. Since segregation of waste at source in India is minimal, wet waste gets mixed with the dry, reducing its calorific value. A 2017 report by GIZ,[5] a German government agency working on waste and sanitation, states that mixed municipal solid waste in developing nations is by nature different from that in industrial countries and has specific characteristics in every city. This diversity must be considered in any technology assessment. There is no countrywide data, but Delhi, for instance, produces 10,500 TPD of waste, of which just 1,300 TPD is suitable for incineration. The rest can be composted, recycled or processed through biomethanisation. However, Delhi has three WTE plants to treat 4,900 TPD and is planning to construct a fourth one.

According to the National Green Tribunal (NGT)[6] order of January 2017, only non-recyclable non-biodegradable high-calorific value waste should be used as waste feed for WTE. Though this portion of waste has high combustibility and low moisture, using it as waste feed is possible only if source segregation of waste is practiced. Without segregation at source, resource recovery — this ensures the required characterisation from mixed waste — is a complex process. It is energy-intensive and has exorbitant costs.

Also, neglecting the livelihood issues of the informal sector workers and rag-pickers dependent on the availability of recyclable waste can cause complex socio-economic problems related to WTE. In its survey 'Give back our waste', Chintan[7], an NGO that works for environmental sustainability and social justice with diverse stakeholders, said that although WTE plants have become a clean development mechanism favorite, they should not be adopted blindly without considering them in the overall socio-economic context.

WTE plants have regularly faced protests from residents and societies in their neighbourhoods. Residents of Sukhdev Vihar in New Delhi, just 35 metres from the infamous Okhla WTE plant, have protested against it since 2003, alleging toxic emissions. The Okhla plant has been allowed to run

Countries that are heavily dependent on WTE have high-calorific value of waste. Studies indicate that in India, the proportion of high-calorific value waste is low

Despite the poor performance of WTE plants, they are being promoted — in most cities, capacity of the plant is equivalent to or even more than the waste generated by the city

despite its close proximity to residential areas, three major hospitals and a significant green cover. While Indian emission standards for incineration plants in the SWM Rules 2016 are more comprehensive than in the SWM Rules 2000, they are not as stringent as international standards.

The Union Ministry of Environment, Forests & Climate Change (MoEF&CC) has made installation of Continuous Emission Monitoring Systems (CEMS) mandatory for WTE thermal-based plants. A plant discharging effluents is required to install a Continuous Effluent Quality Monitoring System (CEQMS) as well. All four operational plants in India on incineration technology have installed CEMS to monitor their air emissions. Real-time data from these systems is sent to the Central Pollution Control Board (CPCB) and the respective State Pollution Control Boards/Committees. However, according to CSE's field surveys conducted in 2016[8], and field studies and assessments (unpublished) carried out in 2017 and 2018, implementation of CEMS and CEQMS in India is marred by insufficient information on different technologies, lack of standardisation in equipment quality, improper installation, and inadequate operation and maintenance for most plants. Also, the emission standards are not as stringent as those in European nations. For now, the CPCB is focusing only on installation and data collection — it is not checking for compliance, as the quality of the data is questionable. Therefore, it is very difficult to say whether the standards are being followed or higher emissions are being under-passed through illegal means.

Despite the poor performance of WTE plants, they are being promoted in the country — in most cities, capacity of the plant is equivalent to or even more than the waste generation of the city! The overriding concern is whether the WTE plants are intended to treat the mixed waste of one city alone rather than of a cluster of cities, as the combustible, non-recyclable fraction of waste in one city is too little to feed a single plant. Additionally, almost all WTE projects in India have faced public protests and some have been subjected to public litigation as well (this is an illustration of the so called Nimby — not in my backyard — effect).

Status of WTE in India

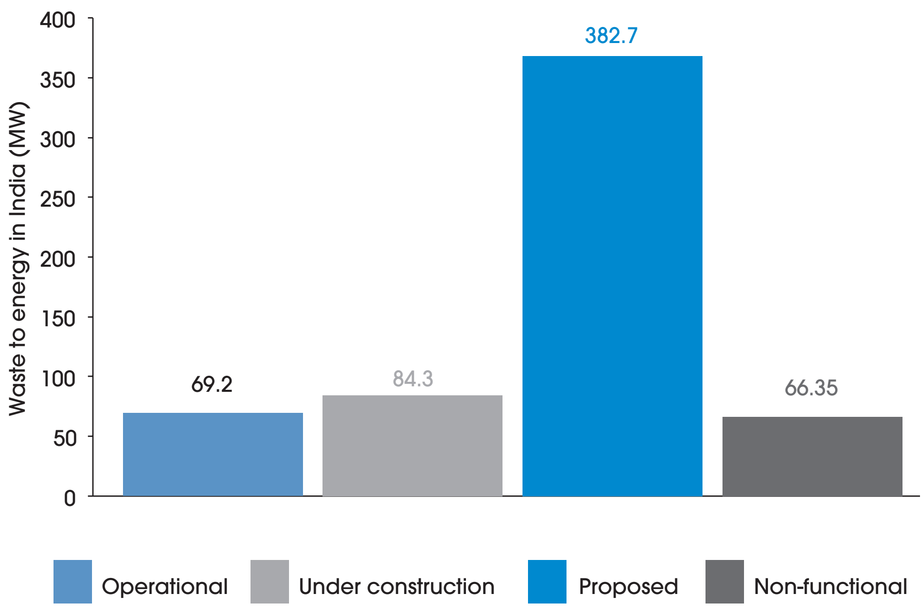
As per a 2016 Standing Committee Report on energy, *Power Generation from Municipal Solid Waste*,[9] the then Ministry of Urban Development (MoUD) (now MoHUA) had claimed that there are seven functional plants of 92.4 MW capacity, four non-functional plants of 40.6 MW capacity, 31 plants of 241.8 MW capacity under construction and 21 plants of 163.5 MW capacity under tendering stage. Data from SBM[10] says that there are seven operational plants with a production capacity of 88.4 MW. Also, under SBM, 56 MSW-based plants with a cumulative installed capacity of 412.5 MW are under consideration.

As per a report of the Parliament session dated[11] August 4, 2017, the MNRE claimed that five projects of 66.4 MW capacity are operational and generating power from MSW. These are running successfully in Solapur (Maharashtra), Jabalpur (Madhya Pradesh), and New Delhi, and are able to process about 4,516 TPD of waste. A gasification technology-based plant was commissioned in Shimla in 2017. Another Parliamentary report[12] suggested that there are 48 MSW-based plants under construction, with a cumulative installed capacity of 412.5 MW. In February 2018, the SBM noted 56 such plants of 415 MW capacity.[12] But CSE's interactions with developers of these plants indicated that only about eight plants were under construction; many had been tendered while the rest were in the process of being tendered. In many cities, the municipal bodies had denied permission to set up such plants.

As it is clear that data in different government reports for installed, under construction and under tendering WTE plants and their operational capacities varies considerably, CSE undertook its own survey. According to this, currently, thermal and thermo-chemical WTE plants in India have a total installed capacity to incinerate 5,375 tonne of waste and produce up to 69.2 MW of electricity per day. Close to 382.7 MW of power generation from waste is under consideration for WTE, while plants with a combined capacity of 84.3 MW are under construction (*see Graph 1: Status of WTE in India*). Plants with a combined capacity of 66.35 MW have been shut down in the last three decades. However, as per the government, a cumulative installed capacity of 412.5 MW is under construction (*see Statistics section).*

Graph 1: Status of WTE in India

Many WTE projects have failed; but over 382 MW of new plants have been proposed



Sources: CSE survey, 2018.

As per Solid Waste Management Rules, 2016 only non-recyclable, high-calorific fractions can be sent to a WTE plant

The policy and regulatory framework

Solid Waste Management Rules, 2016 and SBM: According to the Solid Waste Management Rules, 2016, municipal bodies have to ensure that recyclables are routed through appropriate vendors and only the segregated, non-recyclable, high-calorific fractions are sent to a WTE plant or for RDF (refuse-derived fuel) production, co-processing in cement plants or to a thermal power plant.

Under SBM, the Government of India will reimburse 100 per cent of the cost of preparing the detailed project report (DPR) as per the unit cost and norms set down by the National Advisory Review Committee (NARC). The State High Powered Committee (HPC) will authorise institutes of national repute for appraisal of the DPRs for projects recommended by urban local bodies.[14]

Besides this, the Central government's grants/VGF can be used for WTE projects, either up-front or as generation-based incentive for the power generated for a given period of time. The Central government incentive for SWM projects will be in the form of a maximum of 35 per cent grant/VGF for each project.[15] The Mission also says that states will contribute a minimum of 25 per cent funds for SWM projects to match the 75 per cent Central share (10 per cent in the case of states in India's northeast and special category states).[16]

Niti Aayog Action Plan, 2017-2020: According to the Niti Aayog Agenda Report for 2017-20[17], the Swachh Bharat Abhiyan has a deliverable for WTE generation: 330 MW in 2017-18 and 511 MW in 2018-19, which is an over 400 per cent increase from the current installed capacity.

The report says: *"…technologies such as composting and biogas are not sustainable solutions since they generate by-products or residues in large quantities that these cities will find difficult to dispose off efficiently. Only*

Criteria for the WTE process as per SWM Rules, 2016

- Non-recyclable waste with calorific value of 1,500 k/cal/kg or more should not be disposed of in landfills, but should only be used for generating energy either through RDF or by giving it away as feedstock for preparing RDF.
- High calorific wastes shall be used for co-processing in cement or thermal power plants.
- The local body, facility operator or designated agency proposing to set up a WTE plant with capacity of over five tonne per day shall submit an application to the State Pollution Control Board (SPCB) or Pollution Control Committee, as the case may be, for authorisation. On receiving such an application, the SPCB or Pollution Control Committee shall examine the same and grant permission within 60 days.

Source: Solid Waste Management Rules, MoEF&CC, 2016 *incineration, thermal pyrolysis and plasma gasification technologies offer sustainable disposal solutions. However, pyrolysis is not suitable for MSW due to its diverse composition and plasma technology remains too costly to adopt so far. Hence, incineration or 'Waste to Energy' is the best option."*

The report also suggests setting up an agency called the WECI (Waste to Energy Corporation of India), which would primarily help set up the plants in the 100 Smart Cities.

Environmental clearance: According to the MoEF&CC[18], WTE plants, if proposed as stand-alone options, are not covered under item 7(i) of the Environment Impact Assessment (EIA) Notification of 2006, and hence do not require prior environmental clearance. In case a WTE plant (up to the capacity of 15 MW) is proposed at an existing landfill site, it will not attract the provisions of the EIA Notification, 2006.

CHINKY SHUKLA /CSE

The money and the market

How much does WTE cost in India?

The Planning Commission Task Force of 2014[19] had taken approximations on capital and operating costs based on various parameters such as procurement of tools and equipment, humanpower, loan payback etc. According to the estimates, for an incineration plant to treat about 1,000 TPD of waste, the capital cost can be as much Rs 200 crore; some bigger plants in India have invested as much as Rs 550 crore in the project. The O&M costs of these plants are also very high, resulting in high cost of per unit of electricity (*see Table 2: Summary of expenditure for a 24-MW plant*).

Table 2: Summary of expenditure for a 24-MW plant

Taking an approximate value based on industry trends and standards

Description	Quantity
Project duration	20 years
Waste quantity	1,500 TPD
Annual escalation on waste quantity	5%
Power generated	24 MW
Auxiliary consumption	16%
PLF	80%
Net power sold to the grid	16.13 MW
Tipping fees	Rs 1,500 per tonne
Annual escalation in tipping fees	5%
WTE tariff	Rs 7.05/kWh
Annual escalation of WTE tariff	0%
Operating and maintenance expenses for power plant	6.5% of normative capital cost
Annual escalation on O&M expenses for power plant	5%
Operating and maintenance expenses for other activities	5% of normative capital cost
Annual escalation on O&M expenses for other activities	4%
Debt	70%
Equity	30%
Rate of interest	7.5%
Rate of depreciation	13%
Number of days in a year	330
Number of hours in a day	24

Source: Calculated by CSE in 2017

Tipping fee for waste collection and processing

One of the major sources of revenue for WTE plants is the tipping fee which is a fee paid to an agency for door-to-door collection, secondary collection, transportation and/or treatment (WTE processing) and disposal (in a landfill) of waste generated. Plant developers that take charge of WTE plants are given tipping fees by municipal bodies. The following tipping fees have been set by some municipal corporations for WTE plants:

- Indore WTE: Rs 1,080/TPD
- Bhopal WTE: Rs 1,120/TPD
- Jabalpur WTE: Rs 1,400/TPD
- Bawana, Delhi WTE: Rs 1,500/TPD

There is, however, an issue here. Since waste is not segregated and tipping fee is paid on quantity, not quality, operators are inclined to get heavy and unusable unsegregated waste. This adds to the processing costs; as a result, the waste has high amounts of rejects (as high as 25 per cent) and little resource recovery. All plants that currently charge tipping fees collect mixed waste. Contracts are based on payment of tipping fees — the more the waste brought, the higher the tipping fee. This practice needs to be re-examined.

Since waste is not segregated and tipping fee is paid on quantity, not quality, operators are inclined to get heavy and unusable unsegregated waste

High electricity tariffs

Another major source of revenue for WTE is through electricity tariffs. The MoHUA had insisted that the Ministry of Power amend the tariff policy to provide for state discoms to 'mandatorily purchase all power generated from municipal solid waste'. The Solid Waste Management Rules of 2016 also included this as a rule for WTE plants. However, this is facing resistance from discoms as electricity from such plants has a much higher tariff than from other sources of energy. Low calorific value of the waste feed, capital-intensive technology, high O&M and humanpower costs, and high cost of treatment of emissions are reasons for the higher tariffs of WTE plants.

According to the 2015 Central Electricity Regulatory Commission (CERC) report,[20] WTE technologies in India are competing for sustenance both commercially and technically. According to the CERC's Renewable Energy Tariff Regulations 2015, the working capital requirement with respect to MSW and RDF projects is computed in accordance with the following: fuel costs for four months equivalent to normative plant load factor (PLF), O&M costs for a month, receivables equivalent to two months of fixed and variable charges for sale of electricity calculated on the target PLF, and maintenance spare at 15 per cent of O&M expenses.

Table 3 *(Tariffs for different technologies for FY 2015-16)* lists tariffs applicable for all WTE plants commissioned in FY 2015-16. It is clear from the data that the tariffs for WTE plants, both MSW and RDF-based, is very high compared to other RE technologies, including biogas. Following the guidelines of the CERC, the State Electricity Commissions have also notified WTE tariffs. Some of the tariffs calculated by states in the year 2016 are as follows — Haryana (7.05 Rs/kWh), Madhya Pradesh (6.39 Rs/kWh), Gujarat (7.25 kWh) and Uttar Pradesh (7.05 kWh). The Centre has put renewable

Table 3: Tariffs for different technologies for FY 2015-16

Tariffs from WTE plants are higher

Technology	Levelled fixed cost (Rs/ kWh)	Variable cost (Rs/ kWh)	Applicable tariff rate (Rs/kWh)	Benefit of accelerated depreciation (if availed)(Rs/ kWh)	Net levelled tariff (upon adjusting for accelerated depreciation benefit) (if availed) (Rs/ kWh)
MSW	7.04	0.00	7.04	0.54	6.50
RDF-based	4.34	3.56	7.90	0.31	7.59
Biogas	3.57	4.29	7.86	0.26	7.60

Source: CERC, 2016; http://www.cercind.gov.in/2017/regulation/Noti131.pdf

energy in the 5 per cent bracket under the Goods and Services Tax (GST). This will make WTE more cost-intensive and discoms will resist any further tariff increase, making electricity generation through WTE more unviable.

Where is the money?

According to a report by Assocham (Associated Chambers of Commerce and Industry in India)[21] titled *Value of Waste 2015*, the investment opportunity in WTE in India was valued at almost US $1.5 billion in 2017 — and was estimated to grow to approximately US $11.7 billion by 2052. According to *The Waste to Energy Opportunities in India 2017-2022 — Research and Market Report, 2017*[22], remunerative tariffs by the CERC has helped raise investor interest in this segment.

But the 2015-16 Standing Committee Report[23] of the MNRE states that the major problems that were hampering the implementation of WTE projects in India were primarily related to non-payment of agreed fees and non-marketability of waste-processed products, including power. According to *Waste to Energy Opportunities in India 2017-2022*[24], municipal corporations are expected to receive Rs 15,000 crore under the Swachh Bharat Mission for the next three years for waste management and WTE projects. The government is also setting up a US $1.25-billion fund, backed by the state-owned Power Finance Corp Ltd and Rural Electrification Corp Ltd along with a few private institutions.

WTE plants are also coming up because municipalities are expected to receive large amounts of money under Swachh Bharat Mission

As per the 2016 paper *Waste to Energy (WTE) Market Size by Technology*[25], solid waste management funding in Asia is done primarily through government allocations. To tide over shortages, funds are also sourced from public-private participation (PPP), as well as international bilateral and multilateral financing.

Fiscal incentives for WTE: According to the *Manual on SWM Rules 2016*,[26] a financial incentive of Rs 1.5-3 crore per MW is given to municipal corporations or ULBs for supplying garbage free of cost at the project site and providing land on a long-term lease (30 years and above) at a nominal rent. Also, state nodal agencies are given an incentive of Rs 5 lakh per MW of power for promotion, coordination and monitoring of such projects.

There is also a provision for financing 50 per cent of the preparation cost of detailed project reports (DPRs) or techno-economic feasibility reports, subject to a maximum of Rs 2 lakh per report. The Indian Renewable Energy Development Agency Ltd (IREDA) provides subsisted loan, which is restricted to energy generation system and excludes pre-fuel processing system. Other financial institutes can also be approached for loans. The *Manual* adds that for commercial projects, financial assistance is provided by way of interest subsidy to reduce the rate of interest to 7.5 per cent capitalised with an annual discount rate of 12 per cent.

Partnerships: Public-private partnerships (PPPs) are strongly recommended by the MoHUA for waste management-related services. The idea is to bring private investment into these public interest-related areas of work. A PPP scheme to avail viability gap funding (VGF) is also an option for private players. The MoUD, which implements the SBM, has a provision under which Central support of up to 35 per cent of the project cost in the form of VGF grant can be provided for setting up WTE plants, subject to availability of overall state-wise funds for waste management.[27]

In September 2017, the National Thermal Power Corporation (NTPC) invited developers and investors to set up 100 WTE plants in the country.[28] The Confederation of Indian Industry (CII) has initiated a Task Force on Waste to Worth, which has also proposed inviting foreign investors for WTE development in India.[29] The Niti Aayog, on its part, has proposed the formation of WECI — the Waste to Energy Corporation of India — which could help set up WTE plants through PPP models.[30]

It is evident that WTE plants are running entirely supported by government subsidies, tipping fees and compulsory power purchase by discoms at higher tariffs; on paper, these plants seem a profitable venture for any city and hence the growing interest in them. But if these factors are removed, a WTE plant will not be financially viable.

WTE plants are running on government subsidies, tipping fees and higher power tariff. Once these factors are removed, a WTE plant will not be financially viable

The way ahead: A misplaced idea?

The fundamental challenge of waste management is to get as much value out of the waste as possible, with the aim of conserving natural resources. The central discussion related to recycling versus incineration is whether it creates value financially, environmentally and in terms of resource management. Given that materials are often worth more than energy partly because they can be transformed into energy (while energy cannot be turned into materials), resource recovery from waste should attract more attention than energy recovery from waste. Hence, whether to burn or not does not have a clear-cut answer. It depends on multiple factors, including segregation of waste at source, feasibility study of composition and characterisation prior to proposal of a specific technology, waste quantity that is suited for incineration and plausible alternatives to WTE.

Co-processing of end-life waste can be an alternative solution to thermal treatment of waste for cement firms. Waste is already widely co-processed in cement kilns in India. Cement plants — almost all the Indian states have these — can be upgraded for use of RDF with a little investment. The infrastructure already exists for cement companies — with retrofitting, the companies can accept non-recyclable waste as alternate fuel and raw materials (AFRs). According to GIZ's Output-based Market Development Assistance (OMDA),[31] the current capacity of cement plants is up to an RDF supply of 227 TPD to each of the 55 cement plants, which is roughly 13,000 tonne a day. Therefore, a major portion of non-recyclable waste can go for co-processing in cement kilns in cities where the cement plant is within accessible distance.

India, along with other developing nations, should turn to WTE technology systems for an agglomeration of cities, but only after other options such as co-processing in industry have been rendered unfeasible. It should be kept in mind that, if chosen, WTE is not the lone solution for waste management of a city — it is simply a part of it.

STATISTICS

Energy access and renewable energy at a glance

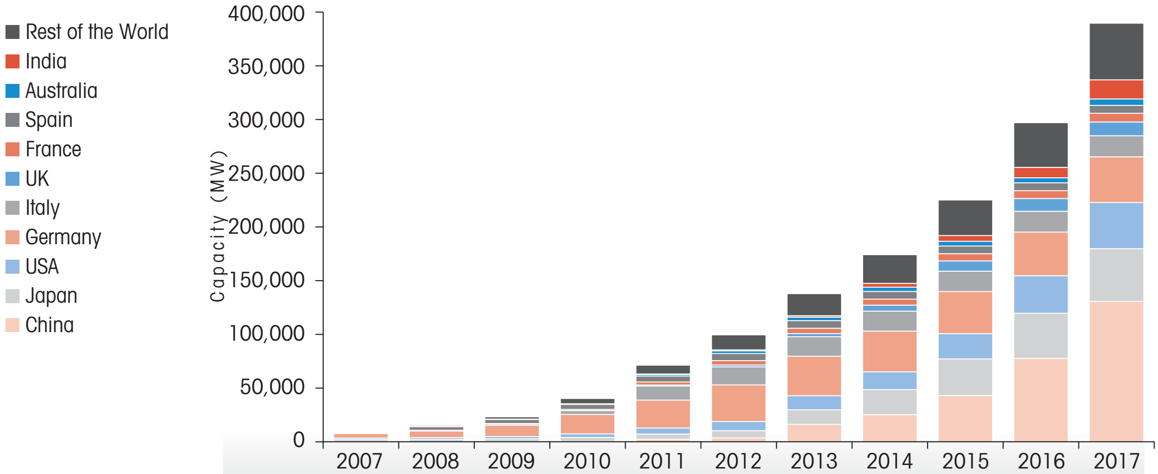
Chapter 1: The road to 175 gigawatt

Renewable Energy Capacity in India

Sector	FY- 2018-19		Cumulative Achievements (as on 31.12.2018)
	Target	Achievement (April-Dec 2018)	
I. GRID-INTERACTIVE POWER (CAPACITIES IN MW)			
Wind Power	4,000	993.15	35,138.15
Solar Power - Ground Mounted	10,000	3,270.09	23,858.13
Solar Power - Roof Top	1,000	290.49	1,354.12
Small Hydro Power	250	31.65	4,517.45
Biomass (Bagasse) Cogeneration	250	374.70	9,075.50
Biomass (non-bagasse) Cogeneration)/Captive Power	100	49.93	704.74
WTE	2	0.00	138.30
Total	15,602	5,002.21	74,786.39
II. OFF-GRID/ CAPTIVE POWER (CAPACITIES IN MW)			
WTE	18	4.79	176.94
Biomass Gasifiers	1	0.00	163.37
SPV Systems	200	132.66	804.06
Total	219	137.45	1,144.37

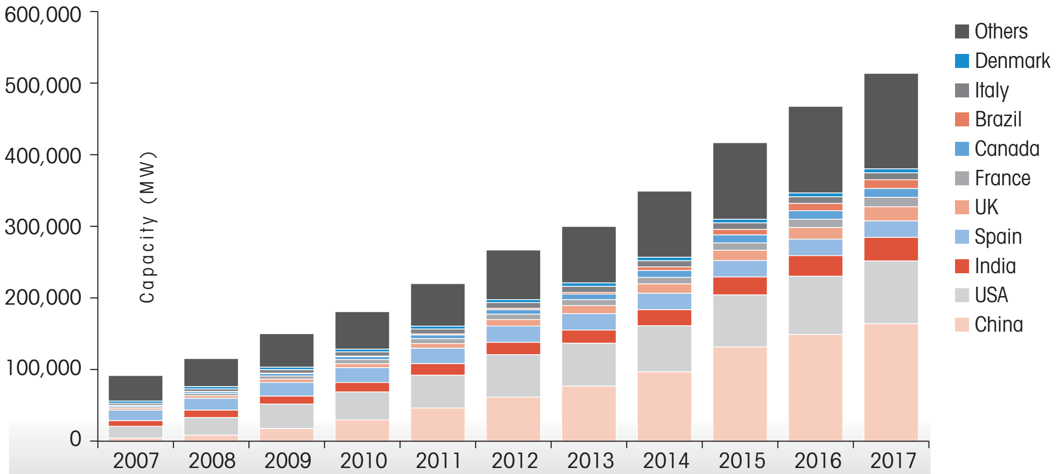
Source: Ministry of New and Renewable Energy (MNRE)

Country-wise Installed Solar Capacity



Source: International Renewable Energy Agency (IRENA), 2018

Country-wise Installed Wind Capacity



Source: International Renewable Energy Agency (IRENA), 2018

Source-wise Installed capacity

Source	Mar-14 (GW)	Mar-14 (%)	Mar-15 (GW)	Mar-15 (%)	Mar-16 (GW)	Mar-16 (%)	Mar-17 (GW)	Mar-17 (%)	Mar-18 (GW)	Mar-18 (%)	June-18 (GW)	June-18 (%)
Coal	145.27	60	164.63	62	185.17	62	192.16	59	197.17	57	196.96	57
Gas	21.78	9	23.06	9	24.51	8	25.33	8	24.90	7	24.87	7
Hydro	40.53	17	41.26	15	42.78	14	44.48	14	45.29	13	45.40	13
Nuclear	4.78	2	5.78	2	5.78	2	6.78	2	6.78	2	6.78	2
Diesel	1.19	0	1.19	0	0.99	0	0.84	0	0.84	0	0.84	0
Renewable	29.46	12	31.70	12	38.82	13	57.26	18	69.02	20	70.65	20

Source: Central Electricity Authority (CEA); Note: Zero percentage points are an approximation

Foreign Direct Investment (FDI) in Renewable Energy

	USD million	Rs crore
FY 2018-19	452	2,996
FY 2017-18	1,204	837
FY 2014-16	2,050	1,608
FY 2000-14	3,131	999

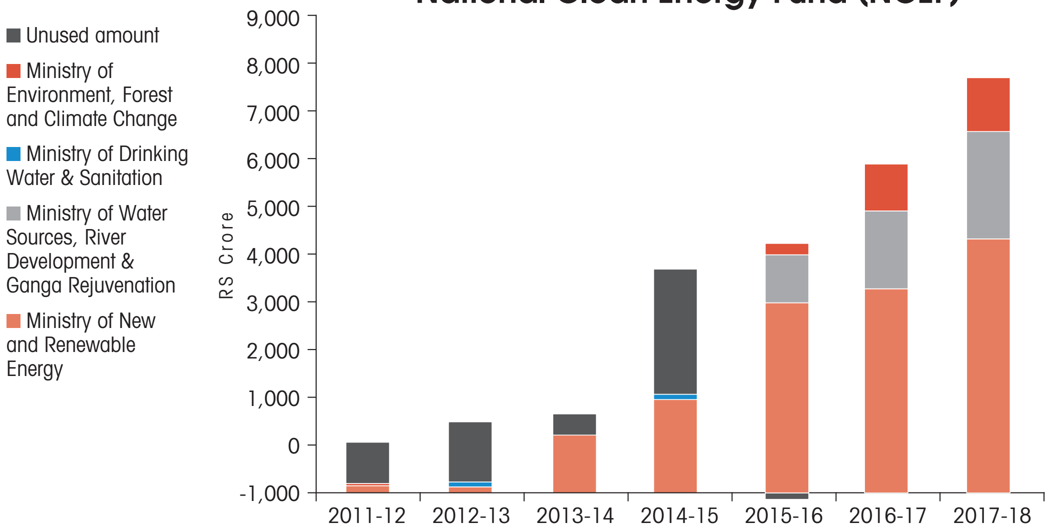
Source: http://dipp.nic.in/foreign-direct-investment/foreign-direct-investment-policy , http://www.makeinindia.com/documents/10281/114126/New+%26+Renewable+Energy+Sector+-+Achievement+Report.pdf

Sector-wise Financing Disbursed by IREDA (Rs Crore)

Sector	1987-12	2012-13	2013-14	2014-15	2015-16	2016-17	Total
Wind	4,874	1,207	1,173	1,355	873	2,535	12,017
Hydro	1,831	356	724	388	340	340	3,979
Biomass and Cogeneration	2081	347	198	259	305	86	3,276
Energy Efficiency & Conservation	273	59	0	0	0	6	338
Solar	562	151	274	576	1,519	1,524	4,606
WTE	56	2	0	2	1	2	63
Biomethanation from Industrial Effluents	57	0	0	0	0	0	57
Biomass Briquetting	10	0	0	0	0	0	10
Biomass Gasification	5	0	0	0	0	0	5
NCEF	0	0	100	0	0	15	115
Bill Discounting	0	0	0	0	9	23	32
Bridge Loan	3	0	0	38	50	27	118
Short Term Loan & LOCS	0	0	0	0	1,125	2,005	3130
Misc (Manufacturing)	0	0	0	0	0	26	26

Source: Compiled from Indian Renewable Energy Development Agency Ltd (IREDA) Annual reports

Allocation of Funding from the National Clean Energy Fund (NCEF)



Source: Comptroller and Auditor General of India (CAG) report

Chapter 2: Utility-scale solar: Charting a new course

Irradiance at Various Solar Park Sites in India (kWh/m²/day)

Month	Bhadla, Rajasthan	Charanka, Gujarat	Kurnool, Andhra Pradesh	Pavagada, Karnataka	Rewa, Madhya Pradesh	India (Average)
Jan	5.83	6.16	6.58	7.25	5.08	6.01
Feb	6.20	6.96	6.90	7.25	6.21	6.86
Mar	6.15	6.58	6.10	6.36	6.69	6.49
Apr	5.59	6.30	5.85	5.98	6.05	6.70
May	6.42	7.16	6.42	6.41	6.51	6.48
Jun	5.63	5.61	4.35	4.63	4.45	4.01
Jul	4.68	2.85	3.41	3.69	2.70	2.44
Aug	4.89	3.05	3.61	3.58	2.99	2.52
Sep	5.93	5.36	4.51	5.16	4.80	4.57
Oct	6.09	6.36	4.91	4.55	5.98	6.12
Nov	5.78	5.97	6.31	5.74	5.81	6.46
Dec	5.35	5.87	6.56	6.70	4.88	6.32
Avg	5.71	5.67	5.45	5.60	5.17	5.40

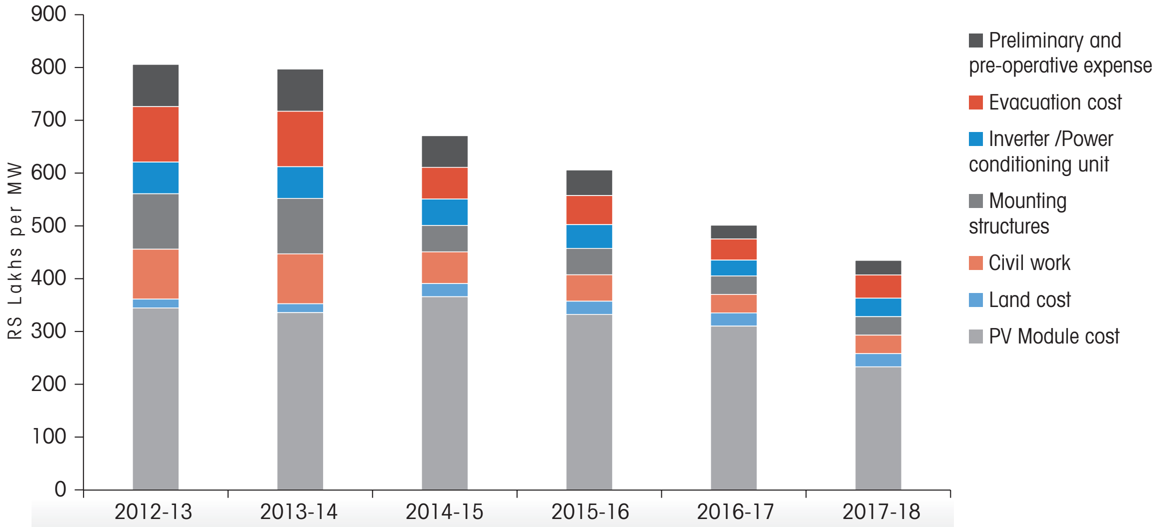
Source: National Renewable Energy Laboratory (NREL)

State-wise Solar Potential and Capacity Installed

State	Potential (GW)	Installed Capacity (MW) as of December 2017
Andhra Pradesh	38.44	2,165.21
Arunachal Pradesh	8.65	4.39
Assam	13.76	11.78
Bihar	11.20	141.52
Chhattisgarh	18.27	179.38
Delhi	2.05	58.02
Goa	0.88	0.71
Gujarat	35.77	1,344.69
Haryana	4.56	203.85
Himachal Pradesh	33.84	1.48
Jammu & Kashmir	111.05	2.36
Jharkhand	18.18	23.27
Karnataka	24.70	1,800.85
Kerala	6.11	88.20
Madhya Pradesh	61.66	1,210.11
Maharashtra	64.32	763.08
Manipur	10.63	1.33
Meghalaya	5.86	0.06
Mizoram	9.09	0.20
Nagaland	7.29	0.50
Odisha	25.78	79.51
Punjab	2.81	905.64
Rajasthan	142.31	2,310.46
Sikkim	4.94	0.01
Tamil Nadu	17.67	1,819.42
Telangana	20.41	2,990.07
Tripura	2.08	5.09
Uttar Pradesh	22.83	550.38
Uttarakhand	16.80	246.89
West Bengal	6.26	39.84
Union Territories	0.79	45.79
Total	**748.99**	**17,027.27**

Source: Ministry of New and Renewable Energy (MNRE) Annual Report 2017-18

Benchmark CAPEX for Solar Photovoltaics



Source: Compiled from CERC annual benchmark costs; 2017-18 data obtained from Karnataka Electricity Regulatory Commission's tariff order

Chapter 3: Solar rooftop: Overshadowed

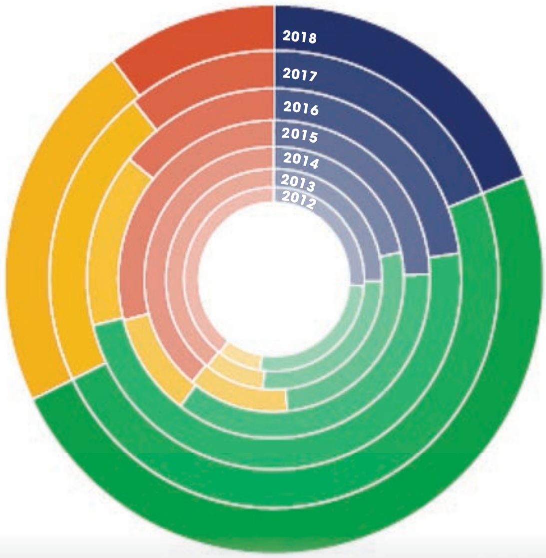
State Policies for Solar Rooftop

State	Nodal Agency	Solar Policy	Policy Scope	Subsidy	Power Purchase	Metering	Max Cumulative Capacity Allowed at a Particular Distribution Transformer	SRT Size Limit
Andhra Pradesh	NREDCAP	Yes (2015)	1 kWp - 1000 kWp	30-50%	ACoS	Net/Gross	60%	100% AC
Arunachal Pradesh	APEDA	No; APSERC Regulations (2016)	1 kWp - 1000 kWp	70%	APPC	Net	15%	100% AC
Assam	AEDA	Yes (2018)	1 kWp - 500 kWp	70%	₹ 3.43	Net/Gross	20%	80% AC
Bihar	BREDA	No; BERC Regulations (2015)	less than 1 MWp	30%	No	Net	15%	90% AC
Chandigarh	CREST	Yes (2015)	1 kWp - 500 kWp	30%	5.87 - 9.19	Net/Gross	30%	30% AC
Chhattisgarh	CREDA	Yes (2013)	50 kWp - 1 MWp	30%	4.35	Net	40%	100% SL
Delhi	EE&REM	Yes (2016)	> 1 kWp	30%	APPC + Rs 2 (GBI)	Net	15%	100% SL
Goa	GEDA	Yes (2017)	up to 100 kWp	30-50%	7.87 - 8.06	Net/Gross	30%	100% AC
Gujarat	GEDA	Yes (2015)	up to 1 MWp	50%	APPC	Net	30%	50% SL
Haryana	HAREDA	Yes (2016)	1 kWp - 1 MWp	30%	APPC + GBI	Net	15%	90% AC
Himachal Pradesh	HIMURJA	Yes (2016)	1 kWp - 1 MWp	80%	₹ 5.00	Net	20%	80% SL
Jammu & Kashmir	JAKEDA	Yes (2016)	1 kWp - 1 MWp	70%	No	Net	20%	50% SL
Jharkhand	JREDA	Yes (2015)	up to 1 MWp	50%	₹ 0.50	Net/Gross	15%	100% SL
Karnataka	KREDL	Yes (2014)	1 kWp - 500 kWp	30%	₹ 4.43 - 7.08	Net/Gross	65%	150% SL
Kerala	ANERT	Yes (2013)	up to 10 kWp	30%	APPC	Net	30%	80%
Madhya Pradesh	MPNRED/ MPUVN	No; MPERC Regulations (2015)	0.5 kWp - 250 kWp	45%	APPC	Net	30%	100% AC
Maharashtra	MEDA	No; MERC Regulations (2015)	up to 1 MWp	30%	APPC	Net	40%	100% SL

State	Nodal Agency	Solar Policy	Policy Scope	Subsidy	Power Purchase	Metering	Max Cumulative Capacity Allowed at a Particular Distribution Transformer	SRT Size Limit
Manipur	MANIREDA	Yes (2014)	1 kWp - 500 kWp	70%	₹ 6.10 - 9.39	Net/Gross	40%	100% SL
Meghalaya	MNREDA	No; MSERC Regulations (2015)	1 kWp - 1 MWp	70%	APPC	Net	15%	90% AC
Mizoram*	ZEDA	Yes (2017)	1 kWp - 500 kWp	70%	₹ 6.10 - 9.39	Net	40%	100% SL
Nagaland	NREDA	No; NERC Regulation (2016)	up to 1 MWp	70%	No	Net	15%	100% SL
Odisha	OREDA	No; OERC Regulations (2016)	>1 kWp	30%	No	Net	75%	100 % AC
Punjab	PEDA	Yes (2015)	1 kWp - 10 MWp	30%	No	Net	30%	90% SL
Rajasthan	RRECL	Yes (2014)	1 kWp - 1 MWp	30%	₹ 4.0 - 5.0	Net	30%	80% SL
Sikkim	SREDA	No; SSERC Regulation (2014)	up to 1 MWp	70%	APPC	Net	80%	--
Tamil Nadu	TEDA	Yes (2012)	>1 kWp	55%	No	Net	30%	90% AC
Telangana	TNREDCL	Yes (2015)	1 kWp - 1 MWp	30%	APPC	Net/Gross	50%	100% SL
Tripura	TREDA	No; TERC Regulations (2016)	>1 kWp	70%	APPC	Net	15%	100 SL
Union Territories†	Regional	No	up to 500 kWp	30 / 70%	Regulated	Net/Gross	30%	100% AC
Uttar Pradesh	UPNEDA	Yes (2017)	up to 1 MWp	30%	₹ 0.50	Net/Gross	15%	100 % SL
Uttarakhand	UREDA	Yes (2013)	1 kWp - 500 kWp	70%	3.10-5.20	Net	--	--
West Bengal	WBGEDCL	Yes (2012)	> 5 kWp	30%	No	Net	--	90% SL

ACoS - Average Cost to Serve (of the Discom as determined by APERC every year); AC - Actual Contracted Load; SL - Sanctioned Load; APPC - Average (Pooled); Power Purchase Cost; GBI - Generation Based Incentive; *Not available on official website
Source: Compiled by CSE from various sources

Consumer Segment-wise Share in Total Rooftop Capacity



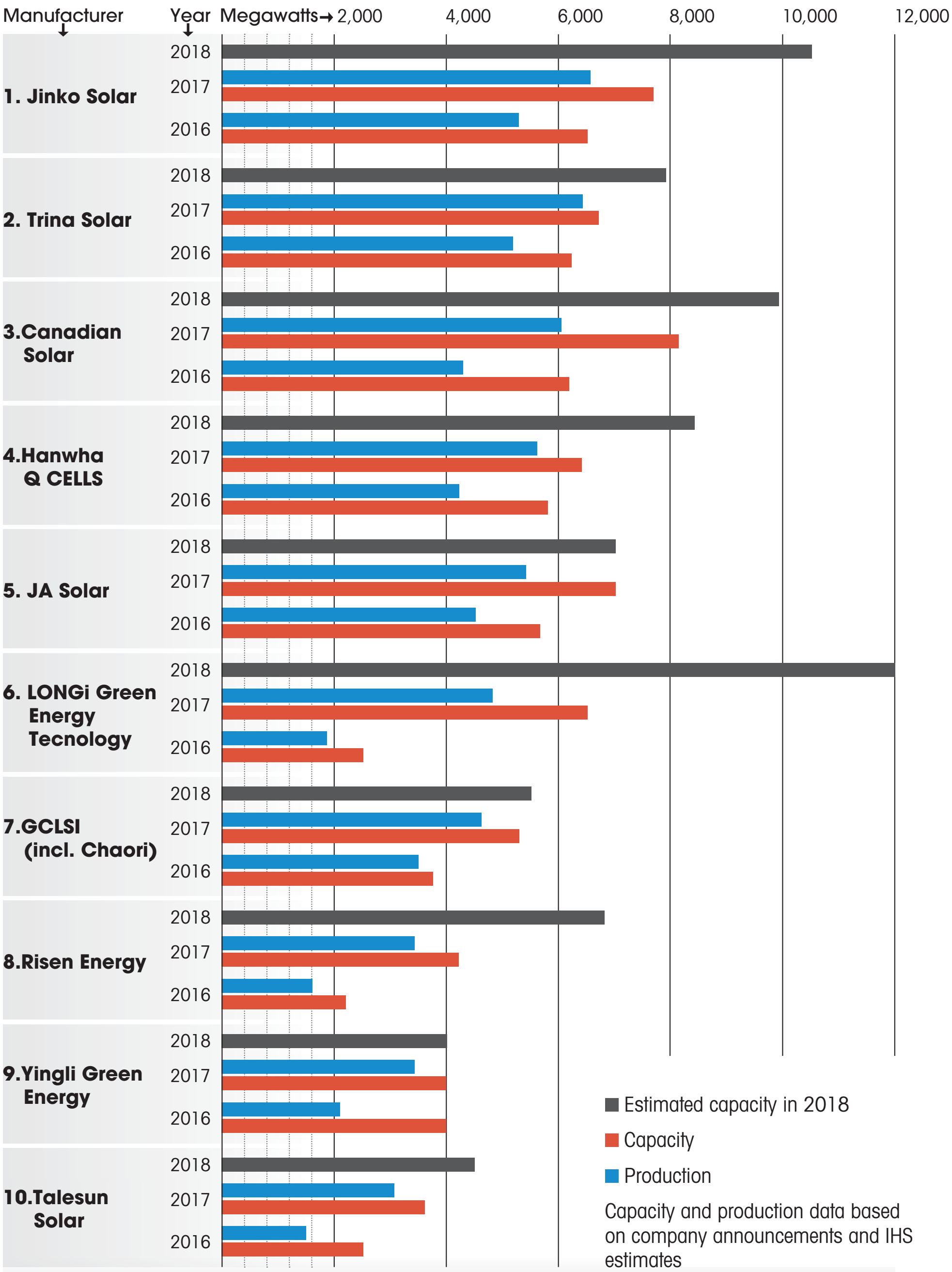
Cumulative capacity (in MW)

2012	38
2013	117
2014	286
2015	623
2016	1,179
2017	2,177
2018	3,399

Source: Bridge to India

Chapter 4: Solar manufacturing: Moving out of the doldrums

Leading Solar Module Manufacturers (2017)



Source : http://16iwyl195vvfgoqu3136p2ly-wpengine.netdna-ssl.com/wp-content/uploads/2018/07/07023_Top_10-solar_module_manufacturers_2017_Korr21.jpg

Solar Capacities under Domestic Content Requirement (DCR)

Programme	Programme capacity (MW)	Domestic Content Requirement (DCR) Provision	Allocated DCR Capacity (MW)	Commissioned Capacity (MW)	Cancelled DCR capacity to date post WTO ruling (MW)
NSM Phase I Batch I	150	Crystalline silicon - indigenous; Thin film - imported	70	70	NA
NSM Phase I Batch II	350	Crystalline silicon - indigenous; Thin film - imported	70	70	NA
NSM Phase II Batch I	750	Cells and modules to be indigenous	375	355	
NSM Phase II Batch II Tranche I	3,000	Cells and modules to be indigenous	400	60	
NSM Phase II Batch III	2,000	Cells and modules to be indigenous	250	100	100
NSM Phase II Batch IV	5,000	Cells and modules to be indigenous (MNRE deletes DCR clause from 5 GW Phase-II Batch-IV VGF scheme)	375	25	350
CPSU Scheme	1,000	1Cr/MW for cells and modules; 50L/MW for modules	930		NA
Defense Scheme	300	Cells and modules have to be indigenous	300		NA

Source: Ministry of New and Renewable Energy (MNRE)

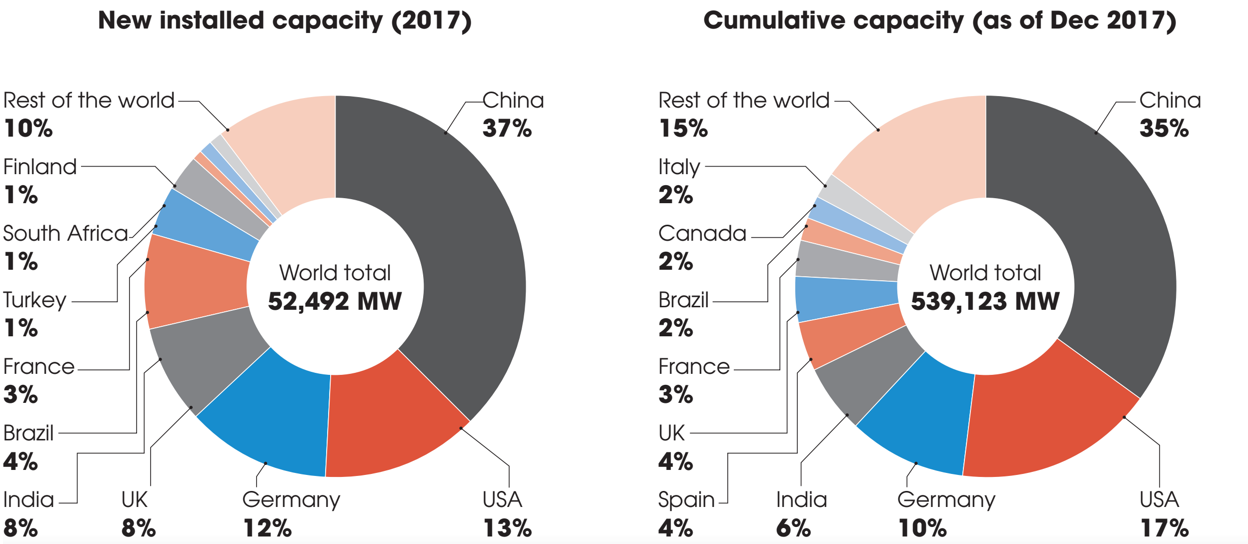
Leading Indian Solar Manufacturers

Indian solar manufacturers	PV module manufacturing capacity (MW)	Solar cell manufacturing capacity (MW)
Adani Solar	1,200	1,200
Waaree Energies	1,500	
Vikram Solar	1,000	
Emmvee Group	500	
Goldie Solar	500	
Indosolar	450	200
Tata Power Solar Systems	400	300
Alpex Solar	400	
Bharat Heavy Electricals	226	105
XL Energies	210	60

Source: Compiled by Centre for Science and Environment (CSE)

Chapter 5: Wind energy: Braving the headwinds

Country-wise Share of Installed Wind Capacity



Source: Global Wind Energy Council (GWEC)

Annual State-wise Wind Installations in India (MW)

State	Andhra Pradesh	Gujarat	Karnataka	Madhya Pradesh	Maharashtra	Rajasthan	Tamil Nadu
Up to March'2002	93.2	181.4	69.3	23.2	400.3	16.1	877
2002-03	0	6.2	55.6	0	2	44.6	133.6
2003-04	6.2	28.9	84.9	0	6.2	117.8	371.2
2004-05	21.8	51.5	201.5	6.3	48.8	106.3	675.5
2005-06	0.4	84.6	143.8	11.4	545.1	73.2	857.5
2006-07	0.8	283.9	265.9	16.4	485.3	111.9	577.9
2007-08	0	616.3	190.3	130.3	268.1	68.9	380.6
2008-09	0	313.6	316.0	25.1	183	199.6	431.1
2009-10	13.6	197.1	145.4	16.6	138.9	350.0	602.2
2010-11	55.4	312.8	254.1	46.5	239.1	436.7	997.4
2011-12	54.1	789.9	206.7	100.5	416.5	545.7	1,083.5
2012-13	202.1	208.3	201.7	9.6	288.5	614.0	174.6
2013-14	335.7	272.7	188.7	37.4	1,043.1	98.6	113.5
2014-15	254.8	195.2	315.6	453.3	372.9	524.7	181.3
2015-16	362.5	385.6	240.3	1,291.9	220.6	687.9	197.1
Total	1,400.6	3,928.0	2,879.8	2,168.5	4,659.2	3,996.0	7,491.0
Total 2018	3,962.7	5,614.3	4,509.1	2,497.8	4,784.7	4,297.72	8,196.5

Source: Ministry of New and Renewable Energy (MNRE)

State-wise Wind Capacity Available for Repowering (kW)

State	Repowering Capacity (kW)		
	<=500 kW	500-1,000 kW	Total Capacity (kW)
Tamil Nadu	717,050	37,900	754,950
Gujarat	143,745	1,600	145,345
Andhra Pradesh	84,390		84,390
Karnataka	24,525		24,525
Maharashtra	63,715	2,250	65,965
Madhya Pradesh	21,100		21,100
Rajasthan	2,900		2,900

Source: Ministry of New and Renewable Energy (MNRE)

Wind Auctions Conducted in India

Date	Winning tariff (Rs/ kWh)	Conducted by	Total capacity (MW)	Company	Capacity (MW)	Bid (Rs/kWh)
Feb-17	3.46	Solar Energy Corporation of India (SECI)	1,050	Mytrah Energy	250	3.46
				Green Infra	250	
				Inox Wind	250	
				Ostro Energy	250	
				Adani Green Energy	50	
Aug-17	3.42	Tamil Nadu Generation & Distribution Co (TANGEDCO)	950	ReGen Powertech	200	3.42
				Leap Green Energy	250	3.43
				Neyveli Lignite	500	3.45
Oct-17	2.64	Solar Energy Corporation of India (SECI)	1,000	ReNew Wind Energy	250	2.64
				Orange Sironj	200	
				Inox Wind	250	2.65
				Green Infra	250	
				Adani Green Energy	50	
Dec-17	2.43	Gujarat Urja Vikas Nigam Limited (GUVNL)	1,527	Sprng Energy	197.5	2.43
				Verdant Renewables	100	2.44
				KP Energy	300	
				Betam Wind Energy	300	
				Powerica	500	
				ReNew Power Ventures	17.6	2.45
Feb-18	2.44	Solar Energy Corporation of India (SECI)	2,000	Inox Wind	200	2.44
				Torrent Power	500	
				ReNew Power	400	
				Green Infra Wind Energy	300	
				Adani Green Energy (MP)	250	2.45
				Saudi Arabia's Alfanar	300	
				Betam Wind Energy	50	
Mar-18	2.85	Maharashtra State Electricity Distribution Company Ltd	500	Adani Green Energy	75	2.85
				KCT Renewable Energy	75	
				Inox Wind	50	2.86
				Mytrah Energy	100	
				Hero Wind Energy	75	
				Torrent Power	125	2.87
Apr-18	2.51	Solar Energy Corporation of India (SECI)	2,000	Srijan Energy Systems	250	2.51
				Sprng Energy	300	
				BLP Energy	285	
				Betam Wind Energy	200	
				Inox Wind	100	
				Adani Green Energy	300	
				Mytrah Energy	300	2.52
				ReNew Wind Energy	265	

Date	Winning tariff (Rs/ kWh)	Conducted by	Total capacity (MW)	Company	Capacity (MW)	Bid (Rs/kWh)
Aug-18	2.77	National Thermal Power Corporation (NTPC)	1,200	Sprng Vayu Vidyut	200	2.77
				Mytrah Energy	300	2.79
				Srijan Energy quoted	50	2.8
				ReNew Wind Energy	300	2.81
				Hero Wind Energy	300	2.82
				Fasten Power	50	2.83
Sep-18	2.76	Tranche V	1,200	Torrent Power	115	2.76
				Adani Green Energy	300	2.76
				Alfanar Company	300	2.77
				SITAC Kabini Renewables	300	2.77
				Ecoren Energy India	175	2.77
				Renew Wind Energy	10	2.77

Source: Compiled from MERCOM reports

Status of Wind Auctions

Project capacity (MW)	Project locations	Tariff (Rs/ unit)	Scheduled date of commissioning	Intermediary
1,049.9	Thirunelveli (Tamil Nadu) and Bhuj & Bachau (Gujarat)	3.46	425.9 MW commissioned.	SECI
1,000	Tuticorin (Tamil Nadu) and Bhuj & Bachau (Gujarat)	2.65	03.05.2019	SECI
2,000	Tuticorin (Tamil Nadu) and Bhuj & Bachau (Gujarat)	2.44	23.11.2019	SECI
2,000	Pugalur, Thirunelveli, & Palakkad (Tamil Nadu) and Bhuj (Gujarat)	2.51	28.02.2020	SECI
1,190	Bhuj (Gujarat) and Hiryur (Karnataka)	2.76	22.07.2020	SECI
1,150	Pavagada (Andhra Pradesh), Osmanabad (Maharashtra), Karur & Tirupur (Tamil Nadu), Kutch (Gujarat) and Devangere (Karnataka)	2.77	13.07.2020	NTPC

Source: Compiled from replies to various Lok Sabha questions

Profile of Four Largest Wind Manufacturing Companies in India

Company and Headquarters	Market Share & Reach	Manufacturing Base	Installed Base
Suzlon - Pune, India	• Global reach: 18 countries • India: 35% market share	• Global: 15 manufacturing units • India: 14 manufacturing facilities located in Tamil Nadu, Karnataka, Maharashtra, Gujarat and Andhra Pradesh • Manufacture various WTG components such as generators, blades, nacelles and hubs etc • Manufactured the largest wind turbine in India – S128 • Hub height: 140 m • Rotor blade: 63 m • Rotor diameter: 128 m	• Global : 17.9 GW • India: 11.9 GW • Installed next generation turbines of S111, which at 120 meters will have a capacity of 2.1 MW • A demonstration model for S111 in Gujarat achieved a plant load factor (PLF) of 42 percent over a span of 12 months. • Hub height: 140 m • Rotor diameter: 111.8 m
Inox - Noida, India	• India: 8 % market share	• India: 3 manufacturing plants in Gujarat, Himachal Pradesh and Madhya Pradesh • Manufacture various WTG components such as blades & tubular towers, hubs & nacelles. • Nacelles and Hubs: 1.1 GW • Blades : 1.6GW • Towers: 0.6 GW	• India: 2.4 GW • Installations of 2 MW each and varying rotor diameters (93 m, 100 m, 113 m). 2 MW platform (100 m, 110 m and 120 m rotor diameter),
Siemens Gamesa - Zamudio, Spain	• Global reach: 90 countries • India: 16% market share		• Global: 84.5 GW; Offshore: 11GW • India: 5 GW
Vestas - Aarhus, Denmark	• Global: 90 GW • India: 8% market share	• Global: 15 manufacturing units • India: 14 manufacturing facilities - nacelle manufacturing facility in Tamil Nadu and a blade manufacturing facility in Gujarat	• Global: 84.5 GW; Offshore: 11GW • India: 2.5 GW • Installations of 2 MW and varying rotor diameters (100 m, 110 m and 120 m)

Source: Compiled from various company websites

Chapter 6: Energy access: Bridging the gaps

Electricity Distribution Circle (EDC): Shamli

Month	Energy Re-ceived (MU)	Energy Sold (MU)	Assess-ment (in Lac)	Realiza-tion (in Lac)	AT&C losses	Through Rate (Rs/ kWh)	Energy Re-ceived (MU) Energy Sold (MU)	Energy Sold (MU)	Assess-ment (in Lac)	Realiza-tion (in Lac)	AT&C losses	Through Rate (Rs/ kWh)
	Year 2017-2018						Year 2018-2019					
Apr-18	107.22	73.06	2,156.82	1,009.04	68.12%	0.94	95.62	78.52	2,410.50	1,363.67	53.54%	1.43
May-18	140.27	83.23	2,605.95	2,563.76	41.63%	1.83	127.93	92.21	3,386.19	2,065.68	56.03%	1.61
Jun-18	142.92	90.11	2,475.11	2,216.85	43.53%	1.55	147.99	80.64	3,353.21	2,701.33	56.10%	1.83
Jul-18	149.92	88.83	2,530.89	1,644.06	61.51%	1.10	139.85	83.48	2,762.26	2,270.38	50.74%	1.63
Aug-18	131.61	99.76	2,612.46	1,602.97	53.49%	1.22	110.99	88.17	3,614.35	1,873.26	58.83%	1.69
Sep-18	114.96	86.65	2,398.59	1,669.93	47.52%	1.45	95.99	81.79	2,932.48	1,924.70	44.07%	2.01
Oct-18	127.79	88.45	2,337.42	1,469.62	56.48%	1.15	0.00					
Nov-18	85.92	79.36	2,180.96	1,531.81	35.13%	1.78	0.00					
Dec-18	97.55	80.12	2,157.03	1,463.73	44.27%	1.5	0.00					
Jan-19	100.99	85.76	2,717.40	1,565.85	51.07%	1.55	0.00					
Feb-19	89.54	76.26	2,367.83	1,468.94	47.17%	1.64	0.00					
Mar-19	99.32	81.25	2,402.13	3,027.12	-3.09%	3.05	0.00					

Circle name	Division name	Rural - metered	Rural - unmetered	Rural - total	Urban - metered	Urban - unmetered	Urban - total
EDC SHAMLI	EDD-I SHAMLI	22,419	8,967	31,386	3,872	0	3,872
	EDD-II SHAMLI	16,268	5,740	22,008	1,426	0	1,426
	EDD-III SHAMLI	24,135	8,339	32,474	6,723	0	6,723
	EDD-IV SHAMLI	22,129	10,193	32,322	6,381	0	6,381

Source: Pashchimanchal Vidyut Vitaran Nigam Limited (PVVNL)

Consumption, Import, Production: LPG

	Consumption (TMT)	Import (TMT)	Production (TMT)
FY 2015	18,000	9,840	8,313
FY 2016	19,623	10,568	8,959
FY 2017	21,608	11,326	11,097
FY 2018	23,343	12,380	11,382

Source: Ministry of Petroleum and Natural Gas (MoPNG)

Subsidized and Non-subsidized Rates of LPG in Delhi (May- Sept 2018)

	Non-subsidized LPG rate	Subsidized LPG rate
May	820	499
June	820	570
July	789	534
August	754	549
September	698	538

Source: Goodreturns.in

Cost of Cooking via Various Mediums

	LPG Stove	Induction cooktop	Electric coil cooktop
Energy (in joules) per unit	1 Cylinder (14.2 kg LPG)	1 kWh	1 kWh
Energy (in joules) per unit factoring efficiency	261 MJ	3 MJ	2.6 MJ
Units required to heat 10 litres of water	0.012	1.042	1.182
Cost per unit (in Rs)	423 (Subsidized) 900 (Non-subsidized)	5	5
Cost of heating 10 litres of water (in Rs)	5.09 (subsidized) 10.8 (Non-subsidized)	5.21	5.91

Source: Bijlibachao

Chapter 7: Discoms: Fundamental reforms required

Ujwal DISCOM Assurance Yojana (UDAY) Performance Parameters for Renewable-rich States

	ACS-ARR (Rs /kWh)	AT&C Losses (%)	Smart metering above 500kWh	Smart metering (200-500kWh)	Feeder segregation (%)
Andhra Pradesh	0.06	11.60	0	0	100
Gujarat	-0.04	14.29	0	0	100
Haryana	0.58	23.80	3	1	100
Karnataka	-0.01	15.46	0	1	97
Punjab	1.10	31.30	0	0	95
Rajasthan	-0.27	27.31	58	0	24
Uttar Pradesh	0.37	37.92	0	0	15
Madhya Pradesh	0.37	31.06	20	1	98
Maharashtra	-0.02	22.33	0	0	66
Himachal Pradesh	0.03	4.33	81	100	
Telangana	0.39	12.55	8	2	9
Tamil Nadu	0.55	14.76	0	0	0

Source: Ujwal DISCOM Assurance Yojana (Uday) Dashboard, as viewed on October 2018

Revenue Gap: Average Cost of Supply (ACS) – Average Revenue Realized (ARR)

	2013-14	2014-15	2015-16	2016-17	2017-18
ACS-ARR Gap	0.72	0.52	0.59	0.45	0.27

Source: Compiled from Power Finance Corp reports and Uday Dashboard

Discoms' Cost of Supply

	2013-14	2014-15	2015-16
ACS (Rs/kWh)	5.19	5.23	5.46
ACS-ARR Gap (Rs/kWh)	0.72	0.52	0.59
Interest expenditure (Rs crore)	55,150	57,895	65,444
Power purchase costs (Rs crore)	409,432	459,506	480,118
Generation cost (Rs crore)	69,968	79,609	74,671
Employee cost (Rs crore)	49,180	55,796	58,924
O&M (Rs crore)	10,704	12,022	12,671
Depreciation (Rs crore)	23,584	27,044	30,995
Admin & general (Rs crore)	8,278	8,993	10,075
Others (Rs crore)	19,547	16,067	49,516
Total expenditure (Rs crore)	645,843	716,933	782,413
% of tariff attributed to servicing debt	8.5%	8.1%	8.4%
% of tariff attributed to power procurement	63%	64%	61%
Y-o-Y increase in PPA expenses	-	12%	4%
Y-o-Y increase in expenses - interest	-	12%	9%

Source: Power Finance Corp (PFC)
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Chapter 8: Integrating RE: Preparing for the future

Status of Green Corridor-I (ISTS Transmission Lines) with a Deadline of Dec 2019

Project Component	Status as of December 2017
Ajmer-Ajmer 400kV DC line	Foundation: 96%
	Tower: 92%
	Stringing: 63%
Chittorgarh (new)- Chittorgarh(RVPN) 400kV DC line	Foundation: 100%
	Tower: 92%
	Stringing: 53%
Tuticorin-Tirunelveli 2x400kV line	Foundation:89%
	Tower: 69%
	Stringing: 0%
Chittorgarh substation 765/400 kV	Civil Work: 80%
	Equipment Supply: 85%
	Erection: 72%
Substation Ajmer 765/400 kV	Civil Work: 84%
	Equipment Supply: 80%
	Erection: 72%
Substation Tuticorin pooling station 765/400kV	Civil Work: 97%
	Equipment Supply: 60%
	Erection: 55%
Banaskantha – Sankhari 400kV line	Foundation:93%
	Tower: 73%
	Stringing: 10%
Chittorgarh – Ajmer 765 kV line	Foundation:100%
	Tower: 99%
	Stringing: 88%
Banaskantha substation 765/400/220 kV	Civil Work: 70%
	Equipment Supply: 60%
	Erection: 30%
Banaskantha – Bhuj 765 kV line	Foundation:51%
	Tower: 20%
	Stringing: 0%
Substation at Bhuj pooling station 765/400/220 kV	Civil Work: 50%
	Equipment Supply: 35%
	Erection: 5%

Source: Power Grid Corporation of India (PGCIL)
http://apps.powergridindia.com/POWERGRID/docs/ENVIRONMENT/KfW%20Monitoring%20Report/Safeguard%20Monitoring%20Report%20Jan-June%202017.pdf

SCADA Compliance by Generators in Southern States as of February 2018

State	Plant type	Capacity with SCADA availability
Andhra Pradesh	Wind (3,751/3,835.77 MW)	97
	Solar (1,911/2,144.88 MW)	89
Telangana	Wind (100.8/100.8 MW)	100
	Solar (3,008.32/3,246.42 MW)	92
Karnataka	Wind (3,633.68/3,633.68 MW)	100
	Solar (3,764.37/3,763.37 MW)	100
Kerala	Wind (16/59.3 MW)	27
	Solar (71.18/90.858 MW)	78
Tamil Nadu	Wind (6,342/7,909.9 MW)	80
	Solar (648/1,950 MW)	33

Source: Southern Regional Load Dispatch Centre
http://www.srpc.kar.nic.in/website/2018/meetings/occ/a142occm.pdf

Status of ADB-financed Solar Park Transmission Projects

Park	Capacity (MW)	Project components	Status as of December 2017	Deadline
Bhadla, Rajasthan	2,250	Power grid Bikaner 765 kV DC line; RVPN Bhadla 400 kV DC line; Bhadla substation (765/400/220kV); extension of Bhadla and Bikaner substations	Construction underway—halfway through civil work	January 2019
Pavagada, Karnataka	2,000	Hiriyur–Mysore 400kV DC line; extension of 400/200kV Tumkur pooling station and substations; extension of 400/220 kV Mysore substation; Tumkur pooling station—Devanahalli (KPTC) 400kV DC line; extension of Devanahalli substation	Construction Underway—commenced civil work	February 2019
Radhanesada, Gujarat	700	Banaskantha pooling station—Banaskantha 400 kV DC line; 400 kV Bay extension at substation	Construction underway; civil work started	September 2018
Rihand–Dadri HVDC line	3,000 (evacuation)	Replacement of existing control and protection systems (SCADA); valve cooling upgradation	Contract to be awarded	-

Source: Power Grid Corporation of India (PGCIL); http://apps.powergridindia.com/POWERGRID/docs/Resettlement%20and%20Rehabilitation/ADB%20SEMI%20ANNUAL%20REPORT/LOAN%203521_8325-IND/Social%20Monitoring%20Report_%20May%20to%20Dec.%202017.pdf

Estimated Cost of Transmission Infrastructure for Solar Parks

Region	Total park capacity(MW)	Estimated cost (Rs crore)	
		Inter-state	Intra-state
Southern	6,700	1,973	2,068
Western	4,700	921	673
Northern	4,121	5,042	795
Eastern	1,500	-	916
North-Eastern	249	105	293
Total	17,270	8,041	4,745

Source: Power Grid Corporation of India (PGCIL)

Summary of Forecasting and Scheduling Regulations across Major States

State	Status of regulation	Forecasting responsibility	Scheduling responsibility	Scheduling requirement
Andhra Pradesh	Final	RE generator individually or via the QCA; alternatively, accept the forecast made by the SLDC	RE generator individually or through the QCA	Week ahead, day ahead and intraday with a maximum of 16 revisions a day for wind and 9 for solar
Karnataka	Final	RE generator individually or via the QCA; alternatively, accept the forecast made by the SLDC	RE generator individually or through the QCA	Week ahead, day ahead and intraday with a maximum of 16 revisions a day
Rajasthan	Final	RE generator individually or via the QCA; alternatively, accept the forecast made by the SLDC	RE generator individually or through the QCA	Week ahead, day ahead and intraday with a maximum of 16 revisions a day
Madhya Pradesh	Draft	RE generator individually or via the QCA; alternatively, accept the forecast made by the SLDC	RE generator individually or through the QCA	Week ahead, day ahead and intraday with a maximum of 16 revisions a day
Tamil Nadu	Draft	RE generator individually or via the QCA; alternatively, accept the forecast made by the SLDC	RE generator individually or through the QCA	Week ahead, day ahead and intraday with a maximum of 16 revisions a day
Gujarat	Draft	RE generator individually or via the QCA; alternatively, accept the forecast made by the SLDC	RE generator individually or through the QCA	Three days ahead, a day ahead and intraday with a maximum of 16 revisions a day
Maharashtra	Draft	QCA; alternatively, accept the forecast made by the SLDC	QCA	Week ahead, day ahead and intraday with a maximum of 16 revisions a day

Source: Forum of Regulators: state Electricity Regulatory Commission (ERCs); http://www.forumofregulators.gov.in/Data/Reports/I.pdf

Chapter 9: Waste to energy: Limited scope

Status of WTE Plants in India

Name of the WTE plant	Capacity (TPD)	City	State	Capacity (MW)	Developer	Status (April 2017)	Type of technology	Electricity purchaser Power	Rate of power
Timarpur-Okhla WTE plant	1,950–2,000 (average quantity of 1,818 tonnes utilized)	Delhi	New Delhi	16	JITF Eco-polis	Operational since 2012	Reciprocating grate technology with new filters. Has Continuous Emission Mon-itoring System (CEMS)	BRPL and Tata Power	Rs 3 for BRPL and Rs 6 for Tata Power
Ghazipur WTE plant	1,300 (aver-age quantity of 502 tonnes utilized)	Delhi	New Delhi	12	ILFS Envi-ron- men-tal Infra-structure Services Ltd	Operational since 2016 on trial run	Forward reverse reciprocating grate technology coupled with semi dry type flue gas treatment system. Has CEMS	BSES Yamuna Power Limit-ed (BYPL) for off take of 49 per cent of energy. The rest is sup-plied to Delhi Metro Rail Corporation (DMRC).	7.9
Bawana-Narela Energy	1,400 (aver-age quantity of 756 tonnes utilized)	Delhi	New Delhi	24	Ramky Group	Operational since 2017	Reciprocating grate technology coupled with semi-dry type flue gas treatment system. Has CEMS	The plant is connected with the grid under NDMC	7.03
Jabalpur MSW Private Limited (JMPL)	600 (average quantity of 400 tonnes utilized)	Jabalpur	Madhya Pradesh	11.5	Essel Infra	Operational since 2016	Forward acting reciprocating grate technology coupled with semi-dry type flue gas compressed treatment system. Has CEMS.	Madhya Pradesh discoms	6.39
Shimla WTE plant	75	Shimla	Himachal Pradesh	1.7	Elephant Energy	Commis-sioned in 2017	Gasification	Himachal State Elec-tricity Board	7.9
Solapur WTE	400 (currently Processing 200–250 tonnes)	Solapur	Maharashtra	4	Organic waste recycling Ltd	Operational since 2013	Thermophilic dry anaerobic digestion oper-ation (DRYADTM process)	(Maharash-tra State Electricity Distribution Co. Ltd.) MSEDCL	Rs 4.88
Saligao–Calangute WTE	35	Saligao	Goa	0.2	Hindustan Treatment Pvt. Ltd	Operational since 2016	Bio-digestion process	On-grid, given to the State Board	Not yet decid-ed
Surat WTE	1,000	Surat	Gujarat	11.5	Essel Infra	Under con-struction	Mass incinerator with reciprocat-ing technology	Gujarat state discoms	7.74

Name of the WTE plant	Capacity (TPD)	City	State	Capacity (MW)	Developer	Status (April 2017)	Type of technology	Electricity purchaser Power	Rate of power
Essel Pallavapuram and Tambaram MSW Pvt. Ltd (EPTMPL)	328	Vengad-aman-galam	Tamil Nadu	5	Essel Infra	Tendered in December 2015 Under construction	Mass incinerator with recipro-cating grate technology	Tamil Nadu discoms	Not de-cided
Indore WTE	1,000	Indore	Madhya Pradesh	21	Essel Infra	Was expect-ed to start operations by end of 2017	Incineration	Madhya Pradesh discoms	6.39
Bibinagar WTE	700	Hydera-bad	Telangana	7	RDF Power Projects Ltd.	Under Com-missioning stage	RDF-based power generation	TSSTCDL	7.9
Jawaharnagar WTE	2,400	Hydera-bad	Telangana	19.8	Ramky (Hyder-abad Integrated MSW Ltd)	Under con-struction	Mass incineration	TSSTCDL	Not known
Visakhapatnam WTE	950	Visakha-patnam	Andhra Pradesh	5	JITF	Under con-struction	Mass incineration	AP discom	6.2

Source: Communication with the plant developers and their reports in 2017; Data taken from the Lok Sabha session held on 4 August 2017.and SBM 2017-18

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In the five years since the publication of the first Citizen's Report on the State of Renewable Energy, the renewable energy sector has made tremendous strides in the country. Riding on a favourable policy environment and dipping prices, capacity and generation have grown. But this success has thrown newer challenges.

The second Citizen's Report on the State of Renewable Energy takes a close look at where we stand now, what are the strengths of and the challenges facing the sector, and whether the sector can overcome these obstacles and emerge as a viable alternative to conventional energy sources. It offers an analysis which covers the key sub-sectors and the associated infrastructure — solar (large-scale, rooftop and manufacturing), wind, waste to energy, integration and transmission, energy access and distribution companies. And it offers a blueprint which could help the sector reach its 175-gigawatt goal seamlessly.

The world stands at the cusp of a momentous shift in the energy sector. For the first time, decarbonised electricity appears feasible in the foreseeable future; it is not an abstract vision. The question that the second Citizen's Report asks is: Can India grab this opportunity and chart a brave new world of 100 per cent renewable quickly and efficiently?

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